BEFORE THE MINNESOTA OFFICE OF ADMINISTRATIVE HEARINGS

600 North Robert Street
St. Paul, Minnesota 55101
FOR THE MINNESOTA PUBLIC UTILITIES COMMISSION

121 Seventh Place East, Suite 350
St. Paul, Minnesota 55101-2147

In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216B.2422, Subd. 3	PUC Docket No. E-999/CI-14-643 OAH Docket No. 80-2500-31888

PROPOSED FINDINGS OF FACTS AND CONCLUSIONS OF LAW OF PEABODY ENERGY CORPORATION

The above-entitled matter came on for evidentiary hearings before Judges LauraSue Schlatter and J. Jeffrey Oxley, Administrative Law Judges from the Office of Administrative Hearings, from September 24, 2015 through September 30, 2015.

The following parties made appearances: Peabody Energy Corporation; Minnesota Center for Environmental Advocacy, Sierra Club, and Fresh Energy (collectively, the "Clean Energy Organizations"); Great River Energy, Minnesota Power, and Otter Tail Power Company; the Minnesota Large Industrial Group; Xcel Energy; the Clean Energy Business Coalition; Doctors for a Healthy Environment; and the Minnesota Department of Commerce and Minnesota Pollution Control Agency (collectively, the "State Agencies"). The Lignite Energy Council and the Minnesota Chamber of Commerce also were parties to the proceeding.

The Minnesota Public Utilities Commission (the "Commission") will make the final determination of the matter after the expiration of the period for filing exceptions or after oral argument if such is requested and had in the matter.

Further notice is given that the Commission may, at its own discretion, accept or reject the Administrative Law Judge's recommendation and that said recommendation has no legal effect unless expressly adopted by the Commission as its final order.

Based upon all the proceedings, records, and files herein, the Administrative Law Judge makes the following recommendations.

TABLE OF CONTENTS

FINDINGS OF FACT

I. THE FEDERAL SOCIAL COST OF CARBON

1. In the current proceeding, the proponents of higher externality values for CO_2 have submitted testimony to the Commission urging it to follow the Federal Social Cost of Carbon (the "FSCC").

2. The FSCC was calculated by the federal Interagency Working Group (the "IWG") and is largely based on data from 2007 and earlier.

3. The FSCC draws on three integrated assessment models ("IAMs"): FUND, DICE, and PAGE.

4. No witnesses in this proceeding participated in the IWG process. Witnesses proffered by the proponents of the FSCC describe, without any personal or direct knowledge beyond that available in publicly available reports, how the IWG used the IAMs to calculate the FSCC.

5. Dr. Hanemann and Dr. Smith described the major steps of an IAM (Ex. 800, Hanemann Direct, 25 (Fig. 1), 25:3-4, 25:10-26:13; Ex. 300, Smith Direct, Ex. 2 (Report) 3-4, 23). First, the IAM attempts to represent the relationship between economic activity and the generation of CO_2 emissions. Second, the IAM estimates how much these emissions will remain in the atmosphere. Third, the IAM estimates how the temperature will change in response. Fourth, the IAM estimates how different regions will react to this change in temperature. Fifth, the IAM estimates the monetary damage that will occur as a result of these temperature changes. Sixth, the IAM attempts to project these steps into the future and discount the damages to a present value.

A. Step One: Population, Technology, Production, Consumption, and Emissions

6. The first step "correspond[s] to the representation of how economic activity generates emissions, and how much those emissions are abated and at what cost." (Ex. 800, Hanemann Direct, 25:3-4).

7. The FSCC is based on estimates of future emissions scenarios for the next 300 years, through the year 2300. (Ex. 100, Polasky Direct Schedule 2 (Feb. 2010 TSD), 25).

8. The IWG chose to use some of the Stanford Energy Modeling Forum ("EMF-22") emissions scenarios (Hanemann, 2B Tr. 32:8-11), which correlate three major variables: population, GDP, and CO_2 emissions. Those scenarios forecast possible population, GDP growth, and resulting CO_2 emissions to the year 2100. (Ex. 600, Martin Direct, 33:1-9). These are projections of future global population growth, future productivity, and how much CO_2 that productivity will generate.

9. Along with the four EMF-22 scenarios – IMAGE, MERGE, Message, and MiniCAM – the IWG invented a fifth scenario, the "550 Average" scenario. (Ex. 100, Polasky Direct Schedule 2 (Feb. 2010 TSD), 26).

10. The IWG also extrapolated the EMF-22 scenarios and the "550 Average" even farther — to the year 2300. (*Id.*).

11. The IWG made its own assumptions about population, GDP, and CO_2 emissions after the year 2100, which drove all subsequent modeling steps (in terms of temperature response and damage estimation). (Ex. 600, Martin Direct, 33:1-9). No proponent of the FSCC explained or gave any evidence to substantiate these extrapolations.

12. The IWG did not account for the possibility of technological change and adaptation, such as the possibility that future societies would develop new technologies with lower CO_2 intensity. (*Id.* at 34:8-17). The IWG's failure to consider adaptation is detailed further in Section I.E.2.

13. The IWG's modifications to the EMF-22 scenarios and development of their own fifth scenario have never been peer-reviewed.

14. There is insufficient evidence to determine that the IWG made correct assumptions about population, GDP, and CO_2 emissions through the year 2300.

15. The preponderance of the evidence is that it is impossible to determine whether the assumptions upon which the IWG based its judgments on population, GDP, and CO_2 emissions through the year 2300 are scientifically reliable because the basis for those assumptions and judgments were neither transparent nor peer reviewed.

B. Step Two: Estimating Atmospheric Concentration from Emissions

16. Once a given level of emissions is known, IAMs must determine how much of those emissions will remain in the atmosphere, "a representation of the carbon cycle." (Ex. 800, Hanemann Direct, 25 n.18). This step of the IWG's estimate of the FSCC is the carbon cycle response—the relationship between (i) human emissions and (ii) atmospheric concentrations of CO_2. As Dr. Hanemann explained, this step and the next two "correspond to the representation of how the resulting emissions lead to climate change." (*Id.* at 25:5-6).

17. In particular, models must determine how much of the emissions will actually remain in the atmosphere, as opposed to being absorbed by plants, oceans, or other carbon sinks.

18. The causal relationship between emissions concentrations is not well-established. A rise in CO_2 emissions does not necessarily correlate with a rise in atmospheric CO_2 concentrations because carbon sink rates exceed emissions rates, drawing more CO_2 from the air.

19. The State Agencies and the Clean Energy Organizations (the "CEOs") offered speculation regarding the relationship between fossil fuel emissions and atmospheric CO_2 levels without evidence offered in the record. For example, Dr. Gurney testified that the connection is "well established through multiple lines of evidence" (Ex. 803, Gurney Rebuttal, 8:21-23; Gurney, 4 Tr. 131:16-132:2), but he never identified or produced this

causation evidence other than his reference to a phenomenon known as the "Suess Effect."

20. Dr. Gurney cited to the Suess Effect as support for his opinion that there is a relationship between fossil fuel emissions and atmospheric CO_2 levels. (Ex. 803, Gurney Rebuttal, 8:6-15). According to the Suess Effect, there is a relationship in the ratio between $^{14}CO_2$, a specific variety of CO_2 that does not come from fossil fuels, and total CO_2 in the atmosphere. (*Id.*; Ex. 213, Lindzen Surrebuttal, 29:21-30:7).

21. The only evidence given by the State Agencies to support their position on the relationship between fossil fuel emissions and atmospheric CO_2 levels was Dr. Gurney's reference to a 1979 article, P.P. Tans, *Natural Atmospheric 14C Variation and the Suess Effect*, 280 Nature 826, 827 (Aug. 30, 1979). During an 11-year period (1939-1950), 16.6 tons of carbon from fossil fuels were released. (Ex. 213, Lindzen Surrebuttal, 30:9-13). Because of the additional fossil fuel emissions that did not contain $^{14}CO_2$, the authors expected a 4-6% decrease in the ratio between $^{14}CO_2$ and CO_2 due to dilution by the fossil fuel emissions. (*Id.*). However, the ratio did not change. (*Id.*). Because there was no ratio change and a baseline could not be established, Dr. Lindzen testified that the relation between emissions and atmospheric concentrations was not conclusively established. (*Id.* at 31:7-16).

22. Dr. Lindzen also explained that the IPCC's assumptions regarding the connection between emissions and concentrations are unproven because "the fraction of human induced CO_2 is small compared to the total CO_2 in the atmosphere, and natural emission and sink rates are about 20 times greater than anthropogenic emissions." (*Id.* at 29:9-11).

23. Further, "as the accumulation rises, the sink rate is increasing. The CO_2 sinks are not static – they respond systematically to the level of forcing. Dynamic systems analysis versus a simple mass-balance argument accounts for this effect. The sinks respond dynamically to the overall CO_2 concentration in the atmosphere, whether it is due to anthropogenic or natural input. As a result, the simple mass-balance arguments supporting the IPCC conclusions are based on circular reasoning starting with the premise that the increased CO_2 is caused by humans." (*Id.* at 29:11-16).

24. Dr. Lindzen cited peer-reviewed publications undermining the assumptions that underlie the carbon cycle assumptions embedded in the FSCC. For example:

- One recent study found that only a very small residual fraction of anthropogenic CO_2 emissions is not captured by carbon sinks and remains in the atmosphere, and further that the anthropogenic CO_2 additional warming extrapolated to the year 2100 was lower than 0.1°C in the absence of positive feedbacks. (*Id.* at 32:1-4). None of the proponents of the FSCC rebutted this evidence.

- Another study found that the present anthropogenic CO_2 fraction in the atmosphere is 7.7%, which is substantially smaller than the IPCC's estimate. The study noted: "The IPCC's latest value for the anthropogenic CO_2-percentage in

the atmosphere is 28%. This huge gap with the other research results originates from the long residence time calculation method of IPCC." (*Id.* at 32:5-9).

- Another study found that CO_2 always lags changes in surface temperatures and that changes in atmospheric CO_2 are not tracking changes in human emissions. (*Id.* at 32:10-11).

- A team of researchers in the U.S. found that "climate models used to predict the rise in CO_2 concentrations in the atmosphere are approximately 17 percent too high because they incorrectly approximate how much CO_2 plants pull from the atmosphere." (*Id.* at 32:12-14).

- Another study found a reverse relationship between atmospheric CO_2 and global temperature: "The primary ingredient of the Anthropogenic Global Warming hypothesis, namely, the assumption that additional atmospheric carbon dioxide substantially raises the global temperature, is studied. This is done by looking at the data of temperature and CO_2, both in the time domain and in the phase domain of periodic data. . . . These results indicate a reverse function of cause and effect, with temperature being the cause for atmospheric CO_2 changes, rather than their effect. These two hypotheses are discussed on basis of literature, where it was also reported that CO_2 variations are lagging behind temperature variations." (*Id.* at 33:1-9).

25. The proponents of the FSCC did not cross-examine Dr. Lindzen on the relationship between emissions and atmospheric concentrations or provide any evidence on this purported relationship other than the evidence rebutted by Dr. Lindzen.

26. There is insufficient evidence to determine the exact relationship between CO_2 from anthropogenic sources and total atmospheric CO_2.

27. The preponderance of the evidence is that the relationship between CO_2 from anthropogenic sources and total atmospheric CO_2 was not established.

28. There is insufficient evidence establishing the amount of CO_2 emissions from Electric Generating Units ("EGUs") in Minnesota that are captured by carbon sinks versus remain in the atmosphere and contribute to CO_2 concentrations.

29. The preponderance of the evidence is that the causal relationship between CO_2 emissions from EGUs in Minnesota and total atmospheric CO_2 concentration was not established.

C. Step Three: Estimating Changes in Temperature

30. Once an atmospheric concentration is established, the model must determine how the temperature changes in response, in terms of "the change in global annual average temperature." (Ex. 800, Hanemann Direct, 25:8-9).

31. From 1880 to 2012, the IPCC reported in its 2013 Fifth Assessment Report that the globally averaged combined land and ocean surface temperature data showed an increase

of 0.85°C. (Ex. 405, IPCC, *Climate Change 2013: The Physical Science Basis* (2013) ("AR5"), at 5).

1. The FSCC Relied on Older Data Inconsistent with Observational Data

32. The IWG relied on the 2007 Fourth Assessment Report ("AR4") of the IPCC for its assumptions regarding future changes in global annual average temperature.

33. AR4 projected that doubling CO_2 concentrations from preindustrial levels would increase equilibrium temperatures by 2°C to 4.5°C, with a "best estimate" of 3.0°C (this is known as an "Equilibrium Climate Sensitivity" value or "ECS"). The IWG used 3.0°C as the midpoint for its probability assessment of ECS, which it used as a key input to the IAMs. AR4 stated that ECS values below 1.5°C were "very unlikely," meaning that they were "<10% probability." (Ex. 268, AR4, at 27).

34. The IWG stated that: "The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts." (Ex. 100, Polasky Direct Schedule 2 (Feb. 2010 TSD), 1).

35. Ground thermometers, weather balloons, and satellite measurements all show actual temperature changes running two to three times below what the models have predicted.

36. As Dr. Spencer observed, "The discrepancy is generally a factor of 2 to 3, that is, models tend to produce at least twice as much warming as the observations over the last several decades, which is the period during which human emissions and atmospheric concentrations have been the greatest." (Ex. 223, Spencer Direct, Ex. 2 (Report), at 1). "Nearly all of the IPCC climate models have predicted several hundred percent more warming over the past twenty years than has actually been observed. There is something seriously wrong with the models." (Ex. 200, Happer Direct, 7:10-12).

37. Observed temperature trends for the past 30 years have also run below the range encompassing 95% of climate models. (Ex. 233, Bezdek Rebuttal, Ex. 1 (Report), at 5:182-6:211 & Fig. 2; Ex. 209, Lindzen Direct, Ex. 2 (Report), at 9 (Fig. 9); Ex. 202, Happer Direct, Ex. 2 (Report), at 7 (Fig. 5), from Fig. 1 of Fyfe, et al. (2015)).

38. The proponents of the FSCC conceded that "[t]he exact relationship between concentrations and temperature is unknown and 'likely to remain unknown for the foreseeable future' . . . ." (CEOs Br. at 14). This is an admission that the causal relationship between CO_2 concentrations in the atmosphere and global warming is unlikely to be known for the "foreseeable future."

39. The IPCC itself has acknowledged the lack of observational data linking increased emissions to extreme temperature and precipitation events. (Ex. 213, Lindzen Surrebuttal, 37:8-38:11; *see also* Ex. 220, Mendelsohn Surrebuttal at 39:3-45:16 (discussing lack of observed increases in extreme temperature and precipitation events from increases in global GHG emissions)).

40. There is insufficient evidence establishing a causal relationship between CO_2 concentrations in the atmosphere and global temperatures.

41. The preponderance of the evidence is that a causal relationship between CO_2 concentrations in the atmosphere and global temperatures was not established.

a. There Has Been a Recent Warming "Hiatus"

42. As Dr. Spencer put it, "Contrary to almost all expectations, there has been no statistically significant warming in either the RSS or UAH satellite data for the last 18 years, nor in the weather balloon data, leading to the well-know[n] 'hiatus' in global warming." (Ex. 221, Spencer Direct, 16:21-24; *see also* Ex. 200, Happer Direct, 8:17-18 ("Global warming basically stopped about the time of the last large El Niño event in 1998. There has been no significant warming since.")).

43. There is a manifest consensus on the existence of a hiatus in warming. (Ex. 213, Lindzen Surrebuttal, 20:1-6 (quoting Ex. 405, AR5, at 40)). As Dr. Abraham put it, "the climate science community has reached a near consensus that the warming rate of global surface temperature has exhibited a slowdown over the last decade to decade and a half." (3B Tr. 80:3-9).

44. IPCC authors such as Kevin Trenberth (IPCC author/editor and early proponent of anthropogenic global warming theory), Rajendra Pachauri (former president of IPCC), and Hans von Storch (IPCC lead author) have all recognized that this hiatus exists and poses a question that requires explanation. (Ex. 235, Bezdek Surrebuttal, 3:9-5:7).

45. Dr. Dessler (the CEOs' witness) also conceded that the hiatus exists: "Dr. Spencer is correct. . . . **[I]t is correct to say that there has been no statistically significant warming since 2000**. . . . [T]he trend is smaller than the uncertainty." (Ex. 103, Dessler Rebuttal, 15:5-9).

46. The models used by the IWG failed to predict this nearly two-decade-long "hiatus" in warming during the very period when CO_2 emissions have been greatest. "The hiatus was not predicted by the models or by the IPCC reports, and it remains largely unexplained." (Ex. 221, Spencer Direct, 5:6-7; *see also* Ex. 200, Happer Direct, 9:13-14; Ex. 207, Lindzen Direct, 10:10-15).

47. In particular, AR4 predicted that the Earth would warm at a much faster rate: "For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios." (Ex. 268, AR4, at 45).

48. The global mean surface temperature record shows a trend of 0.04°C per decade during the 1998-2012 period. (Ex. 405, AR5, at 61; Ex. 803, Gurney Rebuttal, 11:14-15).

49. As Dr. Spencer noted, the National Oceanic and Atmospheric Administration ("NOAA") essentially conceded that a hiatus of more than 15 years would invalidate current climate models: "even NOAA has admitted that 'The simulations rule out (at the 95% level) zero

trends for intervals of 15 years or more,' and yet we now stand at 18 years without warming in the real climate system." (Ex. 223, Spencer Direct Report, 4).

50. The preponderance of the evidence is that the difference in warming between 1998 and the present is not statistically significant.

b. Recent Data Invalidates the FSCC

51. Further, since the release of the FSCC, dozens of studies and papers have also invalidated the FSCC's assumptions of a large temperature increase, and leading scientists have found that the ECS is very unlikely to exceed 2.0°C.

52. Climate model simulations (CMIP3, CMIP5) fail to track the strong warming trend from 1910-1945, the cooling from 1945-1970, or the flat temperature trend in the 21st century. While climate models appear to accurately simulate warming in the last quarter of the 20th century, they diverge from observed temperatures over the last 15 years.

53. According to AR5, the rate of warming over the past 15 years (1998-2012) "is estimated to be about one-third to one-half of the trend over 1951-2012." (Ex. 405, AR5, at 769).

54. The evidence shows that the rate of warming is slowing, not increasing.

55. Parties to this proceeding also concede that the climate models are flawed. Dr. Dessler admitted that "over the last decade," the models have "run hot." (Ex. 103, Dessler Rebuttal 25:16-18). His proposed cause is that the models assumed that the sun was hotter than it really is, which caused the models to indicate higher-than-observed temperatures for about a decade. (*Id.* at 25:16-18; Dessler, 3B Tr. 10:11-18). Dr. Dessler did not present any evidence of the temperature of the sun compared to its estimated temperature in the models. Regardless of whether Dr. Dessler's view as to the cause is correct, his admissions mean the models were wrong when the IWG based its FSCC calculation on them.

56. The preponderance of the evidence is that the models have not accurately predicted future temperature.

57. Based upon the past problems with accurately predicting current global atmospheric temperatures, the preponderance of the evidence is that the models are not sufficiently reliable to predict future temperatures.

c. Attempts to "Disprove" the Hiatus

58. Despite the evidence-based consensus that the rate of warming recently has slowed even though CO_2 emissions have increased, some scientists have attempted to deny the uniform observations of the hiatus. But a closer observation shows that none of these attempted explanations save the models from their over-predictions of warming.

59. For example, a paper by Thomas R. Karl, *Possible Artifacts of Data Biases in the Recent Global Surface Warming Hiatus*, 348 Science 1469 (June 26, 2015), DOI:

10.1126/science.aaa5632 (the "Karl Paper"), claims to "refute[] the notion that there has been a slowdown or 'hiatus.'" (Ex. 102, Abraham Rebuttal, 10:8-9 (quoting a NOAA summary of the Karl Paper)). The paper does not draw on new observations of data, but instead manipulates existing data sets. The Karl Paper manipulates existing observations into showing that there has been warming by "adjusting" earlier measurements downward in comparison to current temperatures, producing an artificial warming trend. (Ex. 213, Lindzen Surrebuttal, 23:10-24:3).

60. Adjusting the models and changing their parameters to make the models fit historic temperature data—known as "backcasting"—is not a rigorous test because it involves simply fitting the curve of existing data. (Ex. 206, Happer Surrebuttal, 5:12-6:3). Dr. Dessler agreed that predicting temperatures in the future is a much more uncertain exercise than curve-fitting to past historical data. (3A Tr. 26:12-20). Further, even though backcasting is a much simpler exercise than predictions, in fact the models have not been able to accurately simulate the 20th century historical record.

61. The Karl Paper has also been heavily criticized for its methods and especially the seemingly outcome-driven nature of its results. For example, Dr. Lindzen noted:

- The adjustments were taken to move the data in favor of warming. (Ex. 211, Lindzen Rebuttal Report, 3:33-50; Ex. 213, Lindzen Surrebuttal, 26:1-13).

- The Karl Paper takes data from sea surface buoys and homogenizes it with data gathered from ship engine intake channels. (Ex. 211, Lindzen Rebuttal Report, 3:53-4:58). "Temperature readings from engine intakes are clearly contaminated by heat conduction from the engine itself and are therefore inappropriate for scientific use." (Ex. 213, Lindzen Surrebuttal, 26:6-8).

- The Karl Paper also refused to use the Argo buoy dataset. (Ex. 213, Lindzen Surrebuttal, 24:5-25:12). Dr. Lindzen described the Argo data set as "a system of more than 3,000 free-drifting buoys that measure the temperature and salinity of the upper 2000 meters of the ocean." (*Id.* at 24:10-11). An October 2014 NASA study using the Argo data set found "[t]he cold waters of Earth's deep ocean have not warmed measurably since 2005, . . . leaving unsolved the mystery of why global warming appears to have slowed in recent years." (*Id.* at 25:2-4). Dr. Lindzen testified that the Karl Paper's refusal to use the Argo data set is "hard to justify" and "likely would have altered the Karl paper's conclusions." (*Id.* at 24:15-16).

- In order to interpolate the data between buoys, the Karl Paper used temperatures from nearby landmasses, which also served to skew the measurements warmer. (*Id.* at 26:18-27:8). As Dr. Lindzen and other researchers have noted, "[m]uch of the Arctic Ocean is ice-covered even in high summer, meaning the surface temperature must remain near freezing. Extending land data out into the ocean will obviously induce substantially exaggerated temperatures." (*Id.* at 27:5-8).

- The Karl Paper also chose start and end dates that manufactured a warming trend. (Ex. 211, Lindzen Rebuttal Report, 4:58-59; Ex. 213, Lindzen Surrebuttal, 27:11-17). For example, the Karl Paper examines a trend starting in 2000 – a cool year due to La Niña – and ending in 2014, a warmer surface temperature year. (Ex. 213, Lindzen Surrebuttal, 27:11-14).

62. Even with all of this manipulation, the Karl Paper still found only minute levels of warming. (Ex. 211, Lindzen Rebuttal Report, 4:60-5:71 & Fig. 1). The Karl Paper finds warming consistent with only the 2.4th percentile of IPCC climate models. (Ex. 213, Lindzen Surrebuttal, 23:1-8): in other words, 97.6% of climate models still over-predict the warming that the Karl Paper purports to have found.

63. Scientists from the National Center for Atmospheric Research, the University of Leeds, and the International Research Institute for Climate and Society have also rejected the Karl Paper's conclusions. (*Id.* at 27:19-28:17 (sources listed therein)).

64. Other scientists have attempted to find the "missing" warming in the ocean, but have failed.

65. AR5 did not find consistent data on ocean warming in the upper 700 meters of the ocean since 2003. (Ex. 405, AR5, Figure 3.2, 13 p. 262). Recent peer-reviewed research confirms that there has been a flattening or slight cooling of the upper 100 meters of the ocean since 2004, and temperatures in the upper 300 meters have flattened or cooled since 2003. (*See* Ex. 213, Lindzen Surrebuttal, at 21 (citing studies)). Analyses of heat content for the upper 700 meters are inconclusive and show substantial regional variations. (*Id.*). A new worldwide system of ocean sensors (Argo) shows that, below 2000 meters, the ocean has cooled since 2005. (*Id.*).

66. NASA has also found no evidence of heat being stored in the deep ocean. (Ex. 235, Bezdek Surrebuttal, 11:15-12:14; Ex. 227, Spencer Surrebuttal, 13:11-14:8). The upper ocean (down to 700 meters depth) appears to show mixed results, warming on some measures and cooling on others.[1] (Ex. 213, Lindzen Surrebuttal, 20:9-21:6 (and sources cited therein)). The deep ocean (below 700 meters) is more of a mystery because observational measures were not available until 2005; since then actual observations show the deep ocean cooling. (*Id.* at 21:7-21 (rejecting model-based theories for warming in favor of actual measured cooling)). Dr. Abraham's research finds that heat is being stored in the ocean at roughly one-third the rate predicted by models. (Ex. 206, Happer Surrebuttal, 7:21-8:3).

---

[1] The study cited by Dr. Dessler to show warming in the upper ocean (Balmaseda et al. 2013) is based on models of the upper ocean, not actual observations. Further, Dr. Dessler conceded that he was not familiar with the Wunsch and Heimbach study and testified, "I don't know, I'm not an expert on ocean temperatures." (3A Tr. at 32:4-5, 11-15).

67. A recent peer-reviewed study from MIT and University of Texas professors (Wunsch and Heimbach) estimates that the oceans are absorbing heat at a much lower rate than climate models predict—only about 0.2 watts per square meter, rather than 0.6 watts per square meter (or even higher) as many climate models predict. (C. Wunsch and P. Heimbach, *Journal of Physical Oceanography*, 44, 2014 (2014) (cited in Ex. 206, Happer Surrebuttal, at 7)).

68. Thus, like the atmosphere, the oceans are warming about three times less rapidly than climate models predict.

69. The preponderance of the evidence is that AR5 and other experts are correct to state that a warming hiatus occurred from 1998 – 2012.

70. The preponderance of the evidence is that the climate models have not been reliably predictive of actual atmospheric and oceanic temperatures.

d. AR5 Rejects the FSCC's Assumptions of Climate Sensitivity Values

71. In 2013, the IPCC released the Fifth Assessment Report ("AR5").

72. AR5 contains charts showing the discrepancy between climate models and observational data. (*See* Ex. 213, Lindzen Surrebuttal, 8:14-9:7).

73. AR5 notes that models are over-predicting warming: "Almost all CMIP5 historical simulations do not reproduce the observed recent warming hiatus." (Ex. 405, AR5, at 63). "[A]n analysis of the full suite of CMIP5 historical simulations (augmented for the period 2006–2012 by RCP4.5 simulations) reveals that 111 out of 114 realizations show a GMST trend over 1998–2012 that is higher than the entire HadCRUT4 trend ensemble," i.e., actual surface temperature data. (*Id.* at 61).

74. In AR5 the IPCC acknowledged the slowdown in warming since 1998: "[T]he rate of warming over the past 15 years (1998–2012) [is] 0.05 [–0.05 to +0.15] °C per decade which is smaller than the rate calculated since 1951 (1951–2012) [of] 0.12 [0.08 to 0.14] °C per decade." (Ex. 405, AR5, at 37). AR5 expressly recognized a "hiatus": "the observed recent warming hiatus [is] defined as the reduction in GMST [Global Mean Surface Temperature] trend during 1998–2012 as compared to the trend during 1951–2012." (*Id.* at 63 (Box TS.3)). "The observed GMST has shown a much smaller increasing linear trend over the past 15 years than over the past 30 to 60 years. Depending on the observational data set, the GMST trend over 1998–2012 is estimated to be around one third to one half of the trend over 1951–2012. For example, in HadCRUT4 [an observational dataset of ground-based temperature readings] the trend is 0.04°C per decade over 1998–2012, compared to 0.11°C per decade over 1951–2012." (*Id.* at 61 (Box TS.3)).

75. Thus, overall, the trend in the model simulations is substantially larger than the observed trend over the past 15 years.

76. In particular, the observed global temperatures, particularly since 2011, are below or just at the bottom bound of the 5-95% envelope of the climate model simulations.

77. AR5 explains that "the implied rates of warming over the period from 1986–2005 to 2016–2035 are lower as a result of the hiatus: 0.10°C–0.23°C per decade, suggesting the AR4 assessment was near the upper end of current expectations for this specific time interval." (*Id.* at 1010).

78. After expecting an increase of 0.2°C per decade in the early decades of the 21st century (according to AR4), AR5 finds that the rate of warming over the past 15 years had slowed dramatically and was approximately 0.05°C (or about 1/6th of the 0.3°C that was projected to occur in a decade-and-a-half).

79. Accordingly, AR5 recognizes that AR4 had overestimated warming.

80. "The discrepancy between simulated and observed GMST trends during 1998–2012 could be explained in part by a tendency for some CMIP5 models to simulate stronger warming in response to increases in greenhouse-gas concentration than is consistent with observations." (*Id.* at 62).

81. AR5 also cites evidence to support lower ECS values. Figure 1 of Box 12.2 in the AR5 report shows that 11 out of 19 observational-based studies of ECS have values below 1.5°C in the range of their ECS probability distribution. (Ex. 213, Lindzen Surrebuttal 16:10-14). Further, the chart shows 22 studies (of all kinds) with sensitivity values below the IWG's value of 3°C and only 11 at or above that value. In other words, the chart shows twice as many studies favoring sensitivity values below 3°C.

82. AR5 lowered the bottom of the "likely" ECS range to 1.5°C (without raising the top of the range), now stating that it was "likely" (Ex. 405, AR5, at 16) (>66% probability) with "high confidence" (*Id.* at 83 (Box 12.2)) that doubling CO_2 concentrations might increase global temperatures by as little as 1.5°C. AR5 states as its reason for the downward adjustment: "This assessment reflects improved understanding, the extended temperature record in the atmosphere and ocean, and new estimates of radiative forcing". AR5 explains that new "**studies suggest a best fit to the observed surface and ocean warming for ECS values in the lower part of the likely range**." (*Id.* at 84).

83. AR5 also notes that increased uncertainty prevents the IPCC from giving a "best estimate" as it had in AR4: "In contrast to AR4, no best estimate for ECS is given because of a lack of agreement on the best estimate across lines of evidence and studies and an improved understanding of the uncertainties in estimates based on the observed warming." (*Id.* at 85; s*ee also id.* at 16 n.16 ("No best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies.")).

84. Thus there is not only first-order uncertainty as to the proper value of ECS, resulting in a probability distribution rather than a point estimate or "best estimate," but also second-order uncertainty regarding the direction that probability range is shifting.

85. Uncertainty regarding ECS is increasing rather than decreasing.

86. To the extent there is any trend to the ECS change, it reflects a greater emphasis on the lower end of the IPCC's ECS range in AR5.

e. A Number of Peer-Reviewed Articles Support an ECS Lower than the AR4 Best Estimate of 3°C

87. AR5's reduction of its ECS estimate is also consistent with other recognized uncertainties.

88. The scientific evidence strongly supports the IPCC's lowering of the ECS, and if anything, shows that it did not go far enough.

89. In addition to AR5, 14 studies and 20 experiments validated a lower range for ECS between the 2010 issuance of the FSCC and its 2013 update. (Ex. 213, Lindzen Surrebuttal, 17:2-3).

90. Dr. Stevens's peer-reviewed 2015 paper, co-authored with Thorsten Mauritsen, *Missing Iris Effect As A Possible Cause Of Muted Hydrological Change And High Climate Sensitivity*, Nature Geosci. (Apr. 20, 2015) (advance online publication) (cited in Ex. 213, Lindzen Surrebuttal, at 15 and Ex. 206, Happer Surrebuttal, at 4), states that "[i]nferences from the observational record . . . place climate sensitivity near the lower end of th[e] range." The paper shows (as explained by Dr. Lindzen) "[t]aking account of the Iris effect moves climate models closer to observed temperatures and suggests that a low-end climate sensitivity value of 1.5°C is likely correct." (Ex. 213, Lindzen Surrebuttal, at 13)**.**

91. In 2014, Nicholas Lewis and Georgia Institute of Technology climate professor Judith Curry, former chair of the School of Earth and Atmospheric Sciences at Georgia Tech, published a peer-reviewed article using AR5 data finding an ECS "best estimate" of 1.65°C, with a 17-83% confidence range of 1.25°C to 2.45°C, and a 5-95% confidence range of 1.05°C to 4.05°C. (Lewis, N. and J.A. Curry, C., *The implications for climate sensitivity of AR5 forcing and heat uptake estimates.* Climate Dynamics, 10.1007/s003820142342y (2014)).

92. In 2013, Lewis published a peer-reviewed article finding an ECS "best estimate" of 1.65°C, with a 17—83% confidence range of 1.25°C to 2.25°C, and a 5-95% confidence range of 1.05°C to 2.95°C. (Lewis, N., *An objective Bayesian, improved approach for applying optimal fingerprint techniques to estimate climate sensitivity. Journal of Climate, 9 doi:10.1175/JCLID1200473.1* (2013) (cited in Ex. 213, Lindzen Surrebuttal, at 14)).

93. A peer-reviewed 2014 study by researchers at the University of Oslo found an ECS "best estimate" of 1.67°C, with a 17-83% confidence range of 1.2°C to 2.35°C, and a 5-95% confidence range of 0.9°C to 3.15°C. (Skeie, R. B., T. Berntsen, M. Aldrin, M. Holden, and G. Myhre, 2014, *A lower and more constrained estimate of climate sensitivity using*

updated observations and detailed radiative forcing time series, Earth System Dynamics, 5, 139–175 (2014) (cited in Ex. 213, Lindzen Surrebuttal, at 18)).

94. A peer-reviewed 2012 study by other researchers at the University of Oslo using two different statistical methods found (i) an ECS "best estimate" of 1.53°C, with a 17-83% confidence range of 1.2°C to 2.0°C, and a 5-95% confidence range of 1.05°C to 2.55°C, and (ii) an ECS "best estimate" of 1.76°C, with a 17-83% confidence range of 1.35°C to 2.45°C, and a 5-95% confidence range of 1.15°C to 3.45°C. (Aldrin, M., et al., *Bayesian estimation of climate sensitivity based on a simple climate model fitted to observations of hemispheric temperature and global ocean heat content. Environmetrics, doi: 10.1002/env.2140* (2012) (cited in Ex. 213, Lindzen Surrebuttal, at 14)).

95. A peer-reviewed study by the Climate Research Group, Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign found that "estimates of climate sensitivity using our [model] and the four instrumental temperature records range from about 1.5°C to 2.0°C." (Ring, M.J., et al., *Causes of the global warming observed since the 19th century. Atmospheric and Climate Sciences. 2*, 401415, doi: 10.4236/acs.2012.24035 (2012) (cited in Ex. 213, Lindzen Surrebuttal, at 14)).

96. A peer-reviewed study by the Canadian Centre for Climate Modeling and Analysis and the Pacific Climate Impacts Consortium at the University of Victoria confirmed that "[r]ecent observed global warming is significantly less than that simulated by climate models." J.C. Fyfe, N. P. Gillett, F. W. Zwiers, *Overestiamted Global Warming over the Past 20 Years*, 3 Nature Climate Change 767 (2013) (cited in Ex. 213, Lindzen Surrebuttal, at 15)).

97. "These studies point to low climate sensitivity values which would imply minimal danger or even net benefit from climate change." (Ex. 207, Lindzen Direct, 9:17-25; *see also* Ex. 209, Lindzen Direct Report, 6:191-7:204 & Fig. 7 & Table 1 (showing the canceling in graphs)).

98. This strong trend toward reduction in ECS in AR5 is also corroborated by AR5's treatment of transient climate response ("TCR"). Whereas ECS is a long-term (equilibrium) measure of the warming that will occur from a doubling of CO_2, TCR measures the immediate temperature change from an increase in emissions. (Ex. 405, AR5, at 1110 (Box 12.2)). AR5 takes the view that TCR "is a more informative indicator of future climate than ECS." (*Id.* at 1112 (Box. 12.2)). AR5 finds TCR likely to fall in the range 1°C to 2.5°C. (*Id.*). This represents a narrowing of the range for TCR from the Fourth Assessment, which concluded that "it is very unlikely that TCR is less than 1°C and very unlikely that TCR is greater than 3.5°C." (Ex. 268, AR4, Section 9.6.2.3).

99. In other words, AR5 lowered the values for both ECS and TCR.

f. The IWG Failed to Update the FSCC to Incorporate New Data

100. The FSCC fails to reflect the significant reduction by AR5 in its ECS estimate, which is a critical input to the IAMs.

101. As confirmed by the Clean Energy Organizations' witness Dr. Dessler, the IPCC released AR5 two months before the IWG's November of 2013 update and almost two years before the IWG's July 2015 update. (Dessler, 3A Tr. 109:11-13 ("But certainly – [AR5] came out in September of 2013, it had to be done significantly before that.").

102. Despite new empirical evidence and acknowledged uncertainty, the IWG did not revise the FSCC in November 2013 or July 2015 to account for AR5's more recent findings. The July 2015 revision reaffirmed the decision to ignore the most recent peer-reviewed science concluding that ECS is much lower—at least 30%-50% lower—than the IWG assumes.

103. After AR5 lowered the climate sensitivity range in September 2013 based on improved science, the IWG, in November 2013 and July 2015, did not decrease the FSCC, indicating that more study was needed:

> The IWG will 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 climate sensitivity distribution for the next update of the SCC.

(Ex. 101, Polasky Rebuttal, Sched. 1 (IWG, *Response to Comments: Social Cost of Carbon for Regulatory Impact analysis Under Executive Order 12866* (July 2015), at 12).

104. In its response to comments, published in July 2015, the IWG noted these changes and said that it would "continue to follow and evaluate the latest science on the equilibrium climate sensitivity." (Ex. 101, Polasky Rebuttal, Sched. 1 (*Id.* at 12).

105. There is insufficient evidence to support the IWG's climate sensitivity probability distribution.

106. The preponderance of the evidence is that the IWG's climate sensitivity probability distribution is not based upon the more recent AR5 and therefore is based upon scientific findings that have been superseded by AR5.

2. AR5 Scaled Back other Climate Change Predications

a. AR5 Demonstrates the FSCC Depends on Unproved "Positive Feedback" Mechanisms

107. The direct "greenhouse" effect of doubling CO_2 is 1°C.

108. In order to reach an ECS value greater than the baseline of 1°C, one must show positive "feedback mechanisms"—phenomena that augment warming—from clouds and water vapor. (Ex. 200, Happer Direct, 7:22-8:2). That is, in order to reach values of ECS any higher than 1°C—such as the values used by the IWG—one would need to demonstrate a feedback sufficiently high.

109. No scientist has yet been able to prove these sufficiently high feedbacks. (Ex. 207, Lindzen Direct 5:6-22; Ex. 213, Lindzen Surrebuttal).

110. The CEOs admitted in their Initial Post-Hearing Brief that the causal relationship between CO_2 concentrations and global warming is unlikely to be known for the foreseeable future because, for example, an insufficient understanding of positive feedbacks exists – whether positive feedbacks exist at all and, if so, how they work to cause global warming. (CEOs Br. at 14).

111. The most recent science validates lower feedbacks and therefore a lower ECS. (Ex. 206, Happer Surrebuttal, 3:1-16).

112. The positive feedbacks that have been proposed, such as the water vapor feedback, can account for only about 0.5°C of further warming. (Ex. 209, Lindzen Direct Report, 11:418-423).

113. No peer-reviewed scholarship has validated sufficient positive feedback mechanisms to get to 3°C. (Ex. 206, Happer Surrebuttal, 2:14-20).

114. Further, these feedback mechanisms are sufficiently complex that the IPCC itself has only "low confidence" in their values.

115. Since the release of AR5, new findings about aerosols indicate that a lower value is more likely. Previously, the greatest uncertainty in external forcing of climate was aerosols. Climate modelers used the uncertain negative feedback effect of aerosols to cancel excess warming produced by their models in an attempt to bring the models more in line with observations. But a new paper by Bjorn Stevens, *Rethinking the Lower Bound on Aerosol Radiative Forcing*, 28 J. Climate 4794 (2015), shows that the negative feedback effect of aerosols is much smaller than the models assume. (Ex. 213, Lindzen Surrebuttal, 10:11-15). Thus, Stevens's paper found that the cooling impact of sulfate emissions has held back global warming less than previously thought, which implies that the ECS should be lowered accordingly. (*Id.*). In short, the models still over-predict global warming.

116. Other recent scholarship has also reduced the uncertainty surrounding aerosols. Nicholas Lewis, who has published papers (both as sole author and jointly with IPCC contributors) cited by the IPCC in its latest report, has used the new aerosols research by Stevens to validate a climate sensitivity value of 1.64°C. (*Id.* at 17:6-10).

117. Further, AR5 notes flaws in how models simulate cloud processes and their effects on temperatures: "Climate models now include more cloud and aerosol processes, and their interactions, than at the time of the AR4, but there remains low confidence in the representation and quantification of these processes in models." (Ex. 405, AR5, at 16).

118. Clouds not only hold in heat by insulating the Earth, but **they also reflect it back out into space.**

119. The IPCC has found that, "Uncertainty in the sign and magnitude of the cloud feedback is due primarily to continuing **uncertainty in the impact of warming on low clouds**."

(*Id.*). "Although trends of cloud cover are consistent between independent data sets in certain regions, substantial ambiguity and therefore **low confidence remains in the observations of global-scale cloud variability and trends**." (*Id.* at 40).

120. AR5 concurs that "cloud feedbacks continue to have larger uncertainties." (*Id.* at 58).

121. The State Agencies agree on this point: "the discrepancy between the IPCC models and observed global mean temperatures over the referenced 15-year period . . . is broadly attributed to the **difficulty of large-scale atmospheric models to capture internal climate variability**." (State Agencies Br. at 86 n.62).

122. Even though cloud feedbacks are central to calculating an ECS (and therefore an externality value), these feedback mechanisms are sufficiently complex that the IPCC itself has only "low confidence" in their values. (Ex. 405, AR5, at 16).

123. The "positive feedback" mechanisms that proponents of the FSCC must prove in order to substantiate the IWG's calculations require a greater understanding of cloud mechanisms than we currently have. (Ex. 221, Spencer Direct, 8:22-25; Ex. 200, Happer Direct, 7:14-20; Ex. 207, Lindzen Direct, 5:6-22).

124. There is insufficient evidence to determine the positive feedbacks necessary to support the FSCC.

b. Evidence of Possible Sources of "Negative Feedbacks"

125. Further, there is evidence of possible sources of negative feedbacks.

126. One such example—the "Iris Effect," first discussed by Dr. Lindzen in 2001—proposes that increased sea surface temperatures in tropics results in reduced cirrus cloud cover and thus more heat leaking into space, like light through the iris of an eye. (Ex. 209, Lindzen Direct Report, 12:447-457; Ex. 213, Lindzen Surrebuttal, 10:19-11:2; Lindzen, 2A Tr. 17:4-18:10).

127. The Iris Effect has never been disproven and is gaining renewed interest. (Ex. 213, Lindzen Surrebuttal, 11:6-13:14). A recent paper, Thorsten Mauritsen & Bjorn Stevens, *Missing Iris Effect As A Possible Cause Of Muted Hydrological Change And High Climate Sensitivity In Models*, 8 Nature Geosci. 346 (April 20, 2015), reviews the scientific literature on the subject and found that the Iris Effect was both robust and validated. (Lindzen, 2A Tr. 34:20-35:4, 35:19-36:4). Dr. Dessler conceded that he published a blog post admitting that the Iris Effect might not be wrong (Dessler, 3A Tr. 35:5-13) and that a recent study found that "cloud cover is reduced as the climate warms" and that "for runs with the strong 'iris' the model's climate sensitivity is reduced from 2.8°C for doubled carbon dioxide to 2.2°C"—well below the IWG's assumed value of 3.0°C. (Ex. 259, Andy Dessler, *The Return of the Iris Effect?*, RealClimate (Apr. 24, 2015)).

128. There is insufficient evidence to disprove the existence of negative feedbacks.

129. The preponderance of the evidence is that negative feedbacks could explain why the models are over-predicting actual global temperatures because cirrus clouds could be reflecting some heat back to space rather than radiating it toward earth, which would lower, rather than increase, global temperatures. Increased CO_2 emissions, therefore, might not lead to the degree of warming predicted by the models because of negative feedbacks.

130. The preponderance of the evidence is that negative feedbacks cannot be ruled out as an explanation for why the models are not reliably predicting global warming from CO_2 emissions.

c. AR5 Shows Evidence that the Sea Level Rise is Part of a Long-Term Trend and that Sea Level Rise in 1920-1950 is of the Same Magnitude as in 1993-2012

131. AR5 explains that sea level rise is a part of a long-term, centuries-long trend: "The results are consistent and indicate a significant acceleration that started in the early to mid-19th century, although some have argued it may have started in the late 1700s." (Ex. 405, AR5, at 289).

132. Sea level rise is a natural phenomenon. (*See* Ex. 405, AR5, at 289-90 & Fig. 3.14).

133. AR5 finds that "[t]he trend in GMSL [the Global Mean Sea Level] observed since 1993, however, is not significantly larger than the estimate of 18-year trends in previous decades (e.g., 1920–1950)." (*Id.* at 290).

134. In contrast, human CO_2 emissions are reckoned to have increased dramatically only from about 1950 and beyond. (See Ex. 209, Lindzen Direct, Ex. 2 (Report) 10:340-367 (comparing warming in the period 1895-1946 and 1957-2008 and showing equivalent amounts—even though only the latter could have been human-generated forcing)).

135. The rate of change in GMSL indicates that the rate of rise during 1920-1950 was comparable to, if not larger than, the value in recent years. (Ex. 405, AR5, at 289 (Fig 3.14)).

136. Additional scientific evidence shows there is no link between sea level rise and CO_2.

137. Sea level has been rising for as long as there has been instrumentation. Actual observations do not support a statistically significant acceleration in the rate of sea level rise over the past century. (Ex. 233, Bezdek Rebuttal Report, 11:345-12:383; Ex. 235, Bezdek Surrebuttal, 13:10-19; Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 154-160).

138. The potential sea level rise mentioned by Dr. Dessler (one meter in a century) (Ex. 103, Dessler Rebuttal, 7:14-15) was disproven by the evidence as outside the realm of possibility.

139. The amounts under discussion are in the realm of 1-2 millimeters per year (10-20 centimeters per century) and there is no sign humans have caused that to accelerate. (Ex. 213, Lindzen Surrebuttal, 36:1-37:4). Dr. Bezdek cited 18 peer-reviewed articles supporting this point. (Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 154-160).

140. There is insufficient evidence that anthropogenic CO_2 emissions have caused any increase in sea levels.

141. At most, the evidence on sea level rise is inconclusive with respect to its causes.

d. AR5 Demonstrates that Sea Ice Is Most Likely Increasing Over the Long Term and Reversing Short-Term Declines

142. AR5 finds that "[i]t is very likely that the annual Antarctic sea ice extent increased at a rate of between 1.2 and 1.8% per decade (0.13 to 0.20 million kilometers squared per decade) between 1979 and 2012 (very high confidence)." (Ex. 405, AR5, at 40).

143. AR5 adds that "[w]hile surface melting will remain small, an increase in snowfall on the Antarctic ice sheet is expected (medium confidence), resulting in a negative contribution to future sea level from changes in surface mass balance." (*Id.* at 25). In other words, the Antarctic ice sheet will grow as well.

144. As for the Arctic, AR5 notes uncertainties: "Arctic temperature anomalies in the 1930s were apparently as large as those in the 1990s and 2000s. There is still considerable discussion of the ultimate causes of the warm temperature anomalies that occurred in the Arctic in the 1920s and 1930s." (*Id.* at 907).

145. AR5 found that the loss of sea ice was not irreversible: "The reversibility of sea ice loss has been directly assessed in sensitivity studies to CO_2 increase and decrease with Atmosphere–Ocean General Circulation Models or Earth System Models. None of them show evidence of an irreversible change in Arctic sea ice at any point." (*Id.* at 71).

146. Given the unknowns involved, AR5 stated that it could not find the sea ice loss in Greenland to be permanent or inevitable. "Considering the present state of scientific uncertainty, a likely range cannot be quantified. The complete loss of the Greenland ice sheet is not inevitable because this would take a millennium or more; if temperatures decline before the ice sheet has completely vanished, the ice sheet might regrow." (*Id.* at 72).

147. In fact, the reduction in summer Arctic ice cover has reversed. (Ex. 209, Lindzen Direct Report, 14:550-555). There is a mechanism (the Wyatt-Curry "stadium wave") to support the argument that the increase is the longer-term trend that will win out. (Ex. 213, Lindzen Surrebuttal, 34:13-35:14).

148. Moreover, even if sea ice were still decreasing, no convincing connection to human causes has been demonstrated. (*Id.* at 34:7-11).

149. The same uncertainty exists with respect to land-based glaciers. (Ex. 206, Happer Surrebuttal, 15:13-17:3). Dr. Bezdek produced 31 peer-reviewed articles supporting this argument. (Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 160-165).

150. There is insufficient evidence that anthropogenic CO_2 emissions cause sea ice to melt.

e. AR5 Finds Low Confidence in Attributing Extreme Weather Events to Anthropogenic Global Warming

151. AR5 also scales back AR4's predictions in terms of floods, droughts, and other kinds of extreme weather.

152. For example:

- AR5 finds no evidence of changes in global precipitation trends since 1990. (Ex. 405, AR5, at 42 ("Changes in precipitation are harder to measure with the existing records, both because of the greater difficulty in sampling precipitation and also because it is expected that precipitation will have a smaller fractional change than the water vapour content of air as the climate warms. Some regional precipitation trends appear to be robust, but when virtually all the land area is filled in using a reconstruction method, the resulting time series of global mean land precipitation shows little change since 1900.")).

- AR5 finds no change in river runoff. (*Id.* at 44 ("The most recent and most comprehensive analyses of river runoff do not support the IPCC Fourth Assessment Report (AR4) conclusion that global runoff has increased during the 20th century.")).

- AR5 finds no evidence that floods are worse in the post-industrial age. (*Id.* at 50 ("With high confidence, floods larger than recorded since the 20th century occurred during the past five centuries in northern and central Europe, the western Mediterranean region and eastern Asia.")).

- AR5 finds no increase in droughts over the past 40 years, and that 20th century droughts are smaller in magnitude and shorter in duration than other droughts during the last millennium. (*Id.* at 44 ("New results also indicate that the AR4 conclusions regarding global increasing trends in droughts since the 1970s **are no longer supported**."); *id.* at 73 ("Although the AR4 concluded that it is more likely than not that anthropogenic influence has contributed to an increased risk of drought in the second half of the 20th century, an updated assessment of the observational evidence indicates that the AR4 conclusions regarding global increasing trends in hydrological droughts since the 1970s **are no longer supported**. Owing to the low confidence in observed large-scale trends in dryness combined with difficulties in distinguishing decadal-scale variability in drought from long-term climate change, there is **now low confidence in the attribution of changes in drought over global land since the mid-20th century to human influence**."); *id.* at 50 ("There is high confidence for droughts during the last

millennium of greater magnitude and longer duration **than those observed** since the beginning of the 20th century in many regions.")).

- AR5 finds little evidence for changes in tropical cyclone activity. (*Id.* at 73 ("Confidence remains low for long-term (centennial) changes in tropical cyclone activity, after accounting for past changes in observing capabilities."); *id.* at 50 ("**Globally, there is low confidence in attribution of changes in tropical cyclone activity to human influence**. This is due to insufficient observational evidence, lack of physical understanding of the links between anthropogenic drivers of climate and tropical cyclone activity, and the low level of agreement between studies as to the relative importance of internal variability, and anthropogenic and natural forcings.")).

- In general, AR5 finds little evidence for increases in severe weather. (*Id.* at 50 ("There is low confidence of large-scale trends in storminess over the last century and there is still **insufficient evidence to determine** whether robust trends exist in small-scale severe weather events such as hail or thunderstorms.")).

153. These AR5 findings contradict the argument that anthropogenic sources of CO_2 are causing increases in severe weather frequency, duration, and intensity. The historical record referenced by AR5 suggests that natural variability is responsible.

154. The State Agencies and CEOs fail to establish by a preponderance of the evidence that these other events are even happening, much less that they are due to human effects on the climate. (Ex. 207, Lindzen Direct, 6:24-7:7, 10:21-11:2; Ex. 209, Lindzen Direct Report, 14:544-15:567; Ex. 213, Lindzen Surrebuttal, 33:3-4, 45:10-16; Ex. 206, Happer Surrebuttal, 17:5-18:7; *see also* Ex. 235, Bezdek Surrebuttal, 13:1-16:11).

155. None of these concerns is "proof" of global warming—climate is always changing. (Ex. 206, Happer Surrebuttal, 15:7-11).

156. The State Agencies and CEOs present an exaggerated picture of climate change that is not consistent with the scientific evidence described in AR5 and peer-reviewed literature.

157. The question is whether human activities have accelerated any of these changes outside natural variation, and the preponderance of the evidence is that they have not. For example:

- There is insufficient evidence on the record of unprecedented temperatures. AR5 acknowledges that contemporary temperatures are not necessarily the highest in human history: "Continental-scale surface temperature reconstructions show, with high confidence, multi-decadal periods during the Medieval Climate Anomaly (year 950 to 1250) that were in some regions as warm as in the late 20th century." (Ex. 405, AR5, at 5). The year 2014 was not the warmest year on record. (Ex. 235, Bezdek Surrebuttal, 17).

- Dr. Abraham admitted, "**[T]he temperature in any single year is not a meaningful development**." (Abraham, 3B Tr. 93:20-21).

- Instead, Dr. Abraham advised to look at long-term trends, with 17 years being the lower bound. (*Id.* at 91:13-18, 92:9-23).

- In any event, reports of the "hottest year on record" look at only recent history. Temperature records have been kept only since the late 19th century, and historical cycles of warming (such as the Medieval Warm Period) have been more significant than predicted temperatures today. (Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 21-33).

- There is no evidence of extreme weather from CO_2. There have been fewer hurricanes and fewer landfalls. (Ex. 213, Lindzen Surrebuttal, 44:2-12). There have been fewer severe tornadoes and the damage they have caused (normalized for GDP) has fallen—and the number of severe thunderstorms that may spawn tornadoes has dropped. (*Id.* at 44:14-17, 45:1-8; Ex. 206, Happer Surrebuttal, 17-18). This is consistent with climate science: storms arise from temperature and moisture gradients, and climate change should be expected to decrease both. (Ex. 209, Lindzen Direct Report, 14:555-15:562). Dr. Bezdek cited 93 articles making this point. (Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 7-21).

- There is no evidence of droughts from CO_2. Current droughts are still within ordinary patterns of severe drought. (Ex. 213, Lindzen Surrebuttal, 40:10-41:3). Even the current drought in California is suspected to be only 20% due to anthropogenic forcings, with natural variability the dominant cause. (*Id.* at 41:1-3). According to the EPA, the number of heat waves was markedly greater in the 1930s (the Dust Bowl), and those were hotter as well. (*Id.* at 41:5-43:11).

158. There is insufficient evidence that anthropogenic CO_2 emissions have caused any increase in extreme weather events.

159. The preponderance of the evidence is that the evidence is inconclusive as to CO_2 emissions' role, if any, in extreme weather events.

f. AR5 Expresses Substantial Doubts Regarding Catastrophic Climate Scenarios

160. AR5 also undermines the argument that anthropogenic sources of CO_2 will cause catastrophic scenarios. For example:

- AR5 generally dismisses catastrophic scenarios without scientific basis. (Ex. 405, AR5, at 70 ("Abrupt climate change is defined in this IPCC Fifth Assessment Report (AR5) as a large-scale change in the climate system that takes place over a few decades or less, persists (or is anticipated to persist) for at least a few decades and causes substantial disruptions in human and natural systems. There is information on potential consequences of some abrupt changes, but in general there is low confidence and little consensus on the likelihood of such events over the 21st century.")).

- AR5 finds that catastrophic scenarios of sea level rise are not supported by the evidence. (*Id.* at 25 ("Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the likely range during the 21st century. However, there is medium confidence that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century."); *id.* at 26 ("The basis for higher projections of global mean sea level rise in the 21st century has been considered and it has been concluded that there is currently insufficient evidence to evaluate the probability of specific levels above the assessed likely range. Many semi-empirical model projections of global mean sea level rise are higher than process-based model projections (up to about twice as large), but there is no consensus in the scientific community about their reliability and there is thus low confidence in their projections.")).

- AR5 finds that "runaway" warming from melting permafrost is not supported by the evidence. (*Id.* at 71 ("The existing modeling studies of permafrost carbon balance under future warming that take into account at least some of the essential permafrost-related processes do not yield consistent results, beyond the fact that present-day permafrost will become a net emitter of carbon during the 21st century under plausible future warming scenarios (low confidence). This also reflects an insufficient understanding of the relevant soil processes during and after permafrost thaw, including processes leading to stabilization of unfrozen soil carbon, and precludes any quantitative assessment of the amplitude of irreversible changes in the climate system potentially related to permafrost degassing and associated feedbacks.")).

- AR5 finds that warming from release of methane deposits is not supported by the evidence. (*Id.* ("Deposits of CH_4 clathrates below the sea floor are susceptible to destabilization via ocean warming. However, sea level rise due to changes in ocean mass enhances clathrate stability in the ocean. While difficult to formally assess, initial estimates of the 21st century feedback from CH4 clathrate destabilization are small but not insignificant. It is very unlikely that CH_4 from clathrates will undergo catastrophic release during the 21st century (high confidence).")).

- AR5 finds that tropical rainforest collapse is not supported by the evidence. (*Id.* ("The existence of critical climate change driven dieback thresholds in the Amazonian and other tropical rainforests purely driven by climate change remains highly uncertain.")).

161. There is insufficient evidence on the record of ocean acidification harms from CO_2. The potential ocean acidification from CO_2 is much weaker than the natural variation of pH among habitats, seasons, days, and even hourly changes. Ocean life already undergoes more pH change than would be expected from CO_2 absorption. (Ex. 235, Bezdek Surrebuttal, 15:4-16:2 (quoting Robert Carter et al., "The Small Print: What The Royal Society Left Out" 13 (Global Warming Policy Foundation March 2015)). Dr. Bezdek cited 150 peer-reviewed studies, explaining (for example) that warmer ocean waters

would benefit corals by allowing them to shift poleward and that corals can adapt to acidification. (Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 69, 132-154). Researchers from the Wildlife Conservation Society found that the impacts of warming and acidification on corals are more complex than models assume, and corals can withstand more stress than expected. (Ex. 206, Happer Surrebuttal, 12). Further, researchers from Singapore and the Woods Hole Oceanographic Institute found that ocean acidification is driven much more by changes in ocean currents than anthropogenic CO_2. (*Id.*).

162. There is insufficient evidence of ocean ecosystem harm from CO_2. (*See* Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 126-132; *see also* Ex. 233, Bezdek Rebuttal Report, 18-19).

163. There is insufficient evidence of terrestrial ecosystem harm from CO_2. (*See* Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 107-114; *see also* Ex. 206, Happer Surrebuttal, 13-14).

D. Step Four: Estimating How Regions Will React to Temperature Changes

164. Once a model determines a degree of warming, it then must compute how different regions will react to that change. This includes local changes in temperature, moisture levels, agricultural productivity, precipitation, weather, and other ecological factors.

165. Mild warming may dry out some wetter areas and make drier ones moister. Overall it will increase agricultural productivity and help plants become more resistant to these negative effects, as well as improve water use efficiency.

166. There is insufficient evidence that temperature changes will harm agricultural productivity or plants.

E. Step Five: Estimating the Damage Caused by Temperature Change

167. Once the global and regional shifts in weather and climate are estimated, the impacts of those changes must be monetized. This step "correspond[s] to the representation of the resulting impacts of the change in climate and their economic valuation." (Ex. 800, Hanemann Direct, 25:6-7). This step is "combined into a single function (or set of functions) characterizing the economic value associated with particular groups of impacts at a point in time as a function of the increase in global average annual temperature occurring at that time." (*Id.* at 27:3-6).

168. Dr. Mendelsohn testified that "[i]mplicit damage in IWG estimates predict near-term (next 30-60 years) damage that is too high." (Ex. 261, Mendelsohn Opening Statement, 3).

169. The damage function in DICE assumes that the percent of GDP lost per year to climate change damage increases with the square of temperature change. When temperatures are 2°C warmer than preindustrial global temperatures, the model assumes climate damage

would be equal to 1% of GDP. When temperatures are 4°C higher, the model assumes damages would be 4% of GDP; 8°C increase would yield 16% of GDP damage.

170. Dr. Mendelsohn testified that this could lead to absurd results. "For example, an $18 dollar SCC implies that a 1 degree warming in 30 years will cause damage equal to $2 trillion per year. There is no known mechanism that can cause such high damages so soon from such a small change in temperature." (*Id.*). In fact, Dr. Mendelsohn testified that "you can't even get within an order of magnitude of that." (3B Tr. 41:22-23).

171. In 2050, just 35 years from now, the DICE model predicts temperatures will be 2°C warmer than preindustrial times. The global GDP according to DICE will be $199 trillion dollars in 2050, so DICE calculates that the annual damage and 2050 from climate change is predicted to be $2.1 trillion. (Ex. 220, Mendelsohn Surrebuttal at 16). "Looking at the sum of the damage across each sector of the economy with a 2°C warming, the net damage should be minimal. . . . It is not clear how warming one more degree than today could possibly have an impact this large." (*Id.* at 16:19-17:1).

172. No party in this proceeding cross-examined Dr. Mendelsohn on that point. He cited substantial peer-reviewed literature to support this conclusion. (Ex. 220, Mendelsohn Surrebuttal, 8:3-14:21 (listing 58 peer-reviewed articles he himself has published), 36:2-48:3 (listing 8 books and 87 articles he and others have written and upon which he relied)).

173. By adjusting DICE so that the annual global damage starts at a slightly higher temperature than the global pre-industrial temperature, Dr. Mendelsohn updated the model to reflect what we currently know about climate change, not speculation. (*See generally* Ex. 216, Mendelsohn Direct, Ex. 2 (Report), at 11-15). Because any warming since that time to date has been a net benefit to society, including through increased agricultural and ecosystem productivity and carbon fertilization, Dr. Mendelsohn adjusted his damage function in the DICE model for two scenarios: that net damage does not begin until temperatures warm to 1.5°C above preindustrial levels, and at 2°C above preindustrial levels. (*Id.*).

174. Dr. Mendelsohn's proposed damage function is based on the fact that the climate damages that would be predicted to be occurring today under the original DICE damage function—$173 billion in annual global GDP loss—are not apparent and do not exist.

175. Dr. Mendelsohn was not using changes in global GDP to measure damage. (Ex. 220 Mendelsohn Surrebuttal at 16.) He looked at individual effects in the sectors that are expected to be damaged by climate change in locations across the planet where these effects should occur. (*Id.*) Although there may be damages in select places and sectors, there are benefits in other places and other sectors. He said that it is not possible to detect any net damage. (*Id.*) Annual damages of $173 billion every year ought to be detectable, but they are not. (*Id.*)

176. Dr. Mendelsohn explained his modified damage function:

> It delayed the damages, and it's trying to get it to fit with the empirical evidence that I and other colleagues have been working on over the last 20 years trying to calibrate the damages. And it turns out if you include all the things that we've learned are important, the carbon dioxide fertilization, the adaptation, what you come up with is that there are going to be damages associated with climate change, but the small changes in temperature that we're going to see in the near term aren't going to cause much damage.

(3B Tr. at 62:5-15).

177. Dr. Mendelsohn supported his adjustments with substantial peer-reviewed research. (Ex. 220, Mendelsohn Surrebuttal, 7:3-15:6 (listing peer-reviewed works supporting his modifications to the damage function)).

178. Moreover, climate changes will also increase the uncertainty of other steps: greater agricultural productivity will change the amount of carbon absorbed by plants by some amount and greater prosperity will permit greater adaptation (resulting in less damage suffered by future generations).

179. Dr. Mendelsohn also testified that the "IWG ignored longer time lags of higher climate sensitivity." (Ex. 261, Mendelsohn Opening Statement, 3).

1. The IWG Failed to Consider Mitigation

180. The IWG inappropriately and without justification assumed that emission rates would continue to grow at their pre-determined pace despite the implementation of mitigation measures such as the FSCC in the vast majority of their emission scenarios. (Ex. 220, Mendelsohn Surrebuttal, 24:10-12).

181. Four of the five emissions models used by the IWG used business-as-usual growth scenarios for population, wealth, and emissions and are associated with CO_2 (only) concentrations ranging from 612 to 889 parts per million ("ppm") in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm CO_2 (i.e., CO_2-only concentrations of 425–484 ppm or a radiative forcing of 3.7 W/m^2) in 2100, a lower-than business-as-usual trajectory. (Ex. 100, Polasky Direct Schedule 2 (IWG Feb. 2010 TSD), at 15). The four business-as-usual 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." (*Id.* at 16).

182. The IWG used these models through the year 2100, and then extrapolated for 200 years. (*Id.* at 15).

183. The fifth scenario, which was invented by the IWG, arbitrarily capped emissions in 2100 by assuming they stabilized and did not exceed a certain threshold for 200 years. (*Id.*). The fifth scenario was created by averaging the GDP, population, and emission trajectories from the other four scenarios. (*Id.* at 15). Dr. Polasky admitted the IWG's

decisions on using emissions scenarios were not peer-reviewed. (1 Tr. 92:16-19). "By assuming zero future mitigation, the IWG is exaggerating the damage of carbon emissions." (Ex. 220, Mendelsohn Surrebuttal, 25:12-13).

184. Only this emission scenario used by the IWG, which assumes future emission stabilization at 550 ppm, "would be consistent with widespread action by countries to mitigate GHG emissions, though it could also result from technological advances," according to the IWG. (Ex. 100, Polasky Direct Schedule 2 (IWG Feb. 2010 TSD), at 15 n.13). Thus, only 20% of the future emission scenarios relied upon by the IWG in running the IAMs considered future mitigation. (*Id.* at 19 ("Because there were five scenarios, and each received equal weighting, the stabilization scenario received 20% of the total probability weight.")).

185. Because the IWG did not properly take into account mitigation, they also failed to capture how society will likely react as it learns more about climate change. (Ex. 214, Mendelsohn Direct, 16:20-21).

186. As Dr. Mendelsohn explained:

> Future mitigation policies will certainly respond to how serious climate change reveals itself to be. If climate damage turns out to be more serious than we currently believe, the obvious policy response is to mitigate more. If damage is less than expected, we will mitigate less. The resulting expected damage across all possible outcomes is much lower. Evaluating uncertainty in an optimal regime causes uncertainty to have a much smaller effect than with a zero mitigation policy.

(Ex. 220, Mendelsohn Surrebuttal, 31:5-10).

2. <u>The IWG Failed to Consider Adaptation</u>

187. The IWG also "implicitly underestimated adaptation." (Ex. 261, Mendelsohn Opening Statement, 3; *see also* Mendelsohn, 3B Tr. 39:1-40:1).

188. Not accounting for adaptation "effectively assume[s] that climate change occurs overnight with no warning." (Ex. 220, Mendelsohn Surrebuttal, 18:8-9). Instead, climate changes are gradual and slow, and are not likely to be a surprise. (*Id.* at 18:10-16; *see also* Ex. 600, Martin Direct, 29:18-19 ("[T]he IAMs do not fully capture adaptation to climate change, which could lead them to over-estimate damages.")).

189. Dr. Mendelsohn testified that society will react and adapt to any changes caused by climate. (Ex. 220, Mendelsohn Surrebuttal, 18:20-21). Dr. Mendelsohn, who has studied adaptation for the last 20 years, testified that "[a]daptation is an essential and inevitable aspect of climate change." (*Id.* at 17:11).

190. Dr. Mendelsohn reported "extensive evidence that people have already adapted to the climate that they live in across the planet." (*Id.* at 17:11-13). "Adaptation will cause the

actual damage from climate change to be a small fraction of potential damage." (*Id.* at 19:4-5).

191. Dr. Bezdek cited numerous peer-reviewed papers for adaptation. (*See* Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 107-114).

3. The IWG Failed to Consider Benefits of Carbon

192. More CO_2 would be a major overall benefit to the Earth through mild warming. (Ex. 200, Happer Direct, 9:22-10:3; Ex. 207, Lindzen Direct, 7:21-23; Ex. 228, Bezdek Direct, 2:21-3:20).

193. CO_2 is plant food that has beneficial impacts as well as potentially adverse ones. CO_2 benefits plants and agriculture by extending growing seasons, increasing photosynthetic efficiency of plants, decreasing water dependency of plants, and increasing tree growth rate. (Ex. 200, Happer Direct, 10:4-11:11; Ex. 204, Happer Rebuttal Report, 3:29-36; Ex. 220, Mendelsohn Surrebuttal, 4:6-15).

194. Dr. Gurney stated, "All available scientific evidence supports the general concept of a CO_2 fertilization effect." (Ex. 803, Gurney Rebuttal, 3:4).

195. AR5 notes that "[e]levated atmospheric CO_2 concentrations lead to higher leaf photosynthesis and reduced canopy transpiration, which in turn lead to increased plant water use efficiency and reduced fluxes of surface latent heat," and finds with high confidence that rising CO_2 will lead to enhanced plant productivity. (Ex. 405, AR5, at 501 (Box 6.3)).

196. AR5 further notes that greater growth from CO_2 fertilization is causing greater CO_2 sinks in Europe and North America. (*Id.*). AR5 acknowledges that the understanding of the dynamic impacts of vegetation, as a consumer of CO_2, has improved since AR4. (*Id.* at 791). It notes that there is "good agreement" on the basic concept of CO_2 fertilization when other nutrients do not constrain growth. (*Id.*). Increased CO_2 has already "virtually certainly" enhanced water use efficiency in key crops (maize, wheat, rice), making them more resistant to drought and warmer temperatures.

197. AR5 also found that the impacts of CO_2 fertilization make a crucial difference in food security. Without factoring in CO_2 fertilization, food prices would be projected to increase between 3 and 80%; if CO_2 fertilization is factored in, price increases are only as "likely as not" and the range goes from -30% to +45%: in other words, properly factoring in CO_2 fertilization both diminishes the severity of a negative impact and reduces its probability, while yielding a possibility of lowering food prices overall. (*Id.* at 489).

198. AR5 also found that increased vegetation results in a stronger carbon sink, drawing more CO_2 out of the atmosphere. Because global net primary productivity for plants is up approximately 5% over preindustrial levels, "[m]any terrestrial ecosystems are now net sinks for carbon over much of the [Northern Hemisphere] and in parts of the Southern Hemisphere . . . despite ongoing deforestation." (*Id.* at 989).

199. Moreover, AR5 found that the declines in crop yield are likely to happen mostly after a rise in temperature of 4°C (Ex. 405, AR5, at 489), which is an increasingly unlikely event according to AR5's recognition of lower ECS values.

200. AR5 relies extensively on laboratory studies. Indeed, AR5 cites specifically to free-air CO_2 enrichment ("FACE") experiments as a key advance since AR4 that allows a better understanding of CO_2 fertilization. (*Id.* at 502). AR5 even points out that FACE experiments tend to underestimate CO_2 response. (*Id.* at 495). The reason AR5 values FACE experiments so highly is that field studies are tougher to generalize: they tend to hold true for the specific region studied and might not obtain in other areas. (*Id.*). Laboratory experiments, by contrast, are designed for generalization, and AR5 relies on FACE experiments in order to overcome that challenge. As Dr. Mendelsohn pointed out, "[c]ontrolled experiments are a very important way to demonstrate cause and effect." (Mendelsohn Surrebuttal at 3:14-15).

201. The record of this proceeding contains citations to hundreds of other peer-reviewed articles and papers confirming the benefits of CO_2 fertilization (not limited to lab experiments). (Ex. 228, Bezdek Direct, 9-11; Ex. 231, Bezdek Direct, Ex. 3 (Compendium), at 69-107; Ex. 233, Bezdek Rebuttal, Ex. 1 (Report), at 13-19; Ex. 234, Bezdek Rebuttal, Ex. 2 (Discovery Responses), Ex. A, at 2-52; Ex. 235, Bezdek Surrebuttal, 24-42). Dr. Bezdek cited 136 articles regarding the fertilization effect, (Bezdek Direct, Ex. 3 (Compendium) at 69-89), 40 articles demonstrating that greening is already occurring, (*id.* at 89-96), and 427 articles on the same topics in response to an information request from the CEOs. For example:

- Field-wide studies show benefits of higher CO_2 concentrations for important crops such as wheat, rice, and cotton. (Vanuytrecht, E., et al., *Quantifying field-scale effects of elevated carbon dioxide concentration on crops*, Climate Research 54:35-47 (2012); *see also* Sommer, et al., *Impact of climate change on wheat productivity in Central Asia,* Agriculture, Ecosystems and Environment 178:78-99 (2013) (describing positive effects of CO_2 on 14 wheat varieties on 18 plots in Central Asia)).

- China has experienced CO_2 fertilization for three decades, based on satellite observation of greening. (Piao, S, et al., *Detection and attribution of vegetation greening trend in China over the last 30 years*, Global Change Biology 21:1601-1609 (2015)). In the field, this has resulted in increased biomass for rice and increased levels of other nutrients such as nitrogen, (Guo, J., Zhang, et al., *Elevated CO2 facilitates C and N accumulation in a rice paddy ecosystem*, Journal of Environmental Sciences 29:27-33 (2015); *see also* Yu, Y, et al., *Impact assessment of climate change, carbon dioxide fertilization and constant growing season on rice yields in China*, Climatic Change 124:763-775 (2014) (finding that rice yields will likely decrease at current CO_2 concentrations but will skyrocket with more CO_2); Zhao, Q, et al., *Impacts of climate change on virtual water content of crops in China*, Ecological Informatics, 19:26-34 (2014) (noting that increased CO_2 will likely promote food security and alleviate water scarcity in China through the integrated effects of precipitation, temperature, and CO_2

concentration changes)) as well as a shorter growing season and higher yields for winter wheat. (Tian, et al., *Warming impacts on winter wheat phenophase and grain yield under field conditions in Yangtze Delta Plain, China*. Field Crops Research, 134:193-199 (2012)).

- Using only the most pessimistic assumptions about climate change, researchers found uniformly positive effects for winter wheat growth in the United Kingdom. (Cho, K., et al., *Winter wheat yields in the UK: uncertainties in climate and management impacts*, Climate Research 54:49-68 (2012)).

- In general, plants under increased levels of CO_2 are healthier: higher levels of photosynthesis, lower transpiration, and greater water-use efficiency. (Lee, S.H., et al., *Effects of elevated CO_2 and water stress on physiological responses of Perilla frutescens var. japonica HARA*, Journal of Plant Growth Regulation 75:427-434 (2015); *see also* Sendall, K.M., et al., *Acclimation of photosynthetic temperature optima of temperate and boreal tree species in response to experimental forest warming*, Global Change Biology 21:1342-1357 (2015) (noting that increased photosynthesis will help ameliorate any negative effects of warming); Preite, V., et al., *Adaptation of flowering phenology and fitness-related traits across environmental gradients in the widespread Campanula rotundifolia*, Evolutionary Ecology 29:249-267 (2015) (noting that evolutionary selection can take place quickly enough that plants can respond to warming without being overwhelmed); Soule, P.T. and Knapp, P.A., *Radial growth and increased water-use efficiency for ponderosa pine trees in three regions in the western United States*, The Professional Geographer 63:370-391 (2011) (noting higher water use efficiency for trees in three regions of the western United States)). Moreover, these effects are multiplied through feedback mechanisms. (Polley, H.W., et al., *Feedback from plant species change amplifies CO_2 enhancement of grassland productivity*, Global Change Biology 18:2813-2823 (2012)).

- Increased CO_2 supports plants in defending against pathogens (Li, X., et al., *Tomato-Pseudomonas syringae interactions under elevated CO2 concentration: the role of stomata*, Journal of Experimental Botany 66:307-316 (2015)) and herbivorous predators (de Rezende, et al., *Is guava phenolic metabolism influenced by elevated atmospheric CO_2?* Environmental Pollution 196:483-488 (2015)) and can help plants to regrow after being partially eaten without dying. Nabity, P.D., et al., *Elevated CO_2 interacts with herbivory to alter chlorophyll fluorescence and leaf temperature in Betula papyrifera and Populus tremuloides*, Oecologia 169: 905-913; *see also* Pilegaard, K., et al., *Increasing net CO_2 uptake by a Danish beech forest during the period from 1996 to 2009*, Agricultural and Forest Meteorology 151:934-946 (2011) (finding, based on a field study, that CO_2 helped trees retain their leaves longer and had other positive effects)). In the field, increased CO_2 after hurricanes and fires speeds recovery by enhancing root growth. (Day, F.P., et al., *The effects of 11 years of CO_2 enrichment on roots in a Florida scrub-oak ecosystem*, New Phytologist 200:778-787 (2013)).

- More CO_2 allows plants to better allocate their resources so they can compete more effectively for resources and survive more easily. (Cao, J. and Ruan, H., *Responses of the submerged macrophyte Vallisneria natans to elevated CO_2 and temperature*, Aquatic Biology 23:119-127 (2015)). Ultimately, laboratory experiments show that this could be generalized to being able to withstand drought conditions. (Song, Y. and Huang, B., *Differential effectiveness of doubling ambient atmospheric CO_2 concentration mitigating adverse effects of drought, heat, and combined stress in Kentucky Bluegrass*, Journal of the American Society of Horticultural Science 139:364-373 (2014); *see also* Keenan, T., et al., *Predicting the future of forests in the Mediterranean under climate change, with niche- and process-based models: CO_2 matters!*, Global Change Biology 17:565-579 (2011) (models predict that CO_2 enrichment increases forest productivity despite drought); Robredo, A., et al., *Elevated CO_2 reduces the drought effect on nitrogen metabolism in barley plants during drought and subsequent recovery*, Environmental and Experimental Botany 71:399-408 (2011) (finding enhanced CO_2 mitigates the effects of drought and permits faster recovery); Darbah, J.N.T., et al., *Differential response of aspen and birch trees to heat stress under elevated carbon dioxide*, Environmental Pollution 158:1008-1014 (2010) (corroborating the findings of Idso and Kimball (1992) that higher CO_2 promotes thermotolerance)).

- Field studies on tree rings corroborate the supportive effects rising CO_2 concentrations have on water use efficiency, especially in dry areas. (Brienen, R.J.W., et al., *Stable carbon isotopes in tree rings indicate improved water use efficiency and drought responses of a tropical dry forest tree species*, Trees 25:103-113 (2011); *see also* Soulé, P.T. and Knapp, P.A., *Analyses of intrinsic water-use efficiency indicate performance differences of ponderosa pine and Douglas-fir in response to CO_2 enrichment*, Journal of Biogeography 42:144-155 (2015) (study by U.S. Forest service noting that the benefits of rising CO_2 were noticed uniformly across all experimental plots, suggesting a pan-regional effect)). Based on observations from 140-year-old forest plots in Central Europe, rising CO_2 levels have helped plants to continue thriving and increasing productivity even when acid rain and drought should have caused a drop. (Pretzsch, H, et al., 2014. *Forest stand growth dynamics in Central Europe have accelerated since 1870*, Nature Communications 5: 10.1038/ncomms5967 (2014); *see also* J. Wilcox, & D. Makowski, *A Meta-Analysis of the Predicted Effects of Climate Change on Wheat Yields Using Simulation Studies*, 156 Field Crops Research 180 (2014) (simulation studies show that benefits of rising CO_2 will outweigh detriments)).

- Higher ambient CO_2 in a field experiment yielded increased carbon uptake in a wetland and also facilitated groundwater recharge to counteract salinity intrusions. (Li, J.H., Erickson, et al., *Evapotranspiration and water use efficiency in a Chesapeake Bay wetland under carbon dioxide enrichment*, Global Change Biology 16: 234-245 (2010)). An extended (28-year) experiment in a Chesapeake Bay wetland corroborated those results and found that, contrary to expectation,

the ability of the wetland to absorb carbon was not constrained by limitations on available nitrogen or other nutrients.

- Field experiments show that the flourishing of plants will not come at the cost of invasive species crowding out native species. (Thomas, C.D. and Palmer, G., *Non-native plants add to the British flora without negative consequences for native diversity*, Proceedings of the National Academy of Sciences USA 112:4387-4392 (2015)).

- Enhanced CO_2 levels even increase the ability of plants to take up and process contaminants such as cesium and cadmium (Song, N., et al., 2012. *Elevated CO_2 increases Cs uptake and alters microbial communities and biomass in the rhizosphere of Phytolacca americana Linn (pokeweed) and Amaranthus cruentus L. (purple amaranth) grown on soils spiked with various levels of Cs*, Journal of Environmental Radioactivity 112:29-37 (2012); Wang, R., et al., *Growth, gas exchange, root morphology and cadmium uptake responses of poplars and willows grown on cadmium-contaminated soil to elevated CO_2*, Environmental Earth Sciences 67:1-13 (2012); *see also* Jia, Y., et al., *Effects of elevated CO_2 levels on root morphological traits and Cd uptakes of two Lolium species under Cd stress*, Journal of Zhejiang University - SCIENCE B (Biomedicine & Beitechnology) 12:313-325 (2011) (finding a similar increase in cadmium uptake but less concentration in the plant's tissues, indicating that CO_2 may have a protective effect on plant tissues)), suggesting possible use for bioremediation.

202. CO_2 fertilization has increased crop yields around the world much more than any decreases. (Ex. 216, Mendelsohn Direct Report, 12; *see also* Ex. 200, Happer Direct, 10-12; Ex. 202, Happer Direct, Ex. 2 (Report), at 10-11; Ex. 206, Happer Surrebuttal, 18-21). "Greening has increased despite other potential obstacles such as wildfires, disease, pest outbreaks, demonstrating a robustness even if other negative climate changes are assumed to occur." (Ex. 235, Bezdek Surrebuttal, 32:1-3).

203. Mild warming also benefits people by reducing winter mortality and winter heating bills. (Ex. 206, Happer Surrebuttal, 10:9-13; Ex. 207, Lindzen Direct, 7:8:-26).

204. The only witnesses in this proceeding who have published in the area of carbon fertilization are Drs. Mendelsohn and Reich. (*See* Mendelsohn Surrebuttal at 2:7-5:1; Ex. 266, Emily B. Peters, et al., *Potential Climate Change Impacts on Temperature Forest Ecosystem Processes*, 43 Can. J. For. Rsch. 939 (2013) ("Reich Article"), at 946).

205. Dr. Reich, the CEOs' witness, agreed that there is a CO_2 fertilization effect (Reich, 5 Tr. at 37:10-11) and that increased levels of CO_2 can lead to increased crop and forest productivity. (*Id.* at 37:15-17). A study he co-authored concluded that: "Our results suggest that, with rising CO_2 and without changes in forest type, average regional productivity [in the Great Lakes area] could increase from 67% to 142% . . . . Increased productivity was almost entirely driven by CO_2 fertilization effects . . . ." (Ex. 266, Reich Article, at 939). He confirmed this at the hearing, stating that "from 67 percent to 142 percent, that's almost a doubling of the forest regional productivity." (5 Tr. at 39:4-6).

The study further found that "[r]educed stomatal conductance to water value is also well-documented under elevated CO_2, with little evidence of acclimation." (Ex. 266, Reich Article, at 939). Dr. Reich testified that "what this is saying is that plants will have their stoma, which are openings on the leaves through which the water vapor escapes, slightly more closed under higher CO_2." (5 Tr. at 56:10-13). In layman's terms, trees lose less water and thereby become more drought-resistant. The study noted "the important role that CO_2 fertilization plays in allowing forests to overcome warming-induced drought stress through increased water-use efficiency." (Ex. 266, Reich Article, at 946). Dr. Reich agreed with the statement that "the presence of CO_2 is important in this model and is shown to be of benefit in this model." (5 Tr. at 58:21-23).

206. More plant growth means a greater carbon sink, which reduces the degree to which more emissions drive higher concentrations, and also reduces the fluctuations in temperature.

207. Underestimating carbon fertilization may be one factor in climate models running hot as well. (Ex. 235, Bezdek Surrebuttal, 40:18-43:6).

208. The weight of peer-reviewed evidence shows that any warming since preindustrial times has been a net benefit to society, including through increased agricultural and ecosystem productivity and carbon fertilization. Empirical evidence shows that the magnitude of global benefit to date is slightly higher than the magnitude of global loss to date. The immediate impact of a warmer, wetter and carbon dioxide enriched environment is likely to be beneficial from 1.5°C to 2°C above preindustrial levels. (Ex. 216, Mendelsohn Direct, Ex. 2 (Report), at 14).

209. Dr. Bezdek also noted that the best available measure for estimating CO_2 damages in resource proceedings should consider both the benefits and the costs of CO_2. He testified that all available scientific evidence supports the general concept of a CO_2 fertilization effect. Doubling of the atmospheric CO_2 content above the current level will increase the productivity of most herbaceous plants by about one-third. The total economic value of the CO_2 benefit for 45 crops cumulatively totaled $3.2 trillion, 1961-2012, and is forecast to total nearly $10 trillion, 2012 – 2050.

210. Fossil fuels are essential for world economic growth, and significant CO_2 emission reductions will be associated with significant reductions in economic growth. This is due to the higher costs and decreased reliability of alternate forms of energy including wind and solar.

211. The benefits of CO_2 emissions in terms of economic growth exceed the costs (as estimated by the IWG) by the following ratios:

- From 180:1 to 250:1 through year 2040, using a 5% discount rate;
- Approximately 70:1 through year 2040, using a 3% discount rate; and
- Approximately 50:1 through year 2040, using a 2.5% discount rate.

4. Medical Impacts Will be Lessened by Any Warming

212. Proponents of the FSCC argued that CO_2 as a traditional pollutant that causes various health effects.

213. The relationship between CO_2 and respiratory problems is illusory, however. Instead, proponents of the FSCC are attempting to blame CO_2 for unproved harms threatened by other pollutants that are already regulated.

214. As far as inclusion in IAMs is concerned, the potential for adverse health effects is already included in the DICE damage function. (Ex. 220, Mendelsohn Surrebuttal, 5:14). Dr. Mendelsohn points out that the IAMs as they were used by the IWG overestimate adverse human health effects by undercounting the benefits of mild warming and both adaptation and mitigation that will take place. (*Id.* at 5:15-20).

215. AR5 found that "[t]he air pollution response to climate-driven changes in the biosphere is uncertain as to sign . . . ." (Ex. 405, AR5, at 999-1000). That means AR5 found that it could not determine whether climate change would be a benefit or cost with respect to health effects.

216. In general, studies of air quality cannot dependably attribute the changes to anthropogenic emissions. (*Id.* at 1000). Ultimately, **AR5 gives "no confidence level" to overall impact of climate change on particulate levels and distributions**. (*Id.* at 1001). Further, "[t]here is high confidence that globally, warming decreases background surface ozone" (*id.* at 24) and "[f]or PM2.5, climate change may alter natural aerosol sources as well as removal by precipitation, but no confidence level is attached to the overall impact of climate change on PM2.5 distributions." (*Id.*).

217. "In summary, declining AOLD in Europe and North America is corroborated by *very likely* downward trends in ground-based *in situ* particulate matter measurements since the mid-1980s. Robust evidence from around 200 regional background sites with *in situ* ground based aerosol measurements indicates downward trends in the last two decades of PM2.5 . . . ." (*Id.* at 178-80 (emphasis in original)).

218. The evidence shows that mild warming will reduce asthma. Daily mean temperature correlates negatively with hospital admissions for respiratory problems. (Ex. 206, Happer Surrebuttal, 22:11-17). Mild warming would alleviate the problems caused by cold weather, which are a greater respiratory threat than heat. (*Id.* at 22:18-23:2).

219. Warming will also increase resistance because of the wider variety of pollens and microbes available. (*Id.* at 23:3-5).

220. Also, insofar as asthma and respiratory illness correlate with poverty, regulatory policies that increase the cost of energy would worsen respiratory health. (*Id.* at 24:9-12).

221. Cold is a worse threat to human health in general. (*Id.* at 23:6-24:8).

222. Dr. Bezdek testified that "there is a large peer-reviewed, scientific literature" showing that "global warming would reduce, not increase, human mortality and disease." (Ex. 235, Bezdek Surrebuttal, 20:5-8). Dr. Bezdek cited 47 articles supporting the argument that mild warming will be on balance beneficial for humans health-wise. (Ex. 231, Bezdek Compendium of Scientific Literature on Climate Change, 107-114).

223. There is insufficient evidence that CO_2 emissions will increase adverse health effects.

F. Step Six: The Discount Rate

224. Last, an IAM must project the output from the five previous steps (and the inherent uncertainty in each) into the future and then discount those impacts to present values.

225. Dr. Hanemann described the steps the IWG took to discount the IAM output. (Ex. 800, Hanemann Direct 46:21-23, 53:5-14).

226. All methods of discounting make broad generalizations about risk aversion, concern for the future, and growth effects, each of which is subject to uncertainty.

227. The discount rate is one of the central variables to the calculation of a social cost of carbon and, as it was in 1997, remains a very controversial input to an IAM. (Ex. 600, Martin Direct, 19:1-2).

1. IWG Did Not Follow OMB Guidance When Setting the Discount Rate

228. Federal agencies are required to follow OMB Circular A-4 in a regulatory impact analysis. (Polasky, 1 Tr. 148:8-11). OMB Circular A-4 directs using 3 and 7 percent discount rates. (Ex. 417, OMB Circular 4-A, 33-34). OMB Circular A-4 instructs federal agencies that "[f]or regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent." (*Id.* at 34). OMB Circular A-94 (Oct. 29, 1992) ("Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs") is to the same effect: "Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent."

229. Dr. Mendelsohn warned that using an artificially low discount rate for the FSCC would cause distorting effects:

> The IWG argues that policy makers can choose whatever discount rate pleases them. However, if policy makers choose one discount rate for greenhouse gases and another discount rate for every other public investment, they are implicitly arguing that climate change should have a different "price of time". There is no theoretical support for this idea. If a lower discount rate is used for greenhouse gases than other investments, policy makers are effectively arguing that greenhouse gas mitigation should have a lower rate of return than other public investments in national

> security, health, education, safety, and infrastructure. It is not at all clear why this is socially desirable.

(Ex. 216, Mendelsohn Direct Report, 17).

230. Dr. Polasky conceded that 3 percent and 7 percent are the only two numbers recommended by the OMB in Circular A-4. (Polasky, 1 Tr. 93:18-20).

231. However, the IWG did not include a 7 percent discount rate in its social cost of carbon estimates. (*Id.* at 93:21-24).

232. The IWG provided little explanation for rejecting a 7 percent discount rate. (Ex. 230, Bezdek Direct Report, 110). The IWG appears to use taxes as its justification: "A measure of the post-tax risky rate for investments whose returns are positively correlated with overall equity market returns can be obtained by adjusting pre-tax rates of household returns to risky investments (approximately 7 percent) for taxes yields a real rate of roughly 5 percent." (Ex. 100, Polasky Direct, Sched. 2 (Feb. 2010 TSD), at 20). In a footnote, the IWG cites a 2006 study for its tax estimation: "In the absence of a better way to population-weight the tax rates, we use the middle of the 20 – 40 percent range to derive a post-tax interest rate (Kotlikoff and Rapson 2006)." (*Id.* at 20 n.19).

233. OMB Circular A-4, however, expressly recommends using a pre-tax discount rate. "As a default position, OMB Circular A-94 states that a real discount rate of 7 percent should be used as a base-case for regulatory analysis. The 7 percent rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy." (Ex. 417, OMB Circular A-4, p. 33).

234. Circular A-4 also expressly rejects a post-tax discount rate:

> Although market forces will push after-tax rates of return in different sectors of the economy toward equality, that process will not equate pre-tax rates of return when there are differences in the tax treatment of investment. Corporate capital, in particular, pays an additional layer of taxation, the corporate income tax, which requires it to earn a higher pre-tax rate of return in order to provide investors with similar after-tax rates of return compared with non-corporate investments. The pre-tax rates of return better measure society's gains from investment.

(*Id.*).

235. Neither the IWG nor any proponent of the FSCC explained why the IWG acted reasonably to directly contradict OMB's guidance on including 7% discount rates and ignoring post-tax rates.

236. In its response to comments, the IWG defended omitting a 7% discount rate by arguing that "[t]he use of 7 percent is not considered appropriate for intergenerational

discounting." (Ex. 101, Polasky Rebuttal, Sched. 1 (July 2015 Response to Comments), at 36).

237. Circular A-4 acknowledges the ethical problem with setting a low discount rate and therefore transferring wealth to future generations: "If one expects future generations to be better off, then giving them the advantage of a lower discount rate would in effect transfer resources from poorer people today to richer people tomorrow." (Ex. 417, OMB Circular A-4, p. 35).

238. Circular A-4 further notes that a 7% discount rate should be included even when there are intergenerational issues: "If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent." (Ex. 417, OMB Circular A-4, p. 36).

239. The IWG instead chose three lower discount rates: 2.5%, 3%, and 5%. The IWG justified the 3% rate by pointing to its use by OMB Circular A-4 to estimate the consumption rate of interest. (Ex. 100, Polasky Direct, Sched. 2 (Feb. 2010 TSD), at 23). The IWG justified the 5% rate as representing "the possibility that climate damages are positively correlated with market returns" (*id.*), but it did not include the 7% rate, which is to be used "when a regulation is expected to displace or alter the use of capital in the private sector." (*Id.* at 19). Finally, the IWG justified the 2.5% rate as representing "the concern that interest rates are highly uncertain over time" and responding to "ethical objections" to rates higher than 3%. (*Id.* at 23).

240. There is insufficient evidence to support the IWG's selection of discount rates.

2. Ethical Considerations Support a Lower Externality Value

241. The Parties proposing the FSCC suggested an artificially low discount rate was needed in order to protect "future generations."

242. However, economically productive activities that generate CO_2 also produce wealth that will benefit future generations. (Ex. 228, Bezdek Direct, 15:12-19; Ex. 230, Bezdek Direct, Ex. 2 (Report), at 7-70; Ex. 235, Bezdek Surrebuttal, 43:10-47:12).

243. OMB Circular A-4, which directs use of 3 percent and 7 percent discount rates, explains that "using the same discount rate across generations is attractive from an ethical standpoint. If one expects future generations to be better off, then giving them the advantage of a lower discount rate would in effect transfer resources from poorer people today to richer people tomorrow." (Ex. 417, OMB Circular A-4, 35).

244. Future generations will almost certainly be wealthier than the current generation. (Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), at 7:151-8:162).

245. Moreover, future generations are protected by market interest rates, which should encourage proper investments. (Ex. 220, Mendelsohn Surrebuttal, 31:13-32:4).

246. Future generations are also protected by investment in technologies and methods of adaptation and mitigation that will make society more resilient to the potential effects of climate change. People adapt to climates that have swings as much as 20°C (*id.* at 17:13-15). Future generations will be unable to adapt. Adaptation will mitigate the negative effects of climate change, including agricultural shifts, drought, sea level rise, and temperature increases. (*Id.* at 19:8-21:4).

II. THE PREPONDERANCE OF EVIDENCE SHOWS THAT MINNESOTA SHOULD NOT ADOPT THE FSCC AS AN EXTERNALITY VALUE FOR CARBON DIOXIDE.

A. Uncertainties in the IAMs Undermine The FSCC's Fitness for Use in Minnesota

247. Mr. Martin testified that "[t]he SCC is inherently uncertain and speculative," rests on "uncertain" assumptions as to future emissions, temperature change, damages, discount rates, and many other factors, and this "uncertainty builds from one step to the next." (Ex. 600, Martin Direct, 3:11-17).

248. Mr. Martin quoted Professor Robert Pindyck, an economist at the Massachusetts Institute of Technology, for the proposition that, "When it comes to the damage function, we know virtually nothing – there is no theory and no data that we can draw from. As a result, developers of IAMs simply make up arbitrary functional forms and corresponding parameter values." (Ex. 601, Martin Rebuttal, 19 n.9).

249. Mr. Martin also testified that climate sensitivity is one of the very most important uncertain parameters driving the social cost of carbon. (*See* Ex. 600, Martin Direct, 18:6-9 ("The most important uncertain parameter in this case is equilibrium climate sensitivity, or the change in temperature expected to result from a doubling of atmospheric CO_2 concentrations above pre-industrial levels.")). He explained that ESC values are highly uncertain. (*See id.* at 39:7-10 ("Most importantly, there is little agreement on equilibrium climate sensitivity – the temperature change associated with a doubling of atmospheric CO_2 concentrations above pre-industrial levels – and little empirical data on which to base this key parameter of the models.")). In fact, he quoted Professor Pindyck: "We know very little about climate sensitivity" and "over the past decade our uncertainty over climate sensitivity has increased." (*Id.* at 39:14-22).

250. Further, Mr. Martin noted that the IAMs on which the FSCC is based do not fully take adaptation into account, which could lead them to over-estimate damages. (*Id.* at 29:18-19 ("[T]he IAMs do not fully capture adaptation to climate change, which could lead them to over-estimate damages.")).

251. He added that "[t]he Federal SCC methodology aggregates and averages the SCC results regardless of IAM and socioeconomic/emissions scenario, obscuring their underlying differences and the broad range of results." (*Id.* at 39:2-5).

252. In addition, Mr. Martin explained that the choice of discount rate "is highly controversial and has a greater effect on the SCC than any other single variable." (*Id.* at 19:1-2).

253. All Parties acknowledged the level of uncertainty involved. (*See, e.g.,* Polasky, 1 Tr. 90:4-11 ("Uncertainties are inherent in the task of developing an externality value for CO_2."); Martin, 3B Tr. 132:18-20 ("The problem remains highly uncertain. I think all the parties have acknowledged that . . . ."). Dr. Hanemann and Dr. Dessler also admitted that uncertainty has increased. (Ex. 801, Hanemann Rebuttal, 32:6-7; Dessler, 3A Tr. 70:1-12). In its calculation of the FSCC, the IWG "effectively assumed that uncertainty never gets resolved. [The IWG] assume[d] society is just as uncertain in 2300 about the various parameters of the model as it is today." (Ex. 214, Mendelsohn Direct, 16:21-23). As Dr. Mendelsohn testified, the effect of greenhouse gases "on temperature is uncertain," "the impact of temperature change on the economy and nonmarket sectors is uncertain," and "it is uncertain how effects will be distributed across the planet": "uncertainty haunts the measurement of climate damage." (Ex. 220, Mendelsohn Surrebuttal, 30:19-31:2).

254. Dr. Dessler, an expert for the CEOs, testified as to increases in uncertainty between AR4 and AR5: "I think there were additional studies that came out. I don't think that improved our understanding, it added to the range. In fact, if anything, it added some uncertainty." (3A Tr. 49:12-16).

255. The Parties' statements reflect the widespread recognition in the academic literature that the FSCC is essentially an arbitrary number. Professor Robert Pindyck, an economist at MIT, has written that the calculation of the FSCC using the IAMs is "close to useless" and "misleading." (Ex. 228, Bezdek Direct, 26:27-27:6; Ex. 230, Bezdek Direct Report, at 95). Professors Jonathan Masur and Eric Posner, economic experts at the University of Chicago, stated: "We believe that agencies conducting cost-benefit analysis cannot use the IWG's SCC. The SCC is highly arbitrary. Even the choice of which of the IWG's four SCCs to use is arbitrary." (Ex. 233, Bezdek Rebuttal Report, 79). A study for the National Academies of Science found that the SCC assessment suffers from **uncertainty, speculation, and lack of information about future emissions, the effects of past and future emissions on the climate system**, the impact of changes in climate on the physical and biological environment, and the translation of these environmental impacts into economic damages. (*Id.* at 77-78).

256. In sum, as Mr. Martin testified:

> The SCC is inherently uncertain and speculative. Deriving the SCC relies on making assumptions – from now until the year 2300 – about population and GDP growth, the emissions that result from that growth, the temperature change that results from emissions, the damages that result from temperature change, and the appropriate discount rates to apply to those damages. Each of these assumptions is uncertain, and uncertainty builds from one step to the next.

(Ex. 600, Martin Direct, 3:11-17).

B. The IWG Improperly Manipulated the IAMs

257. The IWG changed critical inputs—emissions rates, discount rates, climate sensitivity, GDP growth, and other factors—in all three models in favor of the IWG's non-peer-reviewed assumptions. (*Id.* at 16:7-15; Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), at 4:63-5:97; Ex. 220, Mendelsohn Surrebuttal, 3:3-9, 17:6-21:4, 27:5-28:14; Mendelsohn, 3B Tr. 59:5-18).

258. The IWG changed the structure of the DICE model and ran the FUND model in such a manner that its creator could not replicate the high results. (Ex. 214, Mendelsohn Direct, 16:7-15; Ex. 238, Tol Rebuttal, Ex. 2 (Report), 6:115-7:133). Dr. Mendelsohn testified that the "IWG made substantial changes to IAMs that altered their internal integrity." (Ex. 261, Mendelsohn Opening Statement, 3). He testified that the IWG "made many mistakes." (Ex. 214, Mendelsohn Direct, 15:17).

259. As Dr. Mendelsohn opined: "The IWG has vastly overstated the social cost of carbon. It states that it uses the DICE and FUND model to calculate the social cost of carbon, but it really has substituted its own unfounded assumptions for both models." (*Id.* at 17:9-11).

260. Dr. Hanemann testified that today, calculation of the social cost of carbon should use updated versions of the IAMs: "I think this was sort of reasonable in 2010, I think it made sense in 2013 not to make any major changes. The models have changed, so you'd want to use the newer version of DICE and FUND and PAGE." (2B Tr. 93:9-13.) In this proceeding, the newest versions of DICE and FUND were presented by Drs. Tol and Mendelsohn.

1. The IWG's Improper Use of the IAMs Corrupted the Models and Created Internal Inconsistencies

261. The IWG made significant changes to the model inputs and DICE's structure, manipulation it said was necessary to "standardize" the three models.

262. This manipulation can create internal inconsistency in a model. (Polasky, 1 Tr. 94:19-24).

263. "There is value in having internal consistency in a model, something which is lost when using assumptions different than what the model dictates." (Ex. 104, Polasky Surrebuttal, 21:20-21). Corrupting a model to "standardize it" may cause it to run differently than initially constructed and not how it was intended. (Polasky, 1 Tr. 95:12-20). "Standardizing" a model can create error. (*Id.* at 96:18).

264. Dr. Mendelsohn testified that the IWG "ruined both the FUND model and the DICE model by harmonizing the inputs." (3B Tr. 38:9-11). 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).

265. The IWG's manipulation resulted in error, evidenced by the fact that the IWG's assumptions are not consistent with each other. (Ex. 214, Mendelsohn Direct, 16:7-13). For example, different GDP paths imply different future interest rates. (*Id.*). However,

because the IWG failed to take into account the effect of different GDP paths on the interest rates used in its models, the interest rates used by the IWG were not consistent with their assumptions about GDP. (*Id.*).

266. By running the DICE model in simulation mode, rather than optimization mode, the IWG removed the assumptions in DICE that generate different interest rates depending on the growth of income per capita (GDP and population). As Dr. Mendelsohn testified, DICE is very carefully calibrated to predict emissions depending on GDP and an observed decay rate and emission per unit of GDP. These assumptions are overridden in the IWG analysis. Emissions and GDP are assumed to be independent by the IWG.

267. The State Agencies admit that "DICE is formulated and solved as an 'optimization' model" (State Agency Br. at 18) and that "the IWG removed the optimization performed by DICE." (*Id.* at 27). When it ran DICE as a simulation model, the IWG made a critical conceptual error because it did not measure the FSCC by equating marginal cost and marginal damage, as economists do with every other damages cost model. (Ex. 261, Mendelsohn Opening Statement, 2).

268. Neither the State Agencies nor the CEOs offer any evidence to support the IWG's deconstruction of the DICE model.

269. Moreover, the model corruption by the IWG was inconsistent with the peer-reviewed models and caused the models to produce unreliable results. (Ex. 600, Martin Direct, 39:2-5 ("The Federal SCC methodology aggregates and averages the SCC results regardless of IAM and socioeconomic/emissions scenario, obscuring their underlying differences and the broad range of results.")).

270. The IWG also erred in 2015 by not using the updated version of DICE. The agencies explained the differences from Dr. Mendelsohn's SCC estimates were due to his use of a newer version of DICE: "And, whereas the IWG 2013 TSD Report used DICE 2010, Dr. Mendelsohn used DICE 2013." (State Agencies' Br. at 71).

271. The IWG's 2015 TSD confirms that the current FSCC is based on the outdated 2010 version of DICE. (Ex. 601, Martin Rebuttal, Schedule 1 (IWG July 2015 TSD), at 5).

2. <u>The IWG Arbitrarily Created, Selected, and Extrapolated Emissions Rate Scenarios</u>

272. The IWG changed the model input for future CO_2 emissions rates.

273. The EMF-22 modeling exercise consisted of ten emissions models. (Ex. 100, Polasky Direct, Sched. 2 (Feb. 2010 TSD), at 15). To prepare its estimates of the FSCC, the IWG used five emissions models: four of the EMF-22 models, and a fixed scenario created by the IWG that averaged factors from the other four models. (*Id.*).

274. The choice to use only four models has not been peer-reviewed. (Polasky, 1 Tr. 92:16-19). The fifth scenario did not exist until the IWG invented it.

275. The EMF-22 models projected emissions to the year 2100. (Ex. 100, Polasky Direct, Sched. 2 (Feb. 2010 TSD), at 15). However, the IWG extrapolated these emissions scenarios for 200 years, to the year 2300. (*Id.* at 24).

276. Dr. Polasky was not aware whether the IWG consulted with the EMF-22 authors and did not know how the IWG did the extrapolation. (Polasky, 1 Tr. 173:16-174:2). No testimony was presented that independently justified the IWG's emissions scenario decisions.

277. With respect to DICE, future emission scenarios are already embedded in the model itself, and all equations inherent in the model depend on this function. As Dr. Mendelsohn stated, "DICE is very carefully calibrated to predict emissions depending on GDP and an observed decay rate in emission per unit of GDP. These assumptions are overridden in the IWG analysis. Emissions and GDP are assumed to be independent." (Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), at 5).

3. The IWG Relied on Outdated IPCC Climate Sensitivity Estimates

278. The IWG also changed the input for climate sensitivity.

279. The IWG used a probability distribution based on AR4.

280. AR4 used the following definitions for its estimates:

> Where uncertainty in specific outcomes is assessed using expert judgment and statistical analysis of a body of evidence (e.g. observations or model results), then the following likelihood ranges are used to express the assessed probability of occurrence: *virtually certain* >99%; *extremely likely* >95%; *very likely* >90%; *likely* >66%; *more likely than not* > 50%; *about as likely as not* 33% to 66%; *unlikely* <33%; *very unlikely* <10%; *extremely unlikely* <5%; *exceptionally unlikely* <1%.

(Ex. 268, AR4, at 27).

281. Using these definitions, AR4 estimated climate sensitivity with the following probabilities [added in brackets]:

> Progress since the TAR enables an assessment that climate sensitivity is *likely* [>66%] to be in the range of 2 to 4.5°C with a best estimate of about 3°C, and is *very unlikely* [<10%] to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded, but agreement of models with observations is not as good for those values.

(*Id.* at 38).

282. The IWG centered its probabilistic distribution (the "Roe and Baker" distribution) on AR4's "best estimate" of 3°C. (Ex. 100, Polasky Direct, Sched. 2 (IWG Feb. 2010 TSD), at 13).

283. As in AR4, two-thirds of the probabilities used by the IWG fell between 2 and 4.5°C. (*Id.*). However, the IWG included far fewer probabilities below 1.5°C than it should have based on AR4. (*Id.*). Instead of 10 percent of probabilities falling at 1.5°C and below, only 1.3 percent did. (*Id.*). In fact, the 10th percentile was nearly at 2°C (10th percentile = 1.91). (*Id.*).

284. The IWG admitted that its distribution strayed from AR4:

> Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5°C is almost 99 percent, is not inconsistent with the IPCC definition of 'very likely' as 'greater than 90 percent probability,' it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC.

(*Id.* at 14).

285. AR5 used the following definitions for its estimates:

> In this Summary for Policymakers, the following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely: 95–100%, more likely than not >50–100%, and extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g., very likely (see Chapter 1 and Box TS.1 for more details).

(Ex. 405, AR5, at 4 n.2).

286. Using these definitions, AR5 estimated climate sensitivity with the following probabilities [added in brackets]:

> Equilibrium climate sensitivity is *likely* [66–100%] in the range 1.5°C to 4.5°C (*high confidence*), *extremely unlikely* [0–5%] less than 1°C (*high confidence*), and *very unlikely* [0–10%] greater than 6°C (*medium confidence*). The lower temperature limit of the assessed *likely* range is thus less than the 2°C in the AR4, but the upper limit is the same.

(*Id.* at 16).

287. AR5 also added that no best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies. (*Id.* at 16 n.16).

288. As noted above, although AR5 no longer included a "best estimate" of climate sensitivity, the IWG did not change its probability distribution in the updates released after AR5. (Ex. 101, Polasky Rebuttal, Sched. 2 (July 2015 IWG Response to Comments), at 12).

289. Thus, the Roe and Baker probability distribution used by the IWG (based on AR4) is outdated because it does not reflect newer, better science that shows a better fit "in the lower part of the likely range." (Ex. 405, AR5, at 1111).

290. Under AR5, two-thirds of the distribution should have fallen between 1.5°C and 4.5°C, rather than the IWG's 2.0°C to 4.5°C range. (*Compare* Ex. 405, AR5 at 16 *with* Ex. 100, Polasky Direct Schedule 2 (Feb. 2010 TSD, 13). The lowest bound also should have changed. Under AR5, five percent of the distribution should have fallen at 1.0°C or lower, rather than the IWG's 5th percentile of 1.72. (*Compare* Ex. 405, AR5 at 16 *with* Ex. 100, Polasky Direct Schedule 2 (IWG Feb. 2010 TSD, 13).

291. Including more distributions between 1.5°C and 2.0°C and more distributions at 1.0°C and below **would have shifted the distribution down and resulted in lower social cost of carbon estimates**.

4. The IWG Arbitrarily Selected Discount Rates Inconsistent with the Models and OMB Guidance

292. The IWG also changed the inputs of discount rates.

293. As discussed above, to prepare its estimates of the FSCC, the IWG used three fixed discount rates: 2.5%, 3% and 5% per year. (Ex. 100, Polasky Direct Sched. 2 (Feb. 2010 TSD), at 23).

294. As designed, DICE internally calculates the discount rate to be consistent with growth in GDP per capita. (Ex. 214, Mendelsohn Direct, 12:1-3). However, the IWG's manipulation of DICE mandated a fixed discount rate that divorced the interest rate from the path of GDP, which is inconsistent with the DICE model and economic theory. (Ex. 220, Mendelsohn Surrebuttal, 30:6-7). Thus, "[t]he IWG did not run the DICE model as it was originally designed." (*Id.* at 30:7-8).

295. Similarly, the IWG did not use the FUND model as it was designed. The FUND model incorporates the Ramsey Rule, under which the discount rate varies with economic growth, rather than the fixed discount rate approach used by the IWG. Dr. Richard Tol, the author of FUND, testified that the Ramsey Rule is "a more appropriate choice." (Ex. 238, Tol Rebuttal, Ex. 2 (Report), at 2).

296. The IWG's approach puts a premium on the impacts in countries that grow faster than the United States. (*Id.* at 5). For instance, using the FUND scenario as used by the IWG,

impacts in China are weighted 46% to 87% higher than impacts in the United States. In other words, a $1 loss in the United States is counted as $1; but a $1 loss in China is counted as $1.46 to $1.87. (*Id.* at 6).

297. A top group of economic experts believe that the correct way to value intergenerational discounting is to use the Ramsey Rule, adjusting the downward discount rate as the rate of income (consumption) growth changes over time. (Ex. 218, Mendelsohn Surrebuttal, 29). The choice of discount rate and the projection of income cannot be treated independently.

298. Even though the IWG itself assumes that income growth rates decline over time, the FSCC does not use a declining discount rate. (*Id.* at 29-30). The IWG assumes that income, population and interest rate are all independent of each other. While accepted economic theory holds that interest rates are tied to growth of income per capita, the IWG abandons this assumption and de-links income growth and interest rates by setting a constant interest rate (discount rate) to apply over the next 300 years. (Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), at 5).

299. The IWG also made changes to the models themselves.

5. IWG Ran DICE as a "Simulation Model" and Assumed No Mitigation

300. DICE is primarily designed as an optimization model designed to determine the optimal level of mitigation that equates marginal cost to marginal damage at every moment. (Ex. 214, Mendelsohn Direct, 5:24-6:4; Ex. 220, Mendelsohn Surrebuttal, 21:6-24:2).

301. However, the IWG ran DICE as a simulation model rather than an optimization model. (Ex. 100, Polasky Direct, Sched. 2 (IWG Feb. 2010 TSD), at 7 n.3 ("We made two modifications to DICE to make it consistent with EMF GDP trajectories (see next section): we assumed a fixed rate of savings of 20% and we re-calibrated the exogenous path of total factor productivity so that DICE would produce GDP projections in the absence of warming that exactly matched the EMF scenarios.")).

302. Converting to a simulation approach rather than an optimization approach requires an assumption that there is no mitigation now or in the future anywhere in the world. This results in and therefore significantly overestimating the social cost of carbon. (Ex. 214, Mendelsohn Direct, 16:18-17:20; Ex. 218, Mendelsohn Rebuttal, 3:26-34; Ex. 220, Mendelsohn Surrebuttal, 17:5-18:6).

303. The IWG could have run DICE to account for mitigation, as Dr. Mendelsohn did. (Ex. 218, Mendelsohn Rebuttal, Ex. 2 (Discovery Responses) at Bates No. Peabody 000014). According to Dr. Mendelsohn, "[t]he IWG did not run the DICE model as it was originally designed." (Mendelsohn, 3B Tr. 30:7-8).

304. When it ran DICE as a simulation model, the IWG did not measure the FSCC by equating marginal cost and marginal damage, as economists do with every other damages cost model. (Ex. 261, Mendelsohn Opening Statement, 2).

6. The IWG Generated Results From FUND that Its Creator Could Not Replicate and Doubted Were Reliable

305. The author of FUND, Dr. Tol, was surprised that the IWG's estimates of the SCC using the FUND model went up substantially between 2010 and 2013. According to the way in which he ran the FUND model, the numbers went down during that time frame.

306. In 2011, FUND estimated a social cost of carbon of $8 per ton. In 2014, it was $6.60 per ton, using the IWG's parameters and estimate of climate sensitivity. (Ex. 238, Tol Rebuttal, Ex. 2 (Report), at 6:111-125).

307. "In other words," reported Dr. Tol, "**FUND as used by the FUND team shows a *lower* social cost of carbon, whereas FUND as used by the US Federal Government shows a *higher* social cost of carbon**." (*Id.* at 6:121-123 (emphasis in original)).

308. The IWG's lack of transparency prevented Dr. Tol from determining why the IWG's results differed from his results. (*Id.* at 7:128-130).

309. The IWG's results caused Dr. Tol to suspect the IWG had incorrectly operated FUND and had produced unreliable results:

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

(*Id.* at 7:127-133).

7. The IWG Relied on PAGE Even Though It Is Deeply Flawed

310. Unlike DICE and FUND, PAGE is not well-grounded in economic theory or empirical evidence. (Ex. 214, Mendelsohn Direct, 7:18-20). Unlike DICE and FUND, PAGE was not designed to optimize and is not reliable for predicting the optimal path of mitigation. (*Id.* at 7:11-12). And unlike DICE and FUND, PAGE is not a cost-benefit tool, but instead relies on a "decision analysis" approach. (Ex. 233, Bezdek Rebuttal, Ex. 1 (Report), at 38:1238-1242).

311. Further, although the IWG uses PAGE to predict global damages, PAGE was designed to focus on the European Union and not the entire world. (*Id.* at 39:1259-1261). PAGE calculates damages in the European Union and then extrapolates those damages to the rest of the world based simply on coastline length. (*Id.* at 39:1261-1264 (quoting Ex. 600, Martin Direct, 40:23-25)).

312. PAGE also includes low probability scenarios that have been debunked by climate literature. (*Id.* at 39:1276-1282).

313. Finally, PAGE is a proprietary model that has been impossible for some researchers to obtain, making it the least transparent of the three models. (*Id.* at 39:1291-40:1296).

314. Lastly, even though PAGE generates substantially higher damages than DICE or FUND (Ex. 100, Polasky Direct, Sched. 2, Tables A2-A4), its results were afforded equal weight as those from DICE and FUND.

C. The IWG's Work Is Not Transparent Or Peer Reviewed

315. Dr. Polasky acknowledged that "[s]ometimes governments make mistakes" and that it is possible that mistakes were made by the IWG. (Polasky, 1 Tr. 156:13-16). Dr. Hanemann admitted the model codes were "susceptible to error." (Hanemann, 2B Tr. 69:12-17). Dr. Polasky conceded that mistakes could be made in operating the models. (Polasky, 1 Tr. 72:11-13).

316. In general, the IWG's work has not been transparent and its many significant changes to the model inputs and model structure have not been peer-reviewed. (*Id.* at 109:5-9; Martin, 4 Tr. 213:9-24; Ex. 232, Bezdek Rebuttal, 45:1466-1478).

317. Despite this risk of error, the public does not know the identity of the people who made the changes or their expertise to do so.

318. With just a few exceptions, the IWG's members are unknown and their credentials are unknown. (Polasky, 1 Tr. 87:19-21, 87:24-88:1, 112:13-16, 113:4-9, 156:4-9).

319. As Mr. Martin testified, "Most of the SCC development process has been a closed interagency process, with[] virtually no public input or scientific peer review." (Ex. 600, Martin Direct, 14:25-15:2). In addition to a lack of peer review, the IWG's model alterations have not been validated. (Polasky, 1 Tr. 81:25-82:1, 83:6).

320. The IWG did not involve the authors of the DICE and FUND models when the IWG manipulated these models to issue the FSCC. (*Id.* at 97:14-17, 98:3-8).

321. The IWG responded to public comments on the FSCC process only in July 2015, long after it published its estimate of the FSCC. Moreover, of the approximately 140 sets of public comments received, the IWG adopted none.

D. The Models Fail to Disaggregate the Effects of Human-Induced Warming and Natural Variability

322. As testified by Dr. Tol, "current models do not disaggregate the effects of human-induced warming and natural variability." (Ex. 238, Tol Rebuttal, Ex. 2 (Report), at 9:187-188). Thus, "[c]urrent estimates of the social cost of carbon are based on the assumptions that short term natural climate variability is irrelevant in that it averages out, and that there is no long term natural climate variability." (*Id.* at 9:183-185).

323. To the contrary, however, every indication shows that short-term natural variation is at least as large as any anthropogenic contribution. (Ex. 207, Lindzen Direct, 3:25-4:6; Ex. 209, Lindzen Direct, 7:209-225, 8:266-280).

324. Expanding consideration of natural variation to longer periods of time only diminishes the ability to attribute the effects to humans. (Ex. 213, Lindzen Surrebuttal, 22:1-9).

325. Moreover, the evidence does not show how to disaggregate any harms caused by Minnesota utility emissions from harms caused by other sources of CO_2—including non-utility sources in Minnesota (such as mobile sources), as well as national and worldwide sources.

326. CO_2 is the byproduct of virtually all human activities. *See Am. Elec. Power Co. v. Connecticut*, — U.S. —, 131 S. Ct. 2527, 2538 (2011) ("After all, we each emit carbon dioxide merely by breathing."). Atmospheric CO_2 is the intermingled result of all human activity and Mother Nature. CO_2 is different in kind from traditional air emissions because it is not unique to the regulated source. Yet the Parties advocating adoption of the FSCC assume that no other source will engage in mitigation and the SCC should be computed as though Minnesota utilities and ratepayers must bear all of the burden of worldwide CO_2 emissions.

327. The Parties have further failed to prove that the supposed "pollution" actually causes the damage. As Dr. Tol has explained, it is "**rather difficult to estimate the climate effect of carbon dioxide emissions, and indeed that effect varies over time and is contingent on human choices within the domain of climate policy (*e.g.*, emissions, land use) as well as outside that domain (*e.g.*, fertilization)**." (Ex. 238, Tol Rebuttal, Ex. 2 (Report), at 11:239-242).

328. For example, even if climate change increased the incidence of river flooding, damages from flooding are also traceable to decisions to build structures in flood plains, decisions not to build levees or floodwalls, and so on. Yet **the SCC automatically attributes all conceivable damages to CO_2 emissions**.

III. ADOPTION OF THE FSCC WILL FORCE LEAKAGE

329. Leakage is an increase in the emissions of other states that is likely to occur when a single state implements a pollution regulation that is very different from its neighbors. (Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), 4:57-61; Ex. 220, Mendelsohn Surrebuttal, 32:16-17).

330. Minnesota's imposition of a high externality value could result in neighboring states exporting lower cost electricity to Minnesota while increasing electricity generation from coal power plants in their states. (*Id.* at 3:53-4:58).

331. The Proponents of the FSCC do not deny the Minnesota's imposition of a high externality value could result in neighboring states exporting lower cost electricity to Minnesota while increasing electricity generation from coal power plants in their states.

(Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), 3:53-4:61; Ex. 220, Mendelsohn Surrebuttal, 32:16-17).

332. Utilities with power plants in neighboring states could benefit because they would have cheaper electricity to sell to Minnesota. (Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), 4:55-57; Ex. 220, Mendelsohn Surrebuttal, 32:18-33:2). Surrounding states could benefit by luring businesses to their states to avoid the high price of carbon in Minnesota. (Ex. 214, Mendelsohn Direct, 5:12-16).

333. Dr. Mendelsohn testified that the "greater the difference between the price of carbon in Minnesota and the rest of the region, the more leakage one should expect." (*Id.* at 33:15-16).

334. Because of its effect on overall emissions, the social cost of carbon must be adjusted for leakage. (Ex. 220, Mendelsohn Surrebuttal, 33:9-11).

IV. ADOPTION OF THE FSCC WILL BURDEN MINNESOTA WITH NO RESULTING BENEFITS

335. None of the 11 regions and countries that have adopted carbon prices has chosen the IWG's estimate. (Ex. 261, Mendelsohn Opening Statement, at 4).

336. Mild warming will benefit Minnesotans by longer growing seasons, increased crop productivity, and reduced winter heating costs. (Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), at 3:40-43).

337. Even without accounting for leakage, reducing Minnesota's emissions will make virtually no impact on global emissions and temperatures. (Ex. 214, Mendelsohn Direct, 5:4-7).

338. However, Minnesota customers would pay higher electricity rates. (Martin, 4 Tr. 17:12-14, 17:24-18:1). Electricity could be more expensive for low-income ratepayers, translating into a lower standard of living for those people who have to spend more of their income on electricity. (*Id.* at 18:16-20, 234:19-235:3). Jobs could be lost and investments could be stranded. (Martin, 3B Tr. 159:21-160:2, 4 Tr. 25:3-8).

V. ANY EXTERNALITY VALUE ADOPTED BY MINNESOTA SHOULD BE MINNESOTA-SPECIFIC

339. There is no provision in Minnesota law expressly directing or authorizing the Commission to take global effects into account in its calculation of social costs.

340. Further, as ALJ Klein observed, "One state, especially a state like Minnesota, cannot make much of a difference. In fact, even if Minnesota's utilities stopped emitting any carbon dioxide, the global problem would be virtually unaffected by our act, except as our action, and similar actions of others in this country and abroad, cause national governments to take the kind of actions that will make a difference." (Findings of Fact, Conclusions, Recommendation, and Memorandum, at 17 (Mar. 22, 1996) [hereafter, "1996 ALJ Recommendation"], p. 37).

341. A Minnesota policy that considered global costs would demand a dramatic shift in all state policies, including state poverty programs. (Ex. 400, Gayer Direct, 9). Similarly, it would suggest that a policy that leads to the relocation of businesses and economic output from Minnesota to other states or countries should not be considered a cost of the policy, and in all likelihood (depending on which state or country the activity is shifted to) should be considered a benefit. (*Id.*).

342. The Parties proposing the FSCC did not propose a Minnesota-specific SCC.

343. Further, Minnesota's geographical location means that it would be a net beneficiary of climate change. (Ex. 214, Mendelsohn Direct 4:15-5:16; Ex. 216, Mendelsohn Direct, Ex. 2 (Report), at 5, 14; Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), at 3:40-47; Ex. 220, Mendelsohn Surrebuttal 5:6-11, 6:10-22, 26:9-18; Ex. 204, Happer Rebuttal, Ex. 1 (Report), at 4:60-71; Ex. 228, Bezdek Direct, 3:18-20, 6:3-7:2; Ex. 235, Bezdek Surrebuttal, 52:4-13). Even if the FSCC were extrapolated to Minnesota, it would amount to 0.4 percent of the global value, suggesting extremely small damage estimates, with a high-end estimate of $0.37 per metric ton of CO_2 (2010 damage value in 2007 dollars). (Ex. 400, Gayer Direct, 10).

VI. QUALIFICATIONS OF WITNESSES

344. **The witnesses presented by Peabody had more experience** with the IPCC, with the IAMs involved in calculating the FSCC, and with the gathering of primary observational data than any of the other Parties.

345. Dr. Richard Tol is the creator of the FUND model—one of the three models from which the IWG constructed the FSCC—and has been active in the IPCC since 1994, longer than any other witness in this proceeding. (Ex. 238, Tol Rebuttal, Ex. 2 (Report), 2:4-21). He is also a regular participant in the Stanford Energy Modeling Forums, the group that produced emissions models on which the IWG based the FSCC. (*Id.* at 1:21-22).

346. Dr. Robert Mendelsohn is the Edwin Weyerhaeuser Davis Professor at the School of Forestry and Environmental Studies at Yale University and has spent the past 22 years studying how to measure the benefits of mitigating greenhouse gas emissions, including authoring 63 peer-reviewed articles and eight books. (Ex. 214, Mendelsohn Direct, 1:15-20). He is an expert regarding the DICE model (developed by his colleague William Nordhaus at Yale). (*Id.* at 6:6-10, 7:22-10:26). Mendelsohn has published peer-reviewed work in which he operated an IAM (the DICE model).

347. Dr. Roy Spencer received the NASA Exceptional Scientific Achievement Medal and the Special Award from the American Meteorological Society for "developing a global, precise record of earth's temperature from operational polar-orbiting satellites, fundamentally advancing our ability to monitor climate"; cited in the text of and referenced in endnotes in AR5 for his satellite data, which was used in AR5. (*See* Ex. 405, AR5, at 194-196, 591). His temperature measurement data constitutes one of the foundations upon which the AR5 based its analysis.

348. Dr. Richard Lindzen of Harvard and MIT began his work with the IPCC as a contributing author in 1995, making his involvement almost as long as Dr. Tol's. Dr. Lindzen was a lead author of Chapter 7 (Physical Climate Processes and Feedbacks) of the Working Group I Report for the Third Assessment Report in 2001. (Ex. 207, Lindzen Direct, 8:6-8). His scholarly work is still depended on by the IPCC, cited extensively in the text and endnotes of AR5. (*See* Ex. 405, AR5, at 402 (Box. 5.2), 589, 591, 922-924, 925 (Fig. 10.20), 1110 (Box 12.2 (Fig. 1))).

349. Dr. William Happer is the former chair of the physics department at Princeton University and chair of the University Research Board, Princeton's equivalent of Vice President for Research. He has published more than 200 peer-reviewed scientific papers. (Ex. 201, Happer Direct, Ex 1 (CV), at 1). He has done research in atmospheric physics and other areas. He is well known for his invention of the "sodium guide star" concept, used in all modern ground-based telescopes to compensate for deleterious effects of atmospheric turbulence on astronomical observations. (*Id.*). He is very familiar with the climate models used by the IPCC and funded some of the early models when he was Director of Energy Research at the United States Department of Energy from 1990 to 1993, where he supervised a research budget of some $3.5 billion, including environmental and climate science. (*Id.*; Happer, 2B Tr. 18:16-22). Neither the State Agencies nor any of the other proponents of the FSCC challenged his qualifications or sought to cross-examine him on any issue regarding his knowledge of climate science. Indeed, Dr. Happer (along with Dr. Lindzen) is a member of the National Academy of Sciences, which the State Agencies describe as "an honorific society, membership of which is considered one of the highest academic honors accorded." (State Agencies Br. at 7).

350. Dr. Roger Bezdek was one of the founders of the Renewable Energy Program at the United States Department of Energy and served as a consultant to EPA, the National Science Foundation, and Al Gore. (Ex. 228, Bezdek Direct, 1:26-2:2). He has published six books and more than 300 articles, including peer-reviewed scholarship in 91 different publications, including *Science* and *Nature*. (*Id.* at 1:10-12; Ex. 235, Bezdek Surrebuttal, 66:8-71:5). He serves as an editorial board member and peer reviewer for multiple publications. (Ex. 228, Bezdek Direct, 1:12-14).

351. Dr. William Wecker has served on the faculties of the University of Chicago, the University of California-Davis, and Stanford University. He has served as an associate editor for the *Journal of the American Statistical Association* for four years and the *Journal of Business and Economic Statistics* for 18 years. (Ex. 240, Wecker Rebuttal, 1:19-22). He has published 35 peer-reviewed articles on statistical methods. (Ex. 241, Wecker Rebuttal, Ex. 1 (CV), at 2-4).

352. **None of the witnesses for parties promoting the FSCC (or values based on the FSCC) has ever operated an IAM, none has designed an IAM used by the IWG to generate the FSCC, none has experience with the IPCC comparable to that of Drs. Tol or Lindzen, and none has ever received awards comparable to those bestowed on Peabody's witnesses**.

353. Dr. Abraham is not a professor of climate science and became a full professor of thermal science only two years ago. (3B Tr. at 69:1-11). His work has never been cited by the IPCC. (*Id.* at 71:17-18). His "peer-reviewed" work was published in "a philosophy journal." (*Id.* at 73:16). He was one of 2,000 reviewers for AR5 but was not selected to edit. (*Id.* at 69:20-70:25). Before AR5, he had not worked in any previous IPCC reports. (*Id.* at 71:12-16).

354. Dr. Dessler participated in the U.S. government's review of the Third Assessment Report ("TAR"), which was released in 2001, but not the IPCC drafting or editorial process, and his participation in TAR has been "wiped from [his] memory." (Dessler, 3A Tr. 19:23-25, 93:2-3). He has not participated in either AR4 or AR5. (*Id.* at 19:24-25). He has never been selected by the IPCC as a lead author, contributing author, or editor. (*Id.* at 20:1-9).

355. Dr. Gurney was a reviewer and contributor but was not selected as an editor of the climate science section of AR5. (Gurney, 4 Tr. 149:14-150:1).

356. Dr. Hanemann never developed or operated an IAM to calculate the social cost of carbon, and did not develop a measure of the FSCC separate from the IWG's work. (Hanemann, 2B Tr. 60:11-14, 62:13-18, 64:3-5). He has not participated in Working Group 1, which focuses on the physical science aspects of climate change.

357. Dr. Polasky has also never developed or operated an IAM to calculate the social cost of carbon, and did not develop a measure of the FSCC separate from the IWG's work. (Polasky, 1 Tr. 63:24-64:2, 64:3-7, 71:12-15; 116:22-23).

358. **Peabody witnesses have cited 1,457 peer-reviewed papers, compared to only 169 peer-reviewed papers cited by the DOC and CEO witnesses combined**.

VII. THERE IS NO SCIENTIFIC CONSENSUS SUPPORTING THE FSCC

359. The State Agencies and the CEOs claim that there is a "consensus" of scientists on the issues.

360. However, as Dr. Bezdek testified, this "consensus" is usually framed so broadly that it is useless: "If the question is whether humans have had some impact on the environment, even I would be part of the consensus." (Ex. 235, Bezdek Surrebuttal, 85:8-9).

361. This "consensus" comes from an article published by John Cook in 2013. The article is frequently mis-cited for the proposition that 97% of climate *scientists* agree on the topic of anthropogenic global warming, but the article only analyzes *papers*, not *scientists*. (Ex. 238, Tol Rebuttal, Ex. 2 (Report), at 9:202-203). Furthermore, the paper assembles an initial population of articles with many unrelated to climate science, unreleased and questionable datasets, biased ratings by readers, and reader collusion.

362. When it comes to articles in the economic literature regarding the SCC, there is a documented publication bias favoring higher values for the FSCC. (*Id.* at 50:8-51:9).

363. As Dr. Tol testified, scientists who point out flaws in climate research are often shouted down: that is what is "wrong with climate research. Studies are praised because the results are politically expedient rather than scientifically valid. Research scandals are covered up. Whistleblowers are vilified." (Ex. 238, Tol Rebuttal, Ex. 2 (Report), at 10:219-223).

364. Moreover, the so-called "consensus" of scientists—especially the often-quoted "97% of climate scientists" who agree with an overly generalized statement not specific to the FSCC—is unsupported by the data or the views of scientists.

365. In the peer-reviewed literature the Cook article has been refuted by Tol (2014) and Legates et al. (2013). (*Id.* at 9:192-10:221; Ex. 233, Bezdek Rebuttal, Ex. 1 (Report), at 6:213-8:258; Ex. 235, Bezdek Surrebuttal 83:12-84:6). Other similar studies cited by Dr. Abraham (*see* Zimmerman (2008), Doran and Zimmerman (2009), Cook et al. (2013), Oreskes (2004)) are flawed by bad design and hidden assumptions. (Ex. 235, Bezdek Surrebuttal, 85:12-89:27).

366. Recent studies by Strengers and Verheggan polled climate scientists directly on the statement: "It is extremely likely [95 to 100% probability] that human activities caused more than half of the observed increase in global average surface temperature from 1951 to 2010." (Ex. 213, Lindzen Surrebuttal, 46:7-47:3). The study broke the proposition into two parts: the likelihood of human causation ("extremely likely") and human responsibility for more than half of the observed increase in temperature. (*Id.*). Only 65.9% of surveyed scientists agreed with the second half (that humans caused more than half of the observed increase). (*Id.*). Of those who agreed with the second half, only 65.2% also agreed that the conclusion was "extremely likely" or "virtually certain." (*Id.*). In the end, therefore, only 43.0% of climate scientists actually agreed with the statement. (*Id.*).

367. Other studies show a range between 47% and 90% for the "consensus" usually given as 97%. (*Id.* at 47:8-21).

368. Further, numerous findings published in peer-reviewed journals and presented in congressional testimony are beginning to question the argument that the evidence of anthropogenic climate change is strong enough to justify policy action. (Ex. 233, Bezdek Rebuttal, Ex. 1 (Report), at 3:88-5:166).

VIII. EXTERNALITY VALUES SUPPORTED BY THE EVIDENCE

369. Dr. Mendelsohn used the DICE model (2013 version), with improvements for the damage function and adjusted ECS values. He is the only expert in this proceeding whose operation of the DICE model has been peer-reviewed. (Mendelsohn Surrebuttal at 7:20-14:21). **As among all the experts in this proceeding, Dr. Mendelsohn has the best credentials for operation of the DICE model**.

370. Dr. Mendelsohn testified that a damages model for determining the externality value of carbon should measure the marginal damage associated with each policy choice. (Ex. 220, Mendelsohn Surrebuttal, 21:9-11.) Measuring marginal damages is the conventional

and universally accepted method that environmental economists use for all pollutants, not just carbon dioxide. (*Id.* at 21:10-11, 24:4-5.) As an optimization model, DICE was designed to calculate the optimal solution to climate change, which maximizes the net benefit to society. (*Id.* at 22:9-10). Marginal damages reflect the level of damage that would occur in the future after application of mitigation measures or policies. (Ex. 214, Mendelsohn Direct, 5:24-6:4; Ex. 220, Mendelsohn Surrebuttal, 21:6-24:2.) The marginal damage depends on the level of mitigation that will be caused by the policy. (Ex. 220, Mendelsohn Surrebuttal, 22:5-6.) The social cost of carbon (or externality value of carbon dioxide) should be measured as the marginal cost of abatement to the marginal damage, in order to maximize the net benefits to society. (*Id.* at 22:8-10.)

371. Dr. Mendelsohn recommended using the emission scenarios inherent in the DICE model itself. The IWG described how the DICE emission scenarios function: "For purposes of estimating the SCC, carbon dioxide emissions are a function of global GDP and the carbon intensity of economic output, with the latter declining over time due to technological progress." (Ex. 100, Polasky Direct Sched. 2 (Feb. 2010 TSD), at 6.)

372. **Because there is convincing evidence that the ECS is lower than 3°C and because AR5 lowered the "likely" range to 1.5°C and no longer recommends a "best estimate" of 3 °C, Dr. Mendelsohn also provided ranges for an ECS at 1.5°C or 2°C.**

373. The damage function in DICE assumes that the percent of GDP lost per year to climate change damage increases with the square of temperature change. When temperatures are 2°C warmer than preindustrial global temperatures, the model assumes climate damage would be equal to 1% of GDP. When temperatures are 4°C higher, the model assumes damages would be 4% of GDP; 8°C increase would yield 16% of GDP damage. However, current empirical evidence supports modification of these assumptions in the DICE damage function. (Ex. 216, Mendelsohn Direct, Ex. 2 (Report), at 11.)

374. Today, global temperature is about 0.8°C warmer than the preindustrial temperature. According to DICE2013, there therefore should already be a global damage from climate change in 2015 equal to $173 billion annually. However, it is very difficult to detect this annual global damage today, even with careful scientific measurements. (*Id.*) In order to measure the damage from climate change over time, one must discern what changes over time are due to the underlying growth in the economy and the human population, versus what is due to the change in carbon dioxide, rainfall and atmosphere. (*Id.* at 12.)

375. Empirical evidence to date shows that the magnitude of global benefit to date is slightly higher than the magnitude of global loss to date. The immediate impact of a warmer, wetter and carbon dioxide enriched environment is likely to be beneficial from 1.5°C to 2°C above preindustrial levels. (*Id.* at 14.)

376. The existing DICE damage function over-predicts damage in the near term. It assumes that the preindustrial temperature in 1900 was optimal for mankind and all warming since then has been harmful. (*Id.*) Because the weight of peer-reviewed evidence shows that in fact any warming since that time has been a net benefit to society, including through increased agricultural and ecosystem productivity and carbon fertilization, Dr.

Mendelsohn adjusted his damage function in the DICE model for two scenarios: that **net damage does not begin until temperatures warm to 1.5°C above preindustrial levels, and at 2°C above preindustrial levels**. (*Id.*; *see also* Ex. 220, Mendelsohn Surrebuttal, 7:3-15:6 (listing peer-reviewed works supporting his modifications to the damage function).)

377. Dr. Mendelsohn's adjustment also is based on current observations about the rate at which damages are occurring and likely to occur in the near future. "Looking at the sum of the damage across each sector of the economy with a 2°C warming, the net damage should be minimal. [However] the current DICE model predicts $2 trillion of damage in 2050 alone [when the DICE model predicts the temperatures will be 2°C higher than preindustrial levels] and yet **the mechanism that will deliver such damage in 35 years is not known**. It is not clear how warming one more degree than today could possibly have an impact this large." (Ex. 220, Mendelsohn Surrebuttal at 16:19-17:1.) Indeed, the IPCC itself has acknowledged the lack of observational data linking increased emissions to extreme temperature and precipitation events. (Ex. 213, Lindzen Surrebuttal, 37:8-38:11; *see also id.* at 39:3-45:16 (discussing lack of observed increases in extreme temperature and precipitation events from increases in global GHG emissions).)

378. DICE has its own internal measure of the discount rate that depends on the path of global consumption over time. The discount rate changes as the growth of per capita consumption changes; in other words, the discount rate internal to DICE changes over time as the economy changes. DICE assumes that because damages in a given year reduce investment in that year, damages propagate forward in time and reduce GDP in future years. DICE assumes that interest rates will fall as per capita income falls. (Ex. 100, Polasky Direct Sched. 2 (Feb. 2010 TSD), at 7.) DICE therefore estimates that the current discount rate is 5%; however, as the rate of GDP growth slows over time, the DICE model predicts that the discount rate should fall to about 3.5% in 2100 and 2.7% in 2200. (Ex. 216, Mendelsohn Direct, Ex. 2 (Report), at 16-17; Ex. 218, Mendelsohn Rebuttal, Ex. 1 (Report), at 6.)

379. Dr. Mendelsohn used DICE's original emission and GDP forecasts and internal sliding discount rate that is calculated to be consistent with the growth in GDP per capita (starting at 5 percent and declining to 3.5 percent in the year 2100 and 2.7 percent in the year 2200). Dr. Mendelsohn therefore provided ranges if the ECS is assumed to be 1.5°C ($0.30 to $0.80 per ton) or 2°C ($1.10 to $2.00 per ton).

380. Dr. Mendelsohn pointed out that his recommended values are consistent with values used by other states and countries, and sufficiently close to the values of neighboring states to limit leakage. (Ex. 220, Mendelsohn Surrebuttal 33:19-35:4.) Rather than using a "last ton" methodology that assumes no future mitigation globally, the SCC should be measured based on the optimal path (optimal SCC), since this equates the marginal cost of mitigation to the SCC, which is the only measure that can lead to an efficient mitigation program. (Mendelsohn 3B Tr. 35:12-37:12.)

381. Dr. Mendelsohn testified that using the IWG's assumed ECS value of **3.0°C**, "a more accurate model in terms of trying to predict damages" would lead to a social cost of

carbon measure of **$4.00-$6.00/ton** in current dollars. (Mendelsohn, 3B Tr. 43:9-13; *see also* Ex. 261.) **He testified that, "[g]iven the strong scientific evidence" for lower ECS values, "a reasonable and the 'best available measure' for the SCC is between $0.30 and $2.00/ton."** (Ex. 220, Mendelsohn Surrebuttal 33:19-35:4.) Significantly, these values include non-market damages, health and ecosystem effects, and the possibility of catastrophes. (Mendelsohn, 3B Tr. 43:20-25.)

382. The testimony of Dr. Tol, the FUND model's creator, strongly supported Dr. Mendelsohn's proposal. Dr. Tol testified that, under the climate sensitivity values used by Dr. Mendelsohn, and using the Ramsey Rule declining discount rates incorporated in FUND (which Dr. Tol believes is appropriate), **FUND calculates the SCC as negative (-) $17.97 for an ECS value of 1°C, negative (-) $12.06 for an ECS value of 1.5°C, and negative (-) $4.05 for an ECS value of 2.0°C.** (Tol Rebuttal, Ex. 2, at 9:179-180.)

383. Dr. Bezdek further supported Dr. Mendelsohn's proposal. Dr. Bezdek noted that the best available measure for estimating CO_2 damages in resource proceedings should consider both the benefits and the costs of CO_2. He concluded that the Minnesota CO_2 values established in 1997 should be **reduced to about $0.20 to $2.00 per ton or lower**. These values are based on the benefits of carbon dioxide in the atmosphere in terms of increased crop production and in terms of worldwide economic growth.

384. Dr. Bezdek testified that all available scientific evidence supports the general concept of a CO_2 fertilization effect. Doubling of the atmospheric CO_2 content above the current level will increase the productivity of most herbaceous plants by about one-third. The total economic value of the CO_2 benefit for 45 crops cumulatively totaled $3.2 trillion, 1961-2012, and is forecast to total nearly $10 trillion, 2012 – 2050. The benefits of carbon dioxide emissions with respect to crop production worldwide are not explicitly included in the IWG's FSCC figures.

385. In addition, the benefits of CO_2 emissions with respect to economic growth exceed by orders of magnitude the FSCC figures. Fossil fuels are essential for world economic growth, and that significant CO_2 emission reductions will be associated with significant reductions in economic growth. This is due to the higher costs and decreased reliability of alternate forms of energy including wind and solar. The benefits of CO_2 emissions in terms of economic growth exceed the costs (as estimated by the IWG) by the following ratios:

- From 180:1 to 250:1 through year 2040, using a 5% discount rate
- Approximately 70:1 through year 2040, using a 3% discount rate
- Approximately 50:1 through year 2040, using a 2.5% discount rate

IX. XCEL'S PROPOSED VALUE

386. Mr. Martin strongly criticized the FSCC as calculated by the IWG, yet his calculations were based on the model runs performed by the IWG, and the ultimate values he

recommended were very close to the FSCC. The very defects Mr. Martin correctly identified in the FSCC also invalidate his recommended values.

387. Mr. Martin properly observed that "[t]he SCC is inherently uncertain and speculative," rests on "uncertain" assumptions as to future emissions, temperature change, damages, discount rates, and many other factors, and "uncertainty builds from one step to the next." (Ex. 600, Martin Direct, 3:11-17.) He quoted Professor Robert Pindyck, an economist at MIT, for the proposition that, "When it comes to the damage function, we know virtually nothing – there is no theory and no data that we can draw from. As a result, developers of IAMs simply make up arbitrary functional forms and corresponding parameter values." (Ex. 601, Martin Rebuttal, 19 n.9.)

388. Mr. Martin also acknowledged that climate sensitivity is one of the very most important uncertain parameters driving the social cost of carbon. (See Ex. 600, Martin Direct, 18:6-9 ("The most important uncertain parameter in this case is equilibrium climate sensitivity, or the change in temperature expected to result from a doubling of atmospheric CO_2 concentrations above pre-industrial levels.").) He explained that ESC values are highly uncertain. (See Ex. 600, Martin Direct, 39:7-10 ("Most importantly, there is little agreement on equilibrium climate sensitivity – the temperature change associated with a doubling of atmospheric CO_2 concentrations above pre-industrial levels – and little empirical data on which to base this key parameter of the models.").) He quoted Professor Pindyck: "We know very little about climate sensitivity" and "over the past decade our uncertainty over climate sensitivity has increased." (Ex. 600, Martin Direct, 39:14-22.)

389. Further, Mr. Martin noted that the IAMs on which the FSCC is based do not fully take adaptation into account, which could lead them to over-estimate damages. (Ex. 600, Martin Direct, 29:18-19 ("the IAMs do not fully capture adaptation to climate change, which could lead them to over-estimate damages").) He added that "[t]he Federal SCC methodology aggregates and averages the SCC results regardless of IAM and socioeconomic/emissions scenario, obscuring their underlying differences and the broad range of results." (Ex. 600, Martin Direct, 39:2-5.) The FSCC simply averages results across the IAMs, obscuring their underlying differences and the broad range of results. In addition, Mr. Martin explained that the choice of discount rate "is highly controversial and has a greater effect on the SCC than any other single variable." (Ex. 600, Martin Direct, 19:1-2.)

390. Despite Mr. Martin's recognition of the fatal flaws in the FSCC, his analysis is based on the raw SCC model results that are infected by all of the errors he previously acknowledged. The IWG data provides the foundation of his analysis, and the validity of his results depends on the validity of that data. (See Ex. 602, Martin Sur-Rebuttal, 25:5-8, 25:19-26:3.) Moreover, he acknowledged that he assumed that each IAM is equally accurate. (See Ex. 600, Martin Direct, 67:5-9 ("Our approach uses results from all three IAMs and five socioeconomic/emissions scenarios used in developing the Federal SCC, not claiming that any IAM is more accurate or any socioeconomic/emissions scenario is more likely than another.").) Thus, Mr. Martin's approach is flawed because (as noted

previously) PAGE is not as accurate as FUND or DICE and because the IWG committed grave errors in its operation of FUND and DICE.

391. Mr. Martin proposes eight criteria for a methodology to estimate the social cost of carbon. (Ex. 600, Martin Direct, 2.) None of these criteria is specified in the statute or in the Order Regarding Burdens of Proof, *In re Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statute 216B.2422, Subdivision 3* (Mar. 27, 2015). Moreover, his own criteria do not support adoption of his recommended value.

392. For example, Mr. Martin's first criterion is "[u]se of a damage cost approach to valuing environmental costs." But other proposals meet this criterion every bit as much as Mr. Martin's. For example, Peabody's proposed values are based on the best scientific evidence as to the marginal damage cost of a ton of carbon.

393. Mr. Martin's second criterion refers to the "inherent uncertainty in estimating climate change damages over almost 300 years." The best way to address that criterion is simply to say that the uncertainty is too great to justify a value greater than zero, or a departure from the current Minnesota figure for the SCC. Mr. Martin agreed that one way of dealing with uncertainty is to say that it is too great to justify a departure from current values. (Martin, 3B Tr. 132:2-7, 134:5-7.) Another way to address the uncertainty would be to wait until better information exists. Uncertainty does not justify premising decisions on models that have been proven to lack predictive reliability. In fact, adopting a range of values for the SCC based on inaccurate information would simply aggravate the problem of uncertainty.

394. Mr. Martin's third criterion cites "the absence of consensus on discount rate choice," but his approach uses only the three discount rates selected by the IWG – 5%, 3%, and 2.5%. (Ex. 600, Martin Direct, 9:26-10:1.) He does not employ the 7% discount rate required by OMB Circular A-4, even though he recognized that "a 7 percent rate is required by applicable OMB guidance, and would reflect the average before tax real rate of return to private capital." (Ex. 601, Martin Rebuttal 41:24-26.) Therefore, instead of reflecting "the absence of consensus on discount rate choice," Mr. Martin's approach simply adopts the IWG's choices of discount rate. (Ex. 602, Martin Surrebuttal 4:10-11.)

395. Mr. Martin's fourth criterion is use of "statistically sound methods." However, Mr. Martin is not a statistician. Dr. William Wecker, a statistician who has taught on the faculties of the University of Chicago, the University of California, Davis, and Stanford University and who has served as associate editor of the Journal of the American Statistical Association (Ex. 242, Wecker Rebuttal, Ex. 2 (Report), at 1:9-17), testified that the adoption of the IWG's averaging technique by Mr. Martin did not represent a well-founded, statistically sound method for aggregating the IWG outputs. (Id. at 2:57-2:66). It failed to consult or apply authoritative statistical literature on combining probabilistic forecasts and decision-making under uncertainty. (Id. at 6:122-11:266). It lacks any reference to the large body of peer-reviewed research literature in the mainstream of statistics and applied mathematics, and instead relies on novel ad hoc procedures of his own invention. (Id.) It is an unprincipled analysis of the uncertainties involved because it merely treated them all as equally probable. (Id. at 11:267-14:325). In addition, for 13

of the 15 distinct sets of IWG cost estimates calculated using the FUND IAM, the 5th percentile falls below zero, implying that the corresponding SCC estimate is not "statistically significantly" greater than zero. (Id. at 15:329-16:334). Dr. Wecker testified that Mr. Martin has failed to employ statistically sound methods, failed to apply his own stated criteria on a rigorous basis, and failed to provide any principled basis for the proposed CO_2 environmental cost values. (Id. at 2:57-66). Mr. Martin's proposed range is the product of entirely arbitrary subjective judgment. (Id.)

396. Mr. Martin's fifth criterion is "an appropriate level of risk tolerance." Yet he acknowledged that there is a risk on both sides, both in setting the SCC too low and too high. For example, he testified that setting a value of the SCC that is too high could influence the decision to invest in new generating capacity that is not actually in the public interest. (Ex. 600, Martin Direct, 13:22-25 ("if the Commission adopted a single SCC value that in fact overestimates the benefits of reducing emissions, that value could influence the decision to invest in new generating capacity that is not in fact in the public interest").) He also testified that "[t]he immediate cost impacts resulting from decisions using the SCC would be borne by utility customers in Minnesota." (Ex. 600, Martin Direct, 3:26-4:3.) And he expressed concern that setting the SCC too high could cause leakage – moving emissions to other states. (Ex. 601, Martin Rebuttal, 39:26-40:1.)

397. Mr. Martin testified that Minnesota has already made significant investments to reduce GHGs, and that a high SCC could lead to relatively high-cost further actions compared to mitigation options available elsewhere – meaning that the benefit would be negligible, while Minnesota utility customers (including low-income customers) could bear greater direct costs. (See Ex. 601, Martin Rebuttal, 40:1-9 ("because Minnesota has already made significant investments to reduce GHGs, a high SCC could lead to relatively high-cost further actions compared to mitigation options available elsewhere. This means the benefit (reduction in climate damages experienced by Minnesotans) would be small to negligible, while Minnesota utility customers could bear greater direct costs than they would under a resource plan that used a U.S. or Minnesota SCC value. This is a concern to the Company, particularly for our low-income and energy-intensive trade-exposed industrial customers.").)

398. Mr. Martin's sixth criterion is minimizing "subjective judgments," but a social cost of carbon based on the best available science (as Peabody's approach reflects) is the best way of minimizing subjective judgments. The IWG made a host of subjective judgments in changing the IAMs and generating the data on which Mr. Martin relied.

399. Mr. Martin's seventh criterion is whether the measure yields a "practicable range." But Peabody's proposed ranges are practicable – and better than Mr. Martin's. His ranges are far too broad to serve as useful tools for the Commission in making resource planning decisions. Schedule 3 to Mr. Martin's direct testimony shows that for emissions year 2020, for example, his proposed values range from $13.61 to $46.14. This is an extremely broad set of values that could raise difficulties for the Commission in making resource planning decisions like whether to operate or retire a power plant, what type of generation capacity to invest in, how to set solar tariffs and so on. Mr. Martin's own testimony acknowledges that an "imprecise SCC" is not helpful in making "individual

resource allocation decisions," which are sometimes binary, difficult to reverse, and often have large and long-term implications for electricity rates, environmental impacts, and reliability." (Ex. 600, Martin Direct 6:12-19; see also Ex. 601, Martin Rebuttal 20:1-10 ("the SCC is designed for a specific, limited purpose: federal regulatory impact analysis under Executive Order 12866. It is intended to help evaluate whether the benefits of a proposed federal regulation outweigh its costs. In this application there is arguably greater tolerance for the imprecise nature of the estimates, since a regulation would be warranted as long as the benefits significantly exceed costs even if the SCC over- or underestimates the actual damages. Regulatory impact analysis is unlike resource planning, where the imprecise SCC would determine not whether to regulate, but could drive specific, binary decisions that are not easy to reverse and have significant costs.").

400. Mr. Martin's eighth criterion is whether the measure is "transparent, replicable, and updatable." Yet Mr. Martin has acknowledged that the IWG process (which generated the data on which Mr. Martin relied) was not transparent. (See Ex. 600, Martin Direct, 14:25-15:2.) Nor has the IWG data been updated to reflect current science. The IWG did not update its climate sensitivity value in November 2013 after AR5's Working Group 1's report was released in September 2013, nor did the IWG update its climate sensitivity value in July 2015. And replicating and updating an admittedly imprecise and invalid methodology only amplifies its flaws.

CONCLUSIONS OF LAW

1. Any of the foregoing Findings of Fact that should more properly be deemed a Conclusion of Law is hereby adopted as such.

2. When the Commission first held a contested case proceeding to set the externality value for CO_2 in 1997, ALJ Allan Klein addressed the criteria by which the Commission would evaluate proposed externality values.

3. ALJ Klein recommended that the Commission adopt conservative values because "the quantification of environmental costs is still in its infancy." (1996 ALJ Recommendation at 17).

4. ALJ Klein listed five "criteria" for "determining which environmental impacts to value and whether and how to value these impacts:"

- First, only the most significant and relevant environmental impacts should be quantified.
- Second, only impacts created during the operational phase should be quantified.
- Third, the adopted values should be conservative.
- Fourth, whenever possible, a damage-cost approach should be used.
- Fifth, at least some of the adopted values should be geographically sensitive.

(*Id.* at ¶ 36).

5. He further emphasized the need for caution in setting externality values where the underlying scientific assumptions are unsettled: "At some point, the degree 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).

> 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. . . . 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.

(*Id.* at 17-18).

6. In that proceeding, ALJ Klein recommended rejecting cost values based on speculation and extreme discount rates: "The MPCA's [Minnesota Pollution Control Agency] proposed range of environmental costs of CO_2 of $4.28 to $28.57 per ton is unreliable because it is based on a speculative measure of damage (2% of global GDP) and uses an unreasonably low discount rate to reduce the stream of damages to present value." (*Id.* at ¶ 112).

7. Instead, ALJ Klein recommended lower CO_2 externality values: "The range of costs for CO_2 emissions, when using [MPCA witness] Ciborowski's lower damage function (1% of global GDP) discounted at rates of 3% to 5%, is $0.28 to $2.92 per ton. Based on the available evidence, this range represents a reasonable estimate of costs. It is also consistent with the policy goal of using conservative values in the face of uncertainty." (*Id.* at ¶ 114).[2]

8. The Commission adopted ALJ Klein's recommendation, and specifically agreed that the "uncertainties inherent in the research" justified more conservative estimates of future damages and discount rates. *In re Quantification of Environmental Costs*, 578 N.W.2d 794, 800 (Minn. Ct. App. 1998).

9. As the Commission stated:

> While the Commission finds the methodology used by MPCA witness Ciborowski sufficient to provide a meaningful estimate of

[2] These values were adjusted by the Commission to 1995 dollar values, resulting in a final range of $0.30 to $3.10 for CO_2. (Ex. 306, Order Establishing Environmental Cost Values, at pp. 4-5, n.1 (Jan. 3, 1997)).

> the potential costs from carbon dioxide emissions, the uncertainties related to the assumptions used and uncertainty related to bringing back to present value the significant damage costs assumed to occur many years into the future certainly make the quantification more complex than for the criteria pollutants.

Order Affirming In Part and Modifying In Part Order Establishing Environmental Cost Values, p. 4 (July 2, 1997).

10. In 1997, the Commission based its CO_2 externality values ($0.30 - $3.10) on the Intergovernmental Panel on Climate Change's [the "IPCC"] then-"likely" "Equilibrium Climate Sensitivity" [the "ECS"] range of 1.5°C to 4.5°C, with a "best estimate" of 2.5°C. (1996 ALJ Recommendation at ¶ 91). The ECS represents the change in global mean near-surface air temperature that would result from a sustained doubling of CO_2.

11. In this proceeding the Commission is acting in its quasi-judicial capacity. As such, the ALJ's recommendation and the Commission's final decision must be supported by substantial evidence in the record.

12. The ALJ and the Commission have jurisdiction over the subject matter of this hearing pursuant to Minn Stat. 216B.2422, subd. 3.

13. This gives the Commission authority to determine whether it is "practicable" to quantify an environmental externality value for CO_2 and whether there is a "reasonable" and "best available" measure.

14. The evidentiary rules that apply in this case are those that govern the Office of Administrative Hearings. Minn R. 1400.7300.

15. According to Minn. R. 1400.7300, subp. 5, the party proposing that certain action be taken must prove the facts at issue by a preponderance of the evidence. Thus, a party proposing that the Commission adopt a new environmental cost value for CO_2 bears the burden of showing by a preponderance of the evidence that the value being proposed is reasonable and the best available measure of the environmental cost of CO_2. A party proposing that the Commission retain any environmental cost value as currently assigned by the Commission bears the burden of showing by a preponderance of the evidence that the current value is reasonable and the best available measure to determine the applicable environmental cost. A party opposing a proposed environmental cost value must demonstrate that the evidence offered in support of the proposed values is insufficient to amount to a preponderance of the evidence. *See also* Order Regarding Burdens of Proof, *In re Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statute 216B.2422, Subdivision 3*, at pp. 2-3 (Mar. 27, 2015).

16. An enabling act such as Minnesota Statute Sec. 216B.2422 subd. 3 must be interpreted so as to authorize only reasonable decisions. *Lee v. Delmont*, 228 Minn. 101, 114 (1949). Additionally, the agency must explain on what evidence it is relying and how that evidence connects rationally with the agency's choice of action to be taken. *Manufactured Hous. Inst. v. Pettersen*, 347 N.W.2d 238, 244 (Minn. 1984). Picking a

value arbitrarily does not generate a reasonable number and will not withstand judicial scrutiny on appeal. *Id.*

17. Under Minnesota law, "An agency's decision is arbitrary and capricious if it represents its will and not its judgment." *Hiawatha Aviation of Rochester, Inc. v. Minn. Dep't of Health,* 375 N.W.2d 496, 501 (Minn. Ct. App.1985), *aff'd,* 389 N.W.2d 507 (Minn. 1986). "When an agency entirely fails to consider an important aspect of a problem, this is a signal that the decision is arbitrary and capricious." *Alich v. Dakota Cty. Cmty. Dev. Auth.*, No. C4-02-818, 2003 WL 230726, at *1-2 (Minn. Ct. App. Feb. 4, 2003) (citing *White v. Minn. Dep't of Nat. Res.,* 567 N.W.2d 724, 730 (Minn. App. 1997), *review denied* (Minn. Oct. 31, 1997)) ("This failure to consider all relevant circumstances suggests that the CDA's determination to terminate assistance was arbitrary and capricious."). Indeed, an agency's decision is arbitrary or capricious if it entirely failed to consider an important aspect of the problem, if it offered an explanation for the decision that runs counter to the evidence, or if the decision is so implausible that it could not be ascribed to a difference in view or the result of agency expertise. *Trout Unlimited, Inc. v. Minn. Dep't of Agric.*, 528 N.W.2d 903, 907 (Minn. Ct. App. 1995). "Where the evidence reveals that the agency has ignored or failed to consider 'a serious environmental consequence' or 'swept stubborn problems or serious criticism . . . under the rug,' the district court may consider new evidence. *Clean Water Action All. of Minn. v. Minn. Pollution Control Agency*, No. A06-1054, 2007 WL 1599156, at *2 (Minn. Ct. App. June 5, 2007) (citing *White*, 567 N.W.2d at 735).

18. Although this is not a federal proceeding, established principles of federal administrative law can guide this Commission. Congress has directed federal agencies to use "(i) the best available, peer-reviewed science and supporting studies conducted in accordance with sound and objective scientific practices; and (ii) data collected by accepted methods or best available methods (if the reliability of the method and the nature of the decision justifies use of the data)." 42 U.S.C. § 300g-1(b)(3)(A).

19. Federal courts have routinely invalidated administrative agency decisions for using weak scientific evidence or speculation, or for failing to address conflicting scientific evidence. For example:

- In *Appalachian Power Co. v. EPA*, 249 F.3d 1032, 1054 (D.C. Cir. 2001), the D.C. Circuit found that EPA acted arbitrarily in failing to "address[] what appear[s] to be stark disparities between its projections and real world observations." The D.C. Circuit opined that "model assumptions must have a 'rational relationship' to the real world." *Id.* at 1053 (quoting *Chem. Mfrs. Ass'n v. EPA*, 28 F.3d 1259, 1265 (D.C. Cir. 1994)). The court pointed out that EPA projections of negative growth in electricity generation "appear arbitrary, and the EPA can point to nothing in the record to dispel this appearance." *Id.* Moreover, when EPA defended its reasoning simply by stating that the choice was reasonable, the D.C. Circuit replied "simply to state such a claim does not make it so. There must be an actual reason articulated by the agency at some point in the rulemaking process. There is none here." *Id.* at 1053-54.

- In *Tex Tin Corp. v. EPA*, 992 F.2d 353, 354-55 (D.C. Cir. 1993), the Court of Appeals held that EPA's reliance upon generic studies in face of conflicting detailed and specific scientific evidence was arbitrary and capricious. The D.C. Circuit rejected EPA's "conclusory statements" based on generic studies of arsenic in waste piles when they were countered by specific studies. *Id.* at 355. Relying on generic reasoning in the face of conflicting scientific evidence is effectively the same as conclusory arbitrary and capricious reasoning.

- In *Chlorine Chemistry Council v. EPA*, 206 F.3d 1286 (D.C. Cir. 2000), the court found that EPA's decision to act in contravention of the "best available" science was arbitrary and capricious. *Id.* at 1290-91. Specifically, the D.C. Circuit rejected EPA's argument that it could not complete its scientific investigations before a deadline, arguing that "that is no reason for acting against its own science findings in the meantime." *Id.* at 1290. Similarly, in the current proceeding the FSCC, when presented with the best available scientific evidence, has simply stood pat and stated that it might update in the future. The D.C. Circuit specifically rejected this position. *Id.* at 1290-91.

- In *Illinois Commerce Commission v. FERC*, 576 F.3d 470, 477 (7th Cir. 2009), the court reversed an agency adjudicatory decision because of a failure to take into account contrary evidence, and because of a lack of evidence to support the decision. In its decision, the Seventh Circuit stated: "Rather desperately FERC's lawyer . . . reminded us at argument that the Commission has a great deal of experience with issues of reliability and network needs, and they asked us therefore (in effect) to take the soundness of its decision on faith. But we cannot do that because we are not authorized to uphold a regulatory decision that is not supported by substantial evidence on the record as a whole, or to supply reasons for the decision that did not occur to the regulators." *Id.*

20. Numerous cases have recognized that decisions based on uncertain and speculative evidence are arbitrary and capricious. These cases demonstrate that simply asking a regulatory body to "just trust us" is asking the body to rule in an arbitrary manner that is contrary to law:

- *Ctr. for Biol. Diversity v. EPA*, 749 F.3d 1079 (D.C. Cir. 2014): In this case, EPA declined to finalize a rule under the Clean Air Act (national ambient air quality standard (NAAQS)) regarding SOx and NOy involving an equation measuring aquatic acidification. *Id.* at 1085-86. "But, like any model, the Index may be scientifically sound in theory, or general concept yet, without the appropriate inputs, too uncertain to apply in practice." *Id.* at 1086, quoting EPA's brief at 3. The court determined that "at some point, action infected by enough uncertainty cannot be called reasoned," *id.* at 1090, and upheld EPA's decision not to regulate: "the Act requires a reasoned judgment, and … EPA found it could not form one." *Id.* at 1091.

- *Holy Cross Wilderness Fund v. Madigan*, 960 F.2d 1515 (10th Cir. 1992): The Army Corp of Engineers rejected alternative proposals for a water project in

Colorado because they were "too speculative and dependent upon too many uncertainties." *Id.* at 1528. The court sustained the refusal.

21. It would also be arbitrary and capricious to adopt the FSCC now and rely on the IWG to continue to study the matter and update the FSCC accordingly. Uncertainty is too great to permit adoption of the FSCC at this time. Further, the IWG already has had two opportunities to update its ECS values since AR5 was issued in 2013, and the IWG has failed to do so on either occasion. In the face of disabling uncertainty, the Commission should not adopt a value for the social cost of carbon. Instead, if the IWG continues to study the matter, the Commission can revisit the question in the future as well. In *Chlorine Chemistry Council v. EPA*, 206 F.3d 1286, 1290-91 (D.C. Cir. 2000), the D.C. Circuit specifically rejected an argument that an agency can rest on findings that it knows to be wrong while promising to update later. *Id*. Uncertainty militates in favor of a zero SCC, not an artificially inflated one.

22. Determining a reasonable and the best available externality value for carbon dioxide requires a thorough analysis of scientific data and economic theory. Any thorough analysis must include all available data and understandings.

23. The critical issue in this proceeding is not whether Earth's climate is static or might be changing in some way—it is always changing—but the magnitude and speed of any anthropogenic contribution to climate change and whether the FSCC properly measures those impacts. As Dr. Spencer testified, the "issue is not so much whether some warming has occurred – I believe it has – it is that the warming has been at a slower rate than can currently be explained by the IPCC models, and those models provide the ultimate quantitative basis for social cost of carbon calculations." (Ex. 227, Spencer Surrebuttal, 4:10-12).

24. **On these questions AR5 undermines, rather than supports, the FSCC. Moreover, the Parties to this proceeding concede the uncertainty inherent in the determination of the FSCC.**

25. Establishing an externality value for CO_2 emissions requires attributing "responsibility" to the emitters by a preponderance of the evidence.

26. As Dr. Hanemann testified, "a party responsible for causing pollution is also responsible for paying for the damage caused by that pollution." (Ex. 800, Hanemann Direct, 8:14-15). The presence of cause in Dr. Hanemann's definition is crucial: the party from whom payment is required must have caused the pollution, and the pollution must cause the damage.

27. For these reasons, the Commission's decision regarding the CO_2 externality value must be based on the best available evidence, not speculation, surmise, or outdated information.

28. Ultimately the Commission must make its decision based on the full record of evidence before it, and there is no basis for finding that either cause exists.

29. **The preponderance of the evidence shows that the FSCC is fatally flawed and therefore is neither reasonable nor the best available measure.**

30. The FSCC is not the "best available" measure because it does not incorporate the most recent and best available science.

31. **The best available science—the IPCC's AR5, the actual observational data, and other recent evidence published since AR4—contradicts the science on which the IWG based the FSCC (namely, AR4).**

32. **The best available science has shown that uncertainty regarding key variables in the FSCC has increased, not decreased.**

33. Further, the causal chains involved with the SCC are long and convoluted, with many confounding factors.

34. The preponderance of the evidence demonstrates that the confounding factors have not been ruled out.

35. The FSCC is too speculative to meet the standard of proof in this proceeding.

36. Rather, the record shows that the level of uncertainty in climate science has increased, not decreased, since the 1997 proceeding.

37. **The resulting increasing uncertainty justifies a zero value at this point, because there is insufficient factual foundation to conclude that any greater value would more accurately reflect the true externality value for carbon dioxide.**

38. The evidence shows that attribution of global warming to anthropogenic CO_2 has not been established at all, much less by a preponderance of the evidence.

39. The preponderance of the evidence supports a negative externality value as reasonable and the best available value.

40. The preponderance of the evidence shows that the globally averaged combined land and ocean surface temperature has increased by 0.85°C from 1880 to 2012.

41. The preponderance of the evidence shows that that there was not a statistically significant increase in temperature from 1998 to 2012, a period known as the "hiatus."

42. The preponderance of the evidence demonstrates that a warmer, wetter and carbon dioxide enriched environment is likely to be net beneficial from 1.5°C to 2°C above preindustrial levels.

43. Dr. Tol, the creator of FUND, ran the IAM properly using a range of ECS values supported by the best available evidence, as suggested by Dr. Mendelsohn, and the appropriate discount rate and found that the best externality value lies between negative (-) $17.97 (for ECS = 1°C) and negative (-) $4.05 (for ECS = 2°C).

44. The FUND results generated when Dr. Tol ran the model are supported by the carbon fertilization evidence presented by Dr. Mendelsohn and Dr. Bezdek and the admissions by Dr. Reich. As Dr. Mendelsohn testified, CO_2 emissions will increase crop productivity as well as increase plant growth that will in turn absorb more carbon.

45. CO_2 is not an ordinary pollutant, and adopting an externality value to curtail its production will mean curtailing the productive activities that drive our economy and our societal well-being.

46. **The preponderance of the evidence supports a value of zero, consistent with ALJ Klein's admonition in 1996 that when uncertainty is so great that the risk of adopting a number too high outweigh the benefits of adopting any number, the value should be zero.**

47. If the Commission does not adopt a zero value, then in the alternative it should use a range near the status quo values of $0.44 to $4.53 (2014$/ton) – a range of $0.30-$2.00/ton, and in no case higher than $4.00-$6.00/ton. In other words, if the Commission establishes an externality value, it should use Dr. Mendelsohn's improved model inputs yielding a $0.30-$2.00/ton range, or at most a $4.00-6.00/ton range, which are close to the existing Minnesota values.

48. Dr. Mendelsohn's approach used the DICE model with an ECS of 1.5°C and 2.0°C, which are appropriately conservative estimates of equilibrium climate sensitivity. This **yields an externality value of $0.30 to $0.80/ton at the low end of the ECS range (1.5°C) and $1.10 to $2.00/ton at the high end of the ECS range (2°C).**

49. Based on the evidence presented by Dr. Mendelsohn on adaptation and mitigation, which is supported by 20 years of peer-reviewed research, the Commission can adjust the value when or if actual damages become apparent and measured. This decision, however, must be based on the current evidence, not on potential future evidence.

50. Today, **the best reading of the evidence and most appropriately conservative approach in the face of the acknowledged uncertainties is to set an externality value of zero or below.**

Dated:

LAURASUE SCHLATTER
Administrative Law Judge