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# NEGOTIATING A RESPONSE TO CLIMATE CHANGE: THE ROLE OF BIOLOGICAL EMISSIONS


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# NEGOTIATING A RESPONSE TO CLIMATE CHANGE: THE ROLE OF BIOLOGICAL EMISSIONS

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## ABSTRACT

*Emissions of methane from enteric fermentation in animals (wild and domestic) have been estimated elsewhere at approximately 80 Tg per year (88 million U.S. tons), 15% of global methane releases. Of this amount, bovines contribute approximately two-thirds. Since methane is a potent greenhouse gas, this source is frequently targeted for emission reductions.*

*The importance of bovine methane as a greenhouse gas is overstated. Estimates to date have focused solely on the emission of gas, ignoring the biological and chemical cycling which removes carbon from the atmosphere. The analysis demonstrates the importance of considering these cycles in terms of overall greenhouse effect for biological sources of methane, such as rice production, termites, and bovine animals. The error may be on the order of 800%. By ignoring this cycling, it seems clear that the role of developing country's total contributions to climate change has been overemphasized.*

*In economic terms, the analysis shows that reducing $CO_2$ emissions from energy use in industrialized countries is more efficient than reducing net greenhouse methane from animal sources.*

## I. INTRODUCTION

Methane released by bovines is said to be a significant environmental threat, partially responsible for altering the earth's climate. And with negotiations proceeding towards an agreement to reduce the risk of climate change, policy makers are looking at bovines as one possible area for reducing greenhouse gas emissions.

This paper reviews how bovines became a policy issue and examines the importance of bovine methane as a greenhouse gas. An analysis is presented which demonstrates the importance of taking into account the removal of $CO_2$ from the atmosphere during the feed growing process in determining the true greenhouse effect. Cost estimates are presented contrasting $CO_2$ reduction costs from energy use with bovine methane reduction costs. Finally, the implications of the issues raised herein for on-going climate negotiations are discussed.

## II. BACKGROUND

For decades, scientists have warned that the continued addition of various gases to the atmosphere, commonly referred to as greenhouse gases, could result in increased global temperatures due to the ability of these gases to absorb infrared radiation. These gases include carbon dioxide ($CO_2$), methane ($CH_4$), chlorofluorocarbons (CFCs), and nitrous oxide ($N_2O$). For $CO_2$ alone, primarily released from the burning of fossil fuels, computer models predict that for a doubling of atmospheric levels over pre-industrial levels, the earth's surface temperature will increase from 1.5 to 4.5 degrees Celsius.[1]

The importance of the individual gases as contributors to climate change depends on three factors: the quantity of emissions, their absorption capacity, and their atmospheric lifetime. Obviously, the greater the emissions of any one gas, the larger a contributor it is. The absorption capability of the gases refers to the ability to change the global solar balance by trapping outgoing infrared radiation. By this measure, the CFCs are most effective, and $CO_2$ the least.[2] Because of this capability, very small quantities of CFCs can have the same effect as large quantities of $CO_2$. Finally, atmospheric lifetime is an important, but often overlooked factor. Methane has a relatively short atmospheric duration (10-14 years) as compared to CFC-12 (130 years) and $CO_2$ (50-200 years). So while methane may have greater absorption capability, it does not last as long as some of the other gases, reducing its overall impact.

In response to the perceived threat to the world's climate, steps have been taken towards limiting climatic change. In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) created the Intergovernmental Panel on Climate Change (IPCC), charging it with assessing the scientific information regarding climate change issues and formulating realistic response strategies. The interim report of the IPCC (WMO, 1988) is seen by many as the transition between exploratory discussions and formal negotiations towards an international convention (Nitze, 1990). While decidedly hesitant at first to be drawn into negotiations, the U.S. joined the process when President Bush proposed to President Gorbachev at the December 1989 Malta Summit that the U.S. host the initial negotiating session. Then at the Western Economic Summit in Texas in July 1990, leaders agreed that a greenhouse convention should be completed in time for the scheduled 1992

U.N. Earth Summit Convention (Houston Economic Declaration, 1990). Under UN auspices, the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC) has begun a series of several meetings leading up to the 1992 conference.

After several meetings of the INC, major disagreements remain regarding how far a framework convention should go towards specifying targets. The Executive Secretary of the INC, Michael Zammit Cutajar, states that the talks appear to be progressing on two tracks (Media Natura, 1991b, Item 5). The first track is the North-North track, with industrialized countries divided as to whether the convention should contain specific dates and targets. The U.S. position is that any framework convention should be very broad and should not contain timetables or levels (Media Natura, 1991a, Item 6). The EC and Canada favor targets stabilizing $CO_2$ emissions at 1990 levels by 2000. Japan calls for the "best efforts" by industrial countries at meeting stabilization goals (Media Natura, 1991b, Item 1). The second track is the North-South track, focussing on what the convention would have to include for the South to enter the agreement, such as compensation from the North.

The U.S.'s basic concern is that agreeing to limits in the emissions of carbon dioxide could severely curtail future energy and industrial expansion plans or that an agreement might require large payments to developing countries to help them meet the agreement. One U.S. response to the problem has been to propose that any agreement not be limited to just carbon dioxide but cover all of the gases, often referred to as the comprehensive approach.

An example of how such an agreement might work was put forth by the U.S. Department of State in February 1990 (Dept. of State, 1990). First each gas would be assigned a weight. One possible weighting scheme assigns each molecule of $CO_2$ a rating of 1, each molecule of methane ($CH_4$) a rating of 25, and each molecule of CFC-12 a rating of 15,000. A reduction goal would then be established giving each country broad latitude as how best to meet the target given its particular needs and cultural values. Consider one view of how this approach might work.

> *Some nations might be able to reduce $CO_2$ emissions below their limit, such as through substitution of non-fossil fuels, but be unable to reduce $CH_4$ output (e.g., a nation importing oil and dependent on rice crops, but endowed with untapped solar power opportunities). Those nations would meet their net limits by reducing $CO_2$ more rapidly than $CH_4$; requiring them to limit each gas by the same amount would prove much more costly (perhaps in terms of lower economic growth, higher taxes, or reduced rice production) and would leave additional affordable $CO_2$ reductions unexploited. Other nations might find themselves in the opposite situation, able to afford to limit $CH_4$ more than $CO_2$ (e.g., a nation dependent on coal reserves) [by modifying] the diet of its ruminant animal husbandry* (Department of State, 1990, pp. 15-16).

This approach is appealing, especially to economists, who have long argued that emissions trading schemes will result in a more efficient outcome than specific regulations on a gas or a source since each country could implement the least costly strategy for reaching an overall target. The State Department Proposal makes it seem sensible that if it is cheaper to eliminate methane from cows than to limit $CO_2$ emissions from a car, then this would be a good way to proceed.

This is how bovines became an issue in international negotiations. But several issues arise about the validity of current estimates regarding bovine produced methane and its overall importance as a greenhouse gas.

The first question concerns the difference between the instantaneous radiative effect and the total long term effect. A kilogram (kg) of $CH_4$ has an instantaneous effect 58 times greater than a kg of $CO_2$, but also has a much shorter atmospheric lifetime, decaying to $CO_2$ in 10-14 years. Does ignoring this fact overemphasize the importance of methane as a greenhouse gas?

The second question concerns the importance of the origin of the gas under consideration. Is methane released from a cow really the same as methane released from the mining and transmission of natural gas? In the latter case, new carbon is being added to the atmosphere, whereas methane from bovine animals includes carbon that was once in the atmosphere as $CO_2$. (Methane, $CH_4$, is a compound of carbon and hydrogen.)

Third, what is it likely to cost to reduce emissions of $CO_2$ compared to $CH_4$? Comparatively little is known to date about the costs of reducing methane emissions from bovine animals. Recent estimates are presented which raise the question of whether $CH_4$ emission reductions would make economic sense.

Finally, a question arises which touches on North-South politics. An international agreement which focusses on reductions in $CO_2$ emissions would put the largest burden of responsibility on industrialized countries, who to date have been responsible for a large percentage of the increased atmospheric $CO_2$. However, by including other gases, such as methane, then the emissions of methane from the animal population and rice paddies of developing countries become much more important in terms of contributions to greenhouse warming.[3]

Is this what the U.S. and other industrialized countries are really pursuing by pushing for a comprehensive agreement?

## III. BOVINE METHANE

Reaching agreement on meaningful reduction strategies for any greenhouse gas requires a thorough understanding of the sources and sinks for that gas. Consider the sources of methane, Table 1. The largest source is natural wetlands and bogs where methane is continuously formed through anaerobic decomposition of organic matter. Other sources include: rice paddies; enteric fermentation (the intestinal fermentation which occurs in animals such as cows); biomass burning; coal mining; the drilling, venting, and transmission of natural gas; and termites. None of the biological sources seem amenable to accurate data estimates of emissions, to effective regulation, or to monitoring of plans for emissions reductions. However, the State Department (1990) targets both rice production and ruminant animals as possible methane reduction sources in its proposal.

Of the 80 million metric tons of methane (1 metric ton is equal to 1.1 U.S. tons) that Cicerone and Oremland (Cicerone and Oremland, 1988) estimate arise from enteric fermentation, approximately two-thirds of that is attributed to bovines (Crutzen, 1986). For the average bovine, Wolin (1979) estimates a methane release due to belching of 200 liters per day.[4]

But while estimates exist for emissions of methane from bovines, translating this knowledge into policy is a difficult step. First, these numbers are for the average animal. Actual emissions vary widely by animal type, climate, and feed quality and quantity. Establishing a baseline for compliance on a country by country basis would be very difficult. It would

**Table 1: Sources of Methane. Annual emissions of methane into the atmosphere, in Teragrams ($10^{12}$ grams or millions of metric tons).**

| Source | Quantity | % of Total |
|---|---|---|
| Natural Wetlands (includes bogs, swamps, tundras) | 115 | 21.5 |
| Rice Paddies | 110 | 20.5 |
| Enteric Fermentation (ruminant animals) | 80 | 15.0 |
| Biomass Burning (includes fuel wood, agricultural burning, forest fires) | 55 | 10.3 |
| Gas Drilling, Venting, Transmission | 45 | 8.4 |
| Termites | 40 | 7.5 |
| Landfills | 40 | 7.5 |
| Coal Mining | 35 | 6.5 |
| Oceans | 10 | 1.9 |
| Fresh Waters | 5 | 0.9 |
| **TOTAL** | **535** | **100.0** |

Source: Cicerone and Oremland. 1988

also be difficult to monitor the effectiveness of any agreement. Countries could claim that they reduced methane emissions through population reductions or by diet alterations, but it would be very time consuming to actually verify these reductions. Finally, estimates to date virtually ignore potential methane releases from manure (Patterson, 1989). Whether or not methane is released from manure depends on how the waste is handled. For manure stored either in waste lagoons or piles, there is potential for significant releases of methane due to anaerobic decomposition. However, if the wastes are spread on fields there is probably little methane released. Similarly, in developing countries, where manure is collected and dried for use as a fuel, carbon is recycled as $CO_2$ without methane production from manure. The implication is that while it is clear that manure may be a significant source of methane, designing international policy to control it would not be simple.

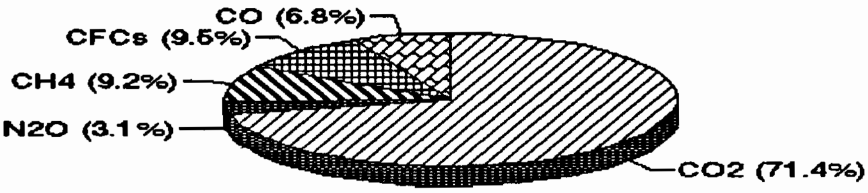
## IV. THE IMPORTANCE OF RUMINANT METHANE IN THE GLOBAL METHANE CYCLE

What is the effect of methane emissions of this magnitude on climate change? Focussing on the instantaneous radiative forcing weights gives an inaccurate picture for two reasons. First these weights ignore the differences in atmospheric residence times of the gases and second they ignore the source of the gases, and whether any cycling of gases occurs. These reasons are considered in turn.

### *A. Consideration of Atmospheric Residence Times*

Methane, with a residence time of 14.4 years (versus some 230 years for $CO_2$) is eventually oxidized to $CO_2$ and $H_2O$. So while $CH_4$ is more effective at trapping infrared radiation, it stays in the atmosphere for a shorter time period. Lashof and Ahuja (1990) propose an alternative weighting index which takes atmospheric residence time into account. Their index weights $CH_4$ at 10 times $CO_2$ on a weight basis. Using this weight, Lashof and Ahuja conclude that "carbon dioxide emissions alone account for 80% of the contribution to global warming of current greenhouse gas emissions",[5] Figure 1. Others have also considered this issue (Rodhe, 1990; WMO, 1990), and disagreement exists over the actual weight that should be applied to the various gases. Resolution of this issue is crucial, with important policy implications. For

**Figure 1: Greenhouse Gas Contributions to Global Warming**




Source: Lashof and Ahuja, 1990

example, Lashof and Ahuja's work suggests that the primary emphasis for greenhouse gas reductions should really remain on $CO_2$, a conclusion that is even more important in light of the recent amendments to the Montreal Protocol which call for a phase out of most chlorofluorocarbons by the year 2000 (Report of the Second Meeting of the Parties, 1990). If one assumes that this phase out will occur, then the total contribution attributable to future $CO_2$ emissions approaches 90%. Lashof and Ahuja's numbers are used in the following analysis.

*B. Consideration of the Carbon Cycle*

The importance of bovines as a contributor to climate change can be significantly overemphasized by overlooking the source of the carbon content of methane. In one important respect, methane released from ruminant animals is not the same as methane released from sources such as leakage from natural gas pipelines or from coal mining operations. Methane from these fossil fuel sources is adding carbon to the atmosphere which was removed tens of thousands of years ago, whereas animals are simply recycling carbon. The following example clearly illustrates the importance of considering both the atmospheric residence times and the source of the carbon.

This example looks at the carbon cycle for a 500 kg beef cow in steady state, meaning the mature animal, Table 2. The cow in this example consumes 9 kg per day (dry weight) of silage with an approximate carbon content of 40%. Inputs of carbon amount to approximately 3600 g. In steady state, the total input and output of carbon fluxes must balance, column 1. Through normal respiration, 2095 g of carbon immediately return to the atmosphere as $CO_2$. Of the remaining quantities, approximately 173 g are returned in the form of $CO_2$ and 94 g (uses Wolin's estimate of 200 liters per day) in the form of $CH_4$ through belching and 1238 g are deposited on the ground in the form of manure. (Assumes 34.4% carbon content of manure. See Tunney, 1980.)

In sum, of the original carbon intake, 66% is returned almost immediately to the atmosphere, some of it as $CH_4$ and some of it as $CO_2$. The remainder of the carbon is deposited on the ground in the form of manure. Whether or not methane is released from manure depends on how the waste is handled, as mentioned previously.

In this example, proper waste handling is assumed so that there is no methane released from this source. However, entries have been included in Table 2 for use in alternative scenarios where one assumes methane production and/or the net addition of carbon to the soil. Here these two items are assumed to be equal to zero.

Consider the overall effect of this carbon cycle in terms of greenhouse gas effect. Columns 2 and 3 indicate the quantities of $CO_2$ and $CH_4$ cycled. The last column indicates the greenhouse gas equivalence of the various components of the cycle, using the weighting factors of Lashof and Ahuja. The

| Table 2: Steady State Daily Carbon and Greenhouse Gas Cycles in a 500 kg beef animal. All figures in g/day. | Carbon | $CO_2$ | $CH_4$ | GEUs |
|---|---|---|---|---|
| **INPUTS:** | | | | |
| Approximately 9 kg/day silage (dry weight) | 3600 | 13200 | | 13200 |
| **OUTPUTS:** | | | | |
| Carbon in $CO_2$ -- belching | 173 | 634 | | 634 |
| Carbon in $CH_4$ -- belching | 94 | | 125 | 1250 |
| Carbon in manure (1238 g) | | | | |
| Carbon released as $CO_2$ | 1238 | 4539 | | 4539 |
| Carbon released as $CH_4$ | | | | |
| Carbon into soil | | | | |
| Carbon in $CO_2$--respiration | 2095 | 7682 | | 7682 |
| Carbon in urine | 0 | | | |
| **Totals** | 3600 | 12855 | 125 | 14105 |

results are enlightening: while 14,105 greenhouse equivalent units (GEUs) are released to the atmosphere, 13,200 units are removed from the atmosphere, for a net increase of just 6.9%. By ignoring this cycling process, the error may exceed 800%.[6]

A similar principle applies to every biological source of methane: rice production, termites, and wild animals. If only the emission is considered, and the ecological cycle of atmospheric $CO_2$ removal is ignored, then the apparent contribution of biological sources to the greenhouse effect will be seriously overstated.

## V. COST ESTIMATES OF VARIOUS GREENHOUSE GAS REDUCTION GOALS

| Table 3: Cost Estimates of Various Greenhouse Gas Reduction Goals | |
|---|---|
| Strategy | $/$CO_2$ Equivalent Metric Ton |
| Compact Fluorescents | -56.00 |
| Fuel Switching (Coal to Natural Gas) | 22.00 |
| Tree Plantations | 54.00 |
| Cow Diet | 352.00 |

Table 3 presents cost estimates for four different strategies to reduce greenhouse gas emissions. Three strategies target $CO_2$ emissions: increase lighting efficiency,[7] fuel switching,[8] and tree plantations[9]. The fourth strategy is an estimate by Adams, Chang, and McCarl[10] for reducing $CH_4$ emissions by altering the diet of ruminant animals.

The estimate by Adams, et al, of $352 per ton $CO_2$ equivalent (in the form of $CH_4$) is quite high compared to the other alternatives presented. Some reductions in $CO_2$ emissions could be achieved at a negative cost. Replacing existing incandescent light bulbs with the new compact fluorescent light bulbs is such an example, saving $56 per $CO_2$ equivalent ton. Other strategies, such as switching from coal-fired generation to natural gas-fired generation ($22 per $CO_2$ equivalent ton), or establishing new forests sinks ($54 per $CO_2$ equivalent ton), could be achieved at relatively modest costs. These estimates indicate that even if bovine methane reduction strategies are feasible, they are unlikely to be more cost effective than $CO_2$ reduction strategies.

## VI. THE NORTH-SOUTH POLITICAL QUESTION

The implications of pursuing $CO_2$ reductions alone versus pursuing a comprehensive approach also raise important questions touching on North-South politics. Which countries should bear the burden of responsibility for curbing global warming? If agreement focusses only on $CO_2$, then industrialized countries are responsible for the largest contributions to date. If other gases are included, particularly $CH_4$, then the emissions from the agricultural sectors in developing countries become much more important.

There is also the issue of starting, or baseline, emission levels. In negotiating a comprehensive approach, countries would have to settle the question of an appropriate bench mark level of emissions for the different gases. In regards to CFCs, one can imagine disagreement arising over starting levels or credit for past reductions achieved under the Montreal Protocol. The U.S., the largest single consumer of CFCs,[11] might insist that it be given credit for already achieved reductions in CFC levels. Consider the following numerical example of such a potential claim by the U.S.[12]

U.S. consumption in 1986 of CFC-12 was about 140 million kg.[13] Using the index based on instantaneous radiative forcing, this implies a value of 805 billion $CO_2$ equivalent units. If one assumes a phase out of CFC consumption by the year 2000, as has currently been agreed to, the U.S. could insist on a credit of 805 billion units per year towards its reduction of greenhouse gases. Compare this estimate with the $CO_2$ equivalent units emitted by U.S. coal consumption. The U.S. consumed 21 billion GJ of coal in 1990, emitting approximately 2.1 billion metric tons of $CO_2$, or 2100 billion $CO_2$ equivalent units, just 2.6 times the radiative forcing effect of current CFC-12 consumption itself.[14] Hence, the U.S. could claim that by agreeing to the

CFC phase out, they have done their share of reducing the risk of future climate change. Meanwhile, those countries with low levels of CFC consumption would not benefit from such a credit. Indeed, it would be these countries, such as India, which would have to decrease methane emissions to capture a similar credit.

Whether intentional or not, the effect of pursuing the comprehensive approach might be a failure to reach any accord. Would India or China, who see the industrialized countries as the prime culprits, agree to reduce greenhouse gas emissions from their agricultural sector? Is this the real goal of the U.S.'s policy of pursuing a comprehensive agreement?

## VII. CONCLUSION

This paper compared various estimates of total methane emissions from bovine animals and discussed the relative addition to greenhouse gas warming due to this one source.

Emissions of methane from enteric fermentation in animals have been estimated elsewhere at approximately 80 Tg per year, 15% of global methane releases. This estimate is misleading for two reasons: it ignores the differences in atmospheric residence time between carbon dioxide and methane; and it overlooks the biological and chemical cycling that occurs. The result is an overemphasis of the role of this methane as a greenhouse gas.

This does not imply that methane emissions are not a greenhouse contributor. Policies for reducing bovine methane emissions which follow from the above calculations include: improving the quality of animal feed, and finding ways to more effectively utilize animal manure, such as through biogas utilization. However, as evidenced by the results of Adams, et al, such reduction strategies may not be economically attractive when compared to $CO_2$ reduction strategies. More important sources of methane are the non-biologic sources, including leakages of natural gas and methane from coal mining.

This has important implications for negotiations on future climate change accords. By ignoring these two factors, the role of developing country's total contributions to climate change has been overemphasized. In economic terms, the analysis shows that reducing $CO_2$ emissions from energy use in industrialized countries is more efficient than reducing net greenhouse methane impact from animal sources. Based on issues presented here, the logical next step for policy makers is to agree to limits in future $CO_2$ emissions.

## FOOTNOTES

*The authors are Research Assistant and Professor of Resource Economics, Department of Agricultural Economics, Cornell University, Ithaca, N.Y. The authors appreciate the assistance of Phoebe Reed in preparing the manuscript and acknowledge the thoughtful comments and suggestions made by Alfred Aman Jr., and Henry Shue.

[1]The current atmospheric concentration of $CO_2$ is 354 ppm, a 26% increase over preindustrial levels (WMO,1990).

[2] The absorption capability is commonly referred to as instantaneous forcing weights. The instantaneous forcing weights for selected gases on a per unit weight basis are: $CO_2$, 1; $CH_4$, 58; $N_2O$, 206; CFC-11, 3970; and CFC-12, 5750.

[3]It is, of course, true that an agreement regulating carbon dioxide alone would affect the future growth rates of energy usage in developing countries. However, an agreement on methane would have to impact current agricultural practices in these same countries.

[4]A common misconception is that bovine animals release the gas through farting; this misconception stems from the definition of flatulence which refers to any gas originating in the stomach or intestines.

[5]Lashof and Ahuja's (1990, p. 531) estimate of 80% is for "the total contribution of $CO_2$, including net $CO_2$ produced from emissions originating as CO and $CH_4$".

[6]Previous calculations consider only the methane released from belching (125 grams) weighted by the instantaneous radiative forcing potential (58) to

yield 7250 greenhouse equivalent units (GEUs). Our calculations indicate a net increase of just 905 GEUs (total inputs minus outputs).

[7]This estimate is based on replacing continuously operated 75 W incandescent light bulbs with 18 W compact fluorescents. Assumes an average electricity cost of .064/kwhr, incandescent cost of $.75, and compact fluorescent cost of $15.99.

[8]This number represents the difference in fuel costs for fossil steam plants operating with natural gas rather than coal. Assumes coal cost of $1.36/MJ, natural gas costs of $2.20/MJ.

[9]Assumes a growth ratio of 13.5 metric tons per hectare per year; cost estimates includes site preparation, weed control, planting costs, land rental costs, fertilizer, harvesting, and removal of trees from the site. Also assumes the use of Short Rotation Intensive Culture (SRIC) which utilizes fast-growing trees on managed plantations (Chapman and Drennen, 1990).

[10]Adams et al. estimate that to reduce emissions of methane by altering ruminant diets would cost between $2,250 to $4,900 per ton of methane. This was converted to greenhouse gas equivalents by applying the Lashof and Ahuja index and taking an average.

[11]The U.S. accounted for 29% of total world-wide consumption in 1986 (Shea, 1988).

[12]Recent scientific evidence further erodes the credibility of such a claim. Measurements of ozone indicate a significant depletion of ozone in the lower stratosphere, where it traditionally acts as a greenhouse gas. This ozone has not, until now, been considered important in terms of the total radiative effect since its concentration was considered stable. However, the depletion of this ozone is now reported to be resulting in a cooling trend,

possibly larger in magnitude than the heating due to CFC increases (UNEP, 1991).

[13]Shea (1988, p. 23) reports U.S. per capita use rates of .34, .58, and .31 kg for CFC-11, CFC-12, and CFC-113 respectively. Multiplied by a U.S. population of 241 million results in an aggregated total of 140 million kg of CFC-12.

[14]Substitutes for CFCs will likely be greenhouse gases also. Their now unknown effect would have to be included in future calculations.

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