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Technical Comments on the Social Cost of Methane As Used in the Regulatory Impact Analysis for the Proposed Emissions Standards for New and Modified Sources in the Oil and Natural Gas Sector

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) proposed emission standards for methane (CH4) and volatile organic compounds from new and modified sources in the oil and natural gas sector (referred to as "the Proposed Rule" in this report) on August 18, 2015.[1] Accompanying this Proposed Rule is a Regulatory Impact Analysis (RIA)[2] that is required under Executive Orders 12866 and 13563 for all major rulemakings from Executive Branch agencies. The RIA contains estimates of the net benefits of each of several options that the Proposed Rule is considering, which are equal to each option's estimated benefits minus its estimated compliance costs.

Our comments address technical issues with the RIA's monetized benefits estimates, which are entirely based on potential reductions in future climate change due to CH4 reductions, using a concept called the social cost of methane (SC-CH4). We demonstrate that EPA's estimates of the benefits are: 1) highly uncertain and very likely overstated; and 2) lack the appropriate peer review that is necessary for use in supporting regulatory policy. We also explore the implications of these issues with the Proposed Rule's net benefits estimates, and find they are far more likely to be negative than positive.

More specifically:

- We conclude that the RIA's estimates of benefits from CH4 reductions using its SC-CH4 estimates are highly uncertain and likely overstated for multiple reasons:
  - The EPA's SC-CH4 estimates are based upon a single study (Marten *et al.*, 2014) whose estimates are significantly greater than, and inconsistent with, available estimates in other published papers (see Section II for a summary of the rest of the literature).
  - EPA relies on SC-CH4 estimates that reflect global benefits rather than domestic benefits, a practice that is contrary to the Office of Management and Budget's (OMB's) *Circular A-4* (OMB, 2003) and inconsistent with the theoretical underpinnings of benefit-cost analysis that endow the method with its ability to guide a society towards policies that will improve its citizens' well-being. *Circular A-4* calls for use of domestic benefits, and notes that any estimates of non-domestic benefits should be presented separately.[3] EPA's use of global SC-CH4 benefits estimates (and failure to even present domestic benefits, which are readily obtained

[1] 80 Fed. Reg. 56,593, August 18, 2015.

[2] EPA, *Regulatory Impact Analysis of the Proposed Emission Standards for New and Modified Sources in the Oil and Natural Gas Sector*, EPA-452/R-15-002, August 2015.

[3] Circular A-4 states "Your analysis should focus on benefits and costs that accrue to citizens and residents of the United States. Where you choose to evaluate a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately." (OMB, 2003, p. 15).

from the same models) results in a significant overstatement of benefits and net benefits of the Proposed Rule.[4]

  - The RIA includes a 2.5% discount rate in its range of benefits, which is inconsistent with the short atmospheric lifespan of CH4. Its inclusion overstates the upper end of EPA's SC-CH4 estimates, and hence its net benefits.
  - Marten *et al.* (2014) have used assumptions regarding indirect effects on radiative forcing from changes in tropospheric ozone and stratospheric water vapor levels that lack clear support from the scientific literature.[5] This assumption, which is uncertain and not validated, could be a substantial source of overstatement in EPA's SC-CH4 estimates. For example, compared to a zero indirect effects assumption, it increases EPA's SC-CH4 estimate by about 36% (when using a 3% discount rate).
  - EPA's SC-CH4 estimates are based on an average of five socioeconomic scenarios, four of which assume no incremental policies to reduce emissions in the future (also known as "business as usual" scenarios). Use of scenarios that assume no future emissions control policies to estimate the benefit of reducing a ton of emissions in the near-term overstates the SC-CH4 estimates.[6]

- The absence of a full scientific peer review of the methodology behind EPA's SC-CH4 estimates calls into question the reliability of all of the RIA's estimated benefits and net benefits. We conclude more extensive peer review is especially warranted in this particular case for several reasons:
  - The integrated assessment models (IAMs) that were used to compute EPA's SC-CH4 estimates were modified in a significant manner that has not been reviewed by the original model developers.[7] Other researchers working in this field have not had a chance to concur or disagree with the methodological changes and alternative input assumptions that EPA believes cause its SC-CH4 estimates to be so much greater than other published estimates.
  - The development of new SC-CH4 estimates by modifying pre-existing IAMs to make "standardized" calculations is inconsistent with the concept of using multiple existing

[4] We are aware that this practice has also been used in the development of Federal social cost of carbon estimates by the Interagency Working Group (IWG), but the IWG decision does not reflect an agreed principle among economists, and we disagree with it for the reasons provided in these comments.

[5] Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism (IPCC 2007). It is expressed in Watts per square meter (W/m^2).

[6] We are aware that this use of business-as-usual scenarios also occurred in the development of Federal social cost of carbon estimates by the IWG, but the IWG method does not reflect an agreed principle among economists, and we disagree with it for reasons provided in these comments.

[7] EPA's modifications to the models are discussed in Section IV.1.

models to identify the range of uncertainty in the best-available science-based estimates.[8]

– EPA conducted an internal peer review process and the paper upon which it has relied (Marten *et al*. 2014) has been published in a peer-reviewed journal. However, those two types of reviews do not replace the need for a more rigorous independent scientific review in light of the types of changes described above. Additionally, EPA's internal reviewers lacked consensus on the use of the paper's SC-CH4 estimates for evaluation of major regulations.

To provide a quantitative assessment of the sensitivity of the RIA's estimates of benefits and net benefits to the technical issues that we have identified, we have re-estimated the SC-CH4 values under several alternative assumptions that we consider more reasonable. These alternative calculations include 1) eliminating from consideration the 2.5% discount rate, 2) limiting benefits to a domestic geographic scope, 3) using alternative assumptions regarding the indirect effects on radiative forcing, and 4) eliminating "business as usual" emissions projections as the reference point for computing future damages from a ton of incremental emission that would occur today. EPA's assumptions on these matters are discussed in Section III, along with our explanations for why our alternative assumptions are more reasonable for estimating SC-CH4 for use in a Federal RIA. All of our alternative SC-CH4 calculations have been made using the same IAMs that Marten *et al.* (2014) used to make their SC-CH4 estimates.

Figure 1 provides a summary of how the EPA's SC-CH4 estimates would change based on assumptions we consider either more reasonable or subject to too much uncertainty for EPA to rely on a single point estimate. The first row shows the range of SC-CH4 included in the RIA based on mean values using 2.5%, 3.0%, and 5.0% discount rates.[9] Each subsequent row includes a revised range based on different cases we constructed to address some of the technical issues we identified in EPA's SC-CH4 estimates. Case A removes from consideration the 2.5% discount rate because it is not appropriate given that the shorter atmospheric lifespan of CH4 implies that the resulting climate benefits are not intergenerational. Cases B, C, and D then use a range of discount rates from 3% to 5%, while layering on additional alternative assumptions. Case B shows the range of SC-CH4 estimates when limited to a domestic geographic scope. Case C removes the assumption EPA made on a 40% enhancement of radiative forcing due to indirect atmospheric effects (in addition to the change for Case B). Case D incorporates the same changes as in Case C, but also ensures the baseline emissions projection provides

[8] We are aware that standardization was also used, although to a lesser extent, in the development of Federal social cost of carbon estimates by the IWG, but the IWG decision does not reflect an agreed principle within the modeling profession, and we disagree with it for reasons provided in these comments.

[9] We have not used the 95th percentile worst-case values in these ranges because the 95th percentile value would confuse uncertainty about climate impacts *per se* with uncertainty in estimating the impact of CH4 on climate change, which is the concern with EPA's SC-CH4 estimates that our comments are highlighting.

consistency between future emissions control policies and the current emissions reduction effort that is implied if the SC-CH4 is to be used to make near-term emissions reduction decisions.[10]

As Figure 1 shows, using all the alternative assumptions produces SC-CH4 estimates that are as much as 90% and 94% lower than EPA's SC-CH4 estimates for 2020 and 2025, respectively.

Figure 1. Alternative Estimates of SC-CH4 Reflecting Key Methodological Uncertainties

Case	Description	SC-CH4, $ per tonne of CH4 (2012$) (% Change Relative to RIA Range) 2020 Min	2020 Max	2025 Min	2025 Max
RIA	RIA Option 2 (2.5%, 3.0%, and 5% discount rates)	587	1,721	702	1,900
A	RIA Option 2 (3.0%, and 5% discount rates)	587 0%	1,309 -24%	702 0%	1,508 -21%
B	Domestic (U.S.) specific SC-CH4 values averaged across all socioeconomic scenarios from PAGE and FUND models.	106 -82%	210 -88%	130 -81%	248 -87%
C	Domestic (U.S.) specific SC-CH4 values averaged across all socioeconomic scenarios from PAGE and FUND model without the indirect effects.	69 -88%	141 -92%	84 -88%	158 -92%
D	Domestic (U.S.) specific SC-CH4 values for the 5th Scenario from PAGE and FUND model without the indirect effects.	58 -90%	99 -94%	69 -90%	115 -94%

Note: The Min and Max values span different discount rates, EPA's Low and High total costs, and climate benefits. For Cases B, C, and D, we do not report U.S-specific SC-CH4 estimates from the DICE model because it is a global model and does not include regional details (see Section III.2 for discussion).

The percentage changes in the SC-CH4 estimates would directly translate to percentage changes in the overall estimated benefits since there is not any change associated with the assumed tons

[10] To do this, Case D relies solely on estimates using one of five scenarios used by EPA, known as the "5th Scenario." This eliminates the 80% weight that EPA has given to estimates using future emissions projections that assume no incremental reductions in greenhouse gas emissions in the future (*i.e.*, the four other socioeconomic scenarios that EPA used that reflect "business as usual" policy). Section III.5 explains these scenario choices in more detail.

of CH4 reductions. Thus, we find that the Proposed Rule is likely to result in net costs, rather than net benefits as shown in Figure 2.

Figure 2. Range of Net Benefits and Costs in 2020 and 2025 (Millions of 2012$)

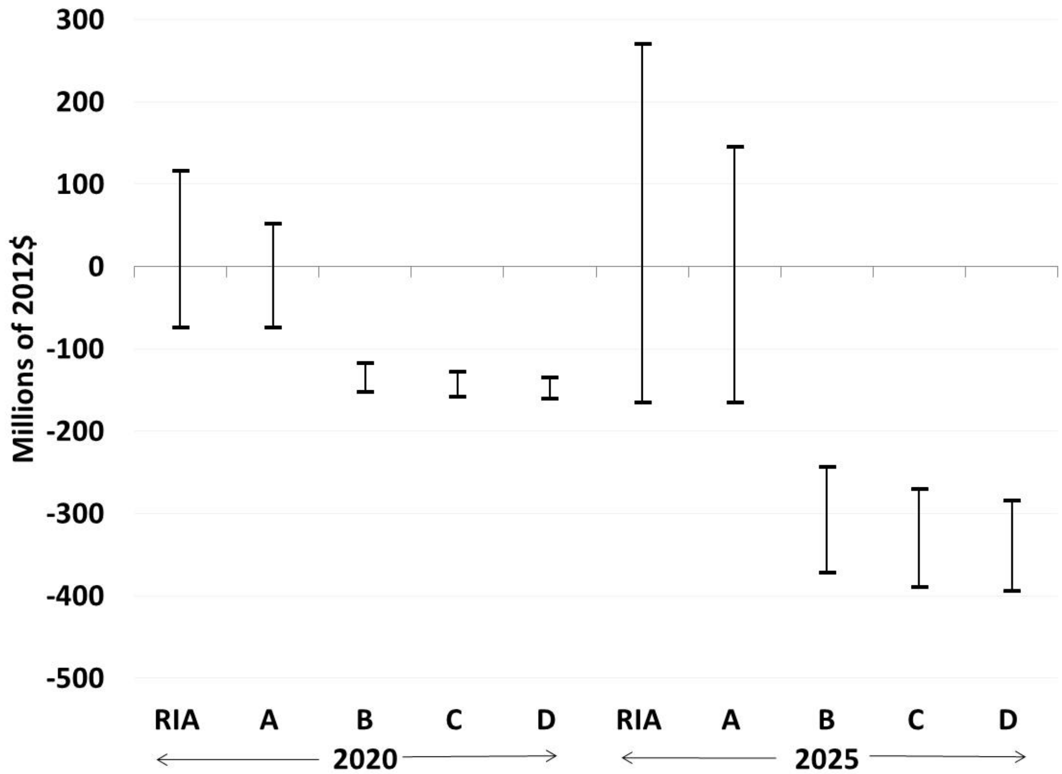

Figure 2 shows that even using EPA's SC-CH4 estimates (labeled "RIA" in the two figures above), the Proposed Rule's net benefits could be negative (or, in other words, the Proposed Rule could have net costs). Figure 2 also shows that when sequentially adjusting for each of the technical issues we have identified, the range of net benefits estimates becomes entirely negative—by more than negative $100 million per year even at the ranges' upper bounds.[11] This exceptional degree of sensitivity of the net benefits estimates to alternative reasonable assumptions and the lack of full scientific peer review of the science and approach used to estimate EPA's SC-CH4 render it inappropriate to use EPA's SC-CH4 estimates in making major national policy decisions. We also note that the downward impact on net benefits associated with each individual assumption that we have explored makes it unsupportable for EPA to suggest that the Proposed Rule will produce positive net benefits.

[11] Although it is not shown here when using a discount rate range of 3% to 5% and changing each of the assumptions associated with Cases B and C *individually*, net benefits remain negative over the entire range by at least -$33 million. When changing the assumption associated with Case D on its own, the net benefits range remains mostly negative (*i.e.*, -$88 million to +$13 million in 2020 and -$204 million to +$55 million in 2025).

I. INTRODUCTION

On August 18, 2015, the U.S. Environmental Protection Agency (EPA) proposed emission standards for new and modified sources in the oil and natural gas sector (referred to as "the Proposed Rule" in this report) as part of the President's Climate Action Plan. The Proposed Rule's goal is to cut methane (CH4) emissions from the oil and gas sector by 40% to 45% from 2012 levels by 2025.[12]

Accompanying this Proposed Rule is a Regulatory Impact Analysis (RIA)[13] that is required under Executive Orders 12866 and 13563 for all major rulemakings from Executive Branch agencies. The RIA contains estimates of the net benefits of each of several options that the Proposed Rule is considering, which are equal to each option's estimated benefits minus its estimated compliance costs. Our comments address technical issues with the RIA's benefits calculations, and their implications for the net benefits estimates. Although our comments do not address any aspect of the compliance cost estimates, that does not imply that we endorse those cost estimates.

The RIA's benefits estimates are calculated by multiplying an estimate of the tons of methane reduction under the Proposed Rule by an estimate of the social cost of methane (SC-CH4). The SC-CH4 is the focus of our comments. It is an estimate of the dollar value of societal damages per ton of methane emission that would occur in a near-term year (such as 2020 or 2025). Although climate damages are attributed to a ton of near-term emission, they are based on projections of future climate outcomes many years into the future, and thus are also determined by future assumed levels of greenhouse gas emissions. These projections are made using one or more "integrated assessment models" (IAMs).

EPA's SC-CH4 estimates are based on a paper by Marten *et al.* (2014). Given a number of technical issues we discuss below, we conclude that SC-CH4 estimates based solely on Marten *et al.* (2014) do not reflect the standards of scientific review and technical maturity that should be required before use in guiding major Federal regulatory decisions. We also conclude that EPA's SC-CH4 estimates are likely overstated. As a result of sensitivity analyses we conduct on alternative assumptions for estimating the SC-CH4 values, we find a high likelihood that the Proposed Rule will result in negative net benefits, contrary to the RIA's conclusions. For our quantitative sensitivity analyses, we focus on EPA's Option 2, but the concerns we raise apply to all of the options in the RIA.[14]

The rest of the report is organized as follows. Section II provides a discussion of the approach EPA used to calculate the SC-CH4 estimates. Section III discusses the technical issues we have

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[12] 80 Fed. Reg. 56,593, August 18, 2015.

[13] EPA, Regulatory Impact Analysis of the Proposed Emission Standards for New and Modified Sources in the Oil and Natural Gas Sector, EPA-452/R-15-002, August 2015.

[14] EPA evaluates multiple options in the RIA, but is proposing to select Option 2 (RIA, p. 1-4).

identified with the SC-CH4 estimation approach and reasonable alternative assumptions. Section IV discusses the importance of a thorough peer review, and how the absence of such a process makes the EPA's SC-CH4 estimates unreliable. Section V provides alternative estimates of the SC-CH4 when using reasonable assumptions. Finally, Section VI provides our conclusions based on the significant technical issues we identified in the SC-CH4 estimation approach and estimation of benefits. Appendix A contains additional summary tables and figures. Appendix B provides some additional commentary about the timing of SC-CH4 benefits and costs.

II. DESCRIPTION OF EPA'S CALCULATIONS OF BENEFITS, COSTS, AND NET BENEFITS IN THE RIA FOR THE PROPOSED RULE

EPA estimated the global social benefits of CH4 emissions reductions for the Proposed Rule using the SC-CH4 estimates from Marten *et al.* (2014), a metric that estimates the monetary value of global impacts associated with marginal changes in CH4 emissions in a given year in the relatively near future (*e.g.*, in 2020 or 2025). The Marten *et al.* (2014) development of SC-CH4 estimates follows closely the work for computing the social cost of carbon (SCC) conducted by an interagency working group (IWG) that included EPA and other executive branch agencies and offices. The IWG used three existing IAMs to estimate the SCC for use in the Federal regulatory evaluation process. The estimates were released in 2010 and then subsequently updated in 2013 using updated data and model versions. The IWG, however, did not estimate any SC-CH4 values in 2010 or in 2013 while estimating SCC values. To value the benefits from this Proposed Rule, EPA worked on its own to develop the SC-CH4 estimates reported in Marten *et al.* (2014), without any apparent input or review from other participants in the SCC's IWG.[15]

As with the SCC work, Marten *et al.* (2014) employed three IAMs to estimate the SC-CH4: 1) the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND), 2) Dynamic Integrated Climate and Economy (DICE), and 3) the Policy Analysis of the Greenhouse Effect (PAGE).[16] The SC-CH4 estimations used the same model version that was used by the EPA researchers for their most recent SCC work (DICE 2010, FUND version 3.9, and PAGE09 version 1.7 models).

For estimating the SC-CH4, these IAMs were run using the same set of baseline assumptions that the IWG SCC process used. A perturbation of one unit of CH4 was applied in a given year to estimate the changes in the climate damage.[17] The SC-CH4 for the year of perturbation was then estimated by summing up the discounted marginal damages over the entire model horizon (*i.e.*, through 2300) starting from the perturbation year.

Marten *et al.* (2014) ran the same five socioeconomic scenarios used by the IWG as part of the SCC process. These include fixed projections of gross domestic product (GDP), population, industrial CO_2 emissions, and other greenhouse gas (GHG) emissions and radiative forcing projections based on a Stanford Energy Modeling Forum model comparison exercise (EMF-22)

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[15] Marten *et al.* (2014) is a research paper written by five EPA staff and published in the *Climate Policy* journal.

[16] FUND model (Anthoff, Hepburn and Tol 2009, Tol 2002), DICE model (Nordhaus, 2008; Nordhaus and Boyer, 2000), and PAGE model (Hope, 2006, 2008).

[17] In the DICE model, a 1 million tonne (Mt) increase in CH4 is assumed in a given "perturbation year." In the PAGE model, an exogenous excess radiative forcing over time due to a 1 Mt increase in CH4 in a given "perturbation year" is assumed. The FUND model simulates an increase of 1 Mt of CH4 in each year for a decade is assumed. In all models, SC-CH4 estimates were computed as dollar per metric ton of CH4 for a year in question. Note that a tonne is a measure of a metric ton and is equivalent to about 1.10 short tons.

from 2009. Four of the five scenarios are Business as Usual (BaU) outlooks from four specific models selected by the IWG from among many models that participated in EMF-22 (*i.e.*, IMAGE, MiniCAM, MERGE, and MESSAGE). The fifth IWG scenario (called the "5th Scenario") is based on the average of the 550 ppm $CO_{2\text{-}e}$ stabilization scenario outlooks from the same four EMF-22 models. In addition, Marten *et al.* (2014) adopted the same equilibrium climate sensitivity distribution that the IWG used to model uncertainty associated with the climate sensitivity input to the IAMs.

To estimate the SC-CH4 for a given year, Marten *et al.* (2014) perturbed all three IAMs by an increment of CH4 emissions in that year.[18] Marten *et al.* (2014) estimated the value of the SC-CH4 assuming a global geographic scope averaging the estimates across all 10,000 simulations,[19] and also then averaging over each of the three IAMs for each of the five scenarios. This process was done using one of three constant discount rates (2.5%, 3%, or 5%) over a time horizon that extended through 2300, resulting in a mean SC-CH4 estimate for each of those discount rates. It is the uncertainty in those mean SC-CH4 estimates that is the focus of our comments.[20] The year-specific SC-CH4 values used in the RIA (taken from Marten *et al.* 2014) are presented in Figure 3.

[18] See footnote 17 about perturbation details.

[19] 10,000 simulations were done to capture the uncertainties in the underlying parameter values. In the DICE model, equilibrium climate sensitivity parameter values were selected probabilistically from the Roe-Baker distribution for each of the 10,000 runs. In the PAGE and FUND models, damage function parameters, equilibrium climate sensitivity parameter values, and other uncertainties were selected for each of the 10,000 runs.

[20] Also following the IWG process, Marten *et al.* (2014) reported a SC-CH4 that was the average of the 95th percentile worst-case values of the 15 IAM cases, using a 3% discount rate. This value is also reported in the RIA. In the quantitative examples in our comments, we focus only on the mean SC-CH4 values because our focus is on the uncertainties in obtaining a reliable estimate of the incremental climate damages of methane emissions. The 95th percentile values reflect a completely different source of uncertainty, which is uncertainty in damages from climate change *per se*.

Figure 3. Social Cost of Methane, 2012-2050 (in 2012$ per tonne of CH4)
(Source: RIA, Table 4-3)

Year	SC-CH4			
	5 Percent Average	3 Percent Average	2.5 Percent Average	3 Percent 95th percentile
2012	430	1,000	1,400	2,800
2015	490	1,100	1,500	3,000
2020	580	1,300	1,700	3,500
2025	700	1,500	1,900	4,000
2030	820	1,700	2,200	4,500
2035	970	1,900	2,500	5,300
2040	1,100	2,200	2,800	5,900
2045	1,300	2,500	3,000	6,600
2050	1,400	2,700	3,300	7,200

NERA obtained the code for all 3 IAMs and was able to run the IAMs for the different socioeconomic scenarios and discount rates, replicating the EPA's SC-CH4 estimates. In doing this, of course, NERA also computed the 15 individual SC-CH4 estimates for each of the 3 IAMs and for each of the 5 socioeconomic scenarios that were averaged together to produce EPA's SC-CH4 values. These 15 mean values, which are not available in any EPA document or in Marten *et al.* (2014), vary substantially around the mean values used in the RIA. Appendix A provides all of those underlying values for each discount rate for perturbation years 2020 and 2025. The analyses we describe in these comments are based on the results of the replication process and subsequent sensitivity analyses of the SC-CH4 values to several assumptions used in EPA's estimation process that we consider inappropriate.

In the RIA, EPA reports net benefits based on ranges for total costs and total climate benefits (the range is based on low and high avoided CH4 emissions and discount rates). The low and high climate benefits in 2020 and 2025 are based on CH4 emissions reductions of 170,000 to 180,000 short tons and 340,000 to 400,000 short tons, respectively.[21]

The RIA net benefits numbers are reproduced in Figure 4. The total monetized benefits are computed by multiplying CH4 emissions reductions by the applicable SC-CH4 estimate. For example, in the 2020 low case, a SC-CH4 of $1,300 per metric ton is multiplied by 158,000 metric tons of CH4 reductions (equivalent to EPA's estimated reductions of a rounded 170,000 short tons) to produce $202 million of climate benefits. Although our comments do not address any aspect of the emission reduction estimates, that does not imply that we endorse those estimates.

[21] RIA, Table 3-3.

Figure 4. RIA Total Costs, Total Monetized Benefits, and Net Benefits (Millions of 2012$)

Discount Rate		2020		2025	
		Low	High	Low	High
	Total Costs	$150	$170	$320	$420
3%	Total Monetized Benefits	$202	$214	$465	$547
	Net Benefits	$52	$44	$145	$127
5%	Total Monetized Benefits	$91	$96	$216	$255
	Net Benefits	-$59	-$74	-$104	-$165

EPA estimated the total compliance costs to industry to meet the requirements in the Proposed Rule. Although our comments do not address any aspect of the compliance cost estimates, that does not imply that we endorse them. EPA's estimated annualized compliance costs reflecting annualized capital costs and ongoing O&M expenditures for Option 2 are $150 to $170 million in 2020 and $320 to $420 million in 2025.[22] Subtracting the total costs from the total monetized benefits results in the estimated net benefits.

[22] RIA, Table 6-2.

III. TECHNICAL ISSUES WITH ASSUMPTIONS USED IN THE SC-CH4 ESTIMATION PROCESS

EPA used SC-CH4 estimates that are based on assumptions that we do not consider the most reasonable. In each case, we find that EPA's assumptions overstate the benefit estimates compared to assumptions that we consider more reasonable. We have identified five specific issues that are each discussed in this section. They are:

1. EPA adopted the SC-CH4 estimates from a single study and the SC-CH4 estimates are inconsistent with, and much greater than, those from other studies;

2. EPA should not provide benefits estimates that reflect only a global geographic scope, without even providing separate estimates for a U.S. geographic scope;

3. EPA's use of SC-CH4 estimates based on a 2.5% discount rate is inconsistent with the short atmospheric lifespan of CH4;

4. EPA's use of SC-CH4 estimates based on an assumption to increase radiative forcing due to indirect effects by 40% is not clearly supported by the scientific literature; and

5. EPA's use of BaU emissions scenarios that reflect no incremental future mitigation policy creates an inappropriate overstatement of SC-CH4.

1. EPA Adopted the SC-CH4 Estimates from a Single Study and the SC-CH4 Estimates are Inconsistent with and Much Greater than Those from Other Studies

As described in Section II, EPA adopted the estimates of SC-CH4 from a single study (Marten *et al.* 2014). EPA researchers and others (Waldhoff *et al.* 2011, 2014) acknowledge that there are only a limited number of published estimates of the social cost of non-CO_2 GHGs that have been estimated using IAMs, compared to a vast number of estimates of the SCC. The primary reason for the lack of non-CO_2 social costs is that the research and knowledge base is very limited. Moreover, there are significant uncertainties associated with how to simulate CH4 and a lack of understanding of temperature and damage impacts. There appear to have been only 12 studies over the span of the past two decades (1993 to 2014) that quantified the impacts and costs of CH4 emissions reduction. They are listed in Figure 5.

Figure 5. Summary of Literature on Estimates of SC-CH4 (1993-2015)
(The first 11 studies are referenced in Marten *et al.*, 2014)

S.No.	Study authors	Published year	IAM Model used	Scenario	Emissions year	SC-CH4 (2012$ / tonne of CH4)
1	Reilly and Richards	1993				*
2	Fankhauser	1994				*
3	Kandlikar	1995				*
4	Kandlikar	1995				*
5	Hammitt et al.	1996				*
6	Tol	1999	FUND 1.6			*
7	Tol et al.	2003	FUND 1.7		2000	$484
8	Hope	2005	PAGE95		2000	$176
9	Hope	2006	PAGE2002		2000	$135
10	Waldhoff et al.	2011	FUND 3.5	SRES A1B, A2, B1, B2	2010	$307
11	Marten and Newbold	2012	DICE2007 with MAGICC	EMF-22 MiniCAM Base	2020	$877
12	Marten et al.	2014	DICE2010/FUND3.8/ PAGE09	EMF-22	2020	$1,309
13	Waldhoff et al.	2014	FUND 3.9	SRES A1B, A2, B1, B2	2010	$469

* We do not report SC-CH4 estimates for these 1990s studies.

Within this limited literature, the initial papers published in the 1990s were largely focused on assessing the trade-offs in controlling different types of GHGs.[23] These early papers also attempted to quantify the potency of non-CO_2 GHGs relative to CO_2 using a "global damage potential" metric. They did not use IAMs to directly simulate the damage per ton of each type of emission.[24] From 1999 forward, IAMs became the tool of choice, offering estimates of social costs of non-CO_2 GHGs using different models and baseline assumptions for different years. These studies produced estimates of social costs of methane that varied widely, as shown in the last column of Figure 5. Notably, Marten *et al.*'s estimates (which are the ones EPA has adopted for the Proposed Rule's RIA) are much higher than all of the other available studies. One of the reasons that Marten *et al.* (2014) provided for its SC-CH4 estimates to be so much higher than prior studies' was their use of more recent versions of the IAMs. However, since the publication of Marten *et al.* (2014), there has been an additional study that has estimated SC-CH4 (Waldhoff *et al.* 2014). Waldhoff *et al.* employed the latest version of the FUND model (version 3.9)[25] and again produced estimates of SC-CH4 that were much lower than Marten *et al.* (2014). Their

[23] Reilly and Richards (1993), Fankhauser (1995), Kandlikar (1995, 1996), and Hammitt *et al.* (1996).

[24] Except for Tol 1999.

[25] FUND model version 3.9 assumes an exogenous SO_2 radiative forcing. This is the only difference between FUND model version 3.9 and FUND model version 3.8 that was used in Marten *et al.* (2014).

2014 estimate is $469 per metric ton of CH_4 (in 2012$); which is 64% lower than the estimate adopted by EPA of $1,309 per metric ton.[26]

Such variability in the literature, combined with the fact that EPA's values are much higher than any of the other six estimates is a clear sign that the RIA may be overstating the Proposed Rule's global benefits. It is also a reason why SC-CH4 methodology should be subjected to close scrutiny and reviewed *by the original IAM developers*, and that the assumptions that are found to cause its much higher estimates should be vetted by relevant scientists in a manner that is more thorough than the internally-controlled review that EPA conducted, or that a journal conducts prior to accepting a paper for publication. (The next section discusses peer review needs in more detail.)

2. EPA Should Not Provide Benefits Estimates That Reflect Only a Global Geographic Scope Without Even Providing Separate Estimates for a U.S. Geographic Scope

In the IWG's SCC development, only global benefits values were presented. EPA has repeated the IWG's global focus in its SC-CH4 estimates. Use of only global benefits instead of domestic (U.S.) benefits to compute climate benefits is inconsistent with almost all past practice in benefit-cost analyses. In justifying their use of global benefits for the SCC, the IWG argued:

> *...accounting for global benefits can encourage reciprocal action by other nations, leading ultimately to international cooperation that increases both global and U.S. net benefits relative to what could be achieved if each nation considered only its own domestic costs and benefits when determining its climate policies…the U.S. government can signal its leadership in this effort.*[27]

This practice by the IWG (and adopted by EPA for the Proposed Rule) is contrary to the OMB's *Circular A-4* (OMB, 2003):

> *Your analysis should focus on benefits and costs that accrue to citizens and residents of the United States. Where you choose to evaluate a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately*.[28]

By considering global benefits (and only global benefits), EPA is fostering a misunderstanding among RIA readers that implicitly overstates the benefits that the U.S. may expect from the Proposed Rule.

Gayer and Viscusi (2015) discuss the precedents for using non-U.S. benefits in evaluating U.S. regulations. They conclude that this practice is not only contrary to the requirements of

[26] Figure 17 in Appendix A shows different SC-CH4 values estimated by Waldhoff *et al.* (2014).

[27] IWG 2015, page 32.

[28] OMB 2003, p. 15.

Circular A-4, but that it is also inconsistent with past U.S. practice. They emphasize the role of legal standing in the determination of which benefits are appropriate to count, and note that legal standing of non-U.S. entities depends on reciprocity of effort in controlling emissions. Until there is more extensive global reciprocity in reducing GHGs to levels consistent with the estimated SC-CH4 in cost per ton, there is no precedent for considering only global benefits for U.S. regulatory policy evaluations.

Gayer and Viscusi provide a number of examples of how use of non-domestic benefits in the absence of reciprocity can cause a benefit-cost analysis to guide policy makers towards policy choices that are detrimental to domestic well-being. Without repeating the examples, we note that benefit-cost analysis is an analytic method designed to guide policy makers towards options that will improve the net welfare of their community. If conducted inconsistently with its original principles, the benefit-cost method loses its ability to inform policy makers whether their decisions will enhance the welfare of their constituents. One of those original principles is to account for the costs, preferences, and benefits of the residents of the political jurisdiction contemplating a policy (*i.e.*, the U.S. in the case of the Proposed Rule). The reason that estimates of benefits should be limited to those within the domestic jurisdiction is that a policy that passes a benefit-cost test is presumed to be welfare-enhancing only because of a principle known as the potential compensation principle. For example, the distributional impacts of a policy may be so imbalanced that the policy would be detrimental to societal welfare; however, if the policy's *aggregate* benefits across the domestic community do exceed its aggregate costs, the deciding policymaker has an ability to establish other (redistributive) policies to spread the benefits or costs more fairly, and create a net welfare improvement. On the other hand, if the domestic benefits of a policy do not exceed its domestic costs, the potential for the deciding policymaker to effectuate the necessary redistribution does not exist. Thus, a policy that passes a benefit-cost test based on global benefits cannot be presumed to indicate a welfare-enhancing change unless it is also passes the benefit-cost test based solely on domestic benefits. This is the theoretical underpinning for the *Circular A-4* requirement that policies report any estimates of non-domestic benefits separately from domestic benefits.

In conclusion, it is inappropriate for the RIA to use SC-CH4 values that reflect *only* global damages until there is global reciprocity in the control of GHG emissions.[29] Although non-domestic benefits may merit some altruistic weight, such altruistic motives should be considered independently of the domestic balance of benefits and costs. We now turn to the question of what a domestic SC-CH4 estimate is, otherwise following the same assumptions and methodology as Marten *et al.* (2014).

In its 2010 report on the SCC, the IWG stated that it was not able to calculate domestic SCC estimates because it lacked details on the regional specifications in the model and because there

[29] The same arguments imply that use of global SCC values for U.S. regulatory policy evaluation is inappropriate.

is a dearth of country-specific social costs estimates in the literature (IWG, 2010).[30] The IWG determined that it was only possible to include an "approximate, provisional, and highly speculative" range of 7% to 23% for the share of domestic benefits. However, we find that both the FUND and PAGE models directly compute and report U.S.-specific values for SCC and SC-CH4. EPA should have at least reported these domestic values for SC-CH4 in the RIA for the Proposed Rule.

We were able to generate the SC-CH4 global estimates from the PAGE and the FUND models running the exact same models as those used to compute EPA's SC-CH4 estimates.[31] Since the PAGE and the FUND model also contain U.S. and other regions, we were able to obtain the U.S.-specific SC-CH4 estimates directly from the same runs that produced the global estimates upon which EPA relied. These are shown in Figure 6 for a 3% discount rate (results for the 5% discount rate are in Figure 18 in Appendix A). The domestic SC-CH4 estimates are between 76% and 95% lower than the corresponding global estimates, depending on the socioeconomic scenario.

Using the PAGE model in 2020 (and using the 3% discount rate), the U.S.-specific SC-CH4 is on average about 78% less than the global SC-CH4; the FUND model U.S.-specific SC-CH4 on average is 94% less than the global SC-CH4. Therefore, the average SC-CH4 could be as small as $78 to $342 per tonne of CH4 compared to EPA's $1309 per tonne of CH4 in 2020 using a 3% discount rate. These significantly lower domestic SC-CH4 estimates would result in significantly smaller climate benefits resulting in net costs for the Proposed Rule. These estimates, completely omitted from the RIA by EPA, demonstrate that EPA's SC-CH4 estimates significantly overstate the potential domestic benefits from the Proposed Rule.

[30] In its response to comments on the SCC, the IWG also noted that there is no bright line between global and domestic benefits because of potential spillover effects in international trade, national security, and public health (IWG 2015). This, however, does not mean that global benefits alone would produce a better understanding of net benefits than can be obtained through a separate evaluation of domestic and non-domestic benefits.

[31] The DICE model is a global model and it does not include regional details. Hence we do not report U.S.-specific SC-CH4 estimates from this model.

Figure 6. Summary of SC-CH4 Assuming Global versus Domestic Damages
(Perturbation year=2020, discount rate=3%, (2012$ per tonne of CH4)

IAM	Socioeconomic Scenario	RIA (Global)	Domestic (U.S.)	% Change Relative to RIA
PAGE	IMAGE	$1,818	$353	-81%
	MERGE	$1,383	$308	-78%
	MESSAGE	$1,712	$411	-76%
	MINICAM	$1,582	$380	-76%
	5THSCN	$1,225	$257	-79%
	Average	$1,544	$342	-78%
FUND	IMAGE	$1,507	$70	-95%
	MERGE	$1,475	$89	-94%
	MESSAGE	$1,374	$73	-95%
	MINICAM	$1,458	$92	-94%
	5THSCN	$1,059	$66	-94%
	Average	$1,375	$78	-94%

3. EPA's Use of SC-CH4 Estimates Based on a 2.5% Discount Rate is Inconsistent With the Short Atmospheric Lifespan of Methane

EPA's SC-CH4 estimates are based on the same set of discount rates used in the IWG SCC analysis (2.5%, 3.0%, and 5.0%), even though CH4 has a much shorter lifespan than CO_2.[32] In its SCC work, IWG argued that a discount rate of 2.5% is based on the intergenerational impacts of CO_2 due to its long lifespan in the atmosphere. Indeed, the IWG selected a 300-year time horizon because CO_2 is presumed to have long-lived effect on climate. This very long atmospheric life does not apply to CH4. EPA's rationale for adopting the SC-CH4 based on the same discount rates was that they wanted to rely on SC-CH4 estimates that were consistent with the SCC approach even though the gases have much different global warming potentials over time. Given that CH4's atmospheric half-life of about 12 years is a small fraction of CO_2's half-life of over 100 years, climate impacts from CH4 do not have the same intergenerational equity and/or uncertainty about future growth that the IWG used to justify a 2.5% discount rate in its SCC deliberations.

Figure 7 shows the sensitivity of the SC-CH4 to the assumed discount rate for each of the three IAMs in 2020. Relative to the 3.0% discount rate, the SC-CH4 values using a 2.5% discount rate are about 27% to 37% higher depending upon the IAMs; while the SC-CH4 values using a 5% discount rate are on average lower by 55% ($587 compared to $1,309 per tonne of CH4).

[32] The atmospheric half-life of CH4 (*i.e.*, its "e-folding lifetime" in precise technical terminology) is 12 years, while it is between 100 and 300 years for CO_2 (Carbon Dioxide Information Analysis Center).

Figure 7. Summary of 2020 SC-CH4 by Socioeconomic Scenarios and IAMs
(Perturbation year=2020, 2012$ per tonne of CH4)

IAM	Socioeconomic Scenario	Discount Rate			Percentage Change Relative to 3% Discount Rate Estimate	
		2.5%	3.0%	5.0%	2.5%	5.0%
DICE	IMAGE	$1,559	$1,167	$536	34%	-54%
	MERGE	$1,105	$855	$412	29%	-52%
	MESSAGE	$1,411	$1,097	$536	29%	-51%
	MiniCAM	$1,416	$1,041	$457	36%	-56%
	5th Scenario	$1,154	$887	$433	30%	-51%
PAGE	IMAGE	$2,337	$1,817	$834	29%	-54%
	MERGE	$1,782	$1,382	$618	29%	-55%
	MESSAGE	$2,175	$1,712	$801	27%	-53%
	MiniCAM	$2,069	$1,581	$688	31%	-56%
	5th Scenario	$1,543	$1,224	$602	26%	-51%
FUND	IMAGE	$2,071	$1,507	$614	37%	-59%
	MERGE	$1,971	$1,475	$618	34%	-58%
	MESSAGE	$1,844	$1,374	$590	34%	-57%
	MiniCAM	$1,965	$1,458	$596	35%	-59%
	5th Scenario	$1,424	$1,059	$468	34%	-56%
Average		$1,722	$1,309	$587	32%	-55%

By including the 2.5% discount rate, the range of benefits from EPA's SC-CH4 estimates extend much higher as shown in Figure 7. While discount rates of 3.0% to 5.0% are reflective of consumption rates of interest,[33] there is little evidence for using 2.5% for the SC-CH4. We demonstrate the timing difference between CO_2 and CH4 damage in our alternate approach later in these comments.

[33] Since the SC-CH4 is measured in consumption-equivalent units in the IAMs, the consumption rate of interest is an appropriate metric to obtain a present value of estimates of future damages. We note, however, that those damage estimates are to be compared to costs of control that are not accounted for endogenously in the IAMs used by the IWG (in the SCC work) and Marten *et al.* (2014) (in the SC-CH4 work). If the control costs were to be properly integrated into the IAMs, they would exert a consumption-reducing opportunity cost in future years, at a higher rate of interest than 3.0% to 5.0%. This effect would somewhat reduce the future consumption-equivalent damage estimates compared to what the IWG IAMs predict. This missing element of the IAM calculations would have an effect similar to using a slightly higher discount rate than the pure consumption rate of interest. Given the uncertainty on the true consumption rate of interest within a range as wide as 3.0% to 5.0% and the complexity of attempting to adjust for opportunity costs of spending, we do not consider it important to attempt to fine-tune the range of 3.0% to 5.0% for purposes of discounting IAM-based damage estimates, but only note that this omitted effect is a reason to give less weight to the lower end of the range of estimates of consumption rates of interest.

4. EPA's Use of SC-CH4 Estimates Based on an Assumption to Increase Radiative Forcing Due to Indirect Effects by 40% Is Not Clearly Supported by the Scientific Literature.

Radiative forcing from CH4 released to the atmosphere can occur both directly and indirectly.[34] The direct effects of CH4 on radiative forcing are characterized by a complex relationship that is a function of pre-industrial atmospheric concentrations of nitrous oxide and overlapping adsorption bands of CH4 and nitrous oxide (Marten *et al.* 2014). Potential indirect effects of CH4 are due to changes in tropospheric ozone which can enhance stratospheric water vapor levels. The indirect effect is accounted for in the three IAMs by assuming that it is equivalent to a fraction of the radiative forcing due to the direct effect. This assumption is uncertain and varies among analyses.

EPA's SC-CH4 estimates are computed based on an assumption that their estimate of direct radiative forcing of CH4 will be increased by 40% in the DICE and the FUND models to get the total radiative forcing.[35] One of the reviewers engaged by EPA noted that this particular assumption is "*ad hoc*."[36]

It is unclear from the model documentation how the indirect forcing effect of methane is applied in the PAGE model with respect to the calculation of SC-CH4 estimates. Since Marten *et al*. (2014) exogenously increased methane radiative forcing in PAGE (using their DICE model's radiative forcing outputs), possibly all the indirect effects assumed in DICE are already subsumed in the exogenous radiative forcing inputs to PAGE. However, because of the lack of clarity, we do not perform any sensitivity analysis for the PAGE SC-CH4 estimates.

To estimate the potential impact of this *ad hoc* assumption we re-ran the DICE and FUND models without the 40% multiplier, with resulting sensitivity estimates shown in Figure 8. We find that the impact of the indirect effects assumption is significant. As expected, lower radiative forcing results in smaller damages and hence lower SC-CH4 values. However, the magnitude of the effect depends upon the strength of the relationship between radiative forcing and temperature changes in each model. In 2020, for a 3% discount rate the average SC-CH4 from the DICE model is $1,009 per tonne of CH4. This value declines to $731 per tonne CH4 if the *ad hoc* assumption of 40% indirect effects on radiative forcing is removed. Across all socioeconomic scenarios in the DICE model, SC-CH4 values are reduced by 29% if indirect effects are removed. In the FUND model, the percentage reduction is even larger. However,

[34] Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism (IPCC 2007). It is expressed in Watts per square meter (W/m^2).

[35] However, Marten *et al.*'s application of the enhancement effect of 40% is not consistently applied between the DICE and the FUND model. In the DICE model, 40% is applied to the total global radiative forcing expression, while in the FUND model it is only applied to the first term of the global radiative forcing equation 2 in Marten *et al.* (2014). The FUND model introduced a parameter that can take on any value to increase the radiative forcing in FUND 3.8 (same version as used to compute the EPA's SC-CH4 estimates).

[36] US EPA (2014), page 19.

since the FUND model has higher SC-CH4 estimates than the DICE model, the resulting 2020 average SC-CH4 from FUND is $789 per tonne of CH4.

Figure 8. Summary of 2020 SC-CH4 Assuming No Indirect Effects on Global Radiative Forcing
(Perturbation year=2020, discount rate=3%, 2012$ per tonne of CH4)

IAM	Socioeconomic Scenario	RIA With Indirect Effects	Without Indirect Effects	% Change Relative to RIA
DICE	IMAGE	$1,167	$834	-29%
	MERGE	$855	$611	-29%
	MESSAGE	$1,097	$783	-29%
	MINICAM	$1,041	$744	-29%
	5THSCN	$887	$634	-29%
	Average	$1,009	$721	-29%
FUND	IMAGE	$1,507	$942	-38%
	MERGE	$1,475	$855	-42%
	MESSAGE	$1,374	$773	-44%
	MINICAM	$1,458	$910	-38%
	5THSCN	$1,059	$581	-45%
	Average	$1,375	$798	-42%

5. EPA's Use of BaU Emissions Scenarios that Reflect No Incremental Future Mitigation Policy Creates an Inappropriate Overstatement of SC-CH4

Following the IWG's approach for its SCC estimates, EPA relied on SC-CH4 estimates that were calculated using a simple average of four BaU scenarios (IMAGE, MERGE, MESSAGE, and MiniCAM) that have growing GHG emissions and one scenario (5^{th} Scenario) that reflects emissions from a substantial global GHG emissions reduction policy. All five socioeconomic scenarios treat emissions as exogenously specified, but the 5^{th} Scenario is the only one of the five scenarios that reflects a consistent policy to price GHG emissions, not just in the near term, but through the entire model horizon. The choice of socioeconomic scenario is important for the social cost computation because the scenario's assumptions regarding far-future emissions levels determine the amount of damage that the IAMs will attribute to a one-ton perturbation now. Damage curves are convex, meaning that at low levels of concentration, emissions pose little or no harm to the society, but as concentration increases, damage from emissions increases at an increasing rate. Thus, the higher the assumed *future* emissions, the higher the damage that ends up being assigned to a ton of emission today. The appropriate socioeconomic scenario to assume about future emissions levels is therefore an important issue, particularly in a case such as this where the analysis treats the emissions from those scenarios as exogenously fixed.

The only appropriate assumption for assigning a price on GHG emissions in the near term is that such pricing will continue to be in place (and gradually increased) into the future. It is illogical, and indeed socially irrational, to choose to price emissions (*i.e.*, to justify reducing them) in the current period based on an assumption that after the current period they will never again be priced (or reduced). However, that is exactly what is being done when exogenously-fixed BaU emissions projections are used to assess the benefit of one ton less of emissions in a year such as 2020 or 2025. The effect of this illogical assumption is to increase the SC-CH4 estimate compared to a more consistent assumption that the current period's reductions are the first step on the path of a long-term global GHG emissions reduction policy.[37] That is, it inappropriately increases the SC-CH4, resulting in an overstatement compared to more reasonable assumptions.[38]

The use of five socioeconomic scenarios, four of which assume BaU emissions trajectories and only one of which assumes any reductions in future GHG emissions, effectively is then estimating the SC-CH4 with an 80% probability of no future emissions reductions and a 20% probably of emissions reductions to achieve 550 ppm. The 5th Scenario is the only scenario among the socioeconomic scenarios used to compute EPA's SC-CH4 estimates that fits with the IWG's belief that other countries will take reciprocal actions to reduce GHG emissions. The 5th Scenario is not necessarily the best or only appropriate emissions projection to use, but it is certainly closer than any of the four BaU scenarios upon which EPA relied. As one can see from Figure 9, the 5th Scenario produces a much lower SC-CH4 (roughly 20% lower across models and years) than the four BaU cases (as one would expect).

We conclude that, as long as one's scenario options are limited to those already developed and adopted by the IWG (for the SCC work) and EPA (for the SC-CH4 work), *only* the 5th Scenario should be used to derive SC-CH4 estimates for use in Federal policy evaluations.[39] In a more ideal situation, multiple different projections of emissions under reciprocal, globally-shared GHG reduction policies could be used to assess a range in the SC-CH4 values. However, we can be sure (given the convexity of IAM damage functions) that even the highest value within such a range would be lower than those produced giving 80% weight to the other four of the IWG scenarios.

[37] We note that the DICE model that Professor Nordhaus created and uses does not treat emissions and other socioeconomic variables as an exogenous input. Rather, it selects a SCC for a ton of emission today that accounts for an endogenously optimized path of future prices and associated emissions reductions. Thus, the true DICE model always produces SCC estimates for near-term emissions that are based on an internally-consistent assumption that such pricing will continue into the future. EPA's SC-CH4 values (and the IWG's Federal SCC values) are purported to have been calculated using this DICE model, but are actually based on a model created by altering DICE so that it can no longer endogenously determine future emissions. In making this new "DICE-based" model, the internal consistency was no longer assured, and uses of it with BaU emissions assumptions ensures its social cost results will lack that internal consistency.

[38] This same concern applies to the IWG's use of BaU scenarios to estimate a Federal SCC value.

[39] The same conclusion holds for estimating Federal SCC values.

Figure 9. Summary of SC-CH4 for the Four BaUs and the 5th Scenario for 3% and 5% Discount Rates
(2012$ per tonne of CH4)

Model	3.0%							
	2020				2025			
	DICE	PAGE	FUND	Average	DICE	PAGE	FUND	Average
BaUs	$1,040	$1,623	$1,453	$1,372	$1,185	$1,946	$1,616	$1,582
5th Scenario	$887	$1,225	$1,059	$1,057	$1,008	$1,460	$1,164	$1,211
Average	$1,009	$1,544	$1,375	$1,309	$1,149	$1,849	$1,526	$1,508
	5.0%							
	2020				**2025**			
	DICE	**PAGE**	**FUND**	**Average**	**DICE**	**PAGE**	**FUND**	**Average**
BaUs	$485	$735	$605	$608	$566	$932	$689	$729
5th Scenario	$433	$602	$468	$501	$502	$754	$522	$593
Average	$475	$709	$577	$587	$554	$896	$655	$702

Conclusions

Compared to the SCC estimates in the literature, the literature on SC-CH4 estimates is very limited (as seen from Figure 5). Also, the climate science behind the social costs of non-CO_2 GHG values in general, and CH4 in particular, is even more at an early stage than that for radiative effects of atmospheric CO_2. Given the poor quality data for non-CO_2 GHGs, the current IAMs make heroic assumptions, which imply lower quality, more uncertain estimates of SC-CH4 than SCC. Current estimates of SC-CH4, including EPA's SC-CH4 estimates, should at best be viewed as the results of "what-if" analytical exercises, and should be interpreted with great caution when applying them to any actual regulatory evaluation.

In addition to the inherently low reliability of any SC-CH4 estimates, we have identified a number of questionable assumptions that determine the EPA's SC-CH4 estimates. These include use of only global benefits (with no separation of domestic from non-domestic benefits), inclusion of a discount rate that is inconsistent with the shorter lifespan of CH4, an *ad hoc* assumption regarding the radiative forcing from indirect effects of CH4, and estimates that are heavily weighted by four socioeconomic scenarios that are inconsistent with the IWG's belief that U.S. actions will lead to reciprocal actions from other countries to reduce GHG emissions. It is for these reasons that it is too premature and inappropriate to apply SC-CH4 estimates as part of the regulatory decision-making process. At a minimum, if any SC-CH4 estimates are to be used in the Proposed Rule's RIA, they should be centered on the much lower quantitative estimates that we derive using a more reasonable set of IAM input assumptions and outputs (see Section V).

IV. EPA'S ESTIMATES LACK THE APPROPRIATE PEER REVIEW FOR USE IN SUPPORTING REGULATORY POLICY

Given the degree of sensitivity to alternative reasonable input assumptions identified in Section III, it is apparent that the approach that EPA has adopted is deficient and requires substantial peer review before the SC-CH4 estimates can be considered ready for use in policy decision making. An independent scientific peer review would have likely identified many of the same technical issues we have discussed. Indeed, some of the issues were identified in EPA's internal peer review process, but appear to have been glossed over.

Below, we discuss three specific issues regarding the lack of an appropriate peer review of EPA's methodology, approach, and estimates. These are:

1. EPA's SC-CH4 estimates are based on significant modifications of the IAMs and render moot any previous peer reviews of those models;
2. EPA's SC-CH4 estimates are based on harmonization of inputs across the IAMs that is not reflective of best available science; and
3. EPA's peer review process of the SC-CH4 estimates was insufficient.

1. EPA's SC-CH4 Estimates are Based on Significant Modifications of the IAMs and Render Moot any Previous Peer Reviews of Those Models

The IAMs used have frequently been cited in the peer-reviewed literature for estimating a global SCC (but not for a SC-CH4) and were used in the most recent Intergovernmental Panel on Climate Change (IPCC) assessment. A 2010 report of the National Academies of Science (NAS) identified these models as "the most widely used impact assessment models" (IWG 2015). The original authors have put in decades of research to incorporate the best available science through the course of these professional exchanges. However, EPA's SC-CH4 estimates are based on an approach that has simplified and modified the IAMs, disregarding the original model developers' scientific efforts; in the process, the models used to derive EPA's SC-CH4 are no longer the well-documented and peer-reviewed models, even though EPA is attempting to represent them as such.

The FUND model is an IAM with a simplified representation of economic growth, the energy-use carbon cycle, and climate (Waldhoff *et al.* 2014). Based on EPA's SC-CH4 documentation (Marten *et al.* 2014), the core structure of the FUND model was not modified because it could compute the social cost of the non-CO_2 GHG gases directly by perturbing the emissions in any future year. The same, however, cannot be said for the other two models that were used to compute EPA's SC-CH4 estimates.

The original DICE model was modified by incorporating the structural equations, but not the developer's structural framework. As one of the most widely-used IAMs, DICE (using its full structural framework) is a policy optimization model that computes an ideal best-response from an economically-efficiently viewpoint.[40] The modification of the DICE model (even for the SCC estimation) resulted in a static or a descriptive model that lacks optimization and behavioral response, which is better described as "DICE-based." There is no documentation as to why the DICE model was simplified from an optimization model to a simulation model or how this change might affect the structural integrity of the original DICE model and the resulting social cost estimates. In addition, the DICE model was also modified to include a representation of the atmospheric concentration of CH4 based on assumed emissions paths (Marten *et al.* 2014). Given the fundamental change in the model framework and inclusion of a simplified gas cycle model, the "DICE-based" model used to compute the EPA's SC-CH4 estimates significantly deviates from the peer-reviewed original DICE model that Professor Nordhaus created and uses. Thus, results from this model should not be accorded the same status of reliability as those that come from the original DICE model.[41]

The PAGE model was also modified by Marten *et al*. (2014) for the SC-CH4 estimation by replacing its pre-existing built-in CH4 mechanisms with a simpler set of exogenously-specified changes in radiative forcing. Similar to the FUND model, the original PAGE model contains a complex structure with uncertainties in many variables, including the radiative forcing from non-CO_2 emissions. Marten *et al*. (2014) replaced the PAGE model's endogenous methane-cycle logic with the exogenously-determined radiative forcing changes that they computed using their modified version of the DICE model. By doing this, the changes in the radiative forcing due to an emission impulse in a given year were harmonized for the DICE and the PAGE models. Beyond desiring consistency with the DICE model, there is neither justification in the model documentation as to why the PAGE model was changed nor any explanation of how this modification affected the original model's SC-CH4 estimates. Further, because the PAGE model's excess forcing over time is tied to the DICE model's radiative forcing, any errors that may exist in the DICE modifications would extend into their PAGE modeling, and may also be compounded by any inconsistencies with the rest of PAGE's pre-existing logic. Thus, as with the DICE model, the version of the PAGE model upon which EPA has relied for its SC-CH4 estimates can no longer be characterized as a peer-reviewed model.

To further demonstrate that the changes made to the IAMs for the EPA's SC-CH4 estimates make any previous peer reviews moot, we note that such changes were made without a complete understanding of how the IAMs function. Our review of comments made directly by the developers of the EPA's SC-CH4 estimates demonstrates limited exploration of the model responses. For example, the PAGE model has varying time intervals. In the near term, it makes

[40] Bohringer, Loschel, and Rutherford (2007).

[41] As noted in the previous section, one (perhaps unintended) error that has occurred when using the modified version of DICE (adopted for computing EPA's SC-CH4 estimates) is that it has been run using an exogenously-fixed emissions projection that is internally inconsistent with the concept of setting a price to reflect GHG emissions' externalities. As described in that section, this has resulted in inappropriately-overstated estimates of both SC-CH4 and SCC that could not have been accidentally produced by the original version of DICE.

its computations on a decadal basis, while in the long term it makes its computations on a century basis. With reference to the implication of changing the model time steps in the PAGE model, the authors of the EPA's SC-CH4 estimates noted, "It is not clear if the result would hold if the size of the time steps in the model were reduced."[42]

Another point that demonstrates limited exploration of the nuances of model responses when computing EPA's SC-CH4 estimates is the observed inconsistent patterns of the underlying temperature changes. The pattern of projected temperature impacts in the DICE and PAGE models is distinctly different from that of the FUND model. Neither Marten *et al.* (2014) nor the RIA provide any discussion or justification for this difference.

In the DICE and PAGE models, temperatures rise quickly and then fall rapidly within this century as a result of a near-term increment in CH4 emissions. For example, in the year of the impulse, the temperature change projected in the DICE and PAGE models is about 80% to 90% of the maximum temperature change.[43] Figure 10 shows that the maximum temperature change occurs within a decade in the DICE model (blue markers) and the PAGE model (orange markers), and then declines to about 10% of the maximum temperature change by 2130. For the FUND model (green markers), the temperature change rises slowly reaching a maximum point by 2050. Decreases in the temperature change in the FUND model are much slower and sustained over a significantly longer time period. Even by the end of the model horizon (year 2300), temperature change in the FUND model maintains 15% of the maximum temperature change, while for the other two models it is only about 2% of the respective model's maximum temperature change by 2300.

To evaluate this inconsistency further, we ran the same models used to compute EPA's SC-CH4 estimates and compared the temperature changes associated with a pulse of CH4 and CO_2 emissions. Figure 11 shows the temperature changes associated with a pulse of CH4 and CO_2 emissions in 2020 for the DICE and FUND models (the blue and green lines, respectively).[44]

[42] Marten *et al.* (2014).

[43] Note that the temperature change in degrees C is different between the three IAM models.

[44] We do not include the PAGE response given that the temperate response is similar to the DICE model and the PAGE model was not run for carbon impulse for this study.

Figure 10. Normalized Temperature Change for CH4 for the 5th Scenario
(Max=100%, Perturbation year=2020, ECS=3)

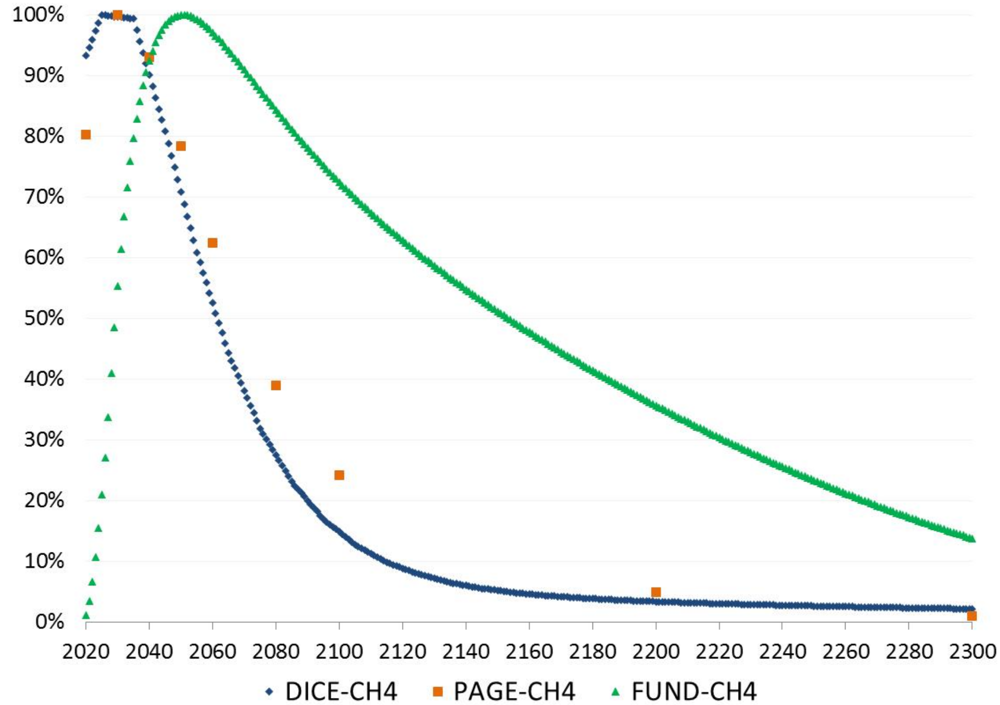
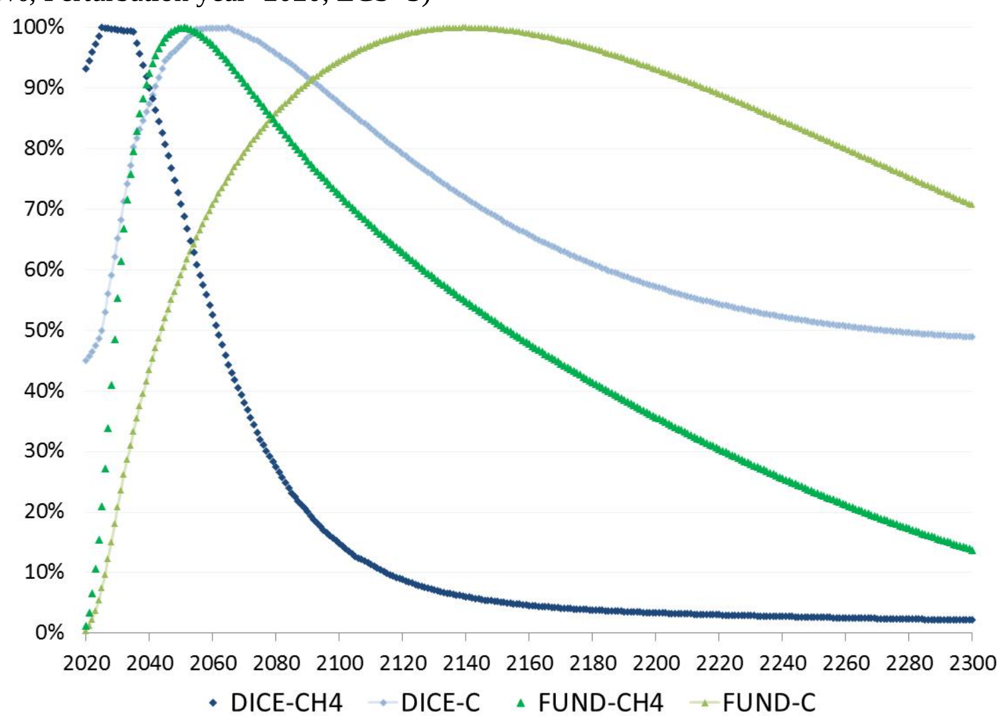


Figure 11. Normalized Temperature Change for CH4 and CO_2 for the 5th Scenario
(Max=100%, Perturbation year=2020, ECS=3)



For these two scenarios, the temperature change for a CO_2 impulse stays higher than the CH4 impulse temperature change response, as one would expect given the longer lifespan of CO_2 compared to CH4. The FUND model pattern is inconsistent with the short lifespan of CH4 and overestimates temperature change compared to the DICE and PAGE models.[45] This suggests that the EPA has not investigated the models properly to sufficiently understand the projected responses. These differences could not have been flagged by any of EPA's selected peer reviewers, or by any journal article reviewers, because this information was never presented to those reviewers. NERA identified these patterns in its own independent replication exercises, and although we cannot explain them, they highlight again the need for a much more thorough peer review process of the modified IAMs before they can be considered mature enough for use in evaluation of major Federal regulations.

2. EPA's SC-CH4 Estimates are Based on Harmonization of Inputs Across the IAMs that Is Not Reflective of Best Available Science

The objective of a model comparison exercise is to understand the different responses based on different model constructs. In any model comparison exercise, caution should be used to avoid harmonization of inputs between the models that would force fundamental features of a model to be eliminated. When efforts to standardize assumptions between models become excessive, they could produce results that are more similar than what they should be, overshadowing the insights about modeling uncertainty that can be derived from the original heterogeneity in individual models, reflecting the independent views and alternative approaches of their developers.

A well-established model comparison platform is the Energy Modeling Forum (EMF) that was established in 1976 at Stanford University. The EMF's goal is to improve the use and usefulness of energy models by testing and understanding the differences between model estimates, while allowing models to operate independently. Models are and will be different, where an input in one model may be an output of other models (Sweeney and Weyant, 1979). Contrary to the approach adopted in computing EPA's SC-CH4 estimates, EMF has always provided for model independence and cautions against over harmonization of input assumptions. This is reflected in the following quote from the Study Design guidelines for EMF-14, which was a forum specifically focused on climate change IAMs:

> *As in all EMF studies, the standardization of input assumptions is accomplished so that important inputs take on common values for each EMF scenario. This process facilitates the interpretation of the model comparison, allowing one to separate the dependence of key model results on model structure and on specific numerical inputs. However, in instances where a particular model includes an endogenous computation of an input selected for standardization, the modeler is urged to pursue the internal calculation in lieu of the EMF 14 input assumption.*

[45] Such an overstatement of the temperature change would result in higher climate damages for a longer time period, which would therefore overstate the SC-CH4 from the FUND model.

By design this situation arises infrequently, but it is important for the modelers to maintain this flexibility.[46]

The statements from EMF suggest that while input harmonization allows for a better understanding of how results are related to a model's structure, it does not require changing the structural integrity of the model. The approach adopted to estimate EPA's SC-CH4 estimates ignored this best practice in light of their changes to the DICE and PAGE model structures described above. Clearly, such model modifications cannot be justified as a standard procedure in model inter-comparison exercises, as it is inconsistent with the guidelines of the premier model inter-comparison forum, EMF. Further, in estimating a Federal SCC or a SC-CH4, the purpose of using three different IAMs was not to conduct an academic exercise in model inter-comparison—it was to reflect current scientific uncertainties by letting three generally-independent models produce their own results. Standardization was not necessary—and probably detrimental—to that goal of characterizing modeling uncertainty. Nevertheless, the fact that EPA made several significant changes to IAMs before using them implies a need for an in-depth review that has not yet been conducted.

3. EPA's Peer Review Process of the SC-CH4 Estimates was Insufficient

EPA relied upon estimates of SC-CH4 from a single research paper, Marten *et al.* (2014), which was written by EPA staff. Although there have been some reviews of the paper that are summarized below, we conclude that the significant modifications (and the absence of scientific justifications for some of the modifications) associated with that paper, combined with the fact that it reports SC-CH4 estimates so much higher than the rest of the literature, demands that a more thorough and independent scientific peer review process should be conducted before its results should be used as the sole determinants of an RIA's benefits estimates.

We note that Marten *et al.* (2014) has been published in a peer-reviewed journal, but we also note that such reviews do not address issues of concern for use in policy deliberations. The focus of peer reviews for journal publication is primarily to determine whether the paper makes a contribution to a particular body of knowledge. Publication peer reviews are not to evaluate or opine on the relevance of the contents of a paper for use in setting public policy. Further, publication of an article in a journal does not necessarily mean that the methodology or the approach laid out in the paper is the best or only approach. It is therefore incorrect to assume that the publication of the paper in an academic journal is an endorsement of the approach used to compute EPA's SC-CH4 estimates, which reflects only one of several published estimates based on a science that is still uncertain and developing. The fact that its estimate is an outlier within the limited available literature suggests even greater concern with such an inference, albeit not a reason to block publication in a journal.

[46] EMF, 1995, p. 1 (emphasis in original document).

Appearing to recognize that publication review is not sufficient for the use EPA has put this to in its RIA, EPA conducted its own internally-managed review (US EPA 2014). In this review, three EPA-selected experts responded in writing to a set of EPA-specified charge questions. Two charge questions (Question-1 and Question-7) were directly related to the application of the SC-CH4 which was the main concern of the internal review.[47] EPA states that in light of the "favorable peer review," EPA proposed to use the Marten *et al.* (2014) SC-CH4 estimates to value CH4 reductions in the Proposed Rule.[48] However, we have read the reviewers comments and we find that they did not provide a consensus view as stated in the Proposed Rule's RIA, as we discuss below:

- Reviewer-1 points out that an application of the direct approach is theoretically better than the Global Warming Potential (GWP) approach and points to the differences between these two approaches when applied to computing CH4 benefits.[49] However, this reviewer cautions in her response, "There, of course, is a host of issues that arises applying any social cost measure to regulatory analyses." In response to Charge Question-7, Reviewer-1 does not offer any definite affirmative or a negative response, but makes a point that EPA should be forthcoming about the shortcomings of the social cost estimates.

- Reviewer-2, in response to charge Question-1, also does not say that it is appropriate for use in benefit-cost analysis of regulatory actions. He only affirms EPA's view that the Marten *et al.* (2014) approach is designed to measure the monetized value of an incremental change in CH4 emission. This reviewer cautions that the estimate of the effect of an addition of CH4 is a simplification of complex atmospheric chemistry. The reviewer referred to the increase in the radiative forcing due to the indirect effects of tropospheric ozone effects and stratospheric water vapor effects as an "*ad hoc* assumption." With regard to Charge Question-7, this reviewer also does not provide an explicit response that endorses such use of the SC-CH4 estimates. The reviewer only acknowledges that Marten *et al.* (2014) consistently applied the IWG's SCC concept to estimating SC-CH4. However, he does not validate the implementation of the models with modifications.

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[47] Question-1: Has EPA correctly interpreted the SC-CH4 estimates provided in Marten *et al.* (2014) as designed to measure the monetized value of the climate impacts from marginal changes in CH4 emissions in a way that is appropriate for use in benefit-cost analysis of regulatory actions projected to change CH4 emissions. Question-7: Are there implementation issues not addressed in the paper that EPA should consider before applying the Marten *et al.* estimates in regulatory analysis?

[48] RIA, p. 4-15.

[49] The Global Warming Potential (GWP) metric indicates the potential of a gas to absorb heat relative to CO_2 over a particular period of time, usually 100 years. The GWP approach translates non-CO_2 emissions to 'CO_2-equivalents' ($CO_{2\text{-}e}$) using estimates of the GWP for the non-CO_2 gas and then multiplied by the SCC (Marten *et al.* 2014).

- Reviewer-3 also agrees with the other reviewers that the direct approach used by Marten *et al.* (2014) (as contrasted to the GWP approach) can be used to monetize the value of an incremental change in CH4. However, his review is the most critical and expresses concerns about moving forward with the direct non-CO_2 GHG social cost estimates based on the IWG's SCC methodology before having a peer-reviewed SCC methodology. This reviewer echoes the sentiments of many others (Pizer *et al.* 2015 and others cited in Marten *et al.* 2014) that have commented on the need for the greater scientific community to formally review the SCC and SC-CH4 approaches. Reviewer-3 is concerned that there are computational issues with calculating the SC-CH4 estimates and implementation issues using the SC-CH4 estimates for regulatory analysis.

The above comments hardly amount to endorsement for use of the EPA SC-CH4 estimates in regulatory impact analyses. Additionally, we note that EPA's review did not address an even more fundamental question of, "What is the scientific basis for using the SC-CH4 estimates?" Ultimately, EPA's justification to use its own SC-CH4 estimates from a single research paper is based on two factors: 1) To improve the current treatment of CH4 in regulatory analysis so that "… they [SC-CH4 estimates] need not be implicitly assigned a value of zero in USG policy assessment,"[50] and that 2) The published estimates are consistent with the SCC approach.

Regarding the first factor, EPA's justification is that any estimate is better than no estimate. Prior to the Proposed Rule, reductions of CH4 emissions were not monetized and in the Proposed Rule EPA felt compelled to come up with a non-zero value (or it could not justify the Proposed Rule on benefit-cost grounds). The need to come up with a non-zero value for SC-CH4 overlooks the reality that even though the state of research is limited, there are several other (and much lower) estimates in the published literature.

The second reason cited is that the published estimates are inconsistent with the SCC approach and the Marten *et al.* (2014) paper is the first and only set of direct estimates of the SC-CH4 that are consistent with the IWG's SCC estimates. The second factor also is not an appropriate justification. Being consistent with the SCC work may be desirable from the EPA's viewpoint, but it is not a sufficient condition to use such premature estimates as part of the regulatory process since it is contrary to using the best-available science. Both of these reasons are not based on science, but rather on subjective judgment and conform to an arbitrary procedural need. As our comments in the prior section reveal, there remain many technical concerns with the IWG approach as well.

The Federal government has recognized that there is a need for more scientific review of the entire process for estimating a social cost of GHGs, and the IWG has stated it plans to seek technical guidance from independent experts such the National Academies of Sciences, Engineering, and Medicine to examine the technical merits of the SCC (IWG 2015). We find that a comprehensive scientific review is even more important for the SC-CH4, given the limited

[50] EPA (2015).

research to date that we have documented above. Nevertheless, there is evidence of a general impatience on the part of the Administration towards the review process, with the IWG deciding to press ahead in using its SCC estimates because "Academies' review will take some time, during which Federal agencies will have continued need for estimates of the SCC to use in benefit-cost analysis."[51] Deferring the scientific review of the SCC and the SC-CH4 to the future, even after recognizing the need for it, sets a dangerous precedent that undercuts the expectation that Federal regulations be based on best available science.

Conclusions

In a regulatory decision-making process such as that for the Proposed Rule, EPA should be using the best-available peer-reviewed science and not relying on estimates produced by models that have been significantly altered in ways not thoroughly and independently peer reviewed, including by those models' original developers. Absent such a review, the SC-CH4 estimates that EPA has used cannot be viewed as reliable and do not meet the standards required by Executive Orders that call for the best available scientific, technical, economic, and other information. Given their substantial sensitivity to several key technical issues that we have flagged in our own cursory review, this lack of thorough review is a major concern.

[51] IWG 2015, p. 5.

V. RECALCULATION OF SC-CH4 USING MORE REASONABLE ASSUMPTIONS

In Section III, we identified five specific issues including questionable assumptions (that we do not consider to be the most reasonable) used to compute EPA's SC-CH4 estimates. These questionable assumptions include the use of a 2.5% discount rate, use of a global geographic scope for benefits instead of a domestic (U.S.) geographic scope, increase radiative forcing due to indirect effects, and use of BaU emissions scenarios that reflect no incremental future mitigation policy.

To provide a quantitative assessment of the sensitivity of the RIA's estimates of benefits and net benefits to the technical issues, we have re-estimated the SC-CH4 values under several alternative assumptions that we consider more reasonable. All of these alternative SC-CH4 calculations have been made using the same IAMs that were used to compute EPA's SC-CH4 estimates.

These alternative calculations include:

A. Eliminating from consideration the 2.5% discount rate;

B. Limiting benefits to a domestic geographic scope instead of global geographic scope;

C. Alternative assumptions regarding the indirect effects on radiative forcing; and

D. Eliminating BaU emissions projections as the reference point for computing future damages from a ton of incremental emission that would occur today.

Figure 12 provides a summary range of EPA's SC-CH4 estimates in 2020 and 2025 based on assumptions we consider either more reasonable or subject to too much uncertainty for EPA to rely on a single point estimate. The values in the "Min" and the "Max" columns show the recomputed low and the high SC-CH4 estimates and percentage change relative to the RIA range assuming different discount rates. The first row (Case RIA) shows the range of SC-CH4 included in the RIA based on mean values using 2.5%, 3.0%, and 5.0% discount rates.[52] Each subsequent row includes a revised range based on different cases we constructed to address some of the technical issues we identified in EPA's SC-CH4 estimates.

Case A removes from consideration the 2.5% discount rate because it is not appropriate given the shorter atmospheric lifespan of CH4 that reduces concerns about the welfare outcomes of far-future generations.

[52] We have not used the 95th percentile worst-case values in these ranges because that would confuse uncertainty about climate impacts *per se* with uncertainty in estimating the impact of methane on climate change, which is the concern with EPA's SC-CH4 estimates that our comments are highlighting.

Case B follows OMB's guidance of using U.S. benefits for preparing benefit-cost analysis of Federal regulations. Our range is therefore bounded by discount rates of 3% and 5%. Case B shows the range of SC-CH4 estimates when limited to a domestic geographic scope (while also not considering the 2.5% discount rate). The domestic SC-CH4 estimates are averaged across all socioeconomic scenarios from the PAGE and FUND models. We do not use the DICE model because it does not report U.S.-specific benefits.

Case C removes the assumption EPA made on a 40% enhancement of radiative forcing due to indirect atmospheric effects. This case also assumes U.S. benefits and discount rates of 3% and 5%. As with Case B, domestic SC-CH4 estimates are averaged across all socioeconomic scenarios from the PAGE and FUND models, for consistency.

Case D relies on an emissions projection that reflects future emissions control policies to complement current emissions reduction efforts (*i.e.*, the "5th Scenario"), giving no weight to future emissions projections that assume no incremental reductions in GHG emissions in the future (*i.e.*, the four socioeconomic scenarios that reflect BaU policy). For this case, we report domestic SC-CH4 estimates for the 5^{th} Scenario *only*, for discount rates of 3% and 5%. Again, for consistency with the prior cases, we use only the PAGE and FUND models.

The alternative SC-CH4 estimates show the progressive drop in the SC-CH4 estimates as we move from Case A to Case D, incrementally altering an additional assumption in each case as described above.[53] We summarize below the SC-CH4 estimates for each of the alternative cases:

1. **EPA's range of SC-CH4 estimates per tonne of CH4 in the RIA is $587 to $1,721 in 2020 and $702 to $1,900 in 2025.**

2. **Removing consideration of the 2.5% discount rate**. This lowers the upper end of EPA's SC-CH4 estimates from $1,721 to $1,309 in 2020 (24% reduction) and from $1,900 to $1,508 in 2025 (21% reduction).

3. **Considering only domestic benefits**. Applying this limitation to the SC-CH4 estimates in the RIA (in conjunction with removing the 2.5% discount rate) reduces the range of SC-CH4 estimates to $106 to $210 in 2020 (reductions of 82% and 88%, respectively) and to $130 to $248 in 2025 (reductions of 81% and 87%, respectively).

4. **The indirect effects on CH4 radiative forcing should not be included as a reference point for calculating the SC-CH4**. Making this change in addition to the above changes reduces the range of SC-CH4 estimates to $69 to $141 in 2020 (reductions of 88% and 92%, respectively) and to $84 to $158 in 2025 (reductions of 88% and 92%, respectively).

[53] As noted in our descriptions above, after Case A, the estimates in this table do not include the DICE model results. Because the DICE model produces the lowest SC-CH4 of the three models, its elimination in Cases B through D probably results in overstatement of the SC-CH4 estimates for these three sensitivity cases.

5. **The 5th Scenario should be the reference point for calculating the SC-CH4, rather than the other four scenarios that do not include any response in emissions.** Making this change in addition to the above changes reduces the range of SC-CH4 estimates to $58 to $99 in 2020 (reductions of 90% and 94%, respectively) and to $69 to $115 in 2025 (reductions of 90% and 94%, respectively).

Figure 12. Alternative Estimates of SC-CH4 Reflecting Key Methodological Uncertainties

		SC-CH4, $ per tonne of CH4 (2012$) *(% Change Relative to RIA Range)*			
		2020		2025	
Case	Description	Min	Max	Min	Max
RIA	RIA Option 2 (2.5%, 3.0%, and 5% discount rates)	587	1,721	702	1,900
A	RIA Option 2 (3.0%, and 5% discount rates)	587 0%	1,309 -24%	702 0%	1,508 -21%
B	Domestic (U.S.) specific SC-CH4 values <u>averaged across all socioeconomic scenarios</u> from PAGE and FUND models.	106 -82%	210 -88%	130 -81%	248 -87%
C	Domestic (U.S.) specific SC-CH4 values <u>averaged across all socioeconomic scenarios</u> from PAGE and FUND model <u>without the indirect effects</u>.	69 -88%	141 -92%	84 -88%	158 -92%
D	Domestic (U.S.) specific SC-CH4 values for the <u>5th Scenario</u> from PAGE and FUND model <u>without the indirect effects</u>.	58 -90%	99 -94%	69 -90%	115 -94%

Note: The Min and Max values span different discount rates, EPA's Low and High total costs, and climate benefits. For Cases B, C, and D, we do not report U.S-specific SC-CH4 estimates from the DICE model because it is a global model and does not include regional details (see Section III.2 for discussion).

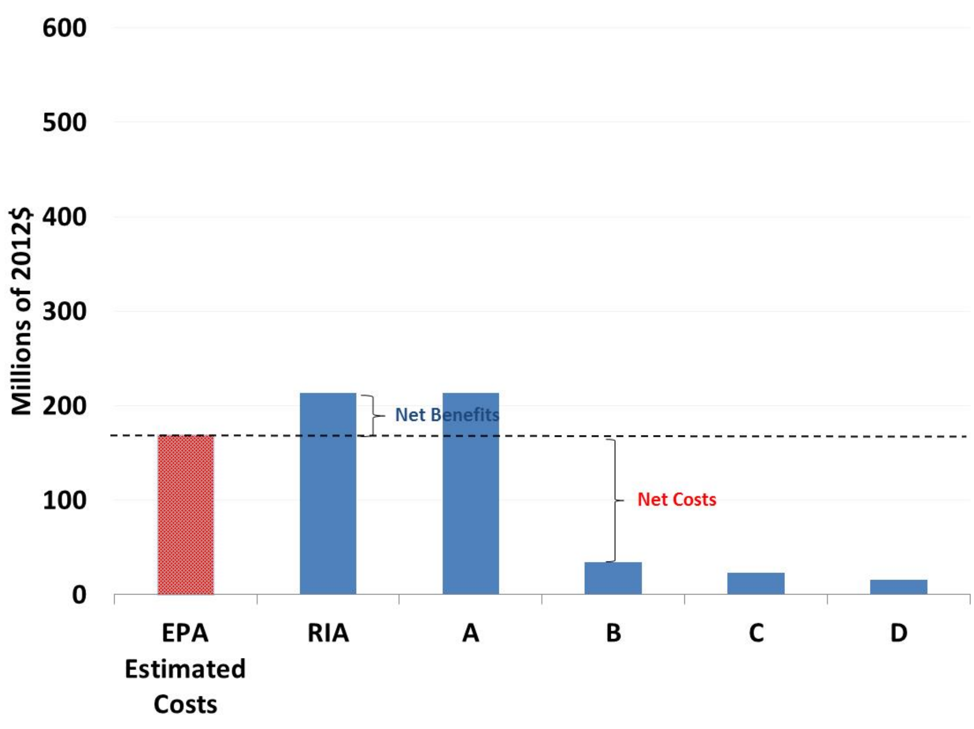
The changes in the SC-CH4 translate to changes in the estimated benefits and net benefits for the Proposed Rule, since none of the changes have an impact on CH4 reductions or compliance costs.[54] Using the revised SC-CH4 estimates from Figure 12, we then compared EPA's net benefits numbers with recalculated net benefits based on our four key assumption changes. The resulting sensitivity cases reflect uncertainties, discussed in the above sections that highlight the extent of EPA's overestimation of SC-CH4 and their net benefits in the Proposed Rule's RIA.

[54] Our comments do not address any aspect of the compliance cost estimates or emissions reduction. That does not imply that we endorse them.

Each of the four alternative ranges of SC-CH4 estimates and the resulting net benefits are shown in Figure 13 (for 2020) and Figure 14 (for 2025). Figure 13 shows net benefits in 2020 for a 3% discount rate for the RIA and for the four alternative cases described above.[55] The "red" bar on the graph indicates the total annualized costs – as estimated by EPA, which is constant across all cases. The "blue" bars show climate benefits for the cases. The difference between the black dotted line and the "blue" bars reflect net benefits or net costs.

For Case A, the SC-CH4 in 2020 is the same as that in the RIA because the change in Case A only impacts the range of results by eliminating the 2.5% discount rate from consideration. All of the other scenarios (Case B, Case C, and Case D, which account for domestic benefits only, no indirect effects on radiative forcing and/or using the 5th Scenario) have net costs, rather than net benefits. The net costs could be as large as \$120 million to \$155 million in 2020 compared to the RIA's stated net benefits of \$44 million to \$52 million with a 3% discount rate.

Figure 13. Total Costs, Climate Benefits, and Net Benefits in 2020 for 3% Discount Rate



As with the 2020 results, the net benefits for Case A are unchanged from the RIA. For all other cases, there are net costs that could be as large as \$245 million to \$380 million (see Figure 14).

[55] Appendix B shows how the climate benefits and compliance costs are spread across the time horizon, and potential payback period. Compliance costs are incurred in the immediate future while climate benefits accrue over a much longer period.

Figure 14. Total Costs, Climate Benefits, and Net Benefits in 2025 for 3% Discount Rate

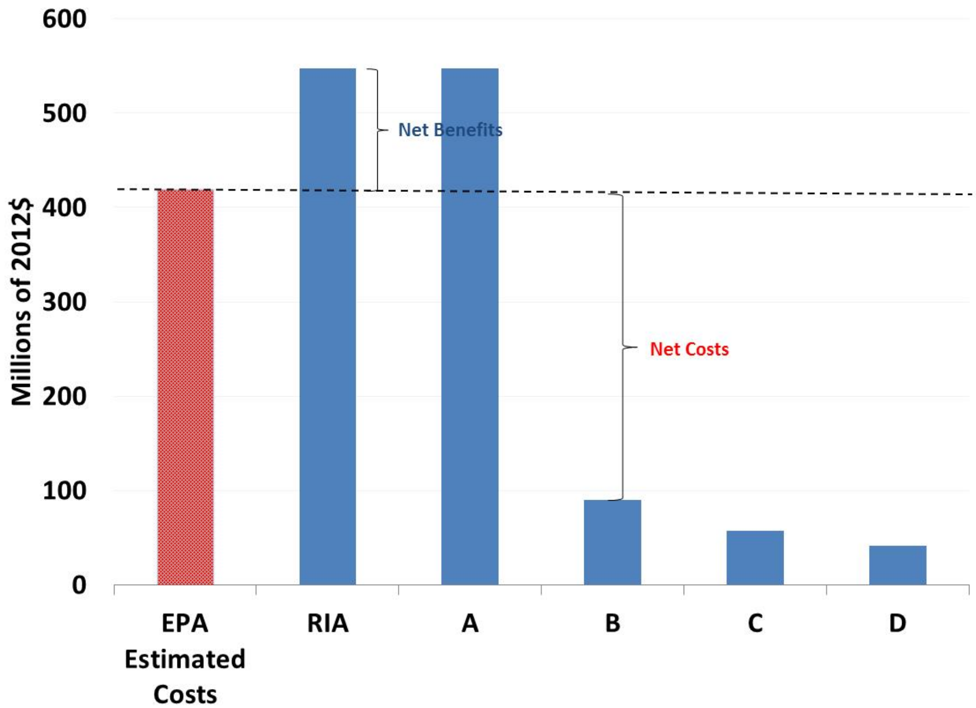


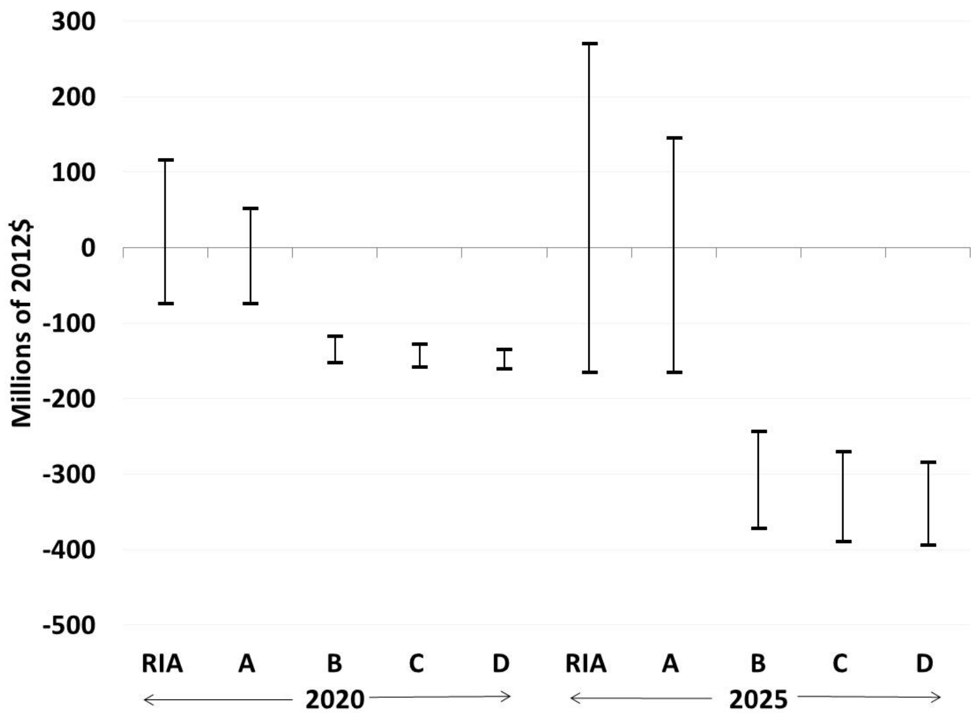
Figure 21 and Figure 22 in Appendix A show the net costs in 2020 and 2025 for the 5% discount rate cases. With a higher discount rate, the SC-CH4 values are lower resulting in all cases showing net costs, including the EPA RIA estimate.

Figure 15 combines the net benefits/costs results for each case in 2020 and 2025 for the 3% and 5% discount rates (also 2.5% for the RIA case). For each case, the 3% and 5% discount rate results define the upper and lower values of the vertical bars. The figure shows that even using EPA's SC-CH4 estimates (labeled "RIA"), the Proposed Rule's net benefits could be negative (or, in other words, the Proposed Rule could have net costs). Figure 15 also shows that when sequentially adjusting for each of the technical issues we have identified, the range of net benefits estimates becomes entirely negative—by more than -$120 million per year and -$240 million even at the ranges' upper bounds in 2020 and 2025, respectively.

Although Figure 15 does not show results when each of the assumptions are changed *individually*, we did run the models for the individual changes, as we briefly summarize here. When using a discount rate range of 3% to 5% and changing each of the assumptions that define Case B and Case C *individually*, net benefits remain negative over the entire range by at least $33 million. When changing assumption that define Case D alone, the net benefits range remains mostly negative (*i.e.*, -$88 million to +$13 million in 2020 and -$204 million to +$55 million in 2025).[56]

Given this exceptional degree of sensitivity of the net benefits estimates to alternative reasonable assumptions, the lack of full scientific peer review of the science and approach used to estimate EPA's SC-CH4 renders it inappropriate for use in making major national policy decisions. We also note that the downward impact on net benefits associated with each individual assumption that we have explored makes it unsupportable for EPA to suggest that the Proposed Rule will produce positive net benefits.

Figure 15. Range of Net Benefits and Costs in 2020 and 2025 (Millions of 2012$)



[56] We do not report the 95th percentile estimates in presenting the ranges for all the cases. We only focus on the mean SC-CH4 values because the 95th percentile values reflect an uncertainty in damages from climate change *per se*, while our focus is on the uncertainties in obtaining a reliable estimate of the incremental climate damages of CH4 emissions.

VI. CONCLUSIONS

Our comments address technical issues with the RIA's benefits calculations, and their implications for the net benefits estimates. Although our comments do not address any aspect of the compliance cost estimates, that does not imply that we endorse those cost estimates. To provide a quantitative assessment of the sensitivity of the RIA's estimates of benefits and net benefits to the technical issues that we have identified, we have re-estimated the SC-CH4 values under several alternative assumptions that we consider more reasonable. All of these alternative SC-CH4 calculations have been made using the same IAMs that Marten *et al.* used to make their SC-CH4 estimates.

We demonstrate that EPA's estimates of the net benefits are highly uncertain and very likely overstated for multiple reasons:

- The EPA's SC-CH4 estimates are based upon a single study (Marten *et al.*, 2014) whose estimates are significantly greater than, and inconsistent with, available estimates in other published papers.
- EPA relies on SC-CH4 estimates that reflect global benefits rather than domestic benefits, a practice that is contrary to the Office of Management and Budget's (OMB's) *Circular A-4* (OMB, 2003) and inconsistent with the theoretical underpinnings of benefit-cost analysis that endow the method with its ability to guide a society towards policies that will improve its citizens' well-being. *Circular A-4* calls for use of domestic benefits, and notes that any estimates of non-domestic benefits should be presented separately. EPA's use of global SC-CH4 benefits estimates (and failure to even present domestic benefits, which are readily obtained from the same models) results in a significant overstatement of benefits and net benefits of the Proposed Rule.
- The RIA includes a 2.5% discount rate in its range of benefits, which is inconsistent with the short atmospheric lifespan of CH4. Its inclusion overstates the upper end of EPA's SC-CH4 estimates, and hence its net benefits.
- Marten *et al.* (2014) have used assumptions regarding indirect effects on radiative forcing from changes in tropospheric ozone and stratospheric water vapor levels that lack clear support from the scientific literature. This assumption, which is uncertain and not validated, could be a substantial source of overstatement in EPA's SC-CH4 estimates. For example, compared to a zero indirect effects assumption, it increases EPA's SC-CH4 estimate by about 36% (when using a 3% discount rate).
- EPA's SC-CH4 estimates are based on an average of five socioeconomic scenarios, four of which assume no incremental policies to reduce emissions in the future (also known as "business as usual" scenarios). Use of scenarios that assume no future emissions control policies to estimate the benefit of reducing a ton of emissions in the near-term overstates the SC-CH4 estimates.

The alternative estimates show that the SC-CH4 estimates could be 90% to 94% lower than the EPA's SC-CH4 estimates. We also demonstrate that EPA's SC-CH4 estimates lack the appropriate peer review that is necessary for use in supporting regulatory policy. In the absence of a full scientific peer review of the methodology behind EPA's SC-CH4 estimates and the degree of sensitivity of the net benefits estimates to alternative reasonable assumptions call into question the reliability of all of the RIA's benefits and net benefits estimates. It is for these reasons that EPA's SC-CH4 estimates are too premature and are inappropriate for use in making major national policy decisions.

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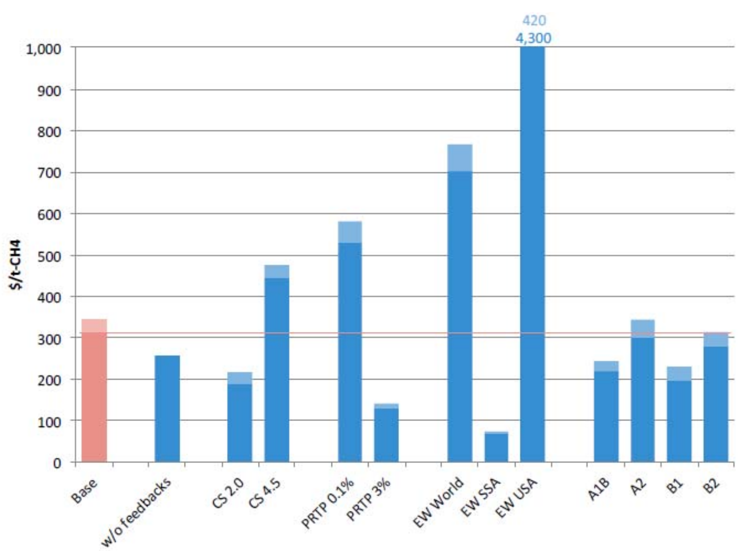
APPENDIX A – ADDITIONAL INFORMATION

Figure 16. NERA Replication of the Social Cost of Methane (in 2012$ per tonne of CH4)

	3%							
Model	2020				2025			
	DICE	**PAGE**	**FUND**	**Average**	**DICE**	**PAGE**	**FUND**	**Average**
IMAGE	$1,167	$1,818	$1,507	$1,497	$1,328	$2,176	$1,675	$1,726
MERGE	$855	$1,383	$1,475	$1,238	$976	$1,669	$1,647	$1,431
MESSAGE	$1,097	$1,712	$1,374	$1,394	$1,244	$2,032	$1,515	$1,597
MiniCAM	$1,041	$1,582	$1,458	$1,360	$1,191	$1,907	$1,628	$1,575
5th Scn	$887	$1,225	$1,059	$1,057	$1,008	$1,460	$1,164	$1,211
Average	$1,009	$1,544	$1,375	$1,309	$1,149	$1,849	$1,526	$1,508

	5%							
	2020				2025			
	DICE	**PAGE**	**FUND**	**Average**	**DICE**	**PAGE**	**FUND**	**Average**
IMAGE	$536	$834	$614	$661	$624	$1,053	$698	$792
MERGE	$412	$618	$618	$549	$481	$789	$707	$659
MESSAGE	$536	$801	$590	$642	$625	$1,007	$667	$766
MiniCAM	$457	$688	$596	$580	$535	$877	$682	$698
5th Scn	$433	$602	$468	$501	$502	$754	$522	$593
Average	$475	$709	$577	$587	$554	$896	$655	$702

Figure 17. Rage of Social Costs of CH4 from the Most Recent Publication - Waldhoff *et al.* 2014 ($ in 1995)



Red denotes the base assumptions. Darker colours include carbon dioxide fertilization, the sum of the dark and light are estimates without carbon dioxide fertilization. Note that the values for EW USA exceed the scale of the chart. The bottom number is the value with CO_2 fertilization and the sum of the two values is the value without CO_2 fertilization.

Figure 18. Summary of SC-CH4 Assuming Global versus Domestic Damages
(Perturbation year=2020, discount rate=5%, (2012$ per tonne of CH4)

IAM	Socioeconomic scenario	RIA (Global)	Domestic (U.S.)	% Change Relative to RIA
PAGE	IMAGE	$834	$179	-79%
	MERGE	$618	$148	-76%
	MESSAGE	$801	$204	-74%
	MINICAM	$688	$176	-74%
	5THSCN	$602	$137	-77%
	Average	$709	$169	-76%
FUND	IMAGE	$614	$48	-92%
	MERGE	$618	$45	-93%
	MESSAGE	$590	$40	-93%
	MINICAM	$596	$47	-92%
	5THSCN	$468	$38	-92%
	Average	$577	$44	-92%

Figure 19. Summary of 2020 SC-CH4 Assuming No Indirect Effects on Global Radiative Forcing
(Perturbation year=2020, discount rate=5%, 2012$ per tonne of CH4)

IAM	Socioeconomic Scenario	RIA With Indirect Effects	Without Indirect Effects	% Change Relative to RIA
DICE	IMAGE	$536	$383	-29%
	MERGE	$412	$294	-29%
	MESSAGE	$536	$383	-29%
	MINICAM	$457	$326	-29%
	5THSCN	$433	$309	-29%
	Average	$475	$339	-29%
FUND	IMAGE	$614	$383	-38%
	MERGE	$618	$389	-37%
	MESSAGE	$590	$370	-37%
	MINICAM	$596	$384	-36%
	5THSCN	$468	$289	-38%
	Average	$577	$363	-37%

Figure 20. Range of Net Benefits (2012$ Million)

Case	Discount Rate		2020 Low	2020 High	2025 Low	2025 High
RIA	3%	Total Monetized Benefits	202	214	465	547
		Total Costs	150	170	320	420
		Net Benefits	52	44	145	127
A	3%	Total Monetized Benefits	202	214	465	547
		Total Costs	150	170	320	420
		Net Benefits	52	44	145	127
B	3%	Total Monetized Benefits	32	34	76	90
		Total Costs	150	170	320	420
		Net Benefits	(118)	(136)	(244)	(330)
C	3%	Total Monetized Benefits	22	23	49	57
		Total Costs	150	170	320	420
		Net Benefits	(128)	(147)	(271)	(363)
D	3%	Total Monetized Benefits	15	16	35	42
		Total Costs	150	170	320	420
		Net Benefits	(135)	(154)	(285)	(378)
RIA	5%	Total Monetized Benefits	91	96	216	255
		Total Costs	150	170	320	420
		Net Benefits	(59)	(74)	(104)	(165)
A	5%	Total Monetized Benefits	91	96	216	255
		Total Costs	150	170	320	420
		Net Benefits	(59)	(74)	(104)	(165)
B	5%	Total Monetized Benefits	16	17	40	47
		Total Costs	150	170	320	420
		Net Benefits	(134)	(153)	(280)	(373)
C	5%	Total Monetized Benefits	11	11	26	30
		Total Costs	150	170	320	420
		Net Benefits	(139)	(159)	(294)	(390)
D	5%	Total Monetized Benefits	9	9	21	25
		Total Costs	150	170	320	420
		Net Benefits	(141)	(161)	(299)	(395)
RIA	2.5%	Total Monetized Benefits	265	281	586	689
		Total Costs	150	170	320	420
		Net Benefits	115	111	266	269

Figure 21. Total Costs, Climate Benefits, and Net Benefits in 2020 for 5% Discount Rate

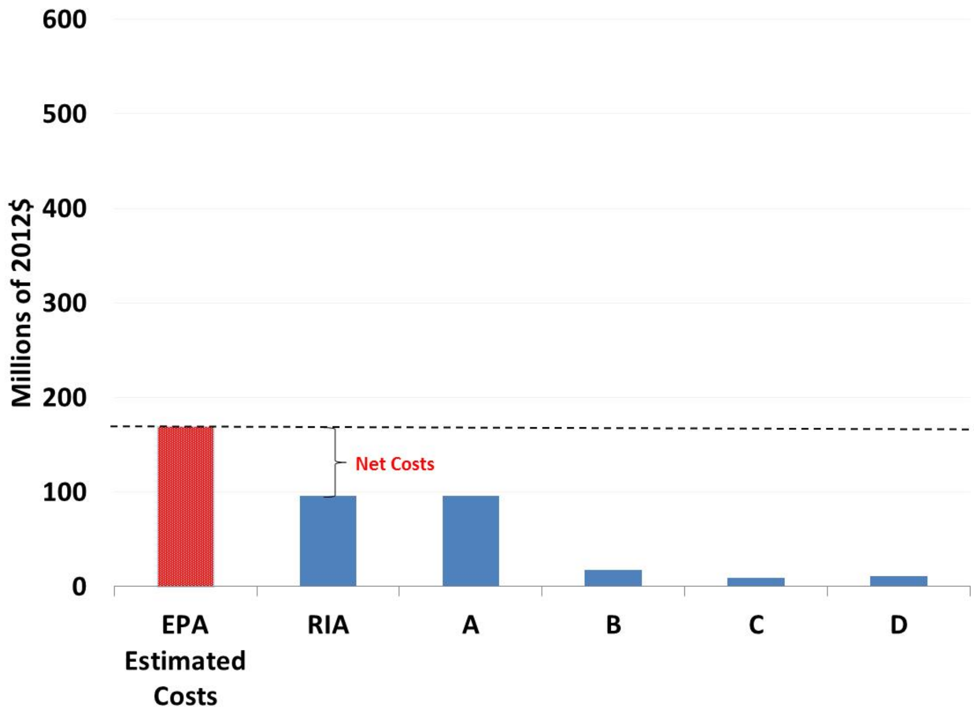
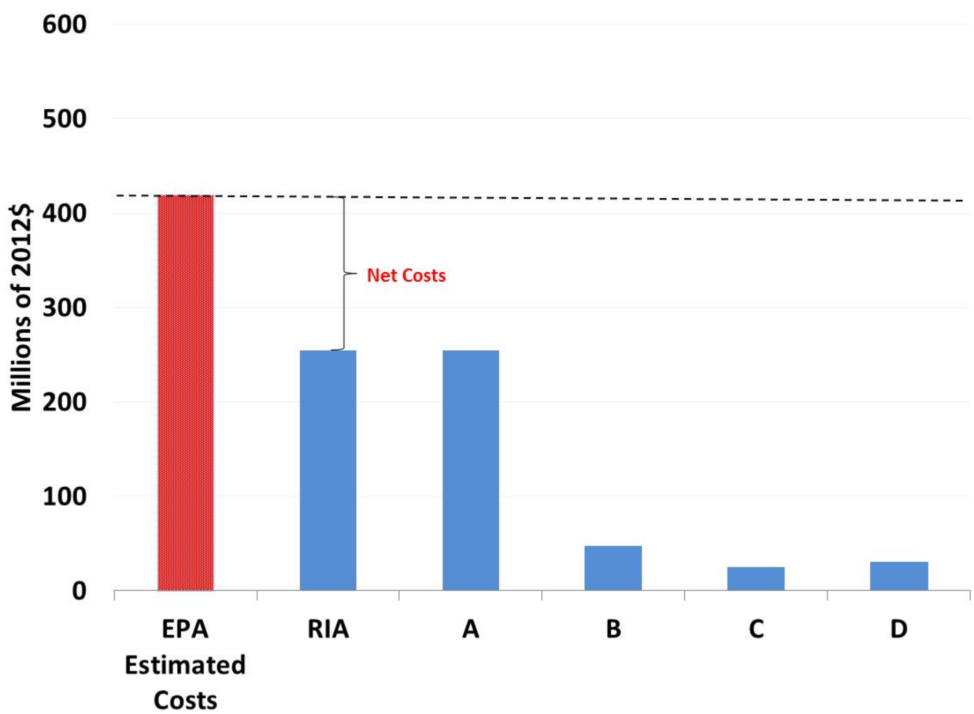


Figure 22. Total Costs, Climate Benefits, and Net Benefits in 2025 for 5% Discount Rate



APPENDIX B - TIMING OF GLOBAL CLIMATE BENEFITS AND TOTAL COSTS

Another issue that we explored is the timing of the benefits and costs. In particular, we explored when the global climate benefits would be realized for cases that have net benefits over the model horizon (*i.e.*, this would not include any of the cases that only focus on domestic benefits since all of these have negative net benefits). In particular, we reviewed the timing of costs and benefits for the DICE and FUND models because we were able to generate annual undiscounted costs. For CH4, an emission reduction today can have climate benefits for several decades. It is important to understand when these benefits are realized in the context of rationalizing public policies that would have an impact on the economy and the society at large in the immediate future.

While capital costs and O&M expenditures are incurred upfront and during the life of the equipment, climate benefits are realized well beyond the life of the pollution control equipment. We decomposed the timing of the costs and global climate benefits to estimate the payback period for an investment that occurs in 2020 with O&M expenditures over the assumed life of the control equipment (8 years). The annual global climate benefits from an incremental ton of emissions avoided in the first year from oil well completions and for an additional seven years from other emissions sources are shown by the blue bars in Figure 23, Figure 25, Figure 27, and Figure 29. These represent global climate benefits from the DICE and the FUND model for the 5^{th} scenario, using a 3% discount rate, and a climate sensitivity of 3. Total costs for achieving CH4 emissions reduction are shown as red bars (note that the capital costs in the first year overlap with the y-axis, but reach $146 million in 2020). Figure 24 shows the cumulative global net benefits in each year through 2300. In the short run, investment costs outweigh global climate benefits, hence negative global net benefits. However, over time global climate benefits add up, and with no additional costs beyond year 8, the cumulative global net benefits become positive around 2070, a payback period of 50 years using 3% discount rate. We do note that the domestic U.S. net benefits would never be positive in this scenario, or any of the other scenarios that we evaluated. The payback period exceeds 300 years if a 5% discount rate is used, see Figure 28 and Figure 30.

Figure 23. Present Value of Spending (red) and Global Climate Benefits (blue) by Year for 5th Scenario (Millions of 2012$)
(Benefits' timing is based on DICE using the 5th Scenario, climate sensitivity=3, and discount rate=3%)

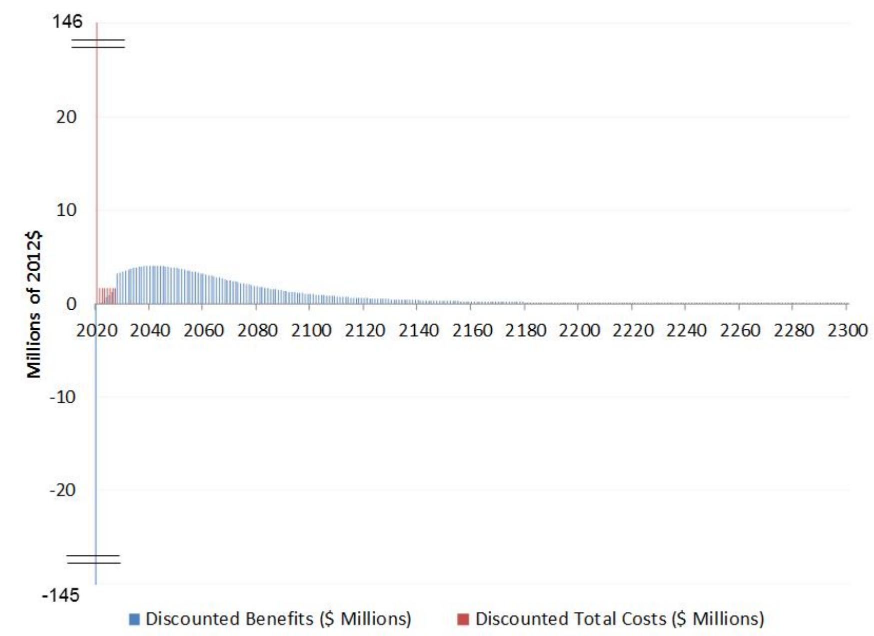


Figure 24. Cumulative Discounted Global Net Benefits over Time by Year for 5th Scenario (Millions of 2012$)
(Benefits' timing is based on DICE using the 5th Scenario, climate sensitivity=3, and discount rate=3%)

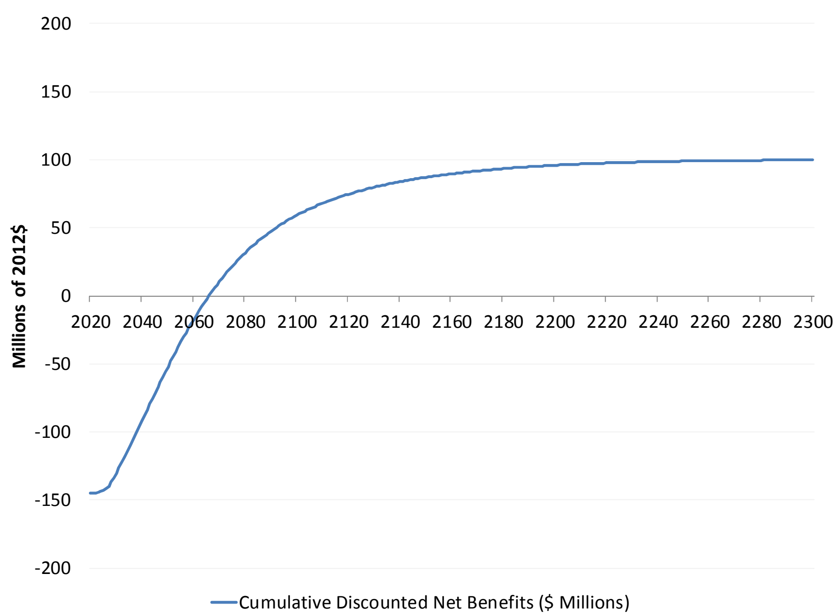


Figure 25. Present Value of Spending (red) and Global Climate Benefits (blue) by Year for 5th Scenario (Millions of 2012$)
(Benefits' timing is based on FUND using the 5th Scenario, climate sensitivity=3, and discount rate=3%)

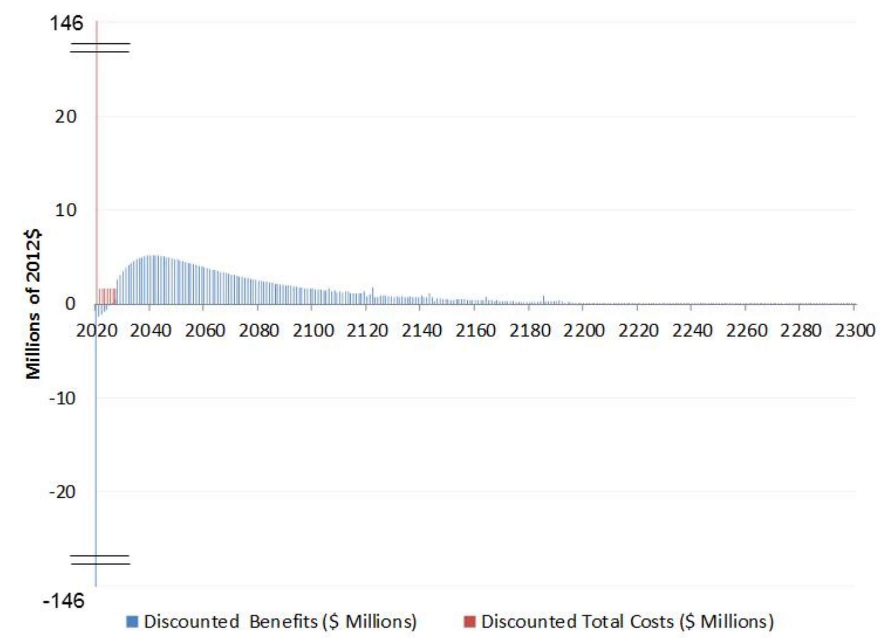


Figure 26. Cumulative Discounted Global Net Benefits over Time by Year for 5th Scenario (Millions of 2012$)
(Benefits' timing is based on FUND using the 5th Scenario, climate sensitivity=3, and discount rate=3%)

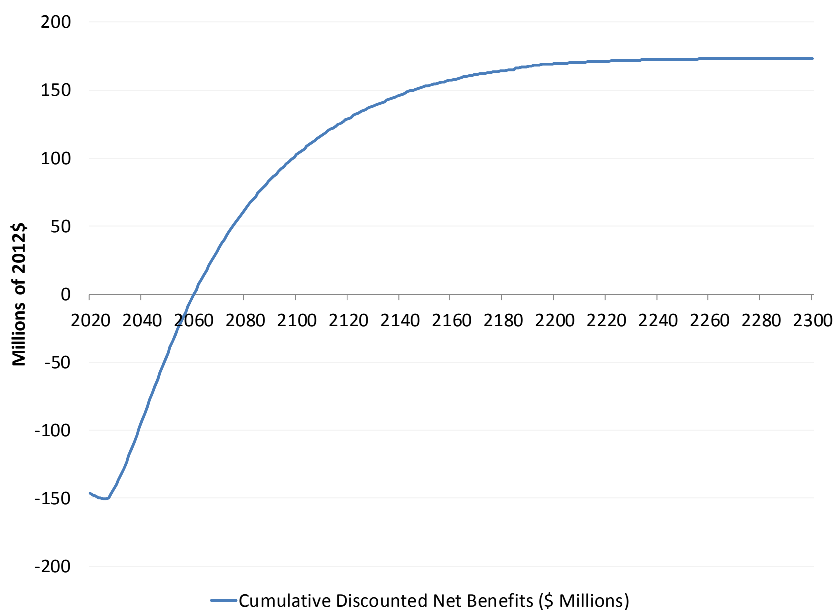


Figure 27. Present Value of Spending (red) and Global Climate Benefits (blue) by Year for 5th Scenario (Millions of 2012$)

(Benefits' timing is based on DICE using the 5th Scenario, climate sensitivity=3, and discount rate=5%)

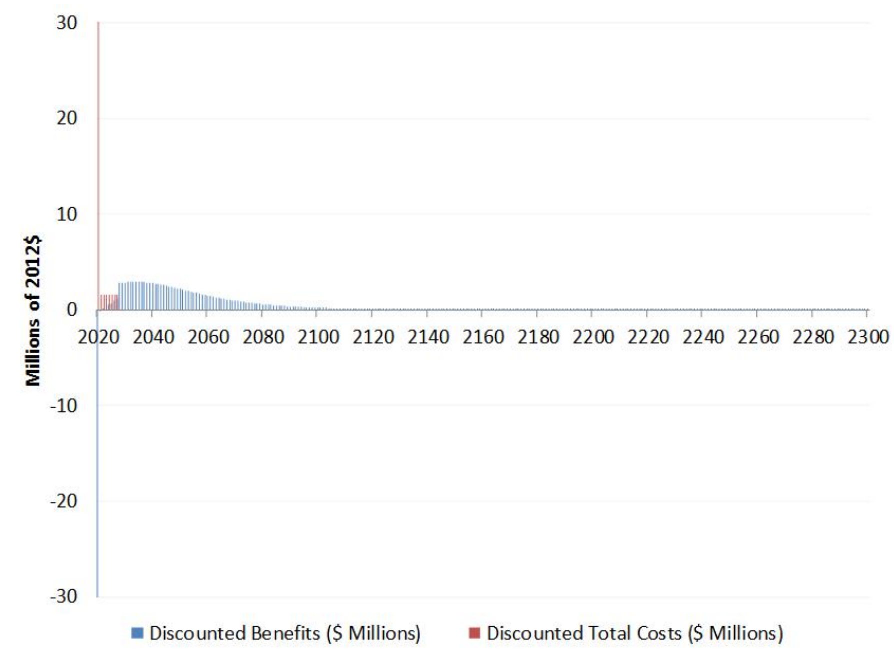


Figure 28. Cumulative Discounted Global Net Benefits over Time by Year for 5th Scenario (Millions of 2012$)

(Benefits' timing is based on DICE using the 5th Scenario, climate sensitivity=3, and discount rate=5%)

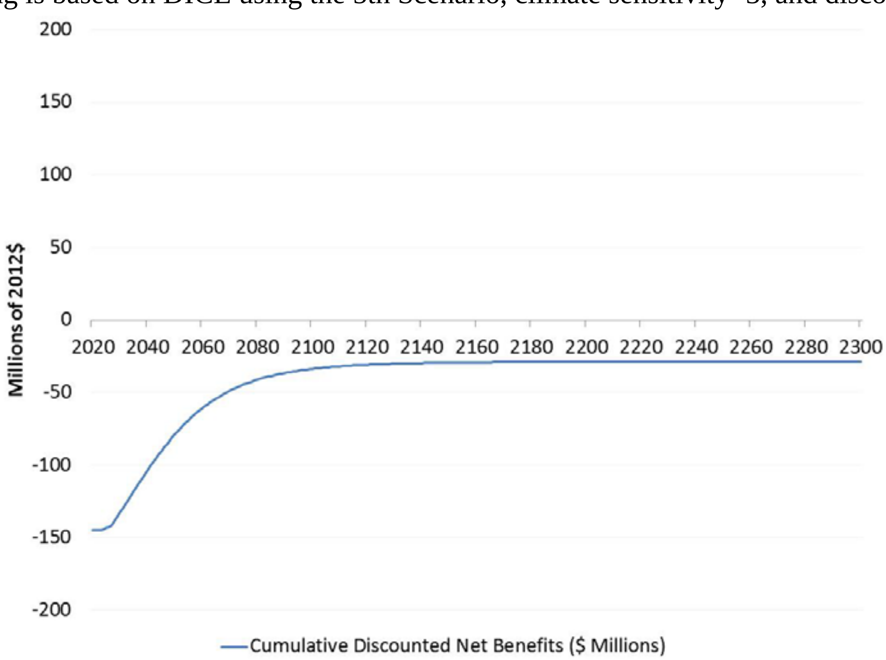


Figure 29. Present Value of Spending (red) and Global Climate Benefits (blue) by Year for 5th Scenario (Millions of 2012$)
(Benefits' timing is based on FUND using the 5th Scenario, climate sensitivity=3, and discount rate=5%)

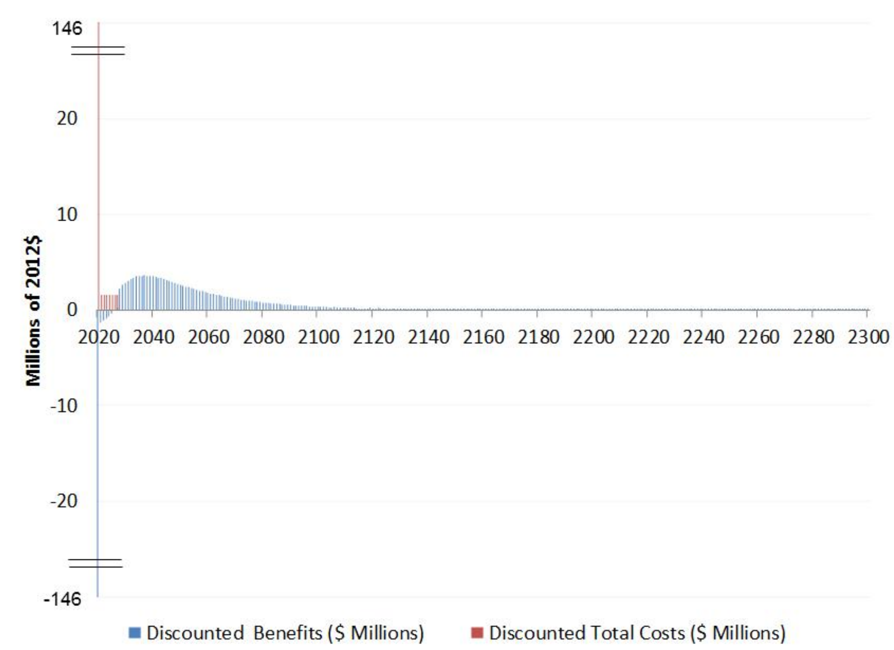
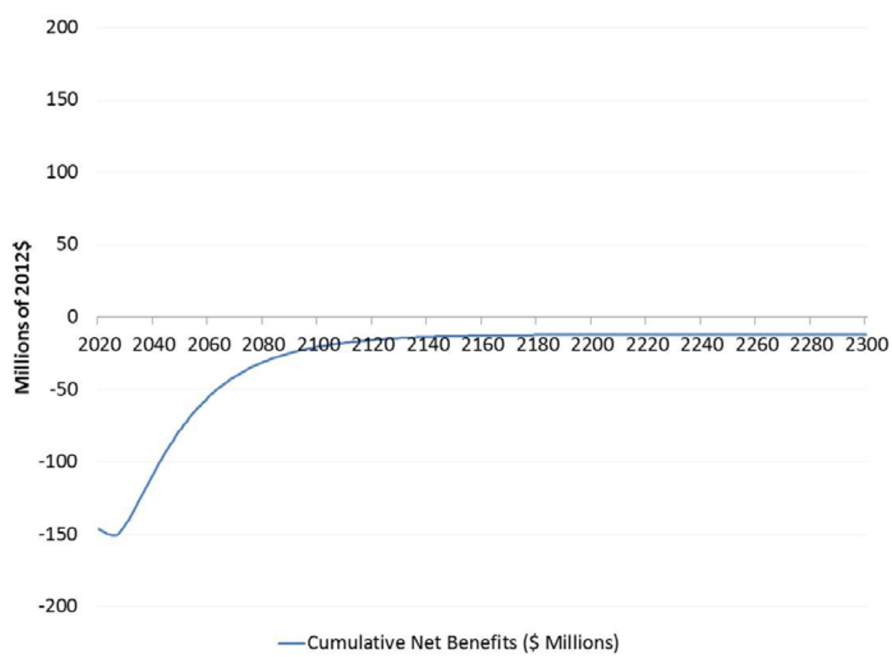


Figure 30. Cumulative Discounted Global Net Benefits over Time by Year for 5th Scenario (Millions of 2012$)
(Benefits' timing is based on FUND using the 5th Scenario, climate sensitivity=3, and discount rate=5%)



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