Climate science

The future costs of methane emissions

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An analysis of the costs of climate change caused by adding one tonne of methane to the atmosphere finds that high-income regions of the world should spend much more on efforts to lower such emissions than should low-income regions. See p.564

Which efforts should we collectively undertake to decrease emissions of carbon dioxide, methane and other greenhouse gases? One answer is that any action aimed at decreasing such emissions should be taken if the cost involved is smaller than the social cost – the monetary value of future damage caused by letting the gas escape to the atmosphere. On page 564, Errickson *et al.*[1] report estimates of the social cost of methane emissions (SC-CH_4), to which one of the main contributors is cattle farming. Their estimates are smaller than those adopted by the US government under the administration of then-president Barack Obama, even though they incorporate new, higher estimates of the warming effect of one tonne of methane. Much of the decrease is because the authors use a more sophisticated approach to calibrate their models to historical climate-system observations.

The SC-CH_4 is defined as the harm, expressed as a present monetary value, of future damage of climate change caused by releasing an extra tonne of methane into the atmosphere. It can also be thought of as the reduction in damage that results from decreasing emissions by one tonne. Its magnitude depends on the time course of the incremental effects on the climate, the resulting consequences for human well-being and the way in which changes in the well-being of current and future generations are compared. The SC-CH_4 can be estimated using an integrated assessment model (IAM), a computer program that simulates the effects of greenhouse-gas emissions on climate and on human well-being now and over future centuries.

Recognizing that every model is imperfect, Errickson *et al.* followed the suggestion of the US National Academies of Sciences, Engineering, and Medicine to mix and match model components[2] to estimate SC-CH_4. The authors combined four simple climate-system models with two damage functions (components of IAMs that translate climate change into effects on well-being). In each of the eight resulting models, uncertainties in many of the climate parameters were accounted for by randomly sampling values from probability distributions for each parameter. The authors then used each model to 'hindcast' historical climate-system parameters, and thereby refined the probability distributions so that each model's projections better fitted the historical record.

Errickson and co-workers then produced probability distributions of future climate change and associated damage by running each model repeatedly using values randomly sampled from the refined probability distributions of climate parameters. Importantly, the likelihood of climate change and damage being at the high end of the estimated range of values was found to be lower than in previous analyses that did not refine the input distributions through hindcasting. This difference more than offsets the effects of using larger estimates of the warming effect of methane, decreasing the mean estimate of SC-CH_4 by 22%.

The authors also report 'equity-weighted' values of the SC-CH_4. The underlying idea is that reductions in income have a smaller effect on the utility (a measure of well-being) of a wealthy individual than on that of someone on a lower income, and that climate policy should maximize the sum of individuals' utilities. This has implications when calculating the harmful effects of climate change across populations. For a given point in time, the conventional SC-CH_4 simply adds up the damage, measured in US dollars, for all individuals, and the value of the damage is increasingly discounted (given less influence in the analysis) the further in the future they occur. Equity weighting alters the calculations: damage experienced by low-income populations is weighted more heavily than is damage that affects wealthier populations; and damage to current generations is weighted more than is that to future generations, working on the assumption that incomes and well-being will continue to rise.

Perhaps the most striking feature of the equity-weighted SC-CH_4 is that the value differs by country (or world region; Fig. 1)). For example, for the baseline set of parameters used in Errickson and colleagues' models, the authors estimate that the equity-weighted SC-CH_4 is US$8,290 in the United States and $134 in sub-Saharan Africa. This means that the most costly US endeavours to decrease methane emissions should be more expensive than the most costly efforts undertaken by countries in sub-Saharan Africa. To put it another way, Americans and sub-Saharan Africans would sacrifice the same amount of well-being by paying about $8,000 and $100, respectively, to prevent one tonne of methane emissions; but they would provide the same climate benefit for future generations. This

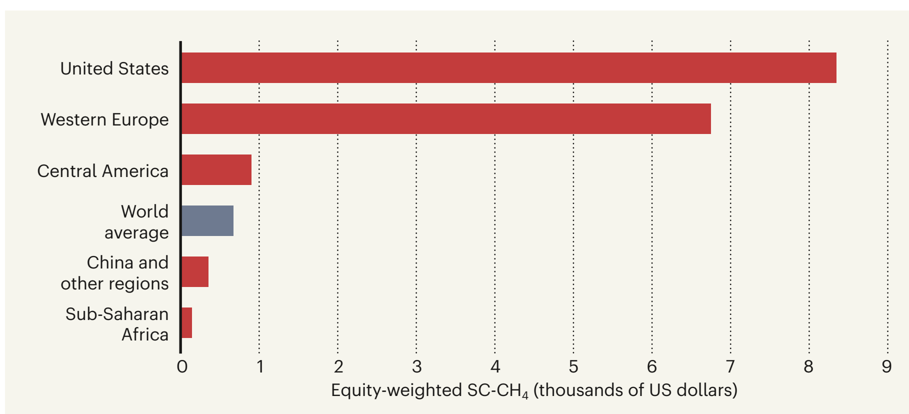

Figure 1 | The price to pay for methane emissions. Errickson *et al.*[1] have estimated the social cost of methane (SC-CH_4) – defined as the loss of human well-being. This is expressed in terms of present monetary values that are associated with future climate change caused by the release of one extra tonne of methane into the atmosphere. The authors also report the 'equity-weighted' SC-CH_4 for different regions of the world (shown here); this takes into account the average income in those regions, and the effects of loss of income on low- and high-earning populations. The equity-weighted SC-CH_4 represents the amount of money that each region could pay to prevent one tonne of methane emissions, while producing an equivalent loss of well-being. The global SC-CH_4 is also shown, for comparison. China and other regions is China, North Korea and Mongolia. (Adapted from Fig. 5c of ref. 1.)

offers a precise quantification of the "common but differentiated responsibilities" required to mitigate global warming described in the United Nations Framework Convention on Climate Change (UNFCCC).

The incremental damage produced by one extra tonne of greenhouse-gas emissions will depend on future emissions — the increment is smaller when future emissions are lower and climate change is less (see ref. 3, for example). Errickson and colleagues find that the mean conventional SC-CH_4 would be 24% smaller for a scenario involving lower greenhouse-gas emissions than was assumed in their simulations. If mitigation actions are adopted in accordance with the authors' estimates of the SC-CH_4, and if these steps reduce future emissions to levels lower than in the authors' baseline scenario, then the actual SC-CH_4 will be less than that for the baseline estimates.

The damage function is the weakest link in the chain of reasoning used to estimate the social cost of greenhouse gases. Forecasting effects on human well-being involves making highly uncertain predictions about the future composition of human activities and their sensitivity to climate — for example, will rain-fed agriculture become less prevalent with the emergence of laboratory-cultured meat? Moreover, it is difficult to quantify the benefits to well-being of protecting ecosystems and coastlines. Errickson *et al.* report that switching damage functions in their models increases the conventional SC-CH_4 by about 160%, a much higher increment than the 22% rise produced by switching climate models.

An alternative approach to setting the social cost of greenhouse gases is to constrain a climate-system parameter (such as mean surface temperature) to a maximum target

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value, and then to find the least-cost emission trajectory that satisfies it[4–6]. This approach echoes the call in the UNFCCC to stabilize greenhouse-gas concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system". Given uncertainty about what constitutes "dangerous anthropogenic interference" and the emissions that would produce it, emissions and climate trajectories should be evaluated from both perspectives: the costs of emission controls should be compared with estimates of social cost to find an emissions and climate trajectory that minimizes both; and that trajectory should be compared with possible thresholds of dangerous interference. This will ensure that models of social costs do not lead us along a path to perilously high levels of climate change.

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