Climate Costs and the "Value of E"

Incorporating the costs of carbon emissions into New York's electric system planning

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1. INTRODUCTION

New York has embarked on an important agenda for energy planning, attempting to monetize and incorporate the environmental costs of electricity generation in order to make price signals operate more efficiently. The results to date, however, have not reflected the current understanding of those costs. All aspects of environmental costs should be included, both those caused by local pollutants and those resulting from greenhouse gas (GHG) emissions. This report focuses on climate impacts, or costs imposed by GHG emissions. To date, only a very partial calculation of climate impacts has been included as a part of the state's proposed "Value of E" – shorthand for the value of nonmarket environmental damages attributable to the electric system.

This brief report addresses several topics in the valuation of climate impacts:

- The arguments for using damage cost calculations, and the practical and theoretical challenges to these calculations (Part 2).
- The definition of the social cost of carbon (SCC), weaknesses of the best-known SCC estimates, and the reasons for estimating global, rather than local, climate damages from emissions (Part 3).
- The alternative of marginal abatement cost valuation of GHG emissions (Part 4).
- A short summary of two recommended approaches to the climate component of the Value of E (Part 5).

The general finding is that the value of GHG damages (and hence the value of emission reduction) is much larger than the estimates proposed by New York to date. No readily available measure comes close to capturing the full impacts of greenhouse gas emissions. In order to set appropriate price signals to guide decisions by generators and customers, New York should use one of the following approaches for the GHG component of the "Value of E":

1. The best available estimate based on already-published analyses is the Interagency Working Group's SCC with a 3 percent discount rate and 95th percentile climate sensitivity (see Part 3).
2. An alternative requiring new analysis is the calculation of a long-term marginal abatement cost curve, setting a value based on abatement costs, as was done by the California Public Utilities Commission in a recent proceeding (see Part 4).

2. DAMAGE COSTS

2.1. The Arguments for Using Damages

The appropriate treatment of environmental impacts is, on one level, a long-settled question in economic theory. Almost a century ago, Pigou (1920) showed that to make markets efficient, all externalities (nonmarket costs or benefits of economic activity imposed on others) must be internalized into the market – i.e., included in prices. The market price of any product should include the cost of all the resources used to make that product; this is true for raw material inputs, for labor, and for environmental impacts. If production of a good "uses up" environmental resources such as clean air, the price of the good should include the cost of clean air – that is, the damages created by air pollution. If such pollution costs are left out of prices, the result would be a "market failure": the market would ignore the harms caused by polluting industries, and therefore production and pollution in those industries would exceed the socially optimal level.

Externality values, in theory, should be based on damage costs. But these costs can be very hard to calculate, as we will see below for GHG emissions. In a textbook model of perfect competition and perfect information, marginal abatement costs would be equal to marginal damage costs at the socially optimal level of emissions. Initially, the cost of abating a small quantity of emissions is very low, but the cost begins to rise as the quantity of emissions abatement increases. Firms would continue to invest in abatement as long as abatement costs per unit were lower than the value of avoided damages. In this theory, investment in abatement would only stop when the marginal cost of abatement reached the marginal value of avoided damages. Due to the relative simplicity of calculating abatement costs, marginal abatement costs have been used as an alternative means of estimating GHG emission damages at the margin. Below we discuss the difficulties associated with estimating marginal damages before turning to the alternative of estimating marginal abatement costs in Section 4.

2.2. Three Problems in Pricing Damages

Although damage costs are, in theory, the appropriate prices to use for externalities, they are difficult to calculate in practice. The results are often incomplete or arbitrary, due to deep problems that arise when pricing damages. Three basic problems, which occur to some extent in the analysis of any environmental damages, are particularly serious for valuation of climate damages. Inadequate treatment of these three problems, in the best-known calculations of climate damage costs (see Section 3), leads to estimates that offer incomplete pictures of climate damages. More appropriate estimates for use in New York's Value of E would undoubtedly be higher, by uncertain but perhaps large amounts.

Problem 1: Priceless values

The first problem is that climate change (like many environmental hazards) affects "priceless" values such as human life and health, natural environments, and other species. Some damages caused by climate change, such as declines in crop yields due to droughts and heat waves, or loss of coastal property to sea-level rise and storm surges, have meaningful monetary values. Other damages, of at least equal importance, do not have price tags attached. What is the value of avoidable human deaths, of the extinction of an endangered species, of the loss of unique natural environments? As the philosopher Immanuel Kant said long ago, some things have a price while others have a dignity. The all-too-common process of fabricating prices for priceless values dishonors the dignity of human life and the natural world. Since many priceless values are involved, any monetary measure of the climate externality will inevitably fail to capture the full meaning of climate-caused harms (Ackerman and Heinzerling 2004).

In practice, many aspects of climate change combine market impacts with meaningful prices and "priceless" impacts that are valuable but almost unquantifiable. Sea-level rise and storm surges destroy coastal property, which typically can be priced. The same events can also cause deaths, and destroy coastal communities, wetlands, ways of life, and long-time family homes and heirlooms, none of which can be replaced with money alone. Wildfires destroy forests, which have market values for timber, recreation, and other uses; they may also represent habitats for endangered species, and unique, irreplaceable natural environments, which are valuable but priceless. Disentangling the priced and priceless damages due to the same climate event is a labor-intensive analytical task; repeating this analysis for all climate events worldwide would require an unimaginable effort.

Problem 2: Deep uncertainty and catastrophic risk

Another problem with estimating damages is that the pace and extent of climate damages remain uncertain. We know that we do not know exactly how far and how fast climate change will unfold. (Sadly, one of the few scenarios that can be ruled out with much confidence is the possibility of escaping without serious harm.) Yet damage-based estimates of climate costs depend on inescapably uncertain projections of how fast crop yields will decline in a warming world, how fast sea levels will rise, the extent of droughts that will cause famines and refugee crises, and so on. Risks of reaching climate tipping points, at which catastrophic, irreversible losses will occur, become more and more likely as the world warms (Ackerman 2017).

Climate change involves a cascade of uncertainties, and it is worth clarifying which ones are involved here. One uncertainty concerns the value of the "climate sensitivity parameter"; it represents the strength of the emissions-to-temperature link.[1] A larger value of the climate sensitivity parameter means that the same level of carbon emissions will cause greater, faster temperature increases. It will take decades to accumulate enough data to resolve the uncertainty about this parameter; it is urgent to take action on climate change long before that.

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[1] The climate sensitivity parameter is defined as the long-run temperature increase resulting from a doubling of atmospheric concentration of CO_2-eq GHGs. There is an extensive technical discussion about the reasons why the value of this parameter remains uncertain at present.

A second, separate uncertainty, the temperature-to-damages link, i.e. how much damage is caused by a given temperature increase, is addressed (less than successfully) by climate economics models, as discussed in Section 3. A crucial, often-overlooked aspect of this discussion is uncertainty about the temperature thresholds at which catastrophic tipping points become likely.

Problem 3: Discounting the future

A third problem arises from the need to combine present and future values into a single monetary estimate of climate damages. Impacts of today's emissions will spread over decades and centuries to come. Even if future damages were known with certainty, the discount rate would remain decisive: How much is it worth spending today to avoid costs in the far future?

There is a common but misleading analogy to short-run private investment choices.[2] When an individual or firm evaluates an investment with costs now and payoffs several years or decades from now, it makes sense to use market interest rates to discount the future payoff. If the discounted payoff is less than the current cost of the investment, it is more profitable to leave the funds in financial institutions or markets. For long-term public investments, in contrast, there is no single individual who experiences costs today and benefits a century or more later. Nor is there a financial market that provides large-scale investment opportunities for a century or longer, as an alternative to investment in climate protection.

Discounting the intergenerational impacts of public policies is ultimately an ethical choice about the relative weight we assign to our welfare today vs. the lives of our descendants – including future generations whose lives will not overlap with our own. A future-oriented ethic, valuing the welfare of those generations to come, requires a near-zero discount rate (a classic source is Stern 2007; see also Ackerman 2009, among many others).[3] A lower discount rate, of course, means a greater present value of future damages. The moderately to extremely high discount rates used in many common models lead to an understatement of the true value of climate damages to people who care about future generations.

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[2] A recent NY DPS calculation of the SCC, for use in evaluating power plant externalities (actually, an estimate of the SCC net of projected RGGI carbon charges), adopted the "central estimate" IWG values (see Section 3), based on a 3 percent real discount rate, but then further discounted 20 years of projected carbon costs back to their present value, using a different discount rate. PSC Staff Letter, *Re: Case 15-E-0751 – Value of Distributed Energy Resources, Updated Environmental Value* (March 13, 2018) (Case No. 15-E-0751) (attached spreadsheet). A single discount rate should of course be used throughout any one analysis. In this case, however, the illogical combination of two discount rates made almost no difference in practice, since the time span was relatively short, and the second discount rate was only moderately higher: the average of six utilities' cost of capital, which was 6.95 percent in nominal terms, or just under 5 percent in real, inflation-adjusted terms. NY DPS calculated a constant annual (SCC – RGGI) carbon charge of $27.41 per ton; if they had used a consistent 3 percent real discount rate, the result would have been $27.94. Even if the second calculation had been done at a zero percent real discount rate, the result would have been only $28.88. Other questions could be raised about this analysis – it appears to calculate an annual carbon charge that is constant in nominal, not real, dollars – but the confusion of using two different discount rates has only a minor effect on the bottom-line result.

[3] A discount rate of exactly zero creates paradoxes in ethics and economic theory. The Stern Review (Stern 2007) proposed a (real, inflation-adjusted) discount rate of 0.1 percent plus the long-term growth rate, or 1.4 percent total in Stern's calculations. This made Stern's discounted future damage values much larger than those found in most economic models.

3. INSIDE THE SOCIAL COST OF CARBON

3.1. The Interagency Working Group Approach

The most common measure of climate damages is known as the "social cost of carbon" (SCC). It is defined as the present value of the present and future damages caused by an incremental emission of one more ton of CO_2-equivalent greenhouse gases. It is typically estimated by running a climate economics model twice, once with and once without a one-year additional spike in emissions, and then comparing the results. SCC values therefore rest on the strengths and weaknesses of the underlying climate models and how well these models address the key problems associated with pricing damages.

By far the most widely cited numerical values are the estimates by the Interagency Working Group (IWG), a task force with representatives from ten federal agencies, first convened in 2009. The IWG released an initial set of estimates in 2010, an update in 2013, and several technical corrections to the 2013 values through 2016.[4] In each set of estimates the SCC values rise over time, because emissions that occur later, when climate change is already more advanced, will cause greater incremental damages.

The IWG estimated the SCC by running three well-known climate economics models, DICE, PAGE, and FUND, and averaging the results. In effect, it outsourced the difficult problem of projecting and monetizing future climate damages to three chosen modelers. While this process involved numerous arbitrary judgments, about which more in a moment, the IWG also explored a limited range of uncertainty in two key parameters: the discount rate, and climate sensitivity (a measure of the expected severity of climate change, defined as the long-term warming that results from a doubling of the atmospheric concentration of CO_2).

Specifically, the IWG published three estimates using a median value of climate sensitivity, with discount rates of 5.0, 3.0, and 2.5 percent. A fourth estimate used the 3.0 percent discount rate and a 95th percentile value of climate sensitivity (implying faster, more damaging climate change). Federal agencies using the SCC in cost-benefit analyses, and other users, have highlighted the forecast at the 3 percent discount rate and median climate sensitivity, sometimes calling it the "central estimate." Yet there is nothing uniquely "central" about this estimate, and all four variants are readily available. In very rough, round-number terms, the 5 percent discount rate estimates are around one-third as high, the 2.5 percent discount rate estimates are around 1.5 times as high, and the 95th percentile climate sensitivity estimates are around 3 times as high as the "central estimates." In other words, there is substantial uncertainty about the SCC based on the assumed range of discount rates and climate sensitivity values alone, in addition to the numerous problems related to measuring damages.

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[4] For EPA's description of the SCC at the end of the Obama administration, see https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html. Note that all IWG publications, through 2016, report the SCC in 2007 dollars per metric ton of CO_2.

3.2. Three Models, and What They Leave Out

In addition to assumptions about the discount rate and climate sensitivity, IWG estimates of the SCC are directly dependent on the damage calculations in the three underlying models. A closer look at the methods used in each of those three models is not reassuring. Some categories of damages are left out entirely, and others are measured in an incomplete or dated manner.[5] In some cases, the difficulties of measurement would occur in any model; in other cases, the IWG models did not even try.

The problems of measurement and estimation differ by category of damages:

Market damages – climate impacts that cause measurable economic losses – have well-defined market prices and can in principle be included in the SCC. The problem arises in practice: developing global data on these damages requires an extraordinary effort. Consider the losses of coastal property to sea-level rise and storm surges. (As noted above, these are not the only storm-related damages; for instance, major storms also cause fatalities.) It is a challenging task to collect the data on property damage from a single storm, let alone the full set of major storms worldwide, or even nationwide. And that is only the beginning: major storms, and associated damages, were not unknown before climate change; how large is the increase in damages caused by global warming? There is a well-documented movement of population into coastal regions, and an increase in property at risk from storms; what fraction of the damages are attributable to this lemming-like migration toward danger, rather than storm risks alone?

Data collection and analysis on this scale would be required for each variety of climate-related market damages, including wildfires, drought and crop losses, health care costs due to the climate-induced spread of diseases, and more.

Non-market damages – climate losses that do not have well-defined prices – are even harder to calculate. Economists have estimated artificial, surrogate prices for some of these losses, but these estimates cannot convey the full meaning of, for example, the loss of human life or the extinction of species. (These priceless damages are frequently entangled with market damages, making it even harder to value non-market impacts). One of the IWG models, FUND, uses economists' valuation of the loss of human life – but argues that economic theory requires a higher value per life in higher-income countries, a claim that most climate researchers firmly reject.

Socially contingent damages, such as climate-driven increases in social conflict and migration, are widely recognized as important, but depend on public policies and the balance of social forces in ways that are virtually impossible to predict. For example, if South Asia is hit by storms, droughts, or other climate impacts, there could be an immense flow of refugees out of the region, far greater than the refugee crises of recent years. Problems like these are routinely omitted from economic models due to their unpredictability, but they have the potential to become very large and very costly, very quickly.

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[5] See Howard (2014) for a short, summary description, or National Academy of Sciences (2017) for an in-depth critique.

Catastrophic damages, resulting from climate tipping points and associated irreversible losses, are large in magnitude but, at least for now, moderately low in likelihood. Problems of prediction and measurement of these damages appear nearly insurmountable, although the risks cannot be ignored. What temperature will trigger the collapse of ice sheets in Greenland and Antarctica? Or the disruption of the South Asian monsoon, which is crucial to the region's food production? Or the abrupt loss of tropical rain forests in the Amazon and elsewhere? Or the coming crisis of ocean acidification and loss of marine life? Limited estimates of catastrophic losses have been included in PAGE, one of the three models used by the IWG, but these estimates fall far short of the worst-case risks that are central to climate policy debate.

To reflect the range of damages, each of IWG's models relies on a "damage function" – a description of the assumed effect of temperature increases (and sometimes, sea-level rise) on economic damages. The damage function is incomplete and problematical, in different ways, in each of the three models, as explained below:

- **DICE**, the best-known of the models, was designed for simplicity and transparency, not for depth of detail. It makes no attempt to evaluate the multiple categories of climate damages. Instead, it represents total damages, of all sorts, with a simple quadratic function of temperature increases, calibrated to guesstimates of global damages that will result from 2° - 3°C of warming. In earlier versions, the global damage estimates were loosely based on published estimates of the costs of warming in several specific sectors (Howard 2014), plus a limited, arbitrary guess at the average expected value of catastrophic risk. Newer versions simply use aggregate estimates of global damages, without tying them to sectoral calculations. Although William Nordhaus, the Yale economist who developed DICE, has expressed serious concern about unmonetized damages and possibilities of catastrophic risk from climate change (Nordhaus 2013), these factors play essentially no role in the DICE model.

- **PAGE**, developed by Cambridge University researcher Chris Hope for use in European policy analyses, is similar in design to DICE, with just a few additional features. Again, there is no attempt at treating most individual damage categories separately. Instead, PACE develops projections for just a few highly aggregated categories of damages, initially calibrated to be consistent with DICE. The most important innovation in PAGE is the treatment of uncertainty, including the possibility of a moderate-sized catastrophic loss; the probability of that loss is low but rises with temperature (in technical terms, it relies on Monte Carlo analysis; see Hope 2013). Perhaps due to its treatment of catastrophes, PAGE consistently produces higher SCC estimates than DICE or FUND.

- **FUND**, developed by Richard Tol and David Anthoff, is the most detailed of the three models, estimating at least 15 separate categories of damages, and assuming limited ranges of uncertainty about many key parameters (i.e., making extensive use of Monte Carlo analysis). Yet the devil is in the details; FUND's overall damage estimates are consistently lower than those of DICE or PAGE. FUND ignores catastrophic risk entirely, and in many cases relies on dated (1990s) research which implied unrealistically low damages (National Academy of Sciences 2017). In practice, all but a few of FUND's 15 damage categories turn out to be trivial in size. Offsetting some of the damages, the first few degrees of warming are projected to bring large benefits in improved crop yields and reduced incidence of tropical disease (the former based on now-obsolete 1990s research; the latter due to an assumed rapid rate of economic growth in developing countries). In some scenarios FUND finds that the greatest cost of global warming will be increased expenditure on air conditioning (Ackerman and Munitz 2012, 2016).

The average of these three models' results is the IWG estimate of the SCC.

3.3. Global or Domestic Impacts?

Cost-benefit analyses of national environmental policies usually focus exclusively on costs and benefits experienced within national boundaries. For pollutants with predominantly local impacts – that is, most pollutants – this practice is uncontroversial.

Climate change is different. GHGs persist in the atmosphere long enough to be distributed worldwide, so the impacts of GHGs emitted anywhere are felt everywhere. Most researchers have assumed that global damage costs should be used in calculating climate impacts. The SCC has almost always been based on global damages from a ton of emissions, regardless of where the emissions occur. This was the approach taken by the IWG, among many others. The Trump administration, however, has rejected this approach. EPA's 2017 proposal to repeal the Clean Power Plan outlines a revised calculation, paralleling the IWG methodology but restricted solely to domestic climate damages. The result is a domestic-only SCC that is 10 to 14 percent as large as the IWG's global values.

The IWG and others have presented a series of arguments for the use of global rather than domestic damages in calculating the SCC (all three IWG models develop global damage estimates). Since GHG emissions circulate throughout the atmosphere worldwide, every country's emissions cause global damage. If every country internalizes only the domestic damages from its own emissions, most of the global GHG externality will be ignored. As of 2015, China accounted for 28 percent of world GHG emissions, the U.S. for 15 percent, and no other country exceeded 6 percent. This means that (counting only damages from current emissions) 72 percent of climate damages in China, 85 percent in the U.S., and 94 percent or more in the rest of the world, are caused by other countries' emissions. These "cross-border" damages, the great majority of damages worldwide, would not be counted in any country's internalization of domestic damages.

Moreover, damages abroad can have consequences for the U.S., for instance, when climate change harms allies and trading partners. Climate-caused droughts and crop failures in other countries could lead to increased flows of international refugees, seeking entry to colder, richer countries such as the U.S. The Pentagon recognizes and plans for multiple climate-driven global threats to national security. A purely domestic SCC calculation would miss these international interdependencies, an important part of the climate crisis.

Finally, climate change is a problem that no country can solve alone. Since negotiations with others are required for climate mitigation, there is a diplomatic value to taking an expansive, global view of damages. It may serve as a signal to other countries, encouraging them to make similar commitments. If climate change were a one-time process of announcing a national policy and sticking to it, independent of other countries' actions, then considering only national damages, as the Trump administration proposes, might make a limited kind of sense. Since, in fact, climate negotiations are a repeated process, in which countries do influence each other, long-run national interest is better served by considering global damages and pricing carbon emissions accordingly (Kotchen 2018).

In short, economic theory, along with political intuition and common sense, supports use of the global, rather than domestic, value of the SCC.

4. MARGINAL ABATEMENT COSTS: AN ALTERNATE APPROACH

In view of the difficulties with damage estimates, it may also be worth considering the alternative of long run marginal abatement costs. GHG emissions could be priced at the per-unit cost of the most expensive abatement measure required to meet a climate target. The underlying assumption is that society has adopted a climate target, implying a decision that it is worth doing everything required to meet that target. In other words, everything included in the least-cost scenario that meets the target must be worth doing. The abatement measures in that least-cost scenario can be sorted, in order of costs per ton of carbon emissions abated. Every one of those measures, including the most expensive, must be worth doing in order to meet the target. Therefore, the value to society of (reducing) emissions must be at least as great as the cost per ton of the most expensive, or marginal, abatement measure.

Unlike the problems of externality valuation, abatement costs typically depend on well-defined, or at least definable, engineering estimates of the abatement costs required to meet a particular climate target or policy requirement. More stringent targets, such as a lower temperature limit or greater GHG reduction, will generally require more, and therefore more expensive, abatement measures.

In the short run, a modest near-term climate target may require only a low level of abatement costs. However, such near-term targets should not be confused with the level of effort over the long run required to effectively address climate change. Thus, a single year's REC prices, or even a few years' costs associated with a renewable portfolio standard, provides information only about the difficulty of reaching a near-term target, but not about the long-run value of climate protection that should be included in New York's value of E. In the long run, a target of complete or near-complete decarbonization will likely require an extensive scenario employing multiple abatement technologies. The marginal abatement cost on that long-term scenario, i.e. the highest-priced measure required to achieve an ambitious carbon reduction goal, is a better indicator of the value society places on emission reduction: by adopting a climate goal we have implicitly decided to require abatement measures, some of which cost as much as $X per ton of avoided CO_2, to protect the climate.

Logically, in other words, avoiding future climate damages must be worth at least as much as the highest-priced abatement measure included in the least-cost scenario for reaching our climate targets. In this sense, long-term marginal abatement costs provide a floor under the value of reducing GHG emissions. The true value of emission reduction could be more, but could not be less, than the most expensive abatement measure that we have implicitly or explicitly agreed upon.

This approach has been adopted by the California Public Utilities Commission (PUC), in its February 2018 decision on requirements for Integrated Resource Plans (IRPs) for load-serving entities.[6] After extensive analysis, they found that, to meet the state's 2030 target for emission reduction, the marginal abatement cost would be $150 per metric ton of avoided CO_2 in 2030. The California PUC therefore proposed a GHG price for planning purposes, rising to $150 per ton by 2030.[7]

5. RECOMMENDATION: HOW TO PICK A NUMBER

Broadly speaking, there are two options available for assigning a value to GHG emissions suitable for inclusion in New York's Value of E: either some version of the SCC, or a calculation of marginal abatement costs required to meet a long-run climate target.

Regarding the SCC option, the IWG's average of three models' estimates, the basis for the Obama-era SCC, does not represent state-of-the-art research and understanding of climate damages. A review of the SCC calculation by the National Academy of Sciences produced an in-depth critique, advocating many changes in the methodology of calculation (National Academy of Sciences 2017). Academic research, including my own among many others, has found that the irreducible uncertainties about the pace and extent of climate damages should be reflected in considerable uncertainty about the value of the SCC (Pindyck 2013; Ackerman and Stanton 2012; Dietz and Stern 2015; Weitzman 2014). Values many times higher than the IWG estimates cannot be ruled out with any confidence. This is not to say that we know how much higher the SCC should be, but rather, we do *not* know that it should *not* be much higher (the double negative is important here).

Yet despite the extensive research on catastrophic risk and uncertainty in climate economics, there is no other SCC estimate that has gained as much recognition as the IWG forecasts. It has become common to use the IWG's SCC values, with or without an understanding of their limitations. Those values should be interpreted as a floor under the (uncertain) true values, not a best guess or most likely point estimate. Ideally, one might like to adopt the results from these models at an even lower discount rate *and* a high value of climate sensitivity, but that scenario is not available in the published results. Nor, of course, is it possible to use an improved model that meets the criteria described by the National Academy of Sciences (2017), because such a model does not yet exist. For now, the IWG values appear to be the only realistic, existing option.

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[6] California PUC, "Decision setting requirements for load serving entities filing Integrated Resource Plans", Rulemaking 16-02-007, issued February 13, 2018. See p.105 and following.

[7] *Ibid.*, Figure 7, p.106. See final recommendation in Table 5, p.116.

The closest approximation to taking the climate crisis seriously, in the IWG estimates, is the scenario with 3.0 percent discount rate and 95th percentile climate sensitivity. This imposes a more ominous view of the pace of climate change, but still relies on the framework of three inadequate models with incomplete and missing categories of damages and an only moderately low discount rate. Nonetheless, as noted above, it produces SCC values roughly three times as large as the more widely quoted “central estimate”, a reflection of the importance of uncertainty and catastrophic risk in the climate policy debate.

Alternatively, the marginal abatement cost approach to valuation could be used. The recent work of the California PUC provides an example, which could be a helpful starting point. This approach requires more work, but yields a perhaps more defensible, well-defined monetary estimate. As noted, its results are dependent on the stringency of the climate target and on the costs of abatement technologies.

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