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

Exhibit _____

Rebuttal Testimony and Exhibits of

Professor Richard S. Lindzen

August 12, 2015

Q. Please state your name.

A. Richard S. Lindzen.

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 Lindzen 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, which are attached as Lindzen Rebuttal Exhibit 2, supply substantial evidentiary support for each of my statements.

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Exhibit 1

To

Rebuttal Testimony of

Professor Richard S. Lindzen

Richard S. Lindzen

I am submitting this rebuttal report to respond to the testimony of Michael Hanemann for the Minnesota state agencies and Stephen Polasky for the Minnesota Center for Environmental Advocacy, as well as the testimony of Nicholas Martin for Xcel Energy. Hanemann and Polasky recommend that Minnesota simply adopt the federal social cost of carbon ("SCC") as calculated by the federal Interagency Working Group ("IWG"), and Martin uses the IWG data to argue for a range of SCC values.

1. All of this testimony is flawed to the extent it simply relies on the IWG, which in turn relied on predictions by the Intergovernmental Panel on Climate Change ("IPCC"). The current federal SCC is based on the IPCC's 2007 projected range of 2°C to 4.5°C, with a "best estimate" of 3.0°C. In 2010, the IWG assumed that the IPCC's range was accurate, in 2013 the IWG declined to revisit the issue, and in July 2015 the IWG made only a technical adjustment in the way the probability distribution of the climate sensitivity value was presented. Yet today the best evidence indicates that the IWG's assumptions are wrong, that a much lower climate sensitivity value of 1°C or 1.5°C is correct, and that a climate sensitivity of more than 2.0□ C is extremely unlikely. Accordingly, the assumptions of Hanemann, Polasky, and Martin are invalid.

As I have previously explained:

- "Current economic damages models attempting to determine a 'social cost' of carbon are inherently biased high because they rely on IPCC's flawed and overestimated conclusions regarding the effect of increases of carbon dioxide concentrations on global climate." Testimony at 2-3.
- "[T]he IPCC claim relies on climate models that suffer from serious flaws. The models do not comport with observational data, and all IPCC models fail to predict the cessation of discernible warming over almost the past 20 years." Id. at 5.
- "In my opinion, the IPCC's estimated sensitivity values are substantially overstated because they depend on feedback effects that have not been shown to exist. For example, studies show that warming leads to reduced cirrus cloud coverage, which acts to counteract the warming (i.e., acts as a negative feedback) by allowing more

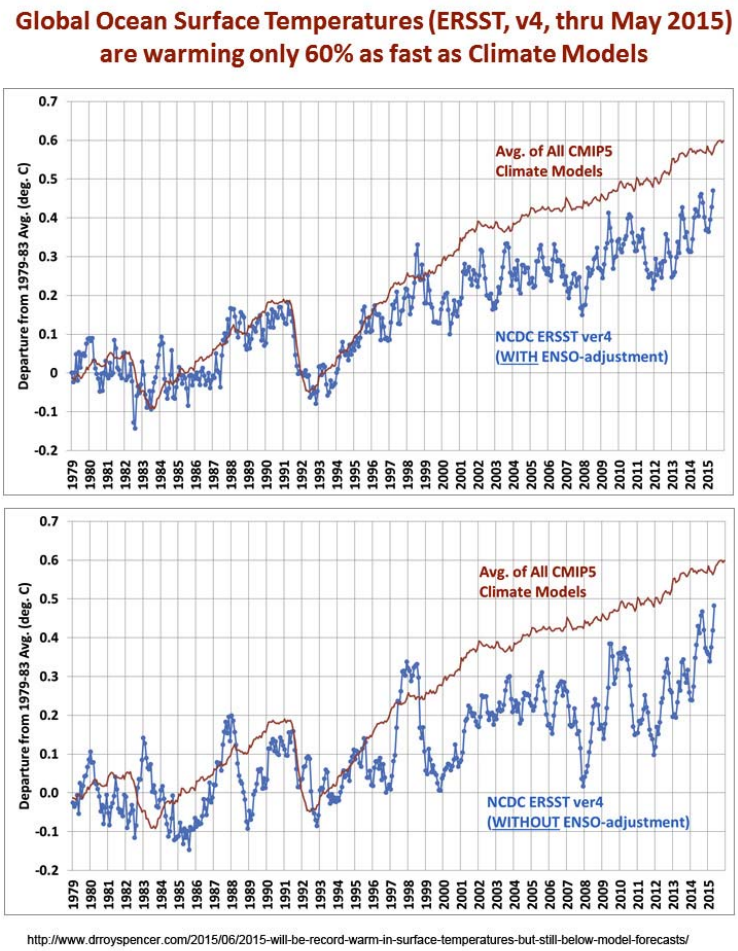
infrared radiation to escape into outer space. This is known as the 'Iris effect.' In my opinion, a climate sensitivity value of 2C or more is highly unlikely. Evidence indicates that climate sensitivity may fall within a range of from about 0.85C to 1.5C. I note that a value of 1.5C is within the IPCC's own projections." Id.

2. This rebuttal report also addresses the issue of the temperature record and a recent paper by Karl et al (2015) that has been described in the press as "disproving" the hiatus in discernible warming for almost the past two decades, which until now has been widely accepted by climate researchers. The temperature record is a source of considerable confusion. The record generally presented is one of the global mean temperature anomaly. That is to say, one is not averaging the temperature itself, but rather the temperature deviation from a thirty year mean at each station. Figure 10 of my testimony displays the main indisputable fact about this quantity: namely, it is very small compared to other changes at any given location. Given that the observations were never designed for climate purposes, it is not surprising that there is uncertainty on the order of tenths of a degree in addition to problems of systematic error (such as the effect of urbanization). This means that 'adjustments' of a few tenths of a degree are always possible. However, as Michaels (2008) noted, the large majority of such adjustments lead to conclusions like 'it is worse than was thought' or 'the data is closer to models than initially thought.' Given that errors are generally assumed to be random, this would suppose that there was an initial bias against global warming and against models; this is implausible to say the least. In other words, it is highly suspicious that "adjustments" almost invariably produce results that favor advocates of a certain camp. That suggests that "adjustments" do not necessarily reflect impartial science.

Under these circumstances, the recent attempt by Karl et al (2015) to adjust data so as to eliminate the so-called 'pause' of the last 18 years is suspect ab initio. Indeed, as Michaels et al (2015) and numerous others have pointed out, there are many bases for such suspicion. For example, the paper made an upward adjustment of 0.12°C in measurements from surface buoys, supposedly to make them "homogeneous" with measurements taken by engine intake channels in marine vessels, even though temperature readings from ship engine intakes are clearly

contaminated by heat conduction from the engine itself and are therefore less appropriate for scientific use. The Karl paper also cherry picks certain start dates and end dates to create intervals yielding equal trends.

However, there is a larger point to be made: namely, all these adjustments act to disguise the fact that we are dealing with small quantities. By emphasizing the question of whether it is warming or not, they deflect attention from the only important question of 'how much.' As Spencer and Christy (2015) note, the adjusted temperature record of Karl et al (2015) still leaves their warming rate much smaller than IPCC models project (viz Figure 1). Note also that the apparent agreement between the models and temperature record before 1998 is largely due to the use aerosol adjustments by models. As I explained in my testimony, recent work by Stevens (2015) shows that the adjustments required by the more sensitive models exceeds what now appears possible. This would substantially increase the apparent discrepancy between the models and observational data.



70

71 **Figure 1 Comparisons of 'adjusted' data with IPCC model projections.**

Groups active in promoting climate concern have recently published papers showing that models with high sensitivity are markedly incompatible with observations. These results are too recent to have been included in the latest IPCC reports which are now out of date. This is especially the case for the reports of Working Groups II and III (dealing with impacts and mitigation respectively, but not with the scientific underpinnings). Working Groups II and III generally use the worst case scenarios from WG I, and these no longer are viable scenarios. Testimonies that rely on these sources (i.e., the testimony of Hanemann, Polasky, and Martin) are flawed to the extent that they rely on these sources.

3. Finally, I am attaching to this document copies of my responses to the discovery requests I have received in this proceeding. My responses supply citations supporting certain elements of my testimony, including the following statements:

- There will be "only mild warming at most, which will be beneficial to the planet and to society as a whole."
- "In fact, there was an almost indistinguishable period of warming from presumably non-man-made causes between 1895 and 1946. The two periods (1895-1946 and 1957-2008) are essentially indistinguishable, though the early one is acknowledged by the IPCC to be natural while the other is claimed to be due in large measure to humans."
- "Evidence indicates that climate sensitivity may fall within a range of from about 0.85C to 1.5C."
- "Warming itself, at the levels that might realistically be anticipated (i.e., under 2C for the foreseeable future) is estimated to be net beneficial."
- "The policy risks of limiting the clean burning of fossil fuels are clear and are likely to exceed such risks of climate change as may exist, particularly when the economic and social impacts of higher energy prices are considered."

My responses supply substantial evidentiary support for each of my statements.

Sources

Sources:

Michaels, P. 2008: Evidence for "PUBLICATION BIAS" concerning global warming in SCIENCE and NATURE, ***Energy & Environment***, 19, 287-301

Karl, T.R., A. Arguez, Boyin Huang, J.H. Lawrimore, J. R. McMahon, M. J. Menne, T. C. Peterson, R.S. Vose, and Huai-Min Zhang, 2015: Possible artifacts of data biases in the recent global surface warming hiatus. *Science* 26 June 2015: 1469-1472.

Spencer, R. and J.Christy, 2015, http://www.drroyspencer.com/2015/06/2015-will-be-record-warm-in-surface-temperatures-but-still-below-model-forecasts/

Michaels, P.J., R. Lindzen, *and* P. C. Knappenberger, 2015: http://www.cato.org/blog/there-no-hiatus-global-warming-after-all

Stevens, B. 2015 Rethinking the Lower Bound on Aerosol Radiative Forcing, *J. Climate*, **28**, 4794- 4819. DOI: 10.1175/JCLI-D-14-00656.1

Stott, P., P. Good, G. Jones, N. Gillett and E. Hawkins, 2013: The upper end of climate model temperature projections is inconsistent with past warming. Environ. Res. Lett. **8** (8pp) doi:10.1088/1748-9326/8/1/014024

Fyfe,J.C., N. P. Gillett and F. W. Zwiers, 2013, Overestimated global warming over the past 20 years, NATURE CLIMATE CHANGE | VOL 3 | SEPTEMBER 2013 | 767-769. www.nature.com/natureclimatechange

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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
Professor Richard S. Lindzen
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:

Related work on carbon fertilization include:

Acock, B. and Allen, L.H. Jr. 1985. Crop responses to elevated carbon dioxide concentration. In: *Direct Effects of Increasing Carbon Dioxide on Vegetation.* DOE/ER-0238. B.R. Strain and J.D. Cure (eds.). US Dept. of Energy, Carbon Dioxide Res. Div., Washington DC. pp. 53-97.

Kimball, B.A., Mauney, J.R., Nakayama, F.S. and Idso, S.B. 1993. Effects of increasing atmospheric CO_2 on vegetation. *Vegetatio* **104/105:** 65-75.

To Richard Lindzen:

7. Provide the basis (including all computer codes) for the graphs contained in Exhibit 2 to Dr. Lindzen's direct testimony.

RESPONSE:

The graphs are the results of simple calculations made by Professor Lindzen in order to identify the amount of cancellation needed by high sensitivity models. The energy balance model used is fully described in Lindzen and Giannitsis (1998). The equation is essentially the one-dimensional heat equation, which is linear and whose numerical solution is standard elementary applied math. (Professor Lindzen used the program Mathcad 15.)

Lindzen, R.S. and C. Giannitsis (1998) On the climatic implications of volcanic cooling. *J. Geophys. Res.*, **103**, 5929-5941.

8. Provide the basis (including, as appropriate, citations to the peer-reviewed literature in which these statements have been published) for the following statements:

a. p. 2, line 22: "only mild warming at most, which will be beneficial to the planet and to society as a whole."

RESPONSE:

The benefits of mild warming and increased CO_2 levels are addressed in Professor Lindzen's report at lines 569-608, which contains references to:

Driessen, P. and R. Arnold, 2014, Miracle Molecule: Carbon Dioxide, Gas of Life, Available as Kindle book from Amazon.com, 40 pp.

Goklany, I., 2012, Humanity Unbound How Fossil Fuels Saved Humanity from Nature and Nature from Humanity, Cato Policy Analysis No. 715, 33 pp.

Guo, Y., Gasparrini, A., Armstrong, B., Li, S., Tawatsupa, B., Tobias, A., & Williams, G. (2014). Global Variation in the Effects of Ambient Temperature on Mortality: A Systematic Evaluation. Epidemiology, 25(6), 781-789

Idso, C. et al, 2000, Ultra-enhanced spring branch growth in CO2-enriched trees: can it alter the phase of the atmosphere's seasonal CO2 cycle? Environmental and Experimental Botany, Volume 43, Issue 2, April 2000, Pages 91-100

Further references include:

David Anthoff & 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).

C.M. Bennett, *et al.*, "Shifts in the Seasonal Distribution of Deaths in Australia, 1968-2007," 58 Int'l J. Biometeorology 835 (2014).

J. Cheng, *et al.*, "Impact of Diurnal Temperature Range on Human Health: A Systematic Review," 58 Int'l J. Biometeorology 2011 (Feb. 18, 2014).

N. Christidis, *et al.*, "Causes for the Recent Changes in Cold- and Heat-Related Mortality in England and Wales," 102 Climatic Change 539 (2010).

Roy F. Darwin & Richard S.J. Tol, "Estimates of the Economic Effects of Sea Level Rise," 19 Envt'l & Res. Econ. 113 (2001).

Randall J. Donohue, *et al.*, "Impact of CO2 Fertilization on Maximum Foliage Cover Across the Globe's Warm, Arid Environments," 40 Geophys. Rsch. Letters 1 (June 2013).

J. Ronald Eastman, *et al.*, "Global Trends in Seasonality of Normalized Difference Vegetation Index (NDVI), 1982-2011," 5 Remote Sensing 4799-4818 (2013).

J.B. Fisher, *et al.*, "African Tropical Rainforest Net Carbon Dioxide Fluxes in the Twentieth Century," 368 Philosophical Transactions of the Royal Society B 1625 (2013).

Gerber, S., J. Fortunat, and I .C. Prentice. 2004. "Sensitivity of a dynamic global vegetation model to climate and atmospheric CO2" *Global Change Biology* 10: 1223–1239.

Guo, Y., Gasparrini, A., Armstrong, B., Li, S., Tawatsupa, B., Tobias, A., & Williams, G. (2014). Global Variation in the Effects of Ambient Temperature on Mortality: A Systematic Evaluation. *Epidemiology*, 25(6), 781-789.

S. B. Idso and B. A. Kimball, Effects of the enrichment of CO2 on regrowth of sour orange trees (Citrus aurantium; Rutacea) after copicing, Am. J. Bot. 81,843 (1994).

Idso, C. et al, 2000, Ultra-enhanced spring branch growth in CO2-enriched trees: can it alter the phase of the atmosphere's seasonal CO2 cycle?, 43 Environmental and Experimental Botany 91 (April 2000).

Kimball, B. A. 1983. "Carbon Dioxide and Agricultural Yields: An Assemblage and assessment of 430 prior observations" *Agronomy Journal* 75: 779-788.

M. B. Kirkham, Elevated Carbon Dioxide, Impacts on Soil and Plant Water Relations, CRC Press. Boca Raton (2011).

P. Michael Link & Richard S.J. Tol, "Estimation of the Economic Impact of Temperature Changes Induced by a Shutdown of the Thermohaline Circulation: An Application of FUND," 104 Climatic Change 287 (2011).

Robert Mendelsohn, "The Impact of Climate Change on Agriculture in Asia," 13 J. Integrative Agric. S2095 (2013).

Mendelsohn et al., *The Impact of Global Warming on Agriculture: A Ricardian Analysis*, 84 Am. Econ. Rev. 753, 769 (1994).

Mendelsohn, R. and J. Neumann (eds.) 1999. *The Impact of Climate Change on the United States Economy* Cambridge University Press, Cambridge, UK.

Mendelsohn, R and A. Dinar. 2009. *Climate Change and Agriculture: An Economic Analysis of Global Impacts, Adaptation, and Distributional Effects.* Edward Elgar Publishing, England.

Mendelsohn, R. 2001. *Global Warming and the American Economy: A Regional Analysis*. Edward Elgar Publishing, England.

Daiju Narita, *et al.*, "Economic Costs of Extratropical Storms under Climate Change: An application of FUND," 53 J. Envt'l Planning and Mgmt. 371 (April 2010).

Office of Management and Budget, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (February 2010), at 9 (Figure 1A).

Roger A. Sedjo & Brent Sohngen, "What are the Impacts of Global Warming on U.S. Forests, Regions, and the U.S. Timber Industry?," 12 Penn. St. Envt'l L. Rev. 95 (Winter 2004).

S. Niggol Seo, *et al.*, "A Ricardian Analysis of the Distribution of Climate Change Impacts on Agriculture across Agro-Ecological Zones in Africa," 43 Envt'l. & Res. Econ. 313 (2009).

Ying Sun, *et al.*, "Impact of Mesophyll Diffusion on Estimated Global Land Co2 Fertilization," 111 Proceedings Nat'l Acad. Scis. 15774 (Nov. 4, 2014).

Richard S.J. Tol, "On the Uncertainty About the Total Economic Impact of Climate Change," 53 Envt'l & Res. Econ. 97 (2012).

R.S.J. Tol, "Targets for global climate policy: An overview," 37 Journal of Economic Dynamics & Control 911, 912 (2013).

Richard S.J. Tol, Corrigendum to "Targets for global climate policy: An overview," Journal of Economic Dynamics & Control 42 (2014) 121.

Richard S.J. Tol & Hadi Dowlatabadi, "Vector-Borne Diseases, Development & Climate Change," 2 Integrated Assessment 173 (2001).

Richard S.J. Tol & Sebastian Wagner, "Climate Change and Violent Conflict in Europe over the Last Millennium," 99 Climatic Change 65 (2010).

Jinxia Wang, *et al.*, "The Impact of Climate Change on China's Agriculture," 40 Agric. Econ. 323 (2009).

J. Wilcox, & D. Makowski, "A Meta-Analysis of the Predicted Effects of Climate Change on Wheat Yields Using Simulation Studies," 156 Field Crops Research 180 (2014).

D.D. Zhang, *et al.*, "Climate Change and Large-Scale Human Population Collapses in the Pre-Industrial Era," 20 Global Ecology and Biogeography 520 (2011).

Professor Lindzen's statement is also supported by the report and testimony of Robert Mendelsohn in this proceeding.

b. p. 4, line 10: "in fact, there was an almost indistinguishable period of warming from presumably non-man-made causes between 1895 and 1946. The two periods (1895-1946 and 1957-2008) are essentially indistinguishable, though the early one is acknowledged by the IPCC to be natural while the other is claimed to be

due in large measure to humans." Document where in the IPCC report the statement is made that the early warming is natural.

RESPONSE:

The IPCC attributes warming to anthropogenic causes only after 1951. (IPCC, Fifth Assessment Report 48.) All of the figures the IPCC offers to support its claim show natural forcings and natural + anthropogenic forcings to overlap until the middle of the 20th century. (*Id.* at 49 (Fig. 1.10).)

c. p. 5, line 24: "Evidence indicates that climate sensitivity may fall within a range of from about 0.85C to 1.5C."

RESPONSE:

The complete context of Professor Lindzen's statement is: "In my opinion, a climate sensitivity value of 2C or more is highly unlikely. Evidence indicates that climate sensitivity may fall within a range of from about 0.85C to 1.5C. I note that a value of 1.5C is within the IPCC's own projections." The appropriate references are:

J. C. Fyfe, N. P. Gillett, F. W. Zwiers, Overestimated Global Warming over the Past 20 Years, 3 Nature Climate Change 767 (2013).

Nicholas Lewis, "The implications for climate sensitivity of Bjorn Stevens' new aerosol forcing paper," Mar. 15, 2015, http://climateaudit.org/2015/03/19/the-implications-for-climate-sensitivity-of-bjorn-stevens-new-aerosol-forcing-paper/.

N. Lewis & J.A. Curry, "The Implications for Climate Sensitivity of AR5 Forcing and Heat Uptake Estimates," *Climate Dynamics* (Sep. 25, 2014), available at http://link.springer.com/article/10.1007%2Fs00382-014-2342-y#page-1.

Richard Lindzen, *et al.*, "Does the Earth Have An Adaptive Infrared Iris?," 82 Bull. Am. Meteorological Soc'y 417 (Mar. 2001), available at http://www-eaps.mit.edu/faculty/lindzen/adinfriris.pdf.

Richard Lindzen & Yong-Sang Choi, "On the Determination of Climate Feedbacks from ERBE Data," 36 Geophys. Rsch. Letters L16705 (2009), available at http://www.drroyspencer.com/Lindzen-and-Choi-GRL-2009.pdf.

R.S. Lindzen and Choi, Y.-S., "On the Observational Determination of Climate Sensitivity and Its Implications." *Asia-Pacific Journal of Atmospheric Science* 47: 377-390, 2011.

Thorsten Mauritsen & Bjorn Stevens, "Missing Iris Effect as a Possible Cause of Muted Hydrological Change and High Climate Sensitivity in Models," __ Nature Geosci. __ (Apr. 20, 2015) (advance online publication), available at http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2414.html.

Bjorn Stevens, "Rethinking the Lower Bound on Aerosol Radiative Forcing," __ J. Climate __ (2015) (early online release), available at http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-14-00656.1.

Peter Stott, *et al.*, The Upper End of Climate Model Temperature Projections is Inconsistent with Past Warming, 8 Envir. Res. Letters (pub. online, Feb. 19, 2013), available at http://iopscience.iop.org/1748-9326/8/1/014024/pdf/1748-9326_8_1_014024.pdf.

d. p. 7, line 21: "Warming itself, at the levels that might realistically be anticipated (i.e., under 2C for the foreseeable future) is estimated to be net beneficial." Provide a basis for both the assertion that realistically anticipated warming is less than 2°C and for the assertion that warming under 2°C will be net beneficial.

RESPONSE:

Please see the responses to Questions 8a and 8c.

Further references indicating inability of current models to simulate weather phenomena or to match observational data:

Branstator, G. (2015) Uncertainty in Decadal Predictions Resulting from Imperfect Knowledge of the Initial Conditions. Marchuk Symposium, Moscow, 9 June 2015. https://dl.dropboxusercontent.com/u/77349951/Branstator15-June9-MarchukSymposiumTalk.pdf

Chikamoto, Y., M. Kimoto, et al (2013) An overview of decadal climate predictability in a multi-model ensemble by climate model MIROC. Clim Dyn (2013) 40:1201–1222, DOI 10.1007/s00382-012-1351-y

Ding, R., Li, J. et al (2015) Estimating the limit of decadal-scale climate predictability using observational data. Cli.m.Dyn DOI 10.1007/s00382-01S-2662-6

Frederiksen, C.S., X. Zheng, and S. Grainger (2015) Simulated modes of inter‑decadal predictability in sea surface temperature. Clim. Dyn. DOI 10.1007/s00382-015-2699-6

Furtado, J.C., E. DiLorenzo et al (2011) North Pacific Decadal Variability and Climate Change in the IPCC AR4 Models. J. Clim., 24, 3049-3067, DOI: 10.1175/2010JCLI3584.1

Jin, Emilia K., J. L. Kinter III et al (2008) Current status of ENSO prediction skill in coupled ocean–atmosphere models. Clim Dyn (2008) 31:647–664, DOI 10.1007/s00382-008-0397-3

Kavvada, A., A. Ruiz-Barradas, and S. Nigam (2013) AMO's structure and climate footprint in observations and IPCC AR5 climate simulations. Clim Dyn (2013) 41:1345–1364. DOI 10.1007/s00382-013-1712-1

Keenlyside, N.S., M. Latif et al (2008) Advancing decadal-scale climate prediction in the North Atlantic sector.Nature, 453, doi:10.1038/nature06921

Kravtsov, S. (2012) An empirical model of decadal ENSO variability. Clim Dyn (2012) 39:2377–2391. DOI 10.1007/s00382-012-1424-y

Krishnamurthy, L., and V. Krishnamurthy (2015) Teleconnections of Indian monsoon rainfall with AMO and Atlantic tripole. Clim. Dyn. DOI 10.1007/s00382-015-2701-3

Marini, Camille and C. Frankignoul (2014) An attempt to deconstruct the Atlantic Multidecadal Oscillation. Clim Dyn (2014) 43:607–625. DOI 10.1007/s00382-013-1852-3

Oshima, K. and Y. Tanimoto (2009) An Evaluation of Reproducibility of the Pacific Decadal Oscillation in the CMIP3 Simulations. Journal of the Meteorological Society of Japan, Vol. 87, No. 4, pp. 755--770, 2009. 755. DOI:10.2151/jmsj.87.755

Preethi, B., R. H. Kripalani, and K. Krishna Kumar (2009) Indian summer monsoon rainfall variability in global coupled ocean-atmospheric models. Clim Dyn (2010) 35:1521–1539. DOI 10.1007/s00382-009-0657-x

Prodhomme, C., P. Terray et al (2014) Impacts of Indian Ocean SST biases on the Indian Monsoon: as simulated in a global coupled model. Clim Dyn (2014) 42:271–290. DOI 10.1007/s00382-013-1671-6

Sabeerali, C.T., S. A. Rao et al (2014) Why ensemble mean projection of south Asian monsoon rainfall by CMIP5 models is not reliable? Clim Dyn (2015) 45:161–174. DOI 10.1007/s00382-014-2269-3

Saha, A., S. Ghosh et al (2014) Failure of CMIP5 climate models in simulating post-1950 decreasing trend of Indian monsoon. Geophys. Res. Lett., 41, 7323–7330, doi:10.1002/2014GL061573.

Sperber, K.R., H. Annamalai et al (2012) The Asian summer monsoon: an intercomparison of CMIP5 vs. CMIP3 simulations of the late 20th century. Clim Dyn (2013) 41:2711–2744. DOI 10.1007/s00382-012-1607-6

Zanchettin, D., A. Rubino et al (2013) Multidecadal-to-centennial SST variability in the MPI-ESM simulation ensemble for the last millennium. Clim Dyn (2013) 40:1301–1318. DOI 10.1007/s00382-012-1361-9

e. p. 7, line 23: "The policy risks of limiting the clean burning of fossil fuels are clear and are likely to exceed such risks of climate change as may exist, particularly when the economic and social impacts of higher energy prices are considered."

RESPONSE:

Please see the responses to previous questions. The policy risks of limiting the clean burning of fossil fuel and the economic and social impacts of higher energy prices are supported by the following, as well as by other expert reports in this proceeding:

Robert U. Ayres & Benjamin Warr, *The Economic Growth Engine: How Energy and Work Drive Material Prosperity* (2009).

Robert U. Ayres, Jeroen C.J.M. van don Bergh, Dietmar Lindenberger, & Benjamin Warr, *The Underestimated Contribution of Energy to Economic Growth*, (INSEAD, Working Paper

No. 2013/97/TOM/EPS/SOCIAL Innovation Centre, 2013), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2328101.

Faith Birol, "*Coal's Role in the Global Energy Mix: Treading Water or Full Steam Ahead?*, "The Official Journal of the World Coal Industry, (May 20, 2013), *available at* http://cornerstonemag.net/coals-role-in-the-global-energy-mix-treading-water-or-full-steam-ahead/.

Matt Ridley, *Fossil Fuels Will Save the World (Really)*, Wall St. J. (Mar. 13, 2015), *available at* http://on.wsj.com/1CdXe05.

Vaclav Smil, *Energy at the Crossroads: Global Perspectives and Uncertainties*, MIT Press (2005).

David I. Stern, *The Role of Energy in Economic Growth*, (The United States Association for Energy Economics and the International Association for Energy Economics, USAEE-IAEE Working Paper No. 10-055, Nov. 2010).

f. Line 260 of Exhibit 2: "Second, if we wish to account for the observed warming over the past 150 years on the basis of greenhouse gases, volcanoes and aerosols, then the new bounds on aerosols rule out sensitivities over about 2C."

RESPONSE:

See answer to question 7. Research includes:

Lindzen, R.S. and C. Giannitsis (1998), On the climatic implications of volcanic cooling. *J. Geophys. Res.*, **103**, 5929-5941.

Bjorn Stevens, "Rethinking the Lower Bound on Aerosol Radiative Forcing," __ J. Climate __ (2015) (early online release), available at http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-14-00656.1

g. Line 274 of Exhibit 2: "But, the IPCC argument for attributing the warming since the 1970's to anthropogenic forcings depended on the assumption that natural variability was small (based on the model behavior)."

RESPONSE:

IPCC, *Fifth Assessment Report* 48 (Fig. 1.9); *id.* at 43 (Box 1.1).

Further references include responses to question 8d as well as:

Habibullo Abdussamatov, "Current Long-Term Negative Energy Balance of the Earth Leads to the New Little Ice Age," 2 Journal of Geology and Geophysics 113 (2013), available at http://omicsgroup.org/journals/grand-minimum-of-the-total-solar-irradiance-leads-to-the-little-ice-age-2329-6755.1000113.php.

D.E. Black, *et al.*, "An 8-Century Tropical Atlantic SST Record from the Cariaco Basin: Baseline Variability, Twentieth-Century Warming, and Atlantic Hurricane Frequency," 22 Paleoceanography PA4204 (2007).

Xianyao Chen & Ka-Kit Tung, "Varying Planetary Heat Sink Led to Global-Warming Slowdown and Acceleration," 345 *Science* 897 (Aug. 2014), available at http://www.sciencemag.org/content/345/6199/897.

Paul J. Durack, *et al.*, "Quantifying Underestimates of Long-Term Upper-Ocean Warming," 4 Nature Climate Change 999 (2014).

S. Frisia, *et al.*, "Climate Variability in the SE Alps of Italy over the Past 17,000 Years Reconstructed from a Stalagmite Record," 34 Boreas 445 (2005).

James A. Johnstone & Nathan J. Mantua, "Atmospheric Controls on Northeast Pacific Temperature Variability and Change, 1900-2012," *Proceedings of the Nat'l Acad. of Sciences Early Edition* 1 (published ahead of print) (Sept. 22, 2014), available at http://www.pnas.org/content/early/2014/09/16/1318371111.short.

A. Kress, *et al.*, "Swiss Tree Rings Reveal Warm and Wet Summers During Medieval Times," 41 Geophys. Rsch. Letters 1732 (2014).

W. Llovel, *et al.*, "Deep-Ocean Contribution to Sea Level and Energy Budget Not Detectable Over the Past Decade," 4 Nature Climate Change 1031 (2014).

G.A. Olafsdottir, *et al*., "Historical DNA Reveals the Demographic History of Atlantic Cod (gadus morhua) in Medieval and Early Modern Iceland," 281 Proceedings of the Royal Society B 1777 (2014).

M.W. Salzer, *et al.*, "Five Millennia of Paleotemperature from Tree-Rings in the Great Basin, USA," 42 Climate Dynamics 1517 (2014).

M. Stancikaite, *et al.*, "Human Activity and the Environment During the Late Iron Age and Middle Ages at the Impiltis Archaeological Site, NW Lithuania," 203 Quaternary International 74 (2009).

B.M. Vinther, *et al.*, "Climatic Signals in Multiple Highly Resolved Stable Isotope Records from Greenland," 29 Quaternary Sci. Revs. 522 (2010).

h. Line 472 of Exhibit 2: "Interestingly, a recent paper (Mauritsen and Stevens, 2015) notes that the inclusion of the iris effect in their model uniquely corrects a variety of serious model deficiencies" Provide a citation to where in the Mauritsen and Stevens paper those authors claim that the iris is a "unique" solution to these model deficiencies — i.e., that no other possible solution exists.

RESPONSE:

Thorsten Mauritsen & Bjorn Stevens, "Missing Iris Effect as a Possible Cause of Muted Hydrological Change and High Climate Sensitivity in Models," __ Nature Geosci. __, p.350 (Apr. 20, 2015) (advance online publication), available at http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2414.html.