

R.Tol

[https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?](https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={A39ADC16-205E-44D3-B080-BC19501F3247}&documentTitle=20158-113190-07)

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REBUTTALS TO: Hanemann, Polasky

First 26p is Tol C.V.but he **failed to mention a very relevant affiliation: Global Warming Policy Foundation**

<http://www.thegwfp.org/who-we-are/academic-advisory-council/>

"Professor Richard Tol

Richard Tol is a climate change economist and a Professor at the Department of Economics at the University of Sussex. He is an editor of the journal Energy Economics."

p.29, 33 denigrate the expertise of Hanemann and Polasky.

He gives negative numbers for SCC, but does not actually say he believes them, just that he was asked to use Mendelsohn's assumptions, and his own earlier uses of FUND gave numbers above any presented by Peabody.

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

Dr. Richard S.J. Tol

August 12, 2015

1 **Q. Please state your name, address, and occupation.**

2 A. Richard S.J. Tol.

3 Apple House, Hamsey Road, Barcombe, BN8 5TG, United Kingdom

4 Professor of economics

5 **Q. Please describe your educational background and professional**
6 **experience.**

7 MSc (econometrics, Vrije Universiteit Amsterdam, 1992)

8 PhD (economics, Vrije Universiteit Amsterdam, 1997)

9 1992-2007, researcher, Vrije Universiteit Amsterdam

10 1998-2008, Adjunct professor, Carnegie Mellon University

11 2000-2006, Michael Otto Professor of Sustainability and Global Change,
12 Hamburg University

13 2005-2006, Visiting professor, Princeton University

14 2006-2011, Research professor, Economic and Social Research Institute,
15 Dublin

16 2010-2011, Adjunct professor, Trinity College, Dublin

17 2008-, Professor of the economics of climate change, Vrije Universiteit
18 Amsterdam

19 2012-, Professor of economics, University of Sussex

20 I have served on the Intergovernmental Panel on Climate Change (IPCC)
21 since 1994. I regularly participate in studies of the Energy Modeling Forum,
22 and I am an editor of Energy Economics. Additional biographical
23 background is provided in Tol Rebuttal Exhibit 1.

24 **Q. Did you previously submit testimony in this proceeding?**

25 A. No.

26 **Q. Have you reviewed other pre-filed testimony?**

27 A. Yes. I reviewed written testimony by Michael Hanemann and Stephen
28 Polasky.

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

3 A. Yes, I have prepared a report, which is attached as Tol Rebuttal Exhibit 2.

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

5 A. No.

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

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Exhibit 1

To

Rebuttal Testimony of

Dr. Richard S.J. Tol

August 12, 2015

Richard S.J. Tol - Biography

Richard S.J. Tol is a Professor of Economics at the University of Sussex and the Professor of the Economics of Climate Change, Institute for Environmental Studies and Department of Spatial Economics, Vrije Universiteit, Amsterdam, the Netherlands. Formerly, he was a Research Professor at the Economic and Social Research Institute, Dublin, an Adjunct Professor, Department of Economics, Trinity College, Dublin, the Michael Otto Professor of Sustainability and Global Change at Hamburg University and an Adjunct Professor, Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA, USA.

He has had visiting appointments at the Canadian Centre for Climate Research, University of Victoria, British Columbia, at the Centre for Social and Economic Research on the Global Environment, University College London, and at the Princeton Environmental Institute and the Department of Economics, Princeton University.

He received an M.Sc. in econometrics (1992) and a Ph.D. in economics (1997) from the Vrije Universiteit Amsterdam. He is ranked among the top 200 economists in the world, and has 170 publications in learned journals (with 108 co-authors), 3 books, 5 major reports, 37 book chapters, and many minor publications.

He specialises in the economics of energy, environment, and climate, and is interested in integrated assessment modelling. He is an editor for Energy Economics, and an associate editor of economics the e-journal.

He is advisor and referee of national and international policy and research. He is an author (contributing, lead, principal and convening) of Working Groups I, II and III of the Intergovernmental Panel on Climate Change, shared winner of the Nobel Peace Prize for 2007; an author and editor of the UNEP Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies; a GTAP Research Fellow; and a member of the Academia Europaea. He is actively involved in the European Climate Forum, the European Forum on Integrated Environmental Assessment, and the Energy Modeling Forum.

Oddly, he failed to mention a very relevant affiliation:

Global Warming Policy Foundation

<http://www.thegwpf.org/who-we-are/academic-advisory-council/>

"Professor Richard Tol

Richard Tol is a climate change economist and a Professor at the Department of Economics at the University of Sussex. He is an editor of the journal Energy Economics."

Books

- Tol, R.S.J. (2014), [Climate Economics: The Economics of Climate, Climate Change, and Climate Policy](#), Edward Elgar, Cheltenham. [Resource pages](#)
- Hertel, T.W., S. Rose and R.S.J. Tol (eds.) (2009), [Economic Analysis of Land Use in Global Climate Change Policy](#), Routledge, London.
- Von Storch, H., R.S.J. Tol and G. Floeser (eds.) (2008), [Environmental Crises: Science and Policy](#), Springer, Berlin, 146 pp.
- Downing, T.E., A.A. Olsthoorn and R.S.J. Tol (eds.) (1998), [Climate, Change and Risk](#), Routledge, London, 407 pp.

Journal articles

[Latest working papers](#)

2014

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2013

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- Calzadilla, A., K. Rehdanz, R. Betts, P. Falloon, A. Wiltshire and R.S.J. Tol (2013), [Climate change impacts on global agriculture](#), Climatic Change, 120 (1-2), 357-374.
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- Hinkel, J., R.J. Nicholls, R.S.J. Tol, Z.B. Wang, J.M. Hamilton, G. Boot, A.T. Vafeidis, L. McFadden, A. Ganopolski, R.J.T. Klein (2013), 'A global analysis of erosion of sandy beaches and sea-level rise: An application of DIVA', Global and Planetary Change, 111, 150-158.
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- Lyons, S., J. O'Doherty and R.S.J. Tol (2010), [Determinants of Water Connection Type and Ownership of Water-Using Appliances in Ireland](#), Water Resources Management, 24 (12), 2853-2876.
- Mayor, K. and R.S.J. Tol (2010), [Scenarios of Carbon Dioxide Emissions from Aviation](#), Global Environmental Change, 20 (1), 65-73.
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- [Morning Ireland \(on carbon taxes\)](#)

- [Tonight with Vincent Browne \(on environmental issue\)](#)

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

Professor Dr. Richard S.J. Tol

August 12, 2015

Rebuttal Report of Dr. Richard S.J. Tol

1 INTRODUCTION

2 My name is Dr. Richard S.J. Tol. I am a Professor of the Economics of Climate
3 Change at Vrije Universiteit Amsterdam and a Professor of Economics at the University of
4 Sussex. I am a Member of the Academia Europaea. I have served on the Intergovernmental
5 Panel on Climate Change (IPCC) since 1994. I regularly participate in studies of the Energy
6 Modeling Forum, and I am an editor of Energy Economics. I am the primary author of the
7 FUND model. https://en.wikipedia.org/wiki/Richard_Tol He withdrew from IPCC team Sept 2013.

8 I have direct experience estimating the social cost of carbon. The Interagency
9 Working Group on the Social Cost of Carbon relies on three integrated assessment models –
10 DICE, PAGE, and FUND. I started building the FUND model in 1993. On the strength of
11 this research, I was invited to be a Principal Lead Author of the Second Assessment Report of
12 Working Group III of the Intergovernmental Panel on Climate Change, and I have
13 participated in several rounds of the Energy Modeling Forum of Stanford University. Until
14 2004, I was the sole developer of the model. Since then, the model has been co-developed by
15 Dr David Anthoff. On the strength of the later research, Dr Anthoff was appointed on a
16 tenure-track position at the University of California at Berkeley. I have published over 30
17 papers in learned journals based on results from the FUND model; these papers have been
18 cited over 800 times. Besides the research with FUND, I have published three literature
19 reviews and meta-analyses on the social cost of carbon (in 2005, 2009 and 2011; a fourth one
20 was submitted earlier this year). IDEAS/RePEc ranks me 124th out of 44,647 economists;
21 and 5th in environmental economics and energy economics.

22 I have been asked to opine as to the testimonies of Dr. W. Michael Hanemann, who is
23 testifying in this proceeding on behalf of the Division of Energy Resources of the Minnesota
24 Department of Commerce, in consultation with the Minnesota Pollution Control Agency, and
25 Dr. Stephen Polasky, who is testifying on behalf of Clean Energy Organizations. Both of

26 them rely on the estimate of the federal social cost of carbon developed by the U.S.
27 government’s Interagency Working Group (“IWG”).

28

29 **1. Dr. Hanemann’s Testimony**

30 It appears to me as though the parties retaining Dr. W. Michael Hanemann have
31 requested him to provide testimony outside his area of prior experience and expertise. To the
32 best of my knowledge, he has never published an estimate of the social cost of carbon. Dr.
33 Hanemann’s relative unfamiliarity with this field shows in several aspects of his testimony:

- 34 i. Dr Hanemann claims that the first estimate of the impact of climate change was
35 published in 1992. (Hanemann Direct at 30:15-16.) But it was in 1979 by Dr.
36 Ralph C. d’Arge, while the first estimate of the social cost of carbon was
37 published in 1982 by Dr. William D. Nordhaus.
- 38 ii. Dr. Hanemann’s Figure 1 (Hanemann Direct at 25:1-2) is accurate for PAGE but
39 not for DICE and FUND. In DICE, the impacts of climate change (7) affect
40 economic growth (1). In FUND, climate change (4, 5) affects emissions (2) and
41 the impacts of climate change (7) affect population and economic growth (1).
- 42 iii. Dr. Hanemann’s further confuses “equilibrium warming” (shown in his Equation
43 (2), Hanemann Direct at 28:13) and “transient warming” (used in DICE, PAGE
44 and FUND). This is a basic error. “Equilibrium warming” refers to equilibrated
45 warming – i.e., the ultimate temperature increase after the full effects of warming
46 have expressed themselves through the “inertia” of ocean heat uptake and
47 otherwise. “Transient warming” refers to the temperature response over a given
48 period of time, such as 20 years, or by a certain date, such as 2100.
- 49 iv. Dr. Hanemann claims that FUND is not “readily available.” (Hanemann Direct at
50 65:1-8.) This is false. FUND has been in the public domain since 1999; at the
51 moment, it can be freely downloaded from GitHub.

52 Dr. Hanemann defends the discount rates used by the IWG. I disagree. The Ramsey
53 rule is a more appropriate choice. The Ramsey rule is named after a 1928 publication in the

54 *Economic Journal* by Frank Ramsey. (F.P. Ramsey, “A Mathematical Theory of Saving,” 38
55 *Econ. J.* 543 (Dec. 1928), available at <http://piketty.pse.ens.fr/files/Ramsey1928.pdf>.)
56 According to the Ramsey rule, the discount rate should vary with economic growth. The
57 Ramsey rule makes sense because it relates the money discount rate to parameters underlying
58 the “time value” of money – i.e., the reasons that receiving money today is preferred over
59 receiving it in the future.

60 The “time value” of money reflects several considerations. We discount future pay-
61 outs because we are impatient and because we expect to be richer in the future. The rate of
62 impatience is often referred to as the “pure rate of time preference” or the “utility discount
63 rate.” The pure rate of time preference measures how much we prefer to get good things now
64 rather than later.

65 Furthermore, because we expect our income to grow, a dollar gain today is worth
66 more than a dollar gain in a year from now, because the relative gain in income is greater
67 now than later. This component of the Ramsey rule has two parameters, viz. the rate of
68 income growth and the rate at which an extra dollar loses incremental value as we grow
69 richer: A dollar means more to a homeless person than to Bill Gates.

70 The Ramsey rule relates to the reasons that receiving money today is preferred over
71 receiving it in the future. As noted, under the Ramsey rule, the discount rate varies with
72 economic growth. As economic growth is unlikely to be constant over long periods of time, a
73 constant discount rate is likely to equal the appropriate discount rate. Similarly, the Ramsey
74 rule dictates that the discount rate should differ between different scenarios of future
75 economic growth, and between countries growing at different rates.

76 The IWG used real discount rates of 2.5%, 3.0% and 5.0% and did not use the
77 Ramsey rule, which had an effect on its analysis. Table 1 shows the social cost of carbon for
78 alternative discount rates. The Office of Management and Budget recommends real rates of
79 3.0% and 7.0%, but the IWG used 2.5%, 3.0% and 5.0%. Table 1 shows the full range. The
80 social cost of carbon rises sharply for higher discount rates. Because the initial impacts of
81 climate change are positive, due to carbon dioxide fertilization, reduced winter heating, and

82 few cold-related deaths, the social cost of carbon is negative for the highest discount rates,
 83 that is, carbon dioxide emissions should be subsidized rather than taxed.

84 The IWG used a consumption rate of discount that is constant over time, rather than
 85 the more appropriate Ramsey discount rate (Ramsey, 1928, Arrow et al., 2013). Table 1
 86 shows the implications. The parameters of the Ramsey rule – the pure rate of time preference
 87 and the rate of risk aversion – are chosen such that the net present value of a stream of \$1
 88 gains for a century is the same for the economic growth rate assumed for the USA. However,
 89 because many other regions are assumed to grow faster than the USA, applying the Ramsey
 90 rule leads, as shown in Table 1, to lower estimates of the social cost of carbon. Because the
 91 Ramsey discount rate and the constant discount rate diverge as we peer further into the future,
 92 the difference is particularly pronounced for lower discount rates.

93 Table 1. Estimates of the social cost of carbon (\$/tC) for alternative discount rates.*

<i>R</i>	<i>P</i>	<i>H</i>	<i>SCC</i>
7.0%			-1.75
	5.5%	1.0	-1.89
	4.8%	1.5	-1.89
	4.0%	2.0	-1.84
5.0%			1.14
	3.6%	1.0	-0.31
	2.9%	1.5	-0.59
	2.1%	2.0	-0.55
3.0%			20.05
	1.6%	1.0	11.15
	0.9%	1.5	9.83
	0.2%	2.0	10.02
2.5%			35.29
	1.1%	1.0	21.09
	0.5%	1.5	17.22
	-0.2%	2.0	19.28

94 * The utility discount rate (ρ) and the rate of risk aversion (η) are chosen to be
 95 equivalent to the consumption discount rate (r) for the Ramsey rule ($r=\rho+\eta g$) and projected
 96 US growth (g) for the 21st century.

97 The social cost of carbon, as estimated by the IWG, reflects the marginal damage to
 98 the whole world. The majority of the impacts of climate change will fall outside the
 99 jurisdiction of the US government. The IWG discounted future impacts with the same

100 discount rate, regardless of the location of those impacts. This is equivalent to using region-
 101 specific weights. According to the Ramsey rule, the consumption rate of discount equals the
 102 utility rate of discount plus the population growth rate plus the growth rate of per capita
 103 consumption times the rate of risk aversion. The Ramsey rule implies that future impacts are
 104 more heavily discounted in more rapidly growing economies. By using the same discount
 105 rate regardless of the prospects for economic growth, the IWG puts a premium on the impacts
 106 in countries that grow faster than the USA. The effect can be substantial. For instance, using
 107 the FUND scenario as used by the IWG, impacts in China are weighted 46% to 87% higher
 108 than impacts in the USA. In other words, a \$1.00 loss in the USA is counted as \$1.00; but a
 109 \$1.00 loss in China is counted as \$1.46 to \$1.87. The result of this approach is that the IWG
 110 effectively places more value on the circumstances in China than on those in the USA.

111 Dr. Hanemann accepts that the IWG increased the social cost of carbon between 2010
 112 and 2013. I am surprised by that. Table 2 shows the estimates of the 2020 social cost of
 113 carbon as recommended by the IWG on the Social Cost of Carbon in 2010 and 2013
 114 (IAWGSCC, 2013, IAWGSCC, 2010). Table 4 also shows the estimates by the three models
 115 used by the IWG on the Social Cost of Carbon. All models show an increase in their
 116 estimates. This is most pronounced for PAGE and least pronounced for DICE, with FUND
 117 somewhere in the middle. PAGE's modeller, Dr. Chris W. Hope, has not published
 118 comparable estimates around 2010 and 2013. The FUND team has (Waldhoff et al., 2014,
 119 Waldhoff et al., 2011). The estimates of the social cost of carbon by the FUND team are not
 120 directly comparable to those by the IWG, but they are comparable to one another. In 2011,
 121 FUND estimated a social cost of carbon of \$8.0/tC; in 2014, was \$6.6/tC. In other words,
 122 FUND as used by the FUND team shows a *lower* social cost of carbon, whereas FUND as
 123 used by US Federal Government shows a *higher* social cost of carbon. I have not tried to
 124 reconstruct the IWG estimates, so I do not know what they did to find a stark increase in their
 125 estimate of the social cost of carbon.

126 Table 2. Estimates of the social cost of carbon (²⁰⁰⁷\$/tCO₂) for emissions in 2020.

	2010			2013		
Model\Discount rate	5.0%	3.0%	2.5%	5.0%	3.0%	2.5%

Here, he explicitly said \$/tCO₂.

DICE	13.0	34.7	50.2	12.2	37.8	56.6
PAGE	9.4	36.7	58.7	21.6	70.6	101.4
FUND	-0.9	7.3	16.2	2.6	21.0	36.0
IAWGSCC	6.8	26.3	41.7	12.0	43.0	65.0

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

134

135 **2. Dr. Polasky's Testimony**

136 It appears to me as though the parties retaining Dr. Stephen Polasky have requested
137 him to provide testimony outside his area of prior experience and expertise. To the best of my
138 knowledge, he has never published an estimate of the social cost of carbon.

139 Dr. Polasky simultaneously argues that the IWG's estimate of the social cost of
140 carbon is too low and about right. He gives four reasons why the estimate would be too low.
141 First, he argues that the federal estimate does not give adequate weight to catastrophic
142 damages. Earlier, Dr. Polasky discusses the representation of catastrophic impacts in DICE
143 and PAGE. Dr. Polasky refers to Weitzman (2009) but omits that that paper was anticipated
144 by Tol (2003), which is based on results from the FUND model. Dr. Polasky cites a
145 speculative estimate by Weitzman that a 6°C warming would cost 50% of GDP, but omits
146 other estimates that put the number closer to 7% of GDP (Nordhaus, 1994, Roson and van der
147 Mensbrugge, 2012).

148 Dr. Polasky argues that the IWG used relatively high discount rates. The IWG used
149 discount rates of 2.5%, 3.0% and 5.0%. The Office of Management and Budget recommends
150 real discount rates of 3.0% and 7.0%.

151 Dr. Polasky argues that integrated assessment models do not account for the impact of
152 climate change on economic growth. This is true for the PAGE model, but not true for DICE
153 and FUND. Dr. Polasky omits reference to Pizer (1999) and Fankhauser and Tol (2005), who
154 find that the growth effect is small. He does refer to Dietz and Stern (2015) and Moore and
155 Diaz (2015), who find large effects but only under the assumption that climate change would
156 affect total factor productivity. While Dietz and Stern (2015) offer no evidence in support of
157 that assumption, Moore and Diaz (2015) refer to Dell et al. (2012). However, as emphasized
158 by (Dell et al., 2014), the Dell 2012 paper is about the effects of weather and it should not be
159 interpreted as evidence that climate (change) affects productivity.

160 Dr. Polasky argues that estimates of the impacts of climate change are incomplete and
161 underestimates. Impact estimates are indeed incomplete. However, the models that are used
162 to estimate the social cost of carbon include all impacts for which a global impact estimate is
163 available. Therefore, the size and indeed the sign of the missing impacts is unknown. Dr.
164 Polasky's assertion that the missing impacts are sizable and negative, is pure speculation.

165

166 **3. The FUND Model**

167 As I mentioned previously, both Dr. Hanemann and Dr. Polasky rely on the estimate
168 of the federal social cost of carbon developed by the IWG, which in turn relied on three
169 Integrated Assessment Models, known as DICE, FUND, and PAGE. I understand that
170 Robert Mendelsohn of Yale has already provided testimony in this proceeding using the
171 DICE model. I have been asked to show the results of the FUND model under the same
172 parameters as Professor Mendelsohn used (which he derived from the testimony of Professors
173 Lindzen, Happer and Spencer). I think this means Mendelsohn assumptions that net damage does
not become positive until either 1.5C or 2.0C.

174 Professor Mendelsohn's testimony in this case used discount rates between 3% and
175 7%, and climate sensitivity values between 1.0 and 3.0. My Table 1 above shows the results
176 of the FUND model using various discount rates. The results of the FUND model using the
177 same assumptions regarding climate sensitivity values as Professor Mendelsohn is as follows:

178

Note wording: Tol was asked to run with Mendelsohn's assumptions. He did not say he believed them, and p.32:136 Table 2 shows numbers done earlier that look quite different.

179 Table 3. Estimates of the social cost of carbon (\$/tC) for the alternative climate
 180 sensitivities (CS) used by Professor Mendelsohn.

CS	1.0	1.5	2.0	2.5	3.0
SCC	-17.97	-12.06	-4.05	7.06	20.05

Short	-16.30	-10.54	-3.67	6.40	18.19
t/CO2	-4.40	-2.95	-0.99	1.73	4.91

\$/tC = \$ / (metric tonne) C, not CO2
 \$/tCO2 is not \$/tC, but rather:
 $\$/tCO2 = 0.27 * \$/tC$
 (Given CO2 ~ 12 + 2* 16, so 12/44)
 Either this is typo, or the \$/tCO2
 is as shown at left.
 IT IS HARD TO KNOW WHAT THIS
 MEANS, BUT PEABODY QUOTED.

181 **4. Disaggregating the Effects Of Human-Induced And Natural Climate**

182 **Variability**

183 Current estimates of the social cost of carbon are based on the assumptions that short-
 184 term natural climate variability is irrelevant in that it averages out, and that there is no long-
 185 term natural climate variability. There are a few papers (Estrada and Tol, 2013a, Estrada and
 186 Tol, 2013b), yet to be published in peer-reviewed journals, that test these assumption, but it is
 187 too early to draw any conclusion. Accordingly, current models do not disaggregate the
 188 effects of human-induced warming and natural variability, and work on that issue is just in its
 189 infancy.

191 **5. The 97% Figure Is Flawed**

192 It is often said that 97% of climate scientists agree that climate change is real, human-
 193 made, and dangerous. There are many things wrong with this assertion, as I have previously
 194 noted. (See Richard S.J. Tol, “Quantifying the Consensus on Anthropogenic Global
 195 Warming in the Literature: A Re-Analysis,” 73 Energy Policy 701 (2014); Richard S.J. Tol,
 196 “Quantifying the Consensus on Anthropogenic Global Warming in the Literature:
 197 Rejoinder,” 73 Energy Policy 709 (2014).) The 97% number is taken from Cook et al.
 198 (2013). The paper is silent about whether climate change is dangerous or not. In this context,
 199 “human-made” means that at least half of the observed warming is due to human activity,
 200 which includes but is not limited to anthropogenic greenhouse gas emissions. And the 97%
 201 refers to the number of papers rather than the number of researchers.

202 The 97% pertains to a sample of the literature, rather than the whole literature, and the
 203 sample is unrepresentative. The sample is dominated by papers that are not about climate

204 change and its causes, but rather about the impacts of climate change and climate policy.

205 Cook and colleagues report two tests for data quality, and fail both.

206 Cook and colleagues have claimed that abstracts were rated by two independent
207 raters, even though these raters freely interacted with each other. They have claimed that the
208 raters did not know journal and author, even though they did. They have claimed that data
209 could not be inspected by independent experts because that would violate a confidentiality
210 agreement, even though such an agreement never existed. They have climate data that could
211 not be inspected because it was never collected, even though it was.

212 Cook and colleagues collected data, inspected the results, collected more data,
213 inspected the results again, changed the way the data was classified, collected yet more data,
214 inspected the results, and changed the data classification again before the final results were
215 presented. The same team collected and analyzed the data. Cook and colleagues thus broke
216 all rules about scientific data gathering.

217 The journal editors and publishers are aware of the paper's problems, but have chosen
218 not to act.

219 Cook's paper illustrates everything that is wrong with climate research. Studies are
220 praised because the results are politically expedient rather than scientifically valid. Research
221 scandals are covered up. Whistleblowers are vilified.

222

223 **6. Differences Between Social Cost of Carbon and Traditional Damages Cost**
224 **Methodologies.**

225 The causal chain for the social cost of carbon is rather long, complex and contingent.
226 In this way it is different from the traditional damages cost methodology for a pollutant like
227 mercury or lead. Let us consider two particular impacts, malaria and coastal flooding.

228 In either case, the emission of a tonne of carbon dioxide leads to a change in the
229 atmospheric concentration of carbon dioxide. However, the precise relationship between
230 emission and concentration is mediated by the terrestrial biosphere, which is influenced by

tonne (Metric tonne) of CO₂

231 such things as the climate, land and water use, and the deposition of fertilizers such as
232 nitrogen.

233 A change in the atmospheric concentration of carbon dioxide leads to a change in
234 radiative forcing of the atmosphere. However, the change in radiative forcing depends on
235 radiative forcing itself.

236 A change in radiative forcing leads to a change in climate. This change in climate
237 sets in motion a number of feedback effects, each of which lead to further climate change and
238 many of which vary with climate itself.

239 This makes it rather difficult to estimate the climate effect of carbon dioxide
240 emissions, and indeed that effect varies over time and is contingent on human choices within
241 the domain of climate policy (e.g., emissions, land use) as well as outside that domain (e.g.,
242 fertilization).

243 Now let us turn to malaria. The parasite develops faster in warmer climates; and the
244 vector thrives in warm and wet conditions. Climate change is likely to lead to an increase in
245 potential malaria. However, there is a difference between potential and actual malaria.
246 Malaria used to be endemic in the southern USA and southern Europe. Malaria outbreaks
247 have been reported as far north as Murmansk. Malaria is now rare in the rich world because
248 mosquito habitat was destroyed, mosquitoes were exterminated, and medicine created herd
249 immunity. Malaria is now largely limited to poor countries.

250 As vulnerability to malaria depends on development, future vulnerability will be
251 different than today's. The impact of climate change is thus contingent on the state of roofs
252 and pavements, on the availability of pesticide-impregnated bed nets, and on the affordability
253 of malaria medicine. Resistance to anti-malarial drugs and the development of new malaria
254 medicine or even vaccines further complicate the matter. As climate change plays out over
255 centuries, major developments can be expected.

256 The social cost of carbon is expressed in money. Estimates of the social cost of
257 carbon therefore do not only estimate the number of climate-change-induced malaria deaths,
258 but also attach a monetary value to these fatalities. So, as a final complication, the

259 willingness to pay to reduce the risk of premature mortality has to be projected over a century
260 or more.

261 Let us consider the impact of coastal flooding in a country like Bangladesh next.
262 Where malaria is driven by temperature and rainfall, coastal flooding are further driven by
263 sea level rise and wind speed and direction. But the impact of a possible increase in coastal
264 flooding is also determined by the quality of flood protection. Flood protection is typically
265 provided by the public sector. Estimates of the social cost of carbon thus require not only
266 projections of future floods and the number and value of properties in the coastal zone, but
267 also projections of decisions made by future politicians.

268 This is rather complicated. Like Bangladesh, the Netherlands is a densely populated
269 delta facing the risks of storms and floods from sea and river. The Netherlands started its
270 modern dike building program in 1850. At the time, the Netherlands was not much richer
271 than Bangladesh is now, and technology was more primitive. In 1850, the Netherlands had
272 long been vulnerable to floods. Dike building started in response to political events. In
273 response to the European Spring of 1848, a new constitution was introduced in 1849 that
274 gave the Netherlands a strong central government that was broadly representative of the
275 population. The new government promptly invested in one of the electorate's main concerns:
276 flood protection.

277 Bangladesh is among the worst-governed countries in the world. As long as that is
278 the case, it cannot muster the large-scale infrastructure projects needed to protect its
279 population against floods. A competent and caring government can. Estimates of the social
280 cost of carbon are thus contingent on assumptions about the future governance of countries
281 such as Bangladesh.

282 Malaria and coastal protection are two examples. Similar issues arise in the other
283 impact of climate change, be it in agriculture, health, energy use, biodiversity, floods or
284 storms.

285 In sum, the causal chain from carbon dioxide emission to social cost of carbon is long,
286 complex and contingent on human decisions that are at least partly unrelated to climate

287 policy. The social cost of carbon is, at least in part, also the social cost of underinvestment in
288 infectious disease, the social cost of institutional failure in coastal countries, and so on.

289

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