R.Bezdek
https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={3AF2FDF7-19CD-4A63-912B-1A70B8E61A25}&documentTitle=20158-113190-02
REBUTTALS TO: Polasky, Hanemann, Martin
SURREBUTTASL BY:Martin, Abraham, Gurney, Reich
.
Exhibit A has much redundancy, supporting "CO2 helps plants grow" (without worrying about downsides, and offering a huge GIsh Gallop of references, including many to the fossil-funded Idso family.
.
p.5 IAMs are "fatally flawed", but Mendelsohn used DICE, and Tol used FUND.
pp.6- attacks on consensus
p.12 Cooling trend in US, 2005-2014
pp.33-34 is an example of misleading strawman and fantasy, including reliance on Heartland's Joe Bast as "reputable economist" !!
Calling Joe Bast a "reputable economist" simply destroys Bezdek's credibility.
http://tfn.org/ouch-texas-judge-slams-right-winger-for-wasting-his-time (August 2014)
"Mr. Joseph Bast, president and CEO of the Heartland Institute, testified for the Intervenors regarding the Texas Taxpayers' Savings Grant Programs ("TTSGP"), a school voucher bill that failed in the 82nd Legislative Session. As a threshold matter, this Court finds that Mr. Bast is not a credible witness and that he did not offer reliable opinions in this matter. **While Mr. Bast described himself as an economist, he holds neither undergraduate nor graduate degrees in economics, and the highest level of education he completed was high school.**
Mr. Bast testified that he is 100% committed to the long-term goal of getting government out of the business of educating its own voting citizens. Further, his use of inflammatory and irresponsible language regarding global warming, and his admission that the long term goal of his advocacy of vouchers is to dismantle the "socialist" public education system further undermine his credibility with this Court."
https://web.archive.org/web/20140915072844/http://www.co.travis.tx.us/courts/civil/district/pdfs/school-finance-findings-conclusions.pdf
printed pp.335-336, PDF pp.354-355

OAH Docket No. 80-2500-31888

MPUC Docket No. E-999-CI-14-643

Exhibit ______

Rebuttal Testimony and Exhibits of

Dr. Roger H. Bezdek

August 12, 2015

7119230

Q. Please state your name.

A. Roger H. Bezdek.

Q. Did you previously submit testimony in this proceeding?

A. Yes. I submitted pre-filed direct testimony on June 1, 2015.

Q. Have you reviewed other pre-filed testimony?

A. Yes. I reviewed written testimony by Michael Hanemann, Nicholas Martin, and Stephen Polasky.

Q. Have you prepared a rebuttal report that responds to this pre-filed testimony?

A. Yes, I have prepared a report, which is attached as Bezdek Rebuttal Exhibit 1.

Q. Have you responded to discovery requests in this proceeding?

A. Yes. I was asked to provide evidentiary support for certain statements. My responses are attached as Bezdek Rebuttal Exhibit 2.

BEFORE THE OFFICE OF ADMINISTRATIVE HEARINGS FOR THE

MINNESOTA PUBLIC UTILITIES COMMISSION

STATE OF MINNESOTA

In the Matter of the Further Investigation in to Environmental and Socioeconomic Costs Under Minnesota Statute 216B.2422, Subdivision 3

OAH Docket No. 80-2500-31888

MPUC Docket No. E-999-CI-14-643

Exhibit 1

to

Rebuttal Testimony of Dr. Roger H. Bezdek

TABLE OF CONTENTS

INTRODUCTION

I am filing this rebuttal report in response to the testimony of Professor W. Michael Hanemann, on behalf of the Division of Energy Resources of the Minnesota Department of Commerce, in consultation with the Minnesota Pollution Control Agency, Professor Stephen Polasky, on behalf of Clean Energy Organizations, and Nicholas Martin, on behalf of Xcel Energy. All of these witnesses rely on estimates of the social cost of carbon (SCC) generated by Integrated Assessment Models (IAMs). Both Professor Hanemann and Professor Polasky urge the court to follow the estimate of the federal social cost of carbon developed by the U.S. government's Interagency Working Group (IWG). Mr. Martin uses the IWG's data but attempts to analyse it in a different way to draw his own conclusions.

In my opening testimony, I explained that IAMs are fatally flawed and unreliable and that the IWG's estimates of the social cost of carbon are also fundamentally invalid and scientifically without basis. Accordingly, my criticisms of IAMs and the IWG's estimates apply with full force to the testimony of Professor Hanemann, Professor Polasky, and Mr. Martin.

I am also attaching to this supplemental report my responses to the discovery requests I have received in this proceeding. Specifically:

1. I was asked to provide references for studies demonstrating that carbon dioxide is beneficial to plant growth. My discovery responses list hundreds of citations to studies that demonstrate that increased carbon dioxide emissions and increased global temperatures will result in increased crop production.

2. I was asked to provide citations to support my statement that "[r]esearchers have thus concluded that IAMs are of little or no value for evaluating alternative climate change policies and estimating the SCC." My discovery responses list the names and publications of the researchers who have reached such conclusions and provide citations to the publications in which those researchers have made those statements.

3. I was also asked to provide support for my statement that "rigorous assessment of these IAMs by leading economists have concluded that the IAMs are 'close to useless.'" My discovery responses name the leading economists who have reached these conclusions and provide citations to the publications in which those economists have made those statements.

After I submitted my discovery responses, additional material became available regarding the fundamental flaws in the IWG's social cost of carbon estimates. In particular, on July 23, 2015, the U.S. House Committee on Natural Resources held a hearing on the social cost of carbon, at which witnesses testified as to the fatal defects in the IWG's estimates. I incorporate the findings reported in testimonies presented at this hearing and other recent information in my rebuttals here.

REBUTTAL TO THE DIRECT TESTIMONY OF DR. STEPHEN POLASKY, ON BEHALF OF CLEAN ENERGY ORGANIZATIONS

P. 3, L. 7: "The overwhelming majority of peer-reviewed articles on climate change and of scientists agree that emissions of CO_2 and other greenhouse gases have a warming effect on the planet and that the evidence is sufficiently strong to justify policy action."

Neither of these statements is correct.

First, numerous distinguished scientists do not agree with this hypothesis, and their findings have been presented in U.S. Congressional testimony and published in peer-reviewed international scientific journals such as *Science*, *Nature*, *Energy Policy*, *Energy & Environment, Theoretical and Applied Climatology, Asia-Pacific Journal of Atmospheric Sciences*, *Journal of Geophysical Research,* and *Geophysical Review Letters*. See, for example:

- Judith A. Curry, "Statement to the Committee on Science, Space and Technology of the United States House of Representatives," Hearing on "The President's U.N. Climate Pledge." 15 April 2015.
- Robert Carter, *et al.*, *The Small Print: What The Royal Society Left Out* (Global Warming Policy Foundation March 2015), http://www.thegwpf.org/content/ uploads/ 2015/03/ Shortguide.pdf.
- Richard S. Lindzen, "The Climate Science Isn't Settled". *The Wall Street Journal,* November 30, 2009.
- Choi, Yong-Sang, "On the observational determination of climate sensitivity and its implications". *Asia-Pacific Journal of Atmospheric Sciences* 47 (4), 2011: 377–390
- J.A. Curry & P.J. Webster, "Climate Science and the Uncertainty Monster," 92 Bull. Am. Meteorological Soc. 1667, 2011.
- Roy Spencer, "2014 as the Mildest Year: Why You are Being Misled on Global Temperatures," *Roy Spencer,* Jan. 18, 2015, http://www.drroyspencer.com/ 2015/01/2014-as-the-mildest-year-why-you-are-being-misled-on- globaltemperatures.
- Richard S.J. Tol, "Quantifying the Consensus on Anthropogenic Global Warming in the Literature: A Re-Analysis," 73 *Energy Policy* 701 (2014)
- David R. Legates, Willie Soon, William M. Briggs, and Christopher Monckton, "Climate Consensus and 'Misinformation': A Rejoinder to *Agnotology, Scientific Consensus, and the Teaching and Learning of Climate Change," Science & Education*, August 2013
- Hans von Storch, "A Survey of Climate Scientists Concerning Climate Science and Climate Change," 2010, www.academia.edu/2365610/A_Survey_of_ Climate_Scientists_ Concerning_ Climate_Science_ and _ Climate Change
- Judith Curry, "Climate Change: No Consensus on Consensus," October 28, 2012, http://judithcurry.com/2012/10/28/climate-change-no-consensus-on-consensus.

- "Challenge to Scientific Consensus on Global Warming: Analysis Finds Hundreds of Scientists Have Published Evidence Countering Man-Made Global Warming Fears, "http://www. prnewswire.com/news-releases/challenge-to-scientific-consensus-on-global-warming-analysis-finds-hundreds-of-scientists-have-published-evidence-countering-man-made-global-warming-fears-580044 7.html.
- Craig D. Idso, Robert M. Carter, and S. Fred Singer, *Climate Change Reconsidered II: Physical Science,* Report of the Nongovernmental International Panel on Climate Change, 2013.
- R.S. Lindzen, Taking Greenhouse Warming Seriously, *Energy & Environment*," 18, 2007, 937-950.

The most recent peer-reviewed literature confirms find that emissions of CO_2 and other greenhouse gases do not have a warming effect on the planet and that the evidence is not sufficiently strong to justify policy action. For example:

- Toth, et al, studied fossil data and found that reconstructed summer temperatures "fluctuated strongly above present-day July temperatures." This refutes the argument of anthropogenic climate change advocates and it proves that previous summer temperatures were significantly warmer than those currently being experienced.[1]
- Bao, G., et al, refuted the claim that increased CO_2 is causing droughts and warming, and concluded that "the recent drought events from late 1990 to the present are not unusual in the context of the past several centuries." By reconstructing drought cycles in the earlier 1900s, they found that more significant droughts occurred before the advent of industrial civilization.[2]
- Levas, et al, found that "research to date has largely neglected the individual and combined effects of OA and seawater temperature." This is important because it proves that climate change alarmists have only speculated about the impacts of climate change without proving the actual science.[3]
- Singh, et al, assessed the Asia Pacific Economic Cooperation Climate Center global climate models and determined that "atmospheric chaotic dynamics uncertainties in the representation of unresolved sub-grid scales in the models may cause large bias in the models. Even more significant, they found that "these spreads were as large as the spread of ensemble means of different models."[4]

---

[1]Toth, M., Magyari, E.K., Buczko, K., Braun, M., Panagiotopoulos, K. and Heiri, O. 2015. Chironomid-inferred Holocene temperature changes in the South Carpathians (Romania). *The Holocene* 25: 569-582.

[2]Bao, G., Liu, Y., Liu, N. and Linderholm, H.W. 2015. Drought variability in eastern Mongolian Plateau and its linkages to the large-scale climate forcing. *Climate Dynamics* 44: 717-8733.

[3]Levas, S., Grottoli, A.G., Warner, M.E., Cai, W.-J., Bauer, J., Schoepf, V., Baumann, J.H., Matsui, Y., Gearing, C., Melman, T.F., Hoadley, K.D., Pettay, D.T., Hu, X., Li, Q, Xu, H. and Wang, Y. 2015. Organic carbon fluxes mediated by corals at elevated pCO2 and temperature. *Marine Ecology Progress Series* 519: 153-164.

[4]Singh, U.K., Singh, G.P. and Singh, V. 2015. Simulation skill of APCC set of global climate models for Asian summer monsoon rainfall variability. *Theoretical and Applied Climatology* 130: 109-122.

- Ao, et al. conducted a "detailed comparison" of CMIP5 models. This international research team concluded that "there was considerable spread among the models" and that "the models were found to have excessive seasonal variability relative to the observations."[5]

Second, the empirical scientific evidence does not support the hypothesis that "emissions of CO_2 and other greenhouse gases have a warming effect on the planet." Figure 1 shows that there has been no global warming for nearly two decades – a period when CO_2 emissions and concentrations have been increasing. The least-squares linear-regression trend on the RSS satellite monthly global mean surface temperature anomaly dataset shows no global warming for 18 years 7 months since January 1997. Thus, the world has not warmed at all for well over half the satellite record – nearly two decades.

Figure 1

In recent Congressional testimony, Dr. Patrick Michaels also addressed failure of climate models to match real-world observational data and the fact that models consistently "run hot" by vastly overestimating warming trends: The observed global average surface temperature evolution for the past 30 years largely lies below the range which encompasses 95 percent of all climate model runs -- an indication that the observed trend is statistically different from the trend simulated by climate models"[6]

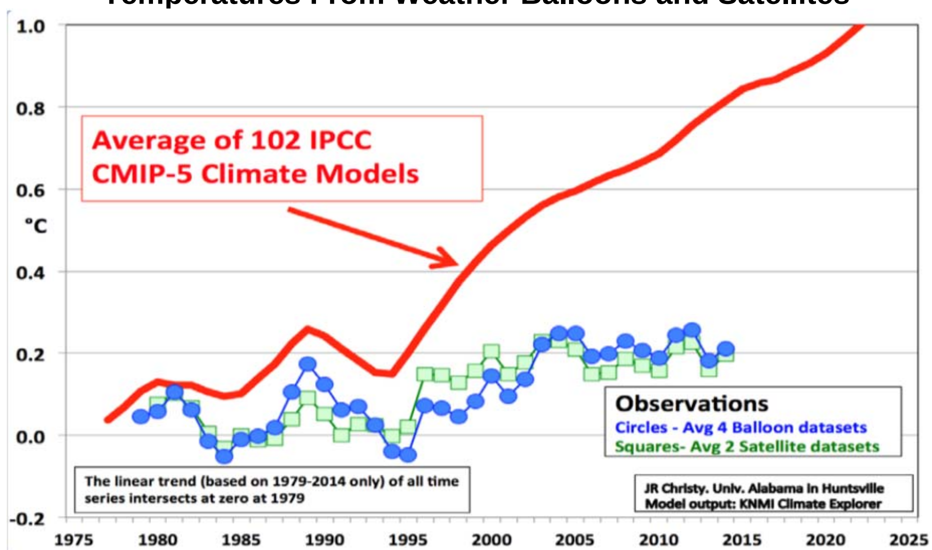
[5]Ao, C.O., Jiang, J.H., Mannucci, A.J., Su, H., Verkhoglyadova, O., Zhai, C., Cole, J., Donner, L., Iversen, T., Morcrette, C., Rotstayn, L., Watanabe, M. and Yukimoto, S. 2015. Evaluation of CMIP5 upper troposphere and lower stratosphere geopotential height with GPS radio occultation observations. *Journal of Geophysical Research: Atmospheres* 120: 1678-1689.

[66]"Written Statement of Patrick J. Michaels," Hearing on an Analysis of the Obama Administration's Social Cost of Carbon Before the U.S. House Of Representatives Committee on Natural Resources, July 22, 2015.

The divergence between observations and climate model projections is even more pronounced in the earth's low-to-mid atmosphere -- Figure 2. As John Christy has shown, there is a gross departure of "reality" from model predictions.[7] He noted that noted that "On average the models warm the global atmosphere at a rate three times that of the real world."[8]

These results provide robust observational evidence that the climate sensitivity has been overestimated by both climate models and the IWG alike.

Figure 2
Five-Year Running Mean Temperatures Predicted by the UN's Climate Models, and Observed Lower Atmospheric Temperatures From Weather Balloons and Satellites



Source: Christy, 2015.

Recent research supports these findings. For example, Steinkamp and Hickler provide further evidence that "global warming has ceased." They "could not identify a general drying trend or an increase in extreme drought events in forests globally."[9]

Third, in reality, the "scientific consensus" is a manufactured myth, as shown in Part III of Bezdek Exhibit 3. For example, John Cook, who claims to have

[7] Christy, J.R., 2015. Testimony before the House Committee on Natural Resources hearing "CEQ Draft Guidance for GHG Emissions and the Effects of Climate Change," May 13, 2015.
[8] Ibid
[9] Steinkamp, J. and Hickler, T. 2015. Is drought-induced forest dieback globally increasing? *Journal of Ecology* 103: 31-43.

reviewed over 11,000 climate science articles,[10] contended that 97.1 percent of the reviewed abstracts conclude that humans are causing global warming. However, in 2013, Legates, et al, published a recount of Cook's data that determined that only 64 – 0.5 percent – of the 11,944 papers published since 1991 endorse the "consensus" that most warming since 1950 is anthropogenic.[11] Among other problems with Cook's work, Duarte noted that Cook included numerous psychology studies, marketing papers, and surveys of the general public as "scientific" endorsement of AGW – which invalidates Cook's research.[12] IPCC author Richard Tol assessed the Cook paper and concluded that is an incompetent piece of research and "a treasure trove of how-not-to lessons for a graduate class on survey design and analysis."[13]

Another widely cited source for "consensus" is an article by Zimmerman and Doran that reported the results of a two-question online survey of selected scientists.[14] In addition to issues such as question wording, only 79 respondents listed climate science as an area of expertise and said they published more than half of their recent peer-reviewed papers on climate change. Seventy-nine scientists – of the 3,146 who responded – does not constitute a "consensus."

The lack of consensus is evident from other surveys and statistics:

- The most recent study finds that less than half (43 percent) of climate scientists who research the topic and for the most part publish in the peer-reviewed literature agree with the IPCC's main conclusion that CO_2 is the dominant driver of climate change.[15]
- Since 1998, 31,000 American scientists, including more than 9,000 with PhDs, have signed a petition which states that there is no convincing scientific evidence that human release of GHGs is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate.[16]

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[10] J. Cook, D. Nuccitelli, S.A. Green, M. Richardson, B. Winkler, R. Painting, et al., "Quantifying the Consensus On Anthropogenic Global Warming In The Scientific Literature," *Environmental Research Letters, 8*, 2013.

[11] David R. Legates, Willie Soon, William M. Briggs, and Christopher Monckton, "Climate Consensus and 'Misinformation': A Rejoinder to *Agnotology, Scientific Consensus, and the Teaching and Learning of Climate Change,"* Science & Education, August 2013.

[12] Jose Duarte, "Cooking Stove Use, Housing Associations, White Males, and the 97 percent," 8- 28-14, www.joseduarte.com/blog/cooking-stove-use-housing-associations-white-males-and-the-97.

[13] Richard Tol, "Mr. Obama, 97 Percent of Experts is a Bogus Number," May 28, 2015, http://www.foxnews.com/opinion/2015/05/28/climate-change-and-truth-mr-obama-97-percent-experts-do-not-agree-with.html.

[14] Peter T. Doran and Maggie Kendall Zimmerman, "Examining the Scientific Consensus on Climate Change," *Eos, Transactions American Geophysical Union*, Volume 90, Issue 3, January 20, 2009, pp.22–23.

[15] Bart Strengers, Bart Verheggen and Kees Vringer, Climate Science Survey, Questions and Responses, PBL Netherlands Environmental Assessment Agency, 2015, pp 1-39.

[16] "Global Warming Petition Project," Oregon Institute of Science and Medicine, www.petitionproject.org. It was organized and circulated by Arthur Robinson, president of the Oregon Institute of Science and Medicine in 1998, and again in 2007. Past National Academy of Sciences president Frederick Seitz wrote a cover letter endorsing it. Dennis Avery, "31,000 Scientists Sign Oregon GW Skeptic Petition," *Canada Free Press*, May 24, 2008; Devin Henry, "Climate Change

- Half of the responses to a 2008 international survey of climate scientists were on the "skeptic" side, with no consensus to support any alarm.[17]
- A survey of meteorologists found that 63 percent of 571 who responded believe global warming is mostly caused by natural, not human, causes.[18]
- A survey by the American Meteorological Society (AMS) found that only 25 percent of respondents agreed with UN IPCC claims that humans are primarily responsible for recent warming. [19]
- A survey of 51,000 Canadian scientists found that although 99 percent of 1,077 replies believed climate is changing, 68 percent disagreed that "The debate on the scientific causes of recent climate change is settled." Only 26 percent attributed global warming to "human activity like burning fossil fuels."[20]

These results demonstrate that the often-asserted "global warming consensus" does not exist.

P. 3, L. 13: "Increased temperatures from CO_2 emissions are predicted to have adverse impacts to humans and the environment."

As discussed above, ***CO$_2$ emissions are not causing increased temperatures, and thus will have no adverse impacts to humans and the environment.*** Further, as John Coleman, co-founder of the Weather Channel, notes, "When the temperature data could no longer be bent to support global warming, they switched to climate change and now blame every weather and climate event on CO_2 despite the hard, cold fact that the 'radiative forcing' theory they built their claims on has totally failed to verify. The current bad science is all based on a theory that the increase in the amount of carbon dioxide in the atmosphere from the exhaust of the burning of fossil fuels leads to a dramatic increase in 'the greenhouse effect' causing temperatures to skyrocket uncontrollably. This theory has failed to verify and is obviously dead wrong."[21]

Petition Pits Scientists Against Each Other," *Minnesota Daily*, May 28, 2008; "What Warming Consensus?" *The Washington Times*, November 16, 1998.

[17]Hans von Storch, "A Survey of Climate Scientists Concerning Climate Science and Climate Change,"2010, www.academia.edu/2365610/A_Survey_of_Climate_Scientists_Concerning_ Climate_Science_and_Climate Change.

[18]Those polled included members of the American Meteorological Society and the National Weather Association. Edward Maibach, *a National Survey of Television Meteorologists About Climate Change: Preliminary Findings*, Center for Climate Change Communication, George Mason University, March 29, 2010.

[19]E. Maibach, N. Stenhouse, S. Cobb, R. Ban, A. Bleistein, et al., "American Meteorological Society Member Survey on Global Warming: Preliminary Findings," Fairfax, VA: Center for Climate Change Communication. 2012.
Survey on Global Warming: Preliminary Findings. Fairfax, VA: Center for Climate Change Communication. 2012.

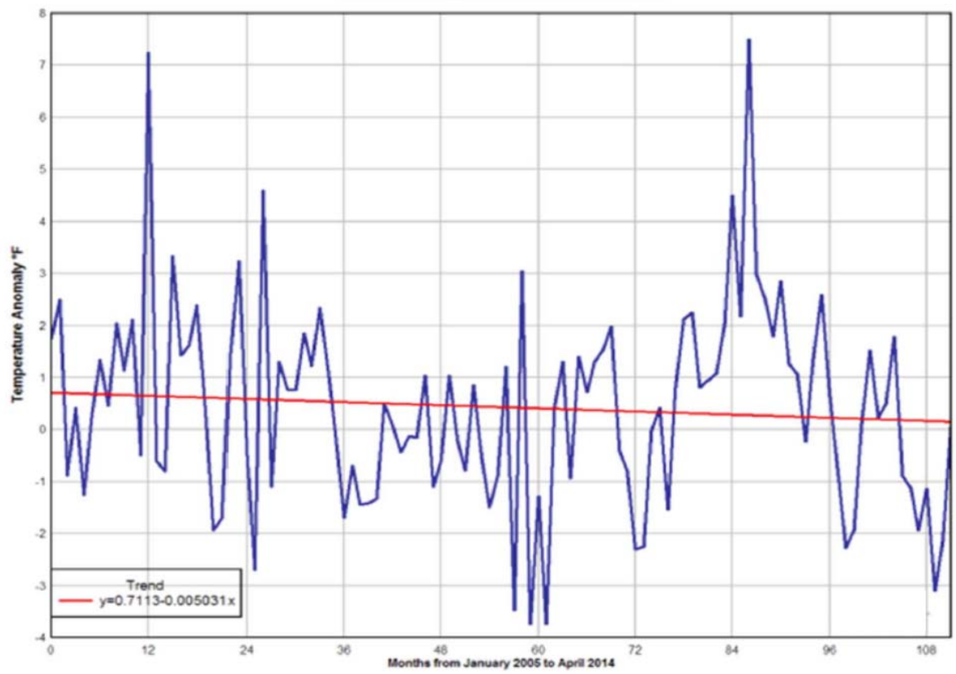
[20]"Causes of Climate Change Varied: Poll," *Edmonton Journal*, March 6, 2008.

[21]John Coleman, "600 Page Litany of Doom: Weather Channel Co-Founder John Coleman Slams Federal Climate Report," www.climatedepot.com, May 7, 2014.

Actually, not only is there a two decade “pause” in the anthropogenic global warming (AGW) predicted global temperature rise from man-made global warming, but there is also a clearly evident slight cooling trend in the U.S. average temperature over past decade, as shown in Figure 3 – over a time period where CO_2 emissions and concentrations were increasing. The trend line illustrates a cooling trend in the minimum temperatures across the contiguous U.S. for nearly a decade: All three temperature sets, average, maximum, and minimum indicate that a cooling trend is clearly noticeable.

The US is not the Earth, 10 years is short. Note typo: contiguous, not continuous.
http://www.ncdc.noaa.gov/temp-and-precip/national-temperature-index/

Continuous U.S. Average Temperature Anomaly -- Degrees F
(Monthly, January 2005 – April 2014)



Source: NOAA/NCDC U.S. Climate Reference Network

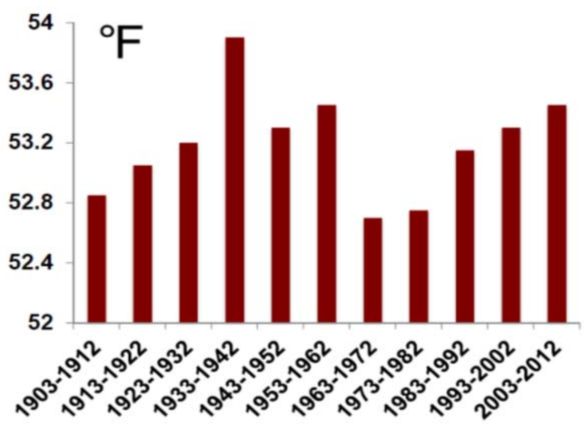
The data in Figure 3 are from state-of-the-art, highly reliable, triple redundant NOAA U.S. Climate Reference Network (USCRN) weather stations located in pristine environments.[22] As a result, these temperature data need none of the

[22]USCRN consists of 114 stations developed, deployed, managed, and maintained by the National Oceanic and Atmospheric Administration (NOAA) in the continental U.S. for the express purpose of detecting the national signal of climate change. The vision of the USCRN program is to maintain a sustainable high-quality climate observation network that 50 years from now can with the highest degree of confidence answer the question: How has the climate of the nation changed over the past 50 years? These stations were designed with climate science in mind. Three independent measurements of temperature and precipitation are made at each station, insuring continuity of record and maintenance of well-calibrated and highly accurate observations. The stations are placed in pristine environments expected to be free of development for many decades. Stations are monitored and maintained to high standards, and are calibrated on an annual basis. See www.ncdc.noaa.gov/crn.

adjustments that plague the older surface temperature networks, such as USHCN and GHCN, which have been heavily adjusted to attempt corrections for a wide variety of biases. Using NOAA's USCRN data eliminates the debate over the accuracy of and the adjustment of temperature data and enables a clear plot of pristine surface data.

There are other indications that the US has actually been cooling since at least the 1930s.[23] For example, as shown in Figure 4, the 1930s was the hottest decade on record in the U.S.[24]

Figure 4
Average U.S. Temperature Per Decade



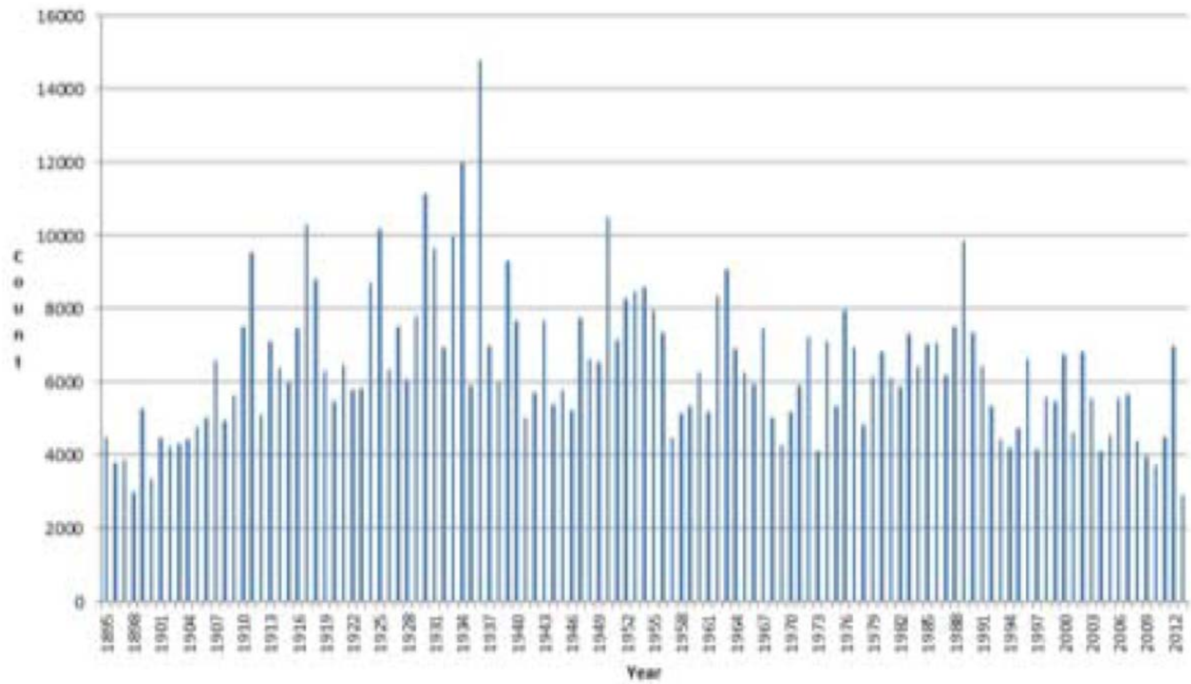
Sources: Real Science; *The Telegraph*, *Forbes*.

Raw temperature data show that U.S. temperatures were significantly warmer during the 1930s than they are today.[25] In fact, raw temperature data show an 80-year cooling trend. This is illustrated in Figure 5, which also indicates a pronounced cooling trend in the U.S, in terms of record temperatures set.[26]

The pause in warming has occurred at the same time emissions of carbon dioxide – which the AGW theory contends increases temperatures – increased uninterruptedly. This "pause" in warming is difficult to explain and has raised scientific doubts and doubts in the scientific community and in the public mind about climate change theories.[27]

[23] Christopher Booker, "The Scandal of Fiddled Global Warming Data," *The Telegraph*, June 21, 2014.
[24] Steve Goddard, "1930s Was By Far the Hottest Decade in the US" Real Science, January 15, 2013.
[25] James Taylor, "Doctored Data, Not U.S. Temperatures, Set a Record This Year," *Forbes*, June 13, 2012.
[26] Steve Goddard, "Number of All-Time Daily Record Maximums and Minimums Set or Tied at All US HCN Stations Since 1930," Real Science, August 30, 2013.
[27] "Global Warming: Who Pushed Pause Button?" *The Economist*, March 8, 2014.

Figure 5
Number of All-Time Daily Record Maximums and Minimums
Set or Tied at All U.S. HSN Stations Since 1930



Source: Steve Goddard, Real Science.

P. 3, L. 14: "Climate change will likely result in sea-level rise."

Dr. Polasky contends that rising temperatures from CO_2-induced global warming will result in an acceleration of sea level rise that will result in a host of economic damages. ***There are two problems with this contention. First, as noted, temperatures are not rising***, much less in the manner or degree projected by the models. Therefore, they cannot cause any changes in sea levels.

Second, empirical observations reveal no acceleration of sea level rise over the past century. In fact, just the opposite appears to be occurring. For example, Holgate derived a mean global sea level history over the period 1904-2003.[28] According to his calculations, the mean rate of global sea level rise was "larger in the early part of the last century (2.03 ± 0.35 mm/year 1904-1953), in

[28] Holgate, S.J., "On the Decadal Rates of Sea Level Change During the Twentieth Century." *Geophysical Research Letters* 34: 10.1029/2006GL028492, 2007.

comparison with the latter part (1.45 ± 0.34 mm/year 1954-2003)." In other words, contrary to model projections, the mean rate of global sea level rise (SLR) has not accelerated over the recent past. If anything, it has done just the opposite. Such observations are striking, especially considering they have occurred over a period of time when many have claimed that:

1. The Earth warmed to a degree that is unprecedented over many millennia.
2. The warming resulted in a net accelerated melting of the vast majority of the world's mountain glaciers and polar ice caps.
3. Global sea level rose at an ever increasing rate.

In another paper, Boretti applied simple statistics to the two decades of information contained in the TOPEX and Jason series of satellite radar altimeter data to "better understand if the SLR is accelerating, stable or decelerating." In doing so, he reported that the rate of SLR is reducing over the measurement period at a rate of -0.11637 mm/year^2, and that this *de*celeration is *also* "reducing" at a rate of -0.078792 mm/year^3 -- Figure 6.[29] In light of such observations, Boretti concludes that the huge deceleration of SLR over the last 10 years "is clearly the opposite of what is being predicted by the models," and that "the SLR's reduction is even more pronounced during the last 5 years."[30] To further illustrate the importance of his findings, he notes that "in order for the prediction of a 100-cm increase in sea level by 2100 to be correct, the SLR must be almost 11 mm/year every year for the next 89 years," but he notes that "since the SLR is dropping, the predictions become increasingly unlikely," especially in view of the facts that (1) "not once in the past 20 years has the SLR of 11 mm/year ever been achieved," and that (2) "the average SLR of 3.1640 mm/year is only 20 percent of the SLR needed for the prediction of a one meter rise to be correct."[31]

The real world, data-based results of Holgate and Boretti, as well as those of other researchers, all suggest that rising atmospheric CO_2 emissions are exerting no discernible influence on the rate of sea level rise.[32] Clearly, SCC damages that are based on model projections of a CO_2-induced acceleration of SLR must be considered inflated and unreliable.

P. 3, L. 14: "Climate change will likely result in sea-level rise, displacing populations living in low-lying coastal areas, increased severity and length of

[29] Boretti, A.A., "Short Term Comparison of Climate Model Predictions and Satellite Altimeter Measurements of Sea Levels." *Coastal Engineering* 60: 319-322, 2012.
[30] Ibid.
[31] Ibid.
[32] N.A. Morner, "Estimating Future Sea Level Changes From Past Records." *Global and Planetary Change* 40: 49-54, 2004; S. Jevrejeva et al., "Nonlinear Trends and Multiyear Cycles in Sea Level Records." *Journal of Geophysical Research* 111: 10.1029/ 2005JC003229, 2006; 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; 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.

heat waves with impacts on human health and agricultural productivity, changes in precipitation patterns with effects on agriculture and water supplies, changes in storm frequency and severity, among other impacts."

The effects of CO_2 on agriculture and agricultural productivity are not negative; rather they are positive and highly beneficial. CO_2 it is essential for life and is the basis of nearly all life on Earth -- without CO_2 life on this planet would not exist. It is the primary raw material or "food" utilized by the vast majority of plants to produce the organic matter out of which they construct their tissues, which subsequently become the ultimate source of food for nearly all animals and humans. Consequently, the more CO_2 there is in the air, the better plants grow, as has been demonstrated in thousands of studies.[33] And the better plants grow, the more food there is available. Plants will flourish under higher CO_2 conditions, becoming healthier and more resistant to pests and disease.

Researchers have identified 55 benefits from increased atmospheric CO_2 concentrations. Plants grow faster; increase their photosynthetic rate by as much as 50 percent; increase their leaf area, plant branch, and fruit numbers; and decrease their water demands and suffer less air pollution stress. In particular, this decreases soil erosion by expanding plant cover. Biodiversity is also enhanced because it increases the niche security of many different forms of plants, and biomass gains a greater ability to remove that carbon from the atmosphere, creating a natural negative feedback on CO_2.[34]

In recent Congressional testimony, Dr. Pat Michaels addressed the failure of climate models to incorporate the agricultural benefits of carbon fertilization, which have amounted to $3.2 trillion in benefits from 1961 to 2011 and which will confer an additional $9.8 trillion in benefits from 2012-2050:

> Carbon dioxide is known to have a positive impact on vegetation, with literally thousands of studies in the scientific literature demonstrating that plants (including crops) grow stronger, healthier, and more productive under conditions of increased carbon dioxide concentration. A recent study by Idso reviewed a large collection of such literature as it applies to the world's 45 most important food crops (making up 95 percent of the world's annual agricultural production).[35] Idso summarized his findings on the increase in biomass of each crop that results from a 300ppm increase in the concentration of carbon dioxide under which the plants were grown. This table is reproduced below, and shows that the typical growth increase exceeds 30 percent in most crops, including 8 of the world's top 10 food crops (the increase was 24 percent and 14 percent in the other two). Idso found that the increase

[35] Idso, C. 2013. *The positive externalities of carbon dioxide: Estimating the monetary benefits of rising CO2 concentrations on global food production*. Center for the Study of Carbon Dioxide and Global Change,

> in the atmospheric concentration of carbon dioxide that took place during the period 1961-2011 was responsible for increasing global agricultural output by 3.2 trillion dollars (in 2004-2006 constant dollars). Projecting the increases forward based on projections of the increase in atmospheric carbon dioxide concentration, Idso[36] expects carbon dioxide fertilization to increase the value of agricultural output by 9.8 trillion dollars (in 2004-2006 constant dollars) during the 2012-2050 period.[37]

Dr. Michaels included a table showing the benefits of CO_2 fertilization – reproduced here as Table 1.

Table 1
Average Percentage Increase in Biomass of Each of The World's 45 Most Important Food Crops Under an Increase of 300ppm of Carbon Dioxide

Crop	% Biomass Change	Crop	% Biomass Change
Sugar cane	34.0%	Rye	38.0%
Wheat	34.9%	Plantains	44.8%
Maize	24.1%	Yams	47.0%
Rice, paddy	36.1%	Groundnuts, with shell	47.0%
Potatoes	31.3%	Rapeseed	46.9%
Sugar beet	65.7%	Cucumbers and gherkins	44.8%
Cassava	13.8%	Mangoes, mangosteens, guavas	36.0%
Barley	35.4%	Sunflower seed	36.5%
Vegetables fresh nes	41.1%	Eggplants (aubergines)	41.0%
Sweet potatoes	33.7%	Beans, dry	61.7%
Soybeans	45.5%	Fruit Fresh Nes	72.3%
Tomatoes	35.9%	Carrots and turnips	77.8%
Grapes	68.2%	Other melons (inc.cantaloupes)	4.7%
Sorghum	19.9%	Chillies and peppers, green	41.1%
Bananas	44.8%	Tangerines, mandarins, clem.	29.5%
Watermelons	41.5%	Lettuce and chicory	18.5%
Oranges	54.9%	Pumpkins, squash and gourds	41.5%
Cabbages and other brassicas	39.3%	Pears	44.8%
Apples	44.8%	Olives	35.2%
Coconuts	44.8%	Pineapples	5.0%
Oats	34.8%	Fruit, tropical fresh nes	72.3%
Onions, dry	20.0%	Peas, dry	29.2%
Millet	44.3%		

Source: Craig Idso, 2013.

Dr. Michaels explained that the IAMs on which the IWG's estimates rest do not adequately take account of the CO_2 fertilization effect and thus substantially overestimate the social cost of carbon:

[36] Idso, C., *The positive externalities of carbon dioxide: Estimating the monetary benefits of rising CO2 concentrations on global food production*. Center for the Study of Carbon Dioxide and Global Change, 2013.
[37] "Written Statement of Patrick J. Michaels," op. cit., pp. 12-13.

> This is a large positive externality, and one that is insufficiently modelled in the IAMs relied upon by the IWG in determining the SCC. In fact, only one of the three IAMs used by the IWG has any substantial impact from carbon dioxide fertilization, and the one that does, underestimates the effect by approximately 2-3 times. The FUND model has a component which calculates the impact on agricultural as a result of carbon dioxide emissions, which includes not only the impact on temperature and other climate changes, but also the direct impact of carbon dioxide fertilization. The other two IAMs, DICE and PAGE by and large do not (or only do so extremely minimally; DICE includes the effect to a larger degree than PAGE).[38]

Recent research verifies that plants will flourish under higher CO_2 conditions ("greening"), and will become healthier and more resistant to pests and disease. This research has been published in some of the leading international peer-reviewed scientific journals, including *Global Change Biology, Journal of Environmental Sciences*, *Journal of Experimental Botany*, *Theoretical and Applied Climatology*, *Environmental Pollution, Environmental Pollution*, *Aquatic Biology, Journal of Plant Growth Regulation,* and *Journal of the American Society of Horticultural Science*. For example:

- Piao, et al, determined that China had experienced increased CO_2 fertilization for three decades now, and that this emphasizes CO_2's positive impacts: "The combined effect of CO_2 fertilization and climate change with the effect of nitrogen deposition, leads to the conclusion that these three factors are responsible for almost all of the average increasing trend of LAIGS observed from the satellites."[39]
- Guo, et al, analyzed increased rice yields and found that "elevated CO_2 stimulated rice aboveground biomass and nitrogen accumulation by 19.1 percent and 12.5 percent, respectively" and that "averaged across the rice growing period, elevated CO_2 greatly increased TOC and TN contents in the surface water by 7.6 percent and 11.4 percent, respectively."[40]
- Li, et al, found increased CO_2 has health benefits in plants combatting diseases. Specifically, they concluded that "this information is important for making proper predictions with regard to disease pressure and for designing strategies to improve plant pathogen resistance."[41]

[38] Ibid, p. 13.
[39] 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.
[40] 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.
[41] 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.

- Song, et al, found that CO_2 has significantly increased rice yields in China, and reported that "38 percent of the yield increases can be related to climatic variation and the remaining 62 percent to changes in rice varieties."[42]

- de Rezende, et al, determined that elevated CO_2 helped certain species produce tannins, which "may result in higher protection of this species against herbivores and pathogens." This demonstrates that increased CO_2 would enhance plants' ability to thrive and green the planet.[43]
- Cao, J. and Ruan studied the impacts of CO_2 on plant life and found that "greater resource allocation to creeping stems may allow V. natans to capture more resources, and reduce competition for soil nutrients with neighboring plants" and that "more buds will likely lead to higher productivity in waters with high CO_2 concentrations." This verifies the argument that increased CO_2 would benefit plant life.[44]
- Lee, Woo, and Je studied CO_2 fertilization effects and concluded that "photosynthetic rate was higher," "stomatal resistance increased," "transpiration rates declined," and "water-use efficiency rose."[45]
- Song and Huang demonstrated the carbon sequestration argument by finding that elevated CO_2 would decrease risks of heat and drought: "The ratio of root to shoot biomass increased by 65 percent to 115 percent under doubling ambient CO_2 across all treatments," "high CO_2 may enhance the capacity of water uptake by the root system, supplying water to maintain leaf hydration," "the positive carbon gain under doubling ambient CO_2 was the result of both increases in net photosynthesis rate and suppression of respiration rate," and "leaf net photosynthesis increased by 32 percent to 440 percent with doubling ambient CO_2."[46]
- Thomas and Palmer challenged the impact that invasive species may have in a warmer world. They reported that out of a wide variety of plants, "Total cover increases by native species are more than nine times greater than those by non-native species." This is significant because it refutes the hypothesis that invasive species will overwhelm native ones.[47]
- Sendall, et al, assessed the impacts of warming on plants and found that "direct negative impacts of modest climate warming on photosynthesis will be

[42]Song, Y., Wang, C., Ren, G., Zhao, Y. and Linderholm, H.W. 2015. The relative contribution of climate and cultivar renewal to shaping rice yields in China since 1981. *Theoretical and Applied Climatology* 120: 1-9.
[43]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.
[44]Cao, J. and Ruan, H. 2015. Responses of the submerged macrophyte Vallisneria natans to elevated CO2 and temperature. *Aquatic Biology* 23: 119-127.
[45]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.
[46]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.
[47]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.

ameliorated as plants come near to optimizing photosynthesis with respect to temperatures experienced." This is important because one of the key points that climate change alarmists make is that climate change would overwhelm plants.[48]

- Preite, et al, examined the ability of plant life to adapt to warming and found that "selection analyses and trait-trait correlations showed that most traits can respond to selection under a warmer climate." They also disproved the hypothesis that warming may overwhelm plants by also finding that "these populations may in reality have time to respond to selection appropriately."[49]
- Costanza, et al, focused specifically on the link between climate change and wildfires and concluded that "While climatic warming had little effect on the wildfire regime, and thus on longleaf pine dynamics, urban growth led to an 8 percent reduction in annual wildfire area."[50]
- Mohring, et al, determined that certain species have fully benefitted from warming temperatures, keeping "a positive relationship between in situ temperature and thermal optima for performance."[51]

Recent research also finds that animals can adapt to moderate warming. For example:

- Refsnider, et al, investigated whether climate change would increase stress levels to animals. They studied animal species in different stress environments outside of their local climate zones and determined that the animals "exposed to novel climatic conditions did not display a detectable stress response, nor did the novel climate depress immune function in the transplanted populations"[52]
- Visinoni, et al, found that certain species that have been known to "be vulnerable to climate warming" actually can adapt very well. This mitigates the species extinction impact, because in many areas "microclimates within a landscape may allow species to exist in regions where the general climate appears to be unsuitable for them."[53]

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[48]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.

[49]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.

[50]Costanza, J.K., Terando, A.J., McKerrow, A.J. and Collazo, J.A. 2015. Modeling climate change, urbanization, and fire effects on Pinus palustris ecosystems of the southeastern U.S. *Journal of Environmental Management* 151: 186-199.

[51]Mohring, M.B., Wernberg, T., Wright, J.T., Connell, S.D. and Russell, B.D. 2014. Biogeographic variation in temperature drives performance of kelp gametophytes during warming. *Marine Ecology Progress* Series 513: 85-96.

[52]Refsnider, J.M., Palacios, M.G., Reding, D.M. and Bronikowski, A.M. 2015. Effects of a novel climate on stress response and immune function in painted turtles (Chrysemys picta). *Journal of Experimental Zoology* 323A: 160-168.

[53]Visinoni, L., Pernollet, C.A., Desmet, J.-F., Korner-Nievergelt, F. and Jenni, L. 2015. Microclimate and microhabitat selection by the Alpine Rock Ptarmigan (Lagopus muta Helvetica) during summer. *Journal of Ornithology* 156: 407-417.

- Narum and Campbell found that through natural selection, "thermal adaptation is a widespread phenomenon in organisms that are exposed to variable and extreme environments."[54]

Finally, recent research finds that moderate warming will not harm oceanic ecosystems, and may actually benefit them. This research has been published in some of the leading international peer-reviewed scientific journals, including *The Lancet*, *Marine Biology, Journal of Experimental Zoology*, *Journal of Ornithology, BMC Genomics, Scientific Reports,* and *Journal of Experimental Marine Biology and Ecology*. For example:

- Gasparrini, et al, found that "tropical seagrasses can increase their photosynthetic rates, adjust photosynthetic performance and increase growth rates in response to CO_2 enrichment." This indicates that "they will thrive under future scenarios of climate change."[55]
- Horwitz, et al, demonstrated that certain aquatic species rely "more on photosynthetically derived carbon under elevated pCO_2." This shows that increased CO_2 would benefit ocean ecosystems.[56]
- Cure, Hobbs, and Harvey examined aquatic species and reported that "high abundances of juveniles (up to 14 fish/40 m2) were found in areas where they were previously absent or in low abundance." They determined that this is because "water temperatures 1 to 2°C higher than long-term averages in the region" made "conditions more favorable for recruits to survive in greater numbers."[57]
- Maneja, et al, studied the impacts of ocean acidification on marine life and found that large populations remained "unaffected by extremely elevated levels of seawater pCO_2. This indicates that at least some larvae in the population are resilient to ocean acidification."[58]
- Cruz, et al, found that arguments about "coral bleaching" have overestimated their negative impacts. They instead reported that "it is clear that white colonies are physiologically healthy and that the number of white M.

[54]Narum, S.R. and Campbell, N.R. 2015. Transcriptomic response to heat stress among ecologically divergent populations of redband trout. *BMC Genomics* 16: 10.1186/s12864-015-1246-5.

[55]Gasparrini, A., Guo, Y., Hashizume, M., Lavigne, E., Zanobetti, A., Schwartz, J., Tobias, A., Tong, S., RocklÖv, J., Forsberg, B., Leone, M, De Sario, M., Bell, M.L., Guo, Y.L.L., Wu, C.F., Kan, H., Yi, S.M., de Sousa, Z., Coelho, S. M., Saldiva, P.H., Honda, Y., Kim, H. and Armstrong, B. 2015. Mortality risk attributable to high and low ambient temperature: a multi-country observational study. *The Lancet*: 10.1016/S0140-6736(14)62114-0.

[56]Horwitz, R., Borell, E.M., Yam, R., Shemesh, A. and Fine, M. 2015. Natural high pCO2 increases autotrophy in Anemonia viridis (Anthozoa) as revealed from stable isotope (C, N) analysis. *Scientific Reports* 5: 10.1038/srep08779.

[57]Cure, K., Hobbs, J-P. A. and Harvey, E.S. 2015. High recruitment associated with increased sea temperatures towards the southern range edge of a Western Australian endemic reef fish Choerodon rubescens (family Labridae). *Environ Biol Fish* 98: 1059-1067.

[58]Maneja, R.H., Frommel, A.Y., Browman, H.I., Geffen, A.J., Folkvord, A., Piatkowski, U., Durif, C.M.F., Bjelland, R., Skiftesvik, A.B. and Clemmesen, C. 2015. The swimming kinematics and foraging behavior of larval Atlantic herring (Clupea harengus L.) are unaffected by elevated pCO2. *Journal of Experimental Marine Biology and Ecology* 466: 42-48

cavernosa occurring in the surveyed reefs is high enough to notably contribute to an over-estimation of coral bleaching."[59]

I also extensively documented the direct impact of carbon dioxide fertilization in my direct testimony Before The Office of Administrative Hearings For The Minnesota Public Utilities Commission State of Minnesota in the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statute 216B.2422, Subdivision 3 OAH Docket No. 80-2500-31888 MPUC Docket No. E-999-CI-14-643, in my Exhibit 2, pp. 48-67, in Part IV of my Exhibit 3 filed in this proceeding, and in my "Responses to the Information Requests Nos. 2-10 of Clean Energy Organizations to Peabody Energy," July 2015, pp. 2-52.

P. 4, L. 15: "The Commission established an estimate of an SCC in 1997 to comply with Minnesota law, but the current values need to be updated to reflect current scientific understanding and current conditions."

I agree. However, to reflect current scientific understanding and current conditions (as discussed throughout my rebuttal testimony here), ***the current 1997 values should be either held constant or reduced***. As I discuss here in my rebuttal testimony, even using the IWG IAMs, in some cases the SCC estimates are actually negative. See my rebuttal here, pp. 45-46, to the testimony in this proceeding of Nicholas F. Martin.

P. 4, L. 18: "Rational decision-making should take account of all costs and benefits and not just those that are currently valued via the market."

P. 4, L. 22: "Damages from climate change are not currently incorporated into the price paid for electricity. As a result, costs of future harm are 'externalized,' i.e., borne, not by the activity that is causing the harm, but by society in general. External costs such as this are a basic form of market failure and lead to inefficient decisions."

P. 5; L. 18: "The IWG's SCC was 19 developed "to allow agencies to incorporate the social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions."

P. 6, L. 4: "The IWG is a collection of experts across agencies of the U.S. Federal government brought together to produce a consistent approach to valuing the benefits of CO_2 emission reductions for federal cost/benefit analysis."

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[59] 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.

Note that the presumption (unfounded assumption) here is that there are "benefits" from reducing CO_2 emissions. ***<u>There are two fatal flaws in this line of reasoning.</u>***

First, as discussed in my Direct Testimony and Bezdek Exhibit 2, the presumption that all of the externalities from CO_2 are negative is not correct.

Second, and more serious, no attempt is made to estimate, or even acknowledge the existence of carbon benefits or positive externalities of carbon. Since the development of rigorous benefit-cost (B-C) analysis by the U.S. Army Corps of Engineers and the Bureau of Reclamation in the 1950s, such analysis has sought to assess both the costs and the benefits of a proposed initiative, program, or regulation to determine if the benefits exceed the costs.[60] It is thus a self-evident truism that a valid B-C analysis must include both costs and benefits and, indeed, under Executive Order 12866, agencies are required "to assess both the costs and the benefits of the intended regulation."[61] It is thus inexcusable that Dr. Polasky and the IWG hypothesize and accept almost every conceivable carbon "cost" – including costs to agriculture, forestry, water resources, forced migration, human health and disease, coastal cities, ecosystems, wetlands, etc. – but fail to analyze potential carbon benefits, either direct or indirect. This is especially true because OMB has recently emphasized that careful consideration of both costs <u>and</u> benefits is important in determining whether a regulation will improve social welfare and to assess whether it is worth implementing at all.[62] This alone invalidates the IWG methodology and disqualify the use of the SCC estimates in any Federal or Minnesota rulemaking or cost-benefit analysis.

There are two types of carbon benefits that must be identified, analyzed, and, to the degree possible, quantified: Direct benefits and indirect benefits. The major direct carbon benefit is to increase agricultural productivity. As discussed above and in Bezdek's Direct Testimony and Bezdek Exhibit 2, in addition to increasing the *quantity* of food available for human consumption, the rising atmospheric CO_2 concentration is also increasing the *quality* of the foods.

Also extremely important, as discussed in the Bezdek's Direct Testimony, the indirect benefits of carbon include the immense benefits to the economy and society of affordable, reliable energy produced by carbon-based fuels. These fuels have literally created modern technological society worldwide, raised the standard of living of everyone on the planet, increased life spans by decades, and over the past 20 years alone have elevated over a billion persons out of poverty. They are simply invaluable and irreplaceable, and will remain so for the foreseeable future.

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[60]See, for example, John S. Dryzek, *The Politics of the Earth: Environmental Discourses*, UK: Oxford University Press, 2013, pp. 84-88.

[61]"Regulatory Planning and Review, Executive Order 12866 of September 30, 1993," *Federal Register*, Vol. 58, No. 190, Monday, October 4, 1993.

[62]U.S. Office of Management and Budget, "2013 Draft Report to Congress on the Benefits and Costs of Federal Regulations and Agency Compliance With the Unfunded Mandates Reform Act," www.whitehouse.gov/sites/default/files/omb/inforeg/2013_cb/ draft_2013_cost_benefit_report.pdf.

Thus, substantial "externalities" from electricity production are positive, not negative as the IWG and others contend. To take only one recent but critical example, it has been shown that the impact of high energy costs is devastating to lower income and minority ratepayers and that the benefits of maintaining fossil fuel energy are much greater for these ratepayers.[63] In July 2015, the National Black Chamber of Commerce (NBCC) found that EPA's proposed Clean Power Plan, which would reduce CO_2 emissions from existing fossil-fueled power plants, would have serious economic, employment, and energy impacts at the national level and for all states, and the impacts on low-income groups, Blacks, and Hispanics would be especially severe.[64] The EPA regulations will increase Hispanic poverty by more than 26 percent and Black poverty by more than 23 percent. Further, the energy burdens for Blacks and Hispanics will increase and large numbers of both groups will be forced into energy poverty.[65] As Harry Alford, NBCC President and CEO, recently testified before the U.S. Senate,

> "The EPA's proposed regulation for GHG emissions from existing power plants is a slap in the face to poor and minority families. These communities already suffer from higher unemployment and poverty rates compared to the rest of the country, yet the EPA's regressive energy tax threatens to push minorities and low-income Americans even further into poverty. For these minority and low-income groups, increased energy costs have an even greater impact on their lives, jobs, and businesses because a larger percentage of their incomes and revenues are spent on energy costs. What may seem like a nominal increase in energy costs to some can have a much more harmful effect on minorities and low-income groups."[66]

I also addressed this issue in my Direct Testimony, pp. 16-20, in this proceeding.

Finally, as noted, AWG proponents equate the social cost of carbon with "damages." However, it is important to note that not all IAMs indicate that there are always damages associated with carbon dioxide emissions. In fact, the FUND model allows for the SCC to be negative, based on feedback mechanisms due to

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[63] National Black Chamber of Commerce, "Potential Impact of Proposed EPA Regulations on Low Income Groups and Minorities," Washington, D.C., June 2015. See also, "Energy Bills Challenge America's Fixed-Income Seniors," 60 Plus Association, Alexandria, Virginia, 2014.

[64] National Black Chamber of Commerce, op. cit.

[65] The "energy burden" is defined as the percentage of gross annual household income that is used to pay annual residential energy bills, and it includes electricity, gasoline, heating, and cooking fuel. The individual household energy burden is calculated for each household and then averaged within income/origin categories. See the discussion in Applied Public Policy Research Institute for Study and Evaluation, *LIHEAP Energy Burden Evaluation Study*, report prepared for the Office of Community Services, U.S. Department of Health and Human Services, July 2005.

[66] Harry C. Alford, testimony on "The Impacts of EPA's Proposed Carbon Regulations on Energy Costs for American Businesses, Rural Communities and Families, and a legislative hearing on S. 1324," Senate EPW Committee Hearing – Tuesday, June 23, 2015, 406 Dirksen Senate Office Building.

http://www.desmogblog.com/national-black-chamber-commerce Much funding by ExxonMobil, API.
http://www.desmogblog.com/60-plus-association $ API,

carbon dioxide emissions, and researchers have actually calculated the probability of a negative SCC under a variety of assumptions.[67] Dr. Kevin Dayaratna, in recent Congressional testimony, reported that, under a reasonable set of assumptions, the SCC is overwhelmingly likely to be negative. This would actually suggest that the government should, in fact, subsidize (not limit) carbon dioxide emissions. Dr. Dayaratna did not use these results to suggest that the government should actually subsidize carbon dioxide emissions, but rather to illustrate the extreme sensitivity of these models to reasonable changes in assumptions.[68]

P. 5, L. 11: "There are different models used to estimate SCC with different assumptions and projections, leading to different estimates."

Yes, there are different models. However, as demonstrated throughout my rebuttal testimony here, ***different models using different assumptions concerning the discount rate, time horizon, specification of equilibrium climate sensitivity distributions, damage functions, and other parameters yield such varying results – often orders of magnitude and sometimes even in terms of sign (positive or negative) that they cannot be used for policy making purposes***. This is not only my conclusion, but the conclusion of numerous other researchers who have assessed such models. For example Dayaratna and Kreutzer report that:

- Our work has repeatedly illustrated that while these models might be interesting for academic exercises, they are far too sensitive to the modeller's assumptions to be legitimate tools for regulatory policy.[69]

More generally, I comprehensively addressed this issue in Roger H. Bezdek, Responses to the Information Requests Nos. 2-10 of Clean Energy Organizations to Peabody Energy," In the Matter of the PUC Docket No. E999/CI-14-643, Further Investigation into Environmental and Socioeconomic Costs Under MN Statute 216B.2422, Subdivision 3, July 14, 2015, pp. 53-88. There I noted and documented that:

- Numerous distinguished researchers have concluded that IAMs are of little or no value for evaluating alternative climate change policies and estimating the SCC, and their studies have been published in books, working papers,

[67] Kevin D. Dayaratna, "An Analysis of the Obama Administration's Social Cost of Carbon," Testimony before Committee on Natural Resources, United States House of Representatives, July 23, 2015.
[68] Ibid.
[69] Kevin D. Dayaratna and David W. Kreutzer, "Unfounded FUND: Yet Another EPA Model Not Ready for the Big Game," Heritage Foundation *Backgrounder* No. 2897, April 29, 2014, http://www.heritage.org/research/reports/2014/04/unfounded-fund-yet-another-epa-model-not-ready-for- the-big-game; Kevin D. Dayaratna and David W. Kreutzer, "Loaded DICE: An EPA Model Not Ready for the Big Game," Heritage Foundation *Backgrounder* No. 2860, November 21, 2013, http://www.heritage.org/research/reports/2013/11/loaded-dice-an-epa-model-not-ready-for-the-big-game; and Kevin D. Dayaratna, and David Kreutzer, "Environment: Social Cost of Carbon Statistical Modeling Is Smoke and Mirrors," *Natural Gas & Electricity*, Vol. 30, No. 12 (2014), pp. 7–11.

conference proceedings, and in the most prestigious international peer-reviewed scientific journals.

- Numerous distinguished economists have concluded that the IAMs are "close to useless" as tools of policy analysis, and their studies have been published in books, working papers, conference proceedings, and the most prestigious international peer-reviewed scientific journals.

P. 9, L 21: "Equilibrium climate sensitivity is defined as the increase in mean global temperature from a doubling of CO_2 concentrations relative to pre-industrial times. This input is used to determine how changes in CO_2 concentrations will change mean global temperatures. There is uncertainty regarding how much the global temperature will increase from greater CO_2 concentrations. The IWG therefore applied a probability distribution for this parameter that matched the range of estimates used by the IPCC. A distribution accounts for the possibility that increased CO_2 concentrations will have a smaller or larger impact on global temperatures than the mean expected value."

In May 2013, the IWG produced an updated SCC value by incorporating revisions to the underlying IAMs used by the IWG in its initial 2010 SCC determination.[70] However, at that time, the ***IWG did not update the equilibrium climate sensitivity (ECS) employed in the IAMs***. This was not done, despite there having been completed, since January 1, 2011, at least 14 new studies and 20 experiments (involving more than 45 researchers) examining the equilibrium climate sensitivity (ECS), each lowering the best estimate and tightening the error distribution about that estimate.[71] Instead, the IWG wrote in its 2013 report: "It does not revisit other interagency modelling decisions (e.g., with regard to the discount rate, reference case socioeconomic and emission scenarios, or equilibrium climate sensitivity)."[72]

This decision was reaffirmed by the IWG in July 2015.[73] But, through its reaffirmation, the IWG again refused to give credence to and recognize the importance of what is now becoming mainstream science -- that the most likely value of the equilibrium climate sensitivity is lower than that used by the IWG and that the estimate is much better constrained. This situation has profound implications for the determination of the SCC and yet continues to be summarily dismissed by the IWG.[74]

The earth's ECS is defined by the IWG in its 2010 report (IWG 2010) as "the long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO_2 concentration relative to pre-industrial levels (or stabilization at a concentration of approximately 550 parts per million (ppm)" and

[70] IWG, 2013.
[71] Written Statement of Patrick J. Michaels," op. cit.
[72] IWG, 2013.
[73] IWG, July 2015, op. cit.
[74] Written Statement of Patrick J. Michaels," op. cit.

is recognized as "a key input parameter" for the integrated assessment models used to determine the social cost of carbon. The IWG2010 report has an entire section (Section III.D) dedicated to describing how an estimate of the equilibrium climate sensitivity and the scientific uncertainties surrounding its actual value are developed and incorporated in the IWG's analysis.[75] The IWG2010, in fact, developed its own probability density function (pdf) for the ECS and used it in each of the three IAMs, superseding the ECS pdfs used by the original IAMs developers. The IWG's intent was to develop an ECS pdf which most closely matched the description of the ECS as given in the *Fourth Assessment Report* of the United Nation's Intergovernmental panel on Climate Change which was published in 2007.

The functional form adopted by the IWG2010 was a calibrated version of Roe and Baker distribution.[76] It was described in the IWG2010 report – see Table 4 and Figure 9.

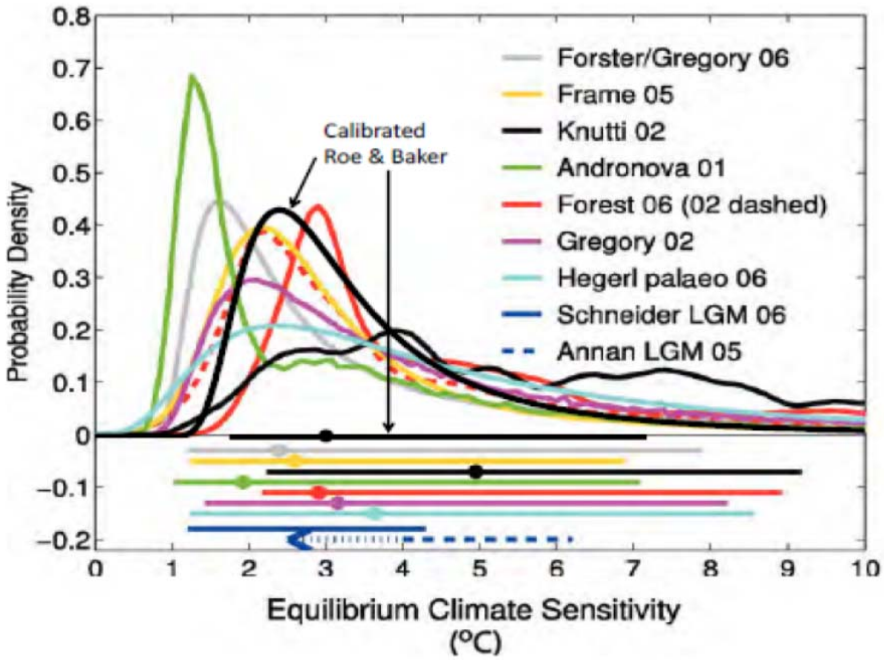
Table 4
Summary Statistics for Four Calibrated Climate Sensitivity Distributions

	Roe & Baker	Log-normal	Gamma	Weibull
Pr(ECS < 1.5°C)	0.013	0.050	0.070	0.102
Pr(2°C < ECS < 4.5°C)	0.667	0.667	0.667	0.667
5th percentile	1.72	1.49	1.37	1.13
10th percentile	1.91	1.74	1.65	1.48
Mode	2.34	2.52	2.65	2.90
Median (50th percentile)	3.00	3.00	3.00	3.00
Mean	3.50	3.28	3.19	3.07
90th percentile	5.86	5.14	4.93	4.69
95th percentile	7.14	5.97	5.59	5.17

Source: IWG2010 report

Figure 9
Estimates of the Probability Density Functions
for Equilibrium Climate Sensitivity, °C

[75] IWG, 2010, op. cit.
[76] Gerard H. Roe and Marcia B. Baker, "Why Is Climate Sensitivity So Unpredictable?" *Science*, Vol. 318, No. 5850 (October 26, 2007), pp. 629–632.



Source: IWG2010 report

The calibrated Roe and Baker functional form used by the IWG2010 is *no longer scientifically defensible;* nor was it at the time of the publication of the IWG 2013 SCC update, nor at the time of the July 2015 update.[77] Figure 10 illustrates this fact, as it compares the best estimate and 90 percent confidence range of the earth's ECS as used by the IWG (calibrated Roe and Baker) against findings in the scientific literature published since January 1, 2011.

In Figure 10, the median (indicated by the small vertical line) and 90 percent confidence range (indicated by the horizontal line with arrowheads) of the climate sensitivity estimate used by the IWG on the SCC Climate[78] is indicated by the top black arrowed line. The average of the similar values from 20 different determinations reported in the recent scientific literature is given by the grey arrowed line (second line from the top). The sensitivity estimates from the 20 individual determinations of the ECS as reported in new research published after January 1, 2011 are indicated by the colored arrowed lines. The arrows indicate the 5 to 95 percent confidence bounds for each estimate along with the best estimate (median of each probability density function; or the mean of multiple estimates; colored vertical line). Ring et al. present four estimates of the climate sensitivity and the red box encompasses those estimates.[79] Spencer and Braswell produce a single

[77]Written Statement of Patrick J. Michaels," op. cit.
[78]Roe and Baker, op. cit.
[79]Ring, M.J., et al., 2012. Causes of the global warming observed since the 19th century. *Atmospheric and Climate Sciences,* 2, 401-415, doi: 10.4236/acs.2012.24035.

ECS value best-matched to ocean heat content observations and internal radiative forcing.[80]

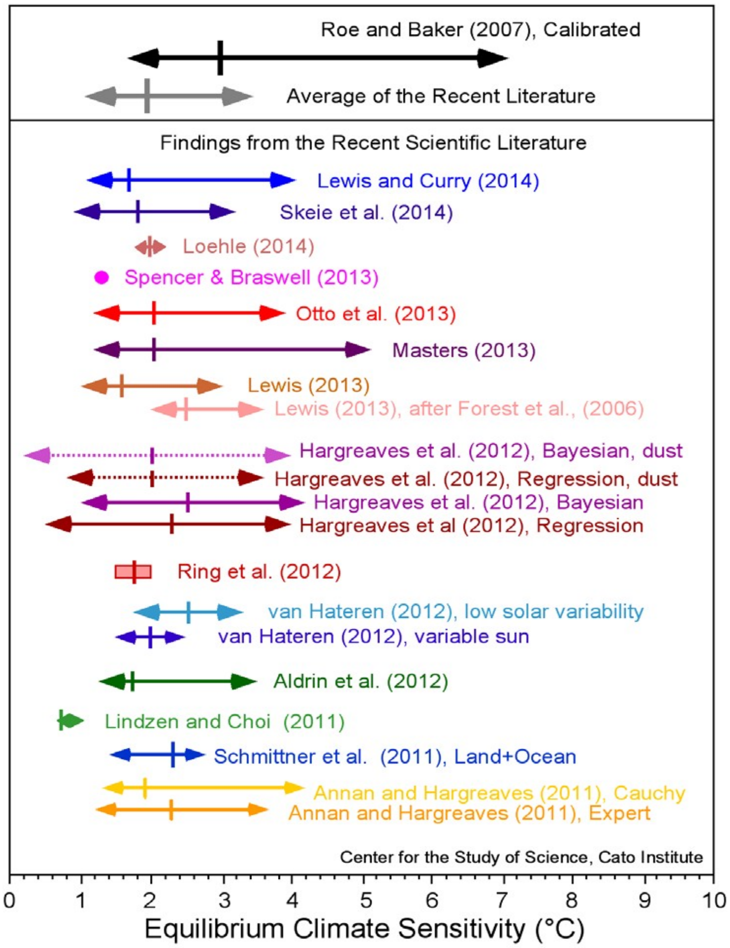
The IWG2010 report noted that, concerning the low end of the ECS distribution, its determination reflected a greater degree of certainty that a low ECS value could be excluded than did the IPCC:

> "Finally, we note the IPCC judgment that the equilibrium climate sensitivity "is very likely larger than 1.5°C." Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5°C is almost 99 percent, is not inconsistent with the IPCC definition of "very likely" as "greater than 90 percent probability," it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC."[81]

In other words, the IWG used its judgment that the lower bound of the ECS distribution was higher than the IPCC 2007 assessment indicated. However, the collection of the recent literature on the ECS shows the IWG's judgment to be in error. As can be seen in Figure 10, the large majority of the findings on ECS in the recent literature indicate that the lower bound (i.e., 5th percentile) of the ECS distribution is lower than the IPCC 2007 assessment. And, the average value of the 5th percentile in the recent literature (1.1°C) is 0.62°C less than that used by the IWG -- a sizeable and important difference which will influence the SCC determination.[82]

Figure 10
Confidence Range of the Earth's ECS

[80] Spencer, R. W., and W. D. Braswell, 2013. The role of ENSO in global ocean temperature changes during 1955-2011 simulated with a 1D climate model. *Asia-Pacific Journal of Atmospheric Science*, doi:10.1007/s13143-014-0011-z.
[81] IWG2010 (p. 14).
[82] Written Statement of Patrick J. Michaels," op. cit.



Source: Michaels, 2015.

In fact, the preponderance of literature supporting a lower climate sensitivity was at least partially reflected in the new IPCC assessment report issued in 2013. In that report, the IPCC stated "Equilibrium climate sensitivity is likely in the range 1.5°C to 4.5°C (high confidence), extremely unlikely less than 1°C (high confidence), and very unlikely greater than 6°C (medium confidence). The lower temperature limit of the assessed likely range is thus less than the 2°C in the AR4."[83]

Clearly, the IWG's assessment of the low end of the probability density function that best describes the current level of scientific understanding of the climate sensitivity is incorrect and indefensible.[84]

[83] IPCC 2013.
[84] Written Statement of Patrick J. Michaels," op. cit.

What is clear is that ***<u>the IWG did not alter its probability distribution of the ECS between its 2010, 2013, and 2015 SCC determination, despite a large and growing body of scientific literature that substantially alters and better defines the scientific understanding of the earth's ECS.</u>*** It is unacceptable that a supposed "updated" social cost of carbon does not include updates to the science underlying a critical and key aspect of the SCC.[85]

P.10. L. 11: "The discount rate is a key parameter that is used to aggregate damages that occur at different times into a single measure of the "present value" of damages. Present value represents the sum of values across all time periods measured in current dollar terms, i.e., the equivalent value if all values were realized in the current time period."

<u>I agree that the discount rate is a key parameter</u>. However, EPA has run these models using 2.5 percent, 3 percent, and 5 percent discount rates despite the fact that the operative official U.S. Office of Management and Budget guidance in Circular A-4 has specifically stipulated that a 7 percent discount rate be used as well.[86]

P. 16, L17: The IWG estimate of SCC summarizes the best available information and provides a well-developed and acceptable estimate of the expected value of the future damages from CO_2 emissions.

<u>This is not correct.</u> As I have exhaustively shown here in my rebuttal testimony, ***<u>the IWG estimate of SCC</u>***:

- ***<u>Does not</u>*** summarize or utilize the best available information
- ***<u>Does not</u>*** provide well-developed and acceptable estimates of the expected value of the future damages from CO_2 emissions

P. 17, L. 2: The IWG has committed to update the estimates of the SCC and incorporate new and better information as it becomes available: "the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time." The IWG produced updated values of the SCC in 2013 (Schedule 3) incorporating newer versions of the three climate change models."

<u>This is not correct.</u> As I have exhaustively shown here in my rebuttal testimony:

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[85] "Written Statement of Patrick J. Michaels," op. cit.
[86] Office of Management and Budget, "Circular A-4," White House, http://www.whitehouse.gov/omb/circulars_ a004_a-4/

- The IWG has ***not*** incorporated new and better information as it becomes available
- The IWG updated values of the SCC in 2013 ***contain serious flaws*** in incorporating newer versions of the three climate change models.

P. 24, L.1: Q. Do other economists agree that the federal SCC is a conservative estimate of the "true" SCC?"

A. "Yes."

Strawman: Polasky did not claim all economists agree. *(If all economists agree, it's rare.)*

This is not correct. ***Numerous reputable economists do not agree that the federal SCC is a conservative estimate of the "true" SCC***. These economists include, among others:

Some economists indeed think FSCC is too high, but this list is misleading at best, from a quick scan, including a few people I know. Some are scientists, amused to be called economists, who criticize FSCC for being low, as do some economists. At least some are neither economists nor relevant scientists. See next page.

- Robert Pindyck
- Frank Ackerman
- Stephen DeCanio https://en.wikipedia.org/wiki/Stephen_DeCanio
- Richard Howarth
- Kristen Sheeran http://climatesolutions.org/member/kristen-sheeran
- Michael Mastrandrea
- Jared L. Cohon
- Maureen L. Cropper
- Mark R. Cullen
- Elisabeth M. Drake
- Mary R. English
- Christopher B. Field
- Daniel S. Greenbaum
- James K. Hammitt
- Rogene F. Henderson
- Catherine L. Kling
- Alan J. Krupnick www.rff.org/people/profile/alan-j-krupnick; www.rff.org/research/publications/putting-carbon-charge-federal-coal-legal-and-economic-issues
- Russell Lee
- H. Scott Matthews
- Thomas E. Mckone
- Gilbert E. Metcalf
- Richard G. Newell
- Richard L. Revesz https://en.wikipedia.org/wiki/Richard_Revesz; http://gwagner.com/wp-content/uploads/Joint-Comments-on-SCC-and-SCM-in-Forest-Service-SDEIS.pdf http://www.nature.com/news/global-warming-improve-economic-models-of-climate-change-1.14991 "Costs of carbon emissions are being underestimated"
- Ian Sue Wing
- Terrance G. Surles
- Richard Tol
- Roger Bezdek Bezdek list himself as a reputable economist in support of his claim.
- Cass Sunstein https://en.wikipedia.org/wiki/Cass_Sunstein
- Jiehan Guo
- James Risbey http://www.marine.csiro.au/~ris009/ scientist
- John Weyant https://emf.stanford.edu/people/john-weyant He runs EMF, whose EMF-22 fed IWG
- Jonathan Masur

John Weyant leads Energy Modeling Forum, whose EMF-22 was used by the IWG. His inclusion (twice) here is bizarre.
https://news.stanford.edu/2015/01/12/emissions-social-costs-011215/ They claim SCC should be much higher than FSCC.
http://www.nature.com/nclimate/journal/v5/n2/full/nclimate2481.html
https://earth.stanford.edu/frances-moore She did MS at Yale and PhD at Stanford. I heard her present this at AGU.
https://chroniclevitae.com/people/189382-delavane-diaz/profile She is now with EPRI, but did her PhD with Weyant.

- Eric Posner
- Rachel Warren
- David Anthoff
- Jose Granados
- Oscar Carpintero
- Elizabeth Stanton
- Kevin Dayaratna http://www.heritage.org/about/staff/d/kevin-dayaratna
- David Kreutzer
- John P. Weyant Listed twice
- John Jelacic
- Elizabeth Stanton
- Ramon Arigoni Ortiz
- Anil Markandya
- Joseph E. Aldy
- Dale S. Rothman
- John B. Robinson
- Jiehan Guo
- Geoffrey M. Heal
- Antony Millner
- William Nordhaus
- Joseph Bast http://www.desmogblog.com/joseph-bast Not economist or college grad
- James M. Taylor http://www.desmogblog.com/james-taylor Heartland, lawyer
- Partha Dasgupta
- Robert Wendling
- Robert P. Murphy http://www.desmogblog.com/robert-p-murphy Think tanks, PRI, IER

I comprehensively addressed this issue in Roger H. Bezdek, "Responses to the Information Requests Nos. 2-10 of Clean Energy Organizations to Peabody Energy," In the Matter of the PUC Docket No. E999/CI-14-643, Further Investigation into Environmental and Socioeconomic Costs Under MN Statute 216B.2422, Subdivision 3, July 14, 2015, pp. 53-88.

Calling Joe Bast a "reputable economist" simply destroys Bezdek's credibility.
http://tfn.org/ouch-texas-judge-slams-right-winger-for-wasting-his-time (August 2014)
"Mr. Joseph Bast, president and CEO of the Heartland Institute, testified for the Intervenors regarding the Texas Taxpayers' Savings Grant Programs ("TTSGP"), a school voucher bill that failed in the 82nd Legislative Session. As a threshold matter, this Court finds that Mr. Bast is not a credible witness and that he did not offer reliable opinions in this matter. **While Mr. Bast described himself as an economist, he holds neither undergraduate nor graduate degrees in economics, and the highest level of education he completed was high school.** Mr. Bast testified that he is 100% committed to the long-term goal of getting government out of the business of educating its own voting citizens. Further, his use of inflammatory and irresponsible language regarding global warming, and his admission that the long term goal of his advocacy of vouchers is to dismantle the "socialist" public education system further undermine his credibility with this Court."
https://web.archive.org/web/20140915072844/http://www.co.travis.tx.us/courts/civil/district/pdfs/school-finance-findings-conclusions.pdf printed pp.335-336, PDF pp.354-355

REBUTTAL TO THE DIRECT TESTIMONY OF DR. MICHAEL HANEMANN ON BEHALF OF THE DIVISION OF ENERGY RESOURCES OF THE MINNESOTA DEPARTMENT OF COMMERCE, IN CONSULTATION WITH THE MINNESOTA POLLUTION CONTROL AGENCY

P. 68, L. 4: Was it appropriate for the IWG to use the Roe and Baker distribution for the climate sensitivity?

A. In my opinion, it was appropriate for the IWG to use the Roe and Baker distribution as the common probability distribution of the climate sensitivity. This probability distribution is based on a theoretical understanding of the climate system's response to increased radiative forcing and it is widely cited in the literature."

<u>It was not appropriate for the IWG to use the Roe and Baker distribution as the common probability distribution of the climate sensitivity.</u> As I noted above as part of my rebuttal to the Direct Testimony of Dr. Stephen Polasky (P. 9, L 21), The calibrated ***<u>Roe and Baker functional form used by the IWG2010 is no longer scientifically defensible</u>***; nor was it at the time of the publication of the IWG 2013 SCC update, nor at the time of the July 2015 update.

The equilibrium climate sensitivity (ECS) ECS distribution used by the IWG is based on a paper published in the journal *Science* eight years ago by Gerard Roe and Marcia Baker.[87] However, since then, a variety of newer, more robust, and more up-to-date distributions have been published in the peer-reviewed literature.[88] Many of these distributions indicate lower probabilities of extreme global warming in response to carbon dioxide emissions.

Using the more up-to-date and reliable ECS distributions given in Otto et al[89] and in Lewis[90] yields drastically lower probabilities of extreme global warming. Dayaratna and his colleagues re-estimated the SCC using these more up-to-date ECS distributions and found that many of these distributions, in fact, suggest lower probabilities of extreme global warming in response to carbon dioxide emissions – as Dayaratna reported in recent U.S. Congressional testimony. [91]

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[87]Gerard H. Roe and Marcia B. Baker, "Why Is Climate Sensitivity So Unpredictable?" *Science*, Vol. 318, No. 5850 (October 26, 2007), pp. 629–632.

[88]See, for example, Nicholas Lewis, "An Objective Bayesian Improved Approach for Applying Optimal Fingerprint Techniques to Estimate Climate Sensitivity," *Journal of Climate*, Vol. 26, No. 19 (October 2013), pp. 7414–7429; and Alexander Otto et al., "Energy Budget Constraints on Climate Response," *Nature Geoscience*, Vol. 6, No. 6 (June 2013), pp. 415–416.

[89]Otto et al, op. cit.

[90]Lewis, op. cit.

[91]Kevin D. Dayaratna, "An Analysis of the Obama Administration's Social Cost of Carbon," Testimony before Committee on Natural Resources, United States House of Representatives, July 23, 2015.

Dayaratna results are summarized in Tables 7, 8, and 9.[92] These tables illustrate that Dayaratna and his colleagues found drastically lower estimates of the SCC using these more up-to-date ECS distributions. These results are not surprising, since, as noted, the IWG's estimates of the SCC were based on outdated assumptions that overstated the probabilities of extreme global warming, which artificially inflated their estimates of the SCC.[93]

Table 7

	FUND Model Probability of Negative SCC – ECS Distribution Based on Outdated Roe–Baker (2007) Distribution, End Year 2300			
Year	**Discount Rate - 2.50 percent**	**Discount Rate - 3 percent**	**Discount Rate - 5 percent**	**Discount Rate - 7 percent**
2010	0.087	0.121	0.372	0.642
2020	0.084	0.115	0.344	0.601
2030	0.080	0.108	0.312	0.555
2040	0.075	0.101	0.282	0.507
2050	0.071	0.093	0.251	0.455

Source: Dayaratna, 2015.

Table 8

	FUND Model Probability of Negative SCC – ECS Distribution Updated in Accordance with Otto et al. (2013), End Year 2300			
Year	**Discount Rate - 2.50 percent**	**Discount Rate - 3 percent**	**Discount Rate - 5 percent**	**Discount Rate - 7 percent**
2010	0.278	0.321	0.529	0.701
2020	0.268	0.306	0.496	0.661
2030	0.255	0.291	0.461	0.619
2040	0.244	0.274	0.425	0.571
2050	0.228	0.256	0.386	0.517

Source: Dayaratna, 2015.

[92] Kevin D. Dayaratna, "An Analysis of the Obama Administration's Social Cost of Carbon," Testimony before Committee on Natural Resources, United States House of Representatives, July 23, 2015.
[93] Ibid.

Table 9

	FUND Model Probability of Negative SCC – ECS Distribution Updated in Accordance with Lewis (2013), End Year 2300			
Year	**Discount Rate - 2.50 percent**	**Discount Rate - 3 percent**	**Discount Rate - 5 percent**	**Discount Rate - 7 percent**
2010	0.390	0.431	0.598	0.722
2020	0.375	0.411	0.565	0.685
2030	0.361	0.392	0.530	0.645
2040	0.344	0.371	0.491	0.598
2050	0.326	0.349	0.449	0.545

Source: Dayaratna, 2015.

P. 68, L 20. "The three values chosen by the IWG and the 3 percent value chosen by the IWG for the central estimate are policy judgments by the IWG. In my opinion, it was appropriate for the IWG to use these numerical values."

***As I have exhaustively shown here in my rebuttal testimony It was not appropriate for the IWG to use these numerical values*.**

P. 69, L.2: "I am not at this time aware of values higher than 5.5 percent or lower than 1.4 percent being used in the existing literature on the economics of climate change."

This statement is not supportable and evidences Dr. Polaksy's lack of familiarity with the relevant literature over at least the past decade. In fact, in the debate over the SCC, IAMs, and related issues in recent years -- including everything from decisions about model structure and damage functions to the value of key variables, arguably ***nothing has attracted as much attention and criticism in the literature over the past decade as the choice of the discount rate used to estimate the present value of future impacts.*** The discount rate is a lightening-rod for criticism, first, because of the heavy ethical baggage that it carries and, more important, in simulations of the sensitivity of IAM and SCC results using different variable values, the choice of the values of the discount rate causes greater variation in model results than do other parameters.

However, almost nothing in the literature of IAMs could be less certain than having a discount rate that is "consistent with estimates provided in the economics literature." Rather, the choice of an appropriate discount rate is the most contentious issue in the IAM literature. In 2007 when Nicholas Stern published "The Economics of Climate Change: The Stern Review,"[94] it was met with a barrage of criticism, most of which pointed out that the major reason for the report's conclusions was it has used a discount rate near zero to generate its gloomy outlook.[95]

Even Nicholas Martin, in his Direct Testimony in this proceeding, states that "Finally, the choice of discount rate -- while not a separate modeling step *per se*, but rather the choice of how to weight costs and benefits in the future versus those in the present -- has a greater impact on the SCC than any other single variable in the methodology.[96]

In fact, ever since IWG 2010 was released, there has been intense criticism and debate over the failure to consider discount rates higher than 5 percent. To begin with, numerous authors have noted that the IWG failure to utilize a 7 percent discount rate violates official Federal government policy. OMB provides explicit guidance (in the form of "OMB Circulars") to federal agencies on how to select discount rates. Specifically, OMB Circular A-4 (relying in turn on Circular A-94) states that "a real discount rate of 7 percent should be used as a base-case for regulatory analysis," [97] since this is the average before-tax rate of return to private capital investment. Thus it states: "For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent." It states that a 3 percent *and* a 7 percent rate should be used, *in all cases*, in order to handle the fact that some regulations will primarily affect industry/capital while others will affect consumption.

The White House issued a subsequent primer on Circular A-4, which (among other topics) dealt with this issue.[98] It stated "If the regulatory action will have important intergenerational benefits or costs, the agency might consider a sensitivity analysis using a lower but positive discount rate, ranging from 1 to 3 percent, in addition to calculating net benefits using discount rates of 3 percent and 7 percent."[99] There is no ambiguity here: OMB did *not* instruct federal agencies that they could pick and choose the appropriate discount rate, based on the context. Rather, it stated that agencies must *always* should include the standard 3 and 7 percent rates. Nevertheless, the IWG only reported the SCC using the 2.5 percent, 3 percent, and 5 percent rates that we mentioned earlier. They *simply did not report* what the

[94]Nicholas Stern, *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, U.K. 2007.
[95]See William Nordhaus, "A Review of the Stern Review on the Economics of Climate Change", *Journal of Economic Literature*, V. XLV, September 2007, pp. 689-97 for an good example of a rebuttal to the Stern Review's conclusions.
[96]Direct Testimony and Schedules of Nicholas F. Martin Before the Minnesota Public Utilities Commission State of Minnesota in the Matter of the Investigation Into Environmental And Socioeconomic Costs Under Minn. Stat. § 216b.2422, Subd. 3 Docket No. E999/Ci-14-643, OAH Docket No. 80-2500-31888 Environmental Cost of CO_2 Emissions, June 1, 2015, p. 44.
[97]U.S. Office of Management and Budget, "Regulatory Analysis," Circular A-4, September 17, 2003.
[98]"Regulatory Impact Analysis: A Primer," The White House, 2011.
[99]Ibid, p. 12.

"social cost of carbon" would be, using a 7 percent rate. They just ignored OMB's rules, the goals of which are stated clearly in Circular A-4.[100]

In examining the use of the SCC in regulatory impact analysis, the State of North Carolina determined that "In the absence of sufficient documentation that would allow calculation of the SCC at 7 percent using any of the models discussed, a value can be estimated through simple extrapolation using a linear regression of the first three points. The estimate is shown in the figure below and indicates that the sign of the SCC is apt to be negative at the 7 percent discount rate. A negative SCC indicates that the beneficial aspects of carbon dioxide emissions actually outweigh the costs."[101]

In assessing the IWG SCC, the Institute for Energy Research found that the problem is that the choice of discount rate is not something that can be settled objectively through technical analysis, and that if policymakers were going to use market rates of interest, there might be some hope of objectivity. There would still be significant "wiggle room" by selecting the time periods and particular interest rates to use in the computation, but at least market rates are externally generated and, in principle, could be measured objectively.[102]

David W. Kreutzer reviewed the SCC discount issue and noted in Congressional testimony that "The IWG's TSD used 2.5 percent, 3 percent, and 5 percent discount rates but neglected to report SCC values based on 7 percent."[103]

Robert Murphy analyzed the importance of the discount rate in estimating the SCC and testified before Congress: "This omission of a 7 percent figure masks just how dependent the SCC is on discount rates. As indicated in Figure 1 from the May 2013 update, when the Working Group used a discount rate of 5 percent, more than a fifth of the computer simulations reported a SCC that was near-zero or even *negative*, and that was for the year 2020. If the Working Group ran the computer models again, this time using a 7 percent discount rate and an earlier reference year such as 2015, presumably a larger fraction of simulations would register zero or negative values for the SCC, so that the mean result would itself be closer to zero -- or conceivably even negative, meaning that carbon dioxide emissions conferred extra *benefits* on humanity."[104] (Emphasis in original testimony)

[100] "OMB's Whitewash on the Social Cost of Carbon," Institute for Energy Research, 2015, http://instituteforenergyresearch.org/analysis/ombs-whitewash-on-the-social-cost-of-carbon/?pfstyle=wp.
[101] North Carolina Department of Environment and Natural Resources, "RE: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866," letter to Howard Shelanski Administrator, Office of Information and Regulatory Affairs, Office of Management and Budget, February 26, 2014.
[102] Institute for Energy Research, "Comment on Technical Support Document: Technical Update of the Social Cost of Carbon For Regulatory Impact Analysis Under Executive Order No. 12866, February 2014.
[103] David W. Kreutzer, "The Impacts of Carbon Taxes on the U.S. Economy," Testimony before the Committee on Finance, United States Senate, September 16, 2014.
[104] Written Testimony Robert P. Murphy, Before the Senate Committee on Environment and Public Works On the Matter of "The 'Social Cost of Carbon': Some Surprising Facts," July 18, 2013

In assessing the IWG SCC discount rate, Paul Knappenberger concluded that "We thus have an absurd situation, in which EPA and other regulatory agencies will be following the rules and calculating benefits and costs at both the 3 percent and 7 percent discount rates. Yet, when they express the "social benefits" of reducing greenhouse gas emissions at the 7 percent rate, they are actually going to plug in the wrong number, and explain in a footnote why they are doing so. To repeat, this is important, because the "right" number would show that there are virtually *no* "social benefits" from reducing greenhouse gas emissions."[105]

William Nordhaus noted that the discount rate should match market interest rates, or rates of return on capital.[106] He maintained that the discount rate should match an interest rate of about 5 percent above inflation – which would currently be in the rage of 7 percent, and higher if inflation increases. Thus, if the U.S. again experienced the type of inflation rates of the 1970s and 1980s, the discount rate could exceed 10 percent.

P. 73, L. 6: In your opinion, was it reasonable to use the three IAMs employed by the IWG?

A. Yes, it was reasonable to use DICE, PAGE and FUND.

Unfortunately, this answer demonstrates that ***Dr. Hanemann does not seem to be aware of the most recent peer-reviewed studies*** published in leading international climate journals that conclude that climate models are ***not*** sufficiently reliable to form a basis for policymaking – such as by the IWG. The peer-reviewed scientific journals in which these findings were published include *Journal of Climate, Earth Systems, Climate Dynamics, Journal of Geophysical Research Atmospheres, Journal of Meteorological Research*, and *Journal of Advances in Modeling*. To cite several of the more relevant studies:

- Li, Xie, and Du found that current climate models have failed to account for large climate variations in monsoons which leads to "a strong equatorial easterly bias accompanied by a physically consistent bias in the precipitation dipole."[107]
- Myers and Norris found 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."[108]

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[105] Paul C. "Chip" Knappenberger, "An Example of the Abuse of the Social Cost of Carbon," Cato Institute, August 23, 2013.
[106] See the discussion in Frank Ackerman, "Debating Climate Economics: The Stern Review vs. Its Critics," Report to Friends of the Earth-UK, July 2007.
[107] Li, G., Xie, S.-P. and Du, Y. 2015. Climate model errors over the South Indian Ocean thermocline dome and their effect on the basin mode of interannual variability. *Journal of Climate* 28: 3093-3098.
[108] 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.

- Kumar and Wang analyzed whether climate prediction models have improved over time, but find that "the results have not been encouraging," and concluded that "the constraint of the coupled ocean-atmosphere variability will still be a basic limitation on prediction skill."[109]
- Wang, Lee, Chen, and Hsu analyzed CAM5 and found that the data contain significant bias that "may result from excessive shallow convection behavior in CAM5," thus proving that the model errors and deficiencies lead to incorrect results.[110]
- Yang and Wu found that "the 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." They condemned climate modelling science, finding that "it remains a great challenge to improve model ability in simulating and predicting the North Atlantic climate variability."[111]
- Nishii, Nakamura, and Orsolini added to the uncertainty of climate models by finding that in Arctic climate projections, "most of the CMIP3/5 models have negative biases." This implies that climate projections are not assuming the cold temperature variables added by the Arctic.[112]
- Gong, et al, analyzed the CMIP5 models compared to CMIP3 results and concluded that current model features "lead to unrealistic climatic impacts," and demonstrated that there is a significant "common bias in coupled general circulation models."[113]
- Chen, Brissette, and Lucas-Picher assessed the new "bias correction methods" to determine if the new models had corrected previous biases skewing results, and found that "the typical 10 to 20 percent 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." This demonstrates that the bias corrections fall prey to the same reasons why previous models have failed.[114]
- Oueslati and Bellon invalidated most current models used to analyze climate change (CMPI5), finding that "the double intertropical convergence zone (ITCZ) bias still affects all the models that participate in CMIP5." This means "overestimated ascending regimes suggest that processes inhibiting deep

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[109]Kumar, A. and Wang, H. 2015. On the potential of extratropical SST anomalies for improving climate predictions. *Climate Dynamics* 44: 2557-2569.
[110]Wang, C.-C., Lee, W.-L., Chen, Y.-L. and Hsu, H.-H. 2015. Processes leading to Double Intertropical Convergence Zone bias in CESM1/CAM5. *Journal of Climate* 28: 2900-2915.
[111]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.
[112]Nishii, K., Nakamura, H. and Orsolini, Y.V. 2015. Arctic summer storm track in IP3/5 climate models. *Climate Dynamics* 44: 1311-1327.
[113]Gong, H., Wang, L., Chen, W., Nath, D., Huang, G. and Tao, W. 2015. Diverse influences of ENSO on the East Asian-Western Pacific winter climate tied to different ENSO properties in CMIP5 models. *Journal of Climate* 28: 2187-2202.
[114]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.

convection (e.g. convective entrainment, downdrafts and large-scale subsidence) are still poorly represented in CMIP5 models."[115]

- Li, Lu, Han, and Gao determined that climate models are not taking into account the major component of the rainfall and monsoon effects, which proves that "further diagnostic work on the relationship between snow and SASM in CMIP5 is clearly required."[116]
- Zhang, et al, concluded that "most climate models fail to reproduce the observed seasonal cycle," which demonstrates that there is a "warm SST bias" significantly impacting and overestimation of climate impacts.[117]

The PAGE model, in particular, suffers from serious flaws and should not be used for policymaking. To begin with, PAGE was not designed for the use to which the IWG puts it. Of the three IAMs used in deriving the SCC, PAGE stands apart: It is not a cost-benefit tool for optimizing policy, but, rather, is based on a categorically different "decision analysis" approach. PAGE was designed as an alternative to the rational-choice, objective cost-benefit analysis that was the focus of DICE and FUND.[118] PAGE was designed as an exploratory tool, not as a model capable of yielding a determinate value. It was designed according to the principles of "decision analysis," which is distinguished by the fact that "the valuation of intangible effects by the decision-maker is accepted as legitimate input into the analysis."[119] First and foremost, it is a "normative theory for how an individual decision-maker might think through his or her decisions and determine sensible actions; it does not set out to do the same for groups of people, or for corporations, or for public bodies."[120] While DICE and FUND are more like calculators, taking in inputs and computing a particular value, PAGE is more like a crystal ball in which one can "explore." PAGE is designed to help policymakers understand the impacts of their *subjective* policy commitments, not to assist with determining a proper outcome. PAGE allows policymakers to "explore" the results of their subjective beliefs; it does not calculate an objective value. "This difference between public and private perspectives can be very important, and calls into question the use of optimizing models that treat them (implicitly or explicitly) as being identical."[121] PAGE is one such optimizing model, and falls into precisely this confusion.

[115]Oueslati, B. and Bellon, G. 2015. The double ITCZ bias in CMIP5 models: interaction between SST, large-scale circulation and precipitation. *Climate Dynamics* 44: 585-607.
[116]Li, R., Lu, S., Han, B. and Gao, Y. 2015. Connections between the South Asian Summer Monsoon and the tropical sea surface temperature in CMIP5. *Journal of Meteorological Research* 29: 106-118.
[117]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 of Advances in Modeling Earth Systems* 6: 1016-1026.
[118]Ingrid Nestle, dissertation, *The Costs of Climate Change in the Agricultural Sector: A Comparison of Two Calculation Approaches* 80 (Flensburg Univ. 2012), available at http://d-nb.info/1028080921/34.
[119] C.W. Hope and S. Owens, *Research Policy and Review 10. Frameworks for Studying Energy and the Environment*, 18 Env. & Planning A 851, 856 (1986).
[120] Stephen R. Watson and M. Dennis Buede, *Decision Synthesis: The Principles and Practice of Decision Analysis* 5 (Cambridge Univ. Press 1987).
[121]John Weyant, "Integrated Assessment of Climate Change: State of the Literature," 5 *J. Cost-Benefit Analysis* 377, 399-400 (May 27, 2015).

Second, to complicate matters further, PAGE's damage equations were not designed to apply to the entire world. PAGE is fundamentally parametrized for the EU, and consequentially is less accurate for other regions.[122] As Nicholas Martin notes on p. 40, lines 23-25, of his testimony in this proceeding, "PAGE calculates damages in the European Union, then simply scales damages in other regions based on length of coastline in proportion to the European Union." This EU parameterization is significant because PAGE's fundamental damages are based solely on a difference between an optimal temperature for a region and the new temperature as the climate warms.[123] This prevents PAGE from ever recognizing negative damages (i.e., benefits) from CO_2, despite the well-established literature on CO_2 fertilization,[124] and as I have discussed in my testimony here, in my Direct Testimony, and in Chapter III of Bezdek Exhibit 2. PAGE fails to adjust for the realities of different optimal temperatures in different parts of the world. Just as thermostats calibrated to the metabolism of a 150-pound man in the 1950s have left female workers freezing cold,[125] a model calibrated to Europe's optimal temperatures will almost certainly not map onto the needs of the rest of the world.

Third, the equations that comprise PAGE place a great deal of weight on low-probability, high-impact events (sometimes referred to as "tails" in the literature, because of how they appear on probability graphs). PAGE's design includes, for example, scientifically bizarre scenarios such as CO_2 concentrations that become self-propagating rather than diminishing. Climate literature has debunked these scenarios, as discussed in the testimonies of Drs. Lindzen, Happer, and Spencer, but these scenarios erroneously drive many of the results in the PAGE model. Significantly, even at low probabilities, these scenarios can be enough to strongly affect the results. For example, low-probability, high-impact events account for 70% of damages at 2.5 °C warming in PAGE.[126] One researcher noted that switching just the shape of the tail could result in enormous swings in the resulting SCC value (from 2x to 7x),[127] indicating that the tail itself drives the model and that PAGE's results are not robust. It is well-known that "PAGE produces the highest average SCC estimates and more uncertainty than the other models."[128]

Finally, PAGE is also the least transparent and publicly available of the three IAMs, generating little peer-reviewed material. Researchers have complained that PAGE is less accessible for peer review and use than the other models. One noted

[122]Anthony Bonen, *et al.*, *Economic Damages from Climate Change: A Review of Modeling Approaches* 38, 44 (Working Paper 2014-3, Schwartz Center for Economic Policy Analysis, March 2014.
[123]Ibid, p 39.
[124]Ibid, p. 41.
[125]Boris Kingma and Wouter van Marken Lichtenbelt, *Energy Consumption in Buildings and Female Thermal Demand*, *Nature Climate Change* (online pub. Aug. 3, 2015), available at http://www.nature.com/articles/nclimate2741.epdf. See also Pam Belluck, "Chilly at Work? Office Formula Was Devised for Men," *New York Times*, August 3, 2015.
[126]Weyant, "Integrated Assessment of Climate Change: State of the Literature, op. cit., p 386.
[127] J. Pycroft, *A Tale of Tails: Uncertainty and the Social Cost of Carbon Dioxide*, 5 *Economics*, pp. 12-15, Tables 1-3, December 22, 2011, available at http://dx.doi.org/10.5018/economics-ejournal.ja.2011-22.
[128]Weyant, "Integrated Assessment of Climate Change: State of the Literature, op." cit., p. 389.

that "the model is proprietary,"[129] and other researchers have found the model impossible to obtain.[130] The lack of transparency surrounding PAGE provides another reason that it should not be used for policy analysis.

P. 74, L. 1 Would it be reasonable to use the IWG's 2010 estimate of the SCC instead of its 2013 estimate?

A. In my opinion, the answer is no. The 2010 estimate of the SCC differs from the 2013 only because it uses what are outdated versions of DICE, PAGE and FUND. The updated versions of the IAMs used for the IWG's 2013 study took account of more recent scientific information, including information from the IPCC Fourth Assessment report. It 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.

As I have exhaustively demonstrated here in my rebuttal testimony, ***the correct answer to this question is that it would it not be reasonable to use either the IWG's 2010 estimate of the SCC or its 2013 estimate.*** On both theoretical and procedural grounds, there are fatal flaws in the use of the SCC for regulatory purposes. The SCC is an arbitrary metric that cannot be "usefully estimated" as required by Executive Order 12866.[131] Patrick Michaels explained in Congressional testimony that the IWG estimates rest on obsolete and disproven climate sensitivity figures and concluded that the IWG's estimate is scientifically invalid:

> The social cost of carbon as determined by the Interagency Working Group in their May 2013 Technical Support Document (updated in November 2013 and July 2015) is unsupported by the robust scientific literature, fraught with uncertainty, illogical, and thus completely unsuitable and inappropriate for federal rulemaking. Had the IWG included a better-reasoned and more inclusive review of the current scientific literature, the social cost of carbon estimates would have been considerably reduced with a value likely approaching zero.[132]

In a study for the National Academies of Science (NAS), researchers found that an SCC assessment suffers from uncertainty, speculation, and lack of information about:[133]

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[129] Weyant, "Integrated Assessment of Climate Change: State of the Literature, op. cit.," p. 386.
[130] Kevin Dayaratna and David Kreutzer (Heritage Fdn.), *Unfounded FUND: Yet Another EPA Model Not Ready for the Big Game*, op .cit. p. 5, n. 22.
[131] Institute for Energy Research, "Comment on Technical Support Document: Technical Update of the Social Cost of Carbon For Regulatory Impact Analysis Under Executive Order No. 12866, op. cit.
[132] Written Statement of Patrick J. Michaels," op. cit.
[133] National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*, Washington, D.C.: National Academies Press, 2009.

1. Future emissions of greenhouse gases
2. The effects of past and future emissions on the climate system
3. The impact of changes in climate on the physical and biological environment
4. The translation of these environmental impacts into economic damages.[134]

NAS thus concludes that "As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional."[135]

Economists at the U.S. Chamber of Commerce concluded that the SCC estimates should be withdrawn and not used in rule-making and policy-making for the following reasons:

1. The SCC estimates fail in terms of process and transparency. The SCC estimates fail to comply with OMB guidance for developing influential policy-relevant information under the Information Quality Act. The SCC estimates are the product of an opaque process and any pretensions to their supposed accuracy (and therefore usefulness in policy-making) are unsupportable.
2. The models with inputs used for the SCC estimates and the subsequent analyses were not subject to peer review as appropriate.
3. Even if the SCC estimate development process was transparent, rigorous, and peer-reviewed, the modelling conducted in this effort does not offer a reasonably acceptable range of accuracy for use in policy-making.
4. The IWG has failed to disclose and quantify key uncertainties to inform decision makers and the public about the effects and uncertainties of alternative regulatory actions as required by OMB.
5. By presenting only global SCC estimates and downplaying domestic SCC estimates in 2013, the IWG has severely limited the utility of the SCC for use in benefit cost analysis and policy-making.[136]

As Robert Murphy has testified before Congress, "The "Social Cost of Carbon" is not an "objective" measurement but instead a malleable concept dependent on modeling assumptions."[137]

As the multi-industry comments on the 2013 IWG SCC noted:[138]

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[134]Ibid.
[135]Ibid.
[136]U.S. Chamber of Commerce, "Petition for Correction: Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866 (February 2010) and Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866 (May 2013)," Washington, D.C., September 4, 2013
[137]Written Testimony Robert P. Murphy, op. cit.
[138]"Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order No. 12866; Docket ID OMB-OMB-2013-0007;" Comments of The American Chemistry Council, the American Coalition for Clean Coal Electricity, the American Exploration & Production Council, the American Forest & Paper Association, the American Fuel & Petrochemical Manufacturers, the American Iron & Steel Institute, the American Petroleum Institute, America's Natural Gas Alliance, the Brick Industry Association, the Council of Industrial Boiler

1. The SCC estimates fail in terms of process and transparency.
2. The SCC estimates fail to comply with OMB guidance for developing influential policy-relevant information under the IQA.
3. The SCC estimates are the product of a "black box" process and any claims to their supposed accuracy (and therefore, usefulness in policymaking) are unsupportable.
4. The models with inputs used for the SCC estimates and the subsequent analyses were not subject to peer review.
5. Even if the process used to develop the SCC estimates was transparent, rigorous, and peer-reviewed, the modeling conducted in this effort does not offer a reasonably acceptable range of accuracy for use in policymaking.
6. The IWG has failed to disclose and quantify key uncertainties to inform decision makers and the public about the effects and uncertainties of alternative regulatory actions as required by OMB.
7. By presenting only global SCC estimates and downplaying domestic SCC estimates in 2010 and 2013, the IWG has severely limited the utility of the SCC for use in cost analysis and policymaking.

P. 74, L. 17:

Q. Is the IWG 2013 estimate of the SCC reasonable for use by MPUC?

A. Yes. For the reasons I have specified throughout my testimony I consider the use of the SCC by the MPUC reasonable.

<u>On the contrary, as I have exhaustively discussed in my rebuttal testimony here, the use of the SCC by the MPUC is not reasonable.</u>

To cite yet another example of the unreasonableness of the MPUC using the Federal SCC, if the MPUC were to use the “official” SCC estimates that are being used to analyze federal regulations, to comply with OMB guidelines these may all have to be reduced by 77 to 93 percent.[139] Thus, to state the obvious, if the MPUC attempts to use the Federal SCC estimates, does it intend to reduce them by up to 93 percent? For example, the IWG 2013 SCC estimate for 2015 is $12 (2007 dollars).[140] Reducing this by 93 percent yields an estimate of $0.84.

Owners, The Fertilizer Institute, the Independent Petroleum Association of America, the National Association of Home Builders, the National Association of Manufacturers, the National Mining Association, the National Oilseed Processors Association, the Natural Gas Supply Association, the Portland Cement Association, and the U.S. Chamber of Commerce, February 26, 2014.

[139] See the discussion in Robert P. Murphy, “IER Comments on the Social Cost of Carbon, Part II,” Institute for Energy Research, April 1, 2014.

[140] IWG 2013, op. cit.

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REBUTTAL TO THE DIRECT TESTIMONY AND SCHEDULES OF NICHOLAS F. MARTIN BEFORE THE MINNESOTA PUBLIC UTILITIES COMMISSION STATE OF MINNESOTA IN THE MATTER OF THE INVESTIGATION INTO ENVIRONMENTAL AND SOCIOECONOMIC COSTS UNDER MINN. STAT. § 216B.2422, SUBD. 3 DOCKET NO. E999/CI-14-643, OAH DOCKET NO. 80-2500-31888 ENVIRONMENTAL COST OF CO2 EMISSIONS, JUNE 1, 2015

Pp. 9-10:

Q. PLEASE EXPLAIN WHY THE COMMISSION SHOULD ADOPT THE COMPANY'S PROPOSAL.

A. In addition to the reasons I described above, the annual ranges we propose are methodologically sound and practicable because they:

- **Are based on a damage cost approach, consistent with the Commission's Order,**
- **Use all Federal SCC modeling results, thus accurately reflecting the degree of uncertainty in predicting emissions, temperature change, and damages out to the year 2300,**
- **Retain all three discount rates (5 percent, 3 percent, and 2.5 percent) used by the IWG, and are thus neutral on the critical normative**
- **Are derived using appropriate statistical methods to capture the underlying uncertainty,**
- **Require minimal subjective judgment, other than the selection of 25th and 75th percentiles as an appropriate balance of risk tolerance and practicability,**
- **Produce a practical range that includes the median SCC values at all three discount rates, and**
- **Require no new modeling, are transparent and replicable, and are easily updated if the Federal SCC values are updated.**

<u>There are numerous errors in this statement.</u> For example:

1. As discussed throughout my rebuttal testimony here, ***<u>the Federal SCC modeling results do not accurately reflect the degree of uncertainty</u>*** in predicting emissions, temperature change, and damages out to the year 2300. To cite just one of their failings, the climate models upon which they rely have been unable to accurately predict temperatures over the past two decades, and these models' predictions are becoming increasingly inaccurate every year. If these models cannot predict what has happened recently or is happening currently, it is ludicrous to think that they can predict anything out to the year 2300. Further, as discussed, it has been shown using that reasonable assumptions the IAMs can estimate negative SCC values. Is Mr. Martin thus suggesting that Minnesota use negative SCC values?

2. As I have discussed in my testimony here, use of ***<u>the three IWG discount rates (5 percent, 3 percent, and 2.5 percent) are not "neutral."</u>*** The IWG violate in-force U.S. OMB guidelines and are lower than the discount rates used in real-world decision making. Further, the "official" rationale for not including a 7 percent discount rate is nonsensical and nearly indecipherable: "So while it is clearly the case that a separate 7 percent number was not listed, and we generally do, where appropriate, ask regulatory agencies to include that in rulemakings, for the purpose of this estimate, which was not a rulemaking, it was an input to rulemakings, the judgment was reached that 7 percent was not appropriate."[141]
3. As I have discussed in my testimony here, and as numerous researchers have shown, the ***<u>underlying uncertainty in the SCC is so large as to render the use of the SCC "close to useless" for policy purposes.</u>***[142]
4. As I have discussed, ***<u>the Federal SCC process is not "transparent," the results, cannot be independently replicated, (when independent simulations are conducted, they show variances of 100 percent or more), and the process has not been peer-reviewed.</u>***[143] The announcement of the 2013 update to the SCC was especially non-transparent: Instead of announcing the update in a proposed rule, the Administration made the announcement in a final rule, in the "Energy Conservation Program: Energy Conservation Standards for Standby Mode and Off Mode for Microwave Ovens; Final Rule."[144] Even Cass Sunstein, the Federal official who convened the SCC Working Group, admitted that "Neither the 2010 TSD nor the 2013 update was subject to peer review."[145] This lack of peer-review is itself a direct violation of the Obama Administration's official guidance "Transparency and Open Government."[146]

P. 19, L. 2: There are arguments in the economics literature for discount rates both lower and higher than those used by the IWG. The IWG acknowledged the absence of consensus on this issue, so it urged agencies to consider the SCC values resulting from all three discount rates when conducting regulatory impact analysis.

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[141]"Testimony of OIRA Administrator Shelanski before the Subcommittee on Energy policy, Health Care and Entitlements of the Committee on Oversight and Government Reform of the House of Representatives," December 20, 2013.

[142]Pindyck, R. S., 2013. Climate Change Policy: What Do the Models Tell Us? *Journal of Economic Literature*, 51(3), 860-872.

[143]See the discussion in [143]Institute for Energy Research, "Comment on Technical Support Document: Technical Update of the Social Cost of Carbon For Regulatory Impact Analysis Under Executive Order No. 12866, op. cit.

[144]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Energy Conservation Program: Energy Conservation Standards for Standby Mode and Off Mode for Microwave Ovens; Final Rule*, 78 Fed. Reg. 36316, June 17, 2013,

[145]Cass R. Sunstein, *On Not Revisiting Official Discount Rates: Institutional Inertia and the Social Cost of Carbon*, Regulatory Policy Program Working Paper RPP-2013-21, Mossavar-Rahmani Center for Business and Government, Harvard Kennedy School, Harvard University,

[146]President Barack Obama, *Memorandum for the Heads of Executive Departments and Agencies on Transparency and Open Government*,

Mr. Martin is either being naive or disingenuous here. As I have discussed in my rebuttal testimony, there are, indeed, intense "arguments in the economics literature," about the discount rates. However, ***the criticism is that the three IWG discount rates used are all too low – not too high.*** Also, as I have noted, the IWG, by not using a 7 percent discount rate violated the Federal government's official guidelines.

P. 33, L. 2: "The IWG used its own, non-peer-reviewed methods to extend these forecasts to the year 2300."

Yes, it did. ***I thank Mr. Martin for making this important point.***

Pp. 46-47: In the context of this uncertainty and lack of consensus regarding discount rate choice, we took essentially a neutral approach, retaining and equally weighting the SCC values at all three discount rates used by the IWG. While acknowledging that lower and higher discount rates are also possible, we did not incorporate SCC values at any discount rates other than those used by the IWG, since this would have required new modeling using the IAMs. One of the benefits of our approach, in terms of replicability and updateability, is that it does not require new modeling.

As I have discussed here:

- First, ***using the IWG's three discount rates is not a "neutral" approach***.
- Second, ***no new modeling is required*** by Northern States Power Company or Xcel Energy to incorporate a 7 percent discount rate. Independent entities have already conducted such modeling, I have extensively discussed the results in my testimony, and the results are publically available. If desired, these results can be proved to NSP/Excel Energy for their use.

P. 47, L 19: Second, key variables in the IAMs suffer from a lack of empirical basis, and the IAMs are highly dependent on assumptions that cannot easily be verified.

I agree, and ***I thank Mr. Martin for making this important point***. Since the key variables in the IAMs suffer from a lack of empirical basis, and the IAMs are highly dependent on assumptions that cannot easily be verified, the Federal SCC estimates are not valid and should not be used by the Commission for any purposes in Minnesota.

P. 48, L 12:

Q. HAS THE IWG'S APPROACH TO THE SCC BEEN SUBJECT TO PEER REVIEW?

A. No. DICE, FUND and PAGE, as well as the socioeconomic/emissions scenarios, have been published in the peer-reviewed literature. However, the IWG methodology itself is distinct from those models and has not been peer reviewed.

I have already discussed here the ***lack of IWG peer-review and the implications of this serious failing.***

P. 50, L. 2:

DID THE IWG ASK FOR PUBLIC INPUT WHEN IT DEVELOPED THE SCC?

A. No. The IWG developed the SCC in 2009-10, and updated it twice in 2013, with very little public input. The OMB took public comment for the first time on the SCC methodology in November 2013, and the docket indicates that OMB received 108 comments in this solicitation. Many of the comments are critical of the methodology and/or transparency of the SCC development process. There has been no response from OMB, nor any indication how or when OMB plans to respond to these comments.

I agree, and ***I thank Mr. Martin for making the following crucial points:***

1. The IWG allowed very little public input.
2. Most of the comments received on the IWG SCC methodology and process were critical of the methodology and/or transparency of the SCC development process.
3. There has been no response from OMB, nor any indication how or when OMB plans to respond to these comments.

Pp. 50-51:

As I have explained above, the Federal SCC was not designed for integrated resource planning or other Commission decisions, and is inherently and irreducibly uncertain. Therefore, we cannot endorse its use if a single SCC value is selected. However, we also recognize the statutory requirement for a CO_2 externality value; the need to revisit values set in the 1990s; the Commission's desire for a damage costs approach rather than the cost of regulation approach; and the practical constraints on conducting new climate modeling to develop a more appropriate value than the Federal SCC. While we do not endorse the Federal SCC, we have not been able to identify an alternative starting point that is practicable and meets the Commission's stipulations in its October 15, 2014 Notice and Order For Hearing.

As I have already recommended in my rebuttal testimony here, the Commission can either 1) use the 1996 SCC values or 2) use values that are less than those estimated in 1996.[147] ***<u>As a service to this proceeding, I provide the following information:</u>***

- In 1996 the Minnesota PUC established a range of $0.28 to $2.92 per ton (1993 dollars) as the environmental cost of carbon dioxide.
- Translated into 2007 dollars to be consistent with the IWG estimates, this is a range of $0.38 to $3.97 per ton.
- Translated into 2014 dollars, this is a range of $0.42 to $4.43 per ton.[148]

As I have discussed, research conducted over the past two decades indicates that these values may be too high, and the Commission may wish to reduce them. Thus, on the basis of the most recent scientific evidence, the Commission may wish to use SCC estimates (2014 dollars) in the range of about $0.20 to $2.00 per ton, or lower.

P. 51, L 18: Others have reviewed the possible alternatives – not using any SCC in regulatory impact analysis until the science is more advanced; basing the SCC on CO2 prices in existing carbon markets (a cost of regulation approach); the U.S. Government creating and maintaining its own IAM; or simply relying on expert judgment – but ultimately concluded the current IWG process is superior to these alternatives and can be improved.

On the contrary, as I have exhaustively discussed in my rebuttal testimony here, ***<u>many researchers and organizations have have reviewed the possible alternatives and have come to the opposite conclusions.</u>***

P. 53, L 12: We have used the underlying Federal SCC data and applied sound statistical methods to identify the low and high ends of a CO2 environmental

[147] See State Of Minnesota, Office of Administrative Hearings For the Minnesota Public Utilities Commission, "In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3 Findings of Fact, Conclusions, Recommendation," March 22, 1996.

[148] All values estimate using the U.S. Bureau of Economic Analysis (BEA) Implicit Price Deflator (IPD). The IPD, is a by-product of the deflation of GDP, and is derived as the ratio of current-to-constant-dollar GDP (multiplied by 100). It is the weighted average of the detailed price indices used in the deflation of GDP, but they are combined using weights that reflect the composition of GDP in each period. Thus, changes in the implicit price deflator reflect not only changes in prices but also changes in the composition of GDP. It is issued quarterly by BEA. Conceptually, the IPD measures the general price level of all final goods and services (including government) produced during a specific period. Thus, the IPD is the only official index which attempts to measure overall price behavior of all goods and services in the nation, and should be used in deflating the SCC estimates,

cost range that reflects a reasonable probability of including the future climate change damage value. Our range, because it uses statistical percentiles, excludes very low and negative SCC values, as well as very high SCC values, that are represented in the IAM results but have a low probability of occurring.

<u>This statement violates a cardinal principle of Statistics 101</u>: No matter how sound or sophisticated the statistical techniques used, if they are applied to faulty or unreliable data the results will not be valid, robust, or reliable. In other words, "garbage in, garbage out." As I have exhaustively discussed in my rebuttal testimony here, the Federal SCC data are simply unreliable and invalid.

P. 58, L 3:

WHAT RANGE OF CO2 VALUES RESULTED FROM THE 25TH AND 75TH PERCENTILES?

A. As shown in Figure 8, the low end of the resulting range – the 25th percentile at 5 percent discount rate – was $2.54 (in $2014 per short ton, for emissions in 2020). The high end – the 75th percentile at 2.5 percent discount rate – was $67.73 7 (in $2014 per short ton, for emissions in 2020).

Given all of the serious flaws in the Federal IWG SCC process and data that I have identified here and in my other testimonies and exhibits in this proceeding, ***<u>these estimates are meaningless.</u>***

Pp. 59-60:

We decided the least subjective method was to equally weight the SCC values for each discount rate at each end of the range. Referring back to Figure 7, equally weighting the three discount rate values at the 25th percentile ($2.54, $13.31 and $21.13) results in a low bound of $12.33 per short ton for emissions in 2020. Equally weighting the three discount rate values at the 75th percentile ($13.28, $44.40 and $67.73) results in a high bound of $41.80 per short ton for emissions in 2020.

Retaining and equally weighting all three discount rates used by the IWG is neutral on the question of discount rate choice. This, in our view, allows the Commission to avoid entering into lengthy and unresolved (perhaps unresolvable) debates regarding the appropriate discount rate for long-term environmental problems. There are rationales in the environmental economics literature for other discount rates, both higher and lower than those the IWG used. If future updates of the Federal SCC use other discount rates, whether higher or lower, our proposed approach would be able to incorporate the updated discount rates and give them equal weight.

<u>These are not valid statements.</u> Using the flawed IWG discount rates does not really permit "the Commission to avoid entering into lengthy and unresolved (perhaps unresolvable) debates regarding the appropriate discount rate for long-term environmental problems." Ignoring the problem and using flawed data do not provide an acceptable solution to the problem.

Further, does the Commission intend to revise all of its rulemakings, proceedings, and decisions every several years as the Federal SCC estimates change radically? To begin with, the differences in the 2010 and 2013 SCC estimates are so large and of such immense potential significance as to raise serious questions as to their validity – especially since, prior to February 2010 the "official" Federal government estimate of the value of SCC was zero. If any valid Federal government economic estimates, such as GDP or unemployment, were revised by 30 - 50 percent within a three year period it would represent a scandal and a farce. For example, in 2010, U.S. GDP was estimated to be about $14.6 trillion.[149] While BEA always makes slight revisions to its GDP estimates in subsequent years, it is inconceivable that in 2013 it would have published a revised estimate of 2010 U.S. GDP in the range of $22 trillion.

Finally, EPA stated that "The U.S. government has committed to updating the current estimates as the science and economic understanding of climate change and its impacts on society improves over time."[150] Thus, it is likely that the current SCC estimates will be repeatedly and substantially revised over time – perhaps even in both directions. How useful or relevant can the SCC estimates be if they continually change dramatically over time? This also raises the question of whether regulatory decisions of this Commission based on one set of SCC estimates will be revisited as the estimates change every few years by 50 percent or more in either direction.

p. 61, L 20: Otherwise, our method makes no subjective judgments because it uses all IAM results, socioeconomic/emissions futures, and discount rates. We do not claim to know that, for example, FUND is more accurate than PAGE, or that one of the socioeconomic/emissions futures is more likely than another. On the most explicitly normative question – discount rate choice – we retain and equally weight the three discount rate values used by the IWG.

This is a seriously flawed statement – see my answers above to Mr. Martin's statements on Pp. 9-10, P. 19, L. 2, and Pp. 46-47.

P. 63, L. 9: "In other words, there is a 3-in-4 chance that our underlying statistics capture the value of future climate change damages as predicted by the IAMs."

This is another example of the misuse of statistics and probability theory.

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[149]Obtained from the U.S. Bureau of Economic Analysis web site www.bea.gov.
[150]U.S. Environmental Protection Agency, "The Social Cost of Carbon: Estimating the Benefits of Reducing Greenhouse Gas Emissions," www.epa.gov/climatechange.

The value of future climate change damages as predicted by the IAMs is simply a meaningless number – as I have emphasized throughout my testimony here. Therefore, a 75 percent probability of capturing a meaningless number is a meaningless statement.

p. 67, L 14: The Federal SCC Appropriately reflects the absence of consensus on discount rate. Our approach:

- **Retains all three discount rates used by the IWG and weights them equally. There are arguments for both higher and lower discount rates than those used by the IWG, but these would require new modeling since they are not published in the SCC reports. In the event the IWG updates the SCC in the future and uses different discount rates, our approach would be able to integrate these rates and weight them equally.**
- **Uses statistically sound methods. Our approach uses appropriate statistics, the median and percentiles, to derive a range from the non-normal probability distribution of Federal SCC values.**

This is a seriously flawed statement – see my answers above to Mr. Martin's statements on Pp. 9-10, P. 19, L. 2, 46-47. And p. 61, L 20.

P. 68, L 8: the Federal SCC minimizes subjective judgments. Other than the question of risk tolerance in choosing to base our range on the 25th and 75th percentiles, our approach does not require subjective judgments. It retains all IAM results, socioeconomic/emissions scenarios, and discount rates.

It is simply not true that "the Federal SCC minimizes subjective judgments." It is just the opposite, as I have exhaustively discussed here and in my other testimonies and exhibits in this proceeding. The SCC is not objective or scientifically valid.

As the Institute for Energy Research has noted in its assessment of the IWG SCC:

> The Administration is treating the SCC as if it is a scientifically valid, objective fact of the external world, akin to the charge on an electron or the boiling point of water at sea level. However, the SCC is no such thing, at least in our present state of understanding. Rather, the SCC is an arbitrary output from very speculative computer models. It can be adjusted up or down as the analyst wishes, simply by changing a few key parameter choices. Simply by adjusting the parameter and modelling choices in plausible ways, a knowledgeable economist can generate SCC estimates that are very high, very low, or even *negative* -- meaning that carbon dioxide emissions actually shower "positive externalities" on humans beyond the direct benefits to the emitters, and

therefore should (according to the Administration's logic) receive federal subsidies.[151]

[151] Institute for Energy Research, "Comment on Technical Support Document: Technical Update of the Social Cost of Carbon For Regulatory Impact Analysis Under Executive Order No. 12866, op. cit.

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

In the Matter of the Further Investigation in to Environmental and Socioeconomic Costs Under Minnesota Statute 216B.2422, Subdivision 3

OAH Docket No. 80-2500-31888
MPUC Docket No. E-999-CI-14-643
Exhibit 2
to

Rebuttal Testimony of
Dr. Roger H. Bezdek
August 12, 2015

CLEAN ENERGY ORGANIZATIONS
INFORMATION REQUESTS

Date of Request: July 6, 2015

Requested By: Leigh Currie
Minnesota Center for Environmental Advocacy
26 East Exchange Street, Suite 206
St. Paul, MN 55101-1667
lcurrie@mncenter.org
651-287-4873 (direct)

Attorney for Izaak Walton League of America – Midwest Office, Fresh Energy, Sierra Club, and Minnesota Center for Environmental Advocacy (collectively "Clean Energy Organizations")

Requested From: Peabody Energy

Response Due: July 16, 2015

In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under MN Statute 216B.2422, Subdivision 3

PUC Docket No. E999/CI-14-643

INFORMATION REQUESTS NOS. 2-10 OF CLEAN ENERGY ORGANIZATIONS TO PEABODY ENERGY

To Roger Bezdek:

2. On pages 2, 9, and 16 of his Direct Testimony, Dr. Bezdek references "thousands" of studies demonstrating that carbon dioxide is beneficial to plant growth. Provide citations for the studies that purport to demonstrate that increased carbon dioxide emissions and increased global temperature will result in increased crop production.

RESPONSE:

Please see response contained in the attached Exhibit A.

3. On page 8 of his Direct Testimony, Dr. Bezdek states: "Researchers have thus concluded that IAMs are of little or no value for evaluating alternative climate change policies and estimating the SCC." List the names of the researchers who have reached these conclusions and provide citations to the publications in which those researchers have made those statements.

RESPONSE:

Please see response contained in the attached Exhibit A.

4. On page 26 of his Direct Testimony, Dr. Bezdek states "rigorous assessment of these IAMs by leading economists have concluded that the IAMs are 'close to useless.'" List the name "leading economists" who have reached these conclusions and provide citations to the publications in which those economists have made those statements.

RESPONSE:

Please see response contained in the attached Exhibit A.

To Robert Mendelsohn:

5. On page 4 of his Direct Testimony, Dr. Mendelsohn states: "Ecological models suggest that Minnesota forests would become more productive and have more standing biomass as a result of near term climate change." Provide citations for the ecological models referenced in this statement.

RESPONSE:

Dr. Mendelsohn's views on ecosystem productivity under climate change were formed as part of his research on forests with Professor Sohngen. This research indicates that global forests will increase the supply of timber as a result of climate change. The papers from that work include:

Sohngen, B. and R. Mendelsohn. 2003. "An Optimal Control Model of Forest Carbon Sequestration" *American Journal of Agricultural Economics* **85** 448-457.

Sohngen, B., R. Mendelsohn and R. Sedjo. 2002. "A Global Model of Climate Change Impacts on Timber Markets" *Journal of Agricultural and Resource Economics* **26:** 326-343.

Sohngen, B., R. Mendelsohn and R. Sedjo. 1999. "Forest Management, Conservation and Global Timber Markets" *American Journal of Agricultural Economics* **81:** 1-13.

Sohngen, B. and R. Mendelsohn. 1998. "Valuing The Market Impact of Large-Scale Ecological Change: The Effect of Climate Change on US Timber", *American Economic Review* **88:** 686-710.

Sohngen, B. and R. Mendelsohn. 1997. "A Dynamic Model of Carbon Storage in the United States During Climatic Change." Critical Reviews in Environmental Science and Technology. 27:s309-s321 (Special Edition).

Sohngen, B., R. Mendelsohn, and R. Neilson. 1998. "Predicting CO_2 Emissions From Forests During Climate Change: A Comparison of Natural and Human Response Models", *Ambio* **27:** 509-513.

EXHIBIT A

RESPONSES TO THE INFORMATION REQUESTS NOS. 2-10 OF CLEAN ENERGY ORGANIZATIONS TO PEABODY ENERGY

In the Matter of the PUC Docket No. E999/CI-14-643

Further Investigation into
Environmental and Socioeconomic Costs
Under MN Statute 216B.2422, Subdivision 3

Dr. Roger H. Bezdek
Management Information Services, Inc.

July 14, 2015

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2. On pages 2, 9, and 16 of his Direct Testimony, Dr. Bezdek references "thousands" of studies demonstrating that carbon dioxide is beneficial to plant growth. Provide citations for the studies that purport to demonstrate that increased carbon dioxide emissions and increased global temperature will result in increased crop production.

Bezdek Response

There are indeed thousands of studies demonstrating that carbon dioxide is beneficial to plant growth and that increased carbon dioxide emissions and increased global temperature will result in increased crop production. These have been published by some of the world's most distinguished scientists in books, working papers, conference proceedings, and the most prestigious international peer-reviewed scientific journals. The peer-reviewed journals in which these studies have been published include, among others:

- *Science*
- *Nature*
- *Environmetrics*
- *Climatic Change*
- *Remote Sensing*
- *Journal of the Association for Environmental Resource Economics*
- *Philosophical Transactions of the Royal Society*
- *Global Change Biology*
- *Journal of Agronomy & Crop Science*
- *Geophysical Research Letters,*
- *Applied Vegetation Science*
- *Agricultural and Forest Meteorology*
- *Journal of Climate*
- *Nature Geoscience*
- *Plant, Cell and Environment*
- *Climate Dynamics*
- *European Journal of Entomology*
- *International Journal of Environmental Research and Public Health*
- *New Scientist*
- *Plant, Cell and Environment, New Phytologist*
- *Journal of Integrative Plant Biology*
- *Agronomy Journal*
- *Journal of the American Society of Horticultural Science*
- *Plant Cell, Tissue and Organ Culture*
- *Annals of Applied Biology*
- *Environmental and Experimental Botany*
- *Ecology and Evolution*

- *Journal of Agronomy and Crop Science*
- *Ecological Informatics*
- *Food Chemistry*
- *Ecology Letters*
- *Plant Physiology and Biochemistry*
- *Climate Research*
- *Plant Biology*
- *Field Crops Research*
- *Journal of Applied Entomology*
- *Horticulture, Environment and Biotechnology*
- *Plant, Soil and Environment*
- *Agricultural and Forest Meteorology*
- *American Journal of Botany*
- *Environmental and Experimental Botany*
- *Environmental Earth Sciences*
- *Agriculture, Ecosystems and Environment*
- *Environmental and Experimental Botany*
- *Proceedings of the National Academy of Sciences*
- *Journal of Geophysical Research*
- *Tree Physiology*
- *Journal of Plant Nutrition and Soil Science*
- *Ecology*
- *Agriculture and Rural Development Notes*
- *Soil Biology & Biochemistry.*
- *Evolutionary Ecology Research*
- *Agriculture, Ecosystems and Environment*
- *Environmental Pollution*
- *Tree Physiology*
- *Journal of Plant Growth Regulation*
- *Journal of Biogeography*
- *Crop and Pasture Science*
- *Journal of Ecology*
- *Functional Ecology*
- *Nature Climate Change*
- *Journal of Experimental Marine Biology and Ecology*
- *Annals of Botany*
- *Photosynthetica*
- *Soil Biology and Biochemistry*
- *Ecology Letters*
- *Agricultural and Forest Entomology*
- *Journal of Phycology*
- *Ecology and Evolution*
- *Environmental and Experimental Botany*
- *Journal of Applied Phycology*

- *Ecological Economics*
- *Theoretical and Applied Climatology*

1. Summary of Selected Researchers' Findings

CO_2 is essential for life on earth. CO_2 concentrations in the atmosphere have been much higher in the past, even well before any human industrial activities were emitting the gas.[1] CO_2 is not known to have any negative impacts on human health, and it is essential to plant life and the process of photosynthesis.

Dr. Patrick Moore contradicts the contention that CO_2 is a pollutant: "What about the undisputed fact that CO_2 is the most important food for all life on earth? Every green plant needs CO_2 in order to produce sugars that are the primary energy source for every plant and animal. To be fair, water is also essential to living things, as are nitrogen, potassium, phosphorus, and many other minor elements. But CO_2 is the most important food, as all life on earth is carbon-based, and the carbon comes from CO_2 in the atmosphere. Without CO_2 life on this planet would not exist. How important is that?"[2] He further states that "plants grow best at a CO_2 concentration of around 1,500 ppm, which increases plant yield by 25-65 percent. The present CO_2 level in the global atmosphere is about 390 ppm. Thus, trees and other plants would benefit from a level of CO_2 about four times higher than it is today. There is solid evidence that trees are already showing increased growth rates due to rising CO_2 levels.[3]

Dr. Craig Idso and Dr. Sherwood Idso identify 55 benefits from increased atmospheric CO_2 concentrations. Plants grow faster, their photosynthetic rate is increased, and plants increase their biomass under higher atmospheric CO_2 concentrations, and they have decreased water demands and suffer less air pollution stress. In particular, this decreases soil erosion by expanding plant cover. Biodiversity is also enhanced because it increases the niche security of many different forms of plants, and biomass gains a greater ability to remove that carbon from the atmosphere, creating a natural negative feedback on CO_2.[4]

More generally, advances in technology and scientific expertise since the Industrial Revolution have led to vast improvements in agricultural yield and production values.[5] More efficient machinery and improved plant cultivars, for example, paved the way for higher crop yields and increased global food production. And with ever-

[1]United States Senate Environment and Public Works Committee, *Critical Thinking on Climate Change Empirical Evidence to Consider Before Taking Regulatory Action and Implementing Economic Policies*, Minority Report, September 4, 2014.
[2]Patrick Moore, *Confessions of a Greenpeace Dropout*, Beatty St. Publishing, Inc. 2013, p. 360.
[3]Ibid, p. 364.
[4]*Farming, Fishing, Forestry, and Hunting in an Era of Changing Climate: Hearing Before the Subcommittee. on Green Jobs and the New Economy of the Senate Committee on Environment and Public Works,* 113th Cong. 5 (2014) (responses to questions for the record of Dr. David R. Legates).
[5]See Craig Idso, "The Positive Externalities of Carbon Dioxide," Center for the Study of Carbon Dioxide and Global Change, 2013, www.co2science.org.

increasing world population, the increase in food production was a welcome societal benefit. But what remained largely unknown to society at that time was the birth of an ancillary aid to agriculture that would confer great benefits throughout the decades and centuries to come. The source of that aid is atmospheric CO_2. Ironically, however, the modern air's CO_2 content is currently viewed by many as a source of concern, not a benefit.

Specifically, thousands of laboratory and field studies have documented growth-enhancing, water-conserving, and stress-alleviating benefits of atmospheric CO_2 enrichment on plants.[6] For a 300-ppm increase in the air's CO_2 content, such benefits typically enhance herbaceous plant biomass by around 30 to 35 percent, which represents an important positive externality entirely absent from current state-of-the-art SCC calculations.

At a fundamental level, carbon dioxide is the basis of nearly all life on Earth. It is the primary raw material or "food" utilized by the vast majority of plants to produce the organic matter out of which they construct their tissues, which subsequently become the ultimate source of food for nearly all animals and humans. Consequently, the more CO_2 there is in the air, the better plants grow, as has been demonstrated in literally thousands of laboratory and field experiments.[7] And the better plants grow, the more food there is available to sustain the entire biosphere.

The idea that an increase in the air's CO_2 content may be of benefit to the biosphere can be traced back over 200 years. As early as 1804, for example, de Saussure showed that peas exposed to high CO_2 concentrations grew better than control plants in ambient air; and work conducted in the early 1900s significantly increased the number of species in which this growth-enhancing effect of atmospheric CO_2 enrichment was observed to occur.[8] In fact, by the time a group of scientists convened at Duke University in 1977 for a workshop on Anticipated Plant Responses to Global Carbon Dioxide Enrichment, an annotated bibliography of 590 scientific studies dealing with CO_2 effects on vegetation had been prepared.[9] This body of research demonstrated that increased levels of atmospheric CO_2 generally produce increases in plant photosynthesis, decreases in plant water loss by transpiration, increases in leaf area, and increases in plant branch and fruit numbers, to name but a few of the most commonly reported benefits. And five years later, at the International Conference on Rising Atmospheric Carbon Dioxide and Plant Productivity, it was concluded that a

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[6]C.D. Idso and Singer, S.F., *Climate Change Reconsidered: 2009 Report of the Nongovernmental International Panel on Climate Change (NIPCC)*. The Heartland Institute, Chicago, Illinois, USA, 2009; C.D. Idso and Idso, S.B., *The Many Benefits of Atmospheric CO_2 Enrichment*. Vales Lake Publishing, LLC, Pueblo West, Colorado, USA, 2011.

[7]Idso and Singer, op. cit.

[8]E. Demoussy, "Sur, La Vegetation Dans Des Atmospheres Riches En Acide Carbonique." *Comptes Rendus Academy of Science Paris* 136: 325-328; 138: 291-293; 139: 883-885, 1902-1904; M.B. Cummings, and Jones, C.H., "*The Aerial Fertilization of Plants With Carbon Dioxide*." Vermont Agricultural Station Bulletin No. 211, 1918.

[9]Strain, B.R., *Report of the Workshop on Anticipated Plant Responses to Global Carbon Dioxide Enrichment*. Department of Botany, Duke University, Durham, NC, 1978.

doubling of the air's CO_2 concentration would likely lead to a 50 percent increase in photosynthesis in C_3 plants, a doubling of water use efficiency in both C_3 and C_4 plants, significant increases in biological nitrogen fixation in almost all biological systems, and an increase in the ability of plants to adapt to a variety of environmental stresses.[10]

Numerous studies conducted on hundreds of different plant species testify to the very real and measurable growth-enhancing, water-saving, and stress-alleviating advantages that elevated atmospheric CO_2 concentrations have for Earth's plants.[11] In commenting on these and many other CO_2-related benefits, Wittwer wrote that "the 'green revolution' has coincided with the period of recorded rapid increase in concentration of atmospheric carbon dioxide, and it seems likely that some credit for the improved [crop] yields should be laid at the door of the CO_2 buildup."[12] Similarly, Allen et al. concluded that yields of soybeans may have been rising since at least 1800 "due to global carbon dioxide increases,"[13] while more recently, Cunniff et al. hypothesized that the rise in atmospheric CO_2 following deglaciation of the most recent planetary ice age, was the trigger that launched the global agricultural enterprise.[14]

In a test of this hypothesis, Cunniff et al. designed "a controlled environment experiment using five modern-day representatives of wild C_4 crop progenitors, all 'founder crops' from a variety of independent centers," which were grown individually in growth chambers maintained at atmospheric CO_2 concentrations of 180, 280 and 380 ppm, characteristic of glacial, post-glacial and modern times, respectively. The results revealed that the 100-ppm increase in CO_2 from glacial to postglacial levels (180 to 280 ppm) "caused a significant gain in vegetative biomass of up to 40 percent," together with "a reduction in the transpiration rate via decreases in stomatal conductance of ~35 percent," which led to "a 70 percent increase in water use efficiency, and a much greater productivity potential in water-limited conditions."[15]

In discussing their results, the five researchers concluded that "these key physiological changes could have greatly enhanced the productivity of wild crop progenitors after deglaciation ... improving the productivity and survival of these wild C_4 crop progenitors in early agricultural systems."[16] And in this regard, they note that "the lowered water requirements of C_4 crop progenitors under increased CO_2 would have been particularly beneficial in the arid climatic regions where these plants were domesticated."[17] For comparative purposes, they also included one C_3 species in their

[10]E.R. Lemon, (Ed.), *CO_2 and Plants: The Response of Plants to Rising Levels of Atmospheric Carbon Dioxide*. Westview Press, Boulder, CO, 1983. C_3 plants are those in which photosynthesis takes place throughout the leaf; C_4 plants are those in which photosynthesis takes place in inner cells.
[11]Idso and Singer, op. cit.; Idso and Idso, op. cit.
[12]S.H. Wittwer, "Carbon Dioxide and Crop Productivity." *New Scientist* 95: 233-234, 1982.
[13]Allen et al. "Response of Vegetation to Rising Carbon Dioxide: Photosynthesis, Biomass, and Seed Yield of Soybean," *Global Biogeochemical Cycles* 1: 1-14, 1987.
[14]Cunniff et al., "Response of Wild C_4 Crop Progenitors to Subambient CO_2 Highlights a Possible Role In the Origin of Agriculture." *Global Change Biology* 14: 576-587, 2008.
[15]Ibid.
[16]Ibid.
[17]Ibid.

study – *Hordeum spontaneum* K. Koch – and they report that it "showed a near-doubling in biomass compared with [the] 40 percent increase in the C_4 species under growth treatments equivalent to the postglacial CO_2 rise."[18] In light of these and other similar findings,[19] it can be appreciated that the civilizations of the past, which could not have existed without agriculture, were largely made possible by the increase in the air's CO_2 content that accompanied deglaciation, and that the peoples of the Earth today are likewise indebted to this phenomenon, as well as the additional 110 ppm of CO_2 the atmosphere has subsequently acquired. And as the CO_2 concentration of the air continues to rise in the future, this positive externality of enhanced crop production will benefit society in the years, decades, and centuries to come.

Recognizing these positive impacts of rising CO_2 concentrations, some researchers have begun to explore ways in which to increase the influence of atmospheric CO_2 on crop yields even more. Many of these efforts are devoted to identifying "super" hybrid cultivars.[20] For example, De Costa et al., for example, grew 16 genotypes of rice (*Oryza sativa* L.) under standard lowland paddy culture with adequate water and nutrients within open-top chambers maintained at either the ambient atmospheric CO_2 concentration (370 ppm) or at an elevated CO_2 concentration (570 ppm).[21] Their results indicated that the CO_2-induced enhancement of the light-saturated net photosynthetic rates of the 16 different genotypes during the grain-filling period of growth ranged from +2 percent to +185 percent in the yala season (May to August) and from +22 percent to +320 percent in the maha season (November to March). Similarly, they found that the CO_2-induced enhancement of the grain yields of the 16 different genotypes ranged from +4 percent to +175 percent in the yala season and from -5 percent to +64 percent in the maha season.

In commenting on the findings, the five Sri Lanka researchers say their results "demonstrate the significant genotypic variation that exists within the rice germplasm, in the response to increased atmospheric CO_2 of yield and its correlated physiological parameters," and they suggest that "the significant genotypic variation in this response means that genotypes that are highly responsive to elevated CO_2 may be selected and incorporated into breeding programs to produce new rice varieties which would be higher yielding in a future high CO_2 climate."[22] Selecting such genotypes, as per the results experienced in the De Costa et al. study, has the potential to increase the CO_2 monetary benefit per ton of rice by a factor of four or more.

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[18] Ibid.
[19] H.S. Mayeux et al., "Yield of Wheat Across a Subambient Carbon Dioxide Gradient." *Global Change Biology* 3: 269-278, 1997.
[20] L. Yang et al., "Yield Formation of CO_2-Enriched Inter-Subspecific Hybrid Rice Cultivar Liangyoupeijiu Under Fully Open-Air Condition in a Warm Sub-Tropical Climate." *Agriculture, Ecosystems and Environment* 129: 193-200, 2009.
[21] W.A. De Costa et al. "Genotypic Variation in the Response of Rice (*Oryza Sativa* L.) to Increased Atmospheric Carbon Dioxide and Its Physiological Basis." *Journal of Agronomy & Crop Science* 193: 117-130, 2007.
[22] Ibid.

Atmospheric CO_2 enrichment also tends to enhance growth and improve plant functions in the face of environmental constraints. For example, Conway and Toenniessen, describe how ameliorating four such impediments to plant productivity – soil infertility, weeds, insects and diseases, and drought – significantly increases crop yields.[23] Therefore, reducing the negative consequences of each of these yield-reducing factors via human ingenuity should boost crop productivity in an additive manner. And a continuation of the historical increase in the air's CO_2 content should boost crop productivity even more.

In the case of soil infertility, many experiments have demonstrated that even when important nutrients are present in the soil in less than optimal amounts, enriching the air with CO_2 still boosts crop yields. With respect to the soil of an African farm where their "genetic and agro-ecological technologies" have been applied, for example, Conway and Toenniessen speak of "a severe lack of phosphorus and shortages of nitrogen." Yet even in such adverse situations, atmospheric CO_2 enrichment has been reported to enhance plant growth.[24] And if supplemental fertilization is provided as described by Conway and Toenniessen, even larger CO_2-induced benefits above and beyond those provided by the extra nitrogen and phosphorus applied to the soil would likely be realized.

In the case of weeds, Conway and Toenniessen speak of one of Africa's staple crops, maize, being "attacked by the parasitic weed Striga (*Striga hermonthica*), which sucks nutrients from roots." This weed also infects many other C_4 crops of the semi-arid tropics, such as sorghum, sugar cane and millet, as well as the C_3 crop rice, particularly throughout much of Africa, where it is currently one of the region's most economically damaging parasitic weeds. Here, too, studies have shown that atmospheric CO_2 enrichment greatly reduces the damage done by this devastating weed.[25]

In the case of insects and plant diseases, atmospheric CO_2 enrichment also helps prevent crop losses. For example, in a study of diseased tomato plants infected with the fungal pathogen *Phytophthora parasitica*, which attacks plant roots inducing water stress that decreases yields, the growth-promoting effect of a doubling of the air's

[23]G. Conway and G. Toenniessen, "Science for African Food Security." *Science* 299: 1187-1188, 2003.
[24]D.J. Barrett, Richardson, A.E. and Gifford, R.M., "Elevated Atmospheric CO_2 Concentrations Increase Wheat Root Phosphatase Activity When Growth is Limited by Phosphorus," *Australian Journal of Plant Physiology,* 25: 87-93, 1998; P.A. Niklaus, Leadley, P.W., Stocklin, J. and Korner, C., "Nutrient Relations in Calcareous Grassland Under Elevated CO_2," *Oecologia,* 116: 67-75, 1998; H.Y. Kim, Lieffering, M., Kobayashi, K., Okada, M., Mitchell, M.W. and Gumpertz, M., "Effects of Free-Air CO2 Enrichment And Nitrogen Supply On The Yield Of Temperate Paddy Rice Crops," *Field Crops Research* 83: 261-270, 2003; A. Rogers, Gibon, Y., Stitt, M., Morgan, P.B., Bernacchi, C.J., Ort, D.R. and Long, S.P., "Increased C Availability at Elevated Carbon Dioxide Concentration Improves N Assimilation in a Legume," *Plant, Cell and Environment* 29: 1651-1658, 2006.
[25]J.R. Watling and Press, M.C., "How is the Relationship Between the C_4 Cereal *Sorghum Bicolor* and the C_3 Root Hemi-Parasites *Striga Hermonthica* and *Striga Asiatica* Affected by Elevated CO_2?" *Plant, Cell and Environment* 20: 1292-1300, 1997; J.R. Watling, and Press, M.C., "Infection With the Parasitic Angiosperm *Striga Hermonthica* Influences the Response of the C_3 Cereal *Oryza Sativa* to Elevated CO_2." *Global Change Biology* 6: 919-930, 2000.

CO_2 content completely counterbalanced the yield-reducing effect of the pathogen.[26] Similarly, in a review of impacts and responses of herbivorous insects maintained for relatively long periods of time in CO_2-enriched environments, as described in some 30-plus different studies, Whittaker noted that insect populations, on average, have been unaffected by the extra CO_2.[27] And since plant growth is nearly universally stimulated in air of elevated CO_2 concentration, Earth's crops should therefore gain a relative advantage over herbivorous insects in a high-CO_2 world of the future.

Finally, in the case of drought, there is a nearly universal bettering of plant water use efficiency that is induced by atmospheric CO_2 enrichment. For example, Fleisher et al., for example, grew potato plants (*Solanum tuberosum* cv. Kennebec) from "seed tubers" in soil-plant-atmosphere research chambers maintained at daytime atmospheric CO_2 concentrations of either 370 or 740 ppm under well-watered and progressively water-stressed conditions.[28] And in doing so, they found that "total biomass, yield, and water use efficiency increased under elevated CO_2, with the largest percent increases occurring at irrigations that induced the most water stress." In addition, they report that "water use efficiency was nearly doubled under enriched CO_2 when expressed on a tuber fresh weight basis." These results indicate, in the words of the three researchers, that "increases in potato gas exchange, dry matter production and yield with elevated CO_2 are consistent at various levels of water stress as compared with ambient CO_2," providing what is currently required and what will be even more urgently required as the world's population continues to grow: Significantly enhanced food production per unit of water used.[29]

The same situation exists with respect to excessive heat, ozone pollution, light stress, soil toxicity and most any other environmental constraints. Atmospheric CO_2 enrichment generally tends to enhance growth and improve plant functions to minimize or overcome such challenges.[30] As researchers continue to explore these benefits and farmers select cultivars to maximize them, the monetary value of this positive externality of raising the global CO_2 concentration of the atmosphere will increase.

It is thus far more likely to expect the monetary benefits of rising atmospheric CO_2 to accrue in the future than it is to expect the accrual of monetary damages and that the modern rise in the air's CO_2 content is providing a significant economic benefit

[26]N.S. Jwa, and Walling, L.L., "Influence of Elevated CO_2 Concentration on Disease Development in Tomato." *New Phytologist* 149: 509-518, 2001.
[27]J.B. Whittaker, "Impacts and Responses at Population Level of Herbivorous Insects to Elevated CO_2." *European Journal of Entomology* 96: 149-156, 1999.
[28]D.H. Fleisher et al., "Elevated Carbon Dioxide and Water Stress Effects on Potato Canopy Gas Exchange, Water Use, and Productivity." *Agricultural and Forest Meteorology* 148: 1109-1122, 2008.
[29]There are numerous studies that have produced similar results, including (J. De Luis et al., "Elevated CO_2 Enhances Plant Growth in Droughted N2-Fixing Alfalfa Without Improving Water Stress." *Physiologia Plantarum* 107: 84-89, 1999; S. Kyei-Boahen, et al., "Gas Exchange of Carrot Leaves in Response to Elevated CO_2 Concentration. *Photosynthetica* 41: 597-603, 2003. 2003; S.H. Kim et al., "Canopy Photosynthesis, Evapotranspiration, Leaf Nitrogen, and Transcription Profiles of Maize in Response to CO_2 Enrichment. *Global Change Biology* 12: 588-600, 2003.
[30]Idso and Singer, 2009, op. cit.; Idso and Idso, op. cit.

to global crop production. As Sylvan Wittwer, the father of agricultural research on this topic, so eloquently stated nearly two decades ago:

> "The rising level of atmospheric CO_2 could be the one global natural resource that is progressively increasing food production and total biological output, in a world of otherwise diminishing natural resources of land, water, energy, minerals, and fertilizer. It is a means of inadvertently increasing the productivity of farming systems and other photosynthetically active ecosystems. The effects know no boundaries and both developing and developed countries are, and will be, sharing equally," for "the rising level of atmospheric CO_2 is a universally free premium, gaining in magnitude with time, on which we all can reckon for the foreseeable future".[31]

The relationship described above was quantified by Wittwer, who used data pertaining to atmospheric CO_2 emissions, food production, and human population. Standardized to a value of unity in 1961, each of these datasets has experienced rapid and interlinked growth over the past five decades. Rising global population has led to rising CO_2 emissions and rising CO_2 emissions have benefited food production.[32]

The very real positive externality of inadvertent atmospheric CO_2 enrichment must be considered in all studies examining the SCC, and its observationally-deduced effects must be given premier weighting over the speculative negative externalities presumed to occur in computer model projections of global warming. Until that time, little if any weight should be placed on current SCC estimates and dire predictions derived from them.

Thus:

- To quote former astronaut and U.S. Senator Harrison Schmitt and professor William Happer of Princeton, former head of research at DOE, "Nowadays, in an age of rising population and scarcities of food and water in some regions, it's a wonder that humanitarians aren't clamoring for more atmospheric carbon dioxide."[33]
- To quote Professor Richard Lindzen of MIT, "Currently elevated levels of carbon dioxide have contributed to increases in agricultural productivity. Indeed, climatologists before the recent global warming hysteria referred to warm periods as a "climate optima."[34]

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[31] S.H. Wittwer, "*Food, Climate, and Carbon Dioxide: The Global Environment and World Food Production*." Lewis Publishers, Boca Raton, FL, 1995.
[32] Ibid.
[33] Harrison H. Schmitt and William Happer, "In Defense of Carbon Dioxide," *Wall Street Journal*, May 8, 2013.
[34] Richard S. Lindzen, "The Political Assault on Climate Skeptics, *Wall Street Journal*, March 4, 2015.

- To quote Dr. Ivar Giaever, a Nobel Laureate in physics, "No one mentions how important CO_2 is for plant growth. It's a wonderful thing. Plants are really starving. They don't talk about how good it is for agriculture that CO_2 is increasing,"[35]

Giaever got Nobel for superconductors, and later was a long time tobacco helper:
http://www.desmogblog.com/2016/01/04/ivar-giaever-nobel-icon-for-climate-deniers

2. Examples of citations for the studies that demonstrate that increased carbon dioxide emissions and increased global temperature will result in increased crop production

Keith Idso testified for Western Fuels Association in earlier Minnesota SCC hearings, as did Lindzen.
http://www.desmogblog.com/center-study-carbon-dioxide-and-global-change Fossil funding

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http://www.co2science.org/articles/V4/N41/EDIT.php
This is an editorial by them on the fossil-funded website they own.

3. On page 8 of his Direct Testimony, Dr. Bezdek states: "Researchers have thus concluded that IAMs are of little or no value for evaluating alternative climate change policies and estimating the SCC." List the names of the researchers who have reached these conclusions and provide citations to the publications in which those researchers have made those statements.

Bezdek Response

Numerous distinguished researchers have concluded that IAMs are of little or no value for evaluating alternative climate change policies and estimating the SCC. Their studies have been published in books, working papers, conference proceedings, and in the most prestigious international peer-reviewed scientific journals. The peer-reviewed journals in which these studies have been published include, among others:

- *Science*
- *American Economic Review*
- *Review of Economics and Statistics*
- *Proceedings of the National Academy of Science*
- *Review of Environmental Economics and Policy*
- *Journal of Economic Literature*
- *Journal of Environmental Economics and Management*
- *Journal of Legal Studies*
- *Global Environmental Change*
- *University of Chicago Law Review*
- *Climatic Change*
- *Environmental Modeling and Assessment*
- *Climate and Development*
- *Climatic Change*
- *Integrated Assessment*
- *Energy Economics*
- *Integrated Assessment Journal*
- *Environmental and Resource Economics*
- *Energy Policy*
- *Environmental Values*
- *Environment and Development Economics*
- *Economics*
- *Global Environmental Change*
- *World Economics*
- *International Journal of Forecasting*
- *National Institute Economic Review*
- *Energy Journal*
- *Energy*
- *Energy Economics*

- *Ecological Economics*
- *Regulation*
- *Journal of Environmental Systems*
- *Climate Policy*
- *Land Economics*
- *Ecology and Society*

1. Summary of Selected Researchers' Findings:

- IAMs form the basis for the SCC estimates.[36] However, as Robert Pindyck notes the IAM models "are so deeply flawed as to be close to useless as tools for policy analysis. Worse yet, their use suggests a level of knowledge and precision that is simply illusory, and can be highly misleading."[37]
- In his 2008 Richard T. Ely lecture at the annual meeting of the American Economic Association, Sir Nicholas Stern stated: "However, as the Stern Review stressed, such analysis (IAM) has very serious weaknesses and must not be taken too literally. It is generally forced to aggregate into a single good, and in so doing misses a great deal of the crucial detail of impacts -- on different dimensions and in different locations -- which should guide risk analysis. It is forced to make assumptions about rates and structures of growth over many centuries. Further, it will be sensitive to the specification of ethical frameworks and parameters. Thus its estimates of marginal social costs of damages provide a very weak foundation for policy. This type of modeling does have an important supplementary place in an analysis, but all too often it has been applied naively and transformed into the central plank of an argument."[38]
- One of the most contentious elements of IAM SCC estimates concerns how estimates of damage are related to projected global temperature changes. In general, most IAMs relate damages to increases in temperature, T, using a quadratic equation that calculates damages as a function of temperature changes. There is no economic basis for using a quadratic equation, nor is there any scientific justification for the parameters of the equations that determine how fast damages increase as temperatures climb. The result is that the structural of

[36]For a detailed review and analysis of IAMs, see Richard S.J. Tol, "Integrated Assessment Modeling," Research Unit Sustainability and Global Change, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg, Germany, Working Paper FNU-102, 2006, https://fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/efieaiamwp.pdf, and Edward Parson and Karen Fisher-Vanden, "Integrated Assessment Models of Global Climate Change," *Annual Review of Energy and the Environment 1997*, 22:589–628.
[37]Robert S. Pindyck, "Climate Change Policy: What Do The Models Tell Us?" National Bureau of Economic Research, Working Paper 19244, July 2013; © 2013 by Robert S. Pindyck.
[38]Stern is professor of economics at the London School of Economics and Political Science and the lead author on the 2006 Stern Report on Global Warming. The source for this quote is found in Stern, "The Economics of Climate Change," *American Economic Review: Papers and Proceedings*, Vol. 98, No. 2, p. 3, 2008.

these equations contain the unstated assumption that damages increase at an increasing rate as temperatures increase. In their review of IAMs, Rachel Warren, C. Hope, Michael Mastrandrea, Richard S. J. Tol, W. N. Adger, and I. Lorenzoni thus concluded that: "The assumption of a quadratic dependence of damage on temperature rise is even less grounded in any empirical evidence. Our review of the literature uncovered no rationale, whether empirical or theoretical, for adopting a quadratic form for the damage function – although the practice is endemic in IAMs.[39]

- In his review of IAMs Pindyck also noted that the "loss functions" are not based on any economic theory, but, rather, "They are just arbitrary functions, made up to describe how GDP goes down when T goes up."[40] MISI economists found that the IAM methodology requires that a large number of assumptions be made to complete the linkages between levels of human activity, today and in the future, and the environmental consequences of that activity today and for generations to come. However, even small variations in the size of the assumed inputs can lead to very large and significant differences in the results produced by the IWG's methodology -- differences in results that are so great as to leave the resulting policy recommendations highly questionable.[41]
- IAMs rely critically on damage functions and are usually based on only one country or region because the literature on the topic of environmentally induced costs (or benefits) is very limited, except in agriculture. For example, as described by Michael Mastrandrea: "Market and non-market damages in DICE are based on studies of impacts on the United States that are then scaled up or down for application to other regions. Many of the estimates to which market damages in PAGE are calibrated are also based on an extrapolation of studies of the United States. Only FUND uses regional and sector-specific estimates. However, in some sectors these estimates also originate in one country, or may be dominated by estimates from one region. For example, in the energy sector, the sector which accounts for most of the economic damages in FUND, estimates for the UK are scaled across the world." [42]
- While some progress is being made in using IAMs to estimate the potential damages from climate change, at present the research is still so limited that one would be hard pressed to describe the results as little more than educated guesses. As Mastrandrea states: "Although the differences in formulation across models do not allow a perfectly parallel comparison, it is clear that the relationship between temperature increase and climate damages varies significantly among IAMs."[43]

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[39]See Rachel Warren, et al, "Spotlighting Impacts Functions in Integrated Assessment," Research Report Prepared for the Stern Review on the Economics of Climate Change, Tyndall Centre for Climate Change Research Working Paper 91, September 2006, p. 172.
[40]Pindyck, op cit. p. 11.
[41]Management Information Services, Inc., *The Social Costs of Carbon? No, the Social Benefits of Carbon*, prepared for the American Coalition for Clean Coal Electricity, Washington, D.C., January 2014.
[42]Michael D. Mastrandrea, *Calculating the Benefits of Climate Policy: Examining the Assumptions of Integrated Assessment Models,* Pew Center on Global Climate Change, 2009, p. 17.
[43]Mastrandrea, op cit. p. 20.

- Robert Pindyck notes that while the IAM damage functions relate changes in GDP levels to changes in global temperature, a more persuasive argument is that temperature changes would impact the rate of GDP growth and not the level. Currently most IAMs estimate an impact on income, but not capital. Concerning this issue, Pindyck states: "First, some effects of warming will be permanent; e.g., destruction of ecosystems and deaths from weather extremes. A growth rate effect allows warming to have a permanent impact. Second, the resources needed to counter the impact of warming will reduce those available for R&D and capital investment, reducing growth. Third, there is some empirical support for a growth rate effect. Using data on temperatures and precipitation over 50 years for a panel of 136 countries, Dell, Jones and Olken have shown that higher temperatures reduce GDP growth rates but not levels. Likewise, using data for 147 countries during 1950 to 2007, Bansal and Ochoa show that increases in temperature have a negative impact on economic growth.[44]
- Elizabeth Stanton, Frank Ackerman, and Sivan Kartha also note that subtracting damages from output with no effect on capital, production or consumption in following periods is an "unrealistic assumption."[45]
- Specifically, as Michael Mastrandrea notes, "In recognition of the fact that the parameters of the damage functions are questionable at best, IAM models increasingly include probability distributions of the parameters to explicitly address the issue of uncertainty. While the use of probability distributions – using a range of values around a norm – serves to acknowledge that we have no real scientific evidence to support one value over another – their use introduces another bias into IAM results. Since the structure of the damage functions are quadratic equations, the results of using probability distributions of equation parameters results in so-called "fat tail" impacts that are larger for higher temperature increases than for lower increases.[46]
- An interesting example of the uncertainty and arbitrariness of damage functions can be shown in a comparison of the results of IAM impact studies conducted by Joseph Aldy, Alan Krupnick, Richard Newell, Ian Parry, and William Pizer.[47] They found that there was a significant amount of consistency among several disparate studies of the economic impact of a 2.5C^{o} warming of average global temperatures, compared to pre-industrial levels, by 2100: Five different models predicted economic damages of between 1% and 2% of global GDP. However, although the gross damages estimates were similar, there were huge differences in the studies' estimates of the sources of the damages.[48] The total damages, although similar, reveal large differences in the source of the damages – market

[44]Pindyck, op cit., p. 12.
[45]See Elizabeth Stanton, Frank Ackerman and Sivan Kartha, "Inside the Integrated Assessment Models: Four Issues in Climate Economics," *Climate and Development*, 1 (2009). P.168op. cit.
[46]Mastrandrea, op cit., p. 48.
[47]Joseph E. Aldy, Alan J. Krupnick, Richard G. Newell, Ian W. H. Parry, and William A. Pizer, "Designing Climate Mitigation Policy," *Journal of Economic Literature*, 2010, 48:4, pp. 903–934.
[48]Only market damages were estimated in these studies, and they used the midpoint of a range of damage estimates. Damage categories are not precisely de-lineated in these studies.

impacts, non-market impacts, or catastrophic impact[49] Thus, it must be concluded that the similar results for the total damage estimates occurs because the selection of damage structures and parameters for the different sectors – economic and noneconomic – in the five model results just happened to aggregate to similar total damage values.

- Importantly, almost nothing in the literature of IAMs could be less certain than having a discount rate that is "consistent with estimates provided in the economics literature." Rather, the choice of the discount rate is the most contentious issue in the IAM literature. In 2007 when Nicholas Stern published "The Economics of Climate Change: The Stern Review,"[50] the report was notable because it was the first major report from a well-respected economist that forcefully argued for immediate and major actions to slow the growth of CO_2 emissions. The report was met with a barrage of criticism, including that from William Nordhaus, most of which pointed out that the major reason for the report's conclusions was it has used a discount rate near zero to generate its gloomy outlook.[51]
- In integrated assessment modeling, the uncertainties confronted at each stage of the process are magnified as the uncertainties surrounding each variable in the chain of computations are compounded by the uncertainties found in the next step, creating a "cascade of uncertainties" as one moves through the chain towards final conclusions. The "uncertainty explosion" occurs as these ranges are multiplied to encompass a comprehensive range of future consequences, including physical, economic, social, and political impacts and policy responses.[52] Each set of uncertainties through the IAM process gets magnified at each step until, by the end, it is unclear what reality is.
- The authors of the IPCC Second Assessment report stated "A single aggregated damage function or a 'best guess' climate sensitivity estimate is a very restricted representation of the wide range of beliefs available in the literature or among lead authors about climate sensitivity or climate damages. The cascade of uncertainty implied by coupling the separate probability distributions for emissions and biogeochemical cycle calculations to arrive at concentrations needed to calculate radiative forcing, climate sensitivity, climate impacts, and valuation of such impacts into climate damage functions has yet to be produced in the literature."[53]
- In addition, the level of uncertainty does not remain constant over time. As David Kelly and Charles Kolstad note in their review of IAMs, there are two kinds of

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[49]The figure and related discussion are included here to illustrate that, in general, IAM's produce inconsistent results (as to where and why damages might occur) even though there may be an (apparent) consistency in the level of the overall level of damages calculated by the different models.

[50]Nicholas Stern, *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, U.K. 2007.

[51]See William Nordhaus, "A Review of the Stern Review on the Economics of Climate Change", op. cit. for an good example of a rebuttal to the Stern Review's conclusions.

[52]See IPCC, *Third Assessment Report: Climate Change 2001* (TAR), Chapter 2: "Method and Tools," p. 130. http://www.ipcc.ch/ipccreports/tar/wg2/pdf/wg2TARchap2.pdf.

[53]Ibid. p. 130.

uncertainty, which they label stochastic uncertainty and parametric uncertainty. [54] The latter can be expected to decline over time as scientists learn more about the operation of the global climate system and the value for parameters such as "climate sensitivity" become more accurate. Stochastic uncertainty refers to those phenomena that impact economic or geophysical processes but are not included in the model, processes such as earthquakes, volcanic eruptions, or abrupt economic downturns such as the Global Financial Crisis. A major element of stochastic uncertainty is the fact that we cannot know the future trend of technology or the economy and are, therefore, always susceptible to "surprises".

- Some of the uncertainty currently present in IAMs may gradually lesson over time, and IAM model builders are including modeling techniques such as Monte Carlo analysis and stochastic simulation within their models to address the uncertainties. Nevertheless, for the foreseeable future IAM analysis will be saddled with the fact that the degree of uncertainty within the process is immense and renders any IAM results highly questionable.[55]
- Numerous IAMs have been developed and used to estimate the SCC and evaluate alternative abatement policies. Indeed, the IWG relied critically on IAMs to develop its SCC estimates. However, as Robert Pindyck notes,[56] these models have crucial flaws that make them "close to useless" as tools for policy analysis; for example: 1) Certain inputs (e.g. the discount rate) are arbitrary, but have huge effects on the SCC estimates the models produce; 2) The models' descriptions of the impact of climate change are completely ad hoc, with no theoretical or empirical foundation; 3) The models can tell us nothing about the most important driver of the SCC, the possibility of a catastrophic climate outcome; 4) IAM-based analyses of climate policy create a perception of knowledge and precision, but that perception is illusory and misleading; 5) The damage functions used in most IAMs are completely made up, with no theoretical or empirical foundation -- and yet those damage functions are taken seriously when IAMs are used to analyze climate policy.[57]
- Pindyck concludes that IAMs are of little or no value for evaluating alternative climate change policies and estimating the SCC. On the contrary, an IAM-based analysis suggests a level of knowledge and precision that is nonexistent, and allows the modeler to obtain almost any desired result because key inputs can be chosen arbitrarily.[58]
- A study by the National Academies of Science (NAS) found that an SCC assessment suffers from uncertainty, speculation, and lack of information

[54] See David L. Kelly and Charles D. Kolstad, "Integrated Assessment Models for Climate Change Control", US Department of Energy grant number DE-FG03-96ER62277, Current Version: November 1998. Pp. 8-9. http://www.econ.ucsb.edu/papers/wp31-98.pdf.
[55] Management Information Services, Inc., op. cit.
[56] Robert S. Pindyck, "Climate Change Policy: What Do The Models Tell Us?" op. cit.
[57] Ibid
[58] Ibid.

about:[59] 1) Future emissions of greenhouse gases, 2) The effects of past and future emissions on the climate system, 3) The impact of changes in climate on the physical and biological environment, and 4) The translation of these environmental impacts into economic damages.[60] NAS thus concludes that "As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional."[61]

- Further, the differences in the 2010 and 2013 IAM-based SCC estimates are so large and of such immense potential significance as to raise serious questions as to their validity – especially since, prior to February 2010 there was no "official" Federal government estimate of the value of SCC.[62] If any valid government economic estimates, such as GDP or unemployment, were revised by 30 - 50 percent within a three year period it would represent a scandal and a farce.[63] For example, in 2010, U.S. GDP was estimated to be about $14.6 trillion.[64] While BEA always makes slight revisions to its GDP estimates in subsequent years, it is inconceivable that in 2013 it would have published a revised estimate of 2010 U.S. GDP in the range of $22 trillion.
- Nevertheless, despite these overwhelming theoretical and empirical difficulties, the IWG proceeded to develop precise SCC estimates (the 2010 IWG report published SCC estimates in tenths of dollars)[65] that it contends are useful in estimating the social benefits of reducing carbon dioxide emissions. The IWG even admitted that "The limited amount of research linking climate impacts to economic damages makes this modeling exercise even more difficult" and that the exercise is subject to "simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships."[66]
- In short, the IAM-based SCC estimates developed and utilized by the IWG have little or no validity and are, as Pindyck concluded, "close to useless."[67] Worse yet, their use suggests a level of knowledge and precision that is simply illusory, and can be highly misleading."[68]
- IAM methodology requires that a large number of assumptions be made to complete the linkages between levels of human activity, today and in the future,

[59]National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*, Washington, D.C.: National Academies Press, 2009.
[60]Ibid.
[61]Ibid.
[62]"Official" government estimates vary widely. For example, in 1996 the Minnesota PUC established a range of $0.28 to $2.92 per ton (1993 dollars) as the environmental cost of carbon dioxide. Translated into 2007 dollars to be consistent with the IWG estimates, this is a range of $0.38 to $3.97 per ton. See State Of Minnesota, Office of Administrative Hearings For the Minnesota Public Utilities Commission, "In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3 Findings of Fact, Conclusions, Recommendation," March 22, 1996.
[63]Management Information Services, Inc., op. cit.
[64]Obtained from the U.S. Bureau of Economic Analysis web site www.bea.gov.
[65]See U.S. Interagency Working Group, 2010 and 2013, op. cit.
[66]Ibid.
[67]Pindyck, op. cit.
[68]Ibid.

and the environmental consequences of that activity today and for generations to come. However, even small variations in the size of the assumed inputs can lead to very large and significant differences in the results produced by such methodology -- differences in results that are so great as to leave the resulting policy recommendations highly questionable.[69]

- Frank Ackerman and Elizabeth A. Stanton found that the SCC assumes climate sensitivity values between 2.0 ºC and 4.5 ºC, which are far higher than the values best supported by science.[70]
- The IAM process remains a very questionable tool for establishing explicit policy goals. In a recent assessment of the limitations of IAMs for use in policy, Jose Granados and Oscar Carpintero concluded: "The lack of robustness of results of different IAMs indicates the limitations of the neoclassical approach, which constitutes the theoretical base of most IAMs; the variety of so-called ad hoc assumptions (often qualified as "heroic" by their own authors), and the controversial nature of the methods to estimate the monetary value of non-market costs and benefits (mortality, morbidity, damage to ecosystems, etc.). These features explain why many contributions of this type of macroeconomics-oriented IAMs have been criticized for their dubious political usefulness and limited scientific soundness.[71]
- Jose Granados and Oscar Carpintero also identified several important shortcomings of IAMs: 1) Lack of transparency to explain and justify the assumptions behind the estimates, 2) Questionable treatment of uncertainty and discounting of the future, 3) Assumption of perfect substitutability between manufactured capital and "natural" capital in the production of goods and services, and 4) The way IAMs estimate monetary costs of non-market effects, which can lead to skepticism about policies based on the results of the models.[72]
- In an overview of questions of ethics and uncertainty that are endemic in the construction and application of IAMs to questions of global climate change, Frank Ackerman and his colleagues make the following points regarding the appropriateness of IAMs for policy choices: "There are two take-home messages here. The first is that policy makers and scientists should be skeptical of efforts by economists to specify optimal policy paths using the current generation of IAMs. These models do not embody the state of the art in the economic theory of uncertainty, and the foundations of the IAMs are much shakier than the general circulation models that represent our best current understanding of physical climate processes. ***Not only do the IAMs entail an implicit philosophical stance that is highly contestable, they suffer from technical deficiencies that are widely recognized within economics.*** Second, economists do have useful insights for climate policy. While economics itself is

[69]Roger H. Bezdek, "White House Study Is Dangerously Delusional," *World Oil*, October 2014.
[70]Frank Ackerman and Elizabeth A. Stanton, *Climate Risks and Carbon Prices: Revising the Social Cost of Carbon*, 6 Economics 1 (Apr. 4, 2012)
[71]Jose A. Tapia Granados and Oscar Carpintero, "Dynamics and Economic Aspects of Climate Change", Chapter 3 in *Combating Climate Change: An Agricultural Perspective*, edited by Manjit S. Kang & Surinder S. Banga, CRC Press, 2013. Pp. 37-38.
[72]Ibid.

insufficient to determine the urgency for precautionary action in the face of low-probability climate catastrophes, or make judgments about inter-generational and intragenerational justice, it does point the way towards achieving climate stabilization in a cost-effective manner. ***IAMs cannot, however, be looked to as the ultimate arbiter of climate policy choices.***"[73] *(Emphasis added by authors.)*

- There is a limited amount of research linking climate impacts to economic damages, and much of this is speculative, at best. Even the Obama White House admits that the scientific community has yet to derive robust quantitative policy recommendations based on a detailed analyses of the link between possible large-scale Earth system changes and their economic consequences.[74]
- Nicholas Stern summarized many of the weaknesses of integrated assessment modeling: "As I have argued, it is very hard to believe that models where radically different paths have to be compared, where time periods of hundreds of years must be considered, where risk and uncertainty are of the essence, and where many crucial economic, social, and scientific features are poorly understood, can be used as the main quantitative plank in a policy argument. Thus, IAMs, while imposing some discipline on some aspects of the argument, risk either confusing the issues or throwing out crucial features of the problem.[75]
- David Anthoff and Richard Tol find a wider variation of outcomes than the Stern Review, suggesting the Review's use of the PAGE model was not robust and led to an overestimation of the SCC.[76]
- Michael Mastrandrea determined that the damage functions used by the three models used by the IWG – DICE, FUND and PAGE – have little or no disaggregation with regard to sectors and/or regions in their estimations. For example, the DICE model uses a single total damage function based on estimates of temperature related damages in several sectors including agriculture, forestry, coastal vulnerability, health, and outdoor recreation to name a few. The PAGE model includes three damage functions that cover economic sectors, noneconomic sectors, and potential climate discontinuities. The damage function in the FUND model is the most disaggregated of the three and it includes damage functions for several sectors: Agriculture, forestry, water resources, sea level increases, health, and several others. In addition, the FUND model includes regional impacts for the various sectors.[77]

[73] Frank Ackerman, et al, "Limitations of Integrated Assessment Models of Climate Change," *Climatic Change*, 2009, 95:297–315, p. 312.
[74] Council of Economic Advisers, "The Cost of Delaying Action to Stem Climate Change," Executive Office of the President of the United States, July 2014, p. 24.
[75] Stern, op cit., "The Economics of Climate Change", p. 17.
[76] David Anthoff and Richard S.J. Tol, "The Impact of Climate Change on the Balanced Growth Equivalent: An Application of FUND," 43 Envt'l & Res. Econ. 351 (2009).
[77] Michael D. Mastrandrea, *Calculating the Benefits of Climate Policy: Examining the Assumptions of Integrated Assessment Models,* The Pew Center on Global Climate Change, 2009.

- Roger Pielke Jr. determined that the Stern Report overestimates future costs of extreme events by an order of magnitude, which affects all of its recommendations.[78]
- Robert Pindyck found that IAM damage functions tend to place too much value ("willingness to pay") on abatement because they track absolute levels of GDP rather than growth rate.[79]
- Richard Tol concluded that the Stern Review can be dismissed as alarmist and incompetent" because it uses unwarranted discount rates, cherry-picks the most pessimistic studies, and did not conduct a valid cost-benefit analysis.[80]
- Richard Tol and Hadi Dowlatabadi described the role that vector-borne diseases (e.g., malaria) play in IAMs and noted that that some GHG-reducing policies may increase the risk of these diseases.[81]
- Roger Bezdek noted that researchers analyzed IAMs and found that they are deeply flawed and useless as tools for policy analysis, imply level of knowledge and precision that is illusory and misleading, contain serious weaknesses, and provide very weak foundation for policy.[82]
- Ramon Arigoni Ortiz and Anil Markandya reported that the three IAM models used by the IWG in their computations of SCC, the FUND and PAGE models treat economic growth as an exogenous variable, while the DICE model uses an optimal growth model based on a Cobb-Douglas production function to forecast GDP. Technological change is treated exogenously in all three models. The failure of IAMs to treat technological change (productivity) as well as population growth as endogenous variables is an important weakness in these models.[83]
- In his review of IAMs Pindyck noted that the "loss functions" are not based on any economic theory, but, rather, "They are just arbitrary functions, made up to describe how GDP goes down when T goes up."[84]
- Michael Mastrandrea finds it troubling that IAM damage functions are usually based on only one country or region because the literature on the topic of environmentally induced costs (or benefits) is very limited, except in agriculture. Market and non-market damages in DICE are based on studies of impacts on the U.S that are then scaled up or down for application to other regions. Many of the

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[78]Roger Pielke Jr., "Mistreatment of the Economic Impacts of Extreme Events in the Stern Review Report on the Economics of Climate Change," 17 Global Envt'l Change 302 (2007).
[79]Robert S. Pindyck, "Modeling the Impact of Warming in Climate Change Economics," MIT Sloan School Working Paper No. 4769-10 (Jan. 11, 2010)
[80]Richard S.J. Tol, "The Stern Review of the Economics of Climate Change: A Comment," 17 Energy & Envir. 977 (Oct. 30, 2006).
[81]Richard S.J. Tol and Hadi Dowlatabadi, "Vector-Borne Diseases, Development & Climate Change," 2 Integrated Assessment 173 (2001).
[82]Roger H. Bezdek, "The Social Benefits of Carbon: *Not* The Social Costs of Carbon," presented at the SPN Energy Freedom Policy & Strategy Meeting, Arlington, Virginia, October 15, 2014.
[83]Ramon Arigoni Ortiz and Anil Markandya, "Integrated Impact Assessment Models of Climate Change with an Emphasis on Damage Functions: a Literature Review," BC3 Working Paper Series 2009-06, Basque Center for Climate Change (BC3), October 2009. http://www.bc3research.org/d7H9dfT3Re2/2009102002 04231130584436.pdf
[84]Robert S. Pindyck, "Climate Change Policy: What Do the Models Tell Us?," NBER Working Paper No. 19244 (July 2013).

estimates to which market damages in PAGE are calibrated are also based on an extrapolation of studies of the U.S. Only FUND uses regional and sector-specific estimates. However, in some sectors these estimates also originate in one country, or may be dominated by estimates from one region. For example, in the energy sector, the sector which accounts for most of the economic damages in FUND, estimates for the UK are scaled across the world. While some progress is being made in estimating the potential damages from climate change, at present the research is still so limited that one would be hard pressed to describe the results as little more than educated guesses. Or, as Mastrandrea states: "Although the differences in formulation across models do not allow a perfectly parallel comparison, it is clear that the relationship between temperature increase and climate damages varies significantly among IAMs."[85]

- Joseph Aldy and his colleagues found that there was a significant amount of consistency among several disparate studies of the economic impact of a 2.5C^{o} warming of average global temperatures, compared to pre-industrial levels, by 2100: Five different models predicted economic damages of between 1% and 2% of global GDP. However, although the gross damages estimates were similar, there were huge differences in the studies' estimates of the sources of the damages. The total damages, although similar, reveal large differences in the source of the damages – market impacts, non-market impacts, or catastrophic impact. Thus, it must be concluded that the similar results for the total damage estimates occurs because the selection of damage structures and parameters for the different sectors – economic and noneconomic – in the five model results just happened to aggregate to similar total damage values.[86]
- Christoph Böhringer, Andreas Löschel and Thomas Rutherford, found that computational limits weigh heavily in fully integrated optimization IAMs based on CGE (computable general equilibrium) economic modules, such as the DICE model, which compute optimal growth paths by computing thousands of iterations over hundreds of periods.[87]
- Of the many parameters found in IAMs, William Nordhaus noted that none attracts as much criticism as the choice of the discount rate used to estimate the present value of future impacts. The discount rate is criticized, first, because of the heavy ethical baggage that it carries. Unlike the majority of benefit-cost studies that use discount rates to assess values only a few years or even decades into the future, IAMs that are developed to evaluate the impacts of climate change must look generations ahead. This characteristic of IAMs raises important ethical issues, and one of the most basic ethical arguments is that to

[85] Michael D. Mastrandrea, *Calculating the Benefits of Climate Policy: Examining the Assumptions of Integrated Assessment Models,* The Pew Center on Global Climate Change, 2009.
[86] Joseph E. Aldy, et al, "Designing Climate Mitigation Policy", Resources For the Future, RFF DP 08-16, May 2009. P. 50. http://www.rff.org/RFF/Documents/RFF-DP-08-16.pdf.
[87] Christoph Böhringer, Andreas Löschel and Thomas F. Rutherford, *Decomposing the Integrated Assessment Climate Change,* Centre for European Economic Research, Discussion Paper No. 05-07. ftp://ftp.zew.de/ pub/zew-docs/dp/dp0507.pdf. Edwards, N.; H. Grepin, A. Haurie and L. Viguier, "Linking Climate and Economic Dynamics", In *The Coupling of Climate and Economic Dynamics: Essays on Integrated Assessment*, Alain Haurie and Laurent Viguier (eds), Amsterdam: Springer. 2005.

use any rate of discount other than zero would be a violation of inter-generational neutrality. That is, a positive value of the discount rate is an indication that future generations are held to be less valuable than the current or "present" one. Second, and more important, in simulations of the sensitivity of IAM results using different variable values, the choice of the values of the discount rate causes greater variation in model results than do other model parameters.[88]

2. Examples of researchers and relevant citations concluding that IAMs are of little or no value for evaluating alternative climate change policies and estimating the SCC

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[88] William D. Nordhaus, "A Review of the Stern review on the Economics of Climate Change," *Journal of Economic Literature*, V. XLV, September 2007, pp. 689-97.

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4. On page 26 of his Direct Testimony, Dr. Bezdek states "rigorous assessment of these IAMs by leading economists have concluded that the IAMs are 'close to useless." List the name "leading economists" who have reached these conclusions and provide citations to the publications in which those economists have made those statements.

Bezdek Response

Numerous distinguished economists have concluded that the IAMs are "close to useless." Their studies have been published in books, working papers, conference proceedings, and the most prestigious international peer-reviewed scientific journals. The peer-reviewed journals in which these studies have been published include, among others:

- *Science*
- *American Economic Review*
- *Journal of Economic Literature*
- *Review of Environmental Economics and Policy*
- *Environmental Modeling and Assessment*
- *Annals of Operations Research*
- *Environmental Science and Policy*
- *Climate and Development*
- *Regulation*
- *Journal of Environmental Economics and Management*
- *Global Environmental Change*
- *Climatic Change*
- *Environmental Values*
- *Journal of Economic Perspectives*
- *Environmental Science and Policy*
- *Economics*
- *Review of Environmental and Economic Policy*
- *Proceedings of the National Academies of Science*
- *National Institute Economic Review*

1. **Summary of Selected Researchers' Findings**

Eminent MIT economist Robert Pindyck's response to the question "What do the IAMs Tell Us" is succinct: "Very little. A plethora of integrated assessment models (IAMs) have been constructed and used to estimate the SCC and evaluate alternative abatement policies. These models have crucial flaws that make them close to useless as tools for policy analysis."[89]

[89]Robert S. Pindyck, NBER, Working Paper No. 19244, op. cit. and *Journal of Economic Literature*, cit.

Numerous IAMs have been developed and used to evaluate alternative abatement policies. Robert Pindyck emphasized that these models have crucial flaws that make them "close to useless" as tools for policy analysis; for example:[90]

- Certain inputs (e.g. the discount rate) are arbitrary, but have huge effects on the social cost of carbon (SCC) estimates the models produce.
- The models' descriptions of the impact of climate change are completely ad hoc, with no theoretical or empirical foundation.
- 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.
- The damage functions used in most IAMs are completely made up, with no theoretical or empirical foundation -- and yet those damage functions are taken seriously when IAMs are used to analyze climate policy.

Pindyck concluded that IAMs are of little or no value for evaluating alternative climate change policies. On the contrary, an IAM-based analysis suggests a level of knowledge and precision that is nonexistent, and allows the modeler to obtain almost any desired result because key inputs can be chosen arbitrarily.[91]

In an overview of questions of ethics and uncertainty that are endemic in the construction and application of IAMs to questions of global climate change, Frank Ackerman, Stephen DeCanio, Richard Howarth, and Kristen Sheeran make the following points regarding the appropriateness of IAMs for policy choices:[92]

> There are two take-home messages here. The first is that policy makers and scientists should be skeptical of efforts by economists to specify optimal policy paths using the current generation of IAMs. These models do not embody the state of the art in the economic theory of uncertainty, and the foundations of the IAMs are much shakier than the general circulation models that represent our best current understanding of physical climate processes. ***Not only do the IAMs entail an implicit philosophical stance that is highly contestable, they suffer from technical deficiencies that are widely recognized within economics.*** Second, economists do have useful insights for climate policy. While economics itself is insufficient to determine the urgency for precautionary action in the face of low-probability climate catastrophes, or make judgments about inter-generational and intragenerational justice, it does point the way towards achieving climate stabilization in a cost-effective manner**.** ***IAMs cannot, however, be looked to as the ultimate arbiter of climate policy choices.*** *(Emphasis added by authors.)*

[90]Ibid.
[91]Ibid.
[92]Frank Ackerman, et al, "Limitations of Integrated Assessment Models of Climate Change," *Climatic Change*, 2009, 95:297–315, p. 312.

In an overview of questions of ethics and uncertainty that are endemic in the construction and application of IAMs to questions of global climate change Frank Ackerman and his colleagues noted that, regarding the appropriateness of IAMs for policy choices: 1) Policy makers and scientists should be skeptical of efforts by economists to specify optimal policy paths using the current generation of IAMs; 2) These models do not embody the state of the art in the economic theory of uncertainty; 3) The foundations of the IAMs are much shakier than the general circulation models that represent our best current understanding of physical climate processes; 4) Not only do the IAMs entail an implicit philosophical stance that is highly contestable, they suffer from technical deficiencies that are widely recognized within economics; 5) IAMs cannot be viewed as the ultimate arbiter of climate policy choices. [93]

Thus, there is a limited amount of research linking climate impacts to economic damages, and much of this is speculative, at best. Even the IWG admits that the exercise is subject to "simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships."[94] Further, the IWG also admits that each model uses a different approach to translate global warming into damages, and that transforming the stream of economic damages over time into a single value requires "judgments" about how to discount them.[95]

Michael Mastrandrea found that "Although the differences in formulation across models do not allow a perfectly parallel comparison, it is clear that the relationship between temperature increase and climate damages varies significantly among IAMs."[96]

The authors of the IPCC Second Assessment report stated "A single aggregated damage function or a 'best guess' climate sensitivity estimate is a very restricted representation of the wide range of beliefs available in the literature or among lead authors about climate sensitivity or climate damages. The cascade of uncertainty implied by coupling the separate probability distributions for emissions and biogeochemical cycle calculations to arrive at concentrations needed to calculate radiative forcing, climate sensitivity, climate impacts, and valuation of such impacts into climate damage functions has yet to be produced in the literature." [97]

In a study for the National Academies of Science (NAS), Jared L. Cohon, Maureen L. Cropper, Mark R. Cullen, Elisabeth M. Drake , Mary R. English, Christopher B. Field, Daniel S. Greenbaum, James K. Hammitt, Rogene F. Henderson, Catherine L. Kling, Alan J. Krupnick, Russell Lee, H. Scott Matthews, Thomas E. Mckone, Gilbert E. Metcalf, Richard G. Newell, Richard L. Revesz, Ian Sue Wing, and Terrance G. Surles, found that an SCC assessment suffers from uncertainty, speculation, and lack of

[97] Ibid.
[94] Interagency Working Group, 2010, op. cit.
[95] Ibid.
[96] Mastrandrea, op cit. p. 20.
[97] IPCC Second Assessment, p. 130.

information about:[98] 1) Future emissions of greenhouse gases, 2) The effects of past and future emissions on the climate system, 3) The impact of changes in climate on the physical and biological environment, and 4) The translation of these environmental impacts into economic damages.[99] NAS thus concludes that "As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional."[100]

Roger Bezdek found that IAM methodology requires that a large number of assumptions be made to complete the linkages between levels of human activity, today and in the future, and the environmental consequences of that activity today and for generations to come. However, even small variations in the size of the assumed inputs can lead to very large and significant differences in the results produced by such methodology -- differences in results that are so great as to leave the resulting policy recommendations highly questionable.[101]

Cass Sunstein, who was the Administrator of the White House Office of Information and Regulatory Affairs in the Obama Administration, reported that "Many people believe that the SCC's technical supporting data relies on unreliable integrated assessment models."[102]

David Anthoff and Richard Tol found that fat-tailed risks do not warrant arbitrarily high carbon taxes/cost-of-carbon measures.[103]

Jiehan Guo, and his colleagues found that a proper discount rate yields a much lower SCC than usually used, and would cause most policies--including the Kyoto Protocol--to fail a cost-benefit analysis.[104]

James Risbey and his colleagues determined that IAM modules frequently take the form of the practitioner's subjective judgments linking the disparate knowledge blocks. Unfortunately, while the bricks may be quite sound and well described, the subjective judgments (glue) are often never made explicit. As a result, it is difficult to judge the stability of the structure that has been constructed. Thus, in the case of integrated assessment, not only do we need criteria for assessing the quality of the individual components of the analysis, we also need criteria that are applicable to the glue or the subjective judgments of the analyst, as also for the analysis as a whole.

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[98]National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*, Washington, D.C.: National Academies Press, 2009.
[99]Ibid.
[100]Ibid.
[101]Roger H. Bezdek, "White House Study Is Dangerously Delusional," *World Oil*, October 2014.
[102]Cass R. Sunstein, On Not Revisiting Official Discount Rates: Institutional Inertia and the Social Cost of Carbon, 104 *Am. Econ. Rev.: Papers & Proceedings*, p.548 (2014).
[103]David Anthoff & Richard S.J. Tol, "Climate Policy under Fait-Tailed Risk: An Application of FUND," 220 Ann. Oper. Res. 223 (2014).
[104]Jiehan Guo, *et al.*, "Discounting and the Social Cost of Carbon: A Closer Look at Uncertainty," 9 Envt'l Sci. & Policy 205 (Feb. 28, 2006).

While criteria for adequacy for the individual components may be obtained from the individual disciplines, a similar situation does not exist for the "glue" in the analysis.[105]

Richard Howarth and his colleagues concluded that "There is no fact-of-the-matter concerning the social cost of carbon that can provide an objective and value-free guide for policy evaluation."[106]

Studies by Stephen Schneider and by John Weyant and his colleagues found troubling and unresolved issues at each stage of an IAM, including: 1) What is the rate of carbon emissions, from natural and human sources? 2) How is the carbon cycle specified: The processes that impact the net change of the amount of carbon in the atmosphere? If more carbon enters the atmosphere than is absorbed by ocean and terrestrial carbon "sinks", then the concentration of carbon will increase. 3) How does the concentration of carbon in the atmosphere impact the climate, e.g. climate dynamics? What are the interactions between climate and oceans, between climate and land mass? 4) How do changes in temperature impact the oceans and the land? 5) What evidence is there that increasing temperatures will cause damages? 6) How much will those damages impact current and future rates of growth? Finally, if there are expected damages to future economic growth and output, how do we compare the current, or present value of those future damages to the costs -- present and future -- of slowing or stopping, (i.e., "mitigating") the emission of carbon into the atmosphere.[107]

Jonathan Masur and Eric Posner examined the IAM-derived SCCs and concluded that "We believe that agencies conducting cost-benefit analysis cannot use the IWG's SCC. The SCC is highly arbitrary. Even the choice of which of the IWG's four SCCs to use is arbitrary."[108]

MISI economists determined that IAM analysis will be saddled with the fact that the degree of uncertainty within the process is immense and renders any IAM results highly questionable.[109]

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[105] James Risbey, et al, "Assessing Integrated Assessments," *Climatic Change*, 1996, Volume 34, Issue 3-4, pp 369-395.

[106] Richard B. Howarth, et al., Risk Mitigation and the Social Cost of Carbon, 24 *Global Envt'l Change* 123, p.130 (2014).

[107] Stephen H. Schneider, "Integrated Assessment Modeling of Global Climate Change: Transparent Rational Tool For Policy Making or Opaque Screen Hiding Value-Laden Assumptions?" *Environmental Modeling and Assessment*, Issue 2, October 1997, pp. 229-49. http://stephenschneider.stanford.edu/Publications/PDF_Papers/Integr_Ass.pdf; and J. Weyant, et al, "Integrated Assessment of Climate Change: An Overview and Comparison of Approaches and Results," pp. 367-439 in J. P. Bruce, et al. (eds), *Climate Change 1995: Economic and Social Dimensions of Climate Change*, Cambridge University Press, Cambridge (1996). http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#1.

[108] Jonathan S. Masur and Eric A. Posner, Law & Economics Working Paper No. 525, Public Law & Legal Theory Working Paper No. 312, "Climate Regulation and the Limits of Cost-Benefit Analysis" at 34 (Aug. 2010).

[109] Management Information Services, Inc., *The Social Costs of Carbon? No, the Social Benefits of Carbon*, prepared for the American Coalition for Clean Coal Electricity, Washington, D.C., January 2014.

A review by Rachel Warren and her colleagues of IAMs concluded that: "The assumption of a quadratic dependence of damage on temperature rise is even less grounded in any empirical evidence. Our review of the literature uncovered no rationale, whether empirical or theoretical, for adopting a quadratic form for the damage function – although the practice is endemic in IAMs.[110]

David Anthoff and his colleagues concluded that most analyses of the discount rate ignore crucial components and thereby yield a completely arbitrary and artificially inflated SCC.[111]

In an assessment of the limitations of IAMs for use in policy, Jose Granados and Oscar Carpintero concluded: "The lack of robustness of results of different IAMs indicates the limitations of the neoclassical approach, which constitutes the theoretical base of most IAMs -- limitations of so-called ad hoc assumptions, and the controversial nature of the methods to estimate the monetary value of non-market costs and benefits (mortality, morbidity, damage to ecosystems, etc.). These features explain why many contributions of this type of macroeconomics-oriented IAMs have been criticized for their dubious political usefulness and limited scientific soundness." They list several important shortcomings of IAMs, including lack of transparency to explain and justify the assumptions behind the estimates, questionable treatment of uncertainty and discounting of the future, assumption of perfect substitutability between manufactured capital and "natural" capital in the production of goods and services, and the way IAMs estimate monetary costs of non-market effects, which can lead to skepticism about policies based on the results of the models.[112]

Economists at the U.S. Chamber of Commerce argued that the IAM-derived SCC estimates should be withdrawn and not used in rule-making and policy-making for the following reasons: 1. The SCC estimates fail in terms of process and transparency. The SCC estimates fail to comply with OMB guidance for developing influential policy-relevant information under the Information Quality Act. The SCC estimates are the product of an opaque process and any pretensions to their supposed accuracy (and therefore usefulness in policy-making) are unsupportable. 2. The models with inputs used for the SCC estimates and the subsequent analyses were not subject to peer review as appropriate. 3. Even if the SCC estimate development process was transparent, rigorous, and peer-reviewed, the modeling conducted in this effort does not offer a reasonably acceptable range of accuracy for use in policy-making. 4. The IWG has failed to disclose and quantify key uncertainties to inform decision makers and the public about the effects and uncertainties of alternative regulatory actions as required by OMB. 5. By presenting only global SCC estimates and downplaying domestic SCC

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[110]Rachel Warren, et al, "Spotlighting Impacts Functions in Integrated Assessment," Research Report Prepared for the Stern Review on the Economics of Climate Change, Tyndall Centre for Climate Change Research Working Paper 91, September 2006.
[111]David Anthoff, *et al.*, "Discounting for Climate Change," 3 Economics 1 (June 9, 2009)
[112]Jose A. Tapia Granados and Oscar Carpintero, "Dynamics and Economic Aspects of Climate Change", Chapter 3 in *Combating Climate Change: An Agricultural Perspective*, edited by Manjit S. Kang & Surinder S. Banga, CRC Press, 2013. Pp. 37-38.

estimates in 2013, the IWG has severely limited the utility of the SCC for use in benefit cost analysis and policy-making.[113]

In an overview of questions of ethics and uncertainty that are endemic in the construction and application of IAMs to questions of global climate change, Frank Ackerman and his colleagues noted that, regarding the appropriateness of IAMs for policy choices: Policy makers and scientists should be skeptical of efforts by economists to specify optimal policy paths using the current generation of IAMs; these models do not embody the state of the art in the economic theory of uncertainty; the foundations of the IAMs are much shakier than the general circulation models that represent our best current understanding of physical climate processes; not only do the IAMs entail an implicit philosophical stance that is highly contestable, they suffer from technical deficiencies that are widely recognized within economics; IAMs cannot be viewed as the ultimate arbiter of climate policy choices.[114]

Elizabeth Stanton and her colleagues found that subtracting damages from output with no effect on capital, production or consumption in following periods is an "unrealistic assumption." Specifically: "In recognition of the fact that the parameters of the damage functions are questionable at best, IAM models increasingly include probability distributions of the parameters to explicitly address the issue of uncertainty. While the use of probability distributions – using a range of values around a norm – serves to acknowledge that we have no real scientific evidence to support one value over another – their use introduces another bias into IAM results. Since the structure of the damage functions are quadratic equations, the results of using probability distributions of equation parameters results in so-called 'fat tail' impacts that are larger for higher temperature increases than for lower increases."[115]

Kevin Dayaratna and David Kreutzer noted that EPA uses three IAMs to determine the value of the SCC, defined by the EPA as the economic damage that a ton of CO2 emitted today will cause over the next 300 years. They analyzed the IAM that generates the intermediate EPA results (the DICE model) and found it to be flawed beyond use for policymaking. In addition to more fundamental problems outlined by others, the authors found that reasonable changes in a few assumptions lead to order-of-magnitude changes in estimates of the SCC.[116]

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[113]U.S. Chamber of Commerce, "Petition for Correction: Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866 (February 2010) and Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866 (May 2013)," Washington, D.C., September 4, 2013
[114]Frank Ackerman, et al, "Limitations of Integrated Assessment Models of Climate Change," *Climatic Change*, 2009, 95: 297–315.
[115]Elizabeth Stanton, et al, "Inside the Integrated Assessment Models: Four Issues in Climate Economics," *Climate and Development*, 1 (2009).
[116]Kevin D. Dayaratna and David W. Kreutzer, "Loaded DICE: An EPA Model Not Ready for the Big Game," Backgrounder #2860 on Energy and Environment, Heritage Foundation, November 21, 2013.

2. Examples of Economists and Citations Concluding That IAMs Are "Close To Useless"

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Roger H. Bezdek, "Benefits of Carbon Use Far Outweigh its Costs," *The Hill*, September 25, 2014.

Robert P. Murphy, "Are Climate Change Mitigation Policies a Form of Insurance?" Institute for Energy Research, April 17, 2014. Robert P. Murphy, "New IPCC Report Unwittingly Shows Weakness of Alarmist Camp," Institute for Energy Research, April 3, 2014.

Jose A. Tapia Granados and Oscar Carpintero, "Dynamics and Economic Aspects of Climate Change", Chapter 3 in *Combating Climate Change: An Agricultural Perspective*, edited by Manjit S. Kang & Surinder S. Banga, CRC Press, 2013. Pp. 37-38.
Geoffrey M. Heal & Antony Millner, "Agreeing to Disagree on Climate Policy," 111 *Proceedings of the Nat'l Acad. of Scis.* 3695 (Mar. 11, 2014).

Robert P. Murphy, "New IPCC Report Unwittingly Shows Weakness of Alarmist Camp," Institute for Energy Research, April 3, 2014.

CLEAN ENERGY ORGANIZATIONS
INFORMATION REQUESTS

Date of Request: July 14, 2015

Requested By:
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Attorney for Izaak Walton League of America – Midwest Office, Fresh Energy, Sierra Club, and Minnesota Center for Environmental Advocacy (collectively "Clean Energy Organizations")

Requested From: Peabody Energy

Response Due: July 24, 2015

In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under MN Statute 216B.2422, Subdivision 3

PUC Docket No. E999/CI-14-643

INFORMATION REQUESTS NOS. 11-15 OF CLEAN ENERGY ORGANIZATIONS TO PEABODY ENERGY

To Roger Bezdek:

11. On page 32 of his Direct Testimony, Dr. Bezdek includes the following quote from Dr. Judith Curry: "In the U.S., most types of weather extremes were worse in the 1930's and even in the 1950's than in the current climate, while the weather was overall more benign in the 1970's. This sense that extreme weather events are now more frequent and intense is symptomatic of 'weather amnesia' prior to 1970. The extremes of the 1930's and 1950's are not attributable to greenhouse warming and are associated with natural climate variability." Dr. Bezdek includes an endnote 43 for this quote, but there is no corresponding endnote 43 in the references cited portion of his testimony. Please provide a citation for this quote.

Response

Judith Curry, "Statement to the Committee on Environment and Public Works of the United States Senate," Hearings on the President's Climate Action Plan, January 16, 2014, p.12

12. On page 32 of his Direct Testimony, Dr. Bezdek includes the following quote from Dr. Richard Tol: "There is a history of exaggeration in the study of climate change impacts." Dr. Bezdek includes an endnote 44 for this quote, but there is no corresponding endnote 44 in the references cited portion of his testimony. Please provide a citation for this quote.

Response

Richard S.J. Tol, *The Economic Effects of Climate Change*, 23 J. Econ. Perspectives 29, 46 (Spring 2009).

13. Please provide a full citation for "Idso, 2013" cited as the source for Figure 18-1.

Response

Craig D. Idso (Ctr. for the Study of Carbon Dioxide and Global Change), "The Positive Externalities of Carbon Dioxide: Estimating the Monetary Benefits of Rising Atmospheric CO_2 Concentrations on Global Food Production" (Oct. 21, 2013), available at http://www.co2science.org/education/reports/co2benefits/MonetaryBenefitsofRisingCO2onGlobalFoodProduction.pdf.

14. Please provide a full citation for "Idso and Idso 2000" cited as the source for Figure 25-1.

Response

Craig D. Idso and Keith E. Idso, "Forecasting World Food Supplies: The Impact of the Rising Atmospheric CO_2 Concentration," 7S Technology 33, 41 (Table 6) (2000).

15. Please provide a full citation for "Goklany and Morris" cited as the source for Figure 44-7.

Response

Indur M. Goklany (Reason Fdn.), *Wealth and Safety: The Amazing Decline in Deaths from Extreme Weather in an Era of Global Warming, 1900-2010*, Policy Study 393 (Sep. 2011), available at https://reason.org/files/deaths_from_extreme_weather_1900_2010.pdf.