

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

PEABODY ENERGY CORPORATION

CORRECTED REPLY BRIEF

Carbon Dioxide

December 18, 2015

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**PEABODY ENERGY CORPORATION’S REPLY BRIEF ON
EXTERNALITY VALUES FOR CARBON DIOXIDE**

I. Introduction and Summary

This proceeding began when certain environmental organizations filed a petition urging the Commission to reopen the environmental externality docket to “reflect the current science.” (Clean Energy Organizations (“CEOs”) Br. at 2.) But now the parties proposing adoption of the Federal Social Cost of Carbon (“FSCC”) as calculated by the federal Interagency Working Group (“IWG”) run away from the current science and name-call rather than engage in substantive debate. The record of this proceeding shows that the preponderance of the evidence refutes rather than supports the FSCC, Xcel’s proposal, or any other exaggerated value for the social cost of carbon. The record shows that the FSCC is not a reasonable or best available measure, because it is based on invalid, disproven, and out-of-date scientific data, as well as arbitrary and unsound economic principles.

A. How to Evaluate the Evidence in This Proceeding

There is a substantial body of evidence in this proceeding, but evaluating it is straightforward. The FSCC is invalidated by both the admissions of the Proponents of the FSCC in this proceeding and by the consensus of the peer-reviewed scientific evidence. This evidence refuting the FSCC includes the Fifth Assessment (“AR5”) of the Intergovernmental Panel on Climate Change (“IPCC”), especially the report of Working Group I (“AR5 WG1”)¹ tasked with explaining the physical science behind climate change, which the Proponents of the FSCC barely cite in their Opening Briefs, even though they describe the IPCC reports as “the best resource” and “authoritative” (State Agencies Br. at 23, 24). The dispositive evidence also includes peer-

¹ IPCC, Fifth Assessment Report, Working Group I, *Climate Change 2013: The Physical Science Basis* (2013). “AR5” will sometimes be used as a shorthand for the findings of the Fifth Assessment as a whole.

reviewed scientific materials cited to in the record or placed into evidence, including peer-reviewed observational data and peer-reviewed studies. On almost every significant issue in this proceeding, the FSCC is invalidated by:

(a) the admissions of the Proponents,

(b) the findings of AR5,

(c) the weight of peer-reviewed evidence, and

(d) the preponderance of other highly probative evidence, such as the testimony of (i) Dr. Richard Tol, the author of the FUND Integrated Assessment Model (“IAM”) (one of the three IAMs on which the FSCC is based), who participated extensively in the IPCC, and (ii) Dr. Robert Mendelsohn (the Yale colleague of Dr. William Nordhaus (the creator of the DICE IAM)), who has published peer-reviewed articles using the DICE model and who has an impressive set of credentials and experience in assessing the economic impacts of climate change.

For the most part, the Proponents of the FSCC do not controvert any of the specific evidence invalidating the FSCC. Instead, they rely merely on broad pronouncements by their experts that the Commission should “trust” the IWG’s non-transparent, non-peer-reviewed process. They repeatedly rely on conclusory assertions that evidence exists (somewhere) on a point, but they never actually put that evidence in the record before the Commission or even cite to it. “Trust us” is not a basis for reasoned decision-making.

The Proponents’ own admissions show:

- **No Warming Since 2000**: Dr. Dessler testified that there has been a hiatus in global warming since 2000: “it is correct to say that there has been no statistically

significant warming since 2000.”² This is significant because, at the same time, CO₂ emissions have been increasing substantially,³ including from development in China and India.

- **All Good Scientists are Skeptics**: Dr. Dessler further testified that “I think all scientists are skeptics. . . . I think all good scientists are skeptics.”⁴
- **Uncertainties are Increasing**: The State Agencies admit that “[m]any uncertainties can arise in the context of long-run decision making on climate mitigation and damage reduction.” (State Agencies Br. at 127.) In fact, they concede that “over the past decade uncertainty over climate sensitivity has increased.” (State Agencies Br. at 124.) Dr. Hanemann also admitted that uncertainty has increased rather than decreased. (Ex. 801, Hanemann Rebuttal at 31:11-32:7.)
- **Models Do Not Track Observational Data**: The State Agencies concede “the discrepancy between the IPCC models and observed global mean temperatures over the referenced 15-year period,” which is “broadly attributed to the difficulty of large-scale atmospheric models to capture internal climate variability.” (State Agencies Br. 86 n.62.) Dr. Dessler admitted that “the models assumed incorrect ‘forcing’ over the last decade . . . which causes the models to run ‘hot.’” (Ex. 103, Dessler Rebuttal 25:16-18.)
- **Causal Link Between CO₂ Emissions and Global Warming is Not Measurable**: The CEOs acknowledge: “The exact relationship between [CO₂] concentrations and temperature is unknown and ‘likely to remain unknown for the foreseeable future’ because it involves complicated feedback loops, the strength of which are not currently measurable.”⁵
- **CO₂ Fertilization Effect**: The State Agencies concede that “all available scientific evidence supports the general concept of a CO₂ fertilization effect.” (State Agencies Br. at 47.) Dr. Reich testified that there is a CO₂ fertilization effect and that increased levels of CO₂ can lead to increased crop and forest productivity.⁶ A study he co-authored concluded that: “Our results suggest that, with rising CO₂ and without changes in forest type, average regional productivity [in the Great Lakes area] could increase from 67% to 142% Increased

² Ex. 103, Dessler Rebuttal at 15:5-7. See also Testimony of Dr. Andrew Dessler, Minnesota Hearing Transcript 3A, 20:14-16 (Sept. 2015) (“And you agree that there has been no statistically significant warming since the year 2000, correct? Correct.”). Citations to the Hearing Transcript hereafter will show the witness and the volume, as well as a page/line pin cite.

³ AR5 WG1 at 12 (Fig. SPM.4).

⁴ Dessler, 3A Tr. 56:3-5.

⁵ CEOs Br. at 14.

⁶ Reich, 5 Tr. at 37:10-11, 15-17.

productivity was almost entirely driven by CO₂ fertilization effects”⁷ When shown that article at trial, Dr. Reich agreed that “from 67 percent to 142 percent, that’s almost a doubling of the forest regional productivity.”⁸

- **IAMs are Flawed Measures of the Social Cost of Carbon.** The State Agencies and their witnesses admit that the IAMs contain inherent uncertainties. In fact, their trial brief quotes the statement of MIT professor Dr. Robert Pindyck that IAMs “have crucial flaws that make them ‘close to useless’ as tools for policy analysis.” (State Agencies Br. 61).

In addition to these admissions by the Proponents, the IPCC’s Fifth Assessment and mainstream climate science undermine the FSCC’s assumptions. For example, on the critical issue of equilibrium climate sensitivity (“ECS”) (the amount of temperature increase resulting from doubling CO₂ concentrations from preindustrial levels), which will determine the speed and magnitude of any warming, the IPCC now says that doubling CO₂ concentrations might increase global temperatures by as little as 1.5°C.⁹ In addition to dialing back its predictions of climate change, AR5 WG1 acknowledges the mis-match between climate models and observational data, and throws cold water on numerous alarmist scenarios. AR5 WG1 finds:

- ***There has been a “hiatus” in warming since 1998.***¹⁰ Even Dr. Dessler, one of the CEOs’ witnesses, admitted that there has been no statistically significant warming since the year 2000.¹¹ Climate models cannot explain this lack of warming, which has occurred at the same time as substantial increases in CO₂ emissions, particularly from India and China.¹²

⁷ Ex. 266 (Emily B. Peters, *et al.*, *Potential Climate Change Impacts on Temperature Forest Ecosystem Processes*, 43 *Can. J. For. Res.* 939, 939 (2013) (abstract)).

⁸ Reich, 5 Tr. at 39:4-6.

⁹ AR5 WG1 at 16.

¹⁰ AR5 WG1 at 37 (“[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.”), 63 (Box TS.3) (“the observed recent warming hiatus [is] defined as the reduction in GMST trend during 1998–2012 as compared to the trend during 1951–2012.”).

¹¹ Dessler, 3A Tr. 20:14-16 (Sept. 2015) (“And you agree that there has been no statistically significant warming since the year 2000, correct? Correct.”).

¹² AR5 WG1, Figure SPM.4 at 12.

Observational datasets, which are extensively peer-reviewed (Spencer, 2B Tr. 12:6-19), show that models predict approximately three times as much warming as has actually occurred, regardless of whether researchers look at satellites, weather balloons, or ground-based thermometers. (Ex. 256, Spencer Opening Statement at 3; Ex. 227, Spencer Surrebuttal at 3.)

- ***AR5 shows that there is not consistent data on ocean warming since 2003 in the upper 700 meters of the ocean.***¹³ 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 2003.¹⁴ Analyses of heat content for the upper 700 meters are inconclusive and show substantial regional variations.¹⁵ A new worldwide system of ocean sensors (Argo) shows that, ***below 2000 meters, the ocean has cooled since 2005.***¹⁶
- Sea levels are not rising any faster now than they were in the early half of the last century, ***calling into serious doubt the claims that any sea level rise is attributable to human CO₂ emissions.***¹⁷
- ***Antarctic sea ice is increasing, not decreasing.***¹⁸
- There are significant uncertainties in the cause of any declines in Arctic sea ice,¹⁹ and warm temperature “anomalies” similar to those being recorded now were also observed in the early half of the last century.²⁰ A July 2015 peer-reviewed report by researchers from University College London and the University of Leeds found that ***Arctic sea ice increased in***

¹³ AR5 WG1 at 262 (Fig. 3.2).

¹⁴ Ex. 213, Lindzen Surrebuttal at 21:7-21 (citing studies).

¹⁵ *Id.*

¹⁶ *Id.*

¹⁷ AR5 WG1 at 289 (“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.”) and 290 (“The trend in GMSL [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).”).

¹⁸ AR5 WG1 at 40 (“It 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 km² per decade) between 1979 and 2012 (very high confidence).”) (emphasis added).

¹⁹ AR5 WG1 at 907 (“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.”).

²⁰ One study found that the warming trend over the Greenland ice sheet was 33% larger from 1919-32 than today. Box, J.E., Yang, L., Bromwich, D.H. and Bai, L.-S. 2009. Greenland ice sheet surface air temperature variability: 1840-2007. *Journal of Climate* 22: 4029-4049 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 5).

the past two years: “we observe 33% and 25% more ice in autumn 2013 and 2014.”²¹

- The IPCC has “low confidence” that extreme weather events (e.g., hurricanes, droughts, tornadoes, floods, heat waves) are attributable to human CO₂ emissions.²² Studies show that there has been *no increase in frequency or intensity of extreme weather*.²³
- *The IPCC finds that alarmist predictions of climate catastrophes lack scientific basis.*²⁴ This includes catastrophic scenarios of sea level rise, “runaway” warming from melting permafrost or release of methane deposits, and tropical rainforest collapse. None of these is supported by the scientific evidence.
- The evidence shows that 2014 was not the hottest year on record, and in any event the *Proponents have conceded that anecdotal evidence of individual years is not probative. (Abraham, 3B Tr. 93:20-21 (“the temperature in any single year is not a meaningful development”).)* Therefore, by the Proponents’ own admission, the temperature data for 2014 is *irrelevant*. Further, the evidence shows that the 1930s were the hottest decade in U.S. history, and that the Earth was actually hotter during the years 900-1200 (the Medieval Warm Period) than it is today, and may have been hotter in Roman times as well. In fact, during numerous times in human history, the Earth has been hotter than it is today. *See* Section III(A)(4)(b), *infra*.

Despite the recognition that alarmist predictions are based on outdated science, the IWG continues to base the FSCC on data from 2007 and earlier.²⁵ The IWG chose to ignore key aspects of the latest IPCC report when it estimated the FSCC.²⁶ The State Agencies

²¹ Tilling, R.L., Ridout, A., Shepherd, A., and Wingham, D.J. 2015. Increased Arctic sea ice volume after anomalously low melting in 2013. *Nature Geoscience* 8:643-646 (cited in Lindzen Surrebuttal 34 n.86).

²² AR5 WG1 at 42, 44, 50, 73.

²³ Ex. 213, Lindzen Surrebuttal at 44-45.

²⁴ AR5 WG1 at 25, 70.

²⁵ Technical Support Document – Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866 (Feb. 2010), at pp. 12-13 (citing the IPCC’s 2007 Fourth Assessment (AR4)) [hereafter “IWG 2010”].

²⁶ Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (July 2015), at 12 (“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

acknowledge that “it would be *unreasonable* to base a scientific assessment of climate change on an old IPCC Assessment Report rather than the current Assessment Report.” (State Agencies Br. at 34 (emphasis added).) *Yet that is exactly what the IWG has done.* By the State Agencies’ own reasoning, the FSCC is not a “reasonable” measure of the externality value

Moderate warming of the kind envisioned by AR5 and supported by mainstream research will not trigger the feared impacts of large temperature rises. In fact, Dr. Tol testified that the peer-reviewed FUND model shows that a moderate amount of warming would be on balance beneficial rather than harmful, because it will boost agricultural yields, lower heating costs, and reduce winter-related deaths.²⁷ The decision of the State Agencies and other Proponents to *waive* their cross-examination of Dr. Tol at trial was telling.

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 an SCC 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.) The DICE model is a practicable and administrable model that produces a schedule of values for the SCC which extend over time (Ex. 216, Mendelsohn Direct, Ex. 2 (Report) at 10-11), and at the Commission’s request Dr. Mendelsohn can provide producing a set of values for whatever model inputs or parameters the Commission wishes.

future revisions to the SCC estimates, including (but not limited to) using the AR5 climate sensitivity distribution for the next update of the SCC.”).

²⁷ Ex. 238, Tol Rebuttal, Ex. 2 (Report) at 4:80-5:83.

Moreover, both Dr. Tol and Dr. Mendelsohn severely criticized the IWG's misapplications of the FUND and DICE models. The State Agencies admit that the IWG overrode many of the models' original inputs and assumptions by "standardizing the model inputs and parameters." (State Agencies Br. 26.) Among other things, this meant that the IWG "change[d] the structure of DICE to make it a simulation model rather than an optimization model." (*Id.*) Dr. Mendelsohn described the IWG's approach to "standardizing" the models as akin to putting gasoline in a diesel car. (3B Tr. 37:19-38:11.) Thus, "standardizing" does not accurately portray what occurred; rather, the changes are more akin to corrupting the original models, which were predicated on different assumptions and judgments. Remarkably, the State Agencies criticize Dr. Mendelsohn for updating the DICE damages function (even though Dr. Hanemann testified that the DICE damages function needed to be updated, 2B Tr. 91:16-20), on the supposed ground that Dr. Nordhaus "is an eminent economist" (State Agencies Br. 70 n.54) and that DICE should not be modified without evidence that "Professor Nordhaus is wrong." (*Id.* at 70.) Yet the IWG necessarily concludes that Professor Nordhaus is wrong when it changed the DICE model as it did. The State Agencies inconsistently give the IWG a free pass for making fundamental changes to DICE and overriding Dr. Nordhaus' decisions and parameters in a non-transparent and non-peer-reviewed fashion. In contrast, Dr. Mendelsohn's improvements do not change the fundamental operation of the DICE but instead improve inputs, which are tied to the current evidence. The former is indefensible, the latter justifiable and proper.

With respect to FUND, the State Agencies concede in their brief:

As the author of FUND, Dr. Tol's assessment was that the IWG may not have correctly operated FUND in generating its estimates. The inconsistency between the damage estimates generated when Dr. Tol operates the FUND model himself,

and those produced by the IWG, raises, in Dr. Tol's view, questions as to whether the IWG's estimates lack economic and scientific reliability.

(State Agencies Br. 28.) Dr. Tol's trenchant criticism of the IWG on this point was some of the most powerful testimony in this proceeding, and the decision by all of the Proponents not even to cross-examine him on the issue is significant. Even Dr. Hanemann agreed that Dr. Tol is far more familiar with FUND than he is. (2B Tr. 67:16-19.)

Dr. Hanemann testified that the IWG's decisions in 2010 and 2013 were reasonable but 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.) Thus, if the Commission decides to set an externality value for CO₂ rather than a zero or negative value, it should use — *according to Dr. Hanemann's own testimony* — the results of the updated versions of the FUND and DICE models, as presented by Drs. Tol and Mendelsohn, rather than the corrupted results derived by the IWG. In fact, the testimony of Drs. Tol and Mendelsohn shows that there is no need to corrupt the IAMs. Before the Commission in this proceeding are the results of the unadulterated DICE and FUND models, which are corroborative and mutually reinforcing.

The Proponents of the FSCC argue, in effect, that the Commission should take a leap of faith and "trust" the IWG without attempting to verify the accuracy of its estimate. But even if Minnesota law permitted such a supine, rubber-stamp approach — and it does not — the stubborn facts remain: *mainstream climate science and 2 out of the 3 IAMs used by the IWG no longer support the FSCC*. In this proceeding, the opponents of the FSCC have cited 9 times as much peer-reviewed literature as the proponents of the FSCC. The credentials of the witnesses opposing the FSCC are head-and-shoulders above the credentials of the witnesses

supporting it. None of the witnesses supporting the FSCC has ever designed or operated one of the IAMs used by the IWG to generate the FSCC, none has experience with the IPCC comparable to that of Dr. Tol, none has served as a lead author for an IPCC physical sciences report (as Dr. Lindzen has), and none has ever received awards comparable to those bestowed on the witnesses opposing the FSCC. None of the opposing witnesses has published peer-reviewed work in which they operated one of the relevant IAMs, as Drs. Tol and Mendelsohn have.

In fact, the Proponents' witnesses were repeatedly impeached with their scholarly materials (written outside this proceeding) which contradicted their testimony before the Commission. For example:

- Dr. Dessler was forced to concede under cross-examination that he had 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” (Ex. 259) – *well below the IWG’s assumed central value of 3.0°C*.
- Dr. Abraham was forced to agree on cross-examination that he had written an article stating that “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. at 80:1-9.)
- Dr. Reich was forced to admit on cross-examination that he had published a *peer-reviewed* article predicting a 67 percent to 142 percent *increase in forest regional productivity* as a result of *increased carbon emissions and global warming* — and that article was inconsistent with his testimony in this proceeding. (5 Tr. at 38:24-39:7, 73:5-8; Ex. 266.)

B. Peabody’s Position

The FSCC is not a reasonable or the best available measure of the social cost of carbon. To the contrary, a preponderance of the evidence supports a zero value: no clear evidence presented in this proceeding supports attributing the dire impacts quantified by an externality value to human origins (much less specifically CO₂ emission).

In the alternative, a preponderance of the evidence supports a negative externality value, as Dr. Tol suggested based on his calculations of the FUND model, when tethered to updated evidence showing ECS values of 2.0°C and below, because of the net beneficial effects of mild warming, which is more likely than the extreme warming assumed by the proponents of the FSCC.

If the Commission does not adopt a zero or negative 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 a positive 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. Dr. Mendelsohn used the DICE model with an improved damages function and an updated 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).

This proceeding presents the opportunity for Minnesota to act as a leader – as an exemplar for the nation by exercising intellectual discipline and adopting an evidence-based carbon policy. As Dr. Mendelsohn testified, “Minnesota has an opportunity to lead by tethering the externality range to the best empirical evidence and science.” (Ex. 261, Mendelsohn Opening Statement, at 4.) But if Minnesota sets an inflated and scientifically invalid SCC, then Minnesota will make itself a sacrificial lamb, impose hardship on its consumers and businesses, and shift emissions to neighboring states (and even overseas) rather than reducing them. Setting an arbitrarily inflated value of the SCC, rather than one grounded in the current science and

sound economic principles, would be self-defeating because it will ensure that others will (rationally) choose not to follow Minnesota.

II. Standard of Review

A. **The Proponents of the FSCC Have Failed To Meet Their Burden Of Proof.**

The State Agencies concede that the March 27, 2015 Order Regarding the Burdens of Proof provides that:

A party or parties proposing that the Commission adopt a new environmental cost value for CO₂, including the Federal Social Cost of Carbon, *bears the burden of showing, by a preponderance of the evidence*, that the value being proposed is reasonable and the best available measure of the environmental cost of CO₂.

(State Agencies Br. 4 (quoting Order; emphasis added).) The Proponents of the FSCC have failed to meet the preponderance-of-the-evidence standard. Indeed, they have failed to address the criteria underlying that standard.

As Peabody showed in its opening brief, in 1996, ALJ Klein addressed the factors by which the Commission would evaluate proposed externality values and listed five “criteria” for “determining which environmental impacts to value and whether and how to value these impacts,” all of which are consistent with his recommendation that the Commission respond to uncertainty by adopting conservative values. (Ex. 305, Findings of Fact, Conclusions, Recommendation, and Memorandum, at ¶ 36 (Mar. 22, 1996).)

Judge Klein 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.” (*Id.* at 17-18).

- “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.*)

ALJ Klein recommended rejection of cost values based on “a speculative measure of damage” and “an unreasonably low discount rate.” (*Id.* at ¶ 112.) He cited “the policy goal of using conservative values in the face of uncertainty.” (*Id.* at ¶ 114.)

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). As the Commission stated:

“While the Commission finds the methodology used by MPCA witness Ciborowski sufficient to provide a meaningful estimate of 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, at p. 4 (July 2, 1997).) It follows that if more uncertainty exists now than existed 20 years ago, the values should be more conservative, or lower.

The Proponents of the FSCC offer little discussion of the criteria established by the Commission in its prior proceeding, and they should not be allowed to raise the issue for the first time in their reply brief.

B. “Uncertainty” Invalidates the FSCC, Rather Than Supporting It

The Proponents of the FSCC admit that “[m]any uncertainties can arise in the context of long-run decision making on climate mitigation and damage reduction.” (State Agencies Br. at 127.) In fact, they concede that “over the past decade uncertainty over climate sensitivity has increased.” (State Agencies Br. at 124.) Similarly, the CEOs acknowledge that climate sensitivity values are not knowable: “The exact relationship between concentrations and temperature is unknown and ‘likely to remain unknown for the foreseeable future’ because it involves complicated feedback loops, the strength of which are not currently measurable.” (CEOs Br. at 14.) Xcel also admits that an evidence-based result is impossible. (Xcel Br. at 5-6.) According to Xcel, “no empirically true or correct value of the SCC . . . can be determined.” (Xcel Br. at 2.)

Ironically, a proceeding that began with a petition asking the Commission to reopen the environmental externality docket to “reflect the current science” (CEOs Br. at 2) has degenerated into a proceeding where the Proponents of the FSCC openly admit that the “current science” does not provide evidentiary support for the FSCC, but they urge the Commission should adopt it anyway.

The State Agencies maintain, paradoxically, that increased uncertainty can lead to a higher value of the SCC because of “risk aversion.” (State Agencies Br. at 89-90, 123-128.) The State Agencies’ counterintuitive argument is deeply flawed and utterly conjectural. No one has performed a survey of Minnesota ratepayers to determine their level of “risk aversion.” The rationale lacks empirical basis and is a speculative invention. Further, setting an arbitrarily high SCC would not *avert* any risk. The Proponents of the FSCC take the cynical view that Minnesota should set an externality value as though no jurisdiction elsewhere will ever take any steps to address climate change (State Agencies Br. at 44), so that Minnesota alone must bear all the costs of what will ultimately be a futile gesture, since Minnesota’s CO₂ emissions are a

negligible portion of worldwide emissions. Thus, it makes no sense to talk about “risk aversion” decision-making, because Minnesota’s adoption of the FSCC would not reduce perceived risks at all.

In addition, the State Agencies’ “risk aversion” theory lacks economic merit. As Dr. Gayer has explained, it confuses risk and uncertainty. Dr. Polasky’s analogy to purchasing insurance assumed that there was a 5% risk of damage, but “[r]isk is the probability of an event occurring; uncertainty is the degree of imprecision in the estimate of risk.” (Ex. 401, Gayer Surrebuttal at 14:18-19.) By conflating uncertainty and risk, Dr. Polasky places too much weight on the 95th percentile resulting in the equivalent of overinsurance: his fear of the ambiguity that goes with uncertainty leads him into an irrational decision. (Ex. 401, Gayer Surrebuttal at 15:8-17:2.) As Dr. Mendelsohn has explained, the proper approach to uncertainty is simply to adapt over time and avoid locking Minnesota into an arbitrarily high SCC value at the outset. (Mendelsohn 3B Tr. 60:21-61:13.)

The State Agencies’ approach to uncertainty is also legally untenable. In the original Externalities Docket, ALJ Klein already rejected the State Agencies’ approach to uncertainty: “[a]t 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.” (Ex. 305, 1996 ALJ Recommendation, at ¶ 31.) ALJ Klein specifically rejected higher proposed externality values because, “[g]iven the current uncertainty regarding the estimation process, overestimating the damages is a distinct possibility.” (*Id.* at 17). The Commission approved this conservative approach in 1997. (*See* Order Affirming In Part and Modifying In Part Order Establishing Environmental Cost Values, at p. 4 (July 2, 1997).)

Today, the Commission’s legal mandate remains limited: to determine a practicable, reasonable, and best available externality value for CO₂ based on the evidence in this docket. As Xcel notes, “this proceeding is not a scientific and economic exercise limited to the climate change context; this is a state-level regulatory process that will affect how regulated utilities in Minnesota will select, allocate, and build resources. . . . The CO₂ externality values established in this Docket will be used in resource planning and certificate of need proceedings, and they will directly affect what kind of resources Minnesota utilities will rely on and build in the future. There simply cannot be a presumption in this proceeding that it is better to err on the side of overestimating than underestimating damages from CO₂.” (Xcel Br. at 25.)

The rampant uncertainty should lead the Commission to adopt a zero value, because the preponderance standard simply cannot be met. The solution to uncertainty or lack of evidence is not to speculate or base the SCC on political preferences. ***The proper response in the face of uncertainty is to set a zero value.*** Uncertainty preventing the Commission from calculating an accurate externality value surely cannot lead the Commission to increase its value by a factor of at least 25.

Indeed, numerous cases have recognized that decisions based on uncertain and speculative evidence are arbitrary and capricious.

- *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 SO_x and NO_y 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.

These cases demonstrate that simply asking a regulatory body to “just trust us” is simply asking the body to rule in an arbitrary manner that is contrary to law. Following such a rule opens the regulatory body to reversal by a court of law. Faced with such uncertainty and mindful of ALJ Klein’s teaching, the Commission should reject the FSCC. The proper response to uncertainty is to avoid picking an arbitrary number and instead to decline to set any externality value.

The Proponents argue that the IWG will continue to study the matter and will update the FSCC accordingly, and that the Commission can do similarly: adopt the FSCC and revise when the IWG does. But they miss the point that *today* uncertainty is too great to permit adoption of the FSCC at this time. In face of disabling uncertainty, the Commission *not* adopt a value for the social cost of carbon (or should set a zero value), and if the IWG continues to study the matter, the Commission can revisit the question in the future as well. (As shown in Section III(A)(3)(b), the IWG has already proven that it will ignore new scientific findings — it has had two opportunities to update its ECS values since AR5 WG1 was issued in 2013, and the IWG has failed to do so on either occasion.)

Adopting the FSCC or Xcel’s value now would be arbitrary and capricious. 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.

III. The Federal SCC Is Neither Reasonable Nor The Best Available Measure

The Proponents of the FSCC have completely failed to submit evidence in this record that would be sufficient to justify adopting the FSCC. Indeed, the Proponents of the FSCC have effectively done the opposite: *evidence from AR5 and concessions from the Proponents of the FSCC alone provide a preponderance of the evidence showing that the FSCC should be rejected*. Moreover, hundreds of citations to peer-reviewed articles supporting its rejection have been placed into the record *without refutation*. The preponderance of unopposed, authoritative evidence in this record supports only one conclusion: rejecting the FSCC and any other value based on its data, such as Xcel's proposed value.

As a background drumbeat, the State Agencies repeatedly — but falsely — criticize Peabody witnesses for supposedly not relying on peer-reviewed literature. (State Agencies Br. at 79, 94-105.) Yet they fail to acknowledge a point that has been made several times now: Peabody witnesses have cited 1,457 peer-reviewed papers, compared to only 169 peer-reviewed papers cited by the witnesses for the State Agencies and the CEOs combined. That amounts to almost *nine times* more peer-reviewed research supporting Peabody. And it includes citations to such eminent journals as *Science*, *Nature*, *Geophysical Research Letters*, *Climate*, and others. Moreover, the real-world observational data records of satellite, weather balloon, and ground-based thermometers are themselves peer-reviewed. (Spencer, 2B Tr. 12:6-19.)

In the face of (i) Proponents' admissions, (ii) the findings of AR5 WG1, and (iii) the overwhelming peer-reviewed evidence submitted by Peabody, the Proponents offer only conclusory appeals to "consensus" not backed up by evidence. Appeals to a false "consensus" cannot fill in gaps in the evidentiary record.

A. Proponents' Concessions, AR5, and the Consensus of Peer-Reviewed Evidence Invalidate The Climate-Science Foundation of the FSCC.

The Proponents of the FSCC have conceded sufficient facts to demonstrate that the FSCC is fatally flawed. Moreover, they hold up AR5 as “the best resource for providing a comprehensive synthes[i]s of what is known and not know[n] on the topic of climate change” (Ex. 803, Gurney Rebuttal at 28:2-4),²⁸ although they barely discuss AR5 in their Opening Briefs. AR5 WG1 completely undermines the scientific assumptions on which the FSCC is based. The conclusions of AR5 WG1 and the admissions by the Proponents of the FSCC, bolstered by the weight of the uncontested peer-reviewed literature, all invalidate the FSCC.

1. AR5 Finds There Has Been a Hiatus in Warming, Which Is Corroborated by Concessions from Dr. Dessler.

The State Agencies deny that the hiatus exists and insist that the temperature record supports the FSCC. (State Agencies Br. 78-81.) Yet Dr. Dessler testified that there has been a hiatus in global warming since 2000: “Dr. Spencer is correct. . . . [I]t is correct to say that there has been no statistically significant warming since 2000.”²⁹ Dr. Abraham has written, “[t]he 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.”³⁰

The existence of a hiatus in warming is incontestable on the basis of the evidence in this record. In 2013 AR5 noted the slowdown in warming since 1998: “[T]he rate of warming over

²⁸ The State Agencies and the CEOs both characterize the IPCC as the leading authority on climate change. (State Agencies Br. at 24 (“Dr. Hanemann explained that IPCC Assessment Reports are internationally regarded as authoritative on the topics covered.”); CEO Br. at 5 (“Worldwide, the international panel on climate change (‘IPCC’) is ‘the leading expert body on assessing climate change[.]’”).)

²⁹ Ex. 103, Dessler Rebuttal at 15:5-7. *See also* Dessler, 3A Tr. 20:14-16 (“And you agree that there has been no statistically significant warming since the year 2000, correct? Correct.”).

³⁰ Ex. 262, Grant Foster and John Abraham, “Lack of Evidence for a Slowdown in Global Temperature,” in U.S. CLIVAR, 13 Variations (Summer 2015).

the past 15 years (1998–2012; 0.05 [–0.05 to +0.15] °C per decade) ... is smaller than the rate calculated since 1951 (1951–2012; 0.12 [0.08 to 0.14] °C per decade).”³¹ AR5 WG1 thus expressly recognized a “hiatus”: “the observed recent warming hiatus [is] defined as the reduction in GMST trend during 1998–2012 as compared to the trend during 1951–2012.”³² “The observed GMST [Global Mean Surface Temperature] 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.”³³ Based on peer-reviewed datasets, Dr. Spencer explained, “[c]ontrary 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.)

AR5 and clear concessions on this record make the existence of the hiatus effectively incontrovertible for this proceeding.

2. AR5 and Key Concessions Prove the Discrepancy Between Models and Peer-Reviewed Observational Datasets

(a) AR5 Finds that Models “Run Hot”

Contrary to the evidence on this record, the State Agencies deny that models overestimate warming. (State Agencies Br. 83-84.) Yet even the CEOs’ own witness, Dr. Dessler, admitted that “the models assumed incorrect ‘forcing’ over the last decade . . . which causes the models to

³¹ AR5 WG1 at 162.

³² AR5 WG1 at 772 (Box 9.2).

³³ AR5 WG1 at 61 (Box TS.3).

run ‘hot.’” (Ex. 103, Dessler Rebuttal 25:16-18.) Similarly, AR5 finds are “running hot” and substantially over-predicting warming: “Almost all CMIP5 historical simulations do not reproduce the observed recent warming hiatus.”³⁴ “[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,”³⁵ i.e., actual surface temperature data. “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.”³⁶ IPCC’s Working Group II summarized Working Group I’s report as finding that climate models do not accurately reproduce the hiatus.³⁷

In short, *AR5 finds that the climate models IWG used consistently overestimate warming*. AR5 recognizes that AR4 and its models overestimated warming.³⁸ The IWG based its calculation of the FSCC on AR4’s overestimations of warming, yielding a number that we now know is wrong — and the IWG stood pat, refusing to update or withdraw its estimates.

Moreover, AR5 notes increased recognition of the flaws in how models simulate cloud processes and their effects on temperatures — essentially, we know better that the models are incapable of modeling clouds well. “Climate models now include more cloud and aerosol processes, and their interactions, than at the time of the AR4, but there remains low confidence

³⁴ AR5 WG1 at 63 (Box TS.3).

³⁵ AR5 WG1 at 769 (Box 9.2).

³⁶ AR5 WG1 at 771 (Box 9.2).

³⁷ AR5 WG2 at 189.

³⁸ AR5 WG1 at 1010.

in the representation and quantification of these processes in models.”³⁹ These cloud processes and their complex effects are central to the calculation of ECS, however. Clouds not only hold in heat by insulating the Earth, they also reflect it back out into space. 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.)

Even though cloud feedbacks are central to calculating and ECS (and therefore an externality value), these feedback mechanisms are sufficiently complex that the IPCC itself has only “low confidence” in their values. “Uncertainty in the sign and magnitude of the cloud feedback is due primarily to continuing uncertainty in the impact of warming on low clouds.”⁴⁰ “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.”⁴¹ AR5 adds: “cloud feedbacks continue to have larger uncertainties.”⁴² Even 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.) *The fact that AR5 found such a high degree of uncertainty in feedbacks — the key factor in proving an ECS value greater than 1 °C — cripples the case for the IWG’s calculations based on outdated science.*

³⁹ AR5 WG1 at 16.

⁴⁰ AR5 WG1 at 16.

⁴¹ AR5 WG1 at 40.

⁴² AR5 WG1 at 58.

AR5 addressed the heat island effect, which the State Agencies repeatedly say has been accounted for properly. AR5 disagrees, noting that the heat island effect may be affecting surface temperature measurements by up to 10%.⁴³ Moreover, in some areas the effect “may be substantially larger.”⁴⁴ AR5 concludes that “UHI [urban heat island] and LULC [land-use land-cover change] are real influences on raw temperature assessments.”⁴⁵ Unlike the State Agencies, AR5 does not shrug off the effects. As Dr. Spencer noted, those concerns are shared by NASA’s Goddard Space Flight Center and Arizona State University. (Ex. 227, Spencer Surrebuttal at 9:14-10:3.) As Dr. Spencer pointed out, the slow nature of the urban heat island effect would make it indistinguishable from global warming to data homogenization techniques. (Ex. 227, Spencer Surrebuttal at 10:4-9.) The State Agencies have never responded to this argument. ***On this record, therefore, there is no substantial evidence showing that surface temperature measurements can reliably adjust to exclude spurious warming from urban heat islands.***

Like the overheated models, AR4, upon which the IWG based the FSCC, 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.” In other words, although IWG made its calculations based on 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 only approximately 0.05°C (or about 1/6 of the 0.3°C that was projected to occur in a decade-and-a-half). The science the IWG used to formulate the FSCC has been superseded by newer, better science that is less extreme in its predictions about warming.

⁴³ AR5 WG1 at 189.

⁴⁴ AR5 WG1 at 189.

⁴⁵ AR5 WG1 at 189.

The Proponents of the FSCC have failed to respond. ***While the Proponents have made many conclusory, undocumented assertions, they have not presented peer-reviewed evidence to back up their claims.*** These discrepancies have been extensively documented on this record. (See Peabody Br. 43-45; Ex. 213, Lindzen Surrebuttal, 8:14-9:7.)

(b) The Commission Cannot “Just Trust” The Proponents that Climate Models are Viable When Peer-Reviewed Evidence Says the Opposite

AR5 found not only that there was a hiatus but that the climate models failed to reproduce it.⁴⁶ In addition to AR5, unrefuted peer-reviewed science shows that the climate models are fundamentally flawed. As Dr. Spencer showed at trial, peer-reviewed observational data also invalidate the models. (See Ex. 256, Spencer Opening Statement at 3). None of the opposing parties challenged Dr. Spencer’s testimony in cross-examination.

Examining the peer-reviewed literature shows the flaws in Dr. Dessler’s assertion that “the overall agreement between models and observations is excellent.” (Ex. 103, Dessler Rebuttal 23:13.) To the contrary, systemic failures of climate models have been widely documented in the peer-reviewed literature:

- A peer-reviewed study in *Nature* found that ***models have failed to reproduce either actual global temperatures or the slowdown in warming for two decades.***⁴⁷
- Another group of researchers found in a peer-reviewed study that ***29 of the 33 models used in the CMIP5 ensemble (used by the IPCC) suffer from serious biases,*** including getting the sign wrong on a sea surface heat gradient across the equator.⁴⁸ A further peer-reviewed study showed that models in CMIP5 are wrong

⁴⁶ AR5 WG1 at 63; AR5 WG2 at 189.

⁴⁷ John C. Fyfe, *et al.*, “Overestimated Global Warming over the Past 20 Years,” 3 *Nature Climate Change* 767, 767 (Sep. 2013) (cited in Ex. 213, Lindzen Surrebuttal 14:5-6; Ex. 202, Happer Direct, Ex. 2 (Report) at 5 (Fig. 3); Happer Surrebuttal 3:20-22, 8:6-15).

⁴⁸ Richter, I., Xie, S.-P., Behera, S.K., Doi, T. and Masumoto, Y. 2014. Equatorial Atlantic variability and its relation to mean state biases in CMIP5. *Climate Dynamics* 42: 171-188 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 44-45).

on sea surface temperatures by multiple degrees in some places — enough, the scientists conclude, to diminish the confidence that can be placed in the models.⁴⁹ Yet another peer-reviewed study found that that models’ uncertainty in recreating the water systems renders them untrustworthy.⁵⁰

- A peer-reviewed study found that *climate models show a large drop-off in predictive ability after 31 days* for land-based (real-life) predictions, and only 15 days for model-only (virtual) predictions.⁵¹
- A peer-reviewed study found that, to make matters worse, the models in the CMIP5 ensemble are both *consistently wrong* and *broadly in agreement*, which leads to a false confidence in the results.⁵²
- A peer-reviewed report from a team of scientists from the Chinese Academy of Sciences shows that the most widely used climate models miscalculate the solar zenith, thereby overestimating the effects of solar radiation and adding “spurious variation” that is 18 times greater than the total effects of CO₂ on temperature since 1750. In short, *a mistake in the climate models has produced a greater anthropogenic effect on warming than CO₂ emissions*.⁵³ (Ex. 213, Lindzen Surrebuttal at 2-3)
- A peer-reviewed study by Chapman University Researchers showed that the weather in the Southwestern United States correlates more strongly with a key

⁴⁹ Wang, C., Zhang, L., Lee, S.-K., Wu, L. and Mechoso, C.R. 2014. A global perspective on CMIP5 climate model biases. *Nature Climate Change* 4: 201-205 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 47).

⁵⁰ Martin, G.M. 2014. Quantifying and reducing uncertainty in the large-scale response of the water cycle. *Surveys in Geophysics* 35: 553-575 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 48).

⁵¹ Lavers, D., Luo, L. and Wood, E.F. 2009. A multiple model assessment of seasonal climate forecast skill for applications. *Geophysical Research Letters* 36: 10.1029/2009GL041365 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 53).

⁵² Maloney, E.D., Camargo, S.J., Chang, E., Colle, B., Fu, R., Geil, K.L., Hu, Q., Jiang, X., Johnson, N., Karnauskas, K.B., Kinter, J., Kirtman, B., Kumar, S., Langenbrunner, B., Lombardo, K., Long, L.N., Mariotti, A., Meyerson, J.E., Mo, K.C., Neelin, J.D., Pan, Z., Seager, R., Serra, Y., Seth, A., Sheffield, J., Stroeve, J., Thibeault, J., Xie, S.-P., Wang, C., Wyman, B. and Zhao, M. 2014. North American climate in CMIP5 experiments: Part III: Assessment of Twenty-First-Century Projections. *Journal of Climate* 27: 2230-2270 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 48). *See also* Chen, L., Pryor, S.C. and Li, D. 2012. Assessing the performance of Intergovernmental Panel on Climate Change AR5 climate models in simulating and projecting wind speeds over China. *Journal of Geophysical Research* 117: 10.1029/2012JD017533 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 51) (CMIP5 ensemble failed to predict decreased windspeed over China — *no model* in the ensemble predicted it correctly).

⁵³ L. Zhou, *et al.*, *On The Incident Solar Radiation In CMIP5 Models*, 42 *Geophys. Res. Lett.*, 1930 (2015), available at <http://onlinelibrary.wiley.com/doi/10.1002/2015GL063239/abstract> (cited in Ex. 213, Lindzen Surrebuttal at 3 n.3).

ocean current in the Atlantic than with the Pacific currents that models assume govern the weather patterns.⁵⁴ Ultimately, *the models are founded on the wrong causal connections*. (Ex. 213, Lindzen Surrebuttal at 3.)

- Scientists from Imperial College in London found in a peer-reviewed study that climate models have been omitting the massive stocks of carbon in dead trees, resulting in greater carbon sequestration than models assume.⁵⁵ (Ex. 213, Lindzen Surrebuttal at 3). *Models consistently underestimate CO₂ fertilization*.⁵⁶
- In a peer-reviewed study, a team from the Centre National des Recherches Météorologiques in France adjusted a model in a manner that reflected recent climate evolutions more faithfully, and found that *existing models overestimated warming not only from 1998 to 2012 but in previous decades as well*.⁵⁷ (Ex. 213, Lindzen Surrebuttal at 4)
- In another peer-reviewed study, a team of researchers from institutions including NASA’s Jet Propulsion Laboratory, the University of Reading, and the Georgia Institute of Technology demonstrated that the *Earth’s albedo (reflectivity) is an inherently stabilizing feedback mechanism that general climate models do not account for properly*.⁵⁸ (Ex. 213, Lindzen Surrebuttal at 4)
- Researchers found in a peer-reviewed study that climate models have failed to produce correct results in temperature data or prediction data, because “most models fail to produce the sign of the relationship between [the] shortwave cloud radiative effect and temperature advection.”⁵⁹ (Ex. 213, Lindzen Surrebuttal at 5) Indeed, other researchers have found that *a lack of understanding of cloud-*

⁵⁴ Boksoon Myoung, *et al.*, *On The Relationship Between The North Atlantic Oscillation And Early Warm Season Temperatures In The Southwestern US*, __ Am. Meteorological Soc’y __ (ahead of print) (2015), available at <http://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-14-00521.1> (cited in Ex. 213, Lindzen Surrebuttal at 3 n.5).

⁵⁵ M. Pfeifer, *et al.*, *Deadwood biomass: an underestimated carbon stock in degraded tropical forests?*, 10 *Environmental Research Letters* (2015), available at <http://iopscience.iop.org/1748-9326/10/4/044019/> (Ex. 213, Lindzen Surrebuttal at 3 n.6).

⁵⁶ Ying Sun, *et al.*, “Impact of Mesophyll Diffusion on Estimated Global Land CO₂ Fertilization,” 111 *Proceedings Nat’l Acad. Scis.* 15774 (Nov. 4, 2014) (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 88).

⁵⁷ H. Douville, *et al.*, *The Recent Global Warming Hiatus: What Is The Role Of Pacific Variability?*, 42 *Geophys. Research Letters* 880-88 (2015), available at <http://onlinelibrary.wiley.com/doi/10.1002/2014GL062775/full> (Ex. 213, Lindzen Surrebuttal at 4 n.7).

⁵⁸ Graeme L. Stephens, *et al.*, *The Albedo of Earth*, 53 *Rev. Geophys.* (2015), available at <http://webster.eas.gatech.edu/Papers/albedo2015.pdf> (cited in Ex. 213, Lindzen Surrebuttal at 4 n.9).

⁵⁹ Myers, T.A. and Norris, J.R. 2015. On the relationships between subtropical clouds and meteorology in observations and CMIP3 and CMIP5 models. *Journal of Climate* 28: 2945-2967 (cited in Ex. 213, Lindzen Surrebuttal at 5 n.11).

*aerosol interactions is one of the key elements preventing models from improving.*⁶⁰

- In a peer-reviewed study, *researchers analyzed whether climate prediction models have improved over time, but found that “the results have not been encouraging,”* and condemned as irredeemable the fact that “the constraint of the coupled ocean-atmosphere variability will still be a basic limitation on prediction skill.”⁶¹ (Ex. 213, Lindzen Surrebuttal at 5)
- In a peer-reviewed study, researchers found that *climate models are still unable to resolve fundamental obstacles.* “[T]he poor ability of climate models in simulating the coupling between the winter atmosphere and preceding summer SST remains an obstacle in predicting the climate variability over the North Atlantic.” The researchers went further to condemn climate modeling sciences, finding that “it remains a great challenge to improve model ability in simulating and predicting the North Atlantic climate variability.”⁶² (Ex. 213, Lindzen Surrebuttal at 5.) In other words, the climate models may be completely untrustworthy until the North Atlantic can be reliably modeled.
- *Even attempts to correct for known biases fail to save model predictions.* In a peer-reviewed study, researchers studying new “bias correction methods” to determine if the new models had corrected previous biases found that “the typical 10 to 20% projected precipitation change in many impact studies ... is possibly of the same magnitude as the uncertainty error brought in by the assumption of bias stationarity.”⁶³ In other words, the bias corrections fall prey to the same bias problems as the models they are attempting to correct. (Ex. 213, Lindzen Surrebuttal at 6.)
- A peer-reviewed study noted that *climate models cannot even accurately reproduce changes due to the seasons,* with the consequence that they measure a sea surface temperature that is too high overall.⁶⁴ Other analyses have found

⁶⁰ Rosenfeld, D., Sherwood, S., Wood, R. and Donner, L. 2014. Climate effects of aerosol-cloud interactions. *Science* 343: 379-380 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 43).

⁶¹ Kumar, A. and Wang, H. 2015. On the potential of extratropical SST anomalies for improving climate predictions. *Climate Dynamics* 44: 2557-2569 (cited in Ex. 213, Lindzen Surrebuttal at 5 n.12).

⁶² Yang, Y. and Wu, L. 2015. Changes of air-sea coupling in the North Atlantic over the 20th century. *Advances in Atmospheric Sciences* 32: 445-456 (cited in Ex. 213, Lindzen Surrebuttal at 5 n.14).

⁶³ Chen, J., Brissette, F.P. and Lucas-Picher, P. 2015. Assessing the limits of bias-correcting climate model outputs for climate change impact studies. *Journal of Geophysical Research Atmospheres* 120: 1123-1136 (cited in Ex. 213, Lindzen Surrebuttal at 6 n.17).

⁶⁴ Zhang, L., Wang, C., Song, Z. and Lee, S.-K. 2014. Remote effect of the model cold bias in the tropical North Atlantic on the warm bias in the tropical southeastern Pacific. *Journal*

excessive seasonal variability compared to real observed patterns.⁶⁵ (Ex. 213, Lindzen Surrebuttal at 7, 8.)

- Peer-reviewed studies have found that *models cannot accurately simulate key ocean currents that are central to any understanding of weather patterns and climate*, including the Atlantic Meridional Overturning Current,⁶⁶ the Pacific Decadal Oscillation,⁶⁷ the Jet Stream and North Atlantic Current,⁶⁸ and the El Niño Southern Oscillation.⁶⁹ (Ex. 213, Lindzen Surrebuttal at 8.) Similarly, even the strongest model for Indian summer monsoons is still systematically wrong — even though it is the only model that is even partially correct.⁷⁰ Models cannot replicate Caribbean rainfall correctly — and researchers do not even understand what the origin of the biases might be.⁷¹

of Advances in Modeling Earth Systems 6: 1016-1026 (cited in Ex. 213, Lindzen Surrebuttal at 7 n.20).

⁶⁵ Ao, C.O., Jiang, J.H., Mannucci, A.J., Su, H., Verkhoglyadova, O., Zhai, C., Cole, J., Donner, L., Iversen, T., Morcrette, C., Rotstajn, L., Watanabe, M. and Yukimoto, S. 2015. Evaluation of CMIP5 upper troposphere and lower stratosphere geopotential height with GPS radio occultation observations. *Journal of Geophysical Research: Atmospheres* 120: 1678-1689 (cited in Ex. 213, Lindzen Surrebuttal at 8 n.22).

⁶⁶ Keenlyside, N.S., M. Latif et al (2008) Advancing decadal-scale climate prediction in the North Atlantic sector. *Nature*, 453, doi:10.1038/nature06921 (cited in Ex. 213, Lindzen Surrebuttal at 8 n.23).

⁶⁷ Furtado, J.C., E. DiLorenzo et al (2011) North Pacific Decadal Variability and Climate Change in the IPCC AR4 Models. *J. Clim.*, 24, 3049-3067, DOI: 10.1175/2010JCLI3584.1 (cited in Ex. 213, Lindzen Surrebuttal at 8 n.24).

⁶⁸ Keeley, S.P.E., Sutton, R.T. and Shaffrey, L.C. 2012. The impact of North Atlantic sea surface temperature errors on the simulation of North Atlantic European region climate. *Quarterly Journal of the Royal Meteorological Society* **138**: 1774-1783 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 38).

⁶⁹ Jin, Emilia K., J. L. Kinter III et al (2008) Current status of ENSO prediction skill in coupled ocean-atmosphere models. *Clim Dyn* (2008) 31:647-664, DOI 10.1007/s00382-008-0397-3 (cited in Ex. 213, Lindzen Surrebuttal at 8 n.25). *See also* Zhang, T. and Sun, D.-Z. 2014. ENSO asymmetry in CMIP5 models. *Journal of Climate* **27**: 4070-4093 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 39) (finding that models cannot simulate El Niño/La Niña variability, a key driver of global climate variability).

⁷⁰ Abhik, S., Mukhopadhyay, P. and Goswami, B.N. 2014. Evaluation of mean and intraseasonal variability of Indian summer monsoon simulation in ECHAM5: identification of possible source of bias. *Climate Dynamics* **43**: 389-406 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 39). *See also* Feng, J., Wei, T., Dong, W., Wu, Q. and Wang, Y. 2014. CMIP5/AMIP GCM simulations of East Asian summer monsoon. *Advances in Atmospheric Sciences* **31**: 836-850 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 40) (noting that models also fail to simulate the East Asian summer monsoon because of systemic errors).

⁷¹ Ryu, J.-H. and Hayhoe, K. 2014. Understanding the sources of Caribbean precipitation biases in CMIP3 and CMIP5 simulations. *Climate Dynamics* **42**: 3233-3252 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 39).

- A peer-reviewed paper found that an advanced paired-model system used by the IPCC *cannot replicate even known periodic temperature anomalies*.⁷²
- Another peer-reviewed paper found that climate models are *subject to systemic errors based on arbitrary choices made regarding how to model the upper atmosphere*.⁷³
- Another peer-reviewed paper found that *models do not reliably improve*: the new CMIP5 ensemble still cannot properly model rainfall over the Amazon, even though the problem has persisted since the CMIP3 model ensemble.⁷⁴

Outside of peer-reviewed literature, climate models have drawn considerable fire because of their systemic failures:

- Hans von Storch, an IPCC lead author, has questioned the basic viability of climate models due to their ongoing inability to predict the hiatus in warming. *“This is a serious scientific problem that the [IPCC] will have to confront”*⁷⁵ (Ex. 235, Bezdek Surrebuttal at 4:17-5:7.)
- Even in this proceeding, Dr. Reich made the fundamental argument most clearly: *“[A] model is not direct evidence, ever.”* (Reich: 5 Tr. 68:17.)
- On March 14, 2015, Prof. Michael Kelly, a member of the Royal Society and the Prince Philip Professor of Technology at Cambridge University, criticized the inability of climate models to explain the hiatus: *“This flies in the face of the*

⁷² Westby, R.M., Lee, Y.-Y. and Black, R.X. 2013. Anomalous temperature regimes during the cool season: Long-term trends, low-frequency mode modulation, and representation in CMIP5 simulations. *Journal of Climate* **26**: 9061-9076 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 38).

⁷³ Marsh, D.R., Mills, M.J., Kinnison, D.E., Lamarque, J.-F., Calvo, N., and Polvani, L.M. 2013. Climate change from 1850 to 2005 simulated in CESM1(WACCM). *Journal of Climate* **26**: 7372-7391 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 42).

⁷⁴ Yin, L., Fu, R., Shevliakova, E. and Dickinson, R.E. 2013. How well can CMIP5 simulate precipitation and its controlling processes over tropical South America? *Climate Dynamics* **41**: 3127-3143 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 43). *See also* Sheffield, J., Barrett, A.P., Colle, B., Fernando, D.N., Fu, R., Giel, K.L., Hu, Q., Kinter, J., Kumar, S., Langenbrunner, B., Lombardo, K., Long, L.N., Maloney, E., Mariotti, A., Meyerson, J.E., Mo, K.C., Neelin, J.D., Nigam, S., Pan, Z., Ren, T., Ruiz-Barradas, A., Serra, Y.L., Seth, A., Thibeault, J.M., Stroeve, J.C., Yang, Z. and Yin, L. 2013. North American climate in CMIP5 experiments. Part I: Evaluation of historical simulations of continental and regional climatology. *Journal of Climate* **26**: 9209-9245 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 43) (noting that models have not improved much and that predictions have as much of a spread of uncertainty as historical back-casts do).

⁷⁵ Olaf Stampf and Gerald Traugetter, “Climate Expert von Storch: Why Is Global Warming Stagnating?” *Der Spiegel* (June 20, 2013), available at <http://www.spiegel.de/international/world/interview-hans-von-storch-on-problems-with-climate-changemodels-a-906721.html>.

confident predictions made by nearly all the climate computer models that the temperature would continue to rise as it did from 1975 to 1998. More than 60 different explanations have been proposed to explain why this ‘pause’ or ‘hiatus’ has happened, and their sheer number is the clearest evidence that the system that climate scientists are seeking to model is irreducibly complex. Human-sourced carbon dioxide is at best one of many factors in causing climate change, and humility in front of this complexity is the appropriate stance.” (Ex. 213, Lindzen Surrebuttal at 2).

These criticisms are not simply a matter of mistaking a short-term trend for a long-term trend, as Dr. Dessler seems to believe. (Ex. 103, Dessler Rebuttal 15:10-23:6.) Peer-reviewed papers by scientists examining climate models have found them fatally flawed. They have failed to predict the hiatus in warming in no small part because they cannot reliably recreate the most basic features of the ocean currents that drive climate (much less climate change). *The only peer-reviewed evidence about the viability of climate models in this record shows that they are fatally flawed and untrustworthy.* The “just trust us” assurance is contradicted by the overwhelming balance of peer-reviewed literature.

(c) *The Proponents Give Only Specious Reasons, Not Evidence, to Defend the Models*

Despite the overwhelming evidence from AR5 and peer-reviewed literature, the State Agencies argue that the past 18-year period (during which models have failed to predict actual real-world temperature trends) is arbitrarily selected or somehow “cherry-picked” by Peabody to invalidate climate models. (Agencies Br. at 80-81, 85.) If that is so, then AR5 is equally guilty for picking the same period and devoting special treatment to the question why models failed to reflect the hiatus.⁷⁶ In fact, there is no “cherry-picking.” The 18-year period is the only period

⁷⁶ See AR5 WG1 at 61-63 (Box TS.3) (setting out consideration of the question in a highlighted box).

during which the models have been tested, and AR5 found that systemic problems with the models resulted in substantial over-prediction of warming.

Further, there can be no accusation of cherry-picking here because *all three peer-reviewed datasets agree: satellites, weather balloons, and ground-based measurements all agree that models failed to predict the hiatus that happened just as CO₂ emissions increased and atmospheric concentrations peaked.* (Ex. 227, Spencer Surrebuttal 2:1-16.) It is important to note that the observational datasets have been extensively peer-reviewed, (2B Tr. 12:6-19 (Spencer)), and they rebut the scientific foundation of the FSCC.

The State Agencies criticize Dr. Happer for testing climate models on the basis of post-1998 data, rather than reaching back to 1951. (State Agencies Br. at 85.)⁷⁷ The State Agencies miss Dr. Happer's point that the earlier data are not useful for testing because they were already known to the modelers, and would therefore simply be an exercise in curve-fitting that would yield no results regarding how predictive the models were. (Ex. 206, Happer Surrebuttal 5:12-6:3.) AR5 eliminated a natural fluctuation in radiative forcing as a potential cause, leaving internal climate variation or model error as the two remaining explanations for the discrepancies,⁷⁸ although there is still a great deal of uncertainty.⁷⁹ AR5 acknowledges the 18-

⁷⁷ Dr. Gurney badly mischaracterizes the evidence on this point. Dr. Happer presented the charts in question from Fig. 1 of the Fyfe et al. (2013) article entitled "Overestimated Global Warming over the Past 20 Years," not, as Dr. Gurney asserts, from the IPCC AR5 (Ex. 803, Gurney Rebuttal 14:24-15:6). He falsely accuses Dr. Happer of omitting "panel c" (Ex. 803, Gurney Rebuttal at 16:1), but *there is no "panel c" in the article Dr. Happer cited.* Dr. Gurney simply mixed up the two articles because the charts look somewhat alike, then tried to turn it into a lack of candor on Dr. Happer's part. Yet again, Dr. Gurney is manipulating the evidence and attempting to concoct a fable of dishonesty on the part of Peabody's witnesses.

⁷⁸ AR5 WG1 at 62 (Box TS.3).

⁷⁹ AR5 WG1 at 63 (Box TS.3).

year hiatus, admits that the models consistently over-predicted warming during this critical period, and concedes that it cannot find a convincing resolution for the models' failure.⁸⁰

In short. AR5 effectively acknowledges that the climate models have failed their only test. It is fatal to the FSCC because it shows that the models were wrong when the IWG based its federal SCC calculation on them. The models have been wrong for at least a decade, and during that time the IWG depended on them to formulate the FSCC. The FSCC is plainly not a reasonable or best available measure, and indeed it is arbitrary and capricious, because it is based on defective and disproven models and outdated scientific information.

(d) AR5 Disproves Attempts to Find “Missing” Warming in the Ocean

The gap between the models and reality has given rise to a hunt for the warming that “should” be there (according to the models) but is not.⁸¹ Scientists including Dr. Abraham have attempted to find the “missing” warming in the ocean, but have failed. Dr. Abraham repeatedly emphasizes the importance of the ocean as representing 93% of the Earth’s heat sink. (Ex. 102, Abraham Rebuttal at 7:20-8:3 & Fig. 1.) It would stand to reason, then, that heating in such a pervasive and crucial thermal reservoir should be manifest.

But there is no such evidence. NASA has 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-

⁸⁰ Dr. Dessler’s assurance that “the models do a reasonable job of simulating the last decade” (Ex. 103, Dessler Rebuttal at 26:4) is not evidence that those models will work for predicting future temperatures. As Dr. Happer noted, back casting (or looking at historical temperature data) is an exercise in fitting a curve to known data – not an exercise in *predicting* the unknown. For that reason it is not useful as a test for robust models. (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.)

⁸¹ Laid bare, this impulse is nothing more than a desire to make the real world conform to climate models. Again, Dr. Reich’s admonition is salient: “[A] model is not direct evidence, ever.” (Reich: 5 Tr. 68:17.)

14:8.) AR5 did not find consistent data on ocean warming in the upper 700 meters of the ocean since 2003.⁸² 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 2003.⁸³ Analyses of heat content for the upper 700 meters are inconclusive and show substantial regional variations.⁸⁴ A new worldwide system of ocean sensors (Argo) shows that, below 2000 meters, the ocean has *cooled* since 2005.⁸⁵

Even Dr. Abraham's own 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.) Research rejects the speculative suggestion that heat from global warming is somehow "hiding" in the ocean. 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.⁸⁶ This means that, like the atmosphere, the oceans are warming about 3 times less rapidly than climate models predict. In other words, climate models predict about three times more warming than observed temperatures for both the atmosphere and oceans. The Proponents of the FSCC did not respond to any of this evidence. In fact, at trial Dr. Dessler acknowledged that he was not familiar with the Wunsch and Heimbach study and conceded, "I don't know, I'm not an expert on ocean temperatures." (3A Tr. at 32:4-5, 11-15.)

⁸² AR5 WG1 at 262 (Fig. 3.2).

⁸³ Ex. 213, Lindzen Surrebuttal at 21 (citing studies).

⁸⁴ *Id.*

⁸⁵ *Id.*

⁸⁶ C. Wunsch and P. Heimbach, *Journal of Physical Oceanography*, 44, 2014 (2014) (cited in Happer Surrebuttal at 7).

3. *AR5 and Unrefuted Peer-Reviewed Evidence Shows the FSCC is Based on Obsolete ECS Values*

AR5 and unrefuted peer-reviewed evidence in this record prove beyond doubt that the ECS values from AR4 on which IWG depended are now obsolete. AR5 has lowered its numbers and withdrawn its confidence, enough that it could not issue a “best estimate” as AR4 had. Yet it was exactly this confidence that the IWG relied upon. Subsequent peer-reviewed science has shown that IWG’s reliance was misplaced: the lower end of the ECS range is more likely and should carry a greater weight in a probability distribution — yet when confronted with this evidence the IWG stood pat and did nothing, closing its eyes to the changing science on which one of the core parameters of its IAMs depends.

The Proponents of the FSCC have not only admitted this rising uncertainty regarding ECS but have noted that it is “likely to remain unknown for the foreseeable future.” (CEOs Br. at 14.) Not only is the exact value unknown, but the Proponents admit that “[t]he exact relationship between concentrations and temperature is unknown.” (*Id.*) To be clear, *the Proponents of the FSCC agree that ECS is so uncertain as to be unknown and unknowable for the foreseeable future.*

This admission is fatal to the FSCC. ECS is a core parameter that dramatically affects the output of the IAMs on which the FSCC is based. Dr. Hanemann agreed that the ECS is a key input to the IAMs. (2Br. Tr. 64:6-10.) The testimony of both Dr. Tol and Dr. Mendelsohn demonstrates that using the incorrect ECS has a profound impact on the calculation of the social cost of carbon. A flawed ECS value taints the entirety of the IWG’s calculation and requires rejection of the FSCC.

(a) *AR5 Fatally Undermines the ECS Values the IWG Used*

AR5 and unrefuted peer-reviewed literature demonstrate that the FSCC is based on a range for ECS that is too high, outdated science that produces a biased externality value. The State Agencies half-heartedly defend the IWG's assumptions as to ECS (State Agencies Br. 88-92), *but never put evidence in the record to support their reading of AR5, asking once more that the Commission "just trust" Dr. Gurney's partial rendition of the figures.* But AR5 lowered the lower bound of ECS by a full half a degree to 1.5 °C, changing the probability of that measure from "very unlikely"⁸⁷ to "likely"⁸⁸ with "high confidence"⁸⁹ in that change. The downward adjustment of the range is driven by better understanding of the science in 2013 as compared to 2007: "This assessment reflects improved understanding, the extended temperature record in the atmosphere and ocean, and new estimates of radiative forcing."⁹⁰ AR5 explained 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*"⁹¹ – i.e., the part of the range nearer to 1.5°C. That sort of change should have been decisive for the IWG, but it went ignored.

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

⁸⁷ AR4 at 21. "Very unlikely" means "<10% probability." (AR4 at 27.)

⁸⁸ AR5 WG1 at 16. "Likely" means ">66% probability." (*Id.*)

⁸⁹ AR5 WG1 at 83 (Box 12.2).

⁹⁰ AR5 WG1 at 16.

⁹¹ AR5 WG1 at 84 (emphasis added).

understanding of the uncertainties in estimates based on the observed warming.”⁹² Uncertainty regarding the proper ECS value is increasing since 2007 — so much so that the IPCC will no longer give a “best estimate.”

This strong trend toward reduction in ECS in AR5 is 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 CO₂, TCR measures the immediate temperature change from an increase in emissions. (AR5 WG1 at 1110 (Box 12.2).) AR5 takes the view that TCR “is a more informative indicator of future climate than ECS.” (AR5 WG1 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.”⁹³ In other words, AR5 lowered the values for both ECS and TCR, indicating that the more relevant values for ECS lie on the lower end of the range. This piece of evidence corroborates the other unrefuted evidence from AR5 documenting the fatal flaws in the ECS values adopted by the IWG.

(b) The IWG Has Refused to Account for AR5 In Its Climate Sensitivity Distribution

The IWG has failed to update its climate sensitivity distribution to match the current assessment of the IPCC, which the Proponents describe as the authoritative source. Accordingly, the IWG cannot be a reasonable or best available measure of the social cost of carbon.

⁹² AR5 WG1, 85. *See also* AR5 WG1 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.”

⁹³ IPCC, Fourth Assessment, Working Group I, *Climate Change 2007: The Physical Science Basis*, Section 9.6.2.3 (2007).

The State Agencies and CEOs offer explanations for the IWG's use of outdated climate sensitivity estimates that are not supported by the facts. The timeline of AR5 and the IWG updates demonstrates that the IWG has repeatedly refused to update its estimates with information from AR5 for more than two years.

September 2013: The IPCC released AR5. (Dessler, 3A Tr. 109:11-13; Dessler, 3B Tr. 25:18-23; Martin, 3B Tr. 124:6-125:8.) AR5 lowered the lower bound of the "likely" range of climate sensitivity to 1.5°C, without raising the top bound of the range. (Ex. 405, AR5, 16.)

November 2013: The IWG updated the FSCC. (Ex. 600, Martin Direct, Schedule 2 (IWG Nov. 2013 TSD) [hereafter "IWG 2013"].) The IWG did not update its climate sensitivity distribution to reflect AR5.⁹⁴

July 2015: The IWG updated the FSCC. (Ex. 601, Martin Rebuttal, Schedule 1 (IWG July 2015 TSD) [hereafter "IWG 2015"].) The IWG did not update its climate sensitivity distribution to reflect AR5. In its response to public comments released at the same time, the IWG acknowledged AR5's different climate sensitivity distribution but refused to update its estimates accordingly. (Ex. 101, Polasky Rebuttal, Sched. 1 (July 2015 Response to Comments), at 12.)

Despite this clear timeline, the CEOs erroneously claim that the IWG has not had the chance to update its estimates to reflect AR5:

"The IPCC has updated sensitivity in its latest assessment, *released after the IWG's most recent update of the Federal SCC*, and the working group may 'updat[e] the ECS distribution in future revisions to the SCC estimates' accordingly."

(CEOs Br. at 14 (emphasis added).)

"As the IWG explained, some legitimate research led the IPCC to update the low end of its ECS estimate in its Fifth Assessment Report. Ex. 101 sched. 1 at 12. *Because the IPCC Fifth Assessment Report came out after the IWG's last updates to the SCC*, it will consider an update to the probability distribution in the future."

(CEOs Br. at 16 (emphasis added).)

In fact, as confirmed by the CEOs' own witness Dr. Dessler, the IPCC released AR5 two months before the IWG's November 2013 update and almost two years before the IWG's July

⁹⁴ Mr. Martin did not provide any evidence to support his claim that the IWG's November 2013 update was done "long before" September 2013. (Martin, 3B Tr. 124:17-18.)

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.”) Thus, contrary to the CEOs’ assertion, the IWG could have updated its FSCC estimates to reflect AR5 for two years.

The Agencies, on the other hand, urge the ALJs to recommend an outdated version of the FSCC to the Commission: “Because the most recent update of the federal SCC occurred in **2013**, the Agencies further recommend that the ALJs find the **2013** estimate of the federal SCC is reasonable and the best available measure to determine the environmental cost of CO₂ under Minn. Stat. § 216B.2422.” (State Agencies Br. at 3 (emphasis added).) In fact, throughout their brief, the Agencies advocate for the IWG’s 2013 numbers:

- “The Commission Should Adopt the IWG’s **2013** Estimate of The SCC” (State Agencies Br. at 33 (emphasis added).)
- “The most recent estimate of the federal SCC is in the IWG **2013** TSD Report, . . .” (State Agencies Br. at 35; *see also* State Agencies Br. at 5 n.10 (identifying the IWG’s November 2013 update as the most recent) (emphasis added).)
- “The Agencies recommend adoption of the federal SCC set out in the IWG **2013** TSD Report, . . .” (State Agencies Br. at 58 (emphasis added).)
- “The Agencies agree and continue to urge that the ALJs recommend use of the federal SCC as adopted by the IWG in **2013**.” (State Agencies Br. at 110 (emphasis added).)
- “The Agencies respectfully request a Recommendation from the Administrative Law Judges and an Order from the Commission, determining that the **2013** estimate of the federal Social Cost of Carbon developed by the federal government’s Interagency Working Group is reasonable and the best available measure to determine the environmental cost of CO₂ under Minn. Stat. § 216B.2422.” (State Agencies Br. at 139 (emphasis added).)

The IWG most recently updated the FSCC in July 2015, which lowered 30 of the 36 FSCC November 2013 estimates and kept the remaining estimates the same. It is unclear why the Agencies support the IWG’s outdated FSCC estimates.

In addition to supporting outdated FSCC estimates, the Agencies acknowledge that “[i]t would be unreasonable to base a current estimate of the SCC on earlier versions of the IAMs, just as it would be unreasonable to base a scientific assessment of climate change on an old IPCC

Assessment Report rather than the current Assessment Report.” (State Agencies Br. at 34.) Yet the IWG has based its climate sensitivity probabilities in its last two FSCC updates on an old IPCC Assessment report rather than the current Assessment Report. Peabody agrees with the Agencies that this is unreasonable.

It should also be noted that the Clean Energy Organizations and the State Agencies both urge the ALJs to recommend, and the Commission to adopt, the IWG’s FSCC. However, no party supporting the FSCC submitted the IWG’s November 2013 or July 2015 technical support documents in this proceeding.⁹⁵ It is astonishing that no party supporting the wholesale adoption of the FSCC provided the Commission with the most recent IWG documents or the current schedule of FSCC values that they support.

(c) Peer-Reviewed Science Rejects the ECS Values Used by the IWG

The need to update ECS values is underscored by the growing peer-reviewed evidence showing that a lower value is appropriate. Figure 1 of Box 12.2 in the AR5 WG1 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 at 16, 19.) 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

⁹⁵ Both Dr. Hanemann and Dr. Polasky attached the IWG’s May 2013 Technical Support Document to their direct testimony, but not the November 2013 Technical Support Document. (Ex. 800, Hanemann Direct, Schedule 3; Ex. 100, Polasky Direct, Schedule 3.) Dr. Polasky referenced the July 2015’s FSCC estimates for a single year in his rebuttal testimony, but did not include all of the estimates or attach the Technical Support Document. (Ex. 101, Polasky Rebuttal, 2:3-10.) Similarly, Dr. Hanemann referenced the July 2015’s FSCC ranges for two years in his rebuttal testimony, but also did not include all of the estimates or attach the technical support document. (Ex. 801, Hanemann Rebuttal, 87:21-22.)

values below 3°C. The State Agencies appear to concede this fact; indeed, they reprint the chart at p. 91 of their Opening Trial Brief.

Beyond the IPCC, 14 studies and 20 experiments validated a lower range for ECS between the IWG's 2010 calculation of the FSCC and its 2013 update. (Ex. 213, Lindzen Surrebuttal at 17.) The IWG's 2013 update ignored all of those studies, and 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. For example:

- A peer-reviewed article published in 2013 in *Nature Geoscience* by 14 mainstream IPCC authors led by Alexander Otto of the Environmental Change Institute at the University of Oxford and Gregory C. Johnson of NOAA found that the most likely ECS value based on the evidence of the past decade is 2.0°C, with a 5–95% confidence interval of 1.2–3.9°C.⁹⁶ (Ex. 213, Lindzen Surrebuttal at 18.) This is markedly lower than the IWG's range, with its midpoint at 3.0°C.
- IPCC author Bjorn Stevens of the Max Planck Institute for Meteorology in Hamburg, Germany, published two important peer-reviewed papers in 2015 that fatally undermine the ECS used by the IWG. First, his paper *Rethinking the Lower Bound on Aerosol Radiative Forcing* found that the cooling impact of sulfate emissions has held back global warming less than previously thought, implying less sensitivity.⁹⁷ As Dr. Lindzen explained, “Thus, a ‘fudge factor’ which previously allowed models to appear to accurately track past temperatures has now been sufficiently constrained that models with sensitivity greater than 2°C are highly improbable.” (Ex. 213, Lindzen Surrebuttal at 2.)
- Climate researcher Nicholas Lewis, whose work has been cited by the IPCC and who has published papers with IPCC contributors, has explained that Dr. Stevens' work on aerosol forcing is “*compelling*” and “a *game changer*.” Lewis calculated that using AR5 data, the aerosol findings imply an ECS “best estimate” of 1.45°C, with a 5-95% confidence range of 1.05°C to 2.2°C.⁹⁸ (Ex. 213, Lindzen Surrebuttal at 14.) The IWG estimates far exceed that range.

⁹⁶ Alexander Otto, et al., Energy Budget Constraints on Climate Response, __ *Nat. Geosci.* 16 __ (advance online publication, May 19, 2013), available at <http://www.iac.ethz.ch/people/knuttir/papers/otto13nat.pdf> (cited in Ex. 213, Lindzen Surrebuttal at 18).

⁹⁷ Stevens, B.J., 2015, Rethinking the lower bound on aerosol radiative forcing, *Journal of Climate*, doi: 10.1175/JCLI-D-14-00656.1 (cited in Ex. 213, Lindzen Surrebuttal at 15).

⁹⁸ Lewis, “The implications for climate sensitivity of Bjorn Stevens' new aerosol forcing paper,” Mar. 15, 2015, <http://climateaudit.org/2015/03/19/the-implications-for-climate->

- Dr. Stevens’ second peer-reviewed 2015 paper, *Missing Iris Effect as a Possible Cause of Muted Hydrological Change and High Climate Sensitivity in Models*, states that “[i]nferences from the observational record . . . place climate sensitivity near the lower end of th[e] range.”⁹⁹ 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.)
- Dr. Stevens’ paper at an important 2015 conference explicitly reconsidered the “Iris” theory as a potential negative feedback reducing ECS.¹⁰⁰ Another paper at the same conference found there is “[o]bservational evidence for an Iris effect” but disagreed over whether it had a negative feedback effect.¹⁰¹ (Ex. 213, Lindzen Surrebuttal at 13.)
- 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.¹⁰²
- 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.¹⁰³

sensitivity-of-bjorn-stevens-new-aerosol-forcing-paper/ (cited in Ex. 213, Lindzen Surrebuttal at 15).

⁹⁹ Thorsten Mauritsen & Bjorn Stevens, “Missing Iris Effect as a Possible Cause of Muted Hydrological Change and High Climate Sensitivity in Models,” *Nature Geosci.* (Apr. 20, 2015) (advance online publication), available at <http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2414.html> (cited in Ex. 213, Lindzen Surrebuttal at 15; Happer Surrebuttal at 4).

¹⁰⁰ Bjorn Stevens, et al., “Report from a Workshop Held on 23-27 March 2015, Schloss Ringberg, Germany,” (Appendix B (Thorsten Mauritsen, “What if Earth Had an Adaptive Iris?")) (May 19, 2015), available at http://www.mpimet.mpg.de/fileadmin/atmosphaere/WCRP_Grand_Challenge_Workshop/Ringberg_2015/Ringberg2015_Final_WEB.pdf (cited in Ex. 213, Lindzen Surrebuttal at 13 n.32).

¹⁰¹ Sandrine Bony, Presentation, “Do Climate Models Over-Estimate Cloud Feedbacks?,” at 9 (Mar. 23-27, 2015), available at http://www.mpimet.mpg.de/fileadmin/atmosphaere/WCRP_Grand_Challenge_Workshop/Ringberg_2015/Talks/Bony_26032016.pdf (cited in Ex. 213, Lindzen Surrebuttal at 13 n.33).

¹⁰² Lewis, N. and J.A. Curry, C., 2014. The implications for climate sensitivity of AR5 forcing and heat uptake estimates. *Climate Dynamics*, 10.1007/s003820142342y (cited in Ex. 213, Lindzen Surrebuttal at 14).

¹⁰³ Lewis, N. 2013. An objective Bayesian, improved approach for applying optimal fingerprint techniques to estimate climate sensitivity. *Journal of Climate*, 9 doi:10.1175/JCLID1200473.1 (cited in Ex. 213, Lindzen Surrebuttal at 14),

- 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.¹⁰⁴
- 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.¹⁰⁵
- 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.”¹⁰⁶
- A peer-reviewed study by the Canadian Centre for Climate Modelling 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.”¹⁰⁷

(d) *Proponents’ Attempt to Defend the IWG’s “Roe and Baker” Distribution Fails.*

In the face of this insurmountable uncertainty, the Proponents note that the IWG did not use a single value for ECS but rather used a “Roe and Baker” probability distribution. The CEOs argue that “the low ECS values that the Peabody witnesses promote *are included* in the IWG’s federal SCC as some among many of the possible climate sensitivity values.” (CEO Br. at 15.) However, since the IWG used a probability distribution, it is not enough for the value simply to be included. Instead, the correct proportion of low ECS values must be included, and the IWG

¹⁰⁴ 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 (cited in Ex. 213, Lindzen Surrebuttal at 18).

¹⁰⁵ Aldrin, M., et al., 2012. 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 (cited in Ex. 213, Lindzen Surrebuttal at 14).

¹⁰⁶ Ring, M.J., et al., 2012. Causes of the global warming observed since the 19th century. *Atmospheric and Climate Sciences*. 2, 401415, doi: 10.4236/acs.2012.24035 (cited in Ex. 213, Lindzen Surrebuttal at 14).

¹⁰⁷ J. C. Fyfe, N. P. Gillett, F. W. Zwiers, Overestimated Global Warming over the Past 20 Years, 3 *Nature Climate Change* 767 (2013) (cited in Ex. 213, Lindzen Surrebuttal at 15).

has failed to do so by refusing to update its distribution with AR5. The Proponents ask the Commission to “trust” that the Roe and Baker probability distributions used by the IWG will capture the uncertainty correctly, compensating for the lack of a best estimate in AR5. This argument *undermines* the IWG’s methods, however, and defeats the Proponents’ own argument.

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.” AR5 explained that “studies suggest a *best fit to the observed surface and ocean warming* for ECS values *in the lower part of the likely range.*”¹⁰⁸ Indeed, if the most recent observational data are included, the range of potential ECS values tightens and they “tend to have reduced upper tails.” (AR5 WG1 at 923, 1111 (Box. 12.2).)

Thus, as we showed in our opening brief (at 76-78), even if it was permissible for the IWG to use a Roe and Baker probability distribution for modeling ECS, AR5 shows without doubt that *IWG used a fatally flawed probability distribution*: the entire distribution should have been shifted downward in response to the newer, better science in AR5.

The IWG centered its Roe and Baker distribution on AR4’s “best estimate” of 3°C. (Ex. 100, Polasky Direct, Sched. 2 (Feb. 2010 TSD), at 13.) 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.*) The IWG admitted that its distribution strayed from AR4:

¹⁰⁸ AR5 WG1 at 84 (emphasis added).

Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5C 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.)

AR5 makes the IWG’s probability distribution even more inaccurate. Although AR5 no longer included a “best estimate” of climate sensitivity, the IWG refused to change its probability distribution in the updates released after AR5. (Ex. 101, Polasky Rebuttal, Sched. 2 (July 2015 IWG Response to Comments), at 12.) 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, 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°C. (*Id.*) 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. The IWG’s Roe and Baker distribution is riddled with errors, and the FSCC is fatally defective.

4. AR5 and the Peer-Reviewed Science Disproves Claims of Other Indicia of Climate Change, Like Sea Level Rise, Antarctic Ice Melting, Severe Weather Ocean Acidification, and Other Impacts.

AR5 overall throws cold water on the overheated predictions that climate change will lead to other harms, like sea level change, severe weather, and ice melting. Importantly, the Proponents never tether their arguments about these effects to the FSCC itself; they only rely on these phenomena as “proof” of climate change. These phenomena do not produce a value, range of values, or probability distribution for ECS, which is the relevant IAM input, and therefore do not assist the Commission in understanding the proper externality value for CO₂.

(a) ***AR5 Contradicts Proponents’ Claims Of Sea Level Rise, Ice Melting, Ocean Acidification, and Other Asserted Impacts.***

AR5 contradicts the Proponents’ dire rhetoric on every disastrous scenario they bring forward:

- ***Sea Level Rise:*** AR5 found that sea level rises began to accelerate in the late 1700s (before significant CO₂ emissions), but were no larger than accelerations in other preindustrial periods.¹⁰⁹ Sea levels are not rising any faster now than they were in the early half of the last century.¹¹⁰ Sea level rise is naturally influenced strongly by local effects that have nothing to do with climate change, such as the El Niño-Southern Oscillation (ENSO), which causes variation up to 40 cm from the global mean.¹¹¹ That is equivalent to the 95th percentile rise (38 cm) in global mean sea level (GMSL) by 2065 projected from a high-emissions scenario.¹¹² In other words, indisputably natural phenomena cause the same sea level rise that would be considered “catastrophic” if the overheated rhetoric is credited. Moreover, a substantial portion of local sea level change on coasts is due to *non-CO₂* anthropogenic causes (e.g., building loads, reduced sediment delivery to the coast, and resource extraction). These changes can exceed GMSL by an order of magnitude (~10 cm/yr).¹¹³ Changes in storm surge and increased coastal flooding

¹⁰⁹ AR5 WG1 at 289-90 & Fig. 3.14. *See also* Boretti, A.A., “Short Term Comparison of Climate Model Predictions and Satellite Altimeter Measurements of Sea Levels.” *Coastal Engineering* 60: 319-322, 2012 (cited in Ex. 230, Bezdek Direct, Ex. 2 (Report) at 63 n.126) (finding overall rate of sea level rise to be decelerating dramatically, contrary to model predictions); Holgate, S.J., “On The Decadal Rates of Sea Level Change During the Twentieth Century.” *Geophysical Research Letters* 34: 10.1029/2006GL028492, 2007 (cited in Ex. 230, Bezdek Direct, Ex. 2 (Report) at 63 n.125) (mean sea level has decreased over recent history, contrary to predictions); A.H. Sallenger, K.S. Doran, and P.A. Howd, “Hotspot of Accelerated Sea-Level Rise on the Atlantic Coast of North America,” *Nature Climate Change*, v. 2, no. 12 (2012), pp. 884–888 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 159) (attributing much supposed sea level rise to land subsidence).

¹¹⁰ AR5 WG1 at 289 (“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.”) and 290 (“The trend in GMSL [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).”).

¹¹¹ AR5 WG2 at 369.

¹¹² AR5 WG2 at 369 (Table 5-2).

¹¹³ AR5 WG2 at 369.

are respectively given low and very low confidence levels.¹¹⁴ *Sea level rise cannot credibly be blamed on anthropogenic CO₂ emissions.*¹¹⁵

- Observational studies on reef islands and vulnerable coasts — precisely the ones hypothesized to be most threatened — have shown an increase in size and volume rather than a decrease.¹¹⁶
- *Severe Weather*: AR5 found little evidence for any trend at all in severe weather, much less a clear increase due to climate change.¹¹⁷ “At present, therefore, the evidence does not support the claim that we are observing weather events that would, individually, have been *extremely unlikely* [0-5%] in the absence of human-induced climate change”¹¹⁸ Studies of normalized losses from storms fail to show any anthropogenic fingerprint.¹¹⁹ AR5 has low confidence that there

¹¹⁴ AR5 WG2 at 370, 993.

¹¹⁵ N.A. Morner, “Estimating Future Sea Level Changes From Past Records.” *Global and Planetary Change* 40: 49-54, 2004 (cited in Ex. 230, Bezdek Direct, Ex. 2 (Report) at 64 n.129); S. Jevrejeva et al., “Nonlinear Trends and Multiyear Cycles in Sea Level Records.” *Journal Of Geophysical Research* 111:10.1029/ 2005JC003229, 2006 (cited in Ex. 230, Bezdek Direct, Ex. 2 (Report) at 64 n.129); G. Wöppelmann et al., “Rates of Sea-Level Change Over the Past Century in a Geocentric Reference Frame.” *Geophysical Research Letters* 36: 10.1029/2009GL0 38720, 2009 (cited in Ex. 230, Bezdek Direct, Ex. 2 (Report) at 64 n.129); J.R. Houston, and Dean, R.G., “Sea-Level Acceleration Based on U.S. Tide Gauges and Extensions of Previous Global-Gauge Analyses.” *Journal of Coastal Research* 27:409-417, 2001 (cited in Ex. 230, Bezdek Direct, Ex. 2 (Report) at 64 n.129); J. M. Gregory, N. J. White, J. A. Church, M. F. P. Bierkens, J. E. Box, M. R. Van Den Broeke, E. J. G. Cogley, F. X. Fettweis, G. E. Hanna, H. P. Huybrechts, L. F. Konikow, P. W. Leclercq, B. Marzeion, J. Oerlemans, M. E. Tamisiea, Y. Wada, M. Wake, and R. S. W. Van De Wale, “Twentieth-Century Global-Mean Sea Level Rise: Is the Whole Greater Than the Sum of the Parts?” *Journal of Climate*, 26, May 2014, pp. 4476–4499 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 158).

¹¹⁶ Dawson, J.L. and Smithers, S.G. 2010. Shoreline and beach volume change between 1967 and 2007 at Raine island, Great Barrier Reef, Australia. *Global and Planetary Change* 72: 141-154 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 155); Webb, A.P. and Kench, P.S. 2010. The dynamic response of reef islands to sea-level rise: Evidence from multi-decadal analysis of island change in the Central Pacific. *Global and Planetary Change* 72: 234-246 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 155); N. Gratiot, E.J. Anthony, A. Gardel, C. Gaucherel, C. Proisy, and J.T. Wells, “Significant Contribution Of The 18.6 Year Tidal Cycle To Regional Coastal Changes,” *Nature Geoscience* 1, 169-172, doi: 10.1038/ngeo127, 2008 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 158).

¹¹⁷ AR5 WG1 at 162-63. “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.” (AR5 WG1 at 50.) See also Haig, J., Nott, J. and Reichert, G.-J. 2014. Australian tropical cyclone activity lower than at any time over the past 550-1,500 years. *Nature* 505: 667-671 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 8) (noting that Australia is undergoing period of cyclonic inactivity).

¹¹⁸ AR5 WG1 at 917 (emphasis in original).

¹¹⁹ AR5 WG2 at 998.

were even any changes in cyclonic activity during the 20th century,¹²⁰ and cannot attribute either tropical or extratropical cyclones to anthropogenic CO₂ emissions, ultimately finding that the changes were likely not outside natural internal variability.¹²¹ **AR5 found that there is essentially no evidence to suggest an increase in storms at all, much less one driven by anthropogenic climate change.**¹²²

- The 2014 “polar vortex” was within the range of natural variation.¹²³
- The Lesser Antilles, which should be on the path of most Atlantic cyclones, have shown no increase in activity over 318 years of records, either as a whole or in sub-samples.¹²⁴
- Studies showing an increase in cyclonic activity in the Indian Ocean are based on faulty data — there is no such increase.¹²⁵ Indeed, even in an

¹²⁰ AR5 WG2 at 370.

¹²¹ AR5 WG1 at 913-14. *See also* Seo, S.N. 2014. Estimating tropical cyclone damages under climate change in the Southern Hemisphere using reported damages. *Environmental and Resource Economics* **58**:473-490 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 7) (frequency and damage of tropical cyclones fell from 1970 to 2006 as CO₂ emissions were climbing); Klotzbach, P.J. 2011. The influence of El Niño-Southern Oscillation and the Atlantic Multidecadal Oscillation on Caribbean tropical cyclone activity. *Journal of Climate* **24**: 721-731 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 11) (finding no warming impact on tropical cyclonic activity in Caribbean); Klotzbach, P.J. 2011. El Niño-Southern Oscillation’s impact on Atlantic basin hurricanes and U.S. landfalls. *Journal of Climate* **24**: 1252-1263 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 11) (finding no warming impact on tropical cyclone activity in Northern Atlantic); Maue, R.N. 2011. Recent historically low global tropical cyclone activity. *Geophysical Research Letters* **38**: 10.1029/2011GL047711 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 12-13) (finding no trend in global tropical cyclone activity); Nott, J. 2011. Tropical cyclones, global climate change and the role of Quaternary studies. *Journal of Quaternary Science* **26**: 468-473 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 13) (finding no increasing trend in cyclone activity across multiple oceans).

¹²² Nott, J. and Forsyth, A. 2012. Punctuated global tropical cyclone activity over the past 5,000 years. *Geophysical Research Letters* **39**: 10.1029/2012GL052236 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 16) (determining that global tropical cyclone activity is most likely cyclical and unconnected to CO₂ levels).

¹²³ Ballinger, T.J., Allen, M.J. and Rohli, R.V. 2014. Spatiotemporal analysis of the January Northern Hemisphere circumpolar vortex over the contiguous United States. *Geophysical Research Letters* **41**: 3602-3608 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 7-8).

¹²⁴ Chenoweth, M. and Divine, D. 2012. Tropical cyclones in the Lesser Antilles: descriptive statistics and historical variability in cyclone energy, 1638-2009. *Climatic Change* **113**: 583-598 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 9).

¹²⁵ Hoarau, K., Bernard, J. and Chalonge, L. 2012. Intense tropical cyclone activities in the northern Indian Ocean. *International Journal of Climatology* **32**: 1935-1945 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 9).

area with known and measured warming (Bay of Bengal), there has been no increase in cyclonic activity.¹²⁶

- Even observed changes in El Niño are likely part of ordinary internal climate variability.¹²⁷
- ***Ice and Glaciers: AR5 finds a great deal of uncertainty in attributing melting sea ice to anthropogenic CO₂ emissions.*** Glaciers and ice shelves are part of complex feedback mechanisms and cycles that confound simplistic explanations.¹²⁸
 - In the Arctic, temperature anomalies in recent years were as large as those in the 1930s — a fact that AR5 cannot yet explain.¹²⁹ There has been no net warming of the Atlantic and Eurasian sub-Arctic climate.¹³⁰ Moreover,

¹²⁶ Kumar, M.R.R. and Sankar, S. 2010. Impact of global warming on cyclonic storms over north Indian Ocean. *Indian Journal of Geo-Marine Science* **39**: 516-520 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 11).

¹²⁷ Yeh, S.-W., Kirtman, B.P., Kug, J.-S., Park, W. and Latif, M. 2011. Natural variability of the central Pacific El Niño event on multicentennial timescales. *Geophysical Research Letters* **38**: 10.1029/2010GL045886; Wolter, K. and Timlin, M.S. 2011. El Niño/Southern Oscillation behavior since 1871 as diagnosed in an extended multivariate ENSO index (MEI.ext). *International Journal of Climatology* **31**: 1074-1087 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 11).

¹²⁸ See, e.g., Alderkamp, A.-C., Mills, M.M., van Dijken, G.L., Laan, P., Thuroczy, C.-E., Gerringa, L.J.A., de Baar, H.J.W., Payne, C.D., Visser, R.J.W., Buma, A.G.J. and Arrigo, K.R. 2012. Iron from melting glaciers fuels phytoplankton blooms in the Amundsen Sea (Southern Ocean): Phytoplankton characteristics and productivity. *Deep-Sea Research II* **71-76**: 32-48 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 162) (describing net *negative* feedback mechanism created when melting glaciers increase phytoplankton growth and carbon sink); Tortell, P.D., Long, M.C., Payne, C.D., Alderkamp, A.-C., Dutrieux, P. and Arrigo, K.R. 2012. Spatial distribution of pCO₂, ΔO₂/Ar and dimethylsulfide (DMS) in polynya waters and the sea ice zone of the Amundsen Sea, Antarctica. *Deep-Sea Research II* **71-76**: 77-93 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 162) (describing net *negative* feedback from coastal polynyas); Lupascu, M., Welker, J.M., Seibt, U., Maseyk, K., Xu, X. and Czimeczik, C.I. 2014. High Arctic wetting reduces permafrost carbon feedbacks to climate warming. *Nature Climate Change* **4**: 51-55 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 162) (noting that melting Arctic ice creates local greening effects and CO₂ sinks, resulting in a net negative feedback and reducing warming); Peck, L.S., Barnes, D.K.A., Cook, A.J., Fleming, A.H. and Clarke, A. 2010. Negative feedback in the cold: ice retreat produces new carbon sinks in Antarctica. *Global Change Biology* **16**: 2614-2623 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 165) (documenting negative feedback mechanism in local Antarctica melt that could fix up to 50 Mtonnes of carbon annually).

¹²⁹ AR5 WG1 at 907. See also Rong Zhang, “Mechanisms for Low-Frequency Variability of Summer Arctic Sea Ice Extent,” 112 Proceedings Nat’l Acad. Scis. 4570 (Apr. 14, 2015) (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 165) (finding that loss of summer sea ice can be attributed to causes other than warming).

¹³⁰ Opel, T., Fritzsche, D., Meyer, H., Schutt, R., Weiler, K., Ruth, U., Wilhelms, F. and Fischer, H. 2009. 115 year ice-core data from Akademii Nauk ice cap, Severnaya Zemlya: high-

AR5 found that recent losses are most likely not irreversible, suggesting they are part of a natural cycle, not a consequence of anthropogenic CO₂ emissions.¹³¹ Ordinary internal variability can easily mask anthropogenic effects.¹³² There is good reason to believe the near-term reversal in Arctic ice loss is part of a long-term increase. (Ex. 209, Lindzen Direct Report, 14:550-555; Ex. 213, Lindzen Surrebuttal, 34:13-35:14.)

- In the Antarctic, sea ice is increasing,¹³³ contrary to rhetoric. Moreover, this increase will ultimately help to lower sea levels overall.¹³⁴ AR5 could not attribute anthropogenic causes to the changes in the Antarctic.¹³⁵

resolution record of Eurasian Arctic climate change. *Journal of Glaciology* **55**: 21-31 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 163). *See also* Brown, Z.W., van Dijken, G.L. and Arrigo, K.R. 2011. A reassessment of primary production and environmental change in the Bering Sea. *Journal of Geophysical Research* **116**: 10.1029/2010JC006766 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 165) (showing no significant ice loss in Bering Sea).

¹³¹ AR5 WG1 at 71. *See also* Frauenfeld, O.W., Knappenberger, P.C. and Michaels, P.J. 2011. A reconstruction of annual Greenland ice melt extent, 1784-2009. *Journal of Geophysical Research* **116**: 10.1029/2010JD014918 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 164) (finding that current melt rate of Greenland Ice Shelf is consistent with historical rates); Murray, T., Scharer, K., James, T.D., Dye, S.R., Hanna, E., Booth, A.D., Selmes, N., Luckman, A., Hughes, A.L.C., Cook, S. and Huybrechts, P. 2010. (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 164) *Journal of Geophysical Research* **115**: 10.1029/2009JF001522 (documenting a negative feedback mechanism that slows down the rate of ice loss through a reversal, making any long-term trend difficult to elucidate).

¹³² Neil C. Swart, *et al.*, “Influence of Internal Variability on Arctic Sea-Ice Trends,” 5 *Nature Climate Change* **86** (2015) (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 165).

¹³³ AR5 WG1 at 40 (emphasis added). *See also* Fan, T., Deser, C. and Schneider, D.P. 2014. Recent Antarctic sea ice trends in the context of Southern Ocean surface climate variations since 1950. *Geophysical Research Letters* **41**: 2419-2426 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 162) (finding overall increase in Antarctic sea ice since 1950); Schroeder, D.M., Blankenship, D.D., Young, D.A. and Quartini, E. 2014. Evidence for elevated and spatially variable geothermal flux beneath the West Antarctic Ice Sheet. *Proceedings of the National Academy of Sciences USA* **111**: 10.1073/pnas.1405184111 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 162) (noting that isolated melting in Antarctic is due to volcanism, not warming); Reid, P.A., Tully, M.B., Klekociuk, A.R., Krummel, P.B. and Rhodes, S.K. 2013. Seasonal climate summary Southern Hemisphere (spring 2012): Warmer and drier across much of Australia, along with a new Southern Hemisphere sea ice extent record. *Australian Meteorological and Oceanographic Journal* **63**: 427-442 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 165) (finding increasing sea ice in Southern Hemisphere, contrary to expectations).

¹³⁴ AR5 WG1 at 25.

¹³⁵ AR5 WG2 at 188, 190. *See also* Mulvaney, R., Abram, N.J., Hindmarsh, R.C.A., Arrowsmith, C., Fleet, L., Triest, J., Sime, L.C., Alemany, O. and Foord, S. 2012. Recent Antarctic Peninsula warming relative to Holocene climate and ice-shelf history. *Nature* **489**: 10.1038/nature11391 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 162-63) (finding Antarctic warming to still be within the bounds of internal variability).

- Land-based glaciers are retreating because they always do after little ice ages. (See Ex. 206, Happer Surrebuttal, 15:13-17:3; Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 160-165.) Some glaciers have stabilized or advanced.¹³⁶ AR5 noted that it could not attribute any of this retreat to anthropogenic causes.¹³⁷ Moreover, in areas where coastal sea ice no longer forms, the extra moisture in the air results in *increased* land-based glacier size, even in local warming conditions.¹³⁸
- Precipitation, Runoff, and Floods: AR5 finds no evidence of changes in global precipitation trends since 1990.¹³⁹ Indeed, AR5 found that it could not convincingly attribute changes in precipitation to forces outside the natural variability of the climate system, whether arising from nature (e.g., volcanoes) or human activity (e.g., CO₂ emissions, aerosols).¹⁴⁰ AR5 specifically rejected AR4's conclusion that river runoff increased during the 20th century.¹⁴¹ Flooding is no worse now than it has been in the past; indeed, past flooding has been

¹³⁶ Hewitt, K. 2011. Glacier change, concentration, and elevation effects in the Karakoram Himalaya, upper Indus Basin. *Mountain Research and Development* **31**: 188-200 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 161-62); Bahuguna, I.M., Rathore, B.P., Brahmhatt, R., Sharma, M., Dhar, S., Randhawa, S.S., Kumar, K., Romshoo, S., Shah, R.D., Ganjoo, R.K. and Ajai. 2014. Are the Himalayan glaciers retreating? *Current Science* **106**: 1008-1013 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 162).

¹³⁷ AR5 WG1 at 909.

¹³⁸ Rolstad Denby, C. and Hulth, J. 2011. Assessment of differentiated surface elevation data from 1949, 1975 and 2008 for estimates of ice-volume changes at Jan Mayen. *Journal of Glaciology* **57**: 976-980 ((cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 161).

¹³⁹ "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 WG1 at 42.)

¹⁴⁰ AR5 WG1 at 912. See also Mass, C., Skalenakis, A. and Warner, M. 2011. Extreme precipitation over the west coast of North America: Is there a trend? *Journal of Hydrometeorology* **12**: 310-318 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 11-12) (rejecting anthropogenic global warming as a cause of extreme precipitation variations on west coast of North America).

¹⁴¹ "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 WG1 at 44.) See also Munier, S., Palanisamy, H., Maisongrande, P., Cazenave, A. and Wood, E.F. 2012. Global runoff anomalies over 1993-2009 estimated from coupled Land-Ocean-Atmosphere water budgets and its relation with climate variability. *Hydrology and Earth system Sciences* **16**:3647-3658 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 9-10) (finding no increase in runoff, even though it should be an indicator of climate change).

worse.¹⁴² *AR5 essentially found that precipitation is still within the bounds of ordinary natural variation and that there has been no real increase in flooding or runoff.*

- *Drought and Heat Wave*: AR5 specifically rejected AR4’s conclusions regarding drought as “overstated,” especially the attribution to human causes.¹⁴³ There is only low confidence that there is even a trend regarding drought,¹⁴⁴ and most droughts in the 20th century have been less intense and of shorter duration than others in the last millennium.¹⁴⁵ The new lack of confidence in the attribution of drought to human causes arose from new evidence showing a wider range of natural variability than previously understood.¹⁴⁶ As for heat waves, AR5 found

¹⁴² “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 WG1 at 50.) See also Kundzewicz, Z.W., Kanae, S., Seneviratne, S.I., Handmer, J., Nicholls, N., Peduzzi, P., Mechler, R., Bouwer, L.M., Arnell, N., Mach, K., Muir-Wood, R., Brakenridge, G.R., Kron, W., Benito, G., Honda, Y., Takahashi, K. and Sherstyukov, B. 2014. Flood risk and climate change: global and regional perspectives. *Hydrological Sciences Journal* **59**: 1-28 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 9) (finding that flood risk has not increased, and that evidence of higher damages arises from people endangering higher-valued assets); Barredo, J.I., Sauri, D. and Llasat, M.C. 2012. Assessing trends in insured losses from floods in Spain 1971-2008. *Natural Hazards and Earth System Sciences* **12**: 1723-1729 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 9) (ruling out “a discernible influence of anthropogenic climate change” to flood damage in Spain); Villarini, G., Smith, J.A., Baeck, M.L. and Krajewski, W.F. 2011. Examining flood frequency distributions in the Midwest U.S. *Journal of the American Water Resources Association* **47**: 447-463 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 12) (finding that anthropogenic climate change has not affected flood frequency and distribution in Midwest).

¹⁴³ AR5 WG1 at 44, 73, 162; AR5 WG2 at 189. See also Chen, G., Tian, H., Zhang, C., Liu, M., Ren, W., Zhu, W., Chappelka, A.H., Prior, S.A. and Lockaby, G.B. 2012. Drought in the Southern United States over the 20th century: variability and its impacts on terrestrial ecosystem productivity and carbon storage. *Climatic Change* **114**: 379-397 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 9) (questioning AR4’s predictions of drought danger based on data from Southern United States).

¹⁴⁴ AR5 WG1 at 162; Spinoni, J., Naumann, G., Carrao, H., Barbosa, P. and Vogt, J. 2014. World drought frequency, duration, and severity for 1951-2010. *International Journal of Climatology* **34**: 2792-2804 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 7).

¹⁴⁵ “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 WG1 at 50.)

¹⁴⁶ AR5 WG1 at 913. See also Kumar, A., Chen, M., Hoerling, M. and Eischeid, J. 2013. Do extreme climate events require extreme forcings? *Geophysical Research Letters* **40**: 3440-3445 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 8) (determining that extreme droughts can occur in the absence of extreme forcing, i.e., through natural variation); Dai, Aiguo et al. “A Global Dataset of Palmer Drought Severity Index for 1870-2002: Relationship with Soil Moisture and Effects of Surface Warming,” *Journal of Hydrometeorology*, Vol. 5, No. 6, pp. 1117-1130, December 2004 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 19) (finding no increase in drought severity in the United States over the past two centuries); Cook, E.R. et al. “Long-Term Aridity Changes in the Western United States, *Science*, Vol. 306, No.

that recent periods of heat are still dwarfed by earlier anomalies.¹⁴⁷ AR5 has “no confidence” that near-term heat waves will be caused by climate change.¹⁴⁸ **AR5 demonstrates that neither droughts nor heat waves are worse now than they have been before, and that neither can be securely blamed on climate change caused by human CO₂ emissions.**

- Droughts appear to be unrelated to warming in the American Corn Belt.¹⁴⁹
- Many areas under drought are wetting rather than becoming dryer, specifically contradicting the findings of several models that predict more widespread droughts.¹⁵⁰
- An extended study of a 576-year record of moisture in Utah found that the Dust Bowl — the worst drought of the 20th century — barely made the “top ten” in terms of intensity; indeed, the 20th century had the fewest dry years of any century in the reconstruction.¹⁵¹
- Ocean Acidification: AR5 corroborates the findings of other studies that show much more complexity to the issue of acidification than the rhetoric admits. Few field observations show significant acidification because regions are still within the scope of natural variation or other local factors confound attribution.¹⁵² Especially along the coast, pH is affected by so many other processes that attribution to CO₂ uptake is very difficult; few studies exceed a time span of five years.¹⁵³ The reaction that animals including corals have to acidification varies

5698, pp. 1015-1018, 5 November 2004 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 19) (same).

¹⁴⁷ AR5 WG1 at 5.

¹⁴⁸ AR5 WG2 at 189 (emphasis in original).

¹⁴⁹ Stambaugh, M.C., Guyette, R.P., McMurry, E.R., Cook, E.R., Meko, D.M. and Lupo, A.R. 2011. Drought duration and frequency in the U.S. corn belt during the last millennium (AD 992-2004). *Agricultural and Forest Meteorology* 151: 154-162 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 10).

¹⁵⁰ Damberg, L. and AghaKouchak, A. 2014. Global trends and patterns of drought from space. *Theoretical and Applied Climatology* 117: 441-448 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 18).

¹⁵¹ R. Justin DeRose, Shih-Yu Wang, Brendan M. Buckley, and Matthew F. Bekker, ‘A 576-Year Weber River Streamflow Reconstruction from Tree Rings for Water Resource Risk Assessment in the Wasatch Front, Utah,’ *Journal of the American Water Resources Association*, April 2014 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 20).

¹⁵² AR5 WG2 at 415. *See also* Murray, C.S., Malvezzi, A., Gobler, C.J. and Baumann, H. 2014. Offspring sensitivity to ocean acidification changes seasonally in a coastal marine fish. *Marine Ecology Progress Series* 504: 1-11 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 134) (finding that fish already occupy many different pH and dissolved CO₂ levels, and adapt rapidly through transgenerational plasticity).

¹⁵³ AR5 WG2 at 372. *See also* Borges, A.V. and Gypens, N. 2010. Carbonate chemistry in the coastal zone responds more strongly to eutrophication than to ocean acidification. *Limnology and Oceanography* 55: 346-353 (cited in Ex. 231, Bezdek Direct, Ex. 3

dramatically.¹⁵⁴ Acidification may even encourage the growth of diatoms in a manner that acts as a net carbon sink, braking any rise in CO₂ concentrations.¹⁵⁵ These findings corroborate studies from the Woods Hole Oceanographic Institute, the Wildlife Conservation Society, and the 150 peer-reviewed studies cited by Dr. Bezdek. (Peabody Br. at 54.) ***Ocean acidification is likely a natural phenomenon, and AR5 underscores that the disastrous consequences foretold are not coming to pass.***¹⁵⁶

(Compendium) at 131) (arguing that river management policies have a stronger effect on coastal systems than acidification because of changes in nutrient deposition).

¹⁵⁴ AR5 WG2 at 443. See also Cross, E.L., Peck, L.S. and Harper, E.M. 2015. Ocean acidification does not impact shell growth or repair of the Antarctic brachiopod *Liothyrella uva* (Broderip, 1833). *Journal of Experimental Marine Biology and Ecology* **462**: 29-35 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 125) (finding little effect from acidification and increased shell size when combined with mild warming); Lohbeck, K.T., Riebesell, U. and Reusch, T.B.H. 2014. Gene expression changes in the coccolithophore *Emiliania huxleyi* after 500 generations of selection to ocean acidification. *Proceedings of the Royal Society B* **281**: 10.1098/rspb.2014.0003 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 126) (phytoplankton evolved rapidly to cope with acidified conditions); Koch, M., Bowes, G., Ross, C. and Zhang, X.-H. 2013. Climate change and ocean acidification effects on seagrasses and marine macroalgae. *Global Change Biology* **19**: 103-132 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 127) (seagrasses and microalgae response positively to elevated pH); Munday, P.L., Cheal, A.J., Dixon, D.L., Rummer, J.L. and Fabricius, K.E. 2014. Behavioral impairment in reef fishes caused by ocean acidification at CO₂ seeps. *Nature Climate Change* **4**: 487-492 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 129) (comparing more acid ecosystem with parallel neutral ecosystem showed no significant differences in biodiversity); Hendriks, I.E., Duarte, C.M., Olsen, Y.S., Steckbauer, A., Ramajo, L., Moore, T.S., Trotter, J.A. and McCulloch, M. 2015. Biological mechanisms supporting adaptation to ocean acidification in coastal ecosystems. *Estuarine, Coastal and Shelf Science* **152**: A1-A8 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 132) (acidification does not uniformly affect marine environments); McClanahan, T.R. and Muthiga, N.A. 2014. Community change and evidence for variable warm-water temperature adaptation of corals in Northern Male Atoll, Maldives. *Marine Pollution Bulletin* **80**: 107-113 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 139) (corals that have been subject to bleaching once show both resilience in bouncing back and resistance to a subsequent event, and management can enhance this effect); Teira, E., Fernandez, A., Alvarez-Salgado, X.A., Garcia-Martin, E.E., Serret, P. and Sobrino, C. 2012. Response of two marine bacterial isolates to high CO₂ concentration. *Marine Ecology Progress Series* **453**: 27-36 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 141) (some marine bacteria react to acid conditions by reducing acid levels, acting as an offsetting feedback).

¹⁵⁵ Wu, Y., Gao, K. and Riebesell, U. 2010. CO₂-induced seawater acidification affects physiological performance of the marine diatom *Phaeodactylum tricornutum*. *Biogeosciences* **7**: 2915-2923 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 132).

¹⁵⁶ Kiessling, W. 2009. Geologic and biologic controls on the evolution of reefs. *Annual Review of Ecological and Evolutionary Systems* **40**: 173-192 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 131) (explaining that the complex life-cycle of reefs cannot simply be attributed to climate change); Beaufort, L., Probert, I., de Garidel-Thoron, T., Bendif, E.M., Ruiz-Pino, D., Metzl, N., Goyet, C., Buchet, N., Coupel, P., Grelaud, M., Rost, B., Rickaby, R.E.M. and de Vargas, C. 2011. Sensitivity of coccolithophores to carbonate chemistry and ocean acidification. *Nature* **476**: 80-83 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 128) (predictions of reduced calcification most likely wrong); Chua, C.-M., Leggat, W., Moya,

- Naturally white coral populations lead to a substantial overestimation of the prevalence of coral bleaching.¹⁵⁷

The upshot of this litany of failures is that *AR5 has found insufficient evidence to credit the extreme scenarios used to justify high externality values.*

(b) Anecdotal Evidence of Individual Years Does Not Support The FSCC

The Proponents of the FSCC cite anecdotal evidence of temperature increases and claim that today's temperatures are unprecedented. But elsewhere they concede that such anecdotal evidence of individual years is not probative. (Abraham, 3B Tr. 93:20-21 (“the temperature in any single year is not a meaningful development”).) In any event, their assertions are not true. U.S. average temperatures, as measured by the NOAA U.S. Climate Reference Network (USCRN) have declined slightly over the last decade. (Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) 9:276-10:299.) Because these monitors are placed in pristine environments they are not prone to

A. and Baird, A.H. 2013. Near-future reductions in pH will have no consistent ecological effects on the early life-history stages of reef corals. *Marine Ecology Progress Series* **486**: 143-151 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 133) (acidification does not have the negative effects on young coral that have been projected); Movilla, J., Gori, A., Calvo, E., Orejas, C., Lopez-Sanz, A., Dominguez-Carrio, C., Grinyo, J. and Pelejero, C. 2014. Resistance of two Mediterranean cold-water coral species to low-pH conditions. *Water* **6**: 59-67 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 134) (finding coral species resistant to acidification even though they are from supposedly sensitive areas); Haynert, K., Schonfeld, J., Schiebel, R., Wilson, B. and Thomsen, J. 2014. Response of benthic foraminifera to ocean acidification in their natural sediment environment: a long-term culturing experiment. *Biogeosciences* **11**: 1581-1597 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 140) (species expected to be sensitive to acidification showed resistance even at higher levels of exposure); Range, P., Pilo, D., Ben-Hamadou, R., Chicharo, M.A., Matias, D., Joaquim, S., Oliveira, A.P. and Chicharo, L. 2012. Seawater acidification by CO₂ in a coastal lagoon environment: Effects on life history traits of juvenile mussels *Mytilus galloprovincialis*. *Journal of Experimental Marine Biology and Ecology* **424-425**: 89-98 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 140-41) (finding no evidence for increased mortality in bivalves, even at the highest levels of possible acidification); Hendriks, I.E., Duarte, C.M. and Alvarez, M. 2010. Vulnerability of marine biodiversity to ocean acidification: A meta-analysis. *Estuarine, Coastal and Shelf Science* **86**: 157-164 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 146) (finding that in general marine biota are more resistant to acidification than expected).

¹⁵⁷ Cruz, I.C.S., Leal, M.C., Mendes, C.R., Kikuchi, R.K.P., Rosa, R., Soares, A.M.V.M., Serodio, J., Calado, R. and Rocha, R.J.M. 2015. White but not bleached: photo-physiological evidence from white *Montastraea cavernosa* reveals potential overestimation of coral bleaching. *Marine Biology* **162**: 889-899 (Happer Surrebuttal at 14 n.19).

heat island and land-use change biases, as other surface measurement networks are. (*Id.* & n.22.) The 1930s were still the hottest decade in the United States. (Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) 10:301-11:334 & Figs. 4-5.) 2014 was not the hottest year on record. Such claims are based on inaccurate surface temperature readings. (Ex. 235, Bezdek Surrebuttal 17:1-18:11.) Satellite and balloon measurements of the troposphere show that 2014 was not the hottest year on record. (Ex. 235, Bezdek Surrebuttal 17:3-9.)

In any event, talk about the hottest year “on record” ignores the fact that temperature records did not start until the 1880s, and so the statement refers to a relatively short period of time. Peer-reviewed evidence indicates that the Earth was actually hotter during the years 900-1200 than it is today, and may have been hotter in Roman times as well. In fact, during numerous times in human history, the Earth has been hotter than it is today.¹⁵⁸

¹⁵⁸ Rosenthal, Y., Linsley, B.K. and Oppo, D.W. 2013. Pacific Ocean heat content during the past 10,000 years. *Science* 342: 617-621 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 22) (“water masses linked to North Pacific and Antarctic intermediate waters were ~0.9°C warmer during the Medieval Warm Period [MWP] than during the Little Ice Age and ~0.65°C warmer than in recent decades.”); He, Y., Zhao, C., Wang, Z., Wang, H., Song, M., Liu, W. and Liu, Z. 2013. Late Holocene coupled moisture and temperature changes on the northern Tibetan Plateau. *Quaternary Science Reviews* 80: 47-57 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 22) (data from China indicate “warmer climatic conditions during the MWP than the current warm period”); Hanhijarvi, S., Tingley, M.P. and Korhola, A. 2013. Pairwise comparisons to reconstruct mean temperature in the Arctic Atlantic Region over the last 2,000 years. *Climate Dynamics* 41: 2039-2060 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 22-23) (“The Arctic Atlantic reconstruction features temperatures during the Roman Warm Period and Medieval Climate Anomaly that are comparable [to] or even warmer than those of the twentieth century”); Olafsdottir, G.A., Westfall, K.M., Edvardsson, R. and Palsson, S. 2014. Historical DNA reveals the demographic history of Atlantic cod (*Gadus morhua*) in medieval and early modern Iceland. *Proceedings of the Royal Society B* 281: 10.1098/rspb.2013.2976 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 23) (analysis of Atlantic cod population vertebrae at historical fishing sites show that Medieval Warm Period may have been much warmer than today); Datsenko, N.M., Ivashchenko, N.N., Qin, C., Liu, J., Sonechkin, D.M. and Yang, B. 2014. A comparison between medieval and current climate warming using the Przewalskii’s juniper tree-ring data. *Russian Meteorology and Hydrology* 39: 17-21 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 23) (tree-ring data from long-lived trees in Tibet show Medieval Warm Period was warmer than today); Ran, L., Jiang, H., Knudsen, K.L. and Eiriksson, J. 2011. Diatom-based reconstruction of palaeoceanographic changes on the North Icelandic shelf during the last millennium. *Palaeogeography,*

(c) ***The Proponents Have Provided No Evidence Of Causation: That Any Such Events Are Attributable To Climate Change.***

Even if extreme weather events and other phenomena were occurring (and they are not), the Proponents have provided no evidence *attributing them to climate change at all, much less specifically to anthropogenic CO₂-driven climate change*. (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.)

AR5 specifically dismisses the argument that any given disaster can be blamed on anthropogenic climate change. “Anthropogenic warming remains a relatively small contributor to the overall magnitude of any individual short-term event because its magnitude is small relative to natural random weather variability on short time scales.”¹⁵⁹ AR5 responsibly understands that the human contribution to climate change is small enough to be dwarfed by

Palaeoclimatology, Palaeoecology 302: 109- 119 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 24) (evidence from Iceland shows temperatures in the past 1,000 years that exceeded today’s); Magny, M., Peyron, O., Gauthier, E., Vanniere, B., Millet, L. and Vermot-Desroches, B. 2011. Quantitative estimates of temperature and precipitation changes over the last millennium from pollen and lake-level data at Lake Joux, Swiss Jura Mountains. Quaternary Research 75: 45-54 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 24) (evidence from Switzerland shows temperatures in the Medieval Warm Period exceeded those of today); Vinther, B.M., Jones, P.D., Briffa, K.R., Clausen, H.B., Andersen, K.K., Dahl-Jensen, D. and Johnsen, S.J. 2010. Climatic signals in multiple highly resolved stable isotope records from Greenland. Quaternary Science Reviews 29: 522-538 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 27) (temperatures during Medieval Warm Period “were as warm as or slightly warmer than present day Greenland temperatures”); Ge, Q.S., Zheng, J.-Y., Hao, Z.-X., Shao, X.-M., Wang, W.-C. and Luterbacher, J. 2010. Temperature variation through 2000 years in China: An uncertainty analysis of reconstruction and regional difference. Geophysical Research Letters 37:10.1029/2009GL041281 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 27) (with respect to three sections of China temperatures in the Medieval Warm Period exceeded or were comparable to today’s); Frisia, S., Borsato, A., Spotl, C., Villa, I.M. and Cucchi, F. 2005. Climate variability in the SE Alps of Italy over the past 17,000 years reconstructed from a stalagmite record. Boreas 34: 445-455 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 29) (Medieval Warm Period in Italy was “characterized by temperatures that were similar to the present,” while with respect to the Roman Warm Period, its “temperatures were similar to those of today or even slightly warmer”).

¹⁵⁹ AR5 WG1 at 916.

natural internal variation that it makes no sense to blame any given disaster on anthropogenic CO₂ emissions — even though the Proponents of the FSCC repeatedly do so. (*See* Ex. 103, Dessler Rebuttal at 27:4-8 (Hurricane Sandy); Ex. 102, Abraham Rebuttal, Sched. 1 (Report) at 3-5 (heat waves and droughts); Ex. 103, Dessler Rebuttal at 6:1-6 (heat wave in France).) This persistent pattern of argumentation blames various events on anthropogenic CO₂ emissions not only without substantial evidence but contrary to the findings of AR5.

It is easy to fall into the trap of believing overheated rhetoric about disasters and catastrophes without examining the evidence closely. Dr. Mendelsohn warned about this effect early in the proceedings, and the Proponents of the FSCC have only doubled down on this tactic. As Dr. Mendelsohn explained:

The popular press and therefore the public are confused about weather versus climate change. Every hurricane that hits a major city is reported in the news today as evidence of climate change. Although the damage per storm has increased because there is more in harm's way today than in the past (Pielke et al. 2008), *extreme events such as tropical cyclones have not changed in either their intensity or their frequency in the last 100 years* (Landsea et al. 2006). That is, hurricanes are not yet evidence of climate change.

(Ex. 216, Mendelsohn Direct, Ex. 2 (Report) at 3 (emphasis added).) None of these concerns is even “proof” of global warming — climate is always changing (Ex. 206, Happer Surrebuttal, 15:7-11) — and they are not useful in setting an externality value for CO₂ emissions.

5. AR5 Disproves Claims of “Tipping Points” And Catastrophic Harms, As Does The Peer-Reviewed Literature.

The State Agencies also raise the bogeyman of “climate tipping points,” irreversible and abrupt harmful scenarios. (State Agencies Br. at 67.) As usually happens with bogeymen, examination of these catastrophic scenarios through the lens of rational science makes them dissipate. AR5 examines the possibility of abrupt, irreversible changes — the “tipping points” cited by the State Agencies. *Out of all of the possibilities, AR5 found only one event that was*

*actually both abrupt and irreversible, and had high confidence that it was very unlikely.*¹⁶⁰ All of the other candidates were either not abrupt or were reversible. Moreover, all but one of the events were either low confidence, very unlikely, or exceptionally unlikely.¹⁶¹ The sole event that had any likelihood (disappearance of Arctic summer sea ice) was reversible — and already shows signs of reversing. (Ex. 209, Lindzen Direct Report, 14:550-555; Ex. 213, Lindzen Surebuttal, 34:13-35:14.) A July 2015 report by researchers from University College London and the University of Leeds found that Arctic sea ice increased in the past 2 years: “we observe 33% and 25% more ice in autumn 2013 and 2014.”¹⁶²

In general, AR5 found that *catastrophic scenarios lacked scientific foundation*,¹⁶³ and that there is “low confidence and little consensus on the likelihood of abrupt or nonlinear changes in the components of the climate system over the 21st century.”¹⁶⁴ The State Agencies acknowledge that uncertainty inflates the externality value, and clear assessment causes the value to fall (State Agencies Br. at 68-69) — and so it should in this instance. *Regulating based on fear is arbitrary, capricious, and contrary to law*, yet that is what the State Agencies effectively ask the Commission to do by raising these bogeymen and not recognizing that the fears are not grounded in rational science.

¹⁶⁰ AR5 WG1 at 1115 (Table 12.4) (clathrate methane release).

¹⁶¹ *Id.*

¹⁶² Tilling, R.L., Ridout, A., Shepherd, A., and Wingham, D.J. 2015. Increased Arctic sea ice volume after anomalously low melting in 2013. *Nature Geoscience* 8:643-646 (cited in Lindzen Surebuttal 34 n.86).

¹⁶³ “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 WG1 at 70.)

¹⁶⁴ AR5 WG2 at 190.

Moreover, Dr. Mendelsohn testified that his recommended values already include non-market damages, health and ecosystem effects, and the possibility of catastrophes. (Mendelsohn, 3B Tr. 43:20-25.) The State Agencies' suggestion that DICE does not include catastrophic impacts (State Agencies Br. at 19) is thus simply wrong. Dr. Mendelsohn specifically testified that his estimates included such impacts, and the State Agencies chose not to cross-examine him on that point. The State Agencies accepted his testimony on that issue as given. The unproven and speculative catastrophic scenarios hypothesized by the Proponents cannot salvage the FSCC.

B. Key Flaws in the IAMs Show That the FSCC is Not a Reasonable or the Best Available Externality Value.

1. The Proponents of the FSCC Admit Flaws In the IAMs

The Proponents of the FSCC claim that it was reasonable for the IWG to calculate the externality value (State Agencies Br. 24-38; CEOs Br. 13-24), but they concede the uncertainty that is inherent to the IAMs. Uncontradicted evidence, and in many cases the admissions of the Proponents of the FSCC, shows that the FSCC is fatally flawed. For example, Dr. Hanemann conceded:

- There was a coding error in FUND, which led to “disastrous results.” (2B Tr. 67:22-24.)
- There were weaknesses in the DICE model. (*Id.* at 76:1-6, 10-12.)
- There are distinctions among the DICE, FUND, and PAGE models (*id.* at 70:24-72:21), which the IWG eliminated in the course of “standardizing” them. (*Id.* at 73:1-4.) Dr. Hanemann admitted that “the inputs matter.” (*Id.* at 77:23.)
- Models make “subjective decisions” as to inputs. (*Id.* at 79:4.)

In fact, the import of Dr. Hanemann's testimony suggested that the Commission should hold off setting an externality value for now and revisit the question in the future, with improved models:

- “[I]t really is time for a new generation of models. . . . Somebody needs to bring together modelers with the scientists who study impacts to really build new damage functions.” (*Id.* at 91:15-23.)
- “[T]he information that goes into the damages, it’s now larger and more messy, and so it’s harder for one individual to keep up with the literature.” (*Id.* at 92:1-4.)
- “My understanding is that EPA has now contracted with MIT to start building damages into that model. . . . [T]hat would give you a calculation of the social cost of carbon when it’s done.” (*Id.* at 92:15-20.)

Similarly, Dr. Polasky made many admissions regarding the uncertainty built into the

IAMs:

- “Uncertainties are inherent in the task of developing an externality value for CO₂ because it requires us to make assumptions in areas where our scientific understanding is still developing.” (1 Tr. 61:7-11.)
- Dr. Polasky agreed with the statement that “there is currently a limited amount of research linking climate impacts to economic damages.” (*Id.* at 84:13-14, 85:2-3.)
- Dr. Polasky was asked about the IWG’s 300-year time horizon: “Realistically . . . the point is . . . the further out you go [in time] the more difficult it is. The greater the range of uncertainty, that is correct.” (*Id.* at 90:9-11.) “Certainly the further out in time you go the more uncertain one would expect it to be.” (*Id.* at 121:9-10.)
- Dr. Polasky admitted that the IWG could have made a mistake in calculating the social cost of carbon. (*Id.* at 156:12-16.)
- Dr. Polasky admitted the questionable assumptions the IWG based its social cost of carbon upon: arbitrarily choosing 4 of 10 scenarios, extending the emissions horizon to 2300 and extrapolating values. (*Id.* at 92:9-19, 173:12-15.) He was also not aware of any validation of the IWG model. (*Id.* at 81:25-82:1, 83:6.) He was also not aware of any other regulatory impact analysis based on a 300-year forecast. (*Id.* at 120:25-121:4.)
- Dr. Polasky admitted that following Circular A-4 is mandatory, and it is indisputable that IWG did not do so in formulating the FSCC and its discount rates. (*Id.* at 148:8-11.)
- Dr. Polasky admitted that the IWG relied on AR4 and has not adjusted to account for AR5 even though it is available — he even hopes they do update it. (*Id.* at 99:2-5, 99:10-13, 100:2-9, 108:23-109:4, 165:10-11.)
- Dr. Polasky admitted that the IWG members are unknown, other than the fact that they were members of the federal government. (*Id.* at 113:4-9.)

In their trial brief, the State Agencies also discuss the views of Dr. Robert Pindyck, MIT Professor of Economics, whom they describe as “an eminent economic theorist who has written papers relating to climate change.” (State Agencies Br. 61.) The State Agencies do not deny that Dr. Pindyck 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, Ex. 2 (Report), at 95.) The State Agencies nevertheless contend that Dr. Pindyck’s views support the FSCC because he contends that “even though we don’t have a good estimate of the SCC, it would make sense to take the Interagency Working Group’s \$21 (or updated \$33) number as a rough and politically acceptable starting point and impose a carbon tax (or equivalent policy) of that amount. . . . Later, as we learn more about the true size of the SCC, the carbon tax could be increased or decreased accordingly.” (State Agencies Br. at 62, quoting Robert S. Pindyck, “Climate Change Policy: What Do Models Tell Us?” (2013a) *Journal of Economic Literature* 51(3), 860-872.)

But this argument essentially admits the FSCC should not be adopted as a reasonable and best available measure of the externality value on the basis of scientific evidence and sound economic principles – but rather on the basis of what would be “a rough and politically acceptable starting point.” Unfortunately for the State Agencies, *the legal standard under which this proceeding operates is not what would be “rough and politically acceptable.”* Rather, as ALJ Klein demonstrated, the Commission should make its decision on the basis of what the evidence shows. On that score, Dr. Pindyck’s position is clear, and it completely refutes the State Agencies’ argument. In the abstract — i.e., the central summary — of the article they cite, Dr. Pindyck explains:

A plethora of integrated assessment models (IAMs) have been constructed and used to estimate the social cost of carbon (SCC) and evaluate alternative

abatement policies. These models have *crucial flaws* that make them *close to useless as tools for policy analysis*: certain inputs (e.g., the discount rate) are *arbitrary*, but have huge effects on the SCC estimates the models produce; the models' descriptions of the impact of climate change are *completely ad hoc*, with *no theoretical or empirical foundation*; and the models can tell us *nothing* about the most important driver of the SCC, the possibility of a catastrophic climate outcome. IAM-based analyses of climate policy create a perception of knowledge and precision, but that perception is *illusory and misleading*.

(Robert S. Pindyck, "Climate Change Policy: What Do Models Tell Us?" (2013a) *Journal of Economic Literature* 51(3), 860-872 (emphases added).)

The Proponents' admissions, together with the uncontradicted evidence regarding the flaws in the IAMs, invalidate the FSCC.

2. The Proponents Of The FSCC Concede That The IAMs Involve A Cascade Of Uncertainties.

The State Agencies agree that IAMs contain five separate analytical steps as part of the process of estimating the social cost of carbon:

(1) how that emission changes the existing accumulation of GHGs in the atmosphere via the carbon cycle; (2) how that, in turn, changes the amount of energy stored in the Earth's system (the change in radiative forcing); (3) how the change in radiative forcing leads to changes in the climate worldwide; (4) how those changes in climate affect things that matter to humans, such as water supply and drought, crop production, disease and human health, outbreaks of wildfire, coastal flooding, and ecosystem functioning and the like; and (5) how humans value the changes in those things.

(State Agencies Br. at 14.) In our opening brief, we offered peer-reviewed evidence and credible testimony demonstrating how each step is infected with uncertainties that accumulate throughout the process. (Peabody Br. at 20-97.)

The Proponents of the FSCC concede the compounding uncertainty and fail to show that there is reliable evidence for each step in the analytical process. For example, with respect to the first step of the five-step chain set out above, the State Agencies admit that the IWG drew upon (but substantially modified) the emissions projections of the Energy Modeling Forum (EMF)

based at Stanford. The State Agencies note that EMF-22 projected emissions only through the year 2100 “and the IWG made some assumptions to extend the projections through 2300.” (State Agencies Br. at 41.) The State Agencies do not deny that the IWG’s modifications to EMF-22 have never been peer-reviewed. Indeed, the State Agencies concede that “EMF-22 had a different objective than the IWG.” (State Agencies Br. at 43.) Moreover, the State Agencies undermine their own position when they insist that the EMF-22 projections were never supported “by fact, available evidence, and peer-reviewed analyses. . . . There is no way to support a projection of anything to 2100 through ‘facts’ or ‘available evidence’ prior to 2100.” (State Agencies Br. at 43-44.) ***The Proponents of the FSCC concede that the EMF-22 projections were unreliable from the start — and then admit that the IWG “made some assumptions” to extend those unreliable projections a further 200 years.*** This analysis is effectively writing science fiction, not reasoned decision-making.

Moreover, the first step of the IAM calculation also requires the Proponents to show how emissions change the existing accumulation of GHGs in the atmosphere via the carbon cycle. ***This record in particular is devoid of evidence demonstrating such a link.*** The State Agencies explicitly rely on a “just trust us” argument regarding the connection between CO₂ emissions (i.e., what the Commission’s externality value can affect) and CO₂ concentrations that drive climate change (i.e., what the Commission is trying to control). Dr. Lindzen explained thoroughly how the relationship was not straightforward, citing numerous peer-reviewed articles demonstrating that a rise in CO₂ emissions does not necessarily correlate with a rise in CO₂ concentrations and indeed increases carbon “sinks,” drawing more CO₂ from the air. (Peabody Br. at 36-37.) In his testimony, Dr. Gurney asserted multiple times that 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 produced this evidence on this record. His only answer is “just trust me” — even though unrefuted peer-reviewed evidence in this record contradicts him.* Moreover, the evidence Dr. Lindzen produced is peer-reviewed observational data, precisely the sort Dr. Gurney insists supports his point. (State Agencies Br. at 94.) The only instrumental support Dr. Gurney gave for his argument (Tans et al. (1979)) actually undermined his argument. (Ex. 213, Lindzen Surrebuttal 31:9-16.) This lacuna in the record is not inconsequential: it means *there is no evidence on this record to support the key link between CO₂ emissions and CO₂ concentrations. Without that link, the argument for any externality value completely falls apart.*

3. *Uncontradicted Testimony Shows that IAMs Exaggerate Damages and Understate Mitigating Factors*

Next, unrefuted evidence shows that the IAMs exaggerate potential harms and understate mitigating factors, resulting in artificially inflated values. The IAM damage functions that calculate the potential harm arising from a given change in temperature are highly uncertain and systematically exaggerate the harms of climate change while understating potential benefits or mitigating factors. Thus, the resulting FSCC is based on unrealistic assumptions that produce absurd results. Dr. Mendelsohn testified, without contradiction, that “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.*” (Ex. 261, Mendelsohn Opening Statement, 3 (emphasis added).) Dr. Mendelsohn testified that “you can’t even get within an order of magnitude of that.” (3B Tr. 41:22-23.) The Proponents of the FSCC failed to meet their burden on this issue.

The damage functions of the IAMs used to calculate the FSCC make patently unrealistic assumptions, namely that (1) there will be no mitigation of any effects of climate change and no

adaptation to climate change, and (2) that damages from climate change are occurring and will continue to occur more rapidly than they actually are. This leads the IAMs to overestimate the damages arising from a change in temperature.

(a) IWG’s Future Emission Scenarios Overestimate Emissions by Failing to Account for Mitigation.

Dr. Mendelsohn described in detail how the IWG’s use of the IAMs was flawed because they assumed no future mitigation.¹⁶⁵ Ironically, the Proponents of the FSCC are in the curious position of praising the recent Paris climate accord and simultaneously arguing that the social cost of carbon should be set on the assumption that no other jurisdiction will ever adopt mitigation measures. If anything, the Paris accord actually undermines one of the key premises of the FSCC and militates in favor of setting lower externality value.

The State Agencies respond by saying that the IWG did in fact account for future mitigation because “the IWG’s emission scenarios all assume that GHG emissions are reduced eventually.” (State Agencies’ Brief at 131.) This is not accurate. As the IWG itself acknowledged, the emission scenarios were primarily “business as usual” (“BAU”) scenarios that did not assume any degree of future mitigation through policy action or technical advances:

Five trajectories were selected from EMF-22 (see Table 2 below). Four of these represent potential business-as-usual (BAU) growth in population, wealth, and emissions and are associated with CO₂ (only) concentrations ranging from 612 to 889 ppm in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm CO₂e (i.e., CO₂-only concentrations

¹⁶⁵ The State Agencies insist that it is inconsistent for Peabody to argue for a zero value SCC and then to fault the IWG for assuming no mitigation. There is no contradiction. The points involve different stages in the decision-making analysis. If the Commission reaches the stage where it decides to set a non-zero value for the SCC, then it must consider mitigation. But if the Commission never reaches such a stage (because there is too much uncertainty and then Proponents have failed their burden of proof), then mitigation is irrelevant.

of 425 – 484 ppm or a radiative forcing of 3.7 W/m²) in 2100, a lower-than-BAU trajectory. (IWG 2010 at 15.)

The four BAU 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.” (IWG 2010 at 16 (emphasis added).) Only the fifth of the five emission scenarios 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.¹⁶⁶ (IWG 2010 at 15, n. 13.) Thus, only 20% of the future emission scenarios relied upon by the IWG in running the IAMs considered future mitigation. (IWG 2015 at 19 (“Because there were five scenarios, and each received equal weighting, the stabilization scenario received 20% of the total probability weight.”).) Further, this small degree of mitigation was entirely arbitrary, not consistent with the parameters of the DICE model, and not tethered to any evidence. It cannot be part of a reasonable or best available externality value.

(b) *Empirical Research Shows That the IAM Damage Functions Overestimate Damages and Should be Adjusted.*

Dr. Mendelsohn testified that IWG estimates predict near-term (next 30-60 years) damage that is far too high. (Ex. 261, Mendelsohn Opening Statement, 3.) His decades of research into the effects of climate change have led him to conclude that the IWG estimates exaggerate damages by as much as 10 times: “there’s no mechanism that can generate that kind

¹⁶⁶ Dr. Polasky testified that the IWG used only four scenarios from EMF-22. (1 Tr. 92:9-11.) According to the IWG, the fifth scenario was created by averaging the GDP, population, and emission trajectories from the other four scenarios. (Ex. 100, Polasky Direct, Sched. 2 (Feb. 2010 TSD), at 15.) Dr. Polasky admitted the IWG’s decisions on using emissions scenarios was not peer-reviewed. (1 Tr. 92:16-19.)

of damage. . . . [Y]ou can't even get within an order of magnitude of that." (3B Tr. 41:17-23.) No party in this proceeding chose to cross-examine Dr. Mendelsohn on that point. No other witnesses in this proceeding can match Dr. Mendelsohn's experience or expertise with the empirical impacts of climate change. He cited a wealth of peer-reviewed literature to bolster his conclusion. (Ex. 220, Mendelsohn Surrebuttal at 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).) His testimony on the question must be taken as authoritative.

For this reason, Dr. Mendelsohn proposed a revised damage function in order to update the DICE model and make its damages function comport with the best available empirical evidence. (Ex. 216, Mendelsohn Direct, Ex. 2 (Report), at 11.) Dr. Mendelsohn explained that the older version of the model was inaccurate because it predicted \$2.1 trillion from a climate in 2050 2°C warmer than in pre-industrial times, which is not consistent with scientific evidence. (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.) Any assumption introduced into DICE that makes the predicted damage even higher is even more unlikely.

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.*) As Dr. Mendelsohn explained his modification at the hearing:

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.

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

The only attempt at refutation was a “trust me” claim by Dr. Hanemann, who criticized Dr. Mendelsohn’s alteration of the DICE damage function. (State Agencies Br. at 70-71.) Dr. Hanemann believes (and presents no evidence) that the empirical evidence on which Dr. Mendelsohn relied is “far from powerful,” “specious,” and lacking in agreement by Prof. William Nordhaus, the model’s author. (*Id.* at 70.) He is wrong on all counts.

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. Dr. Hanemann responded that damages of \$173 billion is too small fraction of global GDP to be noticed. This misconstrues Dr. Mendelsohn’s testimony.¹⁶⁷

¹⁶⁷ Dr. Hannemann also testified that Dr. Mendelsohn’s acknowledgment that there have been detectable changes since preindustrial times undermines his theory. (State Agencies Br. at 71.) But this too misconstrues Dr. Mendelsohn’s testimony. While he clearly described changes since pre-industrial times, the changes have been both benefits and damages, but resulting in no current *net* damage. (*See, e.g.,* Ex. 216, Mendelsohn Direct Ex. 2 (Report) at 14 (describing

Dr. Mendelsohn was not using changes in global GDP to measure damage. (Ex. 220, Mendelsohn Surrebuttal at 16.) He was not referring to aggregate reductions in welfare that might be difficult to measure in the overall global economy — a needle in a haystack — but to specific instances of damage that (according to theory) ought to be detectable on a local basis. Dr. Mendelsohn was “looking 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.” (Ex. 220, Mendelsohn Surrebuttal at 16:8-10.) In other words, he was looking for these damages where they are supposed to occur — and still not finding them. He concluded 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.*)

There is also no evidence that the author of the DICE model, Prof. Nordhaus, would disagree or believe a higher number is appropriate, contrary to Dr. Hanemann’s implications otherwise. Dr. Hanemann falsely alleged that Professor Nordhaus “gives” or endorses a value of \$25 in his recent book *The Climate Casino*. (State Agencies Br. at 74, n. 56.) Dr. Hanemann proffered that Nordhaus wrote that “A U.S. Government report provided the best estimate of about \$25 per ton of CO₂ for 2015.” (*Id.*) ***Again, the State Agencies manipulate a quotation and distort what the author actually said.*** In his book, Prof. Nordhaus said that the U.S. government provided “*a* best estimate” of \$25. (*The Climate Casino* (Nordhaus 2013) at 228.) This is a far cry from saying or implying that in his opinion the government provided “*the*” best estimate. Nordhaus was not endorsing or opining on the number, as the State Agencies suggest, but was merely reporting it. More importantly, he wrote that book two years before the IPCC, in AR5, dropped any “best estimate” of climate sensitivity and lowered the most likely range of changes worldwide and concluding “Looking across the planet, the magnitude of the global benefit to date is slightly higher than the magnitude of global loss to date”).)

climate sensitivity. Dr. Hanemann's criticism of Dr. Mendelsohn lacks any basis in current evidence (he cites none), and relies on blatant misstatements of Prof. Nordhaus. It should be ignored.

4. The IAMs Do Not "Underestimate" Damages.

The parties favoring the FSCC make a number of unsupported allegations that the FSCC is potentially too low because the IAMs may understate actual damages. This again is a concession of the uncertainty in the FSCC; but as described above, the weight of the evidence shows that the FSCC is biased *high* (overstates damages) not low (understates damages).

Dr. Hanemann and Dr. Polasky each allege that the FSCC is probably too low, but none of them have suggested a higher number that reflects their personal beliefs that the damage estimates included in the FSCC are under-inclusive. For that reason alone, their testimony regarding additional damages not considered in the FSCC should be disregarded as irrelevant.

Dr. Hanemann and Dr. Polasky each reference the IWG's Response to Comments, which asserts that the IPCC in AR5 noted that the FSCC may not account for the full range of potential damages. Dr. Polasky argues that the damage functions in the IAMs underestimate damage, but he cites no research supporting the claim nor does he cite research that the aggregate estimates in the IAMs are too low. (Polasky testimony at 18-20, 21-24.) Similarly, Dr. Hanemann testified that "his assessment of the newer literature is that these studies generally indicate more severe damages than the earlier literature and thus, if anything, the damage estimates in the IWG SCC are too low". (Ex. 801, Hanemann Rebuttal at 48.) But Dr. Hanemann did not cite specifically any such studies to support this claim, other than the IWG's own statements that certain potentially significant damage categories were not monetized. (See State Agencies Brief 66-67, 76; Ex. 801, Hanemann Rebuttal at 63.) Indeed, Dr. Hanemann's claim is refuted, not supported,

by AR5, which acknowledges a continuing lack of any certainty in tying more severe impacts to climate change based on current data. AR5 shows that the IPCC and the state of peer-reviewed literature remain deeply uncertain about the extent of any connection between CO₂ emissions and future damages.

While Dr. Hanemann and the State Agencies believe that more specificity in the models (“increased granularity”) would lead to higher figures (Ex. 801, Hanemann Rebuttal at 49), they have cited no evidence to support that claim other than Dr. Hanemann’s own personal belief. Such surmise is not adequate proof.

5. The FSCC Understates CO₂ Fertilization.

Dr. Mendelsohn, on the basis of two decades of experience researching climate damages, testified that IAMs were flawed because they understated the effects of CO₂ fertilization. (Mendelsohn, 3B Tr. 38:12-23.) His testimony on this point was supported by AR5 and the overwhelming consensus of peer-reviewed evidence.

In fact, the State Agencies *concede* that “all available scientific evidence supports the general concept of a CO₂ fertilization effect.” (State Agencies Br. at 47.) Dr. Reich testified that there is a CO₂ fertilization effect and that increased levels of CO₂ can lead to increased crop and forest productivity.¹⁶⁸ A study he co-authored concluded that: “Our results suggest that, with rising CO₂ 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 CO₂ fertilization effects”¹⁶⁹ When shown that article at trial, Dr. Reich agreed that “from

¹⁶⁸ Reich, 5 Tr. 37:10-11, 15-17.

¹⁶⁹ Ex. 266, at 939 (Emily B. Peters, *et al.*, *Potential Climate Change Impacts on Temperature Forest Ecosystem Processes*, 43 Can. J. For. Rsch. 939, 939 (2013) (abstract)).

67 percent to 142 percent, that's almost a doubling of the forest regional productivity."¹⁷⁰ The article also noted the "the important role that CO₂ fertilization plays in allowing forests to overcome warming-induced drought stress through increased water-use efficiency."¹⁷¹ Dr. Reich acknowledged that elevated CO₂ reduces the size of stomata in trees (5 Tr. 56:3-25), which reduces the loss of water vapor. "More specifically, the predicted increases in productivity when the CO₂ routine was implemented could largely be attributed to the indirect effect of rising CO₂ on reduced water stress and, hence, higher photosynthetic rates."¹⁷²

AR5 flatly notes that "[e]levated atmospheric CO₂ 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 CO₂ will lead to enhanced plant productivity.¹⁷³ AR5 even notes that greater growth from CO₂ fertilization is causing greater CO₂ sinks in Europe and North America.¹⁷⁴ AR5 acknowledges that the understanding of the dynamic impacts of vegetation, as a consumer of CO₂, has improved since AR4.¹⁷⁵ AR5 notes that there is "good agreement" on the basic concept of CO₂ fertilization when other nutrients do not constrain growth.¹⁷⁶ Increased CO₂ has already "virtually certainly" enhanced water use efficiency in key C₃ crops (maize, wheat, rice), making them more resistant to drought and warmer temperatures.¹⁷⁷ Even Dr. Gurney stated, "All

¹⁷⁰ Reich, 5 Tr. 39:4-6.

¹⁷¹ Ex. 266, at 946.

¹⁷² Ex. 266 at 948.

¹⁷³ AR5 WG1 at 501 (Box 6.3).

¹⁷⁴ AR5 WG1 at 501.

¹⁷⁵ AR5 WG1 at 791.

¹⁷⁶ AR5 WG1 at 791.

¹⁷⁷ AR5 WG2 at 493.

available scientific evidence supports the general concept of a CO₂ fertilization effect.” (Ex. 803, Gurney Rebuttal, 3:4.) Dr. Reich, the CEOs’ own witness, corroborated the existence of a CO₂ fertilization effect with both his testimony (Reich, 5 Tr. at 37:10-11, 39:4-6) and with published peer-reviewed science that he admitted undermined his other testimony.¹⁷⁸

When it turns to the impacts of CO₂ fertilization, AR5 found that it makes a crucial difference, for example, in food security. Without factoring in CO₂ fertilization, food prices would be projected to increase between 3 and 80%; if CO₂ fertilization is factored in, price increases are only “likely as not” and the range goes from -30% to +45%: in other words, properly factoring in CO₂ fertilization both diminishes the severity of a negative impact and reduces its probability, while yielding a possibility of lowering food prices overall.¹⁷⁹ AR5 also found that increased vegetation results in a stronger carbon sink, drawing more CO₂ 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.”¹⁸⁰

Despite this strong evidence, the State Agencies continue to nitpick. (State Agencies Br. 47-51.) They assert, incorrectly, that Dr. Bezdek for relies on a single non-peer-reviewed report to support his views on CO₂ fertilization (State Agencies Br. at 48), but inexplicably ignore the fact that the article in question is a review article, a compilation of hundreds of peer-reviewed sources. (See Ex. 235, Bezdek Surrebuttal at 27:1-31:20 (listing 43 peer-reviewed sources.) Moreover, the State Agencies have *repeatedly* ignored the fact that Dr. Bezdek cited 136 articles

¹⁷⁸ Ex. 266 at 939; Reich 5 Tr. 73:5-8.

¹⁷⁹ AR5 WG2 at 489.

¹⁸⁰ AR5 WG2 at 989.

regarding the fertilization effect,¹⁸¹ 40 articles demonstrating that greening is already occurring,¹⁸² and 427 articles on the same topics in response to an information request from the CEOs,¹⁸³ all for an argument where Dr. Gurney acknowledges Dr. Bezdek is essentially correct. (Ex. 803, Gurney Rebuttal 3:5-6 (“All available scientific evidence supports the general concept of a CO₂ fertilization effect.”).) Dr. Gurney’s attention has *repeatedly* been drawn to this evidence, yet he persists in stating falsely that Dr. Bezdek relies predominantly on non-peer-reviewed literature. (State Agencies Br. at 47.)

The State Agencies (and the other Proponents of the FSCC) waived their right to call Dr. Bezdek for cross-examination on this or any other issue. Beyond Dr. Bezdek, *the refusal to cross examine many of Peabody’s witnesses permits an adverse inference against the Proponents of the FSCC and opponents (and an inference favorable to Peabody’s position)* because it suggests these parties were concerned that cross examination would reveal the credibility and reliability of these witnesses, and the Proponents could no longer rely on “trust us” reasoning.

In fact, the overwhelming consensus of peer-reviewed evidence supports the fact of CO₂ fertilization:

- *Field-wide peer-reviewed studies show benefits of higher CO₂ concentrations for important crops such as wheat, rice, and cotton.*¹⁸⁴ Peer-reviewed reports

¹⁸¹ Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 69-89.

¹⁸² Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 89-96.

¹⁸³ Ex. 234, Bezdek Rebuttal, Ex. 2 (Information Request Response) at 11-52.

¹⁸⁴ Vanuytrecht, E., Raes, D., Willems, P. and Geerts, S. 2012. Quantifying field-scale effects of elevated carbon dioxide concentration on crops. *Climate Research* **54**: 35-47 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 73). *See also* Sommer, R., Glazirina, M., Yuldashev, T., Otarov, A., Ibraeva, M., Martynova, L., Bekenov, M., Kholov, B., Ibragimov, N., Kobilov, R., Karaev, S., Sulstonov, M., Khasanova, F., Esanbekov, M., Mavlyanov, D., Isaev, S., Abdurahimov, S., Ikramov, R., Shezdyukova, L. and de Pauw, E. 2013. Impact of climate change on wheat productivity in Central Asia. *Agriculture, Ecosystems and Environment* **178**: 78-99 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 85) (describing positive effects of CO₂ on 14 wheat varieties on 18 plots in Central Asia).

show that China has experienced CO₂ fertilization for three decades, based on satellite observation of greening.¹⁸⁵ In peer-reviewed field studies, this has resulted in increased biomass for rice and increased levels of other nutrients such as nitrogen,¹⁸⁶ as well as a shorter growing season and higher yields for winter wheat.¹⁸⁷ Using only the most pessimistic assumptions about climate change, researchers in a peer-reviewed study found uniformly positive effects for winter wheat growth in the United Kingdom.¹⁸⁸ In general, ***plants under increased levels of CO₂ are healthier***: higher levels of photosynthesis, lower transpiration, and greater water-use efficiency.¹⁸⁹ Moreover, ***these effects are multiplied through feedback mechanisms***.¹⁹⁰

¹⁸⁵ Piao, S., Yin, G., Tan, J., Cheng, L., Huang, M., Li, Y., Liu, R., Mao, J., Myneni, R.B., Peng, S., Poulter, B., Shi, X., Xiao, Z., Zeng, N., Zeng, Z. and Wang, Y. 2015. Detection and attribution of vegetation greening trend in China over the last 30 years. *Global Change Biology* 21: 1601-1609 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 15 n.39).

¹⁸⁶ Guo, J., Zhang, M., Wang, X. and Zhang, W. 2015. Elevated CO₂ facilitates C and N accumulation in a rice paddy ecosystem. *Journal of Environmental Sciences* 29: 27-33 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 15 n.40). *See also* Yu, Y., Zhang, W. and Huang, Y. 2014. Impact assessment of climate change, carbon dioxide fertilization and constant growing season on rice yields in China. *Climatic Change* 124: 763-775 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 70) (finding that rice yields will likely decrease at current CO₂ concentrations but will skyrocket with more CO₂); Zhao, Q., Liu, J., Khabarov, N., Obersteiner, M. and Westphal, M. 2014. Impacts of climate change on virtual water content of crops in China. *Ecological Informatics* 19: 26-34 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 72) (noting that increased CO₂ will likely promote food security and alleviate water scarcity in China through the integrated effects of precipitation, temperature, and CO₂ concentration changes).

¹⁸⁷ Tian, Y., Chen, J., Chen, C., Deng, A., Song, Z., Zheng, C., Hoogmoed, W. and Zhang, W. 2012. Warming impacts on winter wheat phenophase and grain yield under field conditions in Yangtze Delta Plain, China. *Field Crops Research* 134: 193-199 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 73).

¹⁸⁸ Cho, K., Falloon, P., Gornall, J., Betts, R. and Clark, R. 2012. Winter wheat yields in the UK: uncertainties in climate and management impacts. *Climate Research* 54: 49-68 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 74).

¹⁸⁹ Lee, S.H., Woo, S.Y. and Je, S.M. 2015. Effects of elevated CO₂ and water stress on physiological responses of *Perilla frutescens* var. japonica HARA. *Journal of Plant Growth Regulation* 75: 427-434 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 16 n.45). *See also* Sendall, K.M., Reich, P.B., Zhao, C., Jihua, H., Wei, X., Stefanski, A., Rice, K., Rich, R.L. and Montgomery, R.A. 2015. Acclimation of photosynthetic temperature optima of temperate and boreal tree species in response to experimental forest warming. *Global Change Biology* 21: 1342-1357 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 17 n.48) (noting that increased photosynthesis will help ameliorate any negative effects of warming); Preite, V., Stocklin, J., Armbruster, G.F.J. and Scheepens, J.F. 2015. Adaptation of flowering phenology and fitness-related traits across environmental gradients in the widespread *Campanula rotundifolia*. *Evolutionary Ecology* 29: 249-267 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 17 n.49) (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. 2011. 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 (cited in Ex. 231, Bezdek Direct, Ex. 3

- Another peer-reviewed study shows that *increased CO₂ supports plants in defending against pathogens¹⁹¹ and herbivorous predators¹⁹²*, and can help plants to regrow after being partially eaten without dying.¹⁹³ In the field, increased CO₂ after hurricanes and fires speeds recovery by enhancing root growth.¹⁹⁴
- Peer-reviewed studies show that *more CO₂ allows plants to better allocate their resources so they can compete more effectively for resources and survive more easily.*¹⁹⁵ Ultimately, laboratory experiments show that this could be generalized to being able to withstand drought conditions.¹⁹⁶ Field studies on tree rings

(Compendium) at 77) (noting higher water use efficiency for trees in three regions of the western United States).

¹⁹⁰ Polley, H.W., Jin, V.L. and Fay, P.A. 2012. Feedback from plant species change amplifies CO₂ enhancement of grassland productivity. *Global Change Biology* **18**: 2813-2823 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 74).

¹⁹¹ Li, X., Sun, Z., Shao, S., Zhang, S., Ahammed, G.J., Zhang, G., Jiang, Y., Zhou, J., Xia, X., Zhou, Y., Yu, J. and Shi, K. 2015. Tomato-Pseudomonas syringae interactions under elevated CO₂ concentration: the role of stomata. *Journal of Experimental Botany* **66**: 307-316 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 15 n.41).

¹⁹² de Rezende, F.M., Souza, A.P., Buckeridge, M.S. and Furlan, C.M. 2015. Is guava phenolic metabolism influenced by elevated atmospheric CO₂? *Environmental Pollution* **196**: 483-488 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 16 n.43).

¹⁹³ Nabity, P.D., Hillstrom, M.L., Lindroth, R.L. and DeLucia, E.H. Elevated CO₂ interacts with herbivory to alter chlorophyll fluorescence and leaf temperature in *Betula papyrifera* and *Populus tremuloides*. *Oecologia* **169**: 905-913 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 72). *See also* Pilegaard, K., Ibrom, A., Courtney, M.S., Hummelshoj, P. and Jensen, N.O. 2011. Increasing net CO₂ uptake by a Danish beech forest during the period from 1996 to 2009. *Agricultural and Forest Meteorology* **151**: 934-946 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 77) (finding, based on a field study, that CO₂ helped trees retain their leaves longer and had other positive effects).

¹⁹⁴ Day, F.P., Schroeder, R.E., Stover, D.B., Brown, A.L.P., Butnor, J.R., Dilustro, J., Hungate, B.A., Dijkstra, P., Duval, B.D., Seiler, T.J., Drake, B.G. and Hinkle, C.R. 2013. The effects of 11 years of CO₂ enrichment on roots in a Florida scrub-oak ecosystem. *New Phytologist* **200**: 778-787 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 70).

¹⁹⁵ Cao, J. and Ruan, H. 2015. Responses of the submerged macrophyte *Vallisneria spiralis* to elevated CO₂ and temperature. *Aquatic Botany* **23**: 119-127 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 16 n.44).

¹⁹⁶ Song, Y. and Huang, B. 2014. Differential effectiveness of doubling ambient atmospheric CO₂ concentration mitigating adverse effects of drought, heat, and combined stress in Kentucky Bluegrass. *Journal of the American Society of Horticultural Science* **139**: 364-373 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 16 n.45). *See also* Keenan, T., Serra, J.M., Lloret, F., Ninyerola, M. and Sabate, S. 2011. Predicting the future of forests in the Mediterranean under climate change, with niche- and process-based models: CO₂ matters! *Global Change Biology* **17**: 565-579 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 72) (models predict that CO₂ enrichment increases forest productivity despite drought); Robredo, A., Perez-Lopez, U., Miranda-Apodaca, J., Lacuesta, M., Mena-Petite, A. and Munoz-Rueda, A. 2011. Elevated CO₂ reduces the drought effect on nitrogen metabolism in barley plants during drought and subsequent recovery. *Environmental and Experimental Botany* **71**: 399-408 (cited in

corroborate the supportive effects rising CO₂ concentrations have on water use efficiency, especially in dry areas.¹⁹⁷ Based on observations from 140-year-old forest plots in Central Europe, a peer-reviewed paper showed that rising CO₂ levels have helped plants to continue thriving and increasing productivity even when acid rain and drought should have caused a drop.¹⁹⁸

- A peer-reviewed study showed that ***higher ambient CO₂ in a field experiment yielded increased carbon uptake in a wetland*** and also facilitated groundwater recharge to counteract salinity intrusions.¹⁹⁹ 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.***²⁰⁰
- Peer-reviewed field experiments show that the flourishing of plants ***will not come at the cost of invasive species crowding out native species.***²⁰¹

Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 76-77) (finding enhanced CO₂ mitigates the effects of drought and permits faster recovery); Darbah, J.N.T., Sharkey, T.D., Calfapietra, C. and Karnosky, D.F. 2010. Differential response of aspen and birch trees to heat stress under elevated carbon dioxide. *Environmental Pollution* 158: 1008-1014 (corroborating the findings of Idso and Kimball (1992) that higher CO₂ promotes thermotolerance) (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 82).

¹⁹⁷ Brienen, R.J.W., Wanek, W. and Hietz, P. 2011. 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 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 75). *See also* Soulé, P.T. and Knapp, P.A. 2015. Analyses of intrinsic water-use efficiency indicate performance differences of ponderosa pine and Douglas-fir in response to CO₂ enrichment. *Journal of Biogeography* 42: 144-155 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 89) (study by U.S. Forest service noting that the benefits of rising CO₂ were noticed uniformly across all experimental plots, suggesting a pan-regional effect).

¹⁹⁸ Pretzsch, H, Biber, P., Schutze, G., Uhl, E. and Rotzer, T. 2014. Forest stand growth dynamics in Central Europe have accelerated since 1870. *Nature Communications* 5: 10.1038/ncomms5967 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 92). *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) (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 71) (simulation studies show that benefits of rising CO₂ will outweigh detriments).

¹⁹⁹ Li, J.H., Erickson, J.E., Peresta, G. and Drake, B.G. 2010. Evapotranspiration and water use efficiency in a Chesapeake Bay wetland under carbon dioxide enrichment. *Global Change Biology* 16: 234-245 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 80).

²⁰⁰ Drake, B.G. 2014. Rising sea level, temperature, and precipitation impact plant and ecosystem responses to elevated CO₂ on a Chesapeake Bay wetland: review of a 28-year study. *Global Change Biology* 20: 3329-3343 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 86).

²⁰¹ Thomas, C.D. and Palmer, G. 2015. 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 (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 16 n.47).

- A peer-reviewed study showed that enhanced CO₂ levels even **increase the ability of plants to take up and process contaminants** such as cesium and cadmium,²⁰² suggesting possible use for bioremediation.
- A peer-reviewed report shows that **statistically, the effects of CO₂ fertilization outweigh the effects of climate change on both C₃ and C₄ crops.**²⁰³

The State Agencies criticize CO₂ fertilization studies for relying on “controlled or laboratory conditions” rather than “real world” conditions (State Agencies Br. at 47), but ignore the fact that AR5 itself relies extensively on laboratory studies and that Dr. Bezdek cited numerous field studies as well. Indeed, AR5 cites specifically to free-air CO₂ enrichment (FACE) experiments as a key advance since AR4 that allows a better understanding of CO₂ fertilization.²⁰⁴ AR5 even points out that FACE experiments tend to **underestimate** CO₂ response.²⁰⁵ The reason AR5 values FACE experiments so highly is that confounding variables are harder to control in field studies.²⁰⁶ Laboratory experiments, by contrast, are designed for generalization, and AR5 relies on FACE experiments in order to overcome that challenge. As Dr.

²⁰² Song, N., Zhang, X., Wang, F., Zhang, C. and Tang, S. 2012. Elevated CO₂ 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 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 73); Wang, R., Dai, S., Tang, S., Tian, S., Song, Z., Deng, X., Ding, Y., Zou, X., Zhao, Y. and Smith, D.L. 2012. Growth, gas exchange, root morphology and cadmium uptake responses of poplars and willows grown on cadmium-contaminated soil to elevated CO₂. *Environmental Earth Sciences* **67**: 1-13 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 73). *See also* Jia, Y., Tang, S.-r., Ju, X.-h., Shu, L.-n., Tu, S.-x., Feng, R.-w. and Giusti, L. 2011. Effects of elevated CO₂ levels on root morphological traits and Cd uptakes of two *Lolium* species under Cd stress. *Journal of Zhejiang University - SCIENCE B (Biomedicine & Biotechnology)* **12**: 313-325 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 76) (finding a similar increase in cadmium uptake but less concentration in the plant’s tissues, indicating that CO₂ may have a protective effect on plant tissues).

²⁰³ Attavanich, W. and McCarl, B.A. 2014. How is CO₂ affecting yields and technological progress? A statistical analysis. *Climatic Change* **124**: 747-762 (cited in Ex. 231, Bezdek Direct, Ex. 3 (Compendium) at 87).

²⁰⁴ AR5 WG1 at 502 (Box 6.3).

²⁰⁵ AR5 WG2 at 495.

²⁰⁶ AR5 WG2 at 495.

Mendelsohn pointed out, “[c]ontrolled experiments are a very important way to demonstrate cause and effect.” (Ex. 220, Mendelsohn Surrebuttal at 3:14-15.) In addition to Dr. Reich’s article, noted above, Dr. Hanemann’s research corroborates the widespread effect of CO₂ fertilization beyond the laboratory (Ex. 220, Mendelsohn Surrebuttal at 3:18-4:5), and other peer-reviewed research is in accord (Ex. 220, Mendelsohn Surrebuttal at 4:7-5:5). AR5 relies on the very studies the State Agencies reject because the broader studies corroborate what is found in the laboratory: that CO₂ fertilization is a significant effect on plant growth.

Dr. Gurney cites selectively to IPCC’s AR5 Working Group II Report in order to bolster his fear of the effects of CO₂ on crop yields (State Agencies Br. at 48), but his cherry-picking obscures the entire story. While he cites to a single graph on p. 506 of AR5 WG2 — which was never put into evidence, so the Agencies are asking the Commission to “trust us” that Gurney’s description is accurate — he neglects to describe the wider discussion. The report he discusses shows a net negative impact on crop yields *only assuming no adaptation*; when adaptation is factored in, yields increase on average of 15-18%.²⁰⁷ These gains are more than enough to offset the negative effects of climate change.²⁰⁸ Moreover, the benefits of adaptation for crop yield increase as the temperature does.²⁰⁹ Increased CO₂ since pre-industrial times has “virtually certainly” enhanced water use efficiency by C₃ crops (wheat, rice, maize), which strengthens them against other potential negative effects of climate change.²¹⁰ Moreover, AR5 found that the

²⁰⁷ AR5 WG2 at 489.

²⁰⁸ AR5 WG2 at 515.

²⁰⁹ AR5 WG2 at 516 (Fig. 7-8).

²¹⁰ AR5 WG2 at 493; *see also* Ex. 200, Happer Direct at 10-11 (discussing increased water use efficiency).

declines in crop yield are likely to happen mostly after a rise in temperature of 4 °C,²¹¹ which is an increasingly unlikely event according to AR5’s recognition of lower ECS values. Dr. Gurney also fails to note AR5’s admission that “little work” has been done to show that climate effects on agriculture are anthropogenic.²¹² In other words, a fuller understanding of the context Dr. Gurney presents as being decisive shows not only that his selective argument is off-base (it assumes neither humans nor nature will adapt to changing circumstances) but also that his core thesis — that these shifts are due to anthropogenic CO₂ emission — has no support in AR5, which he deems the gold standard for peer-reviewed science. *Taking a closer look at the actual information Dr. Gurney cites to in AR5 reveals that indeed his account of the evidence cannot be trusted.*

The State Agencies fare no better when responding to Dr. Mendelsohn. In another example of nitpicking in order to avoid grappling with the actual scientific evidence in the record, the State Agencies criticize Dr. Mendelsohn because “the phrase ‘net benefit’ appears nowhere in Gerber, et al.” (State Agencies Br. at 54.) The State Agencies ignore the response Dr. Mendelsohn has already given to this argument, as if the surrebuttals never occurred:

I actually cited Gerber for a different proposition, namely that “the carbon fertilization of trees has also led to an overall increase in ecosystem productivity and standing biomass” (Direct Testimony, Ex. 2 (Report) at 12). I argue that an “overall increase in ecosystem productivity and standing biomass” would be a “net benefit” to society. The phrase “net benefit” does not appear in Gerber’s work because that is *my* conclusion, not his, based on the net changes that ecosystem models predict from climate change.

(Ex. 220, Mendelsohn Surrebuttal at 15:11-17.) Dr. Hanemann misinterpreted Dr. Mendelsohn in order to score low-value points: Dr. Hanemann still presents insufficient evidence to overcome

²¹¹ AR5 WG2 at 489.

²¹² AR5 WG2 at 492.

the conclusions of AR5 regarding CO₂ fertilization. *Drs. Mendelsohn, Bezdek, and Happer have presented vastly more credible peer-reviewed literature regarding CO₂ fertilization than any of the Proponents have, and their attacks at best nibble around the edges*: the core effect is conceded, and the strong preponderance of the evidence shows that it is given insufficient consideration by the IAMs.

6. Standardizing the IAMs Corrupts The Results and Invalidates The FSCC

The State Agencies admit that the IWG “standardiz[ed] the model inputs and parameters.” (State Agencies Br. 26). For example, the IWG “change[d] the structure of DICE to make it a simulation model rather than an optimization model.” (*Id.*) Dr. Mendelsohn compared “standardizing” the models to putting gasoline in a diesel car. (3B Tr. 37:19-38:11.) The State Agencies praise Dr. Nordhaus as “an eminent economist” (State Agencies Br. 70 n.54) and contend that DICE should not be modified without evidence that “Professor Nordhaus is wrong.” (*Id.* at 70). Yet the State Agencies ignore the fact that IWG made fundamental changes to DICE and the other IAMs, overriding the authors’ decisions and parameters in a non-transparent and non-peer-reviewed fashion.

Dr. Mendelsohn testified (without contradiction) that a key problem with IWG’s use of the IAMs is that they eliminated the models’ own inherent consideration that society will react to observed climate damages by taking mitigative action. (*See* Peabody Br. at 64-65.) Dr. Mendelsohn explained in his direct testimony that a damages model for determining the externality value of carbon should measure the marginal damage associated with each policy choice this is a familiar procedure that environmental economists use for all pollutants, not just carbon dioxide. (Ex. 220, Mendelsohn Surrebuttal at 23). The IWG, however, measured the social cost of carbon at the highest possible level of emissions, which assumes there is no

mitigation – even though the purpose of the SCC is to encourage mitigation. (Ex. 220, Mendelsohn Surrebuttal at 24.) But instead of taking into account what effect the SCC would have on future mitigation, the IWG assumed it would have no effect. ***The SCC measurement made by the IWG is accurate only as long as it is never used.***

In addition, by running the DICE model in standardization 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. Further, the IWG assumptions for population, GDP, and emissions from 2100-2300 have never been peer-reviewed.

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 at 2.) By converting DICE to a simulation model, the IWG “is basically saying we don’t really care about what the DICE model has to say, we’re going to substitute something else for it, and it’s not using the DICE model.” (Mendelsohn, 3B Tr. 59:13-16.) Like putting gasoline in a diesel car, “[t]he IWG did not run the DICE model as it was originally designed.” (*Id.* at 30:7-8.) Mr. Martin agreed with this criticism as well. (Martin, 3B Tr. 112:20-25.)

The CEOs' only argument against this is that running DICE in optimization mode — as it was originally intended — is not supported by existing evidence because “to assume coordinated policies will be in place any time soon... seems highly unrealistic.” (CEOs Br. at 36 (quoting Ex. 101 at 46).) The State Agencies acknowledge that optimization “is common in the theoretical literature in economics,” yet proffer that this wrongly models global emissions as though they were controlled “by a single decision-maker who controls emissions made around the world.” (State Agencies Br. at 71.) They argue that the optimization version of DICE implies that “abatement occurs more speedily than in the real world, that warming builds up less than is likely in the real world, and that the damages are smaller than is likely in the real world. The simplifications, therefore, generate a lower estimate of the social cost of carbon than is likely to occur in the real world.” (*Id.* at 72 (citing Ex. 801, Hanemann Rebuttal at 43-44.)

Yet neither the State Agencies nor the CEOs offer any actual evidence to support the IWG's deconstruction of the DICE model. Dr. Hanemann speaks of how damages will be larger or happen more quickly “in the real world,” but this is absolutely refuted by what is actually *currently being observed* (or more accurately, what is not being observed) “in the real world.” The damages are *not* occurring as quickly or as significantly as once believed or as predicted in climate models, as discussed in detail above.

Moreover, the State Agencies are in the curious position of arguing that, despite the recent climate accord in Paris the social cost of carbon should be set on the assumption that no other jurisdiction will ever adopt mitigation measures. The FSCC proponents' argument in favor of gutting the DICE model to ignore the inextricable relationship between growth, emissions, interest rates and population has no basis in the evidence or in current accepted economic theory. The State Agencies' argument that the IWG was required by necessity to change the IAMs by

standardizing them in order to make a comparison (State Agencies Br. 26-27) is patently untrue. In this proceeding, the Commission has before it the results of the unadulterated versions of DICE and FUND, and it may compare their estimates directly to see that they are mutually reinforcing.

7. The IWG Used Flawed Discount Rates.

The discount rates used by the IWG were fundamentally arbitrary. The Agencies and the Clean Energy Organizations support the IWG's selection of discount rates, including the omission of the 7% discount rate recommended by OMB Circular A-4. (State Agencies Br. at 31-32; CEOs Br. at 18-19.) As Peabody discussed in its opening brief, the IWG's selection of discount rates did not follow OMB's guidance, made arbitrary decisions, and ignored ethical considerations. (Peabody Br. at 70-73.) Neither the IWG's initial explanation nor its subsequent explanation justifies its discount rate decisions.

(a) The IWG's Initial Explanation Directly Contradicts OMB Guidance.

Both the Agencies and the Clean Energy Organizations suggested that not including a 7% discount rate was reasonable. (State Agencies Br. at 31-32; CEO Br. at 18-19.) However, no proponent of the FSCC explained the IWG's justification for not following the guidance's clear instruction: "For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent." (Ex. 417, OMB Circular A-4, p. 34.) Although the Clean Energy Organizations argue that Circular A-4 offers only "suggestions" (CEO Br. at 19), Dr. Polasky testified that OMB Circular A-4 is mandatory to be followed by executive agencies in a regulatory impact analysis. (Polasky, 1 Tr. 148:8-11.)

In its original Technical Support Document, the IWG does not explicitly address why a 7% discount rate was not used. Instead, the IWG appears to use taxes as its justification for not

including a 7% discount rate: “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.) Buried in a footnote, the IWG cites a single 2006 study for its rough 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.)

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 (emphasis added).) Circular A-4 also expressly rejects an after-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.* (emphasis added).) But instead of following Circular A-4’s instruction that pre-tax rates of return are better indicators of investment gains, the IWG directly contradicts Circular A-4 by reducing the 7% discount rate due to taxes. (Ex. 100, Polasky Direct, Sched. 2 (Feb. 2010 TSD), at 23; *see also* Ex. 101, Polasky Rebuttal, Sched. 1 (July 2015 Response to Comments), at 22.) Neither the IWG nor any proponent of the FSCC explained why the IWG acted reasonably in directly contradicting OMB’s guidance on including 7% discount rates and ignoring after-tax rates.

(b) *The IWG's Subsequent Explanation Directly Contradicts OMB Guidance.*

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.) The Agencies and the Clean Energy Organizations refer to the IWG’s statements on intergenerational discounting in their defense of the IWG’s selection of discount rates. (State Agencies Br. at 120-121, 122; CEO Br. at 19.)

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.) As Peabody argued in its opening brief, ethical considerations support a lower externality value. (Peabody Br. at 72-73.)

In fact, Circular A-4 expressly 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 (emphasis added).) Both the IWG and the Agencies quote this statement. (Ex. 101, Polasky Rebuttal, Sched. 1 (July 2015 Response to Comments), at 22; State Agencies Br. at 121.) Accordingly, even if the IWG believed it was justified in including a discount rate lower than 3%, Circular A-4 still dictated use of the 3% and 7% discount rates.

It was not reasonable for the IWG to rely on Circular A-4 to justify a lower discount rate but ignore the same Circular A-4 provision calling for a 7% discount rate.

8. Response to Doctors for a Healthy Environment: Health Effects Do Not Justify the FSCC.

(a) Dr. Rom's Testimony Provides No Support for the FSCC

Doctors for a Healthy Environment (“DHE”) has filed a brief in support of the FSCC, but at trial its sole witness, Dr. Rom, did not “propose any specific value” in this proceeding, has not assigned any values to damages that supposedly may not be included in the IAMs, and has not provided “any specific way of determining what the right value should be in this proceeding.” (4 Tr. at 165:1-7; 165:25-166:4.) Dr. Rom admitted that he has no firsthand knowledge working with the IAMs, that he does not have any expertise on DICE, PAGE, or FUND, that he has no training as an economist or environmental economist. (*Id.* at 165:1-166:3.) In fact, he acknowledged that while there is harm from increased temperatures, there “would be a positive effect on less cold-related morbidity.” (*Id.* at 163:1-17; 166:15-18.) Unrebutted evidence from Dr. Mendelsohn shows that health effects are already accounted for and, if anything, the IAMs overestimate future health effects because they do not account for future preventative measures. (Ex. 220, Mendelsohn Surrebuttal at 5:14-20, 20:20-21:4.)²¹³

Dr. Rom's testimony cannot provide the basis for DHE's position in its trial brief. Dr. Rom could not explain how much warming his testimony assumed, what level of equilibrium climate sensitivity (“ECS”) he was assuming, and what sort of warming predictions he was assuming. We have already demonstrated the errors in Dr. Rom's assumptions. Climate models predict far too much warming because of high ECS values — as demonstrated by peer-review literature — and observational data refutes the value of the climate models. Indeed, the current climate models use inappropriately high values for ECS despite the empirical data demonstrating

²¹³ DHE admits that DICE considers health effects (DHE Br. at 5) and so does FUND (DHE Br. at 6), although DHE asserts they do not account for ozone and particulate (PM_{2.5}) (DHE Br. at 9).

the flaws in this approach. Accordingly, DHE's trial brief does not provide any support for the FSCC.

(b) *DHE is Wrong About Health Effects, and Its Attacks on Drs. Happer and Bezdek are Misguided*

Despite only tangentially addressing the issue that is at the core of this proceeding, DHE raises a series of unwarranted attacks against Dr. Happer and Dr. Bezdek that warrant a response.

- Far from being the claims of a “particular niche researcher” as DHE claims (DHE Br. at 3), ***Dr. Happer’s argument that climate change poses little threat to human health draws on the insights of AR5 and extensive peer-reviewed research.*** AR5 found that “[t]he air pollution response to climate-driven changes in the biosphere is *uncertain as to sign . . .*” (AR5 WG1 at 999-1000 (emphasis added).) That means AR5 found that it could not determine whether climate change would be a benefit or cost with respect to health effects. In general, studies of air quality cannot dependably attribute the changes to anthropogenic emissions. (AR5 WG1 at 1000.) ***Ultimately AR5 WG1 gives “no confidence level” to overall impact of climate change on particulate levels and distributions.*** (AR5 WG1 at 1001 (emphasis in original).) Additionally, contrary to the DHE’s assertions, “[t]here is high confidence that globally, warming decreases background surface ozone” (AR5 WG1 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.*). “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 indicate downward trends in the last two decades of PM2.5 . . .” (AR5 WG1 at 178-80 (emphasis in original).) Finally, the IPCC Fifth Assessment Working Group 2 found that “there is little evidence that climate change, per se, will affect long-term particle levels in a consistent way.” (Part A of the IPCC Fifth Assessment Working Group 2, “AR5 WG2”) at 728 (citing AR5 WG1 at Section 11.3.5 and Annex II.) ***The best science available completely undercuts the foundations of DHE’s positions, which appear to be based more on rhetorical assumptions rather than data.***
- DHE incorrectly argues that Dr. Happer “distort[s] the medical literature” by citing a study concluding that there was a significant negative correlation between asthma hospitalizations and daily mean temperature. (Ex. 206, Happer Surrebuttal, at 22 n.35.) The study found that the effects in cold weather were acute and long-lasting while warmer temperatures were not associated with asthma hospital admissions. (*Id.*) Those were indeed the conclusions of the study, upon which Dr. Happer relied. It is DHE that distorts when it states that

the study at issue “*concluded* that ‘climate change . . . may relate to the increased burden of asthma.’” (DHE Initial Brief, at 12 (emphasis added; original emphasis omitted).²¹⁴) To the contrary, *the study did not so conclude—the language DHE quotes is from the introduction to the study* and is based not on the authors’ study but instead relies upon another study²¹⁵ that presumed that in a world with more significant warming (as the flawed models using higher ECS values previously indicated) there could be higher burden of asthma. Further, what DHE omit in their ellipses was the key assumption that “changes in temperature and humidity” *may* result in increased prevalence of asthma. DHE disregards the best science in AR5, which indicates that significant increase in mean temperatures is unlikely. Meanwhile, DHE has demonstrated that it will distort the language of published articles similarly to Dr. Gurney. And it bears repeating that *the study does in fact conclude in relevant part that there were a higher prevalence of acute asthma attacks in colder temperatures.*

- DHE also misconstrues the second study upon which Dr. Happer relies. Dr. Happer noted that the study “found that hospitalization rates for asthma and severe allergies were substantially higher in cold weather.” (Happer Surrebuttal at 22.)²¹⁶ DHE claims that Dr. Happer “draws unsupported conclusions” from the study because although winters will be “less severe in places,” moderately increasing mean temperatures “will not of a sudden eliminate deaths due to cold.” (DHE Br. at 12-13.) But DHE tacitly concedes that Dr. Happer correctly described the article, and only quibbles with the inferences drawn from it. DHE’s objection is unsupported and makes little sense. The point is that if the world is moderately warmer there will be less cold-weather hospitalizations. That is exactly what the study that Dr. Happer relies upon concluded. *Simply stating the opposite without any evidentiary or scientific support (as DHE tries to do) does not make it so.*
- DHE cites Dr. Rom for what it asserts is a competing perspective, that increased heat-related mortality will “overwhelm[]” any reduction in cold-related mortality. (DHE Br. at 13.) *But this is simply a competing perspective, and to call Dr. Happer’s position a distortion of the medical literature is nakedly an attempt to beg the question.* It bears repeating that Dr. Rom’s views are based on his assumption that the amount of warming the world will experience will be close to

²¹⁴ DHE is quoting Zhang, Y., Peng, L., Kan, H., Xu, J., Chen, R., Liu, Y. and Wang, W. 2014. Effects of meteorological factors on daily hospital admissions for asthma in adults: A time-series analysis. *PLOS ONE* 9: e102475.

²¹⁵ Reid CE, Gamble JL (2009) Aeroallergens, allergic disease, and climate change: impacts and adaptation. *Ecohealth* 6: 458–470 (cited in Zhang, *et al.*, *supra* n.214 at n.7, which is cited in DHE Br. at 12).

²¹⁶ Dr. Happer is citing Son, J.-Y, Bell, M.L. and Lee, J.-T. 2014. The impact of heat, cold, and heat waves on hospital admissions in eight cities in Korea. *International Journal of Biometeorology* 58: 1893-1903.

what the current climate models predict — and they have been admitted to be “running hot.”

- DHE fails to address the point that policies that raise the price of energy will have a negative impact on those financially marginalized in society, such as those on fixed incomes, who are most at risk for aggravated asthma and other respiratory diseases.²¹⁷ ***DHE fails even to consider or address Dr. Happer’s concerns regarding the impact of climate policy on impoverished populations.***
- DHE makes further misstatements regarding the studies cited by Dr. Happer. For instance, two of the studies explicitly compare heat- and cold-related mortality.²¹⁸ These studies may not draw the conclusions regarding climate change that DHE would like, but they provide the data and analysis that is necessary to provide the bases for Dr. Happer’s conclusions. Additionally, when DHE dismisses other studies as only relating to those who live on farms they miss the fundamental point, which is that CO₂ crop fertilization will not only increase yields but will also make more prevalent a wider variety of pollen and microbes. This is exactly what these studies found would actually decrease incidence and severity of asthma and respiratory complications.²¹⁹
- DHE again misconstrues another study which they claim “comes closest to supporting” Dr. Happer’s position. (DHE Initial Brief, at 14 (citing Happer Surrebuttal at 23 n.38.²²⁰) The study found that in the United Kingdom warming did not lead to increased heat-related mortality but did decrease cold-related mortality “by more than 33%.”²²¹ DHE grudgingly agrees that in this context “some warming may be beneficial” (DHE Initial Brief, at 14), but DHE attempts

²¹⁷ Happer Surrebuttal, at 24 (citing Acevedo, Nathalie, et al. “Particular characteristics of allergic symptoms in tropical environments: follow up to 24 months in the FRAAT birth cohort study.” *BMC Pulmonary Medicine* 12.1 (2012): 13; Heinrich, Joachim. “Influence of indoor factors in dwellings on the development of childhood asthma.” *International Journal of Hygiene and Environmental Health* 214.1 (2011): 1-25).

²¹⁸ See Happer Surrebuttal, at 23 nn. 38, 39 (citing Christidis, N., Donaldson, G.C. and Stott, P.A. 2010. Causes for the recent changes in cold and heat-related mortality in England and Wales. *Climatic Change* 102: 539-553; Vardoulakis, S., Dear, K., Hajat, S., Heaviside, C., Eggen, B. and McMichael, A.J. 2014. Comparative assessment of the effects of climate change heat- and cold-related mortality in the United Kingdom and Australia. *Environmental Health Perspectives* 122: 1285-1292).

²¹⁹ Happer Surrebuttal, at 23 n.37 (citing Markus J. Ege, et al. “Exposure to environmental microorganisms and childhood asthma.” *New England Journal of Medicine* 364.8 (2011): 701-709; Dick Heederik and Erika von Mutius. “Does diversity of environmental microbial exposure matter for the occurrence of allergy and asthma?” *Journal of Allergy and Clinical Immunology* 130.1 (2012): 44-50).

²²⁰ Dr. Happer is citing Christidis, N., Donaldson, G.C. and Stott, P.A. 2010. Causes for the recent changes in cold and heat-related mortality in England and Wales. *Climatic Change* 102: 539-553.

²²¹ Christidis, *supra* n.220, at 540.

to cabin this conclusion as much as possible within “economically developed areas.” Although this study does not limit its conclusions in this way, DHE must admit at least that Dr. Happer did not “distort the medical literature” on this point, and its broad dismissive allegations regarding his scholarship are unfounded.

- DHE argues that Dr. Happer misconstrued a study regarding United Kingdom and Australian temperature-related mortality, but again it is DHE that is obfuscating. (DHE Initial Brief, at 14-15.) Indeed, *DHE claims that “this study also did not conclude that warmer temperatures would produce a net decrease in temperature related mortality”* (DHE Initial Brief, at 14-15), *but that is exactly what the study concluded.*²²² Specifically, the study shows that in absolute numerical terms, should the world warm the number of decreased cold-related mortalities would be greater than the number of increased warm-related mortalities. By focusing on the changes in the *rate* of mortality, which is irrelevant to the absolute numbers, DHE attempts to obscure what it does not want to admit: Dr. Happer correctly identifies a study that demonstrates that more people would survive in a warmer world.
- DHE next attempts to dismiss a study that collected data from 384 locations in Australia, Brazil, Canada, China, Italy, Japan, South Korea, Spain, Sweden, Taiwan, Thailand, the United Kingdom, and the United States of America, and analyzed over 74 million deaths from 1985 to 2012. (DHE Initial Brief, at 15 n.49.) In the face of this overwhelming data, DHE quibbles that the study addressed past as opposed to future mortality, did not include particular countries with cold regions from its analysis, and did not draw any conclusions about the net effect of climate change. (DHE Initial Brief, at 15 n.49.) But Dr. Happer only points out (entirely correctly) that the researchers “found that most of the temperature-related mortality burden was attributable to the contribution of cold and that cold weather kills 20 times as many people as hot weather does.” (Ex. 206, Happer Surrebuttal, at 24.²²³)

DHE is thus wildly off-base when it accuses Dr. Happer of “citing studies that quite clearly do not conclude what he believes they conclude” (DHE Initial Brief, at 11) or “tak[ing] a cursory look at a few papers in order to find ‘support’ for a preconceived idea.” (DHE Initial Brief, at

²²² See Vardoulakis, S., Dear, K., Hajat, S., Heaviside, C., Eggen, B. and McMichael, A.J. 2014. Comparative assessment of the effects of climate change heat- and cold-related mortality in the United Kingdom and Australia. *Environmental Health Perspectives* 122: 1285-1292 (cited in Happer Surrebuttal at 23 n.39).

²²³ Dr. Happer is citing Antonio Gasparrini, et al, “Mortality risk attributable to high and low ambient temperature: a multicountry observational study,” the *Lancet*, Volume 386, No. 9991, p. 369–375, 25, July 2015.

13.) The evidence quite clearly shows that Dr. Happer has properly cited directly to the findings of the relevant studies.

DHE next turns to Dr. Bezdek, whom it also unfairly maligns (yet declined to cross-examine). (DHE Initial Brief, at 17.) DHE oversimplifies and unfairly dismisses Dr. Bezdek's point, supported by substantial peer-reviewed and scientific literature, and as discussed above, that global warming would reduce, not increase, human mortality. Calling Dr. Bezdek an economist working "outside of his field" does not address or in any way dispute Dr. Bezdek's conclusions and the science upon which such conclusions are based. At every turn, DHE attempts to argue that Dr. Happer and Dr. Bezdek are drawing conclusions unsupported by the studies they cite, but it is actually DHE that has misconstrued the studies. DHE's testimony regarding the health effects of CO₂ is not credible, and its attacks on Drs. Happer and Bezdek are groundless.

C. Statutory and Due Process Implications Counsel Against Adopting FSCC on this Evidentiary Record

The State Agencies admit that greenhouse gases like CO₂ are different from familiar pollutants because they are a "stock externality." (State Agencies Br. at 10.) Any harm stems "from the effects of the accumulated stock of emissions, including past as well as present emissions." (*Id.*) Indeed, any harm stems from a long chain of causation that makes it impossible to identify a simple connection between emissions and the externality value — yet that is the key connection that matters: without such a connection, there is no point to establishing an externality value. The causal connection is crucial: the responsible party must cause the pollution, and the pollution must cause the damage. In order for an externality value to work, it must give an incentive to the responsible party not to cause the pollution, thereby

preventing damage: without proof of those causal links, the whole justification for setting an externality value falls apart.

The entire concept of setting an externality value for CO₂ assumes that human-induced impacts can be disaggregated from natural variability — yet that is a crucial point on which this record is barren of evidence. Dr. Tol testified, without contradiction, that “[C]urrent models do not disaggregate the effects of human-induced warming and natural variability.” (Ex. 238, Tol Rebuttal, Ex. 2 (Report), at 9:187-188.) 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.) ***On this record there is no evidence to support attribution of the harms of CO₂ emissions to anthropogenic causes.*** Yet the Commission cannot simply assume such a connection exists; to do so would be blatantly arbitrary decision-making and a violation of due process because it would eliminate the burden of proof for some advocates but not others.

This problem is especially clear when evaluating Minnesota’s role as a separate State. CO₂ is the byproduct of virtually all human activities. *See American Elec. Power Co. v. Connecticut*, 131 S. Ct. 2527, 2538 (2011) (“After all, we each emit carbon dioxide merely by breathing.”). Atmospheric CO₂ is the intermingled result of all human activity and Mother Nature. CO₂ 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 proceed on the assumption 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 CO₂ emissions. Those assumptions are unsupportable and irrational.

In a nutshell, the Proponents of the FSCC have failed to carry their burden of proof because they have failed to prove that the supposed “pollution” actually causes the damage. Despite the convoluted causal chains relating CO₂ emissions to various impacts, the FSCC automatically attributes all conceivable damages to CO₂ emissions – without attempting to make any allocations, even when the damages are just as likely to be the “fault” of city planners, farmers, corrupt governments, or others. *The higher values the other Parties advocate simply assume this causation into existence*: only that irrational assumption can support those higher values. Making such an assumption in a proceeding governed by a preponderance of the evidence standard would not only be arbitrary but would be “otherwise not in accordance with law.” 5 U.S.C. § 706(2)(A).

D. Adoption Of The FSCC Will Force Leakage And Will Unfairly Burden Minnesota With No Resulting Benefits; The Commission Should Set a Minnesota-Specific SCC

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.) Thus, even though Minnesota may have reduced CO₂ emissions, the emissions from the region may not change overall (or may not change as much as predicted) because Minnesota emissions may merely be reassigned (in whole or in part) to neighboring states. (*Id.* at 4:57-60.)

The State Agencies do not dispute that this leakage may occur, but they insist that they effect is irrelevant because “the Commission regulates only utilities in Minnesota and does not regulate utilities in other states or other countries.” (State Agencies Br. 130.) That statement is correct, but it proves the opposite of what the State Agencies believe. Precisely because the

Commission's territorial jurisdiction is limited to Minnesota, the Commission should consider only the effects of CO₂ *within Minnesota* and should set a *Minnesota-specific SCC*. (See Peabody Opening Trial Br. 96-97.)²²⁴ Because the Proponents have failed to establish any harm at all in Minnesota from global warming, the value of a Minnesota-specific SCC should be zero.²²⁵

Moreover, consideration of leakage becomes all the more important *precisely because* of the territorial limits on the Commission's jurisdiction. As Dr. Mendelsohn testified, it makes no sense for Minnesota to make itself a sacrificial lamb for no net reduction in emissions. The State Agencies do not advance their case by insisting that emissions policies "are determined by the 196 members of the UNFCCC, who each have their own interests and concerns. Reduction of global CO₂ emissions is an exercise in global collective action, and it is well known that collective action can be fraught with problems." (State Agencies Br. at 44.) "To represent UNFCCC actions as though all members spoke with one voice is not a reasonable way to characterize how the world will proceed in dealing with climate change." (*Id.* at 72.) The defeatist position of the State Agencies and CEOs appears to be that no jurisdiction will ever

²²⁴ The State Agencies object to a Minnesota-specific SCC on the ground that GHGs from all sources intermingles in the atmosphere. (State Agencies Br. 59). But that physical process does not give Minnesota regulatory jurisdiction over all GHG emissions, as the State Agencies acknowledge (State Agencies Br. at 130), nor it change the fact that would be exceedingly poor policy for Minnesota to damage its own businesses and consumers for no benefit.

²²⁵ Dr. Reich purported to establish harm to Minnesota forests, but he was forced to concede that his testimony was not tethered to any specific temperature change. (5 Tr. 39:23-24 ("Correct. I do not give a specific temperature range in which warming would have negative effects.")) He testified that the chief study he cited is based on plants in different regions with different temperatures, not a linear time-series rise in temperature. (5 Tr. 46:21-47:17.) He also testified that that he did not how bad any harms might be and could not quantify any increase or decrease in crop production. (5 Tr. 42:5-25.) Indeed, he explained that harms documented in studies are not directly from warming but from changes such as drought (Reich: 5 Tr. 41:10-20), and the evidence in this proceeding shows that such changes are not linked to warming.

follow Minnesota (despite the environmental organizations' support of the December 2015 Paris accord). But if that is the case, then adopting a high SCC will only shift emissions to neighboring states (or even overseas), while imposing hardship on Minnesota consumers and businesses.

The Proponents of the FSCC have never come to grips with (much less refuted) Dr. Mendelsohn's testimony that none of the 11 regions and countries that have adopted carbon prices have chosen the IWG's estimate, and that the figure of \$5/ton is consistent with the values used by other regions and countries. (Ex. 261.) In short, the experience of other jurisdictions and other environmental externality values refutes the FSCC rather than supporting it.

Indeed, the FSCC departs from every other environmental externality calculation — not merely those involving CO₂ — because it is not based on “optimizing” costs and benefits. (*Id.* at 2.) Dr. Mendelsohn showed that the IWG measured the marginal damage of carbon at the wrong place on the curve of the chart he presented. (Mendelsohn, 3B Tr. 36:14-37:12, 52:14-56:7.) The FSCC violates the maxim of environmental economics that externality values should be set where marginal damage equals marginal cost. This is where society can “balance the twin objectives of preserving the environment for the future while economizing losses in living standards along the way.” (Ex. 261, quoting W. Nordhaus (2013).)

In this proceeding, Minnesota has the opportunity to act as a leader — as an exemplar for the nation by exercising intellectual discipline and adopting an evidence-based carbon policy. As Dr. Mendelsohn testified, “Minnesota has an opportunity to lead by tethering the externality range to the best empirical evidence and science.” (Ex. 261). The FSCC is premised on the cynical assumption that no other jurisdiction would ever follow Minnesota (as the State Agencies and other Proponents of the FSCC acknowledge, State Agencies Br. at 44). But picking an

artificially high SCC would make it rational for other jurisdictions *not* to follow Minnesota. Minnesota should not accept the invitation of the Proponents of the FSCC to make itself a sacrificial lamb, impose hardship on its consumers and businesses, and shift emissions to neighboring states (and even overseas) rather than reducing them.

E. “Trust Us” is Not a Basis for Reasoned Decision-Making; Where There is Conflicting Evidence, Better Information from More Credible Sources Supports Rejecting the FSCC.

The Commission need not wade into factual disputes in order to resolve the key dispositive issues in this proceeding. The Proponents’ concessions, the authoritative conclusions of AR5, the overwhelming weight of peer-reviewed evidence, and unrefuted testimony all compel the rejection of the FSCC. Nevertheless, should the Commission wish to resolve disputed issues, Peabody submits that it has provided superior evidence at the points where it has been contested. Peabody’s evidence is stronger and more consistent, and its experts are markedly more qualified and experienced than any others in the proceeding.

In fact, the Proponents made a strategic decision not to call Dr. Tol at trial at all and not to engage in extensive cross-examination of any Peabody witnesses. This decision speaks volumes: the Proponents evidently concluded that cross-examining the witnesses would only bolster their testimony and further undermine the FSCC. Therefore, the Proponents’ decision to waive cross-examination adds weight to the testimony of Peabody’s witnesses.

On the other side, the Proponents habitually rely on conclusory assertions that evidence exists (somewhere) on a point, but they never actually put that evidence in the record before the Commission. “Trust us” is not a basis for reasoned decision-making. In fact, *the Proponents’ witnesses were repeatedly impeached at trial with their own scholarly writing:*

- Dr. Dessler was forced to concede under cross-examination that he had 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” (Ex. 259) – well below the IWG’s assumed central value of 3.0°C.
- Dr. Abraham was forced to agree on cross-examination that he had written an article stating that “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. at 80:1-9.)
- Dr. Reich was forced to admit on cross-examination that he had published a peer-reviewed article predicting a 67 percent to 142 percent increase in forest regional productivity as a result of global warming. (5 Tr. at 38-39; Ex. 266.)

1. Proponents’ Pot-Shots at Peabody’s Witnesses Miss Their Mark.

Dr. Gurney levels the sweeping accusation (without any substantiation other than his own acclamation and repetition) that the testimony of Peabody witnesses “was misleading, biased, or otherwise flawed.” (State Agencies Br. 8.) Dr. Gurney paints with a broad brush based on “guilt by association,” conflating arguments advanced by witnesses in this proceeding with arguments “seen repeatedly over the last 30 years regarding anthropogenic climate change.” (Ex. 804, Gurney Surrebuttal 1:21-23; State Agencies Br. at 95.) The persistent attempt to resort to ad hominem attacks rather than engage in substantive discussion is a tacit admission that the actual scientific evidence does not support the FSCC. It is a desperate attempt at distraction, and it does not withstand scrutiny. For example:

- ***Dr. Gurney repeatedly criticizes Dr. Bezdek for not having published in the area of carbon fertilization.*** (State Agencies Br. at 47.) ***Yet there is no evidence that Dr. Gurney has done so himself.*** (Gurney Direct, Ex. 1 (CV) at 2-6.) The only witnesses who have done so in this proceeding are Drs. Mendelsohn and Reich.²²⁶ (Ex. 220, Mendelsohn Surrebuttal at 2:7-5:1.) Dr. Mendelsohn’s testimony and Dr. Reich’s publication all corroborate Dr. Bezdek’s conclusions. Dr. Gurney’s criticisms are baseless.

²²⁶ Reich Article at 946.

- The State Agencies rehash pointless attempts to impeach Drs. Happer and Mendelsohn without responding to the answers that have already been given.*** Dr. Gurney (yet again) accused Dr. Happer of mis-citing a figure from a study. (State Agencies Br. at 48, 56-57.) Yet Dr. Happer has already explained that the figure was published as part of the study by the organization that commissioned it, and the author agreed that there was no mistake and that the figure was accurate. (Ex. 206, Happer Surrebuttal at 18:16-19:18.) The author confirmed that he created the figure for a media release that accompanied the paper, then ***thanked Dr. Happer*** for “chasing [him] down to get the correct source.” (Ex. 206, Happer Surrebuttal at 19:17-18.) “The organization publishing the article still stands by it, and the author still distributes it.” (Ex. 206, Happer Surrebuttal at 18:10-11.) Dr. Gurney ignores this explanation completely. Dr. Happer did not have any “confusion” about the issue. (State Agencies Br. at 58.) ***Rather it was Dr. Gurney who mis-cited and misinterpreted evidence in a more blatant and troubling fashion.*** (See Ex. 206, Happer Surrebuttal at 20:10-21:9 (demonstrating that Dr. Gurney omitted words from a quotation that reversed the author’s meaning).) Indeed, it is remarkable that the State Agencies have persisted in advancing the baseless accusations against Dr. Happer in their Opening Trial Brief, when Dr. Happer’s Surrebuttal Testimony thoroughly debunked Dr. Gurney’s assertions. At trial, Dr. Happer testified again on the issue of CO₂ fertilization and presented the same chart. (Ex. 257, at 6). The State Agencies chose not to cross-examine him at all. For them to resurrect their disproven and scurrilous accusations in their Trial Brief does not aid the Commission in its decision. Indeed, it only underscores the paucity of real evidence supporting their argument.
- Dr. Gurney criticizes Dr. Bezdek’s citation of Steinkamp and Hickler (2015), arguing that the quotation must have come from a different paper. (Ex. 804, Gurney Surrebuttal at 18:22-27; State Agencies Br. at 81-82.) Dr. Gurney seems not to have read to the conclusion, where the excerpt quoted by Dr. Bezdek was published.²²⁷ The authors themselves describe their study as about more than whether “the biological models employed (‘LPJ-GUESS’) ... do a good job at representing [increased] mortality.” (State Agencies Br. at 82.) The authors “calculated three drought indices to investigate, at a global scale, (i) Which forests have been affected by drought, (ii) If the field observations summarized by Allen et al. (2010) and Scholes et al. (2014) are representative of all forests and (iii) If the LPJ-GUESS model can reproduce the reported mortality events.”²²⁸ Dr. Gurney’s representation of the content of the article only captures the third aim. In other words, ***Dr. Gurney omitted two-thirds of what the authors of the article were trying to do with their study in order to falsely claim that they were doing less.*** Once more, Dr. Gurney is distorting peer-reviewed publications by

²²⁷ Jörg Steinkamp and Thomas Hickler, *Is drought-induced forest dieback globally increasing?*, 103 J. Ecol. 31, 40 (2015) (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 6 n.9) (“We could not identify a general drying trend or an increase in extreme drought events in forests globally.”).

²²⁸ *Id.* at 32.

manipulating what the authors actually say, then blaming Dr. Bezdek and other Peabody witnesses for the same faults he commits.

- Dr. Gurney similarly misconstrues the analysis Dr. Bezdek performed of the survey results in Strengers et al. (2015). (State Agencies Br. at 101-02.) He noted that Dr. Bezdek combined the results of two separate survey questions to arrive at a conclusion that only 43% of the scientists surveyed supported the full AR5 statement attributing climate change to anthropogenic causes. Dr. Bezdek did so because *the questions were asked separately in the original survey*.²²⁹ The authors themselves note that the two questions “*together* mirror the attribution statement.”²³⁰ The authors even varied the second question (regarding confidence level) depending on the answer to the first question (regarding attribution).²³¹ The follow-up article, cited by Dr. Lindzen in his discussion of the same point (Ex. 213, Lindzen Surrebuttal at 46 n.114), notes that one of the key advantages of the survey is that it yields “a more detailed description of what exactly is agreed upon.”²³² If Dr. Gurney is correct that separating the two questions is “bad survey protocol” and that “[t]he only way to achieve an accurate assessment of the survey response is to ask the complete question to those being surveyed” (State Agencies Br. at 102), then Dr. Gurney’s target should be Dr. Strengers and his co-authors, not Dr. Bezdek.²³³

2. Peabody’s Witnesses Are More Qualified Than Those of The State Agencies, CEOs, or Xcel Energy

Peabody’s witnesses are significantly more qualified to opine on the issues raised by this proceeding than those witnesses proffered by the State Agencies, CEOs, or Xcel.

The State Agencies argue that Dr. Hanemann “is very familiar with the literature” on IAMs (State Agencies Br. 6), but he has never created or operated an IAM to measure the social cost of carbon, or even developed a measure independently, rather than simply adopting the

²²⁹ Strengers, *et al.*, PBL Netherlands Environmental Assessment Agency, *Climate Science Survey, Questions and Responses 7-9* (2015) (cited in Ex. 233, Bezdek Rebuttal, Ex. 1 (Report) at 7 n.15; Ex. 213, Lindzen Surrebuttal at 46 n.114).

²³⁰ *Id.* at 7 (emphasis added).

²³¹ *Id.* at 9.

²³² Bart Verheggen, *et al.*, *Scientists’ Views about Attribution of Global Warming*, 48 *Env’tl Sci. & Tech.* 8963, 8964 (Aug. 11, 2014), available at <http://pubs.acs.org/doi/pdf/10.1021/es501998e> (cited in Ex. 213, Lindzen Surrebuttal at 46 n.114) [hereafter, “Views about Attribution”].

²³³ In yet another example of ignoring surrebuttal testimony, Dr. Gurney fails to note that **Dr. Lindzen** also raised this point (Ex. 213, Lindzen Surrebuttal at 46:7-47:3) and noted the other study by Verheggen et al. (2014) (Ex. 213, Lindzen Surrebuttal at 46 n.114).

FSCC. (DOC (Hanemann) Response to Peabody IR No. 8; Hanemann, 2B Tr. 60:11-14, 62:13-18, 64:3-5.) Dr. Hanemann's IPCC experience is limited to Working Group III, which focuses on the economic impacts of climate change. (State Agencies Br. at 7.) He has not participated in Working Group I, which focuses on the physical science aspects of climate change. Dr. Hanemann does not have expertise on any of the predicate scientific issues in this case, and his experience with calculating the social cost of carbon is markedly inferior to that of Drs. Mendelsohn and Tol.

Dr. Gurney was a reviewer and contributor for AR5 but was not selected as an editor of the climate science section. (Gurney, 4 Tr. 149:14-150:1.) He also repeatedly criticizes Peabody witnesses like Dr. Bezdek for not having published on the areas they opine on, yet he fails to fault himself for the same behavior, relying in "just trust me" fashion on partial citations to AR5 (which, when read in full, undermines his argument). (*See supra* Section III-C-1.)

For the CEOs, 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.)

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 and 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.)

Dr. Dessler participated in the U.S. government's review of the Third Assessment Report (TAR) (released 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.)

Xcel claims, on Dr. Martin's behalf, that his credentials have been essentially unchallenged (Xcel Br. at 21-22), but that position makes no sense when his statistical calculations were directly challenged by Dr. Wecker, a specific witness put on the stand and opened for cross examination for that very purpose. Xcel declined the opportunity to cross examine Dr. Wecker on his critique of Dr. Martin, allowing his testimony to stand. Dr. Martin's credibility has been drawn into serious question, contrary to Xcel's portrayal of him as unimpeached.

Several parties attempt to impugn Dr. Happer's credentials by suggesting incorrectly that he is opining outside of his expertise. The State Agencies contend that "Dr. Happer appears to have limited experience in the subject of climate science or economics." (State Agencies Br. 58.) In the same vein, DHE attempts to discredit Dr. Happer by arguing that his expertise is in physics, not medicine. (DHE Initial Brief, at 13.) These criticisms are beside the point. Dr. 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 over 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 testified that 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.) *At trial, neither the State Agencies, DHE, nor any of the other Proponents of the FSCC challenged his eminent 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). If Dr. Happer’s experience with climate science is limited, the State Agencies have taken no steps to prove it through cross-examining his credentials or impeaching him through any means other than conclusory statements.

IV. The Preponderance of the Evidence Shows A Value of Zero is Proper at this Point

The unrefuted preponderance of the evidence demands a rejection of the FSCC and an externality value of zero, given the increasing uncertainties surrounding climate science and the cascading uncertainties that infect IAMs. ALJ Klein’s admonition to adopt a zero value in the face of uncertainty is highly persuasive if not determinative:

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.*²³⁴

As noted earlier (*see supra* at n.165), there is no inconsistency in arguing for a zero value SCC, while simultaneously faulting the IWG for assuming no mitigation. The issues arise at different stages in the decision-making calculus. If the Commission never reaches the stage of setting a

²³⁴ 1996 ALJ Recommendation, at pp. 17-18 (emphasis added).

positive value for the SCC (because there is too much uncertainty and then Proponents have failed their burden of proof), then mitigation is irrelevant. If the Commission reaches the stage where it decides to set a non-zero value for the SCC, then it must consider the effects of an SCC on mitigation, as Dr. Mendelsohn testified.

V. In the Alternative, the Preponderance of the Evidence Shows A Negative Value is Proper at this Point

In the alternative, a preponderance of the evidence supports a negative externality value, as Dr. Tol suggested based on his calculations of the FUND model, when tethered to updated evidence showing ECS values of 2.0°C and below, because of the net beneficial effects of mild warming, which is more likely than the extreme warming assumed by the proponents of the FSCC. (*See* Section III(B), *supra*.)

The preponderance of the evidence shows that global average temperatures are only 0.8°C above pre-industrial levels and have not statistically changed in the last fifteen (15) years. AR5 finds — and the weight of peer-reviewed scientific evidence confirms — that doubling CO₂ concentrations might increase global temperatures by as little as 1.5°C. Dr. Tol testified, without contradiction, that the FUND model demonstrates that such moderate warming would be a benefit, not a cost. None of the proponents of the FSCC proffered any proof that moderate warming at the level of 0.8°C or 1.5°C above pre-industrial levels would be net harmful. Accordingly, the preponderance of the actual evidence in this case supports a negative externality value.

VI. If the Commission Does Not Adopt A Zero or Negative 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.

If the Commission chooses to establish or retain a CO₂ externality value, the best evidence shows that it should be no greater than the current Minnesota values. In fact, the very models used by the IWG, when run with inputs supported by the current evidence, show that CO₂ values below the current range are appropriate.

A. 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.

If the Commission establishes an externality value, it should use Dr. Mendelsohn’s range, which are close to the status quo externality values. Dr. Mendelsohn’s improvements to the DICE model damages function and updated ECS values of 1.5°C to 2.0°C yield an externality value of \$0.30 to \$0.80/ton at the low end of the ECS range (1.5°C) or \$1.10 to \$2.00/ton at the high end of the ECS range (2°C).

The State Agencies insist that the “only” empirical evidence cited by Dr. Mendelsohn to justify his improvement and updating of DICE was his statement that

According to DICE 2013, there should already be a global damage from climate change in 2015 equal to \$173 billion annually. Clearly damage this great would be conspicuous. In practice, however, it is very difficult to detect this global damage today, even with careful scientific measurements.

(State Agencies Br. at 70.) That claim is simply false. The State Agencies once again ignore filed surrebuttal testimony and misstate the record by ignoring the volumes of additional evidence cited by Dr. Mendelsohn to support his modification of the DICE damages function. (Ex. 220, Mendelsohn Surrebuttal at 6:5-15:6 (explaining in detail why he modified DICE and citing 60 peer-reviewed articles justifying his alternations).) In fact, the State Agencies themselves admit

that the IAMs exclude adaptation and technological change (State Agencies Br. at 134), which will lead them to overestimate damages.

Further, the State Agencies misunderstand Dr. Mendelsohn's point that losses of \$173 billion should be detectable today, as discussed in Section III(B)(3)(b), *supra*.

B. Dr. Tol's Testimony Supports Dr. Mendelsohn's Estimate.

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. (Ex. 238, Tol Rebuttal, Ex. 2 (Report), at 9:179-180.)

C. Dr. Bezdek's Testimony Supports Dr. Mendelsohn's Estimate.

Dr. Bezdek testified that the evidence of CO₂ fertilization shows that doubling of the atmospheric CO₂ content above the current level will increase the productivity of most herbaceous plants by about one-third. The total economic value of the CO₂ benefit for 45 crops cumulatively totaled \$3.2 trillion, 1961-2012, and is forecast to total nearly \$10 trillion, 2012 – 2050. (Ex. 228, Bezdek Direct 10:13-16:2, 17:5-9.)

The State Agencies claim that Dr. Bezdek erred in using gross revenue and that net revenue would be substantially lower. (State Agencies Br. at 50.) The State Agencies ignore the response Dr. Bezdek gave in his surrebuttal: "My analysis was conducted in order to assess the *net* benefits of carbon, so the comparison of the *gross* revenue gained in the agricultural sector is appropriate to weigh against the *gross* social cost of that carbon. Dr. Hanemann's method would

improperly double-count the effects of carbon.” (Ex. 235, Bezdek Surrebuttal at 23:13-17.) It is the State Agencies that are improperly double-counting, not Dr. Bezdek.

Dr. Bezdek also showed that affordable and reliable energy is central to human progress. Energy from fossil fuels has created the modern world. It enabled successive industrial revolutions (including the 21st century electricity-based information revolution), produced our advanced technological society, and makes possible the high quality of life we take for granted.²³⁵ In the future, fossil fuels will continue to play a critical role in alleviating poverty worldwide and bringing the benefits of modern life to the more than one billion people who lack access to electricity. The UN Development Fund has ranked electrification as the world’s most significant engineering achievement of the past century. The experience of the last 30 years proves that there is no energy technology remotely ready to take over from fossil fuels on the scale needed and at a price the public is willing to pay. (Ex. 228, Bezdek Direct at 18:2-30:8; Ex. 230, Bezdek Rebuttal, Ex. 2 (Report) at 19:612-22:713; Ex. 235, Bezdek Surrebuttal at 20:2-57:17, 101:2-114:12.)

The State Agencies argue that Dr. Bezdek “failed to control for other explanatory factors that may affect global GDP.” (State Agencies Br. at 52.) To the contrary, Dr. Bezdek controlled for other factors both through regression analysis and through his choice of inputs (i.e., choosing inputs that already accounted for alternate possible explanations). (Ex. 235, Bezdek Surrebuttal at 52:17-53:14.) Once again, the State Agencies fail to grapple with surrebuttal arguments on the record.

The State Agencies also contend that Dr. Bezdek’s testimony is irrelevant “because it does not concern the environmental externalities that are at issue in this proceeding.” (State

²³⁵ Ex. 230, Bezdek Direct, Ex. 2 (Report) at 3.

Agencies Br. at 53.) But their inscrutable argument makes little sense and misses the point: CO₂ is not a negative externality at all, because the social benefits of carbon overwhelm the supposed harms calculated by the IWG. In addition to ignoring filed surrebuttal testimony, the State Agencies seem to have forgotten that the ALJs have already rejected the State Agencies' attempt to exclude Dr. Bezdek's testimony in their pretrial order. The ALJs correctly reasoned that "evidence of the benefits of CO₂ goes to [the] argument that a better measure of the cost of CO₂ is one which takes those benefits into account."²³⁶ The ALJs noted that "it is Peabody's right as a party to advance its theory that more CO₂ can be beneficial The Agencies are free to challenge Peabody through cross examination,"²³⁷ yet the State Agencies failed to cross examine Dr. Bezdek. Even the U.S. Supreme Court disagrees with the State Agencies' position on the issue of weighing the benefits as well as the costs of carbon in order to reach an externality value. *Michigan v. EPA*, 135 S. Ct. 2699, 2711 (2015). The relevance of the potential benefits of CO₂, to which Dr. Bezdek testified, is incontrovertibly relevant.

D. Mr. Martin's Proposed Range of Values Should Be Rejected.

In our Opening Brief (Peabody Br. at 105-111), we showed that Mr. Martin properly criticized the FSCC as speculative and flawed by numerous arbitrary assumptions, yet his own 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. The Commission should give no weight to Xcel's separate approach, which has never been peer-reviewed and simply borrows

²³⁶ Order on Motions by Peabody Energy Corporation, the Minnesota Department of Commerce, and the Pollution Control Agency to Exclude and Strike Testimony, 8 (Sept. 15, 2015).

²³⁷ *Id.*

fundamentally flawed data from the IWG. Indeed, Xcel's own chart shows that its proposed range for the SCC *excludes* the very values that its own analysis shows as the most likely values. (Xcel Br. at 21.) A proposal that excludes what is likely to be the correct value cannot be reasonable or the best available measure.

Further, in our Opening Brief we showed that Mr. Martin's proffered criteria actually support Peabody's proposed values. Mr. Martin testified that Dr. Mendelsohn is "proposing ranges based on the DICE model that's been peer reviewed." (3B Tr. 128:25-129:1.) He agreed that "Dr. Mendelsohn's proposal is a damage cost approach." (*Id.* at 130:23-24.) Indeed, Dr. Mendelsohn's approach meets Mr. Martin's criteria: it addresses uncertainty and the risk of catastrophes by incorporating them into its calculations; it addresses discount rate issues by allowing for a changing rate over time; it uses statistically sound, peer-reviewed methods; it includes an appropriate amount of risk tolerance; it minimizes subjective judgments, yields a practicable range, and is transparent, replicable, and transparent.

Xcel's claim that Mr. Martin was the "only" witness "who has broad enough knowledge to testified on the Federal SCC methodology" (Xcel Br. at 2) does not withstand scrutiny. Mr. Martin did not participate in the IWG, has no expertise in climate science, has never played a role in the IPCC, and has no academic or publication experience on any of the issues in this proceeding. His credentials cannot compare to those of witnesses like Drs. Mendelsohn and Tol, who are intimately familiar with the IAMs on which the SCC is based, or witnesses with such distinguished credentials as Drs. Lindzen, Spencer, Happer, and Bezdek, who are experts on the climate science on which the SCC rests. Mr. Martin has no expertise in creating or operating IAMs for calculating the SCC, nor does he have any expertise on the issues of climate science.

In fact, Mr. Martin's cross-examination at trial showed that he has a conflict of interest. Mr. Martin acknowledged that a higher SCC value "would favor plans that have more wind energy" (4 Tr. at 30:1-4) and that Xcel is the nation's Number 1 provider of wind energy. (*Id.* at 26:1-4.) Thus, Xcel would disproportionately benefit from a higher SCC value. It is better able to provide the kinds of energy that a high SCC value forces. And a higher SCC value could attract consumers to locate in Xcel's territory. As Mr. Martin admitted, "new consumers" and especially "businesses using a lot of energy, will certainly consider electricity costs in where they locate." (*Id.* at 34:9-12.)

Xcel's assertion that "[n]one of the other 18 witnesses has offered testimony challenging the accuracy of the statistical calculations presented by Mr. Martin" (Xcel Br. at 22) is simply incorrect. 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 Mr. Martin 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 CO₂ environmental cost values. (*Id.* at 2:57-66). Mr. Martin's proposed range is the product of entirely arbitrary subjective judgment. (*Id.*) It is telling that Xcel did not seek to cross-examine Dr. Wecker at trial, to respond to his trenchant criticisms of Mr. Martin's analysis.

Mr. Martin's proposed values should be rejected.

VII. Evidence of the Environmental Effects of Wind Energy Was Improperly Excluded

At trial, the ALJs excluded evidence regarding environmental externalities of wind turbines. (5 Tr. 26:21-28:11.) This was error. The Minnesota statute governing resource

planning requires a comparative exercise, Minn. Stat. § 216B.2422, and therefore comparative evidence was relevant and should have been admitted.

VIII. Conclusion

Any externality value set by the Commission must be supported by the administrative record in this case. While this statement may seem obvious, in this proceeding it is a crucial limitation: *Concessions by the State Agencies and the CEOs, the findings of AR5 (which the State Agencies and CEOs concede are authoritative), and unrefuted peer-reviewed science yield a preponderance of the evidence invalidating the FSCC and compelling the adoption of an externality value of zero, or at most a range close to the existing Minnesota values.*

The evidence in the record conclusively shows:

- The climate models that the IWG assumed in calculating the FSCC are fatally flawed. They failed to predict the current hiatus, and consistently predict temperatures that are too high.
- The best climate science available now has undercut the science used by the IWG — and the IWG has unreasonably simply ignored it.
 - The ECS probability distribution used by the IWG is wrong, proven incorrect by AR5.
 - AR5 has also undercut every prophecy of doom underlying the harms related to climate change incorporated into the IAMs.
 - The chain of causation and attribution linking anthropogenic emissions to climate change is assumed, not proven.
- The IAMs themselves, especially as applied by the IWG, are fatally flawed.
 - The IAMs inherently reproduce uncertainty and then magnify it in a cascade that makes using the output as an externality value an exercise in arbitrary decision-making.
 - The IAMs exaggerate the damages from emissions and underestimate mitigating factors and potential benefits of CO₂ emissions — they simply do not measure accurately.
- The FSCC dramatically understates the beneficial effects of carbon.

- The IAMs do not “underestimate” damages but likely over count them because they make speculative and irrational assumptions.
- The IWG used flawed discount rates in violation of OMB Circular A-4.
- Overheated rhetoric about the “hottest year on record” and the negative health effects of warming not only are overblown but most importantly, the proponents of the FSCC admit they are entirely irrelevant because one year of temperature data is not “meaningful.” (Abraham, 3B Tr. 93:20-21) Therefore, this evidence is entitled to no weight and should be disregarded.

If the Commission does not set a value of zero or below, then the preponderance of the evidence does not support a value greater than the existing Minnesota range, as shown by Dr. Mendelsohn’s suggested range of \$0.30-\$2.00/Ton, which is supported by Dr. Tol and Peabody’s other elite scholars and superior expert witnesses.

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