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THE CLIMATE CHANGE BENEFITS OF REDUCING METHANE EMISSIONS

Chris Hope

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Chris Hope
Judge Institute of Management
University of Cambridge
chris.hope@jims.cam.ac.uk

Abstract

Methane emissions contribute to climate change. Reducing them would bring benefits. This paper uses the PAGE95 model to find out how big the benefits would be, and compare them with the benefits of carbon dioxide reductions.

Immediate cutbacks of methane bring benefits of between $30 and $260 per tonne, with a mean value of $110 per tonne. This compares to benefits of between $10 and $50 per tonne of carbon, with a mean value of $20, for immediate cutbacks of carbon dioxide. All values are in 1990 dollars.

About two-thirds of the benefits are non-economic; only one-third comes from a reduction in the impacts on economic activity. Only about 5% of the benefits are in the EU, and 8% in the USA; the vast majority of the benefit is felt in other regions, particularly in the developing world.

The benefits from an immediate reduction in methane emissions continue throughout the next century, peaking after 2050, even though methane only stays in the atmosphere for about a decade. This is because the earth takes time to respond to the changes in radiative forcing that greenhouse gases cause. Carbon dioxide stays in the atmosphere much longer than methane. The benefits of an immediate reduction in carbon dioxide emissions continue throughout the 21st and 22nd century.

The benefits from methane reduction are sensitive to the discount rate. Using a pure time preference rate of 2% per year, instead of 3% per year, almost doubles the mean benefits to $190 per tonne; a rate of 1% per year doubles the mean benefits again to $380 per tonne.

Introduction

Climate change is likely to bring harmful impacts in the decades to come (IPCC WGII, 2001, p5). Reductions in greenhouse gas emissions would therefore bring benefits. But which gases should we reduce? Although carbon dioxide has captured most of the headlines, methane is also a potent greenhouse gas. It accounts for about 20% of the increase in radiative forcing since pre-industrial times (IPCC WG I, 2001, p41).

For some years, the standard way of comparing the potency of different greenhouse gases has been to calculate their Global Warming Potential (GWP). The GWP of a gas is defined as the relative radiative effect of a tonne of that gas compared to a tonne of CO2, integrated over a chosen time horizon (IPCC WG I, 2001, p46). Latest estimates of the GWP of methane are 62 over a 20 year horizon, 23 over 100 years and seven over 500 years (IPCC WG I, 2001, p47).

GWPs have at least three obvious drawbacks: they are very sensitive to the arbitrary time horizon chosen, as the results for methane show. They do not allow impacts that occur soon to be valued more highly than those that occur in the distant future, and they are relative, rather than absolute, measures. Knowing the GWP of a gas does not necessarily help very much in deciding how much effort, if any, should be devoted to reducing the emissions of it.

Instead of GWPs, the most useful information would be the marginal reduction in impacts that would result from an immediate one tonne cutback in the emissions of the gas. This would be an absolute measure. It would not require the assumption of an arbitrary time horizon. It would allow near-term impacts to be valued more highly. It would also be able to be compared with estimated costs for abating emissions of the gas. Of course, it is also a very difficult calculation to do, requiring an integrated assessment model which tracks the effects of emissions right through to the impacts that they cause.

In 1996 the integrated assessment model PAGE95 was used to calculate the benefit of an immediate reduction in carbon dioxide emissions. The result was a 90% chance of the value lying between $10 and $48 per tonne of carbon, with a mean value of $21 per tonne (discounted back to 1990 and expressed in 1990 dollars) (Plambeck and Hope, 1996).

The PAGE95 model uses relatively simple equations to approximate complex climatic and economic phenomena. This is justified because the results approximate those of the most complex climate simulations, and because all aspects of climate change are subject to profound uncertainty. PAGE95 represents more than 70 key inputs by probability distributions. Full details of the structure of the model can be found in Plambeck, Hope and Anderson (1997).

The PAGE95 model can be used to calculate the benefit of an immediate reduction in methane emissions, in exactly the same way as for carbon dioxide. This is the calculation that is reported in this paper.

Benefits of immediate cutbacks

The global emissions of methane in the base year of 1990 in PAGE95 were 352 million tonnes of methane (plus about 150 million tonnes of natural emissions). The first analysis year in the PAGE95 model is 2000, the next is 2020. Emission changes specified in one analysis year are assumed to persist half the way back to the previous analysis year and half the way forward to the next. So a change in emissions specified for 2000 would actually be applied for a 15-year period (1995 – 2010).

A 100% change of base year emissions was specified in the first analysis year of 2000. This gives a change in emissions of 352 million x 15 = 5.3 billion tonnes of methane. The changes in impacts that result need to be divided by 5.3 billion to obtain the benefits per tonne of methane reduction.

We need to use changes in emissions that are this big to get changes in the impacts that can be measured to an acceptable degree of accuracy (see Table 1 and Figure 1 below for evidence that these changes are at the limits of measurability).

Mean benefit

The mean impacts from these runs are shown in Table 1. They are expressed in 1990 dollars and discounted to 1990 at a pure time preference rate of 3% per year. This enables them to be compared directly with the results for carbon dioxide calculated in Plambeck and Hope (1996). To convert any value to 2000 dollars, multiply by 1.24 (EIA, 2001).

Table 1   Mean impacts with decreases of methane emissions

Global		*$bill NPV 1990-2200*
	Impacts	change from base
Base run	19900	-----
Methane decrease	19300	- 600

Source: PAGE95 full runs

Decreased methane emissions lead to a reduction in mean global impacts of $600 billion. The mean benefit per tonne is $600 billion divided by 5.3 billion = $110 per tonne of methane reduction. This compares to a mean benefit for carbon dioxide reductions of $20 per tonne (Plambeck and Hope, 1996).

So, using the mean values, one tonne of methane causes a little over five times as much impact as one tonne of carbon as CO_2, or about 20 times as much impact as one tonne of CO_2. This is not too dissimilar to the 100 year GWP of methane of 23.

To put the value into context, the average US price of natural gas, which is almost pure methane, in 2000 was $3.60 per thousand cubic feet (EIA, 2001). In 1990 dollars, this converts to about $150 per tonne. The climate change benefits of methane reduction are a significant proportion of this.

So any utility considering, say, pipeline replacement to decrease losses, should be encouraged to go ahead if the Net Present Cost were less than about $260 per tonne saved in 1990 dollars – made up of not just $150 from having the gas available to sell, but also $110 from the reduction in climate change impacts.

Distribution over sectors and world regions

PAGE95 calculates the distribution of these benefits across sectors and world regions. About $200 billion of the benefits come from reduction in economic impacts; about $400 billion are reductions in non-economic impacts, such as the inundation of wetlands, and the destruction of valuable habitats. Only about $30 billion of the benefits, or 5% of the total, are in the EU, with $50 billion, or 8% in the USA; the vast majority of the benefit is felt in other regions, particularly in the developing world. Table 2 shows how the benefits are distributed across the regions of the world

**Table 2   Benefits of decreased methane emissions
                 by world region**

Global   *$ bill NPV 1990-2200*

| World region	Benefit
EU	30
FSU & E.Eur	0
USA	50
China & CP Asia	90
India & SE Asia	90
Africa & ME	120
Latin America	140
Other OECD	80
Total	600

Source: PAGE95 full runs

The method used to obtain this valuation is essentially the same as the method used in the REGIONAL experiment in Plambeck and Hope (1996), which should be consulted for details of adaptation measures taken, discount rates applied etc. The only difference is that the emissions are based upon the new IPCC 'marker' A2 scenario, that most closely reflects contemporary thinking about emission prospects (Nakicenovic and Swart, 2000), rather than the older IPCC scenario used in Plambeck and Hope.

Distribution over time

The distribution of these benefits over time is shown in Figure 1. The mean yearly benefits of an immediate reduction in carbon dioxide are also shown for comparison.

Figure 1 Annual benefits of immediate reductions in methane and carbon dioxide
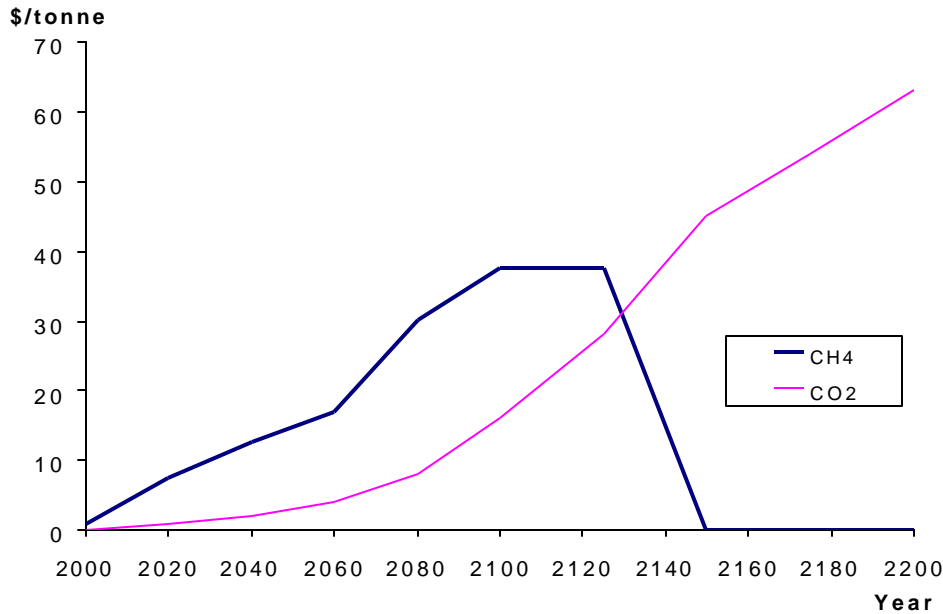
Source: PAGE95 full runs

The reduction in mean impact for methane peaks around 2100 at about $40 per year. Methane only stays in the atmosphere a decade or so, but the extra radiative forcing continues to have an effect for much longer as the earth takes a long time to respond fully to increased forcing. The reduction in impacts does not peak earlier because the temperature rise and so the total impacts before 2050 are small. Rounding errors caused by working at the limit of resolution of the model mean that these results are only accurate to one significant figure at best. The strong influence of discounting can be detected in reducing decades of yearly benefits of the order of $40 per tonne to a net present value of $110 per tonne.

The benefit of the immediate carbon dioxide reductions continues to rise right through the 22nd century, reaching over $60 per year in 2200. Carbon dioxide stays in the atmosphere much longer than methane.

Probability distribution

Uncertainty is represented in the PAGE95 model by using probability distributions for the most important inputs. The model then performs 250 runs sampling from the input

distributions. The 250 runs give the results shown in Figure 2. The modal values are between $50 and $100 per tonne of methane. The 90% range is about an order of magnitude. This compares with a 90% range of benefits of about $10 to $50 per tonne for reductions in carbon dioxide (Plambeck and Hope, 1996).

Figure 2 Probability distribution of the benefits of methane reduction
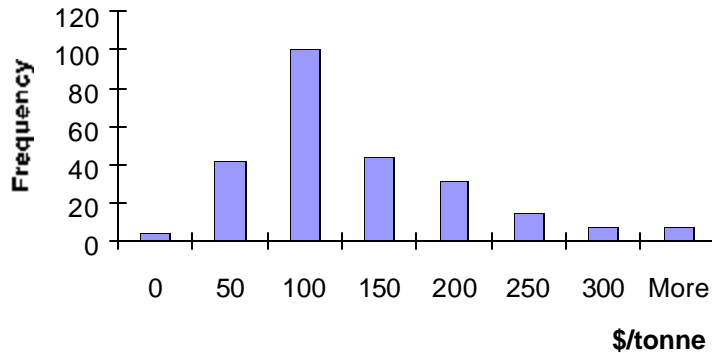
Source: PAGE95 full runs

Lower baseline of carbon dioxide emissions

How do things change if we look at the benefits of methane reduction against a background of carbon dioxide emissions that implement the Kyoto protocol of 5% cutbacks in the industrialised countries by about 2010 and then reduce at 1% per year until 2100 in the industrialised countries? The answer is not much. Table 3 shows the mean impacts.

Table 3   Mean impacts with increases of methane emissions against a lower baseline of carbon emissions

Global		*$bill NPV 1990-2200*
	Impacts	change from base
Base run	16700	-----
Methane decrease	16100	- 600

Source: PAGE95 full runs

Of course, the total impacts are smaller than under business-as-usual emissions of carbon dioxide as the emissions of carbon dioxide are much lower. Recall from Table 1 that with a business-as-usual base, the benefit of the reduced methane emissions was also $600 billion. So the benefit of reducing methane emissions is not perceptibly affected by the emissions scenario on which it is superimposed, at least within the range of emission scenarios considered here.

Different discount rates

The results so far use a pure time preference rate of 3% per year to convert impacts to a net present value. Table 4 shows how the benefits depend upon the discount rate.

**Table 4   Benefits of methane reductions
by discount rate**

Global   NPV 1990-2200

PTP rate (% per year)	Benefit ($ per tonne)
3	110
2	190
1	380

Source: PAGE95 full runs

Unlike the background emissions of carbon dioxide, changes in discount rate have a large effect upon the benefits of methane reduction. This is because the global warming problem is a long-term one. A reduction in methane emissions affects the climate for many decades. As would be expected, the lower the discount rate, the higher the benefit. But the appropriate discount rate to use is not an issue that can be solved here.

Conclusion

The calculations in this paper provide a theoretically defensible way of comparing the benefits of methane reduction with the benefits of reducing carbon dioxide. The results depend strongly on the discount rate used, and are still highly uncertain. But they do provide enough information to start a rational discussion about the appropriate trade-off between gases.

Acknowledgement

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