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A coal-fired power plant in Montana.

Eight priorities for calculating the social cost of carbon

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Advice to the Biden administration as it seeks to account for mounting losses from storms, wildfires and other climate impacts.

One of the first executive orders US President Joe Biden signed in January began a process to revise the social cost of carbon (SCC). This metric is used in cost–benefit analyses to inform climate policy. It puts a monetary value on the harms of climate change, by tallying all future damages incurred globally from the

emission of one tonne of carbon dioxide now.

This month, the Biden administration is publishing an interim value of the SCC, which could be used immediately. Within a year, a newly reconstituted Interagency Working Group (IWG) will issue a review of the latest scientific and economic thinking, to inform what it calls a final number. The IWG will be co-led by the Council of Economic Advisers, the Office of Management and Budget and the Office of Science and Technology Policy. The group will also assess the social costs of methane, nitrous oxide and other greenhouse gases, and will provide recommendations for using and revising the SCC.

The time is ripe for this update. Climate science and economics have advanced since 2010, when a working group in the administration of former president Barack Obama

first calculated the metric, and since its most recent update in 2016. That IWG did a careful job, but devastating storms and wildfires are now more common, and costs are mounting. Advances in attribution science mean that researchers can now link many more extreme weather events directly to climate change, and new econometric techniques help to quantify the dollar impacts. The monetary losses exceed the predictions of early models. The same goes for sea-level rise and many other types of damage.

In its 2013 revision of the SCC, the Obama IWG arrived at a central value of around US\$50 per tonne of CO₂ emitted in 2020 (all values expressed in today's dollars). It also established a range for the SCC (\$15–75) and presented an estimate at the 95th percentile (\$150). The Obama administration used these values to set

many policies, from energy-efficiency standards for refrigerators and fuel-efficiency standards for cars to emissions targets for power plants.

Former president Donald Trump changed the terms for the SCC from 2017. He limited damages to those within the United States, omitting impacts that will be felt in other countries. And he gave an unrealistically low estimate of the costs of future damages as counted in today's dollars. Together, these changes slashed the SCC to \$1–7 per tonne: too low to influence policy. Climate economists viewed those steps as illegitimate.

Biden's actions mark a return of science-based policy in the United States. An open, transparent and inclusive IWG process will help to re-establish the SCC as central to climate policy. Reversing Trump's changes will be quick and pragmatic for the interim number. Other steps require much more deliberation. Plenty of scientific and economic judgements need to be made. These include how to deal with endemic uncertainties, including sudden and irreversible 'tipping points', such as ice-sheet collapses. Ethical questions must be considered, including the consequences for vulnerable communities and future generations.

Revising the SCC will take extensive research. A 2017 study by the US National Academies of Sciences, Engineering, and Medicine proposed building a new climate-economy model¹ based on modules – separate components that handle climate change, socio-economic projections, damages, valuation and discounting (a method of converting future damages into present dollars). Each component would then be easier to update than in previous analyses, which used the average results from three models originally developed in the 1990s (one of which was the 'dynamic integrated climate-economy' model, or DICE, developed by US economist William Nordhaus).

Other nations use widely different SCC values or overall approaches². Germany's 2020 guidance presented two values: €195 (US\$235) and €680 (\$820). Some countries instead establish a goal for emissions reductions (such as the United Kingdom's 68% reduction by 2030 compared to 1990 levels) and then focus on minimizing the costs of achieving it, estimated at \$20–100 per tonne of CO₂. This is called a target-consistent approach. Others have leaned heavily on the Obama-era SCC – including Canada, the state of New York and many major corporations. The Biden review will be influential well beyond the US government.

Here we set out eight steps so that the US

SCC can pass muster legally, guide climate policy and win trust at home and abroad. It must reflect the latest and best science and economics. All assumptions – ethical and otherwise – must be made explicit.

Eight steps

We recommend the IWG does the following.

Reverse Trump's changes. Overturning these will bring the SCC back to the \$50 mark. That alone will make it relevant to climate-policy decisions, for example in helping to reverse Trump's roll-backs of Obama-era policies on cars and power plants.

The SCC must cover global damages. One tonne of CO₂ emitted in the United States causes more than 85% of its damages abroad. A metric that takes only domestic impacts into consideration undervalues the benefits of emissions reductions, and thus reduces incentives for achieving them. It also ignores interactions between countries. Even a purely domestic

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focus leads back to an SCC of close to the \$50 value using global damages, when interactions between countries are taken into account³.

Trump's discount rates were also much too high. A low value leads to a high SCC, making mitigation efforts more valuable. The two Trump values of 3% and 7% were drawn from guidance dating back to 2003. The lower rate is meant to be used to assess trends in consumption, and the higher rate for capital investments. Climate damages affect consumption, so the lower value is better. Obama's estimate assumed 3% for its central value, leading to the \$50 SCC figure. Starting at this value would be a first step. Here we discuss evidence that discount rates could be even lower.

Seek broad input. Biden is committed to restoring trust in government, and to using science to guide decisions. The IWG is an opportunity to do just that, so it should not expect unanimity. There will be differences of opinion, as in any vibrant field of inquiry. The process needs to solicit knowledge from a wide variety of experts and stakeholders, ranging from Federal Reserve economists to philosophers and legal scholars. Doing so will yield an SCC that has broad buy-in.

Even the 'final' 2021–22 number is just the start. The year-long review is an opportunity to establish an authoritative process for regular SCC updates.

Update 'damage functions'. These equations quantify the impacts of climate change on human welfare. The best way is to calculate them sector by sector, looking at measures from human deaths to crop losses. There has been a lot of progress and change in this area since the Obama days. The Climate Impact Lab, a US research collective that was explicitly formed to quantify such damages, puts the contribution of mortality to the SCC at more than \$20 per tonne of CO₂. It was almost zero in previous estimates – and this is just one component of the damages⁴.

Similarly, the thinking on how climate damages in the agricultural and energy sectors influence the SCC has flipped in light of new evidence on extreme temperatures, not just averages. Some early estimates focused on CO₂ fertilization effects and increased plant productivity to suggest that mild global warming would be good for crops⁴. Now, predictions indicate smaller or failed harvests. For the energy sector, the latest numbers from the Climate Impact Lab suggest that modest global warming might reduce heating costs overall⁴. Those conclusions could yet switch again, as physical evidence and econometric methods improve. SCC figures should be updated accordingly.

Key research questions include: how do climate damages affect long-term economic growth? What are the impacts of extreme temperatures on people's abilities? Heat decreases how well students learn and makes workers less productive, for example⁵.

Reappraise climate risks. Better costings are needed for undesirable surprises – from thawing permafrost or changes in ocean circulation to civil conflict and mass migration⁶. Work in this area should be along two lines. One is further quantification of probabilities and impacts, so that more climate risks move from 'known unknowns' into damage functions. The other is developing a framework for incorporating 'unknown unknowns'. Doing so has important effects on equity and discounting.

Address equity. The impacts of climate change affect some people much more than others. That includes slow-moving temperature rises as well as extreme events such as floods and droughts. Rich individuals might lose more money but be able to withstand

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the change, whereas a loss of \$1,000 might mean homelessness to a poorer person. Past calculations of the SCC did not factor this in, and the National Academies' 2017 report did not explore the issue. This is because existing federal regulatory guidance calls for 'distributional effects' to be catalogued and evaluated in a separate analysis.

Enter a second crucial document signed by Biden on his first day. This seeks to 'modernize regulatory review' and revisit guidance on cost-benefit analysis (see [go.nature.com/3dn3jyc](https://www.nature.com/3dn3jyc)).

To address fairness explicitly, the SCC might need to draw on 'equity weights'. These accounting adjustments are designed to reflect how a poorer person stands to lose more in terms of well-being from a loss of \$1,000 than a rich person does. A similar logic applies across high- and low-income countries. Equity weighting can proceed in two ways. One is estimation, by observing consumer behaviour or how averse to inequality society is. The other is based on ethical views of how averse to inequality society should be. Either way, more emphasis on equity can raise the SCC.

Review discount rates. In total, risk-free interest rates have fallen in the past three decades by one percentage point or more⁷. That implies a discount rate lower than the 2003 value of 3% currently assumed in the US SCC. Most experts favour discount rates of 1–3% for pay-offs in 100 years' time⁸. Some governments have adopted these low rates, including those of Germany, the Netherlands, Norway and the United Kingdom.

Much still needs to be considered. First, how do long-term rates vary with time? Economists have shown that discount rates can become lower as the time horizon lengthens. This reflects uncertainty about the future

growth in consumption⁹. How are these rates affected by climate change? A higher discount rate will be required if climate damages are positively correlated with future economic outcomes. If climate-change mitigation is more like an insurance policy that pays off in the bad times, then a lower discount rate is warranted. Catastrophic risk might outweigh these effects altogether, in favour of a lower discount rate.

Other approaches to discounting consider explicit ethical considerations related to our duties to future generations. In 2006, a UK report on the economics of climate change, called the Stern Review¹⁰, invoked intergenerational fairness to justify an average discount rate of 1.4%. Others argue that the present generation has the moral right to prioritize its own well-being. As with equity weights, current regulatory guidance limits the extent to which ethical arguments can inform discount rates in the SCC. That might change. The IWG should evaluate and draw on ethical arguments whenever permitted.

Update socio-economic pathways. Forecasts for gross domestic product and population need updating. Economic growth in developed economies has slowed by around one percentage point in total over the past four decades, to around 2% per year. Some projections suggest even lower rates, but uncertainties abound. Population projections must also be updated. Both affect predictions of emissions and damages, so the uncertainty in these estimates must be factored in when computing the SCC¹¹. A decrease in the cost of green energy, such as cheaper renewables, will also affect the SCC. For this, consistency with other forecasts is important, such as with those of the US Energy Information Administration and independent academic efforts.

Clarify limitations. In many more areas, knowledge is not ready to be included in the SCC. We don't know enough, for example, about how temperature changes will affect ecosystems and biodiversity, or how societies will react. Policymakers must recognize these caveats when they use the SCC. And researchers need to plug the gaps to improve future estimates.

A virtue and a limitation of the SCC is that it evaluates only small changes in emissions. That's fine for assessing the costs and benefits of small interventions, such as setting emissions rules in one sector – transport, say, or power. It is ill-suited, however, to policies aimed at broader targets, such as determining an economy-wide carbon tax rate to achieve net-zero emissions by some date.

There might be good reasons for nations to base climate policies on external targets of temperature or emissions, as in the United Kingdom and in Biden's plan to decarbonize the US electricity sector by 2035. This approach requires further modelling to map out a path and set milestones. Such policies can be used alongside evidence-based SCC values in regulatory cost-benefit analyses to meet international commitments under the Paris climate agreement.

Although the SCC is not the last word in climate-policy analysis, it is an essential and clarifying metric. It is feasible to improve it within one year and to launch a process for continued updates thereafter. Let's get to work.

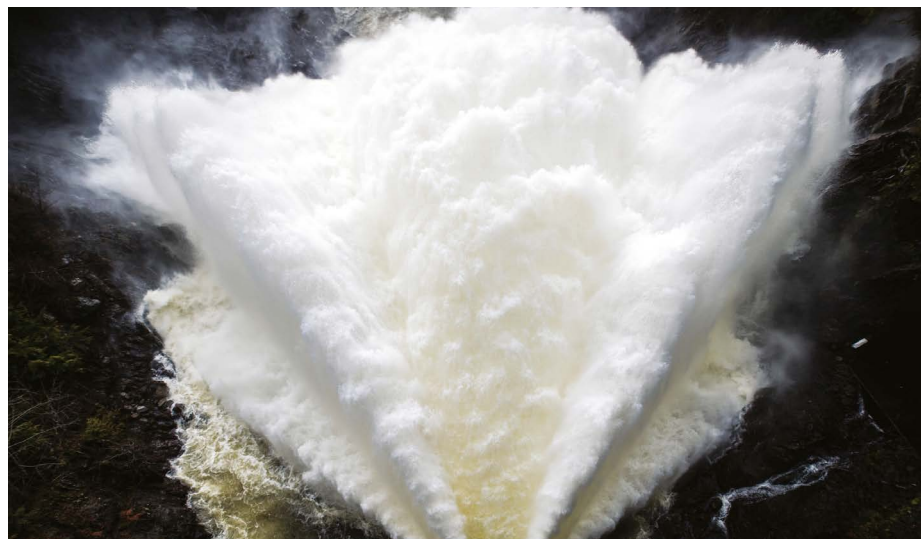
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A water plume from a hydropower plant in British Columbia. Canada has relied heavily on the Obama-era calculation for the social cost of carbon.