EXPERT REPORT OF DR. PETER H. HOWARD, Ph.D. AND JASON A. SCHWARTZ, J.D.

Peter H. Howard and Jason A. Schwartz state and declare as follows:

1. Peter H. Howard is 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] His fields of expertise include climate economics and natural resource economics. He received his Ph.D. in Agricultural and Resource Economics from University of California–Davis. He has published in academic journals on the social cost of greenhouse gases, including in *Science*, *Nature*, *Environmental and Resource Economics*, *Harvard Environmental Law Review*, and the *Columbia Journal of Environmental Law*. His work has been cited by the Interagency Working Group on the Social Cost of Carbon, the National Academy of Sciences' Committee on Assessing Approaches to Updating the Social Cost of Carbon, and Nobel Laureate Dr. William Nordhaus. Please see his attached curriculum vitae for a full description of his professional background, experience, and relevant publications.

2. Jason A. Schwartz is the Legal Director at the Institute for Policy Integrity and an Adjunct Professor at New York University School of Law. He lives and works from Denver, Colorado. His fields of expertise include climate policy and the use of economic analysis in state and federal regulation. He received his J.D. from New York University School of Law. He has published in academic journals on the social cost of greenhouse gases, including in *Science* and the *Columbia Journal of Environmental Law*. He has published a report on the use of economic analysis in all fifty states, including Colorado, and he presented public comments to the Colorado Public Utilities Commission on incorporating the social cost of greenhouse gases into its resource planning procedure. Please see his attached curriculum vitae for more details on his professional background, experience, and relevant publications.

3. To summarize our findings: the Colorado Air Quality Control Commission (Commission) should consider the monetized environmental benefits of its proposed low emission vehicle requirements in the Colorado Low Emission Vehicle Automobile Program (CLEAR) and its amendment to establish a Colorado Zero Emission Vehicle (ZEV) Program. In particular, the

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

Commission should use the federal Interagency Working Group (IWG)'s 2016 estimates of the social cost of greenhouse gases to monetize the proposed regulatory program's climate benefits. Optimally, the proposed program's climate benefits would be calculated from quantitative estimates of the yearly upstream and downstream reductions in carbon dioxide, methane, and nitrous oxide emissions that will result from each proposed program. The IWG's separate metrics for the social cost of carbon, the social cost of methane, and the social cost of nitrous oxide can then be applied to those quantitative estimates of emissions reductions. To give a range of likely climate benefits and to reflect the fact that many important categories of climate damages currently cannot be fully monetized, the Commission should consider using at least the IWG's "central estimate" as well as its "high-impact estimate." The climate benefits of emissions reductions in each year should then be discounted back to present value and summed.

This report demonstrates how the proposed program's climate benefits can be monetized. To demonstrate the methodology for monetizing climate damages, we first need quantified estimates of the program's anticipated greenhouse gas reductions. To measure the greenhouse gas (GHG) benefits of ZEVs, we use the Commission's estimate of the lifetime GHG (CO_2, CH_4, and NO_2) emission reductions for model years 2023 to 2030.[2] Because the quantification of emissions reductions included in the Air Pollution Control Division's (APCD) Initial Economic Impact Analysis (EIA) is preliminary, provides estimated reductions for only a subset of model years (2023 to 2030), and does not include upstream emissions, we have opted to also include a complimentary set of quantified emissions estimates for CLEAR and ZEV jointly. Specifically, a July 2019 Report commissioned by Environmental Defense Fund ("ZEV Report")[3] provides, for purposes of this report, valuable data because it includes estimates of joint GHG reductions from the CLEAR and ZEV programs, provides estimates for a longer time period (calendar years 2025 to 2050), and includes both upstream and downstream emissions; the ZEV report's additional details and more complete picture allow us to generate a more fulsome example of the methodology for monetizing climate damages and to show the likely scale of the CLEAR and ZEV proposed programs' joint climate benefits. We may revisit our example

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[2] Colorado Air Pollution Control Division. Initial Economic Impact Analysis Per C.R.S. 25-7-110.5(4)(c)(I) for Revisions to AQCC Regulation Number 20: Zero Emission Vehicle Program. Request for Hearing: May 10, 2019. [hereinafter Economic Impact Analysis].

[3] Richard Rykowski, Colorado Zero Emission Vehicle Program Will Deliver Extensive Economic, Health and Environmental Benefits (Rykowski, July 2019) [hereinafter ZEV Report].

calculations once the APCD updates its initial estimates. Meanwhile, though we take no position at this time on what the proposed program's quantitative estimates of greenhouse gas emissions reductions actually will be, our report's example calculations will affirm the overall significance and likely magnitude of the proposed program's monetized climate benefits.

If, for example, for model years 2023 to 2030 the proposed ZEV program will reduce about 2.2 million metric tons of carbon dioxide and about 710 metric tons of methane, then the climate benefits from those emissions reductions in calendar years 2023 to 2040 (following the EIA's assumption of a 10-year lifespan for vehicles and the EIA's schedule of vehicle-miles traveled) would have a present value today of about $84 million under the IWG's central estimate, or about $260 million under the IWG's high-impact estimate. And if, for example, in the calendar years 2025 to 2050 the proposed CLEAR and ZEV programs will jointly reduce about 152 million metric tons of carbon dioxide, about 258,293 metric tons of methane, and about 5,581 metric tons of nitrous oxide, then the climate benefits from those emissions reductions would have a present value today of about $6.1 billion under the IWG's central estimate, or about $18.4 billion under the IWG's high-impact estimate; approximately 81% of these benefits come from a reduction in downstream emissions. Because the IWG's methodology omits many important climate damage categories that cannot fully be monetized, it is important to inform policy decisions not only by using both the central estimate and the high-impact estimate, but also by qualitatively discussing additional significant but not-yet-monetized climate effects.

Over the lifetime of the vehicles affected by the proposed program, the greenhouse gas reductions under the CLEAR and ZEV will almost certainly deliver billions of dollars' worth of cumulative climate benefits.

Colorado Can and Should Monetize the Environmental Benefits of Its Proposal

4. Monetizing the impacts of emissions changes will facilitate comparisons against other costs and benefits. Without such values, decisionmakers and the public are faced with imperfect information; by contrast, when impacts are translated into the common metric of money, decisionmakers can more readily compare society's preferences for competing priorities, and the public can more readily understand the consequences of a regulatory choice.

If an analysis discusses the externalities of emissions only qualitatively, decisionmakers and the public will both tend to overly discount the significance of the effects. In general, non-monetized effects are often irrationally treated as worthless.[4] This may be especially true when some effects (like compliance costs and fuel savings) are monetized, while other effects (like climate and health benefits) are discussed only quantitatively or qualitatively.

It also may be especially difficult for the public and decisionmakers to give appropriate consideration to climate effects that are presented only through estimates of emissions volumes. As the U.S. Environmental Protection Agency's website explains, "abstract measurements" of so many tons of greenhouse gases can be rather inscrutable for the public, unless "translat[ed] . . . into concrete terms you can understand."[5] After all, Colorado's 33 million metric tons of carbon dioxide emitted per year from transportation[6] may seem like a small fraction of global emissions,[7] and reducing that figure down to 30 million metric tons per year may seem like an insignificant difference. A well-documented mental heuristic called "probability neglect" causes people to irrationally reduce small probability risks entirely down to zero;[8] another well-document mental heuristic called "scope neglect" suggests that abstract volume estimates will fail to give people the required informational context to understand climate risks.[9] In this case, for example, many decisionmakers and interested citizens would wrongly reduce down to zero the climate risks associated these emissions, simply based on their relative scale. Similarly, while decisionmakers and the public certainly can tell that 30 million metric tons per year of carbon dioxide is less than 33 million metric tons, without any context it may be difficult to weigh the climate consequences of that 3-million-ton reduction. Yet the monetized expected benefits of the avoiding the climate damages of 3 million metric tons of carbon dioxide emitted annually from

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[4] Richard Revesz, *Quantifying Regulatory Benefits*, 102 Cal. L. Rev. 1424, 1434-35, 1442 (2014).

[5] EPA, Greenhouse Gas Equivalencies Calculator, https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (last updated Sept. 2017).

[6] Colorado Dept. of Public Health & Enviro., *Colorado Greenhouse Gas Inventory—2014 Update* (2014) at Exhibit ES-3 https://www.colorado.gov/pacific/sites/default/files/AP-COGHGInventory2014Update.pdf (projecting carbon dioxide emissions from transportation at 32.6 million metric tons in 2020).

[7] Ctr. for Climate Change and Energy Solutions, *Global Emissions*, https://www.c2es.org/content/international-emissions/ (last visited Jan. 31, 2018) (estimating global carbon dioxide emissions as approaching 35 billion metric tons per year by 2020).

[8] Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law*, 112 Yale L61, 63, 72 (2002) (drawing from the work of recent Nobel laureate economist Richard Thaler).

[9] Scope neglect, as explained by Nobel laureate Daniel Kahneman, among others, causes people to ignore the size of a problem when estimating the value of addressing the problem. For example, in one often-cited study, subjects were unable to meaningfully distinguish between the value of saving 2,000 migratory birds from drowning in uncovered oil ponds, as compared to saving 20,000 birds. Daniel Kahneman et al., *Economic Preferences or Attitude Expressions? An Analysis of Dollar Responses to Public Issues*, 19 J. Risk & Uncertainty 203, 212-213 (1999).

Colorado's transportation section—about $150 million per year in climate benefits[10]—is less likely overlooked. Monetization contextualizes the significance of the emissions reduction.

Such context is helpful to the Colorado Air Quality Control Commission in considering whether to adopt the amendments to Regulation 20 as well as in explaining the climate benefits of the decision to Coloradans. Because monetizing environmental and health benefits is useful to decisionmakers and the public, the Commission should do so when feasible. Several important categories of environmental and health benefits from the proposed adoption of CLEAR and/or ZEV in Colorado can be monetized using readily available and thoroughly vetted methodologies. The rest of this expert report focuses on how the Commission can monetize climate effects using the social cost of greenhouse gas metrics. For more details on how states can also monetize, for example, the health benefits of local air pollutant reductions, see Policy Integrity's report on *Valuing Pollution Reductions*.[11]

5. 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 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.

Colorado is undeniably already experiencing the effects of climate change. The most recent National Climate Assessment grimly reported that "projections show large declines in snowpack in the western United States and shifts to more precipitation falling as rain rather than snow in many parts of the central and eastern United States"[12]—an outcome with devastating consequences to any economic sector dependent on snow or water.[13] Colorado will also experience damages from temperature increases and spikes, more frequent and more dangerous

[10] The Interagency Working Group's central estimate of the social cost of carbon for year 2020 emissions is $42 in 2007$. *See* IWG, *2016 Technical Update*. Using the CPI Inflation Calculator, that equals about $50 in 2017$. A reduction of 3 million metric tons per year * $50/ton=$150 million (undiscounted). See *infra* for more details on such calculations.

[11] Jeffrey Shrader, Burcin Unel & Avi Zevin, *Valuing Pollution Reductions: How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy* (Policy Integrity, Electricity Policy Insight Report, 2018), *available at* https://policyintegrity.org/files/publications/Valuing_Pollution_Reductions.pdf.

[12] U.S. Global Change Research Program, *Climate Science Special Report* 91 (2018), https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf

[13] See R. Steiger et al., *A critical review of climate change risk for ski tourism*. Current Issues in Tourism, 1-37 (2017); C. Wobus et al., *Projected climate change impacts on skiing and snowmobiling: A case study of the United States*, Global environmental change, 45, 1-14 (2017).

wildfires like the 2012 High Park Fire,[14] more extreme weather events like the 2013 Boulder floods,[15] and myriad other impacts.

Economists can estimate and monetize many such categories of 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[16] of the most important categories of climate damages, including, but not limited to:

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

[14] Z. Liu et al., *Climate change and wildfire risk in an expanding wildland–urban interface: A case study from the Colorado Front Range Corridor*, Landscape Ecology, 30(10), 1943-1957 (2015); U.S. GCRP, *supra* note 12, at 450, 649, 1067.
[15] *See* U.S. GCRP, *supra* note 12, at 491.
[16] For a list of important damages categories not currently included in the models, see *infra* on unquantified damages.

- some general measures of catastrophic and ecosystem impacts.

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."[17] 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.[18] It is more accurate to apply each greenhouse gas's own social cost metric, rather than converting non-carbon gases into CO_2-equivalent units by using the relative global warming potentials of gases, because the individual metrics better reflect the damages associated with each gas's unique atmospheric chemistry.

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 and taking the average from a probability distribution; a "high-impact estimate" based on the 95th percentile of that probability distribution calculated at 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.[19] Discount rates are important because of the nature of greenhouse gases and climate change. Once emitted, greenhouse gases can linger in the atmosphere for centuries, building up the concentration of radiative-forcing pollution and affecting the climate in cumulative, non-linear ways.[20] The integrated assessment models project future climate damages over roughly a 300-year timescale. However, for a variety of reasons, society tends to care more about economic effects today than about economic effects in the

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[17] 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.

[18] 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.

[19] *See generally* 2010 TSD, *supra* note 17.

[20] Carbon dioxide also has cumulative effects on ocean acidification, in addition to cumulative radiative-forcing effects.

future.[21] A discount rate is used to take all the marginal climate damages that an additional ton of emissions emitted this year will inflict over the next 300 years, and translate those future damages back into present-day values. See *infra* for more on the IWG's choice of discount rates.

The social cost of greenhouse gases increases over time, because an additional ton of emissions will inflict greater damages in the future as emissions accumulate in the atmosphere and baseline atmospheric concentrations of greenhouse gases are already much higher. The following table shows the IWG's central and high-impact estimates for the social cost of greenhouse gases, by year of emissions.[22] The values in this table have been updated to account for inflation. IWG presented its estimates in 2007$; we have used data from the Bureau of Labor Statistics on the Consumer Price Index to convert those original figures into 2017$.

Importantly, the IWG's central estimate omits key categories of climate damages—like the risk of catastrophic and irreversible consequences.[23] The high-impact estimate was intended to serve as a partial proxy for, among other things, omitted catastrophic damages, risk aversion, and other uncertainties.[24] It is therefore important to inform policy decisions by using both sets of numbers. Additionally, the final section of this report further discusses the need to qualitatively disclose omitted climate damages and other unquantified effects.

[21] However, many experts on climate policy and economics believe that a non-zero discount rate is inappropriate in the context of long-term climate change, because society really does not or should not care less about the welfare of future generations. *See* Richard Revesz & Matthew Shahabian, *Climate Change and Future Generations*, 84 S. Cal. L. Rev. 1097 (2011).

[22] 2016 Addendum, *supra* note 18, & 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.

[23] 2010 TSD, *supra* note 17; Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (2014), https://costofcarbon.org/files/Omitted_Damages_Whats_Missing_From_the_Social_Cost_of_Carbon.pdf.

[24] 2010 TSD, *supra* note 17.

Table 1. Social Cost of Greenhouse Gas Estimates (in 2017$)[25]

	Social Cost of Carbon Dioxide (per metric ton)		Social Cost of Methane (per metric ton)		Social Cost of Nitrous Oxide (per metric ton)	
Calendar Year	IWG's Central Estimate (@ 3% Discount Rate)	IWG's High-Impact Estimate (95th Percentile)	IWG's Central Estimate	IWG's High- Impact Estimate	IWG's Central Estimate	IWG's High-Impact Estimate
2020	**$50**	**$145**	**$1,419**	**$3,783**	**$17,733**	**$46,106**
2021	$50	$149	$1,419	$3,901	$17,733	$47,288
2022	$51	$153	$1,537	$4,019	$18,915	$48,470
2023	$52	$156	$1,537	$4,138	$18,915	$49,652
2024	$53	$160	$1,655	$4,256	$18,915	$50,835
2025	**$54**	**$163**	**$1,655**	**$4,374**	**$20,097**	**$52,017**
2026	$56	$167	$1,655	$4,492	$20,097	$53,199
2027	$57	$169	$1,773	$4,611	$20,097	$54,381
2028	$58	$173	$1,773	$4,729	$21,280	$55,563
2029	$58	$176	$1,892	$4,847	$21,280	$56,746
2030	**$59**	**$180**	**$1,892**	**$4,965**	**$22,462**	**$57,928**
2031	$60	$183	$1,892	$5,083	$22,462	$59,110
2032	$61	$187	$2,010	$5,320	$22,462	$602,92
2033	$63	$190	$2,010	$5,438	$23,644	$61,474
2034	$64	$194	$2,128	$5,556	$23,644	$63,839
2035	**$65**	**$199**	**$2,128**	**$5,793**	**$24,826**	**$65,021**
2036	$66	$202	$2,246	$5,911	$24,826	$66,203
2037	$67	$206	$2,246	$6,029	$24,826	$67,385
2038	$69	$209	$2,364	$6,147	$26,008	$68,568
2039	$70	$213	$2,364	$6,384	$26,008	$69,750
2040	**$71**	**$216**	**$2,364**	**$6,502**	**$27,191**	**$70,932**
2041	$72	$220	$2,483	$6,620	$27,191	$72,114
2042	$72	$223	$2,483	$6,739	$27,191	$73,296
2043	$73	$227	$2,601	$6,857	$28,373	$75,661
2044	$74	$229	$2,601	$6,975	$28,373	$76,843
2045	**$76**	**$233**	**$2,719**	**$7,211**	**$29,555**	**$78,025**
2046	$77	$236	$2,719	$7,330	$29,555	$79,207
2047	$78	$240	$2,837	$7,448	$30,737	$80,390
2048	$79	$244	$2,837	$7,566	$30,737	$81,572
2049	$80	$247	$2,956	$7,684	$30,737	$83,936
2050	**$82**	**$251**	**$2,956**	**$7,921**	**$31,919**	**$85,118**

[25] Inflated from 2007$ to 2017$ using CPI data to adjust by a factor of 1.1822.

To monetize the climate damages associated with greenhouse gas emissions, first those emissions must be accurately quantified. Quantification issues are discussed in the following paragraphs.

Properly Quantifying Yearly Estimates of Upstream and Downstream Emissions Is Required for an Accurate Monetization of Climate Benefits

6. The APCD's Initial Economic Impact Analysis accompanying the notice of the proposed ZEV Program lists an estimate of GHG emission reductions only for model years 2023 to 2030. Furthermore, the EIA presents GHG reductions only in terms of CO_2 equivalents (CO_2e), though the Division's CO_2 and CH_4 emission estimates that were used as inputs in its CO2e calculation are available. Finally, the analysis focuses almost exclusively on downstream GHG emissions (thus, ignoring most upstream GHG emissions resulting from the extraction, refining, distribution, and storage of gasoline, coal, and natural gas).[26] To more accurately monetize the complete climate benefits of the CLEAR or ZEV programs, a more complete quantification of greenhouse gas emissions is required.

First, calculating emissions for a limited set of model years will grossly understate the benefits of the program. As mentioned already above, the social cost of greenhouse gases increases over time. The climate damage generated by each additional ton of greenhouse gas emissions depends on the background concentration of greenhouse gases in the global atmosphere. Once emitted, greenhouse gases can linger in the atmosphere for centuries, building up the concentration of radiative-forcing pollution and affecting the climate in cumulative, non-linear ways.[27] As physical and economic systems become increasingly stressed by climate change, each marginal additional ton of emissions has a greater, non-linear impact. The climate damages generated by a given amount of greenhouse pollution is therefore a function not just of the pollution's total volume but also the year of emission, and with every passing year an additional ton of emissions inflicts greater damage.[28] Optimally, the proposed program's climate benefits should be based on quantifications of year-by-year emissions changes for the

[26] See EIA, at 16. The EIA captures the majority of GHG emission reductions as "greenhouse gas emission benefits from a ZEV program would principally be in the form of carbon dioxide emission reductions from vehicle tailpipes and some associated methane emission reductions from power plants and refineries." However, the Commissions ignores all upstream emissions except some methane emission from refineries.

[27] Carbon dioxide also has cumulative effects on ocean acidification, in addition to cumulative radiative-forcing effects.

[28] *See* 2010 TSD, *supra* note 17, at 28 (explaining that the social cost of greenhouse gas estimates grow over time).

foreseeable future—based on reasonable projections of vehicles sold, miles traveled over vehicle lifetimes, and changes in the upstream production of gasoline and electricity—or at least for over the same time period as other effects, like fuel savings, are monetized. That said, any sound estimate of even a single model or calendar year's emissions reductions can be used to monetize climate benefits for that single model or calendar year.

Second, a more complete picture of the program's climate benefits would become available if the Commission were to consider each greenhouse gas individually (i.e., disaggregates by pollutant), rather than combining them into a single carbon dioxide-equivalent number. As explained above, it is more accurate to use the separate social cost metrics developed for each greenhouse gas.

Third, a more complete picture of the benefits of this program would be available if the Commission considers net changes in upstream emissions, instead of just methane emissions from the refining of natural gas. Decreased use of gasoline will decrease emissions not just from vehicle tailpipes, but also from the upstream extraction, refining, distribution, and storage of gasoline. Meanwhile, increased use of electric vehicles under the standard may increase upstream emissions from electricity generation, depending on electricity's fuel mix: as Colorado increasingly moves toward renewable energy, possible increases in upstream emissions from electricity demand will diminish.

Finally, the Commission should be sure to count all upstream and downstream emissions changes that result from the proposed program, even if the emission does not occur within the borders of Colorado. Cars sold under CLEAR and ZEV programs may be driven outside Colorado, and fuel combusted in those cars may be extracted and refined outside Colorado. Nevertheless, greenhouse gases are global pollutants that mix freely in the atmosphere and affect climate worldwide regardless of their point of origin. Because climate damages are the same regardless of where the greenhouse gas was emitted, any change in worldwide emissions fairly traceable to the proposed program should be quantified and monetized. (See *infra* for more on why a global perspective on damages is required for calculating and using the social cost of greenhouse gas metric.)

The IWG's 2016 Estimates of the Social Cost of Greenhouse Gases Are the Best Available Tools to Monetize the Climate Benefits of Colorado's Proposal

7. In 2009, an Interagency Working Group assembled experts from a dozen federal agencies and White House offices to "estimate the monetized damages associated with an incremental increase in [greenhouse gas] emissions in a given year" based on "a defensible set of input assumptions that are grounded in the existing scientific and economic literature."[29] The estimates are based on the three most cited, most peer-reviewed models built to link physical impacts to the economic damages of each additional ton of greenhouse gas emissions. The IWG ran these models using inputs and assumptions drawn from the peer-reviewed literature, and its estimates were updated every few years—most recently in 2016—to reflect the latest and best scientific and economic data.[30]

The 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.[31] In 2016, the U.S. Court of Appeals for the Seventh Circuit held that the IWG's estimates used by federal agencies were reasonable.[32] The U.S. District Courts for the Districts of Colorado and Montana have chided other agencies for their failure to use the IWG's estimates of the social cost of carbon.[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]

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[29] 2010 TSD, *supra* note 17.

[30] 2016 TSD, *supra* note 18.

[31] Gov't Accountability Office, *Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates* 12-19 (2014).

[32] Zero Zone, Inc. v. Dep't of Energy, 832 F.3d 654, 679 (7th Cir. 2016).

[33] High Country Conservation Advocates v. Forest Service, 52 F. Supp. 3d 1174, 1191 (D. Colo. 2014); Montana Environmental Information Center v. Office of Surface Mining, 15-106-M-DWM, at 40-46, Aug. 14, 2017.

[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); Decl. of Michael Hanemann ¶ 17, Wyoming v.

In March 2017, President Trump's Executive Order 13,783 disbanded the IWG.[36] But the Executive Order does not alter the fundamental legal and economic principles that support full and accurate monetization of externalities. In fact, the Executive Order presumes that agencies may continue "monetizing the value of changes in greenhouse gas emissions,"[37] and some agencies under the current administration have continued to use the IWG's estimates. For example, in August 2017, the Bureau of Ocean Energy Management called the IWG's social cost of carbon "a useful measure" and applied it to analyze the consequences of offshore oil and gas drilling,[38] and in July 2017, the Department of Energy used the IWG's 2016 estimates for carbon and methane emissions to analyze energy efficiency regulation, describing the social cost of methane as having "undergone multiple stages of peer review."[39] Most importantly, Executive Order 13,783 in no way changes the fact that the IWG's 2016 estimates still reflect the best science and economics, and the Commission should continue to rely on those estimates.

A growing list of states have begun to incorporate the IWG's estimates or methodologies into their own decisionmaking. Most relevantly, the Colorado legislature passed a law earlier this year, signed into law by the Governor, that directs the Colorado PUC to evaluate "the cost of carbon dioxide emissions" and to promulgate rules to require public utilities to include the cost of CO_2 emissions related to the evaluation of electric generation and heating resources. Starting in 2020, the Commission is required to establish a base cost of CO_2 emissions of at least \$46 per short ton—which is equivalent to the IWG's central estimate for year 2020 emissions in 2018\$ of about \$51 per metric ton—and must modify the cost thereafter based on "escalation rates" established by the IWG in the 2016 Technical Support Documents.[40] This law follows up on the March 2017 order from the Colorado Public Utilities Commission mandating that Xcel Energy consider the IWG's estimates of the social cost of carbon in a sensitivity analysis to its Electric

Interior, No. 16-00285 (D. Wyo. Dec. 14, 2016), available at https://www.edf.org/sites/default/files/content/69.1-2016.12.15-Dec-of-M-Hanemann.pdf (explaining that IWG's social cost of methane estimates are "the best available estimate of the environmental cost of an additional unit of methane emissions.").

36 Exec. Order. No. 13,783 § 5(b), 82 Fed. Reg. 16,093 (Mar. 28, 2017).

37 *Id.* § 5(c).

38 BOEM, *Draft Envtl. Impact Statement: Liberty Development Project* at 3-129, 4-246 (Aug. 2017).

39 Energy Conservation Program: Energy Conservation Standards for Walk-In Cooler and Freezer Refrigeration Systems, 82 Fed. Reg. 31,808, 31,811, 31,857 (July 10, 2017).

Resource Plan.[41] Furthermore, the following states have used the IWG's estimates and methodologies in 2018,[42] notwithstanding the federal efforts to disband the group:

- In November 2017, the California Air Resource Board incorporated the IWG's central estimates of the social cost of carbon and social cost of methane into its scoping plan for the state's updated climate change policy.[43]
- In January 2018, the Minnesota Public Utilities Commission used the IWG's methodology to develop a social cost of carbon estimate and ordered utilities to use it when planning new projects, including resource acquisition and diversification.[44]
- In March 2018, the California Public Utilities Commission's administrative law judge issued a ruling, along with a proposed staff report, which, if adopted by the Commission, would require utilities to conduct a societal cost test to determine the cost-effectiveness of distributed energy resources.[45] The approach would require utilities to calculate the climate benefits of distributed energy resources by using the social cost of carbon estimates developed by the IWG in 2016. Specifically, the ruling recommends using the IWG's "high-impact" estimate, because many of the climate damage categories most relevant to California's electricity infrastructure and economy—such as flooding, wildfires, thermal efficiency decreases, wind turbine efficiency effects, and overheating of electricity system components—are not fully incorporated into the central estimates of the social cost of carbon; consequently, the ruling "find[s] that the high impact value is the more appropriate and defensible estimate." The ruling and staff report are currently awaiting formal adoption by the California Public Utilities Commission.
- In May 2018, the New Jersey legislature approved a Zero Emission Credit program, similar to ZEC programs in New York and Illinois. While the legislation stipulates that the value of ZECs would be lower than the social cost of carbon, it acknowledges that "[t]he social cost of carbon, as calculated by the U.S. Interagency Working Group on the Social Cost of Carbon in its August 2016 Technical Update, is an accepted measure of the cost of carbon

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[41] Colo. PUC, Decision No. C17-0316, In the Matter of the Application of Public Service Company of Colorado for Approval of its 2016 Electric Resource Plan, Proceeding No. 16A-0396E.

[42] For more on these state proceedings, please see https://costofcarbon.org/states.

[43] Cal. Air Res. Bd., *California's 2017 Climate Change Scoping Plan* (2017).

[44] Minn. PUC, E-999/CI-14-643.

[45] Before the Cal. PUC, ALJ's Ruling Seeking Responses to Questions and Comment on Staff Amended Proposal on Societal Cost Test (Mar. 14, 2018), http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M212/K023/212023660.PDF.

emissions."[46] Note that in September 2018, both New York's ZECs program and Illinois's ZECs program were upheld in federal court, partly because the values for the ZECs had been rationally and explicitly tied to the IWG's social cost of carbon estimates.[47]

- In May 2018, the Washington State Utilities and Transportation Commission issued approvals for the integrated resource plans for the state's three investor-owned utilities. The acknowledgement letters indicated that, in the future, utilities would need to use a more robust estimate of the cost of carbon, and suggested the companies use the 2016 estimates from the IWG in their next integrated resource plans, scheduled for 2019.[48]
- In August 2018, the New York Independent System Operator and the New York State Public Service Commission released draft recommendations on incorporating the social cost of carbon into the wholesale electricity market in New York State through a carbon price.[49]
- In August 2018, the Nevada Public Utilities Commission updated their regulations requiring utilities to consider the economic and environmental benefits of their integrated resource plans, specifically requiring the monetization of the social costs of carbon and recommending use of the IWG estimates as reflecting "the best available science and economics."[50]
- In November 2018, *Benefits and Costs of Utility Scale and Behind the Meter Solar Resources in Maryland*, under Public Conference 44, "Transform Maryland's Electric Grid," was released. The report based its calculation of the non-monetized social value of carbon dioxide on the 2016 IWG Social Cost of Carbon.[51]
- In March 2019, the California Public Utility Commission proposed a decision that would require utilities to use the IWG's Social Cost of Carbon estimates to conduct cost-benefit analyses of proposed distributed energy resources. The staff proposal underlying the proposed decision recommended adopting the catastrophic, high-impact (95th percentile)

[46] N.J. P.L. 2018, Ch. 16, S. No. 2313 (2018), https://www.njleg.state.nj.us/2018/Bills/AL18/16_.PDF.

[47] Electric Power Supply Ass'n v. Star, No. 17-2433, 17-2445 (7th Cir., Sept. 13, 2018); Coalition for Competitive Electricity v. Zibelman, No. 17-2654-cv (2d. Cir., Sept. 27, 2018).

[48] Wash. Utilities & Transp. Comm'n, *Energy Regulators Want Closer Look at Utilities' Coal Plant Costs*, May 7, 2018, https://www.utc.wa.gov/aboutUs/Lists/News/DispForm.aspx?ID=527.

[49] NYISO, *Carbon Pricing Draft Recommendations* (2018), http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_miwg_ipptf/meeting_materials/2018-08-06/Carbon%20Pricing%20Draft%20Recommendations%2020180802.pdf.

[50] Nev. PUC, Order: Investigation and Rulemaking to Implement Senate Bill 65 (2017) (Aug. 20, 2018), http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2017-7/32153.pdf.

[51] *See generally* Denise A Grab, Iliana Paul, & Kate Fritz, *Opportunities for Valuing Climate Impacts in U.S. State Electricity Policy* (Policy Integrity Presentation 2020); https://costofcarbon.org/states.

Social Cost of Carbon estimate, which would be approximately $150 per metric ton of CO_2e for 2020 emissions.[52]

- Passed in April 2019, SB5116 requires Washington State utilities to use the IWG Social Cost of Carbon estimates at the 2.5% discount rate for integrated resource plans and clean energy action plans.[53]

Indeed, as Nevada and several other states have explicitly acknowledged, the IWG estimates do reflect the best available science and economics. The following sections explain why the IWG's choices of a global perspective and a focus on a 3% discount rate are the most reasonable choices given the state of understanding of climate science and economics.

8. The IWG selected a global perspective on damages to calculate the social cost of greenhouse gases not only because existing integrated assessment models cannot calculate a reliable and complete domestic-only estimate, but also because the United States is directly affected by international financial, security, and health spillovers from foreign climate effects; by foreign reciprocal actions; and by the extraterritorial interests of U.S. citizens. The same reasons counsel in favor of Colorado also adopting a global perspective on the social cost of greenhouse gases.

Greenhouse gases do not stay within geographic borders, but rather mix in the earth's atmosphere and affect climate worldwide. Greenhouse gases emitted in Colorado contribute to climate damages around the world just as, conversely, greenhouse gases emitted outside Colorado contribute to climate damages in Colorado. Colorado cannot solve climate change on its own. Colorado is also undeniably already benefiting from the efforts of other jurisdictions to curb their greenhouse gas emissions. From Europe's Emissions Trading System to California's newly launched cap-and-trade program, every ton of emissions reduced abroad delivers some direct benefit to Colorado. Global actions on climate change have already helped the United States as a whole avoid more than $200 billion in direct economic damages, with potentially hundreds of billions more at stake if other countries continue to take efficient actions on climate

[52] *Id.*
[53] *Id.*

change.[54] As the 19th biggest economy in the United States,[55] and given its unique mountain geography and climate, Colorado earns a significant portion of those benefits.

Colorado stands to benefit greatly if every other U.S. state and every other country applied a global social cost of greenhouse gas value to their regulatory decisions and so weighed the externalities of their emissions that will fall on Colorado. It is therefore rational for Colorado to use the social cost of greenhouse gases in its own decisionmaking, because it will encourage other states and countries to follow suit. Indeed, several significant players—including the United Kingdom, Sweden, Germany, and Norway—have already developed their own estimates of the global social cost of greenhouse gases.[56] Canada and Mexico have previously explicitly borrowed the U.S. Interagency Working Group's estimates to set their own carbon emission standards.[57] Similarly, several U.S. states have begun to apply the IWG's global estimates to their electricity policy and regulatory decisions, including California, Colorado, Illinois, Maine, Maryland, Minnesota, Nevada, New Jersey, New York, and Washington.[58]

Colorado should continue the initial stance of its PUC on the social cost of carbon and should join this growing list of states as a leader in climate policy by continuing to apply the social cost of greenhouse gases in its regulatory decisionmaking. Not only will it help continue to set a precedent for other states to follow suit, but it will be a strong signal to foreign countries that the United States remains committed to reducing the global externalities of our emissions. Such a signal is consistent with the pledge Colorado made when it joined the U.S. Climate Alliance.[59] As other states and other countries respond by likewise applying the social cost of greenhouse gases and continuing to reduce their externalities as well, Colorado will benefit.

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[54] Peter Howard & Jason Schwartz, *Foreign Action, Domestic Windfall: The U.S. Economy Stands to Gain Trillions from Foreign Climate Action* (Policy Integrity Report, 2015), http://policyintegrity.org/publications/detail/foreign-action-domestic-windfall.

[55] U.S. Bureau of Economic Analysis, *Colorado*, at 3, https://www.bea.gov/regional/bearfacts/pdf.cfm?fips=08000&areatype=STATE&geotype=3 (last published Sept. 26, 2017).

[56] Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Columb. J. Envtl. L. 203 (2017).

[57] *Id.*

[58] *See generally* Iliana Paul, Peter Howard & Jason Schwartz, *The Social Cost of Greenhouse Gases and State Policy: A Frequently Asked Questions Guide* (Policy Integrity Report 2017) http://policyintegrity.org/publications/detail/social-cost-of-ghgs-and-state-policy; https://costofcarbon.org/states; *See generally* Denise A Grab, Iliana Paul, & Kate Fritz, *Opportunities for Valuing Climate Impacts in U.S. State Electricity Policy* (Policy Integrity Report 2019) https://policyintegrity.org/publications/detail/opportunities-for-valuing-climate-impacts-in-u.s.-state-electricity-policy.

[59] Colorado Public Radio, *Colorado Joins States Upholding Paris Climate Accord*, July 11, 2017, http://www.cpr.org/news/story/colorado-climate-alliance.

Additionally, climate damages do not respect political borders. Coloradans have financial and personal interests in businesses and property located outside Colorado that may be affected by climate change. Colorado businesses depend on non-local economies to buy their exports, sell imports, and fill their supply chains. If rising temperatures and rising seas cause climate refugees or infectious disease vectors to migrate toward the United States, Colorado will feel the impacts along with the rest of the country. Colorado's economy, public health, and security are all linked to globally interconnected systems. Because climate damages occurring outside Colorado borders can spill over and affect Coloradans, a global perspective on the social cost of greenhouse gases is required.[60]

Finally, no existing methodology can calculate accurately a domestic-only estimate. The models simply were not designed to produce such estimates: for example, the models do not account for any inter-regional spillover effects. Any approximate and speculative estimates based on factors like percentage of global GDP, or share of global coastline or landmass, will be inherently misleading, as they ignore inter-regional spillover effects and extraterritorial interests of citizens. Put quite simply, there is no Colorado-only estimate of the social cost of greenhouse gases; the only currently reliable estimates are global estimates.[61]

Limiting the social cost of greenhouse gas estimates to so-called domestic-only or state-only effects is as irrational as a homeowner dumping trash in her neighbor's yard without considering whether that might attract pests and generate odor on her own property, affect her property value, or provoke her neighbor to retaliate in kind. For all these reasons, Colorado should use the IWG's global social cost of greenhouse gas estimates.

9. 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 (based on the average rate of return on Treasury notes) to drive its central estimate of the

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[60] *See Think Global*, *supra* note 56.

[61] *See also* Joint Comments to U.S. Forest Service on Use of Social Cost of Carbon in Colorado Roadless Rule, at 11-14 (Jan. 15, 2016), *available at* http://policyintegrity.org/documents/Forest_Service_SDEIS_comments.pdf (explaining there is no national-only or Colorado-only estimate of the social cost of carbon).

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."[62] The IWG specifically rejected any discount rate higher than 5% as "not considered appropriate,"[63] 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%.[64] 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."[65] In fact, the Council of Economic Advisors and other recent studies support a rate closer to 2%.[66]

While there is a growing consensus that even a 3% discount rate is too high for the context of intergenerational climate change and should give way to a declining discount rate framework, this analysis will conservatively focus on the IWG's central estimate based on the average of the probability distribution calculated at a 3% discount rate, as well as the high-impact estimate based on the 95th percentile of that distribution at the 3% discount rate. The Commission may wish to also consider the IWG's estimates at a 2.5% or 5% rate for a sensitivity analysis, though it must be consistent with the rate employed in its EIA more generally.[67] However, anything higher than a 5% rate would certainly be too high: the National Academies of Sciences, the U.S. Office of Management and Budget, and many prominent economists, including the independent economists who build the models underlying the social cost of greenhouse gas methodology, 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.[68]

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[62] 2010 TSD, *supra* note 17, at 23.

[63] 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.

[64] 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.

[65] 2010 TSD, *supra* note 17, at 23.

[66] *Supra note 64*.

[67] Kenneth J. Arrow et al., Determining Benefits and Costs for Future Generations, 341 SCIENCE 349 (2013); National Academies of Sciences, Engineering, and Medicine, Valuing climate damages: Updating estimation of the social cost of carbon dioxide at 51 (2017) [hereinafter NAS Second Report].

[68] For more details and citations, see Joint Comments to FERC on the Social Cost of Greenhouse Gases, July 25, 2018, at 12-19 https://policyintegrity.org/documents/Joint_Comments_FERC_Pipeline_NOI_Comments_072518.pdf.

For more on the IWG's discount rate and other methodological choices, please see:

- Iliana Paul, Peter Howard & Jason Schwartz, *The Social Cost of Greenhouse Gases and State Policy: A Frequently Asked Questions Guide* (Policy Integrity, 2017), https://policyintegrity.org/files/publications/SCC_State_Guidance.pdf
- Comments from Policy Integrity to the California Air Resources Board on the Advanced Clean Cars Midterm Review (2017), https://policyintegrity.org/documents/Policy_Integrity_California_ARB_ACC_comments.pdf
- Joint Comments from Policy Integrity et al. to the National Highway Traffic Safety Administration, on Quantifying and Monetizing Greenhouse Gas Emissions in the Environmental Impact Statement for Model Year 2022-2025 Corporate Average Fuel Economy Standards (2017), https://policyintegrity.org/documents/Joint_SCC_Comments_to_NHTSA_on_MY2022_Scoping.output.pdf

Methodology for Monetizing the Proposed Program's Climate Benefits

10. To demonstrate the methodology for monetizing climate damages, we first need quantified estimates of the CLEAR and ZEV programs' anticipated greenhouse gas reductions. Because the quantification of emissions reductions included in the APCD's Initial Economic Impact Analysis is preliminary, provides estimated reductions for only a subset of model years (2023 to 2030), and does not include upstream emissions, we have opted to also include a complimentary set of quantified emissions estimates for CLEAR and ZEV jointly. Specifically, a July 2019 Report commissioned by Environmental Defense Fund ("ZEV Report")[69] provides, for purposes of this report, valuable data because it includes estimates of joint GHG reductions from CLEAR and ZEV programs, proves estimates for a longer time period (calendar years 2025 to 2050), and includes both upstream and downstream emissions; the ZEV report's additional details and more complete picture allow us to generate a more fulsome example of the methodology for monetizing climate damages and to show the likely scale of the CLEAR and ZEV proposed programs' joint climate benefits. We may revisit our example calculations once the APCD updates its initial estimates. Meanwhile, though we take no position at this time on

[69] Richard Rykowski, Colorado Zero Emission Vehicle Program Will Deliver Extensive Economic, Health and Environmental Benefits (Rykowski, July 2019) [ZEV Report].

what the proposed program's quantitative estimates of greenhouse gas emissions reductions actually will be, our report's example calculations will affirm the overall significance and likely magnitude of the proposed program's monetized climate benefits.

Specifically, we use the data from the input files used to create Table 12 of the Initial Economic Impact Analysis[70] and Appendix Tables A7 to A9 of the ZEV Report. Table 12 of the Initial EIA shows the change in greenhouse gas emissions if Colorado adopts its ZEV program in addition to its low emissions vehicle program in CLEAR, and if the federal standards for fuel efficiency and vehicle emissions are rolled back to and held constant at Model Year 2020's target levels. The EIA estimates emissions reductions only for vehicles in model years 2023 to 2030, and it assumes those vehicles will have a 10-year lifespan. Using the EIA's assumptions about vehicle lifespan and the schedule for vehicle-miles traveled, we can estimate greenhouse gas reductions in calendar years 2023 through 2040 for covered vehicles. Note, however, that because the EIA does not provide estimates for vehicles after model year 2030, the estimates provided by this report based on the EIA data for calendar years 2031-2040 are only partial estimates. For example, the estimates for calendar year 2040 include only emissions reductions achieved by vehicles from model year 2030 that are in their tenth (and assumed final) year of life, but the estimates do not include any emissions reductions achieved in calendar year 2040 by vehicles of model year 2031 or beyond. As such, the estimates provided below in Table 2 of this report are conservative partial estimates. Note also that, as discussed above, the EIA data focus almost entirely on downstream emissions, and so does not reflect important changes in key upstream emission categories.

As an alternative source of emission reduction estimates, this report also uses Appendix Tables A7 to A9 in the ZEV Report, which shows the change in greenhouse gas emissions if Colorado jointly adopts its ZEV and CLEAR programs, if the ZEV market growths at 3% annually from 2026 to 2035 (i.e., Scenario 3 in the ZEV Report),[71] and if the federal standards for fuel efficiency and vehicle emissions are rolled back to and held constant at Model Year 2020's target levels. In addition to calculating downstream emissions, the ZEV Report covers

[70] Specifically, we use "CO2 & GHG Emissions" Worksheet of IEA.Technology Costs.NEXT.Scenerio 6.042219.xlsx.

[71] In Scenario 3, the ZEV report at 3 also assumes that "automakers will not exploit any GHG averaging with the higher ZEV sales under the ZEV program.

more upstream emissions than the EIA data. The estimates based on the ZEV Report data are provided below in Table 3 of this report.

Table 2. EIA's Estimates of Greenhouse Gas Savings for Vehicle Model Years 2023 to 2030, If Colorado Includes ZEV in CLEAR, by Calendar Year of Emissions (2023 through 2040) and by GHG[72]

Calendar Year	**Carbon Dioxide: Metric Tons Reduced (or Increased)**	**Methane: Metric Tons Reduced (or Increased)**	**Total GHG (CO_2e): Metric Tons Reduced (or Increased)**
2023	17,581	(0.3)	17,580
2024	38,179	(0.7)	38,178
2025	61,856	(1.1)	61,855
2026	86,742	(1.5)	86,740
2027	113,694	(1.8)	113,692
2028	142,594	(2.1)	142,592
2029	173,584	(2.4)	173,582
2030	206,218	(2.6)	206,215
2031	209,530	(2.5)	209,528
2032	211,996	(2.3)	211,994
2033	201,894	(2.1)	201,892
2034	179,866	(1.7)	179,865
2035	155,600	(1.4)	155,598
2036	129,538	(1.1)	129,537
2037	102,020	(0.8)	102,020
2038	73,631	(0.5)	73,630
2039	44,550	(0.3)	44,550
2040	14,283	(0.1)	14,283
Total	2,163,356	(710.0)	2,162,646

[72] Table 12 from the initial Environmental Impact Analysis, including the inputs into its calculation from the "CO2 & GHG Emissions" Worksheet of IEA.Technology Costs.NEXT.Scenerio 6.042219.xlsx.

Table 3. ZEV Report Estimates of Greenhouse Gas Savings If Colorado Preserves the Original Federal Targets for Fuel Economy and Vehicle Emissions (CLEAR) and Adopts the Proposed ZEV Program, by Calendar Year and GHG [73]

Calendar Year	Carbon Dioxide: Metric Tons Reduced (or Increased)	Methane: Metric Tons Reduced (or Increased)	Nitrous Oxide: Metric Tons Reduced (or Increased)	Total GHG (CO_2e): Metric Tons Reduced (or Increased)
2025	**900,000**	**1,592**	**26**	951,466
2026	1,320,000	2,312	40	1,395,272
2027	1,740,000	3,031	54	1,839,078
2028	2,160,000	3,751	67	2,282,883
2029	2,580,000	4,470	81	2,726,689
2030	**3,000,000**	**5,190**	**95**	3,170,495
2031	3,460,000	5,961	113	3,656,917
2032	3,920,000	6,733	131	4,143,339
2033	4,380,000	7,504	150	4,629,762
2034	4,840,000	8,276	168	5,116,184
2035	**5,300,000**	**9,047**	**186**	5,602,606
2036	5,680,000	9,698	202	6,005,180
2037	6,060,000	10,349	219	6,407,754
2038	6,440,000	11,000	235	6,810,328
2039	6,820,000	11,651	252	7,212,902
2040	**7,200,000**	**12,302**	**268**	7,615,476
2041	7,480,000	12,746	280	7,911,147
2042	7,760,000	13,190	292	8,206,817
2043	8,040,000	13,635	305	8,502,488
2044	8,320,000	14,079	317	8,798,158
2045	**8,600,000**	**14,523**	**329**	9,093,829
2046	8,780,000	14,832	337	9,284,713
2047	8,960,000	15,141	346	9,475,596
2048	9,140,000	15,451	354	9,666,480
2049	9,320,000	15,760	363	9,857,363
2050	**9,500,000**	**16,069**	**371**	10,048,247
Total	151,700,000	258,293	5,581	160,411,169

[73] Tables A7 to A9 of the ZEV Report (numbers have been annualized from estimates for 2025, 2030, 2035, 2040, 2045, and 2050 in bold; the GHG estimates between these five year intervals are calculated using linear interpolation similar to the social cost of carbon calculations. See IWG, Technical Update of the Social Cost of Carbon (2010), at 28. https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf

Using Tables 14, A22, and A25 of the ZEV report, we can disaggregate the joint GHG emission reductions from the proposed low emission vehicle and zero emission vehicle programs in CLEAR by emission source. Of the GHG emission reductions displayed in Table 3, approximately 82% overall come from downstream sources, with the remaining 18% from upstream sources: -7% from upstream electricity emission increases and 25% from upstream gasoline emission decreases. Downstream emissions represent about 73% of GHG emission reductions starting in 2025, and rise to about 83% of GHG emission reductions starting in 2048.

To monetize the climate damages from these estimated greenhouse gas reductions, the IWG's social cost estimates can be applied. A quantity of emissions in a given year can be multiplied by the social cost estimate for that pollutant in the given year to yield an undiscounted estimate of monetized climate damages. One discount rate is already built into that calculation. For example, a ton of carbon dioxide emitted in the year 2030 will continue to cause marginal climate damages for up to 300 years. The social cost of greenhouse gas metric already discounts all those future damages back to the year of emissions: in this case, to 2030. However, from the perspective of society in the year 2019, those damages calculated for year 2030 emissions may still be valued differently than other costs and benefits occurring today. Consequently, another round of discounting is required, to derive the present value in 2019 of the damages that will be caused by those 2030 emissions. Because the IWG's central and high-impact estimates of the social cost of greenhouse gases were calculated at a 3% discount rate, for consistency a 3% discount rate should also be used in this second round of discounting. Note that this process of discounting is unrelated to the need to adjust the IWG's estimates (originally calculated in year 2007$) to account for inflation by converting to 2017$, as shown above in Table 1 of this report.

Using the EIA's data on quantitative emissions reductions achieved by the proposed ZEV program—that is, a total reduction of about 2.2 million metric tons of CO_2e through calendar year 2040—the climate benefits from those emissions reductions have a present value today of about $86 million under the IWG's central estimate, or about $260 million under the IWG's high-impact estimate. Alternatively, using the ZEV Report's data on quantitative emissions reductions achieved jointly by the CLEAR and ZEV programs—that is, about 152 million metric tons of carbon dioxide, about 258,293 metric tons of methane, and about 5,581 metric tons of nitrous oxide—the climate benefits from those emissions reductions would have a present value today of about $6.1 billion under the IWG's central estimate, or about $18.4 billion under the

IWG's high-impact estimate; approximately 81% of these benefits come from a reduction in downstream emissions.[74] Because the IWG's methodology omits many important climate damage categories that cannot fully be monetized, it is important to inform policy decisions not only by using both the central estimate and the high-impact estimate, but also by qualitatively discussing additional significant but not-yet-monetized climate effects.

[74] The error from using global warming potentials to calculate CO_2e instead of calculating net benefits directly from CO_2, CH_4, and NO_2 is between -3% to 5% in any given year, though it averages out over time to -2% using the central SCC and -1% using the high-impact SCC for joint GHG benefits from CLEAR and ZEV programs from 2025 to 2050.

Table 4. Monetizing Climate Benefits from the Initial Environmental Impact Analysis' Estimates of GHG Emissions Savings from the Zero Emission Vehicle Program for Vehicle Model Years 2023 to 2030, by Calendar Year (2023 through 2040) and by GHG

Calendar Year	Central-Estimate: Millions $ (2017 USD)				High-Impact Estimate: Millions $ (2017 USD)			
	Carbon Dioxide	Methane	Nitrous Oxide	Total	Carbon Dioxide	Methane	Nitrous Oxide	Total
2023	1	(<1)	0	1	3	(<1)	0	3
2024	2	(<1)	0	2	6	(<1)	0	6
2025	3	(<1)	0	3	9	(<1)	0	9
2026	5	(<1)	0	5	14	(<1)	0	14
2027	6	(<1)	0	6	18	(<1)	0	18
2028	8	(<1)	0	8	23	(<1)	0	23
2029	10	(<1)	0	10	29	(<1)	0	29
2030	12	(<1)	0	12	35	(<1)	0	35
2031	12	(<1)	0	12	36	(<1)	0	36
2032	12	(<1)	0	12	37	(<1)	0	37
2033	12	(<1)	0	12	36	(<1)	0	36
2034	11	(<1)	0	11	33	(<1)	0	33
2035	9	(<1)	0	9	29	(<1)	0	29
2036	8	(<1)	0	8	25	(<1)	0	25
2037	7	(<1)	0	7	20	(<1)	0	20
2038	5	(<1)	0	5	15	(<1)	0	15
2039	3	(<1)	0	3	9	(<1)	0	9
2040	1	(<1)	0	1	3	(<1)	0	3
Total Present Value (discounted @ 3% to year 2019 value)	86	(<1)	0	86	261	(<1)	0	260

Table 5. Illustrative Example: Monetizing Climate Benefits from the ZEV Report's Estimates of Emissions Savings of the CLEAR and ZEV Programs from 2025 to 2050, by Calendar Year and GHG

Calendar Year	Central-Estimate: Millions $ (2017 USD)				High-Impact Estimate: Millions $ (2017 USD)			
	Carbon Dioxide	Methane	Nitrous Oxide	Total	Carbon Dioxide	Methane	Nitrous Oxide	Total
2025	**49**	**3**	**1**	**52**	**147**	**7**	**1**	**155**
2026	74	4	1	79	220	10	2	233
2027	99	5	1	106	294	14	3	311
2028	125	7	1	133	374	18	4	395
2029	150	8	2	160	454	22	5	480
2030	**177**	**10**	**2**	**189**	**540**	**26**	**6**	**571**
2031	208	11	3	221	633	30	7	670
2032	239	14	3	256	733	36	8	777
2033	276	15	4	295	832	41	9	882
2034	310	18	4	331	939	46	11	996
2035	**345**	**19**	**5**	**368**	**1,055**	**52**	**12**	**1,119**
2036	375	22	5	402	1,147	57	13	1,218
2037	406	23	5	435	1,248	62	15	1,325
2038	444	26	6	476	1,346	68	16	1,430
2039	477	28	7	511	1,453	74	18	1,545
2040	**511**	**29**	**7**	**548**	**1,555**	**80**	**19**	**1,654**
2041	539	32	8	578	1,646	84	20	1,750
2042	559	33	8	599	1,730	89	21	1,841
2043	587	35	9	631	1,825	93	23	1,942
2044	616	37	9	661	1,905	98	24	2,028
2045	**654**	**39**	**10**	**703**	**2,004**	**105**	**26**	**2,134**
2046	676	40	10	726	2,072	109	27	2,208
2047	699	43	11	752	2,150	113	28	2,291
2048	722	44	11	777	2,230	117	29	2,376
2049	746	47	11	803	2,302	121	30	2,454
2050	**779**	**47**	**12**	**838**	**2,385**	**127**	**32**	**2,543**
Total Present Value (discounted @ 3% to year 2019 value)	5,662	331	79	6,071	17,331	882	210	18,423

Unquantified Damages Are Likely Substantial

11. The IWG's methodology for calculating the social cost of greenhouse gases excludes 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.[75]

Consequently, while the IWG's estimates remain among the best available for government decisionmakers to use, they are widely acknowledged to be underestimates, perhaps severely so.[76] Though the IWG's high-impact estimate was developed as an imperfect proxy for some of these omissions, it is still important for analysts to make clear when using the IWG's estimates that important climate effects may be underestimated, and analysts should disclose and qualitatively discuss the important categories of omitted damages listed above.

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[75] Howard, *Omitted Damages*, *supra* note 23.
[76] *See* Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, *supra* note 35.

Conclusion

12. Monetizing the climate benefits of the greenhouse gas reductions that will be achieved by the CLEAR and ZEV programs can play a hugely important role in helping the Commission understand this regulatory choice and explain the economic benefits of the programs to Coloradans. The Colorado Low Emission Vehicle and Zero Emission Vehicle programs in CLEAR could deliver tens to hundreds of millions of dollars' worth of climate benefits per year, and many billions of dollars' worth cumulatively over the lifetime of the vehicles.

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

Executed on July 9, 2019 in New York, New York.

/s/Peter H. Howard

Dr. Peter H. Howard, Ph.D.

Executed on July 9, 2019 in Denver, Colorado.

/s/Jason A. Schwartz

Jason A. Schwartz

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

Expert Report: An Evaluation of the Revised Definition of "Waters of the United States"
Peter Howard and Jeffrey Shrader, April 2019

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

Social Cost of Greenhouse Gases and State Policy
Iliana Paul, Peter Howard and Jason Schwartz, October 2017

The Bureau of Land Management's Modeling Choice for the Federal Coal Programmatic Review
Peter Howard, June 2016. Available at http://policyintegrity.org/publications/detail/BLM-model-choice.

Illuminating the Hidden Costs of Coal
Jayni Hein and Peter Howard, December 2015. Available at http://policyintegrity.org/publications/detail/hidden-costs-of-coal.

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Foreign Action, Domestic Windfall: The U.S. Economy Stands to Gain Trillions from Foreign Climate Action
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Flammable Planet: Wildfires and the Social Cost of Carbon
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Henry An, Rachael Goodhue, Peter Howard, Richard Howitt. *Agricultural and Resource Economics Update*, University of California, Giannini Foundation 12(5) May/June 2009.

Effects of the January, 2008 CDPR Field Fumigation Regulations: Ventura County Case Study
Rachael Goodhue, Richard Howitt, Peter Howard, and Henry An. Final report submitted to the California Department of Food and Agriculture. April 2009. Available at www.cdfa.ca.gov/files/pdf/GoodhueHowitt042309.pdf.

Effects of Proposed VOC Emission Reduction Rule on California Agriculture: A Statewide Industry Analysis
Rachael Goodhue, Peter Howard, and Richard Howitt. Interim report submitted to the California Department of Food and Agriculture. June 2007.

COMMENTS

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Bethany Davis Noll, Peter H. Howard, Jason Schwartz, and Avi Zevin, May 2019.

Comments on the Replacement of the Clean Water Rule
Ian David, Bethany Davis Noll, Peter H. Howard, James Meresman, and Jason Schwartz, April 2019.

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Bethany Davis Noll, Peter H. Howard, Jason Schwartz, and Avi Zevin, Zevin December 2018.

Comments on NHTSA's Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2016 Passenger Cars and Light Trucks
Bethany Davis Noll, Peter H. Howard, Jason Schwartz, and Avi Zevin, Zevin October 2018.

Comments on Interior's Offshore Oil and Gas Leasing 2019-2024 Draft Proposed Program,
Jayni Hein, Peter H. Howard, Alexander Leicht, Kelly Lester, March 2018.

Comments on Use of the Social Cost of Greenhouse Gases in Environmental Impact Statements,
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
Denise Grab, Peter H. Howard, Iliana Paul, Jason A. Schwartz, July 2017

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Susanne Brooks et al., April 2017.

California Air Resources Board – Comments on the 2017 Scoping Plan Update
Denise A. Grab, Peter H. Howard, Iliana Paul, Jason A. Schwartz, April 2017.

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Denise A. Grab, Jayni Foley Hein, Peter H. Howard, Iliana Paul, Jason A. Schwartz, and Burcin Unel, December 2016.

Comments on the Department of Energy's Use of the Social Cost of Carbon
Tomás Carbonell et al., December 2016.

Comments on the U.S. Department of Interior's Regulatory Impact Analysis and Environmental Impact Statement for the Proposed Stream Protection Rule,
Peter Howard and Jayni Hein, August 2016.

Comments on the Draft Proposed 2017-2022 Outer Continental Shelf (OCS) Oil and Gas Leasing Program, BOEM-2014-0059
Jayni Hein and Peter Howard, June 2016.

Comments to the National Academy of Sciences on the Social Cost of Carbon
Peter Howard and Jason Schwartz, April 2016, Available at http://policyintegrity.org/what-we-do/update/national-academy-of-sciences-reviews-social-cost-of-carbon.

Comments on the Energy Conservation Standards for Walk-In Coolers and Freezers
Laurie Johnson, Peter Howard, Megan Ceronsky, Rachel Cleetus, Richard Revesz, and Gernot Wagner. November 12, 2013. Available at
http://policyintegrity.org/documents/Comments_on_use_of_SCC_in_Walk-in_Coolers_and_Commercial_Refrigeration_Rules.pdf

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

Comments on the Energy Conservation Program: Energy Conservation Standards for Metal Halide Lamp Fixtures; Proposed Rule, 78 Fed. Reg. 51,464 (August 20, 2013)
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. 2018. *Managing Global Warming: an interface between technology and human issues*

Sociopolitical Feedbacks and Climate Change
Michael Livermore and Peter Howard. 2019. *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.

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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.

WORKING PAPERS

Option value and the social cost of carbon: What are we waiting for?
Peter Howard, Alexander Golub, and Oleg Lugovoy

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

Two Heads are Better than One: Using Economic Consensus to Address Positive and Normative Uncertainties in Climate-Economic Models
Peter Howard and Derek Sylvan, 2018 at 2018 World Congress of Environmental and Resource Economists

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)

EXPERT TESTIMONY

Testimony Before the New Jersey Legislature: Senate Environment and Energy Committee and the Assembly Environment and Solid Waste Comm.
Peter Howard, April 2019

Testimony on Colorado's Law Emission Vehicle Program and the Social Cost of Carbon.
Peter H Howard and Jason A Schwartz, October 2018

WESTERN ORGANIZATION OF RESOURCE COUNCILS et al., Plaintiffs, vs. U.S. BUREAU OF LAND MANAGEMENT et al. Defendants.
Peter Howard, May 2018

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

- Adjunct Assistant Professor of Public Service, Wagner Graduate School of Public Service, Environmental Economics: developed and taught course
- 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

- Agricultural and Applied Economics Association
- 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
- Spatial: ArcGIS
- Microsoft office: Word, Excel, Access, PowerPoint
- Other word processing: Latex

Attachment: Curriculum Vitae of Jason A. Schwartz

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POSITIONS

New York University School of Law
Legal Director, Institute for Policy Integrity, January 2011—present
Legal Fellow, Institute for Policy Integrity, August 2008—January 2011

Adjunct Professor, Advanced Regulatory Policy Clinic, August 2016—present
Adjunct Professor, Regulatory Policy Clinic (formerly ARS Clinic), August 2013—May 2016

Administrative Conference of the United States
Consultant, Marketable Permits Project, October 2016—June 2017
Consultant, Petitions for Rulemaking Project, March 2014—December 2014

Pillsbury Winthrop Shaw Pittman LLP, Washington, DC
Associate, Public Policy, August 2006—July 2008

EDUCATION

New York University School of Law, New York, NY
J.D. ***magna cum laude***, May 2006
Honors: Order of the Coif; Articles Editor, *Environmental Law Journal*

Harvard University, Cambridge, MA
A.B. (Bioethics), ***magna cum laude***, June 2003

ADMISSIONS

Commonwealth of Virginia; U.S. District Court of Colorado; U.S. Courts of Appeals for the Second, Ninth, Tenth, and D.C. Circuits; U.S. Supreme Court

SELECTED, RELEVANT PUBLICATIONS

Best Cost Estimate of Greenhouse Gases, 357 Science 655 (2017) (with R. Revesz, M. Greenstone, M. Hanemann, M. Livermore, T. Sterner, D. Grab, and P. Howard)

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Approaches to Cost-Benefit Analysis (chapter in Dunlop, Claire & Claudio Radaelli, eds., *Handbook of Regulatory Impact Assessment*, 2016).

Foreign Action, Domestic Windfall: The U.S. Economy Stands to Gain Trillions from Foreign Climate Action (Policy Integrity Report, 2015) (with P. Howard).

52 Experiments with Regulatory Review: The Political and Economic Inputs into State Rulemakings (Policy Integrity Report, 2010).