# Exhibit 8

**IN THE UNITED STATES DISTRICT COURT**

**FOR THE DISTRICT OF MONTANA**

**GREAT FALLS DIVISION**

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| WESTERN ORGANIZATION OF RESOURCE COUNCILS *et al.*,<br><br>Plaintiffs,<br><br>vs.<br><br>U.S. BUREAU OF LAND MANAGEMENT *et al.*,<br><br>Defendants. | Case No. CV-16-21-GF-BMM<br><br>**DECLARATION OF DR. PETER H. HOWARD, Ph.D.** |

I, Peter H. Howard, state and declare as follows:

1. I am the Economics Director at New York University School of Law's Institute for Policy Integrity, a nonpartisan think tank dedicated to improving the quality of government decisionmaking through advocacy and scholarship in the fields of administrative law, economics, and public policy.[1] My fields of expertise include climate economics and natural resource economics. I received my Ph.D. in Agricultural and Resource Economics from University of California–Davis. I have published in academic journals on the social cost of greenhouse gases, including in *Science*, *Nature*, *Environmental and Resource Economics*, and the *Columbia Journal of Environmental Law*. I have published reports on the Bureau of Land Management (BLM)'s coal leasing program and on the valuation of health and environmental damages from

[1] This declaration does not purport to represent the views, if any, of New York University.

coal production. Please see my attached curriculum vitae for a full description of my professional background, experience, and relevant publications.

2. Plaintiffs asked me to prepare this Declaration to analyze the environmental, public health, and social welfare costs associated with the extraction, processing, transportation, and combustion of the fossil fuel resources that will be leased and developed under BLM's 2015 Approved Resource Management Plans (RMPs) for the Buffalo Field Office and the Miles City Field Office.

3. To summarize my findings, the emissions of greenhouse gases, particulate matter, and other harmful pollutants from the extraction, processing, transportation, and combustion of the coal, oil, and natural gas developed under these two RMPs will cause **monetized damages of at least $802 billion over the 2018-2028 timeframe** (present value in 2017$, at a 3% discount rate), plus significant but unquantifiable additional damages to the environment, public health, and social welfare. That figure is quite substantial but unsurprising given that the Powder River Basin has been producing 44% of all U.S. coal in recent years,[2] and given that the production and burning of coal is responsible for a vast share of U.S. emissions of greenhouse gases, particulate matter, mercury, and other hazardous pollutants. Per unit of fossil fuels, I calculate:

- at least $150.86 in damages per short ton of coal produced in 2018, from the methane emissions from coal mining, the air pollution and fatalities caused by coal transportation, and the greenhouse gases, particulate matter, and other pollution from coal combustion;
- at least $17.79 in damages per barrel of oil produced in 2018, from just the greenhouse gas emissions from oil combustion (other impacts from oil extraction, processing, and combustion are unquantified but could be quite substantial); and

[2] U.S. Energy Information Administration, *2016 Coal Report*, tbl. 1 (2017).

- at least $2.58 in damages per thousand cubic feet of natural gas produced in 2018, from just the greenhouse gas emissions from gas combustion (other impacts from gas extraction, transportation, and combustion are unquantified but could be quite substantial).

4. From the fossil fuel development anticipated under these two RMPs during 2018 alone, I calculate over $80 billion in damages in that single year. Those annual economic costs dwarf any estimate of annual economic benefits from the production of coal, oil, and gas under these two RMPs. For example, the total estimated mineral production in 2018 from both the Buffalo and Miles City planning areas would have an economic output worth, at most, $6.8 billion. Of that amount, BLM's methodologies for calculating economic benefits estimate only slightly over $1 billion worth of labor income, royalties, and taxes from the two RMPs' production. Meanwhile, the $80 billion in annual damages is almost certainly a substantial underestimate, since many important categories of damages are omitted due to data limitations. Some recent literature suggests that the actual climate and air pollution damages may be double or triple what I have reported here. I used conservative assumptions at each step in my calculations.

5. I calculated these damages by undertaking the following six steps:

- First, I derived the production schedules for coal, oil, and natural gas from the two RMPs and their associated Final Environmental Impact Statements (FEISs).
- Second, I applied emissions factors developed by the U.S. Environmental Protection Agency (which BLM used recently in separate but similar proceedings), to calculate the greenhouse gas emissions from combustion of the fossil fuels.
- Third, I applied values for the social cost of greenhouse gases, as estimated by the federal Interagency Working Group on the Social Cost of Greenhouse Gases in 2016, and as

used by the Department of the Interior as recently as August 2017, to monetize the climate damages from combustion of the fossil fuels.

- Fourth, I used the heating value of coal and the National Research Council's estimates of non-climate damages from coal combustion per kilowatt-hour to monetize additional public health and environmental damages from the combustion of coal.
- Fifth, I used a methodology I previously developed,[3] based on the peer-reviewed literature and government reports, to estimate the health, climate, and welfare costs from the mining and transportation of Powder River Basin coal.
- Sixth, I listed additional key categories of damages that could not be quantified due to data or time limitations, including: catastrophic damages and other significant impacts omitted from the social cost of greenhouse gas estimates; unquantifiable health impacts from particulate matter and toxic pollutants like mercury emitted by the combustion of coal; the non-climate damages from the combustion of oil and gas; and the damages from the extraction, processing, and transportation of oil and gas.

This declaration now explains each step, including data and assumptions.

6. **Production of Coal, Oil, and Gas**

To the extent possible, I used the same estimates for the production of coal, oil, and gas that BLM used to calculate the RMPs' "economic benefits," such as royalty revenue, employment income, and taxes. *Proposed RMP & FEIS for the Buffalo Field Office* (2015; hereinafter BFO-FEIS) at 1640; *accord. Proposed RMP & FEIS for the Miles City Field Office* (2015; hereinafter MCO-FEIS) at 4-383 (touting the benefits to local government of royalty revenue).

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[3] Jayni Hein & Peter Howard, *Illuminating the Hidden Costs of Coal* (Policy Integrity Report, Dec. 2015), *available at* http://policyintegrity.org/publications/detail/hidden-costs-of-coal.

The Buffalo Field Office calculated oil and gas royalty and tax revenue using the IMPLAN model, BFO-FEIS at 1644, and Appendix U of the FEIS reveals its assumed production schedule for new federal oil and gas wells (including both coalbed and conventional gas) under Alternative D (i.e., the proposed RMP), *id.* at 2591, tbl. U.2.[4] Because this schedule estimates production only through year 2028, my analysis focuses primarily on the time period of 2018–2028.

The Buffalo Field Office estimates that "approximately 10.2 billion tons of coal" would be leased "over the next 20 years." *Id.* at 823.[5] That works out to 510 million tons per year over a twenty-year period. The FEIS never defines exactly which years comprise the planning period, though given that the RMP was finalized in September 2015, one could assume that the "*next* 20 years" would stretch from 2016–2035. However, since the oil and gas production figures were given only through 2028, and in order to focus this analysis on future damages, I will assume in my primary analysis that the Buffalo planning area will produce 510 million short tons of coal per year from 2018–2028.

The Miles City Field Office calculated royalty revenue and other economic benefits based on estimated annual average production of coal, oil, and natural gas. MCO-FEIS at 4-374, tbl. 4-80. For Alternative E (i.e., the proposed RMP), the FEIS estimates that "Over the next 20 years, 22,487,143 tons of coal are anticipated to be extracted from BLM-administered lands in the MCFO on annual average." *Id.* at 4-370. The FEIS also estimates for Alternative E an

[4] Because private and state leasing of oil and gas resources is not necessarily contingent on federal leasing, and because BLM's estimates of royalty benefits are based on federally leased wells alone, production from private- and state-leased oil and gas is not included here. Including that additional production would further increase estimates of associated damages.

[5] Elsewhere the FEIS estimates as much as "12 billion tons of coal will be produced" under any of its alternatives, including 500–700 million tons annually by year 2030. BFO-FEIS at 43. The 10.2 billion ton figure that Plaintiffs and the Court focus on therefore represents a conservative estimate of coal production.

average annual production of 7,928,421mcf (i.e., thousand cubic feet) of natural gas (including both coalbed and conventional wells), and 5,924,211 barrels of oil from federal wells. *Id.* at 4-382, tbl. 4-80. Like with the Buffalo FEIS, the Miles City FEIS does not define "the next 20 years," but for consistency, I will conservatively limit my primary analysis to the 2018–2028 time period.

Not all oil and gas produced is ultimately combusted to generate energy; some resources become petrochemicals and other non-combustible products. A few adjustments must be made to raw figures of oil and gas production to yield the amounts that will be combusted and so emit pollution. In a recent (March 2018) environmental impact statement for a separate but similar onshore oil and gas development project in Alaska,[6] BLM explains in Appendix H[7] that the following adjustments are necessary: first, the U.S. Energy Information Administration (EIA) estimates that when oil is refined, the volume of the product increases by 6.7% due to the addition of other ingredients; second, EIA estimates that 1.6% of all natural gas and 1.2% of all oil is never combusted; and third, there are 42 gallons in a barrel of oil.

After applying those adjustments, the production schedule for coal, oil, and gas is as follows:

**Table 1. Production of Coal, Oil, and Gas**
(with oil and gas figures converted to combustible products)

| | Miles City | | | Buffalo City | | |
|---|---|---|---|---|---|---|
| Year | Coal (short tons) | Natural Gas (cubic feet) | Oil (gallons) | Coal (short tons) | Natural Gas (cubic feet) | Oil (gallons) |
| 2018 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 35,424,000,000 | 132,828,696 |

[6] BLM, *Alpine Satellite Development Plan for the Proposed Greater Mooses Tooth 2 Development Project: Draft Supplemental Environmental Impact Statement* (March 2018).
[7] Appendix H of the Greater Mooses Tooth 2 SEIS adopts the methodology and assumptions developed by the Bureau of Ocean Energy Management in its lifecycle analyses. *Available at* https://eplanning.blm.gov/epl-front-office/projects/nepa/65817/127980/155727/Appendix_H-_BOEM_Greenhouse_Gas_Lifecycle_Model_Methodology.pdf. *See* page 1 of Appendix H on adopting BOEM's assumptions; see pages 4–6 of Appendix H on these adjustments.

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|---|---|---|---|---|---|---|
| 2019 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 40,147,200,000 | 150,539,189 |
| 2020 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 46,248,000,000 | 168,249,682 |
| 2021 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 53,628,000,000 | 181,532,551 |
| 2022 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 61,893,600,000 | 208,098,290 |
| 2023 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 69,175,200,000 | 225,808,783 |
| 2024 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 75,768,000,000 | 256,802,146 |
| 2025 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 79,507,200,000 | 278,940,262 |
| 2026 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 82,164,000,000 | 278,940,262 |
| 2027 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 81,376,800,000 | 278,940,262 |
| 2028 | 22,487,143 | 7,801,566,264 | 262,301,741 | 510,000,000 | 78,326,400,000 | 296,650,754 |

### 7. Assumption about Total Production versus Energy Substitutes

The production of coal, oil, and gas as estimated above would not occur in a vacuum. In reality, each ton or gallon or cubic foot produced would compete in the marketplace against other coal, oil, and gas, as well as against other energy sources like renewables, and even against the choice to use energy at all versus increasing energy efficiency or conservation. Under real market conditions, some of the fossil fuels developed from these two RMPs would substitute for other energy sources. An analysis of the economic costs of pollution should then, ideally, compare the relative emissions of the various energy substitutes.

The degree to which production of coal, oil, and gas in the Powder River Basin can substitute for other energy sources is a complex issue that requires computer modeling. BLM has access to such computer models, as evident by the substitution analysis it recently conducted using the MarketSim model in a separate EIS for an onshore oil and gas development project in Alaska.[8] Nevertheless, BLM conducted no such substitution analysis for either RMP here.

Instead, in its calculations of royalty revenue and other economic benefits from the RMPs, BLM implicitly assumes no substitution of coal, gas, and oil; in other words, BLM

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[8] *See supra* notes 6–7 and accompanying text, referring to Appendix H of a recent SEIS. *See* pages 309-310 of the Greater Mooses Tooth SEIS, conducting a substitution analysis.

assumes that the additional production under the RMPs will not be offset by decreased consumption of other coal, gas, or oil, or of other energy sources. For example, the Miles City Office calculates annual coal royalties by multiplying the total short tons produced on federal lands by a market price per ton and a royalty percentage per market transaction. MCO-FEIS at 4-374, tbl. 4-80. There is no discussion of how the production of this coal and the associated royalties might come at the expense of the production of other coal, oil, or gas on other federal or state leases, which would cancel out the royalties from those substituted leases and reduce net government revenue.

To the extent any given ton of coal produced under these two RMP substitutes for a single ton of the same kind of coal produced elsewhere, subsequently combusting that ton of coal at a power plant may not increase net emissions from combustion (though net emissions from transportation and processing could still be different). But neither would that ton of coal's production contribute to net employment gains, net labor income, net value added, net tax revenue, or (for substitutes on federal leases) net royalties. Instead, from a national perspective, it would simply replace the employment gains, value added, or royalties from some other mine, and any economic gains in the Powder River Basin region would be offset by losses to other U.S. regions.[9]

Perfect substitution of coal-for-coal, oil-for-oil, and gas-for-gas for the entire amount of production under these two RMPs is extremely unlikely, if not impossible, given economic theory and the reality of energy markets. Rather, basic economic principles predict that the increase in the supply of coal, oil, and gas authorized by these two RMPs will decrease the prices

[9] Even under an assumption less extreme than perfect substitution, any substitution of externalities from one region to another implies a substitution of (near) identical magnitude of market costs and benefits (including revenue) from one region to another.

of those commodities; that decrease in price will increase demand for those commodities; and that increased demand will lead to increased consumption of coal, oil, and gas at the expense of energy efficiency, energy conservation, or cleaner energy alternatives like renewable sources. These types of substitutions would increase emissions relative a no-leasing RMP scenario.[10]

In short, had a substitution analysis been performed, it would have changed both the estimates of economic costs from emissions and the estimates of economic benefits from energy production. Because BLM has not performed such an analysis, and because BLM instead assumes no substitution for the purposes of calculating economic benefits, to be consistent I will also assume no substitution for the purposes of calculating economic costs. Therefore, this analysis assumes that the entire amounts of production tallied in the section above constitute additional coal, oil, and gas, and so the emissions associated with that coal, oil, and gas likewise constitute net increases in pollution.

8. **Quantifying the Greenhouse Gas Emissions from Combustion**

In a recent EIS for a separate but similar onshore oil and gas development project in Alaska,[11] BLM used EPA's 2015 *Emission Factors for Greenhouse Gas Inventories*[12] to compare emissions from coal, oil, and gas. My analysis will use those same emission factors.

EPA gives a single set of emissions from natural gas of carbon dioxide, methane, and nitrous oxide per standard cubic foot, since all combustion processes for natural gas produce the same emissions.

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[10] While these price changes induce demand changes of their own, resulting in a variety of generation equilibrium impacts with their own impacts on production, these secondary adjustments are unlikely to offset the primary emission increases.

[11] *See supra* notes 6–7 and accompanying text, referring to BLM's adoption of BOEM's assumptions in Appendix H of the recent *SEIS for Greater Mooses Tooth* issued by BLM. See pages 5, 6, 8, and 14 of Appendix H for citations to the EPA document.

[12] *Available at* https://www.epa.gov/sites/production/files/2015-11/documents/emission-factors_nov_2015.pdf.

Oil's emissions, however, vary between petroleum products. For example, residual fuel oil emits nearly twice as much carbon dioxide per gallon when burned as propane does. EPA gives separate emission factors for different categories of petroleum products. In its recent Alaskan oil and gas EIS, BLM recommended weighting those EPA emission factors by each petroleum product's share of total U.S. oil consumption, as reported by a 2016 EIA report.[13] For example, since 52% of oil consumed in the United States goes to motor gasoline, the emission factors for motor gasoline are weighted by 0.52. Summing up the weighted factors for each product yields a single average set of factors for oil.

Coal's emissions vary depending on the type of coal. For the Miles City planning area, the FEIS reports that four of the mines that will produce coal under the RMP (Absaloka, Decker, Rosebud, and Spring Creek) are within the Tongue River region of the Fort Union coal formation, and "the coal is sub-bituminous in rank." MCO-FEIS at 3-97. The remaining mine (Savage) is in the Williston Basin and is mainly lignite, *id.* at 3-98. However, since the Savage mine will produce only 1% of the total coal under the RMP (8.9 million tons of 927 million tons total through year 2040), *id.* at MIN-130, I will assume all Miles City coal is sub-bituminous. Likewise, though the Buffalo FEIS briefly mentions lignite coal, BFO-FEIS at 356, it focuses predominantly on the fact that the RMP covers "some of the largest accumulations of low-sulfur sub-bituminous coal in the world," *id.* at 398; *accord.* at 1308, 2030. Therefore, I make the reasonable simplifying assumption that all Buffalo coal is sub-bituminous for purposes of applying EPA's emissions factors.[14]

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[13] See page 4 of Appendix H for the EIA table of U.S. Oil Consumption by Petroleum Product.

[14] Note that EPA's emission factor for carbon dioxide from sub-bituminous coal is 99% similar with a value that BLM has previously used to calculate carbon dioxide emissions from Powder River Basin coal. EPA's 2015 report estimates 1.676 metric tons of carbon dioxide per short ton of sub-bituminous coal. In its 2010 environmental impact statement for the Wright Area Coal

**Table 2. Greenhouse Gas Emission Factors (kilograms)**

| | Carbon Dioxide ($CO_2$) | Methane ($CH_4$) | Nitrous Oxide ($N_2O$) |
|---|---|---|---|
| Coal (per short ton) | 1,676 | 0.19 | 0.028 |
| Oil (per gallon) | 8.92 | 0.00038 | 0.00008 |
| Natural Gas (per standard cubic foot) | 0.05444 | 0.00000103 | 0.0000001 |

Multiplying these emission factors by the production schedules for coal, oil, and natural gas yields the following greenhouse gas emissions from the combustion of the fossil fuels produced under the two RMPs combined:

**Table 3. Greenhouse Gas Emissions from Combustion of Buffalo & Miles City Coal, Oil, and Gas (metric tons)**

| | Coal | | | Natural Gas | | | Oil | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ | $CH_4$ | $N_2O$ |
| 2018 | 892,448,452 | 101,173 | 14,910 | 2,353,200 | 45 | 4 | 3,524,563 | 150 | 32 |
| 2019 | 892,448,452 | 101,173 | 14,910 | 2,610,331 | 49 | 5 | 3,682,541 | 157 | 33 |
| 2020 | 892,448,452 | 101,173 | 14,910 | 2,942,458 | 56 | 5 | 3,840,519 | 164 | 34 |
| 2021 | 892,448,452 | 101,173 | 14,910 | 3,344,226 | 63 | 6 | 3,959,002 | 169 | 36 |
| 2022 | 892,448,452 | 101,173 | 14,910 | 3,794,205 | 72 | 7 | 4,195,968 | 179 | 38 |
| 2023 | 892,448,452 | 101,173 | 14,910 | 4,190,615 | 79 | 8 | 4,353,946 | 185 | 39 |
| 2024 | 892,448,452 | 101,173 | 14,910 | 4,549,527 | 86 | 8 | 4,630,407 | 197 | 42 |
| 2025 | 892,448,452 | 101,173 | 14,910 | 4,753,089 | 90 | 9 | 4,827,879 | 206 | 43 |
| 2026 | 892,448,452 | 101,173 | 14,910 | 4,897,725 | 93 | 9 | 4,827,879 | 206 | 43 |
| 2027 | 892,448,452 | 101,173 | 14,910 | 4,854,870 | 92 | 9 | 4,827,879 | 206 | 43 |
| 2028 | 892,448,452 | 101,173 | 14,910 | 4,688,806 | 89 | 9 | 4,985,856 | 212 | 45 |

## 9. **Monetizing the Climate Damages from Combustion**

Climate change is already causing quantifiable and monetizable damages, such as increased extreme storm activity and coastal destruction. In both the near future and over the

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Lease Applications, BLM cited a 1994 Department of Energy report to estimate that Powder River Basin coal had an average BTU value of 8,600 per pound of coal, and therefore would emit 1.659 metric tons of carbon dioxide per short ton of coal burned. *See* Wyoming State Office, BLM, *FEIS for the Wright Area Coal Lease Applications* at 4-136, 4-140 (2010), *at* eplanning.blm.gov/epl-front-office/projects/nepa/67033/82290/97260/01WrightCoalVol1.pdf. There is only about a 1% difference between 1.659 and 1.676.

long term, unabated climate change will cause significant impacts to both market and nonmarket sectors, including agriculture, forestry, water, energy use, sea-level rise, human health, and ecosystem services. Economists can estimate and monetize climate damages by linking together global climate models with global economic models, producing what are called integrated assessment models. These integrated assessment models can take a single additional unit of greenhouse gas emissions (such as from driving a car or burning coal at a power plant) and calculate the change in atmospheric greenhouse concentrations, translate that change in concentration into a change in temperature, and model how that temperature change and associated weather changes will cause economic damages. The resulting monetary estimate of how each additional unit of greenhouse gases will impact our health, our economic activity, our quality of life, and our overall well-being is called the social cost of greenhouse gases.

The three leading integrated assessment models are DICE (by William Nordhaus of Yale University), FUND (by Richard Tol and David Anthoff of Sussex University and University of California-Berkeley), and PAGE (by Chris Hope of Cambridge University). These models are able to estimate and monetize many[15] of the most important categories of climate damages, including, but not limited to:

- property lost to sea-level rise,
- increased coastal storm damage,
- changes in agricultural output and forestry due to alterations in temperature, precipitation, and $CO_2$ fertilization,
- changes in energy demand, via cooling and heating,
- changes in heat-related illnesses,
- some changes in disease vectors, like malaria and dengue fever,
- changes in fresh water availability, and
- some general measures of catastrophic and ecosystem impacts.

[15] For a list of important damages categories not currently included in the models, see *infra* on unquantified damages.

In 2009, a federal Interagency Working Group (IWG) was convened to develop consistent estimates of the social cost of greenhouse gases for agencies to use in their analyses, based on "a defensible set of input assumptions that are grounded in the existing scientific and economic literature."[16] Using DICE, FUND, and PAGE, combined with other reasonable assumptions and the best available data transparently drawn from the peer-reviewed literature, the IWG began first estimating the social cost of carbon dioxide. By 2016, the IWG added separate estimates for the social cost of methane and the social cost of nitrous oxide as well, since different greenhouse gases have different climate impacts based on their individual capacity to absorb the sun's energy and their lifespans in the earth's atmosphere.[17]

For each greenhouse gas, the IWG issued a central estimate of social costs per metric ton of emissions per year based on a 3% discount rate, as well as additional estimates that explore the calculation's sensitivity to a lower (2.5%) or higher (5%) discount rate.[18] Discount rates determine how future costs and benefits are weighed compared to present-day costs and benefits. Because of the long lifespan of greenhouse gasses and the long-term or irreversible consequences of climate change, the effects of today's greenhouse emissions will stretch out over the next several centuries. Recognizing the importance of selecting a discount rate that reflected the economic consensus and was grounded in the literature, the IWG chose a 3% rate

[16] IWG, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (2010) (hereinafter 2010 TSD), *available at* https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/foragencies/Social-Cost-of-Carbon-for-RIA.pdf.

[17] IWG, *Addendum: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide* (2016) (hereinafter 2016 Addendum), *available at* https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf.

[18] *See generally* 2010 TSD. A fourth estimate, based on the 95th percentile value of the distribution of estimates at a 3% discount rate, is also included, as a proxy for omitted catastrophic damages, risk aversion, and other uncertainties. *See infra* on omitted damages.

(based on the average rate of return on Treasury notes) to drive its central estimate of the social cost of greenhouse gas. To reflect the "possibility that climate damages are positively correlated with market returns," the IWG also considered an "upper value of 5 percent."[19] The IWG specifically rejected any discount rate higher than 5% as "not considered appropriate,"[20] and three recent, independent surveys indicate a strong consensus among economists and climate experts for using a discount rate below 3% for climate analyses, with little to no support for a rate above 5%.[21] The IWG also developed a "low value" based on a 2.5% discount rate, to reflect the fact that "interest rates are highly uncertain over time."[22] My analysis will focus on the central estimate, based on a 3% discount rate, but will disclose the range of estimates for context.

The social cost of greenhouse gases increases over time, because an additional ton of emissions will inflict greater damages in the future when total atmospheric concentrations of greenhouse gases are already much higher. As emissions accumulate in the atmosphere, each additional ton becomes that much more damaging. The following table shows the IWG's 2016 estimates for the social cost of greenhouse gases, by year of emissions.[23]

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[19] 2010 TSD at 23.
[20] IWG, *Response to Comments* at 36 (2015), *available at* https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc-response-to-comments-final-july-2015.pdf.
[21] M. Drupp et al., *Discounting Disentangled: An Expert Survey on the Determinants of the Long-Term Social Discount Rate* (Ctr. for Climate Change Econ & Pol'y, Working Paper 195, 2015); Peter Howard & Derek Sylvan, *Expert Consensus on the Economics of Climate Change* (Policy Integrity Report, 2015); U.S. Council of Economic Advisers, *Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate* (2017), *at* https://obamawhitehouse.archives.gov/sites/default/files/page/files/201701_cea_discounting_issue_brief.pdf.
[22] 2010 TSD at 23.
[23] 2016 Addendum, *supra*, & IWG, *Technical Update of the Social Cost of Carbon* (2016, hereinafter 2016 TSD), https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf.

**Table 4. Interagency Working Group Estimates of the Social Cost of Greenhouse Gases**
(per metric ton of emissions, in 2017$)[24]

| Year | Social Cost of Carbon Dioxide | | | Social Cost of Methane | | | Social Cost of Nitrous Oxide | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low (5% discount rate) | **Central (3% discount rate)** | High (2.5% discount rate) | Low (5% discount rate) | **Central (3% discount rate)** | High (2.5% discount rate) | Low (5% discount rate) | **Central (3% discount rate)** | High (2.5% discount rate) |
| 2018 | $14 | **$47** | $71 | $603 | **$1,300** | $1,773 | $5,202 | **$16,551** | $24,826 |
| 2019 | $14 | **$48** | $72 | $615 | **$1,419** | $1,773 | $5,438 | **$17,733** | $26,008 |
| 2020 | $14 | **$50** | $73 | $638 | **$1,419** | $1,892 | $5,556 | **$17,733** | $26,008 |
| 2021 | $14 | **$50** | $74 | $662 | **$1,419** | $1,892 | $5,793 | **$17,733** | $27,191 |
| 2022 | $15 | **$51** | $76 | $697 | **$1,537** | $2,010 | $5,911 | **$18,915** | $27,191 |
| 2023 | $15 | **$52** | $77 | $721 | **$1,537** | $2,010 | $6,147 | **$18,915** | $27,191 |
| 2024 | $15 | **$53** | $78 | $745 | **$1,655** | $2,128 | $6,384 | **$18,915** | $28,373 |
| 2025 | $17 | **$54** | $80 | $768 | **$1,655** | $2,128 | $6,502 | **$20,097** | $28,373 |
| 2026 | $17 | **$56** | $82 | $792 | **$1,655** | $2,246 | $6,739 | **$20,097** | $29,555 |
| 2027 | $18 | **$57** | $83 | $828 | **$1,773** | $2,246 | $6,975 | **$20,097** | $29,555 |
| 2028 | $18 | **$58** | $84 | $851 | **$1,773** | $2,364 | $7,093 | **$21,280** | $30,737 |

Applying the central estimates of the social cost of greenhouse gases to the previous calculations of emissions from the combustion of the coal, oil, and gas produced under these two RMPs yields the figures in Table 5 below. The undiscounted estimates of damages from emissions in future years are then discounted back at a 3% rate to produce a cumulative present value over the 2018-2028 period.

Altogether, emissions from combustion of the coal, oil, and gas extracted under these two RMPs in the years 2018 through 2028 will cause at least **$451 billion in climate damages**, using IWG's central estimates. Using IWG's low and high estimates for sensitivity (corresponding to the 5% and 2.5% discount rates, respectively), the range is between $122 billion and $682 billion.

Importantly, even the central estimate omits key categories of climate damages—like the risk of catastrophic, irreversible consequences—and so should be treated as a conservative underestimate of total climate damages from combustion. The final section of this declaration discusses omitted climate damages and other unquantified costs.

[24] Inflated to 2017$ using the CPI inflation calculator.

**Table 5: Central Estimates of Climate Damages from Combustion of Buffalo & Miles City Coal, Oil, and Gas (in 2017$)**

| Coal Emission | | | |
|---|---|---|---|
| Year | Carbon Dioxide | Methane | Nitrous Oxide |
| 2018 | $42,202,102,382 | $131,566,817 | $246,766,470 |
| 2019 | $43,257,154,942 | $143,527,437 | $264,392,646 |
| 2020 | $44,312,207,502 | $143,527,437 | $264,392,646 |
| 2021 | $44,312,207,502 | $143,527,437 | $264,392,646 |
| 2022 | $45,367,260,061 | $155,488,056 | $282,018,823 |
| 2023 | $46,422,312,621 | $155,488,056 | $282,018,823 |
| 2024 | $47,477,365,180 | $167,448,676 | $282,018,823 |
| 2025 | $48,532,417,740 | $167,448,676 | $299,644,999 |
| 2026 | $49,587,470,299 | $167,448,676 | $299,644,999 |
| 2027 | $50,642,522,859 | $179,409,296 | $299,644,999 |
| 2028 | $51,697,575,419 | $179,409,296 | $317,271,175 |
| **Present Value for Coal Emissions (2018-2028) @ 3% Discount Rate** | **$442.52 billion** | **$1.49 billion** | **$2.67 billion** |
| **Natural Gas Emissions** | | | |
| Year | Carbon Dioxide | Methane | Nitrous Oxide |
| 2018 | $111,278,113 | $57,898 | $71,542 |
| 2019 | $126,523,258 | $70,063 | $85,028 |
| 2020 | $146,100,121 | $78,977 | $95,846 |
| 2021 | $166,048,827 | $89,761 | $108,933 |
| 2022 | $192,876,886 | $110,325 | $131,830 |
| 2023 | $217,982,390 | $121,852 | $145,603 |
| 2024 | $242,030,297 | $142,464 | $158,074 |
| 2025 | $258,478,696 | $148,838 | $175,468 |
| 2026 | $272,134,277 | $153,367 | $180,807 |
| 2027 | $275,492,526 | $162,884 | $179,225 |
| 2028 | $271,612,244 | $157,313 | $183,277 |
| **Present Value for Gas Emissions (2018-2028) @ 3% Discount Rate** | **$1.92 billion** | **$1.09 million** | **$1.28 million** |
| **Oil Emissions** | | | |
| Year | Carbon Dioxide | Methane | Nitrous Oxide |
| 2018 | $166,669,559 | $195,257 | $523,178 |
| 2019 | $178,493,503 | $222,556 | $585,673 |
| 2020 | $190,690,970 | $232,103 | $610,797 |
| 2021 | $196,573,945 | $239,264 | $629,641 |
| 2022 | $213,300,369 | $274,717 | $711,817 |
| 2023 | $226,478,332 | $285,060 | $738,617 |
| 2024 | $246,333,004 | $326,480 | $785,516 |
| 2025 | $262,545,835 | $340,404 | $870,205 |
| 2026 | $268,253,353 | $340,404 | $870,205 |
| 2027 | $273,960,871 | $364,718 | $870,205 |
| 2028 | $288,819,684 | $376,652 | $951,543 |
| **Present Value for Oil Emissions (2018-2028) @ 3% Discount Rate** | **$2.14 billion** | **$2.72 million** | **$6.94 million** |

### 10. The IWG's 2016 Estimates of the Social Cost of Greenhouse Gases Remain the Best Available Estimates

In March 2017, President Trump's Executive Order 13,783 officially disbanded the IWG.[25] Since then, in an attempt to justify the repeal of a massively net beneficial rule that would prevent methane leaks and wasteful flaring on federal oil and gas leases, BLM has issued a regulatory impact analysis that proposes "interim" estimates of the social cost of greenhouse gases.[26] Relying on faulty economic theory, these "interim" estimates drop the social cost of carbon from $50 per ton in year 2020 down to as little as $1 per ton, and drop the social cost of methane from $1420 per ton in year 2020 down to $58. These "interim" estimates are inconsistent with accepted science and economics; the IWG's 2016 estimates remain the best available estimates. In fact, as recently as August 2017, BLM's sister agency in the Department of the Interior (the Bureau of Ocean Energy Management) continued to use the IWG's 2016 numbers. The IWG's methodology and estimates have been repeatedly endorsed by reviewers as transparent, consensus-based, and firmly grounded in the academic literature. By contrast, the "interim" estimates ignore the interconnected, global nature of our climate-vulnerable economy, and obscure the devastating effects that climate change will have on younger and future generations.

To begin, it is notable that the Department of the Interior was a member of the interagency team that produced the IWG's 2016 estimates of the social cost of carbon, methane, and nitrous oxide.[27] BLM and its sibling agencies at Interior have often applied the IWG's

[25] Exec. Order. No. 13,783 § 5(b), 82 Fed. Reg. 16,093 (Mar. 28, 2017). The Order instructed agencies to use the "best" estimates of the social cost of greenhouse gases. In fact, the IWG estimates remain the best estimates available.
[26] BLM, *Regulatory Impact Analysis for the Proposed Rule to Rescind or Revise Certain Requirements of the 2016 Waste Prevention Rule* at 71 (2018).
[27] *See* 2016 Addendum, listing the Department of the Interior as a participant in the IWG.

estimates of the social cost of greenhouse gases in its environmental impact statements, including after when the IWG was officially disbanded. For example:

- In August 2017—several months after Executive Order 13,783—the Bureau of Ocean Energy Management called IWG's estimates "a useful measure to assess the benefits of CO2 reductions and inform agency decisions," *Draft Environmental Impact Statement—Liberty Development Project in the Beaufort Sea, Alaska* at 3-129, 4-50 (2017)[28];
- The Office of Surface Mining explained in 2015 that using IWG's social cost of carbon to assess resource management decisions "provide[s] further context and enhance[s] the discussion of climate change impacts in the NEPA analysis." *Final Environmental Impact Statement—Four Corners Power Plant and Navajo Mine Energy Project* at 4.2-24 to 4.2-27 (2015)[29];
- The Bureau of Land Management's Idaho office used the IWG estimates to calculate the annual climate costs associated with the Little Willow Creek Protective Oil and Gas Lease. *Final Environmental Assessment*, DOI-BLM-ID-B010-2014-0036-EA, at 35, 81, 83 (2015) (describing IWG's estimates as developed by "EPA and other federal agencies")[30]; and
- The Bureau of Land Management's Montana office used the social cost of carbon to calculate the annual climate costs associated with its Miles City Oil and Gas Lease Sale.

[28] *Available at* https://cdxnodengn.epa.gov/cdx-enepa-II/public/action/eis/details?eisId=236901.
[29] *Available at* https://www.wrcc.osmre.gov/initiatives/fourCorners/documents/FinalEIS/Section%204.2%20-%20Climate%20Change.pdf.
[30] See pdf pages 66 & 72-74 of the pdf file available at https://eplanning.blm.gov/epl-front-office/projects/nepa/64290/77147/85662/WEG.pdf.

*Environmental Assessment*, DOI-BLM-MT-C020-2014-0091-EA at 51, 76 (2014) (describing IWG's estimates as developed by "EPA and other federal agencies").[31]

IWG's estimates have been repeatedly endorsed by reviewers. In 2014, the U.S. Government Accountability Office reviewed the IWG's methodology and concluded that it had followed a "consensus-based" approach, relied on peer-reviewed academic literature, disclosed relevant limitations, and adequately planned to incorporate new information via public comments and updated research.[32] In 2016, the U.S. Court of Appeals for the Seventh Circuit held that it was reasonable for agencies to use the IWG's estimates.[33] In 2016 and 2017, the National Academies of Sciences issued two reports that, while recommending future improvements to the methodology, supported the continued use of the existing IWG estimates.[34] It is, therefore, unsurprising that scores of economists and climate policy experts have endorsed the IWG's values as the best available estimates.[35]

By comparison, the so-called "interim" estimates that BLM has developed in an attempt

[31] *Available at* https://www.blm.gov/sites/blm.gov/files/MT-DAKs%20MCFO%20EA%20October%202014%20Sale_Post%20for%2030%20day.pdf.
[32] Gov't Accountability Office, *Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates* 12-19 (2014).
[33] Zero Zone, Inc. v. Dep't of Energy, 832 F.3d 654, 679 (7th Cir. 2016).
[34] Nat'l Acad. Sci., Eng. & Medicine, Valuing Climate Damages: Updating Estimates of the Social Cost of Carbon Dioxide 3 (2017); Nat'l Acad. Sci., Eng. & Medicine, Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update 1 (2016).
[35] *See, e.g.*, Richard Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 Science 655 (2017); Michael Greenstone et al., *Developing a Social Cost of Carbon for U.S. Regulatory Analysis: A Methodology and Interpretation*, 7 Rev. Envtl. Econ. & Pol'y 23, 42 (2013); Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 Nature 173 (2014) (co-authored with Nobel Laureate Kenneth Arrow, among others); Richard G. Newell et al., *Carbon Market Lessons and Global Policy Outlook*, 343 Science 1316 (2014); Bonnie L. Keeler et al., The Social Costs of Nitrogen, 2 Science Advances e1600219 (2016).

to justify repealing a massively net beneficial rule[36] rely on two manipulations of the social cost of greenhouse gases: a spurious "domestic-only" calculation and an inappropriately high 7% discount rate. The IWG appropriately took a global perspective on climate damages. In proposing a "domestic-only" calculation, the "interim" estimates disregard how climate damages in foreign countries spill back into the U.S. economy through globally interconnected trade, health, and national security. It further ignores how foreign countries could respond to U.S. deregulatory actions on climate change by increasing their own emissions, which would directly harm the United States. Limiting the social cost of greenhouse gases to so-called "domestic-only" effects is as irrational as a homeowner dumping trash in her neighbor's yard without considering whether that might attract pests and generate odors on her own property, affect her property value, or provoke her neighbor to retaliate in kind. The global value of the social cost of greenhouse gases is the best way to measure all the climate damages that matter to the United States, including spillovers from foreign climate impacts, foreign reciprocity on emissions reductions, and U.S. extraterritorial interests in foreign businesses, foreign property, and foreign welfare. Based on these considerations, the National Academies of Sciences warned against using "domestic-only" estimates.[37]

Similarly, the IWG appropriately rejected a 7% discount rate. A growing consensus of economists suggests that the discount rate for intergenerational climate impacts should be even lower than the 3% rate used now for IWG's central estimate: around 2%, or else declining over

[36] The proposed regulatory repeal is separate but related to these RMPs: the original rule that BLM now wants to repeal was designed to reduce methane leaks and wasteful flaring on oil and gas leases on federal lands.

[37] National Academies of Sciences, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide* (2017); *see also* Institute for Policy Integrity, *How the Trump Administration is Obscuring the Costs of Climate Change* (2018), http://policyintegrity.org/files/publications/Obscuring_Costs_of_Climage_Change_Issue_Brief.pdf.

time and eventually approaching 0%.[38] Including a 7% discount rate in the analysis has no purpose aside from obscuring the full costs of climate change, and contradicts the economic literature.[39] The National Academies of Sciences, the Office of Management and Budget, and many prominent economists, including the independent economists who built the models underlying the social cost of greenhouse gas estimates, all agree that a discount rate based on the rate of return on private investment (such as a 7% rate) is not sound or defensible in the context of intergenerational climate damages.[40]

11. **Monetizing the Non-Climate Damages of Coal Combustion**

Besides greenhouse gases, coal-fired power plants emit sulfur dioxide, nitrogen oxides, particulate matter, volatile organic compounds, and toxic heavy metals (including mercury).[41] These pollutants cause significant public health impacts, including cardiovascular disease and premature mortality, as well as negative impacts to property, crops, forests, and recreation. *See* NRC (2010) and Epstein et al. (2011).[42]

Some of those key health impacts, as well as some other welfare effects, have been monetized (per kilowatt-hour of coal-fired electricity generation) in peer-reviewed studies. Those studies begin with data on the average emissions of power plants burning a mix of coal. Air quality models translate those emissions into changes in air pollution concentrations, and then apply concentration-response functions to transform exposure to pollution into specific impacts.

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[38] *See* citations *supra* note 21.
[39] *See* Richard G. Newell, *Unpacking the Administration's Revised Social Cost of Carbon*, Oct. 10, 2017, http://www.rff.org/blog/2017/unpacking-administration-s-revised-social-cost-carbon.
[40] *See* citations at *supra* note 37.
[41] Note that sulfur dioxide and nitrous oxide are particulate matter precursors.
[42] Nat'l Res. Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use* (2010); P.R. Epstein et al., *Full Cost Accounting for the Life Cycle of Coal*, 1219 Annals of the N.Y. Acad. of Sci. 73 (2011). Examples of non-health impacts include acid rain and harmful algal blooms, dead zones, and decreased water quality from excess nitrogen.

Finally, dollar values are assigned to various impacts based on, for example, the average U.S. willingness to pay to reduce the risk of mortality (a metric also known as the value of statistical life). Various estimates in the literature are broadly consistent,[43] though some differences arise from factors like assumptions made about the relationship between health responses and exposure to fine particulate matter, or the year of the study, which may affect estimates as older plants retire or plants comply with new emission standards. *See* Machol & Rizk (2013).[44]

One key estimate was developed by the National Research Council (NRC) in 2010. *See* NRC *supra*. The NRC estimates the marginal damages of sulfur dioxide, nitrogen oxide, and particulate matter emissions from the 406 U.S. coal-fired power plants that were in operation in 2005. The study primarily focuses on mortality and morbidity, especially from exposure to particulate matter (including the sulfur dioxide and nitrogen oxide precursor components of particulate matter), though it also includes impacts to crops, timber, buildings, visibility, and recreation. Critically, the study relies on the frequently cited analysis by Pope et al. (2002) to measure the relationship between mortality and exposure to particulate matter (including particulate matter resulting from sulfur dioxide and nitrogen oxide emissions). The NRC study values avoided mortalities at $6 million (in 2000$). The study estimates an average marginal damage of $0.032 per kilowatt-hour (in 2007$)[45]—which equals $0.038/kWh when adjusted into 2017$. 94% of these damages are due to health impacts and 86% of damages are attributable to sulfur dioxide emissions (primarily as a precursor to particulate matter).

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[43] I omit the estimate of benefits of reducing sulfur dioxide and nitrous oxide from the Clean Air Interstate Rule because it focused exclusively on the Eastern United States. NRC at 98.

[44] B. Machol & S. Rizk, *Economic Value of U.S. Fossil Fuel Electricity Health Impacts*, 52 Enviro. Iternational 75, 76, 79 (2013).

[45] This value is for weighting plants by electricity generated (compared to 4.4 cents/kWh when equally weighting plants).

NRC notably found that its estimate was sensitive to the assumption about the concentration-response function for particulate matter exposure. If the Pope et al. numbers were replaced (with, for example, numbers from Dockery et al. (1993) or Schwartz et al. (2008)), the damages per kilowatt-hour approximately tripled. *See* NRC (2010) at 97. A paper by Epstein et al. (2011), *supra*, highlighted the NRC's sensitivity analysis as its own valid and separate estimate of the health damages from coal-fired power plants. Specifically, Epstein et al. finds an initial range of damages from $0.032/kWh to $0.093/kWh (in 2008$), with a preferred estimated toward the high end of that range.[46] On top of that initial range of damages, Epstein et al. further include a calculation of damages from mercury emissions, valuing the effects of coal plants' mercury emission on lost productivity, mental retardation, and cardiovascular disease as between $0.0002/kWh to $0.0172/kWh, with a best estimate of $0.0033/kWh. Adjusting for inflation to 2017$, Epstein et al.'s total valuation of the health impacts from coal-fired power plants is $0.037/kWh to $0.126/kWh, with a best value of $0.11/kWh.

A study by Machol and Rizk (2013), *supra*, based on work by Fann et al. (2009),[47] produced much higher estimates. These works focused on particulate matter effects, including mortality, morbidity, and lost labor productivity. For the concentration-response functions for mortality, both Pope et al. (2002) and Laden et al. (2006) were used. The resulting values—$0.19/kWh to $0.45/kWh of coal in 2006$, which equals $0.23/kWh to $0.55/kWh in 2017$—are much higher than the NRC numbers, perhaps in part because the underlying work by Fann et

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[46] Epstein et al. (2011) argues that the alternative methodology is "more recent, used elaborate statistical techniques to drive the concertation-response function $PM_{2.5}$ and mortality, and is now widely accepted," while the original methodology is "an outlier when compared to other studies examining the $PM_{2.5}$-mortality." relationship."

[47] N. Fann et al., *The Influence of Location, Source, and Emission Type in Estimates of the Human Health Benefits of Reducing a Ton of Air Pollution*, 2 Air Quality, Atmosphere & Health 169 (2009).

al. focused mostly on urban areas, instead of both urban and rural areas as in other models. The additional estimates of lost labor productivity could also explain some of the difference. Finally, this is the sole study to apply the Laden et al. mortality-response function for particulate matter, which produces higher mortality estimates than Pope et al.

One final estimate falls roughly in the middle of the previous studies. Levy et al. (2009)[48] focused on mortality impacts from coal plants' particulate matter emissions from the year 1999. Picking a different air quality model and using the Schwartz et al. concentration-response function, Levy et al. find the median health cost of coal plant emissions to be $0.14/kWh in 1999 USD ($0.21/kWH in 2017 USD).

Distilling those various studies, I select an initial range of estimate for the marginal non-climate costs of coal plants to be between $0.037/kWh to $0.55/kWH, with a central preferred estimate of $0.110/kWh. The low end of the range comes from NRC's estimate based on the Pope et al. concentration-response function for particulate matter, and excludes some harder-to-quantify impacts, like from mercury. The upper end of the range uses Machol and Rizk's high estimate, based on the Laden et al. concentration-response function. Finally, I select the Epstein et al.'s best estimate as my central estimate. That central estimate is also roughly consistent with the results of Levy et al., after accounting for different emission years. My range is consistent with other estimates applied in the literature.[49]

[48] J. Levy, *Uncertainty and Variability in Health-Related Damages from Coal-Fired Power Plants in the United States*, 29 Risk Analysis 1000 (2009).

[49] *See, e.g.*, K.E. Brown et al., *How Accounting for Climate and Health Impacts of Emissions Could Change the U.S. Energy System*, 102 Energy Policy 396, 397 (2017); Declaration of Thomas Michael Power in *Mont. Envtl. Info. Ctr. v. U.S. Office of Surface Mining*, 9:15-cv-106-DWM (D. Mont., filed Sept. 25, 2017 as doc. 82-3); D. Burtraw et al., *The True Cost of Electric Power: An Inventory of Methodologies to Support Future Decision-Making in Comparing the Cost and Competitiveness of Electricity Generation Technologies* (Res. for the Future 2012); S.

The range of estimates that I have assembled represents the average marginal non-climate costs of U.S. coal plants in the 2000s. However, a few adjustments are necessary to calculate the non-climate costs of burning the coal produced under the Buffalo and Miles City RMPs. First, while sulfur-based particulate matter is responsible for much of coal plants' health impacts, Powder River Basin coal is relatively low in sulfur compared to other types of coal. Additionally, coal plants' efficiency and heat rates have improved since 2005, while their emissions of particulate matter, sulfur dioxide, and nitrous oxide have decreased, in response to new pollution regulations. To calculate the average marginal non-climate damages of U.S. coal plants burning low-sulfur sub-bituminous coal in 2018, I use EPA's eGrid dataset and EPA's National Emissions Inventory Data to adjust the damage components for individual pollutants from NRC's table 2-9 and Machol & Rizk's table 3. Emissions data is only available up to year 2016 (and 2014 in the case of particulate matter), and so I adjust my estimates to 2016 emissions and assume that damages for year 2018 emissions are approximately the same.

**Table 6. Non-Climate Damage Estimates for Combusting Coal per Kilowatt-Hour**
(as of year 2016 emissions, in 2017$)

| **Adjustment** | **Low Estimate** | **Central Estimate** | **High Estimate** |
|---|---|---|---|
| Unadjusted, derived from the literature | $0.04 | $0.11 | $0.55 |
| Adjusted to Powder River Basin coal's sulfur content and modern coal plant's heat rates | $0.01 | $0.04 | $0.22 |

I interpret these as conservative, lower-bound estimates for two reasons. First, each study discussed above omits an array of key damages. Some studies (Machol and Rizk (2013) and Levy et al. (2009)) estimate the health damages only from fine particulate matter exposure, and

Grausz, *The Social Cost of Coal: Implications for the World Bank* (World Bank, 2012) (highlighting the NRC and Epstein estimates).

omit all other impacts. NRC (2010) captures some additional health and non-health impacts, but still omits a variety of health (e.g., mercury) and non-health impacts (e.g., reduced water quality due to nitrogen deposit).[50] Epstein et al. (2011) accounts for some mercury damages. Second, population density in the United States increased by 10% from 2005 to 2016; higher density levels should increase damages. However, the actual damages depend on whether these density increases occur in the path of emissions from coal-fired power plants. To determine the impact of new density levels (and ambient air pollution levels), new model estimates would be necessary. I interpret the adjusted range of damages in Table 6 as relatively conservative, given these omitted damages, and I list the unadjusted estimates as well to provide context.

This is an active area of research within environmental economics. New models are being developed,[51] and new air pollution damage estimates are frequently released. While the above discussion is not an exhaustive list, it reflects the most up-to-date estimate of marginal damages from non-GHG emissions from U.S. coal-fired power plants that I was able to identify and that were in the appropriate units ($/kWh). My range of estimates is likely in the correct ballpark but is also very likely to be conservative, since these estimates omit various damages and air pollutants (like volatile organic compounds). See *infra* on unquantified damages.

To apply this range of adjusted damage estimates, I adopt the same assumption that BLM has made elsewhere, that Powder River Basin coal has an average heating value of 8600BTU per

[50] In addition to the limitations of each study discussed in the studies themselves, see also P. Jaramillo & N.Z. Muller, *Air Pollution Emissions and Damages from Energy Production in the U.S.*, 90 Energy Policy 202 (2016).

[51] New models include AP2, as used by Jaramillo and Muller (2016), *supra*; EASIUR, as used by J. Heo et al., *Reduced-Form Modeling of Public Health Impacts of Inorganic PM2.5 and Precursor Emissions*, 137 Atmospheric Envt. 80 (2016); and SCAR, as used D. Shindel, *The Social Cost of Atmospheric Release*, 130 Climatic Change 313 (2015).

pound,[52] and I use recent data from the U.S. Energy Information Administration showing that the average heat rate for coal generators in the United States is 10,493BTU/kWh.[53] After applying those figures, the average annual short tons produced in the Buffalo and Miles City regions under these RMPs will generate over 872 billion kilowatt-hours per year during the 2018-2028 period. I multiply by my per-kilowatt-hour damage figures from above.

**Table 7: Annual and Cumulative Non-Climate Damages from Buffalo and Miles City Coal Combustion**

| | Low Estimate | Central Estimate | High Estimate |
|---|---|---|---|
| Annual Damages: | $9,958,668,806 | $32,109,599,658 | $195,028,137,071 |
| Cumulative Damages (2018-2028), discounted at 3% to Present Value | $95 billion | **$306 billion** | $1,859 billion |

To summarize, the emissions of particulate matter, nitrogen oxides, sulfur dioxide, and other hazardous pollutants from the combustion of the coal produced under these two RMPs will result in premature mortality, cardiovascular diseases, lost work productivity, and other damages **worth at least $306 billion over the 2018-2028 period**. For the reasons given above, this is a conservative estimate, and additional unquantified damages could be substantial.

Due to data and time limitations, I could not quantify or monetize the non-climate damages associated with the combustion of the oil and gas produced under these RMPs. The health and environmental damages from the particulate matter, volatile organic compounds, heavy metals, and other pollutants from combustion of oil and gas could be substantial.

[52] Wyoming State Office, BLM, *Final Environmental Impact Statement for the Wright Area Coal Lease Applications* 4-136 (2010), *available at* https://eplanning.blm.gov/epl-front-office/projects/nepa/67033/82290/97260/01WrightCoalVol1.pdf.
[53] EIA, Average Operating Heat Rate for Selected Energy sources (listing data for year 2016), https://www.eia.gov/electricity/annual/html/epa_08_01.html.

12. **Monetizing the Damages from the Mining and Transportation of Coal**

Both the Buffalo FEIS and the Miles City FEIS quantify emissions from the extraction of the coal, oil, and gas. However, their methodologies are incomplete and their estimates are improbably low. For example, the Buffalo FEIS describes its methodology for estimating greenhouse emissions from coal "mining and post-mine (processing) activities in the Powder River Basin," as based on EPA's 2011 State Inventory Tool Module. *See* BFO-FEIS at 2250. The 2017 version of that module,[54] indicates that it estimated the *methane* emitted during post-mining activities, including transportation, but does not indicate that *carbon dioxide* emissions from transportation were included. When it comes to transporting coal by train from the Powder River Basin all the way to the power plants where it is burned, carbon dioxide from the train will be the largest effect; yet that costly pollution is apparently omitted from BLM's estimates.

Meanwhile, the Miles City FEIS's estimate of methane emissions from coal mining—just a single ton per year, MCO-FEIS at 4-26—seems improbably low. It is easy to derive an average methane emission rate of approximately 0.00085 per metric ton of coal for surface mining (using data from 2005 to 2013).[55] That would imply at least 17,340 metric tons of methane leaks and other emissions annually from coal mining under the Miles City RMP—not a single ton.

For these reasons, I do not rely on BLM's estimates of emissions from extraction, processing, and transportation. Unfortunately, due to data and time limits, I cannot fully quantify and monetize the emissions and other environmental impacts from the extraction, processing, and transportation of oil and gas resulting from these two RMPs. However, I have previously

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[54] https://www.epa.gov/sites/production/files/2017-12/documents/coal_users_guide.pdf, at p.11.
[55] *See* Jayni Hein & Peter Howard, *Illuminating the Hidden Costs of Coal* at tbls. B7-B8 (Policy Integrity Report 2015), http://policyintegrity.org/files/publications/Hidden_Costs_of_Coal.pdf.

developed a methodology for monetizing the damages from the extraction and transportation of Powder River Basin coal,[56] and I modify that methodology to apply here.

My methodology adjusts upstream costs estimates from both the lifecycle of coal and the transportation literature to develop an average cost estimate ($/ton) for mining and transporting Powder River Basin coal. The average ton of coal mined from the Powder River Basin differs substantially from other U.S. and global mining regions with respect to its: lower surrounding population density; reliance on strip mining; mining of sub-bituminous coal that is unprocessed; and long shipping distance (primarily by train) for domestic use in power plants. To my knowledge, the methodology I developed in Hein & Howard (2015) is the sole publication to focus exclusively on the external cost of mining coal in the Powder River Basin.

Coal mining produces a variety of local, national, and global externalities. Locally, the establishment of a mine implies a loss of amenities and recreational services of the land. Due to the low population density in the Powder River Basin area, these services are likely to be small here. Even so, the 1977 Surface Mining Control and Reclamation Act requires inactive mines (including those in the Power River Basin) be returned to their prior condition. While the Abandoned Mine Reclamation Fund is supposed to fund these reclamations, many mining sites go unfunded. This leaves the government to pay for this reclamation, resulting in an externality to the public. The mining process itself produces air, noise, and water pollution, though the former two are small here given the low population density of the surrounding area. Water pollution (in particular alkaline mine drainage in the Power River Basin) can be more damaging and farther-reaching because of its impacts on groundwater and the surrounding ecosystems. Finally, coal mining releases methane (a greenhouse gas) that is trapped in the coal seams, and

[56] Hein & Howard (2015), *supra*, Appendices A and B.

those emissions impact society globally through its contribution to climate change. While methane remains the atmosphere for a shorter time period than carbon dioxide, it has a greater capacity to absorb solar radiation (i.e., it has higher warming potential). Of the impacts that I can value (e.g., water pollution is hard to value due to its location-specific nature), greenhouse gas emissions from these sites is likely the largest externality from Powder River Basin mining; see previous discussion of the social cost of methane.

Though the rural nature of the Powder River Basin may reduce the externality costs from air pollution and other local effects, it also increases the external cost of transportation. The transportation of coal from the Powder River Basin to the final destination at power plants requires large amounts of energy and includes some risks. In the United States, coal companies transport 70% of their product by rail, accounting for almost half of all tonnage, a quarter of all carloads, and over 40% of commercial freight sent by rail domestically. Reliance on rail is even higher from the Powder River Basin. For example, 90% of coal in Wyoming is shipping out of state for use in power plants (with some coal going as far as the Eastern United States); 96% of that coal shipped out of state was transported by rail in 2013. Transportation by rail results in multiple externalities: increased risk to public health through accidents; impacts from air pollution (including nitrogen oxide, sulfur dioxide, particulate matter, and carcinogens); emissions of greenhouse gases; and dis-amenities from congestion and noise.

Below, I derive two cost estimates for the Powder River Basin: the marginal cost of methane emissions from its mines, and the average cost of transporting its coal. I do not provide cost estimates for non-greenhouse emissions from mining, water pollution, water use, lost amenities, option value, and abandoned mines. I exclude these values for the most part because they are difficult to monetize, and as such the below estimates should be interpreted as lower bounds. The exception is the cost of abandoned mine lands, which Hein and Howard (2015), value at $0.44 per metric ton of coal (in 2015 USD) based on the work of Epstein et al. (2011). Given the context of the coal production under consideration (i.e., the extension and/or expansion of current mines), it is unclear whether this value applies. See Hein and Howard (2015) for an in-depth discussion of the valuation of each of these omitted impacts in detail.

To adjust for the fact that methane emissions from surface mines in the Powder River Basin are far less than the methane emissions from the underground mines analyzed in some other studies of the cost of coal mining, my methodology first calculates average U.S. surface mine methane emissions per ton of coal from 2005 to 2009 by dividing EIA's total surface-mine emissions by EIA's corresponding production data, and then multiplies these emissions by the IWG's estimates for the social cost of methane.[57] After adjusting to 2017$, my methodology estimates that the costs of coal mining range from $0.46 to $2.83 per metric ton of Powder River Basin coal mined, with a most likely value of $1.01 per metric ton. This cost range is for coal mined in 2015, but costs would increase for future mining along with the social cost of methane, because damages from greenhouse gas emissions increase as greenhouse gases accumulate in the atmosphere over time.

For transportation externalities, Hein and Howard (2015) value the cost of greenhouse gas emissions, non-GHG emissions, public fatalities, and dis-amenities like noise from transporting coal by train. While other studies have valued transport impacts for U.S. coal on average, these estimates undervalue the cost of transporting Powder River Basin coal due to its

[57] My previous work used Marten et al. (2015)'s social cost of methane estimates, since the IWG 2016 estimates were not yet available. The IWG based its estimates on Marten et al.'s work, though, so the two sets of estimates are consistent. *Compare* IWG, 2016 Addendum *with* A.L. Marten et al., *Incremental CH4 and N2O Mitigation Benefits Consistent with the U.S. Government's SC-CO2 Estimates*, 15 Climate Policy 272 (2015).

above-average travel distance (relative to U.S. coal in general). Specifically, Hein and Howard (2015) adjust the average U.S. cost estimates on a dollar per ton-mile basis to reflect average Powder River Basin estimates.[58] The methodology also uses the IWG's estimates of the social cost of carbon and a range of damage estimates drawn from the literature for the remaining impacts.[59]

Several factors are important to keep in mind when referring to these transportation externalities. First, like the upstream GHG damage estimates for mining, the GHG damage estimates applied here refer to 2015 emissions. Since GHG emissions are a stock pollutant, these cost estimates will increase over time as carbon dioxide becomes more concentrated in the atmosphere and the marginal social cost of carbon rises. Second, Hein and Howard (2015) adjust downward the non-GHG cost estimates from the literature to account for a 2008 EPA rule[60] that regulates some airborne emissions from diesel freight trains. However, the methodology does not account for the impact of that regulation on GHG emissions, since the rule's effect on trains' fuel consumption is unclear. Third, Hein and Howard (2015) adjust public fatality cost estimates to be consistent with the EPA and Department of Transportation's value of a statistical life.[61]

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[58] See pages A13 and A47 in Hein & Howard (2015) for the four-step simple adjustment methodology based on the Lee et al. (1995) methodology for converting total mortality costs of US freight trains to the total mortality costs of U.S. coal freight trains. R. Lee, A. Krupnick & D. Burtraw *Estimating Externalities of Electric Fuel Cycles: Analytical Methods and Issues, and Estimating Externalities of Coal Fuel Cycles* (Nat'l Acad. Press, 1995).

[59] See pages A13 to A17 in Hein & Howard (2015) for a complete discussion of the derivation.

[60] The rule was entitled "Control of Emissions of Air Pollution from Locomotive engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder."

[61] Following the literature, Hein & Howard (2015) also assume that the train transportation industry internalizes some portion of the public fatality cost, and passes it on to consumers. However, only some of the studies that they considered when deriving their range of estimates of the externality costs of public fatalities due to train transport accounted for this internalization. For those estimates that fail to account for this internalization, they assumed a 40% internalization of fatality costs by the industry.

**Table 8. Costs of Mining and Transporting Powder River Basin Coal**
(2017$/metric ton of coal)[62]

| Damage Category | Low Estimate | Best Estimate | High Estimate |
|---|---|---|---|
| Production | | | |
| Methane emissions from mines | $0.46 | $1.01 | $2.83 |
| Air Pollution from mining | – | – | – |
| Water Pollution | – | – | – |
| Water Use | – | – | – |
| Transportation | | | |
| Fatalities to public due to coal transport | $1.79 | $2.73 | $10.29 |
| GHG emissions from trains | $0.58 | $1.81 | $5.35 |
| Air pollution from trains | $0.17 | $3.29 | $12.41 |
| Congestion | $0.00 | $0.64 | $0.77 |
| Noise | $0.00 | $1.05 | $1.05 |
| Pavement | $0.00 | $0.83 | $0.99 |
| Total Costs | | | |
| Variable external costs | $2.98 | $11.37 | $33.69 |

Adjusting to 2017 USD, my final range of upstream externalities from coal mining in the Powder River Basin is $2.98 to $33.69 per metric ton of coal, with a best estimate of $11.37/ton. As the social cost of carbon and methane represent lower bound estimates of the marginal costs of these greenhouse gases and many of the impacts of coal mining are omitted, this range of estimates should be interpreted as lower bounds.

[62] For sources for the damage estimates, see Hein & Howards (2015).

Focusing on the central estimates from that range, and using a 3% discount rate, the total coal production under the two RMPs from 2018-2028 will cause the following damages from extraction and transportation:

**Table 9. Cumulative Damages from Mining and Transporting Coal from the Buffalo and Miles City RMPs** (2018-2028, at a 3% discount rate)

| | |
|---|---|
| Methane emissions from mines | $6 billion |
| Greenhouse gas emissions from transporting the coal | $10 billion |
| Non-greenhouse gas emissions from transporting the coal | $39 billion |

Altogether, coal mining and transportation under these two RMPs will generate **additional damages of at least $56 billion over the 2018-2028 period**. This figure represents a central estimate. Using the low and high estimates gives a range from $14 billion to $144 billion. Again, many important damage categories from the mining and transportation of coal, including water pollution, could not be monetized here.

### 13. **Unquantified Damages Are Likely Substantial, and Could Double or Triple Some Estimates of Climate and Air Pollution Damages**

Due to limits on data and time, I was unable to quantify and monetize the non-climate damages from the combustion of oil and gas, as well as any of the damages from the extraction, processing, and transportation of oil and gas. Such damages would include health impacts from the emission of particulate matter and heavy metals from oil combustion, methane leaks from natural gas transportation, and water impacts from oil and gas extraction, among other significant damage categories.

Additionally, even monetized categories of damages exclude significant health, environmental, and welfare impacts. For example, as noted above, the monetized value of damages from the mining and transportation of coal excludes effects from air pollution and water pollution. Furthermore, the estimates of the non-climate damages from coal combustion exclude key damage categories like:

- Cancer, mutagenicity, and genotoxicity effects,
- Reproductive and development effects,
- Neurologic effects, including IQ loss and developmental delays,
- Strokes and cerebrovascular disease,
- Ecosystem effects, including reproductive effects on fish, birds, and mammals,
- Acid rain deposition effects to ecosystems, forests, and recreational fishing,
- Decreased outdoor work productivity,
- And many more categories.[63]

Some newer models and literature have attempted to adjust the methodology from NRC (2010) and Epstein (2011) that I rely on for my range of damage estimates, in order to capture some of these omitted damages and make other corrections. For example, Jaramillo & Muller (2016)[64] find a doubling of damages from the NRC estimates after making these adjustments: (1) updating the mortality data, (2) including the impact of fine particulate matter on bronchitis, and (3) accounting for the health effects of ammonia and volatile organic compounds. Though Jaramillo & Muller only give estimates for all power plants, and not specifically for coal-fired power plants, if I apply their findings and assume that non-climate damages specifically from coal combustion are also double what NRC (2010) and Epstein (2011) had originally estimated, my best estimate of non-climate damages from coal combustion would increase from $306 billion to $612 billion (increasing total damages to $1.1 trillion). In my professional opinion, that

[63] *See, e.g.*, EPA, *Regulatory Impact Analysis for the Clean Power Plan Final Rule* at tbl. ES-6 (2015), https://www3.epa.gov/ttnecas1/docs/ria/utilities_ria_final-clean-power-plan-existing-units_2015-08.pdf.

[64] *See* Jaramillo & Muller, *supra* note 50, at 209-210.

would be an appropriate adjustment to capture some of the omitted damages, though I continue to apply a more conservative approach to my primary estimates described above.

Similarly, the social cost of greenhouse gas calculations exclude significant health, environmental, and welfare impacts, such as:

- Catastrophic impacts and tipping points, including rapid sea level rise and damages at very high temperatures;
- Death, injuries, and illnesses from omitted natural disasters and interruptions in the supply of water, food, sanitation, and shelter;
- Agricultural impacts, including food price spikes and changes from heat and precipitation extremes;
- Ocean acidification and extreme weather effects on fisheries and coral reefs;
- Wildfires, including acreage burned, health impacts from smoke, property losses, and deaths;
- Biodiversity and habitat loss, and species extinction;
- Impacts on labor productivity from extreme heat and weather;
- Changes in land and ocean transportation;
- National security impacts from regional conflict, including from refugee migration stemming from extreme weather and from food, water, and land scarcity;
- And many more categories.[65]

The Interagency Working Group on the Social Cost of Greenhouse Gases included, along with its range of three estimates across different discount rates, a fourth estimate. That fourth and

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[65] Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (Cost of Carbon Project Report, 2014), http://costofcarbon.org/reports/entry/omitted-damages-whats-missing-from-the-social-cost-of-carbon.

highest estimate, calculated as the 95th percentile of the distribution of damages estimates at a 3% discount rate, was intended to serve as an imperfect proxy for, among other things, omitted catastrophic damages.[66] In any given year over the time period of this analysis, this high 95th percentile estimate is about three times the central estimate of the social cost of greenhouse gases.[67] Applying it would, for example, increase my calculation of combustion-related climate damages from $451 billion to $1.339 trillion (increasing total damages to $1.7 trillion over 2018-2028). That large difference gives some sense of the scale of unquantified damages omitted from the social cost of greenhouse gas estimates.

### 14. Conclusion: The Best Estimate of Damages Far Exceeds BLM's Estimate of Economic Benefits from the RMPs

The table below summarizes the full results of this analysis. In addition to presenting my best estimate of damages over the 2018-2028 time period, based on central estimates and a 3% discount range, I also disclose a range of lower and higher estimates, and also extend the analysis through the year 2035 (i.e., twenty years after the RMPs were adopted, which the FEISs imply is the time period for the full production schedule). Note that all the estimates below, whether labeled as low, best, or high, are still likely substantial underestimates to the extent that they exclude significant unquantified damage categories.

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[66] IWG, 2010 TSD, *supra*.

[67] IWG, 2016 TSD & 2016 Addendum, *supra*. For example, for year 2020 emissions, the central estimate of the social cost of carbon (in 2007$) is $42, while the 95th percentile estimate is $123. Similarly, for year 2020 emissions, the central estimate of the social cost of methane (in 2007$) is $1200, while the 95th percentile estimate is $3200. For nitrous oxide, the social cost for year 2020 emissions increases from $15,000 at the central estimate to $39,000 at the 95th percentile value.

**Table 10. Summary of Best, Low, and High Estimates of Total Quantified Damages**
(billions of dollars)

| Time Period | Damages | Low Estimate (at 5% discount rate) | Best Estimate (at 3% discount rate) | High Estimate (at 2.5% discount rate) |
|---|---|---|---|---|
| 2018 to 2028 | Climate Damages from Combustion | $122 | $451 | $682 |
| | Non-Climate Damages from Coal Combustion | $87 | $306 | $1,902 |
| | Upstream GHG from Coal Mining | $3 | $6 | $8 |
| | Upstream GHG from Coal Transportation | $3 | $10 | $16 |
| | Upstream Non-GHG from Coal Transportation | $8 | $39 | $120 |
| | Unquantified Damages | Omitted damages from social cost of greenhouse gases;<br>Unquantified damages from particulate matter, mercury, and other non-greenhouse gas pollution;<br>Non-climate damages from the combustion of oil and gas;<br>Damages from the extraction and processing of oil and gas | | |
| | **Total** | $220 billion + unquantified | **$802 billion + unquantified** | $2,712 billion + unquantified |
| 2018 to 2035 | Downstream GHG | $186 | $708 | $1,079 |
| | Downstream Non-GHG | $122 | $455 | $2,869 |
| | Upstream GHG from Coal Mining | $4 | $10 | $13 |
| | Upstream GHG from Coal Transportation | $4 | $16 | $25 |
| | Upstream Non-GHG from Coal Transportation | $12 | $58 | $181 |
| | Unquantified Damages | Omitted damages from social cost of greenhouse gases;<br>Unquantified damages from particulate matter, mercury, and other non-greenhouse gas pollution;<br>Non-climate damages from the combustion of oil and gas;<br>Damages from the extraction and processing of oil and gas | | |
| | Total | $323 billion + unquantified | $1,231 billion + unquantified | $4,143 billion + unquantified |

The best estimates of damages can also be translated into other units, such as damages per unit of fossil fuels, or damages for a single year. Per unit of fossil fuels, I find:

- at least $150.86 in damages per short ton of coal produced in 2018, from the methane emissions from coal mining, the air pollution and fatalities caused by coal transportation, and the greenhouse gas, particulate matter, and other pollution from coal combustion;

- at least $17.79 in damages per barrel of oil produced in 2018, from just the greenhouse gas emissions from oil combustion (other impacts from oil extraction, processing, and combustion are unquantified but could be quite substantial); and
- at least $2.58 in damages per thousand cubic feet of natural gas produced in 2018, from just the greenhouse emissions from gas combustion (other impacts from gas extraction, transportation, and combustion are unquantified but could be quite substantial).

Finally, I compare my best estimate for damages in a single year with BLM's estimates of the economic benefits of production in that year. For the fossil fuel development anticipated in year 2018 under these two RMPs, I calculate over $80 billion in damages in that single year. Such annual economic costs dwarf any estimate of annual economic benefits from the production of coal, oil, and gas under these two RMPs. For example, the following benefits are calculated by or inferred from the two FEISs:

**Table 11. Annual Average Economic Benefits as Calculated by BLM's Methodologies**[68]

| | | |
|---|---|---|
| **Miles City Planning Area** | Labor Income from All Minerals Development | $33,231,000 |
| | Coal Rents and Royalties | $25,967,228 |
| | Oil and Gas Rents, Royalties, and Bonus Bids | $77,235,500 |
| | Taxes | Unquantified |
| | Total Miles City | $136,433,728 + unquantified |
| **Buffalo Planning Area** | Labor Income from Oil and Gas Development | $202,900,000 |
| | Oil and Gas Taxes and Royalties | $118,800,000 |
| | Coal Royalties (uncalculated by Buffalo, but quantified here using the same method that Miles City applied for its coal) | $586,781,010 |
| | Coal Rents, Employment, and Taxes | Unquantified |
| | Total Buffalo | $908,481,010 + unquantified |

[68] MCO-FEIS at 4-372, tbl. 4-78 (I count only minerals employment for Alternative E, and not BLM expenditures or payments to states, which at best represent transfers and not net gains); MCO-FEIS at 4-375, tbl. 4-81; BFO-FEIS at 1643, tbl 4.65 & 1644, tbl. 4.67. Buffalo figures are for federal oil and gas wells, *see id.* at 1651 ("The impacts of oil and gas drilling and production described in the *Economic Conditions* section of this chapter relate to activities on BLM surface and federal mineral estate within the planning area.") Recall that my analysis focuses on damages from federal oil and gas leases. Note that the Buffalo FEIS's tables are in 2011$, while the Miles City FEIS's tables do not specify a dollar-year.

The Buffalo FEIS did not estimate labor income, royalties, or other economic benefits for coal because it assumed that "economic activity related to coal . . . would be similar across all the alternatives." BFO-FEIS at 1641. Nevertheless, I can take the formula for coal royalties used in the Miles City FEIS (coal royalties=short tons * $9.91/ton market value * 11.61% royalty rate; *see* MCO-FEIS at 4-374, tbl. 4-80), and apply it to the average 510 million short tons produced per year under the Buffalo RMP, to estimate coal royalties for the Buffalo RMP (i.e., about $586,781,010 per year). The additional categories of unquantified benefits, including various taxes and coal rents under the two RMPs, would most likely contribute relatively little compared to the total figures calculated above. Altogether, BLM's calculations and methodologies identify slightly over $1 billion per year in labor income and government revenue—suggesting that the health and environmental damages from fossil fuel development under the two RMPs are nearly 80 times greater than economic benefits.

The only other calculation of economic benefits in the two FEISs is the Buffalo Field Office's calculation of annual output for oil and gas ($1,012.6 million). BFO-FEIS at 1643, tbl. 4.65. The Buffalo FEIS defines output as the market value of the product. *Id.* at 2593, tbl. U.5. The Buffalo FEIS assumes an oil price of $86.785 per barrel, and a gas price of $4.186 per mcf, *id.*, while the Miles City FEIS assumes an oil price of $88.61 per barrel, a gas price of $5.11 per mcf, and a coal price of $9.91 per ton, MCO-FEIS at 4-374, tbl. 4-80. Applying these various values to the production schedules, I can use BLM's methodology and numbers to calculate a maximum annual output of: $5.3 billion from the 532.5 million tons of coal annually (Buffalo and Miles City combined); $565 million from Miles City oil and gas; plus the $1.01 billion in annual output that BLM calculated for Buffalo oil and gas.[69] In total, BLM could at most claim an annual value of $6.8 billion in economic output. Yet compared to my calculation of economic damages, that would still suggest net damages of over $73 billion per year, not including the significant unquantified damages omitted from my estimates.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Executed on May 25, 2018 in New York, New York.

/s/Peter H. Howard

Dr. Peter H. Howard, Ph.D.

[69] It is unclear to me how Buffalo City finds $1.01 billion in annual output from Buffalo oil and gas. Using the numbers that they provide (see above), I find total revenue for Buffalo oil and gas of $447 million in 2018, increasing to $995 million in 2028.

# Attachment: Curriculum Vitae of Peter H. Howard

**Peter H. Howard**
Institute for Policy Integrity
New York University School of Law
Wilf Hall
139 MacDougal Street, Third Floor
New York, NY 10012
(551)208-1863
HowardP@mercury.law.nyu.edu

## FIELDS OF INTEREST

Environmental Economics and Policy, Climate Economics and Policy, Natural Resource Economics, Land Economics and Policy, Agri-Environmental Policy, Agricultural Marketing and Organization

## EDUCATION

**Doctor of Philosophy** June 2012
*Department of Agricultural and Resource Economics*
*University of California, Davis, CA*

Dissertation
*The Economics of Climate Change at the Local Level: The Case of Shifting Oak Habitat Range in the Tulare Lake Basin*

**Bachelor of Arts** 2003
*Economics*
*Bard College, Annandale-on-Hudson, NY*

## CURRENT POSITION

**Economics Director** February 2015-Present

*Institute for Policy Integrity, New York University School of Law*
Research, mathematical programming, econometric analysis, reviewing literature, writing, hiring and managing economic fellows, research assistants and interns, and grant writing
Projects: Conduct research, write policy briefs, and develop and submit legal comments on climate change, resource extraction, and automobile emissions
Supervisor: Richard Revesz

## PROFESSIONAL EXPERIENCE

**Economic Fellow** August 2012-February 2015

*Institute for Policy Integrity, New York University School of Law*
Research, mathematical programming, econometric analysis, reviewing literature, writing, and hiring and managing research assistants and interns
Projects: Develop an interactive website on the social cost of carbon (SCC); write policy briefs; co-write comments on the SCC; develop research projects that address potential shortcomings in the current SCC estimates
Supervisors: Michael Livermore, Richard Revesz
Work in Conjunction with: Environmental Defense Fund and Natural Resource Defense Council

**Research Assistant** April 2006-August 2012

*Department of Agricultural and Resource Economics, University of California, Davis*
Mathematical programming, data collection and cleaning, reviewing literature, econometric analysis, writing, and managing graduate student research assistants
Projects: Estimate the economic cost to California agriculture of a proposed state-wide ban on chloropicrin; estimate the economic cost to California agriculture of California Department of Pesticide Regulation's proposed surface water regulations; estimate the economic cost of fumigant and emulsifiable concentrate regulations in Fresno County, California; estimate the economic cost to California agriculture of the non-registration of methyl iodide; estimate the

economic cost of fumigant regulations in Ventura County, California; estimate the economic cost to California agriculture of California Department of Pesticide Regulation's VOC regulations
Supervisors: Rachael Goodhue, Richard Howitt
Work in Conjunction with: California Department of Food and Agriculture

**Research Assistant** January 2006-April 2006

*Department of Agricultural and Resource Economics, University of California, Davis*
Write a summary explaining the Statewide Agricultural Production Model (a mathematical programming model for California agriculture), and data collection and cleaning
*Supervisor: Richard Howitt*

**Teaching Assistant** September 2005-December 2005

*Department of Agricultural and Resource Economics, University of California, Davis*
Design lesson plans, teach, and grade
Undergraduate Course: Econometrics
Supervisor: Sandeep Mohapatra

**Conference Coordinator** January 2004-May 2004

*Association for Geo-classical Studies, NY*
Create contact list, plan conference, and contact potential attendees
Supervisor: Kris Feder

## REPORTS

**Analyzing EPA's Vehicle-Emissions Decisions**
Bethany Davis Noll, Peter Howard, and Jeffrey Shrader, May 2018

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Jayni Hein, Peter H. Howard, Alexander Leicht, Kelly Lester, March 2018.

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Elly Benson et al., March 2018.

**Comments on Arctic Drilling to the Bureau of Ocean Energy Management**
Rachel Cleetus, Denise Grab, Jayni Hein, Peter H. Howard, Benjamin Longstreth, Richard L. Revesz, Jason A. Schwartz, December 2017.

**Comments on EPA Methane Rule Stay**
Susanne Brooks et al., December 2017.

**Comments to Minnesota on the Social Cost of Carbon**
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**Comments to California Air Resources Board on the 2017 Scoping Plan Update**
Denise A. Grab, Peter H. Howard, Iliana Paul, Jason A. Schwartz, April 2017.

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Tomás Carbonell et al., December 2016.

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Laurie Johnson, Peter Howard, Megan Ceronsky, Rachel Cleetus, Richard Revesz, and Gernot Wagner. October 21, 2013.

## PUBLISHED PAPERS AND CHAPTERS

**Chapter 22 - The Social Cost of Carbon: Capturing the Costs of Future Climate Impacts in US Policy**
Peter H Howard. Forthcoming in *Managing Global Warming: an interface between technology and human issues*

**Sociopolitical Feedbacks and Climate Change**
Michael Livermore and Peter Howard. Forthcoming in *the Harvard Environmental Law Review*

**Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates**
Peter Howard and Thomas Sterner. 2017. *Environmental and Resource Economics*, 68(1), 197-225.

**Best Cost Estimate of Greenhouse Gases**
Ricky Revesz, R., M. Greenstone, M. Hanemann, M. Livermore, T. Sterner, D. Grab, P. Howard, and J. Schwartz. 2017. *Science*, 357(6352), 655-655.

**The social cost of carbon: A global imperative." Review of Environmental Economics and Policy**
Richard L. Revesz, Jason A. Schwartz, Peter H. Howard, Kenneth Arrow, Michael A. Livermore, Michael Oppenheimer, and Thomas Sterner. 2017. *Review of Environmental Economics and Policy*, 11(1), 172-173.

**Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon**
Peter Howard and Jason Schwartz. 2016. *Colum. J. Envtl. L*. 42, 203.

**Global warming: Improve economic models of climate change**
Revesz, R. L., Howard, P. H., Arrow, K., Goulder, L. H., Kopp, R. E., Livermore, M. A., ... & Sterner, T. 2014. *Nature*, *508*(7495), 173-175.

**Potential Economic Impacts of Draft Restrictions to Address Pesticide Drift and Runoff: Rice Case Study Analysis**
Kaitlyn Smoot, Luis Espino, Rachael Goodhue, Peter Howard, Karen Klonsky, and Randall G. Mutters. *Agricultural and Resource Economics Update*, University of California, Giannini Foundation 15(3) Jan/Feb 2012.

**Costs of Methyl Iodide Non-Registration**
Rachael Goodhue, Peter Howard, Richard Howitt. *Agricultural and Resource Economics Update*, University of California, Giannini Foundation 13(5) May/June 2010.

**Reducing Volatile Organic Compound Emissions from Pre-plant Soil Fumigation: Lessons from the 2008 Ventura County Emission Allowance System**
Henry An, Rachael Goodhue, Peter Howard, Richard Howitt. *Agricultural and Resource Economics Update*, University of California, Giannini Foundation 12(5) May/June 2009.

## WORKING PAPERS

**Wisdom of the Experts: Using Economic Consensus to Address Positive and Normative Uncertainties in Climate-Economic Models**
Peter Howard and Derek Sylvan

**The Wisdom of the Economic Crowd: Calibrating IAMs by Consensus**

Peter Howard and Derek Sylvan

**The Relative Price of Agriculture: The Effect of Food Security on the Social Cost of Carbon**
Peter Howard and Thomas Sterner

**Optimal Preservation of Private Open Space within a Municipality under Irreversibility and Uncertainty**
Peter Howard

**Measuring the Welfare Loss to Landowners of Future Geographic Shifts in the Suitable Habitat for Vegetation Due to Climate Change**
Peter Howard

PRESENTATIONS AND POSTERS

**Wisdom of the Experts: Using Economic Consensus to Address Positive and Normative Uncertainties in Climate-Economic Models**
Peter Howard and Derek Sylvan, 2018 at Environmental Defense Fund

**The Wisdom of the Economic Crowd: Calibrating Integrate Assessment Models Using Consensus**

Peter Howard and Derek Sylvan, 2016 AAEA Annual Meeting

**Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates**

Peter Howard and Derek Sylvan, 2016 AAEA Annual Meeting

**Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates**

Peter Howard and Derek Sylvan, 2016 EAERE Annual Meeting

**Comments on the 2017-2022 Outer Continual Shelf (OCS) Oil and Gas Leasing Program**

Peter Howard, Invited speaker to BOEM's Energy Supply/Demand Modeling, Market Substitutions, and Implications of Downstream GHGs/Climate Policy Change. June 2016.

**The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change**

Peter Howard, Invited speaker to Bard College's Environmental and Urban Studies Colloquium

**The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change**

Peter Howard and Derek Sylvan, 2015 AAEA Annual Meeting

**Estimating the Option Value of Offshore Drilling in United States' OCS Regions**
Peter Howard, 2015 Society for BCA Conference

**The Social Cost of Carbon: How the Federal Government Values Carbon Dioxide Emissions**
Peter Howard, 2015 Climate Leadership Conference sponsored by the Environmental Protection Agency

**What's the Cost of Climate Change? How to Improve the Social Cost of Carbon**
Peter Howard, Invited Speaker to Bard College

**Raising the Temperature on Food Prices: Climate Change, Food Security, and the Social Cost of Carbon**
Peter Howard and Thomas Sterner, 2014 AAEA Annual Meeting

**Loaded DICE: Refining the Meta-analysis Approach to Calibrating Climate Damage Functions**
Peter Howard and Thomas Sterner, 2014 AAEA Annual Meeting

**The Relative Price of Agriculture: the Effect of Food Security on the Social Cost of Carbon**
Peter Howard and Thomas Sterner, 2013 AAEA & CAES Joint Annual Meeting

**The Relative Price of Agriculture: the Effect of Food Security on the Social Cost of Carbon**
Peter Howard and Thomas Sterner, 2013 AERE Summer Conference

**The Relative Price of Agriculture: the Effect of Food Security on the Social Cost of Carbon**
Peter Howard, 2013 Society for BCA Conference

**Climate Change, Vegetation, and Welfare: Estimating the Welfare Loss to Landowners of Marginal Shifts in Blue Oak Habitat**
Peter Howard, 2012 AAEA Annual Meeting

**Are Pesticide Buffers Expensive? Using Positive Mathematical Programming to Estimate the Cost of Proposed Pesticide Buffers in California**
Peter Howard, Rachael Goodhue, Pierre Mérel. 2012 AAEA Annual Meeting

**Optimal Preservation of Agricultural and Environmental Land within a Municipality Under Irreversibility and Uncertainty**
Peter Howard, 2011 AAEA & NAREA Joint Annual Meeting

**Measuring the Welfare Loss to Landowners of Future Geographic Shifts in the Suitable Habitat for Vegetation Due to Climate Change**
Peter Howard, 2011 AERE Summer Conference

**Optimal Preservation of Oak Woodlands within a Municipality**
Peter Howard, 12th Occasional California Workshop on Environmental and Resource Economics (2010)

**Optimal Preservation of Oak Woodlands within a Municipality**
Peter Howard, 2010 Belpasso International Summer School on Environmental and Resource Economics, Sicily

**Optimal Preservation of Oak Woodlands within a California Municipality**
Peter Howard, 2010 Giannini ARE Student Conference

**Optimal Preservation of Oak Woodlands within a California Municipality**
Peter Howard, 2010 UCD Brown Bag Presentation

**Should More California Oak Habitat Be Protected Because of Global Warming?**
Peter Howard, 2009 AAEA & ACCI Joint Annual Meeting

**The Economic Effects of Regulations to Reduce VOC Emissions from Pesticides: The Case of Fumigants**
Peter Howard, 40th California Nematology Workshop (2008)

## BLOG

**How Much Higher? The Growing Consensus on the Federal SCC Estimate**
Peter Howard, September 2014, Cost of Carbon Pollution Project
Available at http://costofcarbon.org/blog/entry/how-much-higher-the-growing-consensus-on-the-federal-scc-estimate.

**Working Group Estimated, GAO Approved**
Peter Howard, September 2014, Cost of Carbon Pollution Project
Available at http://costofcarbon.org/blog/entry/working-group-estimated-gao-approved.

**Is the rift between Nordhaus and Stern evaporating with rising temperatures?**
Peter Howard and Charles Komanoff, August 2014, Carbon Tax Center
Available at http://www.carbontax.org/blogarchives/2014/08/21/is-the-rift-between-nordhaus-and-stern-evaporating-with-rising-temperatures/.

**Playing Catch Up to the IPCC**
Peter Howard, April 2014, Cost of Carbon Pollution Project
Available at http://costofcarbon.org/blog/entry/playing-catch-up-to-the-ipcc.

## TEACHING

- Advised on projects at Policy Integrity's Regulatory Policy Clinic (worked with New York University Law Students)
- Guest lecture at University of Cape Town
- Guest lecture for Katrina Wyman, New York University School of Law (Multiple times)
- Guest lecture for Rickey Revesz and Nathaniel Keohane, New York University School of Law
- Guest lecture for Principles of Macroeconomics at the University of North Carolina Asheville (UNCA)
- Guest lecture at Bard College (Multiple times)
- Supervised undergraduate summer interns
- Teaching Assistant in graduate school for undergraduate economics course
- Taught 7th Grade

## GRANTS, FELLOWSHIPS, AND HONORS

- Gamma Sigma Delta - The Honors Society of Agriculture 2010-Present
- Giannini Foundation Mini-grant with Richard Howitt 2009-2010
- Non-Resident Tuition Fellowship 2005-2006

## AWARDS

- UCD & Humanities Graduate Research Award 2010-11
- Jastro-Shields Graduate Research Scholarship Award 2010-2011
- UCD & Humanities Graduate Research Award 2009-2010
- Jastro-Shields Graduate Research Scholarship Award 2009-2010

## PROFESSIONAL MEMBERSHIPS

- Association of Environmental and Resource Economists
- Former Board Member of the Henry George School

## COMPUTER PROGRAMS

- Programming: Julia, MATLAB and GAMS
- Statistics: Stata
- Spatial: ArcGIS
- Microsoft office: Word, Excel, Access, PowerPoint
- Other word processing: Latex

## SELECTED MEDIA COVERAGE

- **Material World: Global Warming Is Coming for Your Shopping Cart.** Available https://www.bloomberg.com/news/articles/2017-11-28/material-world-global-warming-is-coming-for-your-shopping-cart
- **Experts reject Bjørn Lomborg's view on 2C warming target.** Available https://www.theguardian.com/environment/2017/may/21/experts-reject-bjorn-lomborg-centres-view-that-2c-warming-target-not-worth-it
- **95% consensus of expert economists: cut carbon pollution.** Available http://www.theguardian.com/environment/climate-consensus-97-per-cent/2016/jan/04/consensus-of-economists-cut-carbon-pollution
- **Economic Impacts of Carbon Dioxide Emissions Are Grossly Underestimated, a New Stanford Study Suggests.** Available http://www.forbes.com/sites/tomzeller/2015/01/13/economic-impacts-of-carbon-dioxide-emissions-are-grossly-underestimated-a-new-stanford-study-suggests/
- **Climate change may add billions to wildfire costs, study says**. Available http://www.latimes.com/nation/la-na-wildfire-climate-change-20140917-story.html
- **Wildfire Cost May Soar With Climate Change, Report Warns**. Available http://www.huffingtonpost.com/2014/09/16/wildfires-climate-change_n_5832612.html
- **'Social Cost Of Carbon' Too Low, Report** Says. Available http://www.huffingtonpost.com/2014/03/13/social-cost-carbon_n_4953638.html

## COMPUTER PROGRAMS

- Programming: Julia, MATLAB and GAMS
- Statistics: Stata
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- Microsoft office: Word, Excel, Access, PowerPoint
- Other word processing: LaTeX