**Memorandum**

TO: Docket for rulemaking, “Oil and Natural Gas Sector – New Source Performance Standards, National Emission Standards for Hazardous Air Pollutants, and Control Techniques Guidelines” (EPA-HQ-OAR-2010-0505)

DATE: October 17, 2017

SUBJECT: Estimated Cost Savings and Forgone Benefits Associated with the Proposed Rule, “Oil and Natural Gas: Emission Standards for New, Reconstructed, and Modified Sources: Stay of Certain Requirements”

The EPA prepared a Regulatory Impact Analysis (RIA) of the potential costs and benefits associated with the 2016 Rule, “Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources” (81 FR 35824). The RIA is available at Docket ID No. EPA-HQ-OAR-2010-0505-7630. On June 16, 2017, the Environmental Protection Agency (EPA) proposed to stay for two years certain requirements that are contained within the Final Rule titled ‘‘Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources,’’ which was published in the Federal Register on June 3, 2016 (2016 Rule).[1] As part of the proposed two-year stay, the EPA presented estimates of the cost savings from those affected provisions and years, but did not present estimates of the forgone benefits because quantitative estimates that were consistent with Executive Order 13783 (E.O. 13783) were not available at that time.

This memo updates the analysis presented in the proposed two-year stay to include quantified estimates of the forgone benefits associated with changes in methane emissions, which were unavailable at the time of the initial proposal. In addition, the analysis updates the calculations of cost savings to reflect a revised time frame. Specifically, the previous analysis assumed that the proposed two-year stay would cover the time period from September 2017 through September 2019. As September has passed, the analysis has been updated to reflect a time frame beginning in January, 2018 and ending in December, 2019. In Section 1, this memo updates the estimates of cost savings to better account for the updated time frame of the stay.[2]

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[1] See 82 FR 27645 for the proposed two-year stay, published on June 16, 2017.

[2] Note the two years of cost savings presented in this memo are not directly comparable to the June 2017 analysis of the proposed rule because of a technical error in the initial analysis. Specifically, the initial analysis published in June 2017 inadvertently excluded cost savings from January 2019 to September 2019.

Second, the initial analysis noted that the stay will result in forgone benefits due to increased emissions of methane and volatile organic compounds (VOC), but that quantified estimates of the forgone benefits were not available at that time. Since then, the EPA has been able to quantify some of the forgone benefits. Section 2 presents the estimated forgone emission reductions of with this action, and Section 3 discusses the associated forgone health benefits and presents the associated forgone domestic climate benefits. Section 4 presents the net benefits of the proposal. While this analysis supports the proposed two-year stay, the results also support the two-year extension of the phase in period as discussed in the Notice of Data Availability.

## 1. Cost Savings

For this analysis, EPA assumes all facilities affected prior to the stay are in compliance with the 2016 Rule. This means that all costs and benefits in 2017, the period prior to the stay, are unaffected by this proposed action.[3] There are small cost effects seen in 2020, the period immediately after the stay ends, due to facilities that become affected during the stay postponing compliance activities until the stay ends. Using the estimated source counts as presented in Table 3-2 of the 2016 Rule RIA, the EPA estimated the capital costs, annual operating and maintenance costs and value of product recovery for 2018 through 2020 for the two requirements under the 2016 Rule and this proposal.[4] This analysis assumes that facilities in compliance with the fugitive emissions requirements prior to January 2018 can pause compliance efforts (monitoring) during the stay. Pneumatic pump affected facilities at well sites incur capital costs when they come into compliance, however they do not incur annual costs while complying, therefore this analysis assumes affected pneumatic pumps at well sites which are in compliance before the proposed stay begins continue to comply during the stay. Total costs in each year are calculated as capital costs plus annual costs minus revenue from product recovery. These undiscounted costs are presented in Table 1, below. All costs are presented in 2016 dollars.

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[3] The EPA published an administrative stay (82 FR 25730) on June 5, 2017, which was vacated by the U.S. Court of Appeals for the D.C. Circuit on July 3, 2017. As this administrative stay is no longer in effect, this analysis assumes all sources that would have paused or delayed compliance due to that action are in compliance before the proposed 2-year stay begins. Therefore, the administrative stay is not an issue in this analysis.

[4] There are three requirements affected by the two-year stay proposal: fugitive emissions, well site pneumatic pumps, and professional engineer certification. This analysis only focuses on the fugitive emissions and well site pneumatic pumps requirements because we do not have the data necessary to determine the effect on costs or benefits related to PE certification. In addition, this requirement was not included in the 2016 Rule RIA.

Careful consideration must be made in comparing costs presented here to those presented in the 2016 Rule RIA. Costs presented in the 2016 Rule RIA are costs in 2020 and 2025 and are presented in 2012 dollars. Costs presented here are for 2018, 2019 and 2020, and are presented in 2016 dollars, in accordance with OMB Guidance M-17-21 for E.O. 13771. In addition, some of the capital costs presented in the 2016 Rule RIA are annualized values, as are the presented total costs; capital costs, and therefore total costs, are not annualized in the analysis presented here. In addition, the assumed price for recovered natural gas in the 2016 Rule was $4.00/Mcf. Using the EIA's 2017 Annual Energy Outlook (AEO) No Clean Power Plan case, the Henry Hub spot prices are projected to be between $3.41/ MMBtu and $4.48/MMBtu between 2018 and 2020. After adjusting these estimates to reflect prices per thousand cubic feet at the wellhead, these prices are $3.43/Mcf in 2018, $3.96/Mcf in 2019, and $4.54/Mcf in 2020. The prices used in this analysis are $3.50/Mcf in 2018, $4.00/Mcf in 2019 and $4.50/Mcf in 2020 to reflect this updated AEO estimate.

**Table 1. Cost Estimates of the 2016 Rule and the Proposal, Undiscounted (2016$ millions)**

| | **2016 Rule** | | | | **Proposal** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Capital Costs** | **Annual Costs** | **Revenue from Product Recovery** | **Total Costs** | **Capital Costs** | **Annual Costs** | **Revenue from Product Recovery** | **Total Costs** |
| **2018** | $21 | $150 | $24 | $150 | $0 | $0 | $0 | $0 |
| **2019** | $21 | $200 | $36 | $180 | $0 | $0 | $0 | $0 |
| **2020** | $21 | $250 | $51 | $220 | $64 | $250 | $51 | $260 |

Note: These costs only account for the fugitive emissions and well site pneumatic pumps requirements. We did not include the costs of professional engineer certification because these costs were not accounted for in the 2016 Rule. Results are rounded to two significant figures. Totals may not sum due to independent rounding.

Table 2 presents the total cost savings of the proposal, which reflect the total capital costs estimated for all affected sources in each year, as well as the accumulated annual operating and maintenance costs and associated product recovery values. The difference in estimated costs between the 2016 Rule and the proposal is largely due to the annual operating and maintenance that would be incurred by affected components under the 2016 Rule that are not incurred under the proposal. The higher costs of the proposal after the stay ends compared to the costs of the 2016 Rule is due to the capital costs borne by sources becoming affected during the stay whose compliance was delayed until the stay ends. When the stay ends and the sources that postponed compliance during the stay start complying, the number of sources in compliance reach the level of compliance that would happen under the 2016 Rule, which means annual costs and emission reductions in 2020 are the same for both scenarios.

**Table 2. Estimated Cost Savings of the Proposal, Undiscounted (2016$ millions)**

| | Capital Cost Savings | Annual Cost Savings | Forgone Revenue from Product Recovery | Total Cost Savings |
|---|---|---|---|---|
| **2018** | $21 | $150 | $24 | $150 |
| **2019** | $21 | $200 | $36 | $180 |
| **2020** | -$43 | $0 | $0 | -$43 |

The cost savings are estimated from a baseline of the 2016 Rule.
Results are rounded to two significant figures. Totals may not sum due to independent rounding.

Table 3 presents the total costs, accounting for the value of product recovery, and their differences discounted to 2018 using both a 7 percent and a 3 percent discount rate, the present values of these costs, and their equivalent annualized values. The equivalent annualized values are the annualized present values, or the even flow of the present values, over the three years affected by the proposal. As can be seen in Table 3, the estimated total present value of cost savings associated with the proposal is $270 million when using a 7 percent discount rate and $280 million when using a 3 percent discount rate. The equivalent annualized values of the cost savings are about $100 million per year when using a 7 percent discount rate and $99 million per year when using a 3 percent discount rate.

**Table 3. Present Value of the Cost Estimates of the 2016 Rule and the Proposal and the Cost Savings, Discounted to 2018 (2016$ millions)**

| | 2016 Rule | | Proposal | | Cost Savings | |
|---|---|---|---|---|---|---|
| | 7% | 3% | 7% | 3% | 7% | 3% |
| **2018** | $140 | $150 | $0 | $0 | $140 | $150 |
| **2019** | $160 | $170 | $0 | $0 | $160 | $170 |
| **2020** | $180 | $200 | $210 | $240 | -$35 | -$39 |
| ***Present Value*** | *$480* | *$520* | *$210* | *$240* | *$270* | *$280* |
| ***Equivalent Annualized Value*** | *$180* | *$180* | *$81* | *$84* | *$100* | *$99* |

Note: These total costs account for the value of product recovery.
Results are rounded to two significant figures. Totals may not sum due to independent rounding.

The estimates presented here are made under a few assumptions, including:

- The EPA is assuming all affected facilities prior to the beginning of the stay perform compliance activities. If some affected entities do not begin performing compliance activities prior to the stay, they will not incur the associated sunk costs and ongoing operating and maintenance costs that are accounted for in the estimates of costs of the proposal; this would increase the cost savings associated with the proposal.

- Affected entities may decide not to delay compliance by the full two years because earlier compliance may allow for coordination of regulatory and non-regulatory capital work, thus minimizing operational downtime. Earlier compliance leads to earlier incurrence of annual costs and benefits, which would reduce the cost savings associated with the proposal.
- However, early compliance may also reduce capital costs for those entities electing to comply earlier under the proposal – for instance, if overtime payments and rush charges can be avoided. This may increase the cost savings associated with the proposal.
- The cost of the professional engineer (PE) certification was not taken into account in the 2016 Rule RIA and therefore the costs of this provision under the 2016 Rule cannot be compared to the costs under the proposal. The inclusion of the costs of this certification would likely increase the cost savings under the proposal, as costs related to the certifications that would otherwise take place during the stay would no longer be incurred.
- The costs and emission reductions presented here are estimated from a baseline which is not adjusted for the Proposed Rule "Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources: Three Month Stay of Certain Requirements" (82 FR 27641). This would slightly decrease the cost savings and forgone emission reductions associated with this proposal.

Given data limitations, the cost estimates related to the proposal have not been adjusted to reflect these analytical considerations. The cost estimates also do not reflect any changes in baseline conditions since the analysis for the 2016 Rule was conducted (e.g., new developments in state level fugitive emissions programs, technological change, or other factors affecting the cost of compliance activities). The potential existence of sunk costs, voluntary early compliance, and changes in baseline assumptions would likely reduce the effects of the proposal to less than the difference shown in Table 2.

## 2. Forgone Emission Reductions

The 2016 Rule was expected to result in health-related benefits by reducing levels of VOC, a pollutant that contributes to the formation of both fine particles ($PM_{2.5}$) and ground-level ozone ($O_3$) in the atmosphere and adversely affects public health, and climate-related benefits by reducing methane emissions. The proposal would therefore forgo the health and climate-related benefits associated with any emissions reductions. Table 4 summarizes the forgone emissions reductions associated with the proposal. These estimated forgone emissions reductions, and the associated forgone benefit estimates presented in section 3 below, are made under the assumptions discussed in section 1 above. The estimates do not reflect voluntary early compliance or any changes in baseline conditions since the analysis for the 2016 Rule was conducted (e.g., new developments in state level fugitive emissions programs, technological change, or other factors affecting the efficacy of compliance activities). In addition, only the two years of the stay are presented. The count of affected facilities before the stay begins and after the stay ends are the same as under the 2016 Rule, which means emission reductions are the same as well.

This proposal is estimated to result in forgone emissions of about 72,500 short tons of VOC, 2,700 short tons of HAP and 266,000 short tons of methane (equivalent to about 6.03 million metric tons of $CO_2$).

**Table 4. Estimated Forgone Emissions Reductions Under the Proposal Relative to the 2016 Rule, 2018 and 2019** (short tons, unless otherwise noted)

| **Year** | **Methane** | **VOC** | **HAP** | **Methane** (million metric tons CO2 Eq.) |
|---|---|---|---|---|
| **2018** | 114,000 | 31,000 | 1,200 | 2.6 |
| **2019** | 151,000 | 41,000 | 1,600 | 3.4 |
| ***Total*** | *266,000* | *73,000* | *2,700* | *6.0* |

The forgone emission reductions are estimated from a baseline of the 2016 Rule.
Results are rounded. Totals may not sum due to rounding.

## 3. Forgone Health and Climate Benefits

The 2016 Rule RIA noted that limitations in data and methods prevented the Agency from quantifying the incidence or economic value of reducing adverse health effects associated with exposure to emissions of VOC. Instead, that document summarized the $PM_{2.5}$ and ozone-related health benefits that were expected to occur, were the Agency able to quantify them. We summarize these effects below, noting that limitations in data and methods preventing the Agency from quantifying the incidence or forgone benefits from these emission changes remain.

### *Estimating Forgone Health Benefits*

The 2016 Rule was expected to reduce emissions of VOC. The 2016 Rule RIA noted that limitations in data and methods prevented the Agency from quantifying the incidence or economic value of reducing these two pollutants. Instead, that document summarized the $PM_{2.5}$ and ozone-related health benefits that were expected to occur, were the Agency able to quantify them (see the 2016 Rule RIA, Docket ID No. EPA–HQ–OAR–2010–0505–7630).

Reducing VOC emissions would reduce the formation of $PM_{2.5}$ in the atmosphere, reducing human exposure to these pollutants, and consequently also the incidence of $PM_{2.5}$-related health effects (U.S. EPA, 2009). These health effects include premature mortality for adults; cardiovascular morbidity, such as heart attacks; and respiratory morbidity, such as asthma attacks and acute and chronic bronchitis. These health effects result in hospital and emergency room visits, lost work days, restricted activity days, and respiratory symptoms.

Reducing ambient ozone concentrations is associated with significant human health benefits, including mortality and respiratory morbidity (U.S. EPA, 2010). Researchers have associated ozone exposure with adverse health effects in numerous toxicological, clinical and epidemiological studies (U.S. EPA, 2013). When adequate data and resources are available, EPA generally quantifies several health effects associated with exposure to ozone (e.g., U.S. EPA, 2010; U.S. EPA, 2011). These health effects include respiratory morbidity such as asthma attacks, hospital and emergency department visits, school loss days, and premature mortality. The scientific literature is also suggestive that exposure to ozone is associated with chronic respiratory damage and premature aging of the lungs.

### *Estimating Forgone Domestic Climate Benefits*

Originally, EPA did not present estimates of the forgone climate benefits expected from the proposed two-year stay because quantitative estimates that were consistent with E.O. 13783 were not available at that time. Since then, EPA has developed estimates of the social cost of methane (SC-$CH_4$) that are consistent with E.O. 13783. This memo applies the SC-CH4 estimates to forgone emissions reductions in years 2018 and 2019 to estimate the forgone climate benefits of the proposed action. The remainder of this memo discusses the SC-$CH_4$ estimates and presents estimates of the forgone climate benefits associated with the proposal.

We estimate the forgone climate benefits from the proposal using an interim measure of the domestic social cost of methane (SC-$CH_4$). The SC-$CH_4$ is an estimate of the monetary value of impacts associated with marginal changes in $CH_4$ emissions in a given year. It includes a wide range of anticipated climate impacts, such as net changes in agricultural productivity and human health, property damage from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning. It is typically used to assess the avoided damages as a result of regulatory actions (i.e., benefits of rulemakings that lead to an incremental reduction in cumulative global $CH_4$ emissions). The SC-$CH_4$ estimates used in this analysis focus on the direct impacts of climate change that are anticipated to occur within U.S. borders.

The SC-$CH_4$ estimates presented here are interim values developed under E.O. 13783 for use in regulatory analyses until an improved estimate of the impacts of climate change to the U.S. can be developed based on the best available science and economics. E.O. 13783 directed agencies to ensure that estimates of the social cost of greenhouse gases used in regulatory analyses "are based on the best available science and economics" and are consistent with the guidance contained in OMB Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (E.O. 13783, Section 5(c)). In addition, E.O. 13783 withdrew the technical support documents (TSDs) and the August 2016 Addendum to these TSDs describing the global social cost of greenhouse gas estimates developed under the prior Administration as no longer representative of government policy. The withdrawn TSDs and Addendum were developed by an interagency working group (IWG) that included the EPA and other executive branch entities and were used in the 2016 Rule RIA.

Regarding the two analytical considerations highlighted in E.O. 13783 – how best to consider domestic versus international impacts and appropriate discount rates – current guidance in OMB Circular A-4 is as follows. Circular A-4 states that analysis of economically significant proposed and final regulations "should focus on benefits and costs that accrue to citizens and residents of the United States." We follow this guidance by adopting a domestic perspective in our central analysis. Regarding discount rates, Circular A-4 states that regulatory analyses "should provide estimates of net benefits using both 3 percent and 7 percent." The 7 percent rate is intended to represent the average before-tax rate of return to private capital in the U.S. economy. The 3 percent rate is intended to reflect the rate at which society discounts future consumption, which is particularly relevant if a regulation is expected to affect private consumption directly. EPA follows this guidance below by presenting estimates based on both 3 and 7 percent discount rates in the main analysis. See the Appendix for a discussion the modeling steps involved in estimating the domestic SC-$CH_4$ estimates based on these discount rates.

The SC-$CH_4$ estimates developed under E.O. 13783 will be used in regulatory analysis until improved domestic estimates can be developed, which will take into consideration the recent recommendations from the National Academies of Sciences, Engineering, and Medicine[5] for a comprehensive update to the current methodology to ensure that the social cost of greenhouse gas estimates reflect the best available science. While the Academies' review focused on the methodology to estimate the social cost of carbon (SC-$CO_2$), the recommendations on how to update many of the underlying modeling assumptions also pertain to the SC-$CH_4$ estimates since the framework used to estimate SC-$CH_4$ is the same as that used for SC-$CO_2$.

Table 5 presents the average domestic SC-$CH_4$ estimates across all the model runs for each discount rate for the years 2015 to 2020. As with the global SC-$CH_4$ estimates, the domestic SC-$CH_4$ increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change, and because GDP is growing over time and many damage categories are modeled as proportional to gross GDP. For emissions occurring in the years affected by the proposal (2018-2019), the domestic SC-$CH_4$ estimates are $52-53 per metric ton of $CH_4$ emissions (2016$), using a 7 percent discount rate, and $170 per metric ton of $CH_4$ using 3 percent discount rate.

**Table 5. Interim Domestic Social Cost of $CH_4$, 2015-2020 (in 2016$ per metric ton $CH_4$)***

| | Discount Rate and Statistic | |
|---|---|---|
| Year | 7% Average | 3% Average |
| 2015 | $46 | $150 |
| 2016 | 48 | 160 |
| 2017 | 50 | 160 |
| 2018 | 52 | 170 |
| 2019 | 53 | 170 |
| 2020 | 55 | 180 |

* SC-$CH_4$ values are stated in $/metric ton $CH_4$ and rounded to two significant digits. The estimates vary depending on the year of $CH_4$ emissions and are defined in real terms, i.e., adjusted for inflation using the GDP implicit price deflator.

Table 6 presents the forgone domestic climate benefits of the proposed action based on these domestic SC-$CH_4$ estimates.

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[5] See National Academies of Sciences, Engineering, and Medicine, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide*, Washington, D.C., January 2017. http://www.nap.edu/catalog/24651/valuing-climate-changes-updating-estimation-of-the-social-cost-of

**Table 6. Estimated Forgone Domestic Climate Benefits of the Proposal (millions, 2016$)***

| Year | **Forgone $CH_4$ reductions** (million metric tonnes) | **Discount rate and foregone benefit** | |
|---|---|---|---|
| | | 7% (average) | 3% (average) |
| 2018 | 0.104 | $5.4 | $17 |
| 2019 | 0.137 | $7.3 | $23 |

The forgone methane reductions and associated forgone benefits are estimated from a baseline of the 2016 Rule.
* The SC-$CH_4$ values are dollar-year and emissions-year specific. SC-$CH_4$ values represent only a partial accounting of domestic climate impacts.

The limitations and uncertainties associated with the global SC-$CH_4$ estimates, which were discussed in detail in the 2016 Rule RIA, likewise apply to the domestic SC-$CH_4$ estimates presented in this analysis.[6] Some uncertainties are captured within the analysis, as discussed in detail in the Appendix while other areas of uncertainty have not yet been quantified in a way that can be modeled. For example, as with the methodology used to calculate SC-$CO_2$ estimates, limitations include the incomplete or inadequate representation in the integrated assessment models of several important factors: catastrophic and non-catastrophic impacts, adaptation and technological change, inter-regional and inter-sectoral linkages, uncertainty in the extrapolation of damages to high temperatures, and the relationship between the discount rate and uncertainty in economic growth over long time horizons. The science incorporated into these models understandably lags behind the most recent research, and the limited amount of research linking climate impacts to economic damages makes the modeling exercise even more difficult.

There are several limitations specific to the estimation of SC-$CH_4$. For example, the SC-$CH_4$ estimates do not reflect updates from the IPCC regarding atmospheric and radiative efficacy.[7] Another limitation is that the SC-$CH_4$ estimates do not account for the direct health and welfare impacts associated with tropospheric ozone produced by methane (see the 2016 Rule

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[6] The SC-$CH_4$ estimates presented in the 2016 Rule RIA are the same as the SC-$CH_4$ estimates presented in EPA-HQ-OAR-2015-0827-5886, “Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide (August 2016)”, except the estimates in the 2016 Rule RIA were adjusted to 2012$. The estimates published in the 2016 Rule RIA were labeled as “Marten *et al*. (2014)” estimates. In addition, EPA-HQ-OAR-2015-0827-5886 provides a detailed discussion of the limitations and uncertainties associated with the SC-GHG estimates.

[7] The SC-$CH_4$ estimates used in the 2016 Rule RIA served as the starting point to calculate the interim domestic estimates presented in this memo. The 2016 Rule RIA SC-$CH_4$ estimates were calculated in 2014 using atmospheric and radiative efficacy values that have since been updated by the IPCC

RIA for further discussion). In addition, the SC-$CH_4$ estimates do not reflect that methane emissions lead to a reduction in atmospheric oxidants, like hydroxyl radicals, nor do they account for impacts associated with $CO_2$ produced from methane oxidizing in the atmosphere. See EPA-HQ-OAR-2015-0827-5886 for more detailed discussion about the limitations specific to the estimation of SC-$CH_4$. These individual limitations and uncertainties do not all work in the same direction in terms of their influence on the SC-$CH_4$ estimates. In accordance with guidance in OMB Circular A-4 on the treatment of uncertainty, the Appendix provides a detailed discussion of the ways in which the modeling underlying the development of the SC-$CH_4$ estimates used in this analysis addressed quantified sources of uncertainty, and presents a sensitivity analysis to show consideration of the uncertainty surrounding discount rates over long time horizons.

Recognizing the limitations and uncertainties associated with estimating the social cost of greenhouse gases, the research community has continued to explore opportunities to improve estimates of SC-$CO_2$ and other greenhouse gases. Notably, the National Academies of Sciences, Engineering, and Medicine conducted a multi-discipline, multi-year assessment to examine potential approaches, along with their relative merits and challenges, for a comprehensive update to the IWG methodology. The task was to ensure that the SC-$CO_2$ estimates that are used in Federal analyses reflect the best available science, focusing on issues related to the choice of models and damage functions, climate science modeling assumptions, socioeconomic and emissions scenarios, presentation of uncertainty, and discounting. In January 2017, the Academies released their final report, Assessing Approaches to Updating the Social Cost of Carbon, and recommended specific criteria for future updates to the SC-$CO_2$ estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process (National Academies 2017). Since the framework used to estimate SC-$CH_4$ is the same as that used for SC-$CO_2$, the Academies' recommendations on how to update many of the underlying modeling assumptions also apply to the SC-$CH_4$ estimates.

The Academies' report also discussed the challenges in developing domestic SC-$CO_2$ estimates, noting that current IAMs do not model all relevant regional interactions—e.g., how climate change impacts in other regions of the world could affect the United States, through pathways such as global migration, economic destabilization, and political destabilization. The

Academies concluded that it "is important to consider what constitutes a domestic impact in the case of a global pollutant that could have international implications that impact the United States. More thoroughly estimating a domestic SC-$CO_2$ would therefore need to consider the potential implications of climate impacts on, and actions by, other countries, which also have impacts on the United States." (National Academies 2017, pg 12-13). This challenge is equally applicable to the estimation of a domestic SC-$CH_4$.

In addition to requiring reporting of domestic impacts, Circular A-4 states that when an agency "evaluate[s] a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately" (page 15). This guidance is relevant to the valuation of damages from methane and other GHGs, given that GHGs contribute to damages around the world independent of the country in which they are emitted. Therefore, in accordance with this guidance in OMB Circular A-4, the Appendix presents the forgone global climate benefits in years 2018 and 2019 from the proposal using global SC-$CH_4$ estimates based on both 3 and 7 percent discount rates. Note the EPA did not quantitatively project the full impact of the 2016 Rule on international trade and the location of production, so it is not possible to present analogous estimates of global cost savings resulting from the proposed action. However, to the extent that affected firms have some foreign ownership, some of the cost savings accruing to entities outside U.S. borders is captured in the avoided compliance costs presented in this memo.

## 4. Net Benefits

Table 7 shows the present value (PV) of the net benefits of the proposal. These net benefits are estimated as the PV of the total cost savings (the benefits of the proposed action) from 2018 through 2020, as seen in Table 3, minus the PV of the total forgone benefits (the costs of the proposed action) presented in Table 6 from 2018 and 2019.[8] The estimated net benefits do not account for the expected forgone $PM_{2.5}$ and ozone-related health benefits under the proposal. As previously noted, limitations in data and methods have prevented the EPA from quantifying the incidence or economic value of reducing negative health effects associated with exposure to emissions of VOC, which is a precursor to both fine particles ($PM_{2.5}$) and ground-level ozone ($O_3$). See Section 3 for details about these forgone benefits. The PV of the estimated net benefits

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[8] There are no forgone benefits in 2020.

of the proposal are $250 when using a 7 percent discount rate and $240 million using a 3 percent discount rate. The monetized present values of net benefits presented in Table 7 are positive, meaning that the estimated benefits (cost savings) of the proposal are greater than the estimated costs (forgone benefits).

**Table 7. Estimated Present Value of the Net Benefits of the Proposal (millions, 2016$)**

| | 7% | 3% |
|---|---|---|
| **PV Benefits**[1] | $270 | $280 |
| **PV Costs**[2] | $11 | $37 |
| **PV Net Benefits** | $250 | $240 |

[1] The PV of benefits are the avoided compliance costs as presented in Section 2.
[2] The PV of costs are calculated from the forgone domestic climate benefits as presented in Section 3. The PV of forgone benefits are the forgone benefits at the 7 percent average (the 3 percent average) discounted to 2018 using a 7 percent (3 percent) discount rate.
Results are rounded to two significant figures. Totals may not sum due to rounding.

Table 8 shows the equivalent annualized values of the net benefits discounted at 7 and 3 percent. The equivalent annualized values (EAV) are the annualized present values, or the even flow of the present values, over the three years affected by the proposal. The equivalent annualized values of the net benefits are $97 million per year when using a 7 percent discount rate and $86 million per year when using a 3 percent discount rate. The positive values indicate that EAV of the estimated benefits (cost savings) of the proposal are greater than the EAV of estimated costs (forgone benefits).

**Table 8. Estimated Equivalent Annualized Value of the Net Benefits of the Proposal (millions, 2016$)**

| | 7% | 3% |
|---|---|---|
| **EAV Benefits**[1] | $100 | $99 |
| **EAV Costs**[2] | $4.3 | $13 |
| **EAV Net Benefits** | $97 | $86 |

[1] The EAV of benefits are the avoided compliance costs presented in Section 2.
[2] The EAV of costs are calculated from the PV of the forgone domestic climate benefits as presented in Section 3.
Results are rounded to two significant figures. Totals may not sum due to rounding.

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## Appendix Uncertainty Associated with Estimating the Social Cost of Methane

### A.1 Overview of Methodology Used to Develop Interim Domestic SC-$CH_4$ Estimates

The domestic SC-$CH_4$ estimates rely on the same ensemble of three integrated assessment models (IAMs) that were used to develop the IWG global SC-$CH_4$ (and SC-$CO_2$) estimates: DICE 2010, FUND 3.8, and PAGE 2009.[9] The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socio-economic (GDP and population) pathways. These emissions are translated into atmospheric concentrations, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter,

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[9] The full models names are as follows: Dynamic Integrated Climate and Economy (DICE); Climate Framework for Uncertainty, Negotiation, and Distribution (FUND); and Policy Analysis of the Greenhouse Gas Effect (PAGE).

equilibrium climate sensitivity. The effect of these Earth system changes is then translated into consumption-equivalent economic damages. As in the IWG exercise, these key inputs were harmonized across the three models: a probability distribution for equilibrium climate sensitivity; five scenarios for economic, population, and emissions growth; and discount rates.[10] All other model features were left unchanged. Future damages are discounted using constant discount rates of both 3 and 7 percent, as recommended by OMB Circular A-4.

The domestic share of the global SC-$CH_4$—i.e., an approximation of the climate change impacts that occur within U.S. borders[11]—is calculated directly in both FUND and PAGE. However, DICE 2010 generates only global estimates. Therefore, EPA approximates U.S. damages as 10 percent of the global values from the DICE model runs, based on the results from a regionalized version of the model (RICE 2010) reported in Table 2 of Nordhaus (2017).[12] Although the regional shares reported in Nordhaus (2017) are specific to SC-$CO_2$, they still provide a reasonable interim approach for approximating the U.S. share of marginal damages from methane emissions. Direct transfer of the domestic share from the SC-$CO_2$ may understate the U.S. share of the IWG global SC-$CH_4$ estimates based on DICE due to the combination of three factors: a) regional damage estimates are known to be highly correlated with output shares (Nordhaus 2017, 2014), b) the U.S. share of global output decreases over time in all five EMF-22 based socioeconomic scenarios used for the model runs, and c) the bulk of the temperature anomaly (and hence, resulting damages) from a perturbation in emissions in a given year will be experienced earlier for $CH_4$ than $CO_2$ due to the shorter lifetime of $CH_4$ relative to $CO_2$.

The steps involved in estimating the social cost of $CH_4$ are similar to that of $CO_2$. The three integrated assessment models (FUND, DICE, and PAGE) are run using the harmonized equilibrium climate sensitivity distribution, five socioeconomic and emissions scenarios, constant discount rates described above. Because the climate sensitivity parameter is modeled

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[10] See the IWG's summary of its methodology in the docket, document ID number EPA-HQ-OAR-2015-0827-5886, "Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide (August 2016)". See also National Academies (2017) for a detailed discussion of each of these modeling assumptions.

[11] Note that inside the U.S. borders is not the same as accruing to U.S. citizens, which may be higher or lower.

[12] Nordhaus, William D. 2017. Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences of the United States,* 114(7): 1518-1523.

probabilistically, and because PAGE and FUND incorporate uncertainty in other model parameters, the final output from each model run is a distribution over the SC-$CH_4$ in year t based on a Monte Carlo simulation of 10,000 runs. For each of the IAMs, the basic computational steps for calculating the social cost estimate in a particular year t are: 1.) calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions; 2.) adjust the model to reflect an additional unit of emissions in year t; 3.) recalculate the temperature effects and damages expected in all years beyond t resulting from this adjusted path of emissions, as in step 1; and 4.) subtract the damages computed in step 1 from those in step 3 in each model period and discount the resulting path of marginal damages back to the year of emissions. In PAGE and FUND step 4 focuses on the damages attributed to the US region in the models. As noted above, DICE does not explicitly include a separate US region in the model and therefore, EPA approximates U.S. damages in step 4 as 10 percent of the global values based on the results of Nordhaus (2017). This exercise produces 30 separate distributions of the SC-$CH_4$ for a given year, the product of 3 models, 2 discount rates, and 5 socioeconomic scenarios. Following the approach used by the IWG, the estimates are equally weighted across models and socioeconomic scenarios in order to consolidate the results into one distribution for each discount rate.

### A.2 Treatment of Uncertainty in Interim Domestic SC-$CH_4$ Estimates

There are various sources of uncertainty in the SC-$CH_4$ estimates used in this analysis. Some uncertainties pertain to aspects of the natural world, such as quantifying the physical effects of greenhouse gas emissions on Earth systems. Other sources of uncertainty are associated with current and future human behavior and well-being, such as population and economic growth, GHG emissions, the translation of Earth system changes to economic damages, and the role of adaptation. It is important to note that even in the presence of uncertainty, scientific and economic analysis can provide valuable information to the public and decision makers, though the uncertainty should be acknowledged and when possible taken into account in the analysis (National Academies 2013).[13] OMB Circular A-4 also requires a thorough discussion of key sources of uncertainty in the calculation of benefits and costs,

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[13] Institute of Medicine of the National Academies. 2013. Environmental Decisions in the Face of Uncertainty. The National Academies Press.

including more rigorous quantitative approaches for higher consequence rules. This section summarizes the sources of uncertainty considered in a quantitative manner in the domestic SC-$CH_4$ estimates.

The domestic SC-$CH_4$ estimates consider various sources of uncertainty through a combination of a multi-model ensemble, probabilistic analysis, and scenario analysis. We provide a summary of this analysis here; more detailed discussion of each model and the harmonized input assumptions can be found in the 2017 National Academies report. For example, the three IAMs used collectively span a wide range of Earth system and economic outcomes to help reflect the uncertainty in the literature and in the underlying dynamics being modeled. The use of an ensemble of three different models at least partially addresses the fact that no single model includes all of the quantified economic damages. It also helps to reflect structural uncertainty across the models, which stems from uncertainty about the underlying relationships among GHG emissions, Earth systems, and economic damages that are included in the models. Bearing in mind the different limitations of each model and lacking an objective basis upon which to differentially weight the models, the three integrated assessment models are given equal weight in the analysis.

Monte Carlo techniques were used to run the IAMs a large number of times. In each simulation the uncertain parameters are represented by random draws from their defined probability distributions. In all three models the equilibrium climate sensitivity is treated probabilistically based on the probability distribution from Roe and Baker (2007) calibrated to the IPCC AR4 consensus statement about this key parameter.[14] The equilibrium climate sensitivity is a key parameter in this analysis because it helps define the strength of the climate response to increasing GHG concentrations in the atmosphere. In addition, the FUND and PAGE models define many of their parameters with probability distributions instead of point estimates. For these two models, the model developers’ default probability distributions are maintained for all parameters other than those superseded by the harmonized inputs (i.e., equilibrium climate sensitivity, socioeconomic and emissions scenarios, and discount rates). More information on the uncertain parameters in PAGE and FUND is available upon request.

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[14] Specifically, the Roe and Baker distribution for the climate sensitivity parameter was bounded between 0 and 10 with a median of 3 °C and a cumulative probability between 2 and 4.5 °C of two-thirds.

For the socioeconomic and emissions scenarios, uncertainty is included in the analysis by considering a range of scenarios selected from the Stanford Energy Modeling Forum exercise, EMF-22. Given the dearth of information on the likelihood of a full range of future socioeconomic pathways at the time the original modeling was conducted, and without a basis for assigning differential weights to scenarios, the range of uncertainty was reflected by simply weighting each of the five scenarios equally for the consolidated estimates. To better understand how the results vary across scenarios, results of each model run are available in the docket.

The outcome of accounting for various sources of uncertainty using the approaches described above is a frequency distribution of the SC-$CH_4$ estimates for emissions occurring in a given year for each discount rate. Unlike the approach taken for consolidating results across models and socioeconomic and emissions scenarios, the SC-$CH_4$ estimates are not pooled across different discount rates because the range of discount rates reflects both uncertainty and, at least in part, different policy or value judgements; uncertainty regarding this key assumption is discussed in more detail below. The frequency distributions reflect the uncertainty around the input parameters for which probability distributions were defined, as well as from the multi-model ensemble and socioeconomic and emissions scenarios where probabilities were implied by the equal weighting assumption. It is important to note that the set of SC-$CH_4$ estimates obtained from this analysis does not yield a probability distribution that fully characterizes uncertainty about the SC-$CH_4$ due to impact categories omitted from the models and sources of uncertainty that have not been fully characterized due to data limitations.

Figure 1 presents the frequency distribution of the domestic SC-$CH_4$ estimates for emissions in 2020 for each discount rate. Each distribution represents 150,000 estimates based on 10,000 simulations for each combination of the three models and five socioeconomic and emissions scenarios.[15] In general, the distributions are skewed to the right and have long right tails, which tend to be longer for lower discount rates. To highlight the difference between the impact of the discount rate on the SC-$CH_4$ and other quantified sources of uncertainty, the bars below the frequency distributions provide a symmetric representation of quantified variability in

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[15] Although the distributions in Figure 1 are based on the full set of model results (150,000 estimates for each discount rate), for display purposes the horizontal axis is truncated with 0.001 to 0.013 percent of the estimates lying below the lowest bin displayed and 0.471 to 3.356 percent of the estimates lying above the highest bin displayed, depending on the discount rate.

the SC-$CH_4$ estimates conditioned on each discount rate. The full set of SC-$CH_4$ results through 2050 is available in the docket.

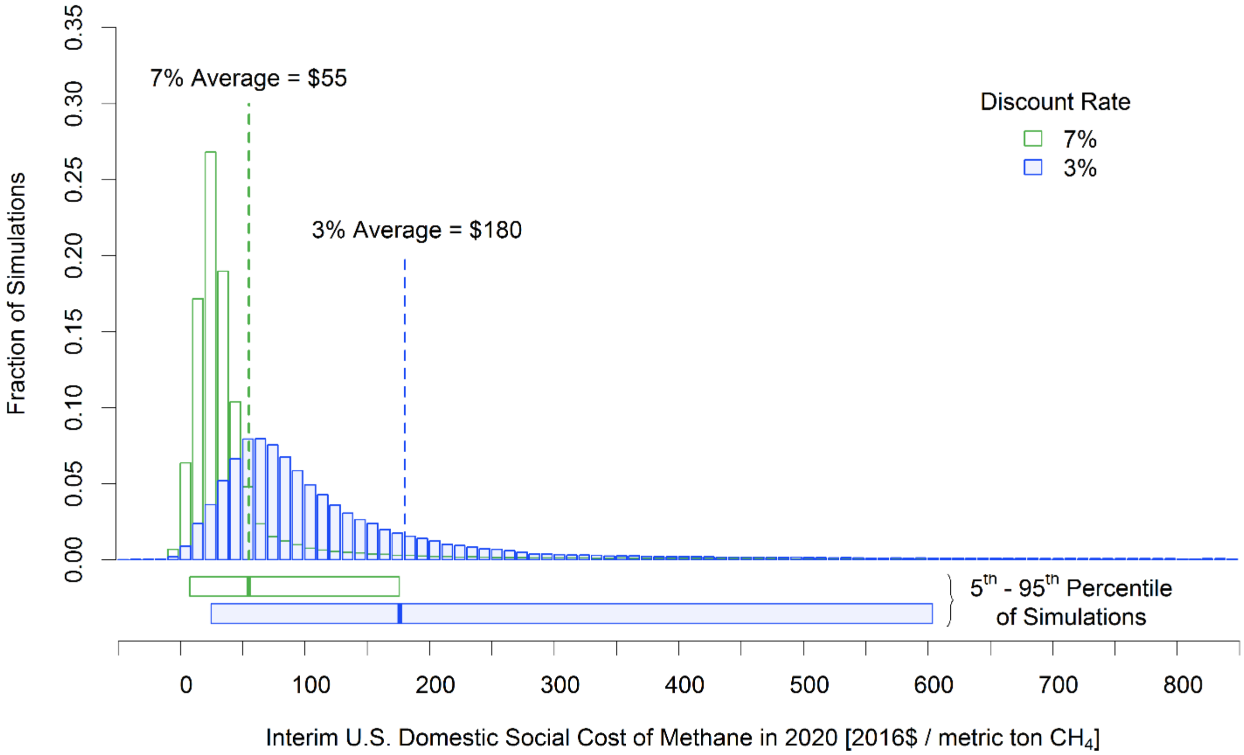

**Figure 1. Frequency Distribution of Interim Domestic SC-$CH_4$ Estimates for 2020 (in 2016$ per metric ton $CH_4$)**

As illustrated by the frequency distributions in Figure 1, the assumed discount rate plays a critical role in the ultimate estimate of the social cost of methane. This is because $CH_4$ emissions today continue to impact society far out into the future,[16] so with a higher discount rate, costs that accrue to future generations are weighted less, resulting in a lower estimate. Circular A-4 recommends that costs and benefits be discounted using the rates of 3 percent and 7 percent to reflect the opportunity cost of consumption and capital, respectively. Circular A-4 also recommends quantitative sensitivity analysis of key assumptions[17], and offers guidance on what

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[16] Although the atmospheric lifetime of $CH_4$ is notably shorter than that of $CO_2$, the impacts of changes in contemporary $CH_4$ emissions are also expected to occur over long time horizons that cover multiple generations. For more discussion, see document ID number EPA-HQ-OAR-2015-0827-5886, “Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide (August 2016)”.

[17] “If benefit or cost estimates depend heavily on certain assumptions, you should make those assumptions explicit and carry out sensitivity analyses using plausible alternative assumptions.” (OMB 2003, page 42).

sensitivity analysis can be conducted in cases where a rule will have important intergenerational benefits or costs. To account for ethical considerations of future generations and potential uncertainty in the discount rate over long time horizons, Circular A-4 suggests "further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefit using discount rates of 3 and 7 percent" (page 36) and notes that research from the 1990s suggests intergenerational rates "from 1 to 3 percent per annum" (OMB 2003). We consider the uncertainty in this key assumption by calculating the domestic SC-$CH_4$ based on a 2.5 percent discount rate, in addition to the 3 and 7 percent used in the main analysis. Using a 2.5 percent discount rate, the average domestic SC-$CH_4$ estimate across all the model runs for emissions occurring in the years affected by the proposal (2018-2019) range from $210 to $220 per metric ton of $CH_4$ (2016$)[18]; in this case the forgone domestic climate benefits of the proposal range from $22 million in 2018 to $30 million in 2019 under a 2.5 percent discount rate.

In addition to the approach to accounting for the quantifiable uncertainty described above, the scientific and economics literature has further explored known sources of uncertainty related to estimates of the social cost of carbon and other greenhouse gases. For example, researchers have examined the sensitivity of IAMs and the resulting estimates to different assumptions embedded in the models (see, e.g., Hope 2013, Anthoff and Tol 2013, Nordhaus 2014, and Waldhoff et al. 2011, 2014). However, there remain additional sources of uncertainty that have not been fully characterized and explored due to remaining data limitations. Additional research is needed to expand the quantification of various sources of uncertainty in estimates of the social cost of carbon and other greenhouse gases (e.g., developing explicit probability distributions for more inputs pertaining to climate impacts and their valuation). On the issue of intergenerational discounting, some experts have argued that a declining discount rate would be appropriate to analyze impacts that occur far into the future (Arrow et al., 2013). However, additional research and analysis is still needed to develop a methodology for implementing a declining discount rate and to understand the implications of applying these theoretical lessons in practice. The 2017 National Academies report also provides recommendations pertaining to discounting, emphasizing the need to more explicitly model the uncertainty surrounding discount rates over long time horizons, its connection

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[18] The estimates are adjusted for inflation using the GDP implicit price deflator and then rounded to two significant digits.

to uncertainty in economic growth, and, in turn, to climate damages using a Ramsey-like formula (National Academies 2017). These and other research needs are discussed in detail in the 2017 National Academies' recommendations for a comprehensive update to the current methodology, including a more robust incorporation of uncertainty.

## A.3 Forgone Global Climate Benefits

In addition to requiring reporting of impacts at a domestic level, OMB Circular A-4 states that when an agency "evaluate[s] a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately" (page 15).[19] This guidance is relevant to the valuation of damages from GHGs, given that most GHGs (including $CH_4$) contribute to damages around the world independent of the country in which they are emitted. Therefore, in this section we present the forgone global climate benefits from this rulemaking using the global SC-$CH_4$ estimates – i.e., reflecting quantified impacts occurring in both the U.S. and other countries—corresponding to the model runs that generated the domestic SC-$CH_4$ estimates used in the main analysis. The average global SC-$CH_4$ estimate across all the model runs for emissions occurring in the years affected by the proposal (2018-2019) range from $340 to $350 per metric ton of $CH_4$ emissions (in 2016 dollars) using a 7 percent discount rate, and $1,300 per metric ton of $CH_4$ using a 3 percent discount rate.[20] The domestic SC-$CH_4$ estimates presented above are approximately 15 percent and 13 percent of these global SC-$CH_4$ estimates for the 7 percent and 3 percent discount rates, respectively. Applying these estimates to the forgone $CH_4$ emission reductions results in estimated forgone global climate benefits ranging from $35 million in 2018 to $48 million in 2019, using a 7 percent discount rate. The estimated forgone global climate benefits are $140 million in 2018 and increase to $180 million in 2019

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[19] While Circular A-4 does not elaborate on this guidance, the basic argument for adopting a domestic only perspective for the central benefit-cost analysis of domestic policies is based on the fact that the authority to regulate only extends to a nation's own residents who have consented to adhere to the same set of rules and values for collective decision-making, as well as the assumption that most domestic policies will have negligible effects on the welfare of other countries' residents (EPA 2010; Kopp et al. 1997; Whittington et al. 1986). In the context of policies that are expected to result in substantial effects outside of U.S. borders, an active literature has emerged discussing how to appropriately treat these impacts for purposes of domestic policymaking (e.g., Gayer and Viscusi 2016, 2017; Anthoff and Tol, 2010; Fraas et al. 2016; Revesz et al. 2017). This discourse has been primarily focused on the regulation of greenhouse gases (GHGs), for which domestic policies may result in impacts outside of U.S. borders due to the global nature of the pollutants.

[20] The estimates are adjusted for inflation using the GDP implicit price deflator and then rounded to two significant digits.

using a 3 percent rate. Under the sensitivity analysis considered above using a 2.5 percent discount rate, the average global SC-$CH_4$ estimate across all the model runs for emissions occurring in 2018-2019 ranges from $1,700 to $1,800 per metric ton of $CH_4$ (2016$). The forgone global climate benefits are estimated to be $180 million in 2018 and $240 million in 2019 using a 2.5 percent discount rate. All estimates are reported in 2016 dollars.

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