Natural Resources Defense Council

COMMENTS ON:

Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards
Environmental Protection Agency
and
National Highway Traffic Safety Administration
Docket No. EPA–HQ–OAR–2009–0472/NHTSA–2009–0059

Natural Resources Defense Council
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Preface

The proposed rule asks for comments on the methodology used to estimate the social cost of carbon (SCC)—a monetized value of the marginal benefit (reduced "social cost") of greenhouse gas emissions reduction. It notes that the specific SCC proposed in the rulemaking is an "emphatically interim" estimate based upon the work of the interagency task force assigned by the Administration to develop an SCC to be used in all future rulemakings. Because the SCC in this proposed ruling has potential implications well beyond this regulation, we are submitting these comments separately from our more specific comments on the proposed motor vehicle standards. Most of our comments are recommendations for improving the methodology for estimating the SCC for future regulations. NRDC recognizes that implementing many of these recommendations will not be possible within the time frame of this ruling. Nevertheless, they should inform what the agencies decide to do in the short- and longer-term.

Introduction

The characteristics of the pollution that drives climate change pose substantial challenges for estimating a sound SCC. Perhaps the most complex and important issue is that climate change could result in very high and potentially catastrophic damages that could affect the entire world population and ecosystem. Few other forms of pollution have these characteristics. Traditional economic tools were developed to estimate marginal changes along continuous functions, and are not well suited for handling abrupt non-linear changes. Greenhouse gas pollutants are also unlike most other pollutants in that they remain in the atmosphere for hundreds of years, and are likely to create irreversible damages. This makes the choice of the discount rate particularly contentious, because the farther into the future climate damages occur, the smaller the weight assigned to them as a result of discounting. Done wrong, discounting could result in a heavy bias toward favoring the current generation and ignoring catastrophic damage several generations hence. Finally, greenhouse gases affect the earth's atmosphere independently of where they occur. A perverse consequence of this is that many of the world's poor, who neither emitted the gases nor benefited from the economic growth that ensued, will be disproportionately impacted. This makes decisions about "equity weighting" important and controversial.

The methodology and proposed SCC estimates set forth in this proposed rulemaking do not address these problems adequately. Our comments are therefore focused on improving the tools we have to better account for the above-described characteristics of climate change. To the extent possible, we hope that our recommendations will be used to revise the SCC estimates used in this proposed rulemaking. More importantly, we hope they will be used to improve the SCC methodology used by the interagency task force in its development of a final SCC estimate for future uses.

Based upon NRDC's analysis, 3% and 5% discount rates are inappropriately high in the context of climate change. Therefore, for the purposes of this rulemaking, the Agencies should *at a minimum* use the Newell-Pizer SCC value of $56. They should also change how the models, and the estimates derived from them, are presented (see point 2 in Section I). These two recommendations would be easy to implement within the time frame of this rulemaking.

I. Summary of NRDC Concerns and Recommendations

1) ***The SCC estimates are systematically biased downward, in large part because they do not adequately reflect the most critical issue in climate change: non-zero probabilities of extremely high and potentially catastrophic damages. This is a result of several factors:*** a) A large number of damages are not, and cannot be, estimated in the economic models. The models are also ill-suited to predicting adaptation capacities, and tend to adopt overly optimistic assumptions; b) There is a tendency for climate projections from the IPCC, upon which the economic models rely, to understate threats from climate change; c) There is a heavy reliance upon central estimates produced by the IPCC and the economic models. The agencies' further compound this error by deciding to "central estimate" these estimates through the "model-weighting" procedure, and then select the central estimate of the model-weighted estimates as their core value. *This reliance upon central estimates is inconsistent with the distribution of damage estimates, which has a "fat" right tail that extends toward infinity (due to the potential for very high and possibly catastrophic damages).*

   Recommendations:

   a) Each of the three main economic models should be re-run, so that the model-weighting procedure, which masks the distribution of potential damages, is unnecessary. Section II.1.c. includes a description of the model weighting procedure.
   b) To better capture uncertainty, the models should be re-run using the Monte Carlo procedure employed in the Stern Review.[1] The Monte Carlo procedure as it applies to climate change is discussed in more detail in Section II.1.c.
   c) To better capture high and potentially catastrophic damages, the agencies should adopt Weitzman's (2009)[2] suggestion of "extending the grid" in the Monte Carlo simulations (i.e. increase the number of, and value for, low probability catastrophic damages). How one might "extend the grid" in a Monte Carlo simulation is explained in Section II.1.c.
   d) Weitzman shows that, in the context of climate change, expected utility theory implies an infinite value for the SCC. NRDC recommends the agencies adopt his suggestion to use the value of a statistical life (the "VSL") to represent infinite utility losses in the Monte Carlo simulations. The VSL has been much maligned: contrary to how it sounds, it does not measure the value of an actual person. Rather, it estimates what individuals are willing to pay to reduce their risk of death.[3] Therefore, throughout the remainder of this document, we will provide this definition parenthetically.
   e) For catastrophic outcomes that affect the entire globe, such as a complete melting of the West Antarctic ice shelf or Greenland's glaciers, or collapse of the earth's ecosystem, NRDC recommends a value implied by Weitzman's analysis: the global population multiplied by the VSL.
   f) One global value for the VSL should be used, i.e. it should not vary by income or the expected number of life years remaining (as is currently done in some of the models).

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[1] Stern, N (2006).The Stern Review: The Economics of Climate Change. HMTreasury, London.

[2] Weitzman, M (2009). On Modeling and Interpreting the Economics of Catastrophic Climate Change. Review of Economics and Statistics 9(1): 1-19.

[3] Literally, the VSL is an estimate of what individuals are willing to pay to reduce their risk of death by 1/100,000. The VSL represents the sum of 100,000 individuals' willingness to pay for this risk reduction.

g) Because catastrophic outcomes would have very low probabilities of being selected in the Monte Carlo simulations, the maximum number of runs should be performed so that infinite utility losses are more accurately represented (Weitzman, 2009). The Monte Carlo procedure as it applies to climate change is discussed in more detail in Section II.1.c.
h) To better capture multiple uncertainties and negative feedback loops that increase probabilities of various catastrophes, the agencies should over sample low probability/high damage outcomes (Weitzman, 2009) in the Monte Carlo simulations. An example of what over sampling might look like in a Monte Carlo simulation is provided in Section II.1.c.
i) Following the PAGE model, a general "adaptation" function should be integrated into all models that can vary by level, speed, and cost (though the default adaptation assumptions in PAGE should *not* be used—see Section II.1.a).[4] All three parameters (level, speed, and cost) should be randomized in the Monte Carlo, given how uncertain adaptation capacities will be.
j) The "damage functions" in the models should be modified to allow for cross-sectoral impacts. For example, there should be an interactive term between extreme weather events or epidemics and the mass migration that could result from either.

2) ***The agencies' <u>presentation</u> of SCC estimates fails to communicate the models' limitations with respect to being able to quantify damages, as well as the uncertainty of the estimates and their distribution. The result is that catastrophic damages are not accurately conveyed.***

Recommendations:

a) Identify what damages are included and not included, for each model, and present them in detailed tables in the main body of the text. Section II.1.a. enumerates these damages and provides an example.
b) Report as sensitivity cases SCC estimates at the 83rd, 95th, and 99th percentiles, and their associated benefits values.

Both of these recommendations can easily be done within the time frame of this ruling, and NRDC believes it would be difficult to find a rationale for why they cannot be.

3) ***The discount rates of 3% and 5% are too high, resulting in valuing the current generation more than future generations and under-estimating the SCC.*** The agencies base the chosen discount rates upon various returns in asset markets. NRDC believes that market returns are not appropriate in the context of climate change. However, if market-based returns are going to be used, they should be corrected for uncertainty and acknowledge that mitigation is more properly represented as an insurance investment (Section II.3 discusses this rationale in more detail). The agencies also base the selected discount rates upon the "Ramsey" social discount rate formula (see Section II.3 for a detailed discussion of the formula). NRDC agrees

[4] The PAGE model currently has this capacity, while most other models do not. Email correspondence with Chris Hope, November 16, 2009.

philosophically with using a social discount rate, but not with how the three variables in the Ramsey equation are treated (the personal rate of time preference, which increases the discount rate to represent the fact that the current generation prefers to have more consumption now than later; the inter-generational "equity weight,"[5] η; and the growth rate in consumption, g). We also note that the agencies fail to give the values for all of the variables in the Ramsey equation: specifically, they only provide the product of η and g.

Recommendations:

a) The discount rate is best informed by a social discount rate. If the Ramsey equation is used, it should: 1) assume a zero value for the personal rate of time preference, because a positive value favors the current generation over future ones based solely upon the fact that its citizens are born first; 2) adjust the growth rate term downward to correct for biases in GDP measures; GDP is widely acknowledged by economists to overstate growth in real welfare (we document this in Section II.3).
b) If the discount rate is going to be informed by the Ramsey equation, the values of g and η should be given, so that they can be properly evaluated. (See Section II.3 for a detailed discussion of the equation).
c) If the discount rate is going to be informed by returns on markets, it should be no higher than the risk free rate of return. That rate should be the long run yield on 6 month U.S. Treasury Notes rather than 10 year U.S. Treasury Bonds, which carry inflation risk. Using a discount rate no higher than the risk free rate of return is based upon the argument that an insurance market framework is more appropriate than an asset market framework in the context of climate change. We discuss this rationale in Section II.3. NRDC recommends against using regular returns in markets, but if they are going to be used they need to be adjusted for uncertainty of the "correct" discount rate, using declining values over time as prescribed by Weitzman (2000), Newell-Pizer (2003), and the UK government.
d) Where not already the case, the models should allow for negative discounting when damages are observed to be larger than growth. See Section II.4 for discussion, as well as the end of Section II.3.
e) Points a) through d), and those made in Section I.1) above, all lead to one unambiguous conclusion: the proposed discount rates of 3% and 5% are too high. Indeed, the SCCs based upon 5% come from a set of 21 SCC estimates, *6 of which are less than zero and 6 zero*. ***<u>At a minimum,</u> for the purposes of this rulemaking, only the Newell-Pizer value of $56 should be used***.

4) ***The SCC estimates should be equity weighted (i.e. damages suffered by low income populations should be weighed more heavily than those suffered by wealthier populations), just as they are between generations as a result of discounting. Correspondingly, the number used for the value of a statistical life (VSL; i.e. the willingness to pay for reducing one's risk of death—see footnote 3) should be equal between all countries and populations.*** Failing to weigh damages by income levels is inconsistent with economic theory (see Section II.4). It is also difficult to justify on ethical grounds: most of the world's

[5] In the literature this parameter is not referred to as an equity weight, but effectively that is what it is. We explain this in Section II.4.

poor neither emitted the CO_2 emissions responsible for current atmospheric concentration levels, nor economically benefited from them—resulting in the poor having the least ability to absorb climate damages. In some models the *reverse* of equity weighting actually occurs, with the VSL calculated as a multiple of one's income level.

Recommendations:

a) Equity weighting should be done within generations, just as it is done between generations.
b) The equity weight used should be comparable to the one used for inter-generational equity weighting.
c) Given that there are reasonable arguments for various equity weight values, the range of values should be based upon the most agreed upon range in the literature, and could be randomized in the Monte Carlo simulations.
d) As recommended under 1.d-f. above, the value of a statistical life (i.e. willingness to pay for reducing one's risk of death—see footnote 3) should be one global value, i.e. it should not vary by income or the number or expected number of life years remaining (as is currently done in some of the models).

5) ***A domestic SCC should not be under consideration.*** Greenhouse gases are a global pollutant; it is fundamentally inconsistent with the global circulation of these pollutants to arbitrarily limit benefits to those accruing within a nation's border. If all countries estimated benefits on this basis, it would create a huge collective action problem of extremely low mitigation. It is also incorrect to assume that damages in other countries will not spill over to the U.S. (e.g. mass migration, spread of infectious disease, political and social unrest, etc.). Finally, it is difficult to justify using a domestic SCC on ethical grounds. See Section II. 5 for a more detailed discussion of these issues.

Recommendation:

a) For this and any future regulation, only global SCCs should be used.

II. Detailed discussion of NRDC's concerns

1) ***The SCC estimates are systematically biased downward, in large part because they do not adequately reflect the most critical issue in climate change: non-zero probabilities of extremely high and potentially catastrophic damages. This is a result of several factors:***

a. ***Excluded damages and overly optimistic adaptation assumptions***

It is widely acknowledged that SCC models exclude so many expected damages that the estimates produced by them will be biased downward, probably by a significant margin. As noted by the IPCC Fourth Assessment Report, "It is *very likely* that globally aggregated figures underestimate the damage costs because they cannot include many non-quantifiable impacts."[6]

Omitted-damages disclaimers are ubiquitous, from developers of the models, analysts using the models, agencies using the estimates from the models, authors of scholarly articles, politicians, commentators, advocacy groups, and so on. Indeed, it would be difficult, if not impossible, to find any serious writing on the topic without an "omitted-bias disclaimer."

The heavy bias downward is due in part to the sheer number of damages that are left out but, perhaps more importantly, to the fact that what is left out are damages that matter most to people. Were it possible to estimate what people were willing to pay to avoid them, SCC figures would be much higher. Consider the following list of impacts omitted from the FUND model48:[7]

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[6] IPCC WGII. 2007. Climate Change 2007—Impacts, Adaptation and Vulnerability Contribution of Working Group II to the Fourth Assessment Report of the IPCC. See EPA Docket, EPA–HQ–OAR–2009–0472. This quote is also provided in the proposed ruling.

[7] This table is taken from Table 3, in Holladay and Schwartz (2009); it adds three categories: 1) damages from ancillary pollutants; 2) ocean acidification; and 3) mass migration due to spread of infectious disease or extreme weather events. Items and categories were also re-ordered. Holladay, JS and Schwartz, JA (2009). The other side of the coin: the economic benefits of climate legislation. Policy Brief No.4. Institute for Policy Integrity, New York University School of Law.

Table 1: List of Impacts Omitted in FUND Model48

Foreign Affairs	Social and political unrest abroad that affects U.S. national security (e.g.,violent conflict, mass migration due to infectious disease or extreme weather events, humanitarian crises)
	Damage to foreign economies that affects the U.S. economy
	Domestic valuation of international impacts
Biomes/Ecosystems	Reverse of carbon uptake, amplification of climate change
	Thresholds or "tipping points" associated with species loss, ecosystem collapse, and long-term catastrophic risk (e.g., Antarctic ice sheet collapse and 20 foot sea level rise)
	Species existence value and the value of having the option for future use
	Loss of coral reefs
	Coral bleaching due to ocean warming
	Poleward and upward shift in habitats; species migration
	Ecosystem service disruption (e.g. loss of cold water fish habitat in the U.S.)
	Increases in algae and zooplankton
	Range changes/earlier migration of fish in rivers
	Shifts in ranges of ocean life
	Ocean acidification (currently in an experimental version of FUND)
	Earlier timing of spring events; longer growing season
Forest	Longer fire seasons, longer burning fires, and increased burn area
	Forest disappearance of alpine habitat in the United States
	Tropical forest dieback in the Amazon
GDP/Economy	Extreme weather events (droughts, floods, fires, and heavy winds)
	Insurance costs with changes in extreme weather, flooding, sea level rise
	Infrastructure costs (roads, bridges)
	Vulnerability of societies highly dependent on climate - sensitive resources
	Global transportation and trade impacts from Arctic sea ice melt
	Distributional effects within regions
Health	Increased deaths, injuries, infectious diseases, stress-related disorders with more frequent extreme weather (droughts, floods, fires, and heavy winds)
	Ancillary benefits from reductions of other pollutants
	Increases in malnutrition
	Air quality interactions (e.g., ozone effects, including premature mortality)
Energy	Energy production/infrastructure
	Water temperature/supply impacts on energy production
Agriculture	Reduction in growing season (e.g., in Sahel/southern Africa)
	Increase in growing season in moderate climates
	Impact of precipitation changes on agriculture
	Impact of weather variability on crop production

The list is long and daunting, yet most documents give no more than a few sentences about them—a token three or four categories might be provided. This is true in the proposed ruling, which provides a few examples in a *footnote*:

> *Examples of impacts that are difficult to monetize, and have generally not been included in the SCC estimates, include risks from extreme weather (death, disease, agricultural damage, and other economic damage from droughts, floods, and wildfires) and possible long-term catastrophic events, such as the collapse of the West Antarctic ice sheet or the release of large amounts of methane from melting permafrost.* (Footnote 379 of proposed ruling)

In the body of the text, EPA/NHTSA acknowledge the likely biases in the SCC, and give an example of one omitted damage: "Some of the potential damages from climate change—for example, the loss of endangered species, are generally not included in current SCC estimates. These omissions may turn out to be significant, in the sense that they may mean that the best current estimates are too low." (p.49676 of proposed ruling)

The models also exclude cross sectoral damages, which are likely to be very large. For example, food and water shortages, extreme weather events, and increases in vector borne disease could lead to mass migration and political instability, but models typically treat these damages separately.

As Freeman and Guzman (2009)[8] write:

> *Most studies calculate costs on a sector-by-sector basis, summing the impact on individual sectors to arrive at an overall estimated aggregate impact. This "enumerative approach," though understandable given the complexity of attempting to consider all sectors simultaneously, understates the impact of climate change because it fails to account for a variety of interactions among the examined sectors. It does not account, for example, for the fact that a substantial melting of the Sierra snowpack might have consequences for water shortages in the western U.S. Nor does it capture how cumulative impacts might affect a particular sector—for example, how climate-induced negative impacts on both water resources and the energy sector might combine to reduce agricultural outputs.*

Finally, many adaptation costs are not accounted for, or assumed to be very small.[9] Ackerman, Stanton, Hope and Alberth (2009) surprisingly report that the Stern Review adopted substantial and nearly costless adaptation assumptions in the PAGE2002 model. Specifically, PAGE2002 assumes that in developing countries, 50 percent of economic damages (e.g. property damage from rising sea levels) are eliminated by low-cost adaptation. In OECD countries, 100 percent of the economic damages resulting from the first 3.6ºF (2ºC) of warming, and 90 percent of economic damages above 3.6ºF are eliminated. For non-economic (e.g. impacts on wilderness areas and animals) and non-catastrophic damages, adaptation is assumed to remove 25 percent of the impact everywhere. No adaptation is assumed for catastrophic damages.[10]

b. *Conservative nature of IPCC review process*

There are reasons to be concerned that the IPCC underestimates the dangers of climate change (as the IPCC itself notes in its report). This is due to the excluded damages discussed above, but also scientific biases that generally lead toward conservative assessments.

There is a tendency (in all sciences) to be cautious. Scientists are naturally averse to making predictions that might not come true, even if they are possible; doing so can jeopardize their academic credibility. Privately, scientists will say that as a matter of disciplinary training and shared norms, they tend to err on the side of caution. One way to do this is to rely upon central

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[8] Freeman, J and Guzman, A (2009). Sea walls are not enough: climate change & U.S. interests. UC Berkeley Public Law Research Paper No. 1357690, available at http://ssrn.com/abstract=1357690.

[9] Some argue that low cost adaptation, which would lower the SCC, is underrepresented in the models, resulting in overestimated SCC estimates. NRDC believes that while some low cost adaptation will surely be available, on net it will be expensive.

[10] Ackerman, F, Stanton, E, Hope, C and Alberth, F (2009). Did the Stern Review underestimate US and global climate damages? Energy Policy 37: 2717–2721.

estimates. There is no reason to expect that the 2,800+ different IPCC authors, review editors, and reviewers, are any different. Compounding this, these scientists rely upon published articles which, for the same motivation, also focus on "best guess" central estimates. As will be discussed in the in Section II.c below, best guesses in climate science will tend to understate the dangers of climate change and misrepresent the data.

A persuasive piece of evidence that IPCC reports are conservative is that, following every IPCC assessment report (four to date), many predictions have turned out worse than expected.[11] Each IPCC assessment report is grimmer than the previous. There are already signs that the last assessment report of 2007 (the Fourth Assessment Report, FAR) had overly optimistic "best guesses."

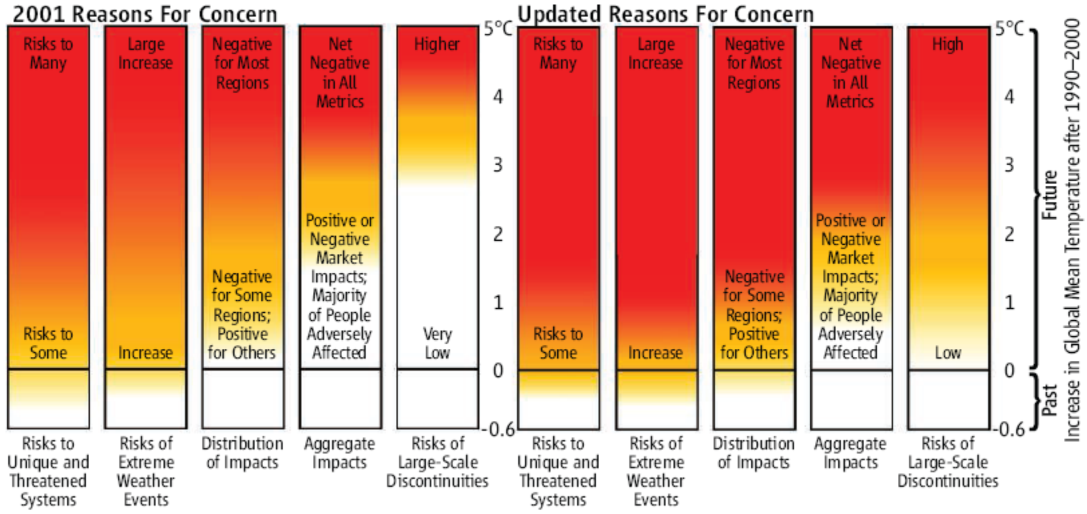
An article in Science Magazine released just this month summarized a number of disturbing signs.[12] Within months of the FAR, arctic sea ice coverage dropped to a record low, prompting talk about catastrophic tipping points. The IPCC report had projected that late-summer sea ice could almost disappear by the end of the century; models and sea-ice specialists now suggest that summer sea ice might be gone by 2030. Sea levels have been rising as fast as FAR's worse-case projection, threatening to raise sea level by a meter or more (assuming no catastrophic melting of the West Antarctic ice shelf or glaciers covering Greenland, either of which would raise sea levels by 20 feet) by the end of the century, rather than the few tens of centimeters projected in FAR.

The article gives a side by side comparison of the "Burning Embers" IPCC diagram (reproduced below; Figure 1). The left diagram was from the 2001 IPCC assessment report, and the right an updated diagram released in March 2009 in the *Proceedings of the National Academy of Sciences*. The charts display risk levels for different categories of damages for a given temperature increase (bounded by 5ºC (9ºF))—just above the upper end of the IPCC's "best guess" temperature change projection). The red/darker areas indicate high risks.

[11] A small number move in the opposite direction, but the majority are in the "wrong" direction.

[12] Kerr, RA (2009). Amid worrisome signs of warming, 'climate fatigue' sets in. Science Magazine 326(5955): 926-928.

Figure 1: IPCC burning embers diagrams, 2001 vs. 2009



Burning brighter. The red denoting high risk has crept down to smaller warmings since 2001.

Recent data has shown that greenhouse gas emissions shot up in the previous five years to exceed the IPCC's worst scenarios. This September, the United Nations Environment Programme issued a report concluding that "the pace and scale of climate change may now be outstripping predictions of the last [IPCC] report."[13] At the same time, the ocean's capacity to absorb CO2 (which itself has very negative environmental impacts) is decreasing much faster than expected, eliminating what has been a huge "carbon sink."[14,15] The Arctic permafrost, too, appears to be melting faster than predicted, and could prove to be a very serious negative feedback loop (warming that causes more warming): the Arctic contains more CO2 than the entire atmosphere holds today, and thawing permafrost can release methane, which is approximately 23 times more potent than carbon dioxide as a greenhouse gas.[16]

Finally, the IPCC fourth assessment report (FAR) estimated climate sensitivity—the global average temperature increase resulting from a doubling of atmospheric CO2—at 3°C (5.4°F; the "central estimate"). More recent work summarizing evidence from the pale climatic record, however, supports a climate sensitivity of 6°C—that is, a doubling of atmospheric concentration of CO2 is likely to increase temperatures twice as much as FAR projected. The authors estimate a 25 percent risk of serious harm with 300-500 ppm CO2 concentration levels, arguing that getting to levels below at least 350 ppm CO2 by 2100 is critical.[17]

The argument for giving more weight to the IPCC's most pessimistic projections is persuasive: virtually all past "best guess" predictions have turned out to be "optimistic guess" projections.

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[13] *Id.*
[14] A "carbon sink" absorbs CO2 from the atmosphere.
[15] Khatiwala1, S, Primeau, F and Hall, T. Reconstruction of the history of anthropogenic CO2 concentrations in the ocean (November, 2009). Nature 462: 346-349.
[16] See supra note 8, Freeman and Guzman.
[17] Hansen, JM, Sato, P, Kharecha, D, Beerling, R, Berner, V, Masson-Delmotte, M, Pagani, M, Raymo, DL, Royer, and Zachos, JC (2008). Target Atmospheric CO2: Where Should Humanity Aim? The Open Atmospheric Science Journal 2: 217-231. Available at http://droyer.web.wesleyan.edu/Target_CO2_(Hansen_et_al).pdf

c. ***There is a heavy reliance upon central estimates produced by the IPCC and the economic models. The agencies' further compound this error by deciding to "central estimate" these estimates through the "model-weighting" procedure, and then select the central estimate of the model-weighted estimates as their core value.***

Estimates provided by the IPCC (which as discussed above are conservative) are the starting point for the economic integrated assessment models (IAMs), which translate emissions and temperature projections into economic damages for different regions of the world. Average ("best guess") impacts are calculated for each region, and then aggregated into one global SCC.

For the proposed rulemaking, EPA/NHTSA take published global SCC estimates from the three main IAMs, FUND (Framework for Uncertainty, Negotiation, and Distribution, developed by Richard Tol), PAGE (Policy Assessment for the Greenhouse Effect, developed by Chris Hope), and DICE (Dynamic Integrated model of Climate and the Economy, developed by William Nordhaus).

Five SCC estimates are proposed for the ruling, based upon various discount rates. The resulting SCCs are $5, $10, $20, $34 and $56/tCO2 (2007$). The proposed primary value for estimating benefits is the $20 SCC, which represents the median of all five estimates, and is obtained by averaging two of the other estimates (i.e. it is the average of the SCC estimates obtained using the 3% and 5% "constant" discount rates; see Section II.3. below). These SCCs are derived using a model-weighting procedure that is intended to give equal weight to each model, since some models have more published results than others.

The weighting procedure is approximately the following: First, SCC estimates from each model are gathered from published estimates for alternate discount rates (3% and 5%). Second, for each model and discount rate, the SCC estimates are averaged. Finally, the averages from each model are averaged, to produce one "model-weighted" SCC estimate per discount rate. For example, if there were 3 published estimates at a specific discount rate from one model, they would be averaged. The same would be done for each of the other models (each of which has a different number of published estimates). Then, for a given discount rate, the three averages from each model are averaged, producing a final "model-weighted" SCC.

This methodology distorts and misrepresents the distribution of climate damage estimates, whose probability distribution has a "fat" right tail (low to medium probabilities of relatively high damages), extending toward infinity (very low probabilities of profound catastrophes). In contrast, the left tail has relatively moderate probabilities of moderate damages, and ends close to zero, with very low probabilities of negligible damages. To summarize, the distribution of damages resembles a normal bell curve to the left of the center, but to the right is fat and long, extending to infinity.

Consider the following table, based upon Tol's (2008) meta review of SCC estimates in the literature:[18]

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[18] These values were calculated from: Tol, RS (2008). The Social Cost of Carbon: Trends, Outliers, and Catastrophes. Economics: The Open-Access, Open-Assessment E-Journal 2(25), from Table 2.

Table 2: Social cost of carbon estimates from Tol (2008) meta analysis $/tCO2 (2008$)[19]

	Hope, Nordhaus, and Tol, plus other authors (n=211)		Hope (n=48)		Nordhaus (n=8)		Tol (n=112)	
	Low	High	Low	High	Low	High	Low	High
Mean	$33	$48	$11	$16	$7	$11	$18	$26
Standard deviation	$92	$133	$23	$45	$16	$33	$33	$52
95th percentile	$141	$226	$33	$44	$39	$55	$66	$94
99th percentile	$615	$768	$160	$167	$64	$174	$139	$225

It is immediately obvious that the spread of the distribution is skewed heavily toward the right, and highly uncertain, as evidenced by the size of the standard deviation.

Table 3 below shows how the various measures of distribution diverge from the mean in percentage terms. The standard deviation is 183-307% above the mean, and the 95th percentile 276-542% above. By way of comparison, an average 40 year old white male in the U.S. is approximately 70 inches tall, with a standard deviation of approximately 3 inches and a 95th percentile of approximately 75 inches (4.3% and 7.1% above the mean, respectively).[20] The 99th percentiles of the SCC estimates are *779-1844%* above the mean.

Table 3: Percentage higher than the mean, corresponding to Table 2

	Hope, Nordhaus, and Tol, plus other authors (n=211)		Hope (n=48)		Nordhaus (n=8)		Tol (n=112)	
	Low	High	Low	High	Low	High	Low	High
Standard deviation	276%	276%	207%	283%	221%	307%	183%	201%
95th percentile	422%	469%	303%	276%	542%	518%	370%	363%
99th percentile	1844%	1594%	1459%	1048%	884%	1639%	779%	872%

Given the heavy bias downward of SCC estimates, these should be viewed as an understatement of the distribution of potential damages.

Let's now review, from start to finish, the derivation of the SCC estimates. They are constructed from multiple layers of central estimates. First, the IAM models rely upon central estimates from the IPCC scientific review process. Damages are then estimated by region in the IAMs, and aggregated up to a global value.[21] The IAMs then produce their own "best guess" global SCC estimates. The agencies then average these estimates, by model, for a given discount rate. These averages are then averaged *again* to produce the model-weighted SCCs. Finally, the proposed ruling focuses its attention on the central estimate of the model-weighted averages ($20).[22]

[19] t/C to was converted to t/CO2, and the SCCs from 1995$ to 2008$.
[20] Estimated from a chart at http://www.halls.md/chart/men-height-w.htm.
[21] Interestingly, Anthoff, Hepburn, and Tol (2009) find that equity-weighted SCC estimates may be more than twice as high if national rather than regional impacts are aggregated. This suggests that the higher the level of geographic aggregation, the lower the estimated SCC. Anthoff, D, Hepburn, C, and Tol, R (2009). Equity weighting and the marginal damage costs of climate change. Ecological Economics 68: 836-849.
[22] As noted above, $20 is an average of the two SCC estimates obtained from the constant (see Section II.3) 3% and 5% constant discount rates, respectively, and also turns out to be the median of the 5 SCC estimates.

This cascading flow of central estimates, given what we know from climate science, is astonishing. In the end, the agencies choose a lower bound that is representative of the left tail of the distribution of damage estimates, and an upper bound that misrepresents the right tail. Further, the lower bound SCC estimates of $5 and $10 come from a set of 21 SCC estimates, *6 of which are less than zero and 6 zero*. ***Not surprisingly, these SCCs are based upon the 5% discount rate***.

Zero or negative SCC estimates cannot possibly be correct. In *Center for Biological Diversity v. NHTSA,* 538 F.3d 1172 (9th Cir., 2008), the Ninth Circuit Court of Appeals overturned NHTSA's light-duty truck CAFE standards because NHTSA had taken the position that CO2 emission reductions had no monetary value. The Court said: "NHTSA's reasoning is arbitrary and capricious for several reasons. First, while the record shows that there is a range of values, the value of carbon emissions reduction is certainly not zero." *Id.* at 1200.

If anything, the estimation procedure should go in the opposite direction *away* from central estimates, expanding the right tail rather than contracting it. As Weitzman (2009) describes, climate change presents a long chain of tenuous inferences with huge uncertainties in every link that undermine the capability of IAMs to estimate damages:

> *When fed into an economic analysis, the great open ended uncertainty about eventual mean planetary temperature change cascades into yet much greater, yet much more open-ended uncertainty about eventual changes in welfare.*
>
> *There exists here a very long chain of tenuous inferences fraught with huge uncertainties in every link beginning with unknown base-case GHG emissions; then compounded by huge uncertainties about how available policies and policy levers transfer into actual GHG emissions; compounded by huge uncertainties about how GHG-flow emissions accumulate via the carbon cycle into GHG-stock concentrations; compounded by huge uncertainties about how and when GHG-stock concentrations translate into global mean temperature changes; compounded by huge uncertainties about how global mean temperature changes decompose into regional temperature and climate changes; compounded by huge uncertainties about how adaptations to, and mitigations of, climate-change damages are translated into utility changes—especially at a regional level; compounded by huge uncertainties about how future regional utility changes are aggregated—and then how they are discounted—to convert everything into expected-present-value global welfare changes. The result of this immense cascading of huge uncertainties is a reduced form of truly stupendous uncertainty about the aggregate expected-present-discounted utility impacts of catastrophic climate change, which mathematically is represented by a very spread out, very fat-tailed PDF [distribution] of what might be called "welfare sensitivity"…[with] the value of "welfare sensitivity"… effectively bounded only by some very big number representing something like the value of statistical civilization as we know it or maybe even the value of statistical life on Earth as we know it." Weitzman (2009)* [23]

This may sound extreme to some, but the associated probabilities are not in the "infinitesimal" neighborhood—they exceed risks of catastrophic outcomes people spend a lot of money to insure themselves against. Weitzman argues that the same IPCC report that found a "best guess"

[23] See supra note 2.

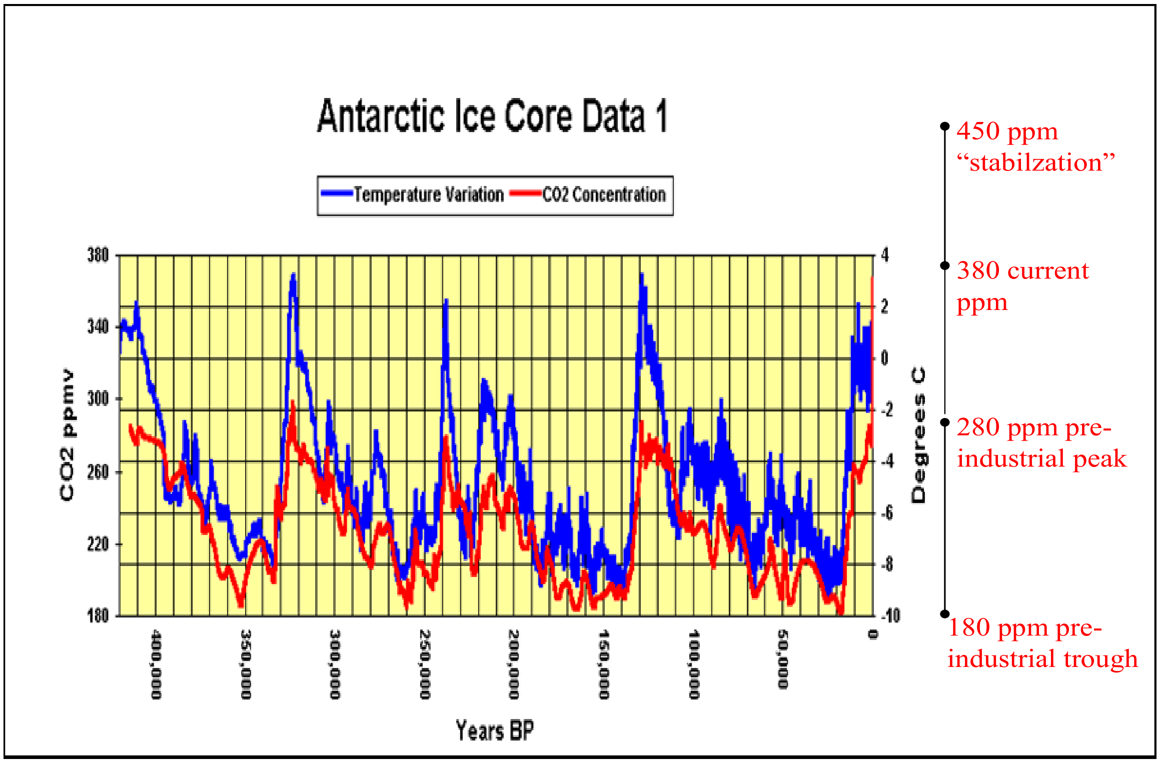
climate sensitivity[24] of 5.4°F (3°C) suggests a 95th percentile value of 12.6°F (7°C), and 99th percentile of 18°F (10°C). If one is shy about venturing "that far" into the fat tail, the central estimates of the IPCC are themselves sobering. The IPCC's fourth assessment "best guess" temperature increase under business-as-usual characterizes risks as "likely to be in the range 3.6°F to 8.1°F [2°C to 4.5°C]," with a best estimate of about 5.4°F (3°C). To put this in perspective, temperature increases exceeding "only" 2.7°F-4.5°F (1.5°C-2.5°C) could put twenty to thirty percent of the plant and animal species studied by the IPCC at increased risk of extinction.[25]

If greenhouse gas emissions are left unabated, the world has an almost 50 percent chance of experiencing global temperature increases of 9°F (5°C) by 2100. The last time temperature was in the region of 5°C above preindustrial times, around 35–55 million years ago, swampy forests covered much of the world and there were alligators near the North Pole.[26] In the opposite direction, temperatures of only 9°F (5°C) below today's world would put many parts of the world into ice age conditions. Discussion of "very small probabilities of catastrophic outcomes," when 8.1°F is given a seat at the table in the "best guess" range, may be viewed by future generations as nothing short of absurd. Changes of these magnitudes should not be taken lightly. They have enormous implications for where species, including humans, live, and history has taught us that conflict and war accompany transitions this large.

It is also instructive to get a relative sense of CO2 concentration levels and emissions targets. Figure 2 below shows CO2 concentrations (red line/lighter colored) over the last 400,000+ years, as estimated from Russian Voskok ice core data.

[24] Climate sensitivity is the amount of temperature increase resulting from a doubling of CO2 levels above pre-industrial levels.
[25] See supra note 8, Freeman and Guzman.
[26] Stern, N (2008). The economics of climate change. American Economic Review: Papers & Proceedings 98(2): 1-37.

Figure 2. Relative Levels of CO2 Concentrations: Historic, Current, and 450 ppm Stabilization Goal (estimated to keep temperature increase below 2ºC)



The first point is that, relative to historical data, we are on a very risky path. Current CO2 concentrations levels stand at 380 ppm over pre-industrial levels by the full historical spread of 100 ppm. If we stabilize greenhouse gas levels at 450 ppm, we will be 170 ppm above the pre-industrial level. The second point is that the climate system is very non-linear, which is why tipping points could be so disastrous and why the fat tail cannot be ignored.

"Best guess" central estimates not only misrepresent climate risks, they are inconsistent with basic economic tenets of decision-making under uncertainty. Weitzman (2009) shows that when potentially catastrophic damages are possible, expected utility theory implies an infinite SCC, as the loss in expected utility is theoretically unbounded at $+\infty$. Weitzman is forced to "close" the model (i.e. get rid of this theoretically unattractive result), by capping expected damages at some non-infinite but very large value, which he decides is the value of a statistical life (i.e. one's willingness to pay for reducing one's risk of death—see footnote 3). Considering the IPCC projections above, this might be an acceptable proxy.

Weitzman goes on to evaluate what he considers to be an imperfect improvement to traditional integrated assessment models (IAMs), the Monte Carlo procedure employed by Nicholas Stern.[27] A Monte Carlo will run an IAM thousands of times, each time randomly picking the uncertain parameters. For example, there would be a continuum of possible temperature changes, each having their own probability of occurring, as estimated by the IPCC. Another uncertain

[27] See supra note 2, Stern.

parameter would be climate sensitivity, the likely temperature response to a doubling of CO2 over pre-industrial levels. The value for this would also be picked at random, and so on for many uncertain parameters. After all of the random values are drawn, the model is run using them. The procedure is repeated thousands of times, each run giving a new SCC estimate. The final collection of SCC estimates are intended to give an idea of what the distribution of possible damages might look like given so many uncertain parameters, and a better "best guess."

While an improvement in treating uncertainty, Weitzman notes that the fat tail dilemma still isn't fully resolved.[28] First, the analyst has to choose values for all of the parameters, and in so doing sets upper limits that necessarily truncate the right end of the fat tail. Second, because the model cannot be run an infinite number of times, the possibility of observing infinite welfare losses is ruled out.

Recognizing that there is no perfect solution, and that an infinite SCC would be hard to defend, Weitzman urges a more aggressive implementation of the Monte Carlo. He suggests oversampling low probability/high damage outcomes, and expanding the "grid size" to extend farther out into the fat tail (i.e. allow for higher damages than currently modeled).

An oversimplified example might be helpful: Suppose possible damages are $10, $15, $20, $50, and $100, and their estimated probabilities 50%, 25%, 15%, 8% and 2%, respectively. To over sample in the Monte Carlo analysis, you might specify that 60% of the draws come from the $20-$100 range, and the other 40% from the $10-$15 range. This would over sample the right end of the distribution (and under sample the left), because the sum of the probabilities of $20, $50, and $100 is only 25%.

After one of the ranges is selected using the 40%/60% sampling rule, you might then weigh the probabilities within the selected tranche relative to one another. In this example, if the "coin is tossed" and the computer is assigned to choose $10 or $15 (which would happen in approximately 40% of the runs), the computer would be two times more likely to pick $10 than $15, since its original probability (50%) is twice that of $15 (25%). To "expand the grid size," you might add a damage value higher than $100, and accordingly reassign probabilities on that end of the tail. For example, you might assign $100 a probability of 1.5%, and add a .5% chance of $200.

Experimentation within the literature suggests that the effect of expanding the grid size is likely to be dramatic, regardless of which of the three main models are used (DICE, FUND, and PAGE). Dasgupta (2007) notes that if Nordhaus's DICE model is run using a more catastrophic worse-case scenario, the SCC increases by $68/tCO2.[29] Ceronsky, Anthoff, Hepburn, and Tol (2005) use FUND to recalculate the SCC adding the potential for three types of non-linear catastrophic climate responses: thermohaline collapse,[30] methane gas hydrate dissociation,[31] and

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[28] See supra note 2.
[29] Dasgupta, P (2007). Commentary: The Stern Review's economics of climate change. National Institute Economic Review 199(4). Converted from $t/CO2 (dollar denomination not given).
[30] Thermohaline refers to the ocean's circulation pattern that moves warm water towards colder regions in the ocean. Among other things, its collapse could return Europe to ice age conditions.

high climate sensitivity.[32] The estimated SCCs increased from $16/tCO2 to $910/tCO2 (2008$).[33] Finally, Ackerman, Stanton, Hope and Alberth (2009) demonstrate using the PAGE model that projected global GDP damages increase in 2100 from 2.2% under traditional "best guess" assumptions,[34] to 16.8%, looking at the 95th percentile and using more pessimistic assumptions (no adaptation, higher expected temperature increases, increased damages, and increased risk of catastrophe) than the model's default scenarios. For the U.S., GDP losses in 2100 increased from .4% to 4.3%.[35]

2) ***The agencies' presentation of SCC estimates fails to communicate the models' limitations with respect to being able to quantify damages, as well as the uncertainty of the estimates and their distribution. The result is that high and potentially catastrophic damages are not accurately conveyed.***

Please see 1a) and 1c) above that outlines the arguments for this concern.

3) The discount rates of 3% and 5% are too high, resulting in valuing the current generation more than future generations and under-estimating the SCC.

Of the five proposed SCC estimates ($5, $10, $20, $34, and $56, two are derived using constant discount rates of 3% and 5% ($5 and $34), one an average of the SCC estimates obtained from using the 3% and 5% constant discount rates ($20, rounded up), and the last two from using the Newell-Pizer method of declining discount rates, with starting rates of 3% and 5% ($10 and $56).

The agencies provide the following rationales for the 3% and 5% discount rates:

3 % discount rate:

1. It is the long run return on 10 year Treasury Bonds, considered the risk free rate of return (we will argue later that this is not the correct risk free rate of return). Economists refer to this as a "descriptive" discount rate, which describes what returns people actually require in markets.

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[31] This term refers to the melting of the West Antarctic permafrost causing large quantities of methane to be released, a greenhouse gas that is 23 times more powerful than CO2. As a separate matter, the Arctic also contains more carbon dioxide than the entire atmosphere holds today.
[32] The temperature increase predicted from a doubling of CO2 levels above preindustrial levels.
[33] Ceronsky, M., D. Anthoff, C. Hepburn and R.S.J. Tol. (2005) Checking the Price Tag on Catastrophe: The Social Cost of Carbon under Non-linear Climate Response. *Research unit Sustainability and Global Change, Working Paper FNU-87,* Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/catastrophewp.pdf
[34] Interestingly, this is the number that Stern would have arrived at had he ended his model in 2100. His damage estimates of 5-20% of global GDP were driven in large part by many of the worst damages happening after 2100, which were then "amortized" over the full time horizon of the model.
[35] See supra note 10, Ackerman et al. Note that to avoid the issue of discounting, the authors express damages as a percentage of forecasted GDP, rather than in dollar terms.

2. It is one of the two discount rates specified by OMB guidelines of 3% and 7%. These two rates are based upon observed long run rates of returns in markets ranging from a risk free rate of return, up to returns on risky assets of 7%, also a descriptive approach to discounting.

3. The agencies note, though they don't appear to be using it as a rationale, that OMB suggests that additional sensitivities using 1-3% could be justified for intergenerational discounting. This appears to be a prescriptive approach (a "social discount" rate) one would "prescribe" to be appropriate in the context of intergenerational discounting.

5% discount rate:

1. It is the post-tax return individuals receive on risky investments (p. 49614 of proposed ruling). This is a descriptive discount rate.

2. It is consistent with inputs to a prescribed *social* discount rate ("prescriptive") from the theoretically derived Ramsey equation using the economic theory of the consumer. The equation is given by the sum of the personal rate of time preference (PRTP) and the multiplication of two terms: the marginal utility of income (η) times the GDP growth rate (g).[36] Formally, the equation is: social discount rate = PRTP + ηg.

In the context of climate change, which will have effects upon many future generations, the parameter η performs "equity weighting" between individuals from different generations. It represents the utilitarian concept in economics of diminishing marginal utility of income. Diminishing marginal utility says that each additional dollar a person receives provides an increase in utility less than the previous dollar did. In the context of climate change, a dollar's worth of damages to a poor person would be valued more highly than a dollar's worth of damage to a wealthier person. Between generations, if income is growing over time (a positive value for g), then an extra dollar of damages to a future person is weighted less than one to a current person; because that future person has more wealth, the additional dollar's worth of damage has a smaller "utility" loss. On the other hand, if income is declining over time (a negative g), a dollar's worth of damage to a future person is worth *more* than a dollar's worth of damage to a current person. The sign of the growth rate is thus critical in how different levels of income are weighted between generations. We discuss equity weighting further in Section II.4.

EPA/NHTSA note that standard estimates from the economic literature of the PRTP are 2%, and for ηg a range of 3-5%. These imply a social discount rate of 2% + (3-5%), or 5-7%. If a PRTP of 0 is assumed, which EPA/NHTSA note is the rate many consider the only appropriate rate for intergenerational problems (any value above zero gives more value to the current generation than any future generation based solely upon when a person is born), then the SRTP would be 3-5%. We note that only the product of ηg is given in the proposed ruling, so there is no way to evaluate the legitimacy of the 3-5% range given for this term.

[36] More formally, g is the growth rate in consumption. GDP is used to proxy consumption.

Discussion

The proposed ruling thus draws upon a combination of different potential discount rates observed in markets (i.e. "descriptive"), and the prescriptive Ramsey approach.

NRDC believes that descriptive discount rates are flawed because they are premised upon an assumption that investors in a market for mitigation, were one to exist, would require similar returns and risk levels as those observed in asset markets today. This is wrong on several counts.

First, using returns in regular asset markets is arbitrary: we have no data on what returns people would actually require (or "accept") in a climate change "mitigation market," because no such market has ever existed. But basing climate change discount rates upon observed markets cannot possibly be correct: the worst-case scenario when investing in regular asset markets is that you lose all of your life savings, hardly comparable to the kinds of catastrophic risks possible from climate change.

Second, theoretically, mitigation investments are more appropriately viewed as an insurance problem, not a profit-maximizing venture. Mitigation is a precautionary investment, and precautionary investments yield their highest returns in "bad" states of nature.

These two factors point to adding a *negative* risk premium to any descriptive discount rate, and a higher weighting of damages.[37] The negative "returns" individuals are willing to pay for in insurance markets, as evidenced by actuarial data, provide an example: purchasers pay to insure themselves against very bad outcomes that may never happen.

Unfortunately, the insurance analogy understates the case: a) damages are often fully recoverable (i.e. not irreversible), examples being property damages resulting from fires or automobile accidents[38]; b) the probabilities of bad outcomes are known. But people are not only averse to investing in risky assets, they are more averse to doing so if the potential losses and the probability of those losses are uncertain (Gollier, 2009).[39] This is called "ambiguity aversion" in the literature. Gollier shows that under certain plausible conditions,[40] aversion to ambiguity will decrease the discount rate, and could do so quite substantially; and c) the probabilities of catastrophic outcomes in climate change are *higher* than those observed in insurance markets. While NRDC objects to using descriptive discount rates, if the discount rate is going to be informed by returns on markets, it should be no higher than the risk free rate of return, and the risk free rate should be the long run yield on 6 month U.S. Treasury Notes (.7%),[41] rather than 10 year U.S. Treasury Bonds, which carry inflation risk. Using the risk free rate of return is based upon the argument that an insurance market framework is more appropriate than an asset market framework in the context of climate change.

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[37] Cochran, JH (2001). Asset Pricing. Princeton: Princeton University Press.
[38] Minus any deductibles.
[39] Gollier, C (2009). Portfolio choices and asset prices: The comparative statics of ambiguity aversion. Toulouse School of Economics (LERNA and IDEI) working paper.
[40] These conditions are: 1) as income rises, a person is more willing to increase investments in assets that are risky, whose risk level and size of potential loss is known; and 2) as income rises, a person is more willing to invest in assets with uncertain losses and uncertain probabilities of such losses.
[41] Ibbotson Associates (2005). Stocks, Bonds, and Inflation. Chicago: Ibbotson Associates.

A second option for a descriptive discount rate, but one which NRDC considers less desirable than the risk free rate of return, would be to use regular returns in markets adjusted for uncertainty of the "correct" discount rate, using declining rates over time as prescribed by Weitzman (2000), Newell-Pizer (2003), and the UK government. The UK government bases its schedule[42] upon the work of Weitzman (1998, 2000),[43] Gollier (2002),[44] and a specially commissioned report by OXERA.[45] The UK schedule provides declining discount rates with and without a "pure rate of time preference" (PRTP); only the latter schedule (see discussion below on the rate of time preference) should be considered.[46]

Turning to the prescriptive discount rates suggested by the agencies for the Ramsey equation, NRDC philosophically agrees with this approach, but objects to how the different terms in the equation are treated. First, the upper end of the range (7%) is a result of assigning a value of 2% for the PRTP. This increases the middle value (central estimate approach here too) chosen for the ruling, which the agencies seem to decide is a balanced approach. However, the only defendable value for the PRTP in an intergenerational context is zero. Ramsey (1928) himself famously commented that discounting future utilities is ethically indefensible.[47] We agree with Ramsey's assessment.

With respect to the g term in the Ramsey equation, we suspect (though it is not possible to judge because only ηg is provided) that the assumed GDP growth rates are overly optimistic. The term g is based upon on historical GDP growth. This is problematic for two reasons: a) as is widely known and accepted among economists, GDP overestimates real welfare; and b) historical growth rates are based upon a world with relatively stable temperatures; it is arbitrary to assume that growth rates in a future of unabated climate change will be the same.

On the first point, GDP excludes many things that decrease real net output, such as depreciation of natural and man made capital and pollution externalities.[48] Alternative measures of growth in welfare have been estimated that adjust GDP to take such factors into account. Estimates vary widely, depending upon the year(s) examined and different methodologies, but all find adjusted growth to be lower than unadjusted.

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[42] Lowe, J (2008). Intergenerational wealth transfers and social discounting: supplementary green book guidance. UK Treasury. http://www.hm-treasury.gov.uk/d/4(5).pdf

[43] Weitzman, M (2001). Gamma Discounting, American Economic Review Vol 91(1). Weitzman, M (1998). Why the far distant future should be discounted at its lowest possible rate, Journal of Environmental Economics and Management (36): 201–208.

[44] Gollier, C (2002). Time horizon and the discount rate. IDEI, University of Toulouse, mimeo. Gollier, C (2002). The Economics of Risk and Time. Cambridge, MA: MIT Press. Gollier, A (2002). Discounting an uncertain future. Journal of Public Economics (85): 149-166. Gollier, C (2002). Time Horizon and the Discount Rate. Journal of Economic Theory 107(2): 463-473.

[45] OXERA report for ODPM (2002), A social time preference rate for use in long-term discounting, a report for ODPM, DfT and Defra.

[46] The schedule is as follows:

	0-30 years	31-75 years	76-125 years	126-200 years	201-300 years	301+ years
UK Treasury Discount Rate Schedule	3.00%	2.57%	2.14%	1.71%	1.29%	.86%

Note: The *Stern Review* used a discount rate of 1.4%.

[47] Ramsey, F (1928). A mathematical theory of saving. Economic Journal 38:543–59.

[48] GDP also excludes things that increase welfare, such as any household labor that is not bought and sold in the market. On net, however, it excludes significantly more "bad" things than "good" things.

A collection of estimates presented in Goodstein (2004), based upon studies and data from various authors, show a range of adjusted annual per capita growth .2 to 3.1 percentage points lower than annual per capita GDP growth, for various time periods.[49] One study relied upon data from Nordhaus and Tobin (1972),[50] another from Zolatas (1981),[51] and a third from Daly and Cobb (1989). [52] The Nordhaus and Tobin estimates had a .7 percentage point difference in annual per capita growth between 1929 and 1965, and a 1.8 percentage point difference between 1947 and 1965. Zolatas' differences were 1.8 (1947-1965), 1.6 (1950-1965), and 1.5 percent (1965-1977). Daly and Cobb estimated .2 (1950-1960), .6 (1960-1970), 3 (1970-1980) and 3.1 (1980-1986). In another source, Stewart (1974), using the data from Nordhaus and Tobin, estimated differences in GDP *levels* (as opposed to growth rates) of 1 and .9 percentage points lower for two specific years, 1929 and 1965.[53] A more recent estimate over the full time period of 1950 to 2006 estimated an annual per capita adjusted growth rate 2.5 percentage points below GDP.[54] Some of the studies from Goodstein were peer-reviewed. Stewart's was also peer reviewed. The Redefining Progress report, and Zolatas, and Daly and Cobb likely were not.

Turning to reliance upon historical growth rates in general (adjusted or unadjusted), as with the descriptive discount rates, these are also obtained from a world without disruptive climate change. However, it is easy to imagine that growth could be negatively impacted in ways that are not captured by the IAMs. For example social disintegration and humanitarian crises could negatively affect productivity, and therefore economic growth.

Another problem is that models usually have damage functions that are independent of the growth rate term in the Ramsey equation. This artificially prevents negative discounting, which is what is required if growth is negative (see next Section). If future generations are worse off than the current generation, a dollar of damages incurred by a future person should be weighed more heavily than a dollar of damages incurred by someone today, due to their lower ability to pay and a higher marginal utility of income (the η parameter discussed above and below). PAGE2009 has just been updated to allow for this possibility.[55]

To conclude, regardless of whether descriptive or prescriptive discount rates are used to justify a discount rate, 3% and 5% are unambiguously too high. They are wrong theoretically, they are wrong empirically, and they are ethically indefensible.

4) ***The SCC estimates should be equity weighted (i.e. damages suffered by low income populations should be weighed more heavily than those suffered by wealthier populations), just as they are between generations as a result of discounting. Correspondingly, the number***

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[49] Goodstein (2004). Economics and the Environment, 3rd edition. Wiley: Hoboken, NJ.
[50] Nordhaus, W, and Tobin, J (1972). Is growth obsolete? In Economic Research: Retrospect and Prospect Vol 5: Economic Growth, National Bureau of Economic Research.
[51] Zolatas, X. (1981). Economic Growth and Declining Social Welfare. New York: New York University Press.
[52] Daly, H and Cobb, J (1989). For the Common Good. Boston: Beacon Press.
[53] Stewart, K (1974). National income accounting and the concept of economic welfare: the concepts of GNP and NEW. Federal Reserve Bank of St. Louis.
[54] Talberth, J, Cobb, C, and Slattery, N (2007). The Genuine Progress Indicator 2006: a Tool for Sustainable Development. Redefining Progress. Oakland: CA.
[55] Email correspondence with Chris Hope, November 12, 2009.

used for the value of a statistical life (i.e. one's willingness to pay to reduce one's risk of death—see footnote 3) should be equal between all countries and populations.

Failing to "equity weight" damages is inconsistent with economic theory. Equity weighting increases SCC estimates when damages are incurred by a poor person versus a wealthy. As discussed above in Section II.3, valuing damages by income levels is based upon the utilitarian concept in economic theory of diminishing marginal utility of income. Diminishing marginal utility says that each additional dollar a person receives provides an increase in utility less than the previous dollar did. In the context of climate change, a dollar's worth of damages to a poor person would be valued more highly than a dollar's worth of damage to a wealthier person.

Interestingly (and inconsistently), the agencies weigh damages by income between generations by discounting the SCC. Recall that the Ramsey equation = social discount rate = personal rate of time preference (PRTP) + ηg). If income is assumed to grow over time (a positive value for g in the Ramsey equation), and η is positive, then an extra dollar of damages to a future person is weighted less than one to a current person. The logic is that because that future person has more wealth (from g), the additional dollar's worth of damage has a smaller "utility" loss, hence the discount rate increases and the present value of the SCC declines. On the other hand, if income is declining over time (a negative g), a dollar's worth of damage to a future person is worth more than a dollar's worth of damage to a current person. Further, as noted above (Section II.3), some models incorrectly restrict g to be greater than zero, even if damages are greater than growth (and the PRTP is zero).

In some models the *reverse* of equity weighting occurs: the value of a statistical life (the "VSL," which equals is one's willingness to pay to reduce one's risk of death—see footnote 3) is calculated as a multiple of one's income level. Separately, some models weigh the VSL based upon how many more years a person is expected to live. There is no empirical evidence that older people are willing to pay less to reduce their risk of death than are younger people.

Equity weighting is not uncommon, and claims that it is too difficult to implement are not a sufficient excuse for failing to do so. Equity weights are used in the academic literature, as well as by the UK, Germany, and the European Union. The U.S. Census also provides a schedule for equity weights.

For the above reasons, NRDC recommends that the models use one global value for the VSL that is the same for all persons, i.e. does not vary by income level or the expected number of years a person has left to live.

Finally, we note here that as with g, the value of η cannot be evaluated because it is not given. It should be provided and explicitly justified.

5) ***A domestic SCC should not be under consideration.***

While the proposed ruling is clearly focused on the global SCC, it is unclear whether and how a domestic SCC is going to be considered in the final ruling. No separate domestic SCC benefits calculations are made in the proposed ruling, but the document asks for comments as to the appropriateness of doing so. NRDC contends that under no conditions should a domestic SCC be used.

There is no good rationale for excluding worldwide damages from potential climate change impacts. Although past analyses of different regulations have considered only domestic impacts, they involved largely localized pollutants.

Carbon dioxide is a global pollutant, and will have effects in other countries that will likely spill over to the U.S. From a purely self-interested standpoint, excluding global damages is not in U.S. interests. Many damages other countries experience could be costly to the U.S. For example, national security threats caused by conflicts over stressed resources, humanitarian crises, sea level rise, epidemics, and extreme weather events could lead to mass migration from heavily impacted areas, substantial political unrest, and quite possibly war. Studies on national security and climate change describe global warming as a “threat multiplier,” and warn of impacts on the U.S. resulting from climate damages in the rest of the world.[56,57]

In addition, emissions reductions the U.S. undertakes could lead other countries to reduce their emissions. If that turns out to be true, the marginal SCC will greatly underestimate the total benefits of emissions reductions. If all countries conducted regulatory analyses using domestic SCCs, the result would be mitigation levels far below the optimum, creating a massive public goods failure.[58]

Finally, it is difficult to justify on ethical grounds that the U.S. should value the damages it imposes upon other countries at zero. Many countries, especially poor ones, did not contribute to the current CO2 levels in the atmosphere, yet will suffer the worst consequences. Perversely, developed countries obtained their income status by emitting greenhouse gases, and as a result have more resources to absorb climate damages, while the opposite is true of the poor countries.

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[56] The CNA Corporation, (2007). National Security and the Threat of Climate Change. http://securityandclimate.cna.org.

[57] National Intelligence Council, (2008). National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030. As presented at the Permanent Select Committee on Intelligence and the Select Committee on Energy Independence and Global Warming, 25 June 2008, in the testimony of Dr. Thomas Fingar, Deputy Director of National Intelligence for Analysis and Chairman of the National Intelligence Council. http://www.dni.gov/testimonies/20080625_testimony.pdf.

[58] Public goods failure in this context refers to a situation in which it is in one’s self interest to ignore negative externalities s/he is imposing on others; with everyone behaving this way, everyone is worse off than they would have been had they taken into account the effects of their choices on others.