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Joint Program on the Science and Policy of Global Change

CLIMATE SCIENCE AND POLICY NOTE

A Caution about Global Warming Potentials (GWPs)

MIT economists and climate scientists explain the shortcomings of the Global Warming Potential, which is an index for comparing the effects of greenhouse gases and deciding climate policy.

Policy Issue

The pressures of policy discussions are forcing unfortunate compromises in the way we compare the relative importance of greenhouse gases. The currently favored method attempts to assess Global Warming Potential or GWP, producing a single set of weights based only on the influence of different gases on the earth's radiant energy budget. The numbers that result leave out much that is important about the greenhouse phenomenon, however, and about the costs and benefits of policies to control our increasing contribution to it.

The role these numbers play in climate discussions can be compared to the role of prices in a trip to the supermarket. You select a basket of very different items—chicken, cookies, lettuce—and when you reach the checkout line you need to be able to add up their total impact on your pocketbook. Further, if the total bill turns out to be $5 more than you intended to spend, you need some way to decide which items to take out of the basket. Do two heads of lettuce add up to more than a chicken? Conveniently, supermarket items are provided with a set of relative weights (their prices) to aid comparison. Moreover, these prices are stated in units of a currency that you care about: that is, the money you are carrying with you.

At issue in climate discussions is the weighing-up of different gases, particularly CO_2, methane, nitrous oxide, and various chlorofluorocarbons (CFCs). Under the Framework Convention on Climate Change, countries are discussing agreements to control their greenhouse contributions, and each may want to reduce its "basket" of emissions by a different mix of cuts. In proposed schemes of "joint implementation," in which one country takes credit for reductions achieved in another, account must be kept of different gases reduced at different points on the globe. For such schemes to work, some way of establishing equivalence must be agreed upon.

How the GWP is Now Calculated

The GWP uses radiant energy (like that emanating from a household radiator) as the unit of measure, and it takes account of two factors influencing the effect of these gases: their potency and their lifetimes in the atmosphere. Molecule for molecule, some gases are much more effective than others at emitting heat back toward the surface of the earth, in a process called radiative "forcing." And although all additions from human emissions are removed eventually by one or another natural process, some are gone within a few years while others remain for centuries. The GWP calculation assumes an additional kilogram of a particular gas is added to the atmosphere today. This kilogram's worth of molecules exerts some radiative forcing (measured in watts) in the first instant, a slightly lower forcing in the next (because some molecules have by then been removed), and so on. These effects are added up over time to yield the "integrated radiative forcing" (measured in watt-years) of the original emission. It's like evaluating a baseball or cricket player who gets lots of hits or runs in his first year, but whose performance declines with age. The number of hits or runs in a year is analogous to the instantaneous forcing; the career total is the integrated value.

The GWP of a gas is computed by dividing its integrated radiative forcing by that of CO_2. So CO_2's GWP is defined as 1.0, nitrous oxide's might be 330, while the CFCs in your car's air conditioner might have a value of 8,500. An immediate problem is that the GWPs for all gases which are removed much faster or slower than CO_2 are very sensitive to the time horizon over which the integration is done, just as a ranking of great batters may look very different measured at 15 career years as compared to the first five. Arguments can be made for integration times ranging from 20 to 500 years, and the choice is essentially arbitrary. Consequently, the GWP for methane ranges from about 70 for a 20-year horizon, down to 11 for a 500-year horizon.

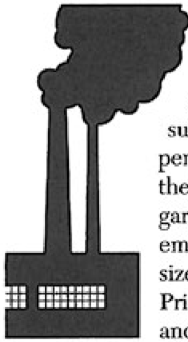
The Wrong "Currency"

Another problem with this GWP definition is that the "currency" is not what one wants for climate policy discussions. The weighting scheme should rest on the quantities that drive policy choices. When returning items to the grocery shelves to reduce your bill, it is not very helpful if the information on hand is not the price but simply the number of calories in each package. Since measures of relative importance are intended for use in comparing the benefits of reducing various emissions, they should reflect some concept of the scale of climate damage or future cleanup costs avoided. Moreover, damages and other costs avoided should be discounted: a benefit to be received in a century is worth less than one that comes tomorrow.

Under some special conditions, described by MIT economist Richard Schmalensee, a damage-based approach turns out to imply a simple GWP-like measure, with increments to future forcing appropriately discounted. This approach solves the problem of the arbitrary time horizon, but unfortunately it runs into trouble if (as appears to be the case) raising CO_2 levels also stimulates plant growth. Regrettably, we simply do not know enough about the impacts of climate change to implement a damage-based approach directly, though a good deal of research is going on in this area. A possible surrogate is some measure of regional climate change, but the capabilities here are not much better than for impacts. We are in better shape in estimating changes in global average climate, such as mean temperature. However, questions remain even at this level, because the influence of emissions on future climate is complex and highly uncertain, and no single procedure for assessing it is yet widely agreed upon.

The Complex Atmosphere

So the GWP based on radiative forcing alone is a surrogate twice removed in that it relates neither to damages avoided nor to any direct measure of climate itself. And even the current



approach neglects important features of the earth's atmosphere. The GWP calculation requires us to assume that the gases are independent of one another, and that their effects are the same regardless of the time or place of emission. In fact, as emphasized by MIT scientist Ronald Prinn, the atmospheric, oceanic, and biological processes that control the lifetimes of the gases are not in general independent; they are coupled, in some cases very closely.

For example, the lifetime of methane depends on the oxidation capacity of the local atmosphere, which is determined by the availability of an atmospheric "cleanser" chemical, the hydroxyl radical. Its concentration in turn depends on the total amount of methane present (since methane uses it up) and on the presence of other atmospheric gases to which humans contribute: NO_x (which is involved in the generation of the hydroxyl radical) and carbon monoxide (which, like methane, uses it up). The chemistry also involves effects on ozone, which is another powerful greenhouse substance. These interactions imply that the effects of methane emissions depend not only on an interplay with other gases, and their changing concentrations over time, but also on the location of the various gas sources. It matters, for example, whether NO_x originates in the tropics or northern or southern hemisphere. Similar issues arise for CO_2 and its interaction with a changing ocean circulation and land biosphere.

This complexity of earth's atmospheric chemistry calls not for a simple number but for an algorithm or computer program to calculate the relative effects of gases, even for a simple index based on radiative forcing alone. Since there is a trade-off between accuracy and the simplicity needed for policy discussions, research is underway to determine how simple the comparison method can be and still not be misleading.

A Need for Flexibility

It is not likely that the current set of GWP constants will be accepted much longer as adequate, and this expectation itself has policy implications. Moreover, MIT economist Richard Eckaus points out that nations do not all face the same potential future damages or abatement costs, so they will be interested not just in global measures but in weighting schemes that reflect their national interests. Work continues on better ways to represent the atmospheric processes, and to introduce the important concept of damages avoided. In the meantime, we should avoid writing international agreements that are tied too firmly to current GWP concepts. These agreements will need to adapt to an evolving definition and continuing reevaluation of the relative roles of the greenhouse gases.

For further background see:

1) Richard S. Eckaus, "Comparing the Effects of Greenhouse Gas Emissions on Global Warming," *The Energy Journal*, Vol. 13, No.1, 1992.

2) Ronald G. Prinn, "The Interactive Atmosphere: Global Atmospheric-Biospheric Chemistry," *Ambio—A Journal of the Human Environment*, Vol. 23, No. 1, Feb. 1994.

3) Richard Schmalensee, "Comparing Greenhouse Gases for Policy Purposes," *The Energy Journal*, Vol. 14, No. 1, 1993.

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