

S.Polasky

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REBUTTALS TO Tol, Mendelsohn, Martin, Smith..

pp.3-4 replies to Tol and Mendelsohn denigration of his experience.

Also notes actual MN experience, unlike either of them.

p.10 Notes that he and Hanemann are elected Members of NAS, unlike Tol and Mendelsohn.

BEFORE THE MINNESOTA OFFICE OF ADMINISTRATIVE HEARINGS

600 North Robert Street

St. Paul, MN 55101

FOR THE MINNESOTA PUBLIC UTILITIES COMMISSION

121 Seventh Place East, Suite 350

St Paul, MN 55101-2147

**In the Matter of the Further
Investigation into Environmental and
Socioeconomic Costs Under
Minnesota Statute 216B.2422, Subd. 3**

**PUC Docket No. E-999/CI-14-643
OAH Docket No. 80-2500-31888**

**SURREBUTTAL TESTIMONY OF DR. STEPHEN POLASKY,
Fesler-Lampaert Professor of Ecological/Environmental Economics, University of
Minnesota Regent's Professor**

On Behalf of

Clean Energy Organizations

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1 **I. INTRODUCTION**

2 **Q. Please state your name.**

3 **A.** Dr. Stephen Polasky.

4 **Q. Are you the same Dr. Stephen Polasky who provided direct and rebuttal**
5 **testimony on behalf of the Clean Energy Organizations in this proceeding?**

6 **A.** I am.

7 **Q. What is the purpose of your surrebuttal testimony?**

8 **A.** In this surrebuttal testimony, I respond to the rebuttal testimony of witnesses for
9 the other parties, including Drs. Robert Mendelsohn and Richard Tol who
10 testified on behalf of Peabody Energy, Mr. Martin who testified on behalf of Xcel,
11 and Dr. Smith on behalf of the Minnesota Large Industrial Group.

12 **Q. Dr. Mendelsohn asserts that you and Dr. Hanneman, witness for the**
13 **Department of Commerce and Pollution Control Agency, have been asked to**
14 **“give opinions outside [your] areas of expertise.” (Mendelsohn Rebuttal, Exh.**
15 **1, p. 2.) Dr. Tol states that you have provided testimony “outside [your] area**
16 **of prior experience and expertise.” (Tol Rebuttal, Exh. 2, p. 7.) What**
17 **response do you have?**

18 **A.** Drs. Tol and Mendelsohn are incorrect. I have extensive experience and expertise
19 in the area of damage-cost assessments and environmental economics, including
20 on climate change economics and the Social Cost of Carbon.

1 I have a long record of work on the economics of climate change and on the social
2 cost of carbon. I was senior staff economist for environmental and natural
3 resources for the President's Council of Economic Advisers (CEA) in 1998-1999.
4 I was at CEA just after the Kyoto Protocol was negotiated and the costs and
5 benefits of reducing CO₂ emissions were a major focus of work at CEA the year
6 that I was there.

7 Unlike Dr. Tol or Dr. Mendelsohn who are based in Europe and on the East
8 Coast, I have worked directly on climate change issues in Minnesota. I was the
9 sole economist on an expert committee that reviewed the impact of climate
10 change on the Great Lakes region (including Minnesota) and participated in
11 writing a report entitled *Confronting Climate Change in the Great Lakes Region:
12 Impacts on Our Communities and Ecosystems*. I was a member of Energy Supply
13 Technical Working Group, and the Cap-and-Trade Technical Working Group, for
14 the Minnesota Climate Change Advisory Group 2007-2008. I testified before the
15 Minnesota Legislature on cap-and-trade policy in 2008.

16 **Q. Have you written peer-reviewed journal articles on climate change**
17 **economics?**

18 **A.** Yes. I have written several peer-reviewed journal articles focused on climate
19 change, including:

20 Costello, C., M. Neubert, S. Polasky, and A. Solow. 2010. Bounded
21 uncertainty and climate change economics. *Proceedings of the National*
22 *Academy of Sciences* 107(18): 8108-8110.

1 Barrett, S., T.M. Lenton, A. Millner, A. Tavoni, S. Carpenter, J.M.
2 Anderies, F.S. Chapin III, A.-S. Crépin, G. Daily, P. Ehrlich, C. Folke, V.
3 Galaz, T. Hughes, N. Kautsky, E. Lambin, R. Naylor, K. Nyborg, S.
4 Polasky, M. Scheffer, J. Wilen, A. Xepapadeas, and A. de Zeeuw. 2014.
5 Climate engineering reconsidered. *Nature Climate Change* 4: 527-529.

6 I also have a working paper on climate change mitigation:

7 Mason, C., Polasky, S., and Tarui, N. 2014. Cooperation on the climate
8 change mitigation.

9 In addition, my research on the value of ecosystem services and natural capital,
10 the full costs of biofuel and fossil-fuels, and decision-making under uncertainty
11 has involved pricing CO₂ emissions using estimates of the social cost of carbon,
12 the costs of adapting to climate change, as well as discounting and uncertainty.

13 Research publications along these lines include:

14 Guerry, A., S. Polasky, J. Lubchenco, R. Chaplin-Kramer, G.C. Daily, R.
15 Griffin, M.H. Ruckelshaus, I.J. Bateman, A. Duraiappah, T. Elmqvist,
16 M.W. Feldman, C. Folke, J. Hoekstra, P. Kareiva, B. Keeler, S. Li, E.
17 McKenzie, Z. Ouyang, B. Reyers, T. Ricketts, J. Rockström, H. Tallis, and
18 B. Vira. 2015. Natural capital informing decisions: from promise to
19 practice *Proceedings of the National Academy of Sciences* 112: 7348-
20 7355.

21 Johnson, J., C.F. Runge, B. Senauer, J. Foley, and S. Polasky. 2014.
22 Global agriculture and carbon tradeoffs. *Proceedings of the National*
23 *Academy of Sciences* 111: 12342-12327.

24 Lawler, J.J., D.J. Lewis, E. Nelson, A.J. Plantinga, S. Polasky, J.C. Withey,
25 D.P. Helmers, S. Martinuzzi, D. Pennington, V.C. Radeloff. 2014.
26 Projected land-use change impacts on ecosystem services in the U.S.
27 *Proceedings of the National Academy of Sciences* 111(20): 7492-7497.

28 Ren, B. and S. Polasky. 2014. The optimal management of renewable
29 resources under the risk of potential regime shift. *Journal of Economic*
30 *Dynamics and Control* 40: 195-212.

31 Isbell, F., P.B. Reich, D. Tilman, S. Hobbie, S. Polasky, and S. Binder.
32 2013. Nutrient enrichment, biodiversity loss, and consequent declines in

- 1 ecosystem productivity. *Proceedings of the National Academy of Sciences*
2 110(29): 11911-11916.
- 3 Kovacs, K., S. Polasky, E. Nelson, B. Keeler, D. Pennington, A. Plantinga,
4 and S. Taff. 2013. Evaluating the return in ecosystem services from
5 investment in public land acquisitions. *PLoS One* 8(6): e62202.
- 6 Crepin, A.-S., R. Biggs, S. Polasky, M. Troell, and A. de Zeeuw. 2012.
7 Regime shifts and management. *Ecological Economics* 84: 15-22.
- 8 Carpenter, S., K. Arrow, S. Barrett, R. Biggs, W. Brock, A.-S. Crepin, G.
9 Engstrom, C. Folke, T. Hughes, N. Kautsky, C.-Z. Li, G. McCarney, K.
10 Meng, K.-G. Maler, S. Polasky, M. Scheffer, J. Shogren, T. Sterner, S.
11 Taylor, J. Vincent, B. Walker, A. Xepapadeas, and A. de Zeeuw. 2012.
12 General resilience to cope with extreme events. *Sustainability* 4(12): 3248-
13 3259.
- 14 Halpern, B.S., C. Longo, D. Hardy, K.L. McLeod, J.F. Samhouri, S.K.
15 Katona, K. Kleisner, S.E. Lester, J. O'Leary, M. Ranelletti, A.A.
16 Rosenberg, C. Scarborough, E.R. Selig, B.D. Best, D.R. Brumbaugh, F.S.
17 Chapin III, L.B. Crowder, K.L. Daly, S.C. Doney, C. Elfes, M.J. Fogarty,
18 S.D. Gaines, K. Jacobsen, L. Bunce Karrer, H.M. Leslie, E. Neeley, D.
19 Pauly, S. Polasky, B. Ris, K. St. Martin, G.S. Stone, U.R. Sumaila, and D.
20 Zeller. 2012. An index to assess the health and benefits of global marine
21 social-ecological systems. *Nature* 488: 615-620.
- 22 Schwartz, M., J. Hellmann, J. McLachlan, D. Sax, J. Borevitz, J. Brennan,
23 A. Camacho, G. Ceballos, J.Rappaport Clark, H. Doremus, R. Early, J.
24 Etterson, D. Fielder, J. Gill, P. Gonzalez, N. Green, L. Hannah, D.
25 Jamieson, D. Javeline, B. Minter, J. Odenbaugh, S. Polasky, D.
26 Richardson, and T. Root. 2012. Managed relocation: Integrating the
27 scientific, regulatory and ethical challenges. *BioScience* 62(8): 732-743.
- 28 Goldstein, J. G. Caldarone, T.K. Duarte, D. Ennaanay, N. Hannahs, G.
29 Mendoza, S. Polasky, S. Wolny, and G.C. Daily. 2012. Integrating
30 ecosystem service tradeoffs into land-use decisions. *Proceedings of the*
31 *National Academy of Sciences* 109(19): 7565-7570.
- 32 Johnson, K.A., S. Polasky, E. Nelson, and D. Pennington. 2012.
33 Uncertainty in ecosystem services valuation and implications for assessing
34 land use tradeoffs: An agricultural case study in the Minnesota River
35 Basin. *Ecological Economics* 79: 71-79.

- 1 Polasky, S., A. de Zeeuw, and F. Wagener. 2011. Optimal management
2 with potential regime shifts. *Journal of Environmental Economics and*
3 *Management* 62: 229-240.
- 4 Polasky, S., S. Carpenter, C. Folke, and B. Keeler. 2011. Decision-making
5 under great uncertainty: environmental management in an era of global
6 change. *Trends in Ecology & Evolution* 26(8): 398-404.
- 7 Polasky, S., E. Nelson, D. Pennington, and K. Johnson. 2011. The impact
8 of land-use change on ecosystem services, biodiversity and returns to
9 landowners: a case study in the State of Minnesota. *Environmental and*
10 *Resource Economics* 48(2): 219-242.
- 11 Walker, B.W., S. Barrett, S. Polasky, V. Galaz, C. Folke, G. Engström, F.
12 Ackerman, K. Arrow, S. Carpenter, K. Chopra, G. Daily, P. Ehrlich, T.
13 Hughes, N. Kautsky, S. Levin, K-G. Mäler, J. Shogren, J. Vincent, T.
14 Xepapadeas, and A. de Zeeuw. 2009. Looming global-scale failures and
15 missing institutions. *Science* 325(11): 1345-1346.
- 16 Richardson, D.M, J.J. Hellmann, J. McLachlan, D.F. Sax, M.W. Schwartz,
17 J. Brennan, P. Gonzalez, T. Root, O. Sala, S.H. Schneider, Dan Ashe, A.
18 Camacho, J. Rappaport Clark, R. Early, J. Etterson, D. Fielder, J. Gill,
19 B.A. Minteer, S. Polasky, H. Safford, A. Thompson, and M. Vellend.
20 2009. Multidimensional evaluation of managed relocation. *Proceedings of*
21 *the National Academy of Sciences* 106(24): 9721-9724.
- 22 Hill, J., S. Polasky, E. Nelson, D. Tilman, H. Huo, L. Ludwig, J.
23 Neumann, H. Zheng, and D. Bonta. 2009. Climate change and health costs
24 of air emissions from biofuels and gasoline. *Proceedings of the National*
25 *Academy of Sciences* 106(6): 2077-2082.
- 26 Nelson, E., G. Mendoza, J. Regetz, S. Polasky, H. Tallis, D.R. Cameron,
27 K.M.A. Chan, G. Daily, J. Goldstein, P. Kareiva, E. Lonsdorf, R. Naidoo,
28 T.H. Ricketts, and M.R. Shaw. 2009. Modeling multiple ecosystem
29 services, biodiversity conservation, commodity production, and tradeoffs
30 at landscape scales. *Frontiers in Ecology and the Environment* 7(1): 4–11.
- 31 Fargione, J., J. Hill, D. Tilman, S. Polasky, and P. Hawthorne. 2008. Land
32 clearing and the biofuel carbon debt. *Science* 319: 1235-1238.
- 33 Nelson, E., S. Polasky, D.J. Lewis, A.J. Plantinga, E. Lonsdorf, D White,
34 D. Bael, and J.J. Lawler. 2008. Efficiency of incentives to jointly increase
35 carbon sequestration and species conservation on a landscape.
36 *Proceedings of the National Academy of Sciences* 105(28): 9471-9476.

1 Barbier, E.B., E.W. Koch, B.R. Silliman, S. D. Hacker, E. Wolanski, J.
2 Primavera, E. F. Granek, S. Polasky, S. Aswani, L.A. Cramer, D. Stoms,
3 C.J. Kennedy, D.Bael, C.V. Kappel, G.M.E. Perillo, and D.J. Reed. 2008.
4 Coastal ecosystem-based management with non-linear ecological
5 functions and values. *Science* 319: 321-323.

6 Hill, J., E. Nelson, D. Tilman, S. Polasky, and D. Tiffany. 2006.
7 Environmental, economic, and energetic costs and benefits of biodiesel
8 and ethanol biofuels. *Proceedings of the National Academy of Sciences of*
9 *the United States of America* 103: 11206-11210.

10 **Q. Have you authored textbooks or given lectures on the subject of climate**
11 **change economics?**

12 **A.** Yes. I am co-author of a textbook on environmental economics that deals with
13 climate change as well as issues of discounting: Goodstein, E. and S. Polasky.
14 2014. *Environmental Economics* (7th edition). John Wiley & Sons.

15 I have lectured on climate change issues in graduate and undergraduate classes at
16 the University of Minnesota including courses on *The Science and Policy of*
17 *Global Change, Science and Politics of Global Warming, Natural Resource*
18 *Economics, Environmental and Resource Economics, and Sustainability Science.*

19 This year I was invited to be the Zurich Financial Services Distinguished Visiting
20 Professor on Climate Change at the University of California, Santa Barbara.

21 **Q. Do you review scholarly papers on climate change economics?**

22 **A.** Yes. I regularly review papers on climate change in my role serving as an editor
23 or reviewer for professional journals. I am currently or have previously served as
24 an associate editor or on the editorial board of *Proceedings of the National*
25 *Academy of Sciences, Annual Reviews of Environment and Resources,*

1 *Environmental Management, Journal of Environmental Economics and*
2 *Management, Journal of the Association of Environmental and Resource*
3 *Economists, Land Economics, Review of Environmental Economics and Policy,*
4 *Ecological Economics, among other journals.*

5 **Q. When you say “review” do you mean that you are among those scholars who**
6 **provide “peer review” to articles submitted for publication in scientific**
7 **journals as that phrase has been used in these proceedings?**

8 **A.** Yes, I do peer reviews of journal articles.

9 **Q. Do you serve on any boards or committees concerning climate change**
10 **economics?**

11 **A.** Yes. I serve on a number of high level advisory boards that regularly deal with
12 climate change issues. These include:

13 Science Advisory Board for the U.S. Environmental Protection Agency

14 Science Advisory Board for the National Oceanic and Atmospheric
15 Administration

16 Sustainability External Advisory Committee, Dow Chemical Company

17 Science Council and Board of Directors, The Nature Conservancy

18 Science Council, Program on Ecosystem Change and Society,
19 International Council of Scientific Unions

20 Policy and Technical Expert Committee, Wealth Accounting for the Value
21 of Ecosystem Services, World Bank

22 National Academies, Board on Environmental Change and Society

1 **Q. Is there anything else you want to say in response to Dr. Mendelsohn and Dr.**
2 **Tol's questioning of your experience and expertise?**

3 **A.** I would also point out that both Dr. Hanemann and I have been elected into the
4 National Academy of Sciences, while Drs. Mendelsohn and Tol have not.

5 **II. DISCOUNT RATES.**

6 **Q. Both Drs. Tol and Mendelsohn state that IWG should have used 3 percent**
7 **and 7 percent discount rate rather than 2.5 percent, 3 percent, and 5 percent,**
8 **and criticized your defense of the IWG discount rates. How do you respond?**

9 **A.** Discounting is important because CO₂ remains in the atmosphere for a long time
10 and damages from climate change are long-lasting. Therefore, estimates of the
11 social cost of carbon (SCC) are sensitive to the discount rate.

12 Most of the issues raised by Drs. Tol and Mendelsohn in their rebuttal testimonies
13 are restatements of points previously raised in direct testimony, and which I have
14 already addressed in my direct and rebuttal testimony. In addition, these points
15 have also been addressed in the direct and rebuttal testimony of Dr. Hanemann.

16 For example, Drs. Tol and Mendelsohn raise yet again the issue of trying to justify using
17 a 7 percent discount rate by referring to OMB Circular A-4. In my rebuttal testimony I
18 made the following points about why it is not reasonable to use a 7 percent discount rate.

19 First, Dr. Tol himself in his meta-analysis found that only two papers used a discount rate
20 above 5 percent while 10 studies used a discount rate below 3 percent. A 7 percent
21 discount rate is outside the range of discount rates used by researchers studying climate

1 change. Second, OMB was an active participant in the IWG process. OMB plays the key
2 role in overseeing the interagency review process for significant policy documents like
3 the *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under*
4 *Executive Order 12866* by the Interagency Working Group on Social Cost of Carbon.
5 OMB is listed as a participant in the IWG on the title page of the report. The OMB
6 agreed on using discount rates of 2.5 percent, 3 percent, and 5 percent, and not using 7
7 percent. Third, Circular A-4 itself states that the discount rates are suggestions “designed
8 to assist analysts” and offer guidance but that it does not define or require a particular
9 approach. OMB has stated there are two conditions for setting lower rates than 3 percent
10 and 7 percent: i) long time frames that give rise to ethical considerations, and ii)
11 considerable uncertainty about future conditions. Both of these conditions hold for
12 climate change. I find it particularly significant that in criticizing my support of the
13 choice of discount rates by the IWG, Dr. Tol did not mention his own survey of the
14 climate change literature, a survey that does not support using a 7 percent discount rate.

15 **Q. Dr. Mendelsohn questions your statements regarding the “ethics” of discounting.**
16 **How do you respond?**

17 **A.** I have not asserted my own view on the ethics of discounting in this testimony.
18 Rather, I have noted that most economists who discuss discount rates as applied to
19 issues related to long-lasting environmental issues that affect future generations
20 recognize that there is a role for ethics. For example, in a Tufts University
21 Economics Department Working Paper that is scheduled to be published later this
22 year in the *Review of Environmental Economics and Policy* that reviews the

1 literature on the SCC Dr. Gilbert Metcalf and Dr. James Stock say the following
2 about the choice of the discount rate:

3 Climate change involves damages that extend many hundreds of years into
4 the future. While there have been advances in our understanding of long
5 term discount rates on the order of a century (see, for example, Giglio,
6 Maggiori, and Stroebel, 2014) it is not clear that an appropriate framework
7 exists for empirically identifying discount rates over the several centuries
8 used to estimate the SCC. One then has two choices: use existing data and
9 – with some assumptions – adapt results to a time span that is an order of
10 magnitude longer than the span over which estimates were made, or adopt
11 an explicitly ethical and normative perspective, along the lines of Stern
12 (2007). Neither approach is entirely satisfying, and our reading of the
13 literature is that it is unresolved on basic issues, such as whether to use
14 market rates, consumption-based (Ramsey) discounting, whether
15 discounting should be horizon-dependent, or whether a normative
16 approach should be adopted. To us, it seems that these basic issues reflect
17 fundamentally different perspectives or philosophies and it is hard to see
18 how debates over discount rates will be resolved soon.

19 In my original testimony, I stated the following:

20 The second approach to determining the discount rate that should be used
21 for climate policy asserts that there is an ethical component to this
22 decision because climate policy affects current and future generations. As
23 opposed to simple investment decisions, determining how to discount
24 environmental damage involves value judgments on the weight that should
25 be applied to the welfare of future generations compared to the welfare of
26 the current generation. Following this approach leads to much lower
27 recommendations for the appropriate discount rate. Nicholas Stern argues
28 for this approach and used a discount rate of 1.4 percent in the Stern
29 Review.

30 From this statement it is quite clear that I am not asserting my own view on ethics
31 but rather pointing out that there is a role for ethics and that those who recognize
32 the role for ethics have made a powerful argument for lower discount rates.

1 **Q. Dr. Tol criticizes the IWG for not basing its choice of discount rates on the**
2 **Ramsey rule. Please explain this point and provide a response.**

3 **A.** The Ramsey rule describes the discount rate that should be used to optimally
4 allocate resources between consumption versus savings/investment. The Ramsey
5 rule shows that the optimal discount rate is based on several underlying
6 parameters: i) the pure rate of time preference (how people weight present versus
7 future consumption, all else equal), ii) the elasticity of marginal utility of
8 consumption (how benefits from consumption decline with increasing
9 consumption), and iii) the growth rate of the economy. There is virtually no
10 disagreement among economists that the Ramsey rule provides the theoretical
11 basis for finding the optimal discount rate.

12 The issue with use of the Ramsey rule for practical purposes like determining the
13 discount rate to use in the SCC is that there is uncertainty in the values of these
14 underlying parameters and therefore the Ramsey rule does not uniquely determine
15 the discount rate that should be used. In fact, various authors have justified use of
16 relatively low and high discount rates with reference to the Ramsey rule by using
17 different assumptions about the underlying parameters. The IWG considered
18 using the Ramsey rule as a basis for choosing the appropriate discount rates but
19 ultimately chose not to do so. In its response to comments, the IWG explained
20 why:

21 The IWG considered this framework explicitly in exploring the
22 implications of setting the ρ term (pure rate of time preference) at or near
23 zero to give equal weight to the welfare of all future generations. As

1 explained above, this analysis was part of the basis for selecting the lower
2 end of the range. However, after reviewing several approaches to
3 estimating specific parameters, the IWG noted that there is no consensus
4 in the literature on the appropriate approach for selecting specific values
5 for the components of the Ramsey equation. For this reason, the IWG used
6 this analysis to inform its choice of a range of discount rates, but
7 concluded that the Ramsey equation alone should not determine a specific
8 choice of discount rate. (p.24)

9 The IWG's choice of discount rates (2.5, 3, and 5 percent) is consistent with
10 studies that use the Ramsey rule to determine discount rates. I find the IWG's
11 choice on this matter to be reasonable.

12 **Q. Dr. Mendelsohn favors using a declining discount rate. Please explain this**
13 **and provide your response.**

14 **A.** I agree that there are sound reasons for using a declining discount rate through
15 time. If economic growth declines through time, which many macroeconomists
16 think is likely, the Ramsey rule would indicate that the discount rate should
17 decline through time as well. In addition, as I explained in my rebuttal testimony,
18 when there is uncertainty about future discount rate Gollier and Weitzman (2010)
19 showed that "there exists a rigorous generic argument that the future should be
20 discounted at a declining rate that approaches asymptotically its lowest possible
21 value." Starting at a given discount rate, having a declining discount rate tends to
22 raise the SCC compared to the choice of a constant discount rate.

1 The IWG chose not to use declining discount rates on practical grounds. The IWG
2 explained in its response to comments its reasons for not choosing declining
3 discount rates:

4 Finally, with respect to declining discount rates, the IWG agrees that this
5 is an important area of emerging research. However, no widely-accepted
6 declining discount rate schedule has yet been developed. Some key
7 technical issues warrant careful consideration before adopting a declining
8 discount rate schedule, such as determining how to update the discount
9 rate schedule as uncertainty is resolved over time and ensuring that the use
10 of declining discount rates does not lead to the possibility of time-
11 inconsistent choices. A recent workshop sponsored by the federal
12 government resulted in a paper in *Science* authored by thirteen prominent
13 economists who concluded that a declining discount rate would be
14 appropriate to analyze impacts that occur far into the future (Arrow et al.,
15 2013). However, additional research and analysis is still needed to develop
16 a methodology for implementing a declining discount rate and to
17 understand the implications of applying these theoretical lessons in
18 practice. The IWG will continue to follow and evaluate the latest science
19 on the use of declining discount rates in intergenerational contexts and
20 seek external expert advice on issues related to discounting in the context
21 of climate change.” (P. 23-24)

22 I think it is likely that the federal IWG will at some point adopt a declining
23 discount rate for the SCC but given the current state of the literature it is quite
24 reasonable not to have done so at present. Again, however, I note that starting
25 from the same discount rate, having a declining discount rate would *increase* the
26 SCC value as compared to a constant discount rate, and therefore the decision not
27 to adopt a declining rate suggests that the adopted values are conservative.

1 **III. RESPONSES TO DR. RICHARD S. J. TOL.**

2 **Q. How do you respond to Dr. Tol’s statement: “Dr. Polasky simultaneously argues**
3 **that the IWG’s estimate of the social cost of carbon is too low and about right.”**

4 **A.** In my testimony I made several points that Dr. Tol confuses in this statement. First, I
5 addressed the question of whether the approach used by the IWG to estimate the SCC
6 was reasonable. I answered yes. The IWG used a reasonable approach and generated
7 a reasonable estimate of SCC as I have explained at length in my original testimony
8 and in my rebuttal testimony. Dr. Hanemann, likewise, concludes the same in his
9 direct and rebuttal testimonies. Second, I pointed out that there was considerable
10 uncertainty about the SCC and the actual value of the SCC might turn out to be
11 higher or lower than the IWG’s expected value. Third, I wanted to provide some
12 reasons for why actual values might differ from the expected value. I anticipated
13 (correctly) that the experts hired by industry would emphasize reasons why the SCC
14 might turn out to be lower than expected by IWG. I wanted to provide some balance
15 and describe several reasons why the actual value of SCC might turn out to be higher
16 than expected by the IWG. Pointing out that there may be reasons for higher or lower
17 values does not in any way contradict my view that the IWG approach was
18 reasonable and that the expected values for the SCC reported by IWG were
19 reasonable.

1 **Q. Dr. Tol questions your reasons for thinking that the SCC values might turn out**
2 **to be low. First he questions the impact of catastrophic damages. What is your**
3 **response?**

4 **A.** Dr. Tol's testimony does not rebut the assertion that placing more weight on the risk
5 of catastrophic damages would raise the value of SCC, which was the point of my
6 testimony. This is a simple matter of arithmetic. Dr. Tol does not appear to question
7 the arithmetic of the basic point.

8 **Q. Second, Dr. Tol states that you incorrectly argued that integrated assessment**
9 **models do not account for the impact of climate change on economic growth as a**
10 **reason to assume the actual SCC may be greater than the IWG's SCC. How do**
11 **you respond?**

12 **A.** **Dr. Tol has once again confused things.** Here is what my testimony actually said.
13 I noted several reasons why the SCC could be higher than estimated by the IWG.
14 One of those reasons was that "The IAMs may not adequately account for impacts
15 of climate change on economic growth." I did not say they do not account for the
16 impact of climate change on economic growth but that they "may not adequately
17 account for impacts of climate change on economic growth." I went on to explain
18 why I thought they may not adequately account for impacts on economic growth:

19 **Two recent articles have examined the DICE model and found that**
20 **accounting for the possible impact of climate change on the growth rate of**
21 **the economy significantly increases the SCC. If climate change reduces**
22 **the growth rate of GDP then the damages are long-lasting because each**
23 **successive year GDP is further behind the baseline without climate**
24 **impacts. Simon Dietz and Nicholas Stern altered the DICE model by**
25 **incorporating growth effects from climate change, as well as increasing**
26 **the probability of catastrophic climate outcomes. They ran the DICE**

1 model with a discount rate of 4.5 percent (higher than the median 3
2 percent discount rate used by the IWG) and found that the SCC increased
3 from \$14 per metric ton of CO₂ to as high as \$73 per metric ton of CO₂.
4 The important conclusion of this article is that changes in how IAMs
5 model the effect on economic growth from climate change and the
6 probability of catastrophic climate change can greatly increase the SCC.
7 The results also highlight that using a high discount rate can still lead to a
8 large estimate of the SCC.

9 Moore and Diaz are/were affiliated with Stanford. I've met both of them.

10 In another article, Frances Moore and Delavane Diaz alter the DICE
11 model to account for climate change effects on economic growth and find
12 even larger increases in the SCC. They incorporate research that suggests
13 that climate change may accelerate the depreciation of capital from
14 extreme weather events and reduce the productivity of capital because
15 resources have to be directed towards climate mitigation in the future.
16 These factors would lower the growth rate of the economy and greatly
17 reduce the prosperity of future generations. These changes to the DICE
18 model can have an enormous effect on the SCC, increasing the estimate
19 from \$33 to \$220 per metric ton of CO₂.

20 Dr. Tol does not refute the findings of these papers but notes that these hold “only
21 under the assumption that climate change would affect total factor productivity.” But
22 it is changes in total factor productivity that largely determine long term growth rates.
23 The point here is that if climate change negatively affects productivity, then the long
24 term damages of climate change are higher and this would increase the SCC.

25 **Q. What is Dr. Tol’s criticism of your argument that the IWG’s SCC may be an**
26 **underestimate because it does not include a comprehensive accounting of**
27 **damages?**

28 **A.** Dr. Tol agrees that estimates of impacts of climate change used to calculate the SCC
29 are incomplete but he claims that the size and the sign of the missing impacts is
30 unknown. He goes on to say that claims about sizable and negative impacts is “pure
31 speculation.”

1 **Q. Do you agree?**

2 **A.** No. Dr. Tol's claim that missing impacts are "pure speculation" ignores
3 mountains of scientific evidence on the biophysical effects of climate change. The
4 impact of the effects left out of the current generation of IAMs on net benefits is
5 overwhelmingly negative. The most recent IPCC synthesis report catalogs
6 numerous negative consequences that become more severe as temperature
7 increases. That we don't know how exactly severe or how to value these damages
8 in monetary terms within the IAMs does not mean they do not exist. Inclusion of
9 such effects would raise the estimates of the SCC. Making the statement that we
10 do not know the sign of impacts on benefits or that trying to incorporate these
11 impacts is "pure speculation" is inexcusable for someone who has worked on the
12 IPCC.

13 **Q. Did your review of Dr. Tol's testimony with regard to whether the IWG's**
14 **SCC may be too low change the opinion offered in your earlier testimony?**

15 **A.** No. I continue to think that the IWG approach is reasonable and that the reported
16 values for the SCC are reasonable. As with any difficult question involving the
17 future, there is uncertainty about the exact value. As set out in my earlier
18 testimony there are several considerations that would suggest that values adopted
19 by the IWG are lower than the actual SCC.

1 **Q. Dr. Tol argues that the SCC is different from traditional damage cost**
2 **methodologies. What is your response?**

3 **A.** Estimating the SCC involves applying the standard tools of environmental and
4 resource economics to climate change. IAMs use fairly standard economic models
5 of resource allocation over time integrated with very simple climate science. This
6 type of integration of economics with natural science is regularly done in areas of
7 the valuation of air pollution, the valuation of ecosystem services and natural
8 capital, and other topics within environmental and resource economics. Climate
9 change models also involve important temporal dimensions and prominently
10 feature discounting, and uncertainty. But having an important temporal
11 dimension, discounting, and uncertainty are central features of virtually all natural
12 resource economic analyses and many environmental economic analyses.

13 **IV. RESPONSES TO DR. ROBERT MENDELSON.**

14 **Q. Dr. Mendelsohn asserts at lines 20-22 of his rebuttal that you “argue[] that**
15 **the damages are even higher than what the IAM’s predict and the true value of**
16 **time (the discount rate) should be even lower than 2.5 percent.” He later says,**
17 **line 118, that you argue for a low discount rate because “the damage function in**
18 **the IAM’s is not high enough to measure the true damage of a 6C warming.”**
19 **What is your response?**

20 **A.** In these statements Dr. Mendelsohn has incorrectly summarized my position. I stated
21 that I thought the IWG approach was reasonable and that the reported values for the

1 social cost of carbon were also reasonable. I pointed out that there was considerable
2 uncertainty about the SCC and the actual value of the SCC might turn out to be
3 higher or lower than IWG's expected value. I wanted to provide some reasons for
4 why actual values might differ from the expected value. I anticipated that the experts
5 hired by Peabody Energy like Dr. Mendelsohn would emphasize reasons why the
6 SCC might turn out to be lower than expected by IWG. I wanted to provide some
7 balance and described several reasons why the actual value of SCC might turn out to
8 be higher than expected by the IWG. Pointing out that there may be reasons for
9 higher or lower value does not in any way contradict my view that the IWG approach
10 was reasonable and that the expected values for the SCC reported by IWG were
11 reasonable. So I am not arguing that the damages "are even higher" or that "true
12 value" of the discount rate should be even lower, only that it is possible that the true
13 value of damages could turn out to be higher and that there are arguments for
14 considering a lower discount rate.

15 In my testimony, I referenced a paper by Weitzman about the degree of damage at 6
16 degrees C warming. My point here was not to establish what the damages actually are
17 at 6 degrees warming. There is great uncertainty about just how much damage that
18 much climate change would cause. My point was to note that if damages with large
19 warming are indeed large and larger than expected in the IAMs, which cannot be
20 ruled out at present, then the SCC could be much larger than estimated by the IWG.

1 **Q. Dr. Mendelsohn, at lines 26-27, says that “Professor Hanemann and Professor**
2 **Polasky appear to be unaware that the IWG is measuring the SCC assuming**
3 **that the rest of the world will never do any mitigation.” What is your response?**

4 **A.** I find it surprising that Dr. Mendelsohn continues to pursue this line of attack on both
5 Dr. Hanemann and myself. I find this line of attack confused and pointless. The IWG
6 considered a wide range of potential future scenarios for emissions including one
7 scenario with declining emissions. Declining emissions can only occur if there is
8 large-scale mitigation of CO₂ emissions in the rest of the world outside of Minnesota.
9 In response to comments, the IWG stated: “Given the level of uncertainty in these
10 trajectories, the IWG felt that it was appropriate to consider a trajectory with
11 significant global mitigation, assuming that this is a distinct possibility even in the
12 absence of U.S. actions.” (p. 19.) Given this, it is just silly to say “that the IWG is
13 measuring the SCC assuming that the rest of the world will never do any mitigation.”

14 **Q. Dr. Mendelsohn questions the wisdom of Minnesota’s policy to establish an**
15 **externality value for carbon. What is your response?**

16 **A.** Dr. Mendelsohn’s comments regarding Minnesota’s role in the mitigation effort are
17 inapposite. The Commission is charged with estimating the external costs associated
18 with carbon dioxide emissions and has requested witnesses in this proceeding to
19 provide expert opinions on whether the IWG’s SCC is a reasonable estimate. The
20 policy process leading to reciprocal emissions, or the failure of other jurisdictions to
21 reduce emissions is not relevant to the Commission’s charge.

1 Likewise, Dr. Mendelsohn's assertion that the costs of reducing emissions may be
2 high and that the benefits of reducing CO₂ emissions fall mostly outside of
3 Minnesota, whether it is true or not, is irrelevant. The distribution of who benefits and
4 who loses does not determine the cost of an externality.

5 As a more general point, Dr. Mendelsohn is confusing the purpose of establishing the
6 SCC, which is a component of the policy process, with the entire policy process. The
7 task facing the IWG (and that facing the Commission) to establish the SCC is not the
8 same as trying to establish policy on optimal emissions mitigation. The IWG in
9 responding to comments stated it well:

10 The SCC is not a measure of social welfare from the consumption of
11 goods and services whose production results in CO₂ emissions, or other
12 positive or negative externalities associated with the production of those
13 goods and services. In other words, the SCC is just one component of a
14 larger analysis that includes consideration of many other potential impacts,
15 including labor market changes, energy security, electricity reliability, and
16 changes in emissions of other pollutants, among others. (p. 11)

17 **Q. Dr. Mendelsohn is critical of the IWG's changes to the DICE, FUND, and PAGE**
18 **models. Do you agree?**

19 **A. Of all of the points raised by Dr. Mendelsohn, I think this one has the most merit.**
20 There is value in having internal consistency in a model, something which is lost
21 when using assumptions different than what the model dictates. But internal
22 consistency is not the only consideration in trying to use IAMs to estimate the
23 SCC for policy purposes. The IWG justified its approach as follows:

24 Regarding potential inconsistencies between scenarios and IAMs, given
25 the nature of estimating the SCC and available data/resources, a full
26 harmonization along all possible dimensions of the three IAMs used to
27 estimate the SCC with the four models used to develop the scenarios was

1 not possible. Therefore, the IWG chose to harmonize the models with
2 respect to the scenario variables to which SCC estimates are most
3 sensitive (GDP, population, and emissions) using common techniques in
4 the literature.”

5 The virtues of being able to compare across models in a transparent fashion meant
6 that the IWG chose to sacrifice internal consistency. There are often tradeoffs that
7 modelers face given data and modeling limitations. Making models comparable,
8 the methods more transparent, and making it easy to update are all positive
9 attributes. I think the IWG made a reasonable decision considering the tradeoffs
10 in its choice of methods. As a researcher, I would be interested in knowing how
11 much difference lack of internal consistency could make on the answers to the
12 SCC. This is an issue that I hope the IWG addresses more fully in future
13 revisions.

14 **Q. Does Dr. Mendelsohn’s critique of the IWG’s decision to change these**
15 **parameters of the models to make them internally consistent change the**
16 **conclusions you reached in your direct and rebuttal testimony?**

17 A. No. The IWG used a standard set of assumptions to facilitate cross-model
18 comparison and increase the transparency of their approach. I think what they did,
19 and the reasons they stated for doing so, were reasonable. Dr. Mendelsohn has
20 failed to make a case for why he thinks the IWG stated purpose in using a
21 standard set of assumptions for GDP, population, and emissions is unreasonable.
22 Additionally, this critique does not suggest that reliance on one model’s outputs
23 based on one modeler’s assumptions and inputs (e.g., the values recommended by

1 Dr. Mendelsohn in his direct testimony) would be more reasonable than the
2 IWG's SCC values.

3 **V. RESPONSE TO NICHOLAS F. MARTIN.**

4 **Q. Are there areas of agreement between your testimony and that of Mr.**
5 **Martin?**

6 **A.** Yes. There are substantial areas of agreement and only a few areas of
7 disagreement. I agree the Commission should adopt the IWGs "four executive
8 summary SCC values from the July 2015 TSD." (p. 4) I agree with Mr. Martin
9 that the Commission should use "IWG's raw modeling results to develop a range
10 of CO₂ environmental cost values..." (p. 1)

11 **Q. What are the areas of disagreement with Mr. Martin?**

12 **A.** I disagree with Mr. Martin in his use of the median rather than the mean as a
13 measure of expected value for purposes of estimating the SCC and his
14 characterization of my testimony as concluding that the federal SCC was not
15 designed for purposes such as integrated resource planning.

1 **Q. Mr. Martin’s Rebuttal, p. 10, ln 10, cites your direct testimony for the**
2 **proposition that the federal SCC was designed for a purpose other than a use**
3 **such as integrated resource planning. Does that accurately reflect your**
4 **opinion?**

5 **A.** No. I addressed this in my Rebuttal Testimony where I stated that Martin’s
6 argument about the purpose for which the SCC was developed is neither relevant
7 nor persuasive. (See Polasky Rebuttal, p. 33). As I said, estimates of the SCC are
8 applicable to a wide range of applications including cost-benefit analysis and
9 tasks such as resource planning.

10 **Q. Mr. Martin argues that the Commission should not adopt the 95th percentile**
11 **value of the federal SCC. Do you agree?**

12 **A.** No. As Mr. Martin has emphasized, potential damages from climate change has a
13 non-normal distribution. In particular, there is long tail on the high side, i.e., there
14 is a small probability for very high damages. There is not an equivalent long tail
15 on the low side. For this reason, the 95th percentile contains useful information
16 about potentially higher than expected damages. As I noted in my rebuttal
17 testimony, the IWG justified its inclusion of the 95th percentile as follows:

18 The IPCC Fourth Assessment Report, which was the most current IPCC
19 assessment available at the time of the IWG’s 2009-2010 review,
20 discussed these limitations and concluded that it was “very likely that
21 [SSC] underestimates” climate change damages. Based on the current
22 scientific understanding of climate change and its impacts, and on the
23 limitations of the IAMs in quantifying and monetizing the full array of
24 potential “catastrophic” and non-catastrophic damages, the IWG
25 concluded that the distribution of SCC estimates may be biased

1 downwards. Since then, the peer-reviewed literature has continued to
2 support this conclusion. For example, the IPCC Fifth Assessment report
3 observed that SCC estimates continue to omit various impacts that would
4 likely increase damages. The 95th percentile estimate was included in the
5 recommended range for regulatory impact analysis to address these
6 concerns.

7 **VI. RESPONSE TO DR. ANNE E. SMITH.**

8 **Q. Dr. Smith’s review of Dr. Mendelsohn’s modeling concluded that his lower**
9 **SCC estimates would be supported by the IWG’s models if his alternative**
10 **assumptions about climate sensitivity and optimal global temperature were**
11 **adopted. Does this change the recommendation you made in your direct or**
12 **rebuttal testimony?**

13 **A. No. One can always obtain a different solution by putting in different**
14 **assumptions. The IWG itself generated a distribution of outcomes for SCC**
15 **depending on the assumptions made about various parameter inputs. The IWG**
16 began summarized the information using the mean value of the distribution for
17 different discount rates as well as the 95th percentile for a 3 percent discount rate.
18 I find the IWG approach based on synthesis of the existing scientific
19 understanding along with using multiple runs for different plausible parameter
20 values a much better approach than relying on the results of a single researcher
21 based their own particular set of assumptions.

1 **VII. CONCLUSION.**

2 **Q. Has your review of the Rebuttal Testimony in this proceeding changed your**
3 **conclusions or your recommendation?**

4 **A.** No. I continue to recommend that the Commission adopt the federal SCC as the
5 externality value for CO₂ emissions in Minnesota.

6 **Q. Does this conclude your testimony?**

7 **A.** Yes.