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Thank you Chairman Biggs, Chairman LaHood, Ranking Member Bonamici, Ranking Member Beyer and members of the Subcommittees on Environment and Oversight for inviting me to speak today.

My name is Michael Greenstone, and I am the Milton Friedman Professor in Economics and Director of the Energy Policy Institute at the University of Chicago. My research focuses on estimating the costs and benefits of environmental quality, with a particular emphasis on the impacts of government regulations.

The social cost of carbon is a key metric used to assess the costs and benefits of environmental regulations that aim to reduce greenhouse gas emissions. It is the monetary cost of the damages caused by the release of an additional ton of carbon dioxide into the atmosphere. Simply put, it reflects the cost of climate change—accounting for the destruction of property from storms and floods, declining agricultural and labor productivity, elevated mortality rates, and so forth.

It is perhaps the most critical component of regulatory policy in this area because, by calculating the costs of climate change, the social cost of carbon allows for the calculation of the monetary benefits of regulations that reduce greenhouse gases. So, for example, a regulation that reduces carbon dioxide emissions by 10 tons would have societal benefits of $100 if the value of the social cost of carbon were $10. These benefits can then be compared to the costs that the regulation imposes to determine whether the regulation is socially beneficial on net. The social cost of carbon has been used to guide the design of about 80 regulations since its original release in 2010.

As such, I appreciate the opportunity to speak with you today about the methods and parameters used to establish the social cost of carbon. I will make several points today that I first summarize here:

1. The courts have ruled that the federal government must both regulate greenhouse gases and develop an estimate of the costs of these emissions. The United States government's social cost of carbon is a response to these rulings. It is also a key tool in the government's reliance on cost-benefit analysis to guide regulatory policy, which President Reagan helped to institutionalize in 1981.

2. The methods and models used to determine the Social Cost of Carbon have been supported by the Government Accountability Office and upheld by the courts. The National Academy of Sciences has suggested some improvements to these methods.

3. The models used to develop the social cost of carbon are based on what was the best available peer-reviewed scientific and economic studies. The updates since its initial release in 2010 reflect advances in scientific understanding.

4. The use of global damages reflects the character of the climate problem and is likely to be beneficial to the United States because it will motivate emissions cuts in other countries that benefit us. The case for using a discount rate higher than 3 percent to calculate the social cost of carbon is weak and indeed there are good reasons to choose a lower discount rate.

5. Ultimately, society needs to balance the costs to our economy of mitigating climate change today with the coming climate damages. Wishing that we did not face this trade-off will not make it go away. The social cost of carbon provides a scientifically and legally valid guidepost to help us responsibly meet this balance. Its credibility is underscored by the fact that it has been adopted by the governments of California, Illinois, Minnesota, Maine, New York, and Washington, as well as Canada and Mexico.

I. Background

The social cost of carbon builds on a long tradition that has sought to bring transparency to the regulatory process. That tradition began in 1981 when President Ronald Reagan issued an executive order institutionalizing the idea that regulatory action should be implemented only in cases when "the potential benefits to society for the regulation outweigh the potential costs to society." It sounds obvious. But this idea of applying cost-benefit analyses in the regulatory arena fundamentally altered the way in which regulations were considered. Democratic and Republican leaders have since followed President Reagan's lead, ensuring that regulations pass the cost-benefit test.

Fast forward to 2007, when the Supreme Court ruled in Massachusetts vs. U.S. EPA[1] that the U.S. Environmental Protection Agency (EPA) could not sidestep its authority to regulate the greenhouse gases that contribute to global climate change unless it could provide a scientific basis for its refusal. The EPA did the opposite, providing a scientific basis for action with the subsequent Endangerment Finding[2]. The Endangerment Finding determined that greenhouse gases—including carbon dioxide and methane, among others—threaten the public health and welfare of current and future generations.

The courts mandated that the United States regulate greenhouse gases, and the laws of the land mandated that those regulations incorporate a cost-benefit analysis. The third part of this equation was solidified in 2008, when the 9th Circuit Court of Appeals ruled[3] that the Department of Transportation needed to update its regulatory impact analysis for fuel economy rules with an estimate of the social cost of carbon. The court directed that, "while the record shows that there is a range of values, the value of carbon emissions reduction is certainly not zero."

So to review: The United States is required to regulate greenhouse gases, use a cost-benefit analysis within those regulations, and incorporate a social cost of carbon *greater than zero* into the cost-benefit analysis.

Under that landscape, the Department of Energy, the Department of Transportation and EPA began to incorporate a variety of individually developed estimates of the social cost of carbon into their regulatory analyses. These estimates were derived from academic literature and ranged from zero—which they were instructed by the court to no longer use—to $159 per metric ton of carbon dioxide emitted.

II. The Development of the U.S. Government Social Cost of Carbon and its Validation

[1] Massachusetts v. Environmental Protection Agency, 549 U.S. 497 (2007).
[2] Environmental Protection Agency, *Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act,* 40 CFR Chapter 1, Vol. 74, No. 239, 15 December, 2009.
[3] *Center for Biological Diversity v. National Highway Traffic Safety Administration,* 538 F. 3d 1172 (9th Cir. 2008)

To improve consistency in the government's use of the social cost of carbon, I, then the chief economist for President Obama's Council of Economic Advisors, along with Cass Sunstein, then the administrator of the White House Office of Information and Regulatory Affairs and now a professor at Harvard, assembled and co-led an interagency working group to determine one government-wide metric. The team consisted of the top economists, scientists and lawyers from four other offices in the Executive Office of the President and six federal agencies, including the EPA and the Departments of Agriculture, Commerce, Energy, Transportation and Treasury.

The process for developing the social cost of carbon took approximately a year and included an intense assessment of the best available peer-reviewed research, and significant debate and discussion amongst the team of climate scientists, economists, lawyers and other experts across the federal government. It also included a careful consideration of public comments on the interim values agencies had been using and an interim value determined by the interagency group. Ultimately, the interagency working group determined[4] a central estimate of $21 per metric ton. That estimate has since been revised to reflect scientific advances and is now about $36.

Both the Government Accountability Office (GAO) and the courts have judged the approach used to determine the social cost of carbon to be valid. Specifically, last August a federal court of appeals rejected a legal challenge to the social cost of carbon by a trade association of refrigerator companies. The association contended that the government lacked the legal authority to consider the social cost of carbon and that its judgments were arbitrary. The court responded that it had no doubt that Congress intended to allow consideration of the social cost of carbon and that the government's judgments were reasonable.

Further, in a 2014 report[5], the GAO said that the working group's processes and methods for developing the estimates reflected three key principles that ensured its credibility as a valid approach. First, it used consensus-based decision-making. Second, it relied largely on existing academic literature and models, including technical assistance from outside resources. Third, it disclosed limitations and incorporated new information by considering public comments and revising the estimates as updated research became available.

I'd like to elaborate further on this third point regarding public comment and the need for revisions. Since 2008, agencies have published about 80 regulatory actions for public comment in the Federal Register that use social cost of carbon estimates. The agencies received many comments on the estimates through this process, and they were discussed and considered by the working group with each update.

In fact, when the working group originally convened, it did so in part to consider public comments on the interim values that agencies had used in several rules. The working group decided to revise the estimates for the first time in 2013 after agencies received a number of public comments encouraging revisions because the models used to develop the 2010 estimates had been subsequently updated.

Then, in November 2013, in response to calls for additional transparency, the Office of Management and Budget (OMB) published a specific request for public comments on the updated social cost of carbon estimate and the methodology used. This was considered a supplement to the comments already routinely received when agencies use the social cost of carbon in specific rulemakings. In response, OMB

[4] Interagency Working Group on Social Cost of Carbon, United States Government, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, February 2010.
[5] United States Government Accountability Office, *Development of Social Cost of Carbon Estimates*, Regulatory Impact Analysis, GAO-14-663, July 2014.

received[6] about 150 substantive comments, as well as about 39,000 form letters that expressed support for the efforts to establish one government-wide metric. OMB subsequently published a detailed summary and formal response to the many thoughtful comments and, in 2015, issued an updated social cost of carbon estimate.

The need to update the social cost of carbon was driven in part by the comments received. But, it was also acknowledged as a necessity by the working group from the start. The Technical Support Document clearly states:

"It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the social cost of carbon values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process."

The working group has adhered to this founding commitment. In keeping up with the latest available science and economics, the social cost of carbon has increased as the peer review literature on climate change has advanced to uncover increases in the expected costs associated with climate change. Whether future research will lead to upward or downward adjustments, or will indicate no change, sound regulatory policy demands that the social cost of carbon reflect any advances in understanding.

Finally, governments around the world have recognized the credibility of the United States government's social cost of carbon. For example, it has been adopted by the governments of California, Illinois, Minnesota, Maine, New York, and Washington, as well as Canada and Mexico.

III. Future Revisions and the National Academies of Sciences

To ensure that the next social cost of carbon update keeps up with the latest available science and economics, in 2015 OMB directed the National Academies of Sciences (NAS) to help in providing advice on the pros and cons of potential approaches to future updates, informed by on-going public comments and the peer-reviewed literature.

The NAS released its recommendations[7] last month after a comprehensive assessment, for which I served as a reviewer. I also testified before the NAS on ways to improve the calculation of climate damages by taking advantage of new research and data. Recognizing that our social and economic understanding of the impacts of climate change have advanced greatly since the original social cost of carbon was released seven years ago, the NAS report identifies important ways to take advantage of those improvements in our understanding. It does so by providing a new framework that would strengthen the scientific basis, provide greater transparency, and improve characterization of the uncertainties of the estimates.

As a blueprint for the future, the report makes a number of recommendations aimed at helping the process "draw more readily on expertise from the wide range of scientific disciplines relevant to estimation." Importantly, this is work my colleagues and I are currently leading as part of an interdisciplinary, inter-organizational effort to calculate hyper-localized climate damages throughout the United States and globally, an effort that would provide further depth to future estimates of the social cost of carbon.

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[6] Shelanski, Howard and Maurice Obstfeld, "Estimating the Benefits from Carbon Dioxide Emissions Reductions," *The White House of President Barack Obama,* Archives, 2 July 2015.

[7] National Academies of Sciences, Engineering, and Medicine, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide*, 2017.

IV. Discount Rates and Global Damages

Before concluding my testimony today, I would like to address two common critiques of the social cost of carbon.

The first is that the discount rates used in the estimate are too low. Before assessing this directly, let me step back and explain why the discount rate is used.

Because CO_2 remains in the atmosphere on a timescale measured in centuries, the damages from the carbon we release today will occur over many, many decades. The discount rate allows us to translate those future damages into their present value. Put simply, using a discount rate helps us determine today's value of future environmental damages.

To provide a range of values for the social cost of carbon, the interagency working group chose to use three different discount rates—2.5 percent, 3 percent, and 5 percent per year, with the value associated with the 3 percent discount rate serving as the central value.

The use of discount rates is an appealing alternative to ad hoc decisions to only allow damages from particular years, such as only counting damages projected to occur this century. Their quantitative importance is seen when one recognizes that $100 of damages 100 years from now has a present value of $8.46, $5.20, and $0.76 when discounted at 2.5 percent, 3 percent, and 5 percent, respectively.

Of course, these are three potential discount rates, but when one opens the newspaper it is evident that there are many interest rates that could potentially be chosen. After all, the long run average nominal yield on junk bonds is 9.23 percent[8], and it is 6.17 percent on German 10-year bonds[9].

Which is the right discount rate for regulations that reduce carbon emissions? If we choose a discount rate that is too low, then we will pay too much today for mitigation efforts. If we choose a discount rate that is too high, then we will impose higher costs on our children and grandchildren than we intend.

The answer from economics is straightforward—we are best off if we use an interest rate from an investment that matches the structure of payoffs that climate mitigation provides. Thus, if the payoffs tend to appear predictably, like they do for holding a diversified portfolio of stocks, then we would want to use something like the average return for the stock market of 5.3 percent[10]. However, if the payoffs tend to appear in lean years when the economy is not growing or is even contracting, like they do for holding gold, then we would want to use a lower discount rate, likely below 3 percent.

It is worth expanding on why a low discount rate is sensible when dealing with climate damages. To give an example, consider gold. Why would anyone hold gold as an investment when its average return over the last 48 years is just 3.3 percent[11]? The answer is that investments like the stock market that pay off in relatively fat years are worth less than investments that pay off when times are tough. This is because additional income is relatively less valuable when the economy is growing. In contrast, people are willing

[8] 20 year average of Bank of America Merrill Lynch US High Yield Effective Yields from 1997 to 2017, retrieved from FRED, Federal Reserve Bank of St. Louis.
[9] 50 year average yield from 1965 to 2015 retrieved from FRED, Federal Reserve Bank of St. Louis.
[10] Real average annual return of S&P 500 with dividends, 1963-2012. Data from Shiller (2012): http://www.econ.yale.edu/~shiller/data.htm
[11] Real average annual return (CAGR), 1968-2016. Gold price data retrieved from FRED, Federal Reserve Bank of St. Louis.

to hold gold exactly because it is like insurance in that it does well in tough times. Additional income is more valuable when the economy isn't doing well. In other words, society's dislike of risk means that people are willing to pay a lot to protect themselves against it, and this high degree of dislike manifests itself with the very low rates of return on gold. This is a message that financial markets deliver very clearly.

A recent example comes from the Great Recession. The stock market declined by 53 percent[12], while gold increased by 14 percent[13]: gold outperformed the stock market by 67 percent. Thus, during this period of global distress, gold played the role of insurance for those investors and households who wisely hedged their exposure to major risk.

Reflecting on this example, the appropriate discount rate comes down to a judgment about whether climate change involves a substantial risk of being disruptive in a way that a significant recession or even war might be. When one considers the possibility of large temperature changes for given increases in emissions (e.g., due to higher than expected equilibrium climate sensitivity), great sea level rise in relatively short periods of time, the possibility of physical "tipping points", or human responses to these changes that include mass migration, then the case for a low discount rate appears strong. The case for using a low discount rate to determine the social cost of carbon is in many respects similar to the case for purchasing life, fire, and other insurance policies that protect against major disruptive events.

In addition to this conceptual reason to prefer low discount rates, the decline in global interest rates since the mid-1980s provide another one. The 3 percent discount rate that has been a cornerstone of regulatory analysis since 2003 draws its justification from the fact that it was roughly equal to the real rate of return on long-term government debt at that time. However, this is no longer true. For example, there has been a secular decline in the real interest rate on the 10-year Treasury note, dating back to the mid-1980s. According to a recent Council of Economic Advisors report, forecasts from the Congressional Budget Office and the Blue Chip consensus imply that the real 10-year Treasury yield is now expected to be below 2 percent.[14] The broader point is that global interest rates have declined since the social cost of carbon was set and, even setting aside the risk characteristics of payoffs from climate mitigation investments, there is a solid case that the discount rates currently used to calculate the social cost of carbon may be too high.

A second criticism of the social cost of carbon is that it measures global, rather than domestic, costs from carbon emissions. The argument goes that the task of the United States government is to improve the well-being of its citizens, and that accounting for benefits in other countries is inconsistent with that goal. The logical conclusion of this argument is that the social cost of carbon should only reflect damages that are projected to occur in the United States. However, this argument ignores the basic nature of the climate challenge, as well as the powerful political economy dynamics of the required solutions.

First, climate change is fundamentally a global, rather than domestic, phenomenon. Any country's domestic carbon emissions impose a global externality. Those emissions enter the earth's atmosphere and contribute to warming that affects the entire planet, with associated damages that vary both geographically and over time. It is undoubtedly true that challenges such as toxic spills in a U.S. river create a more straightforward calculus—the entity that imposes harm and the entity that benefits from

[12] S&P 500 (TR), % change from start of recession (December 2007) to lowest point (3/9/2009). (S&P Dow Jones Indices)
[13] Dow Jones Commodity Index (Gold) (TR), % change over same time period. (S&P Dow Jones Indices)
[14] Council of Economic Advisers, *Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate*, 2017.

regulation are both domestic in nature. Yet, the fact that climate change does not fit neatly within this paradigm is not a justifiable cause for inaction.

This raises the second issue, which relates to the international political economy. Just as U.S. emissions contribute to global damages, each ton of CO_2 emitted outside the United States inflicts damages on the United States. Thus, we would like China, India, the European Union, and other major emitters to reduce emissions to our (and their) benefit. Yet, it is highly improbable that these countries' reductions will be just as large if we fail to account for the damages our emissions cause in their countries. This, in effect, is the classic case of a collective action problem. The point is that using global damages in calculating the social cost of carbon is likely to increase the benefits we receive in the form of greater emissions reductions abroad. In many respects, the Paris Climate Agreement, where nearly 200 countries agreed to take action on carbon emissions, is a validation of the importance of treating this as a global problem.

V. Conclusions

Ultimately, society needs to balance the costs to our economy of mitigating climate change today with climate damages. Wishing that we did not face this trade-off will not make it go away.

As the courts have underscored, the social cost of carbon provides a necessary guidepost to help us responsibly meet this balance. The best available peer-reviewed research was used to set the United States government's value of the social cost of carbon and it has since been validated by the government's own accountability office and the courts. We will be better off if a social cost of carbon based on sound science, economics, and law continues to serve as a linchpin of regulatory policy.