Introduction

Any *emissions trading scheme* (ETS) needs to have two goals:

1. Reduce CO_2 emissions sharply so that there is a fighting chance of the planet being climatically not too dissimilar in 100 years from what it is today.
2. Reduce current net radiative forcing. i.e., cool the place down right now. This is to reduce the risk of crossing dangerous climate tipping points.

Unfortunately, climate science findings show that meeting the first goal won't guarantee meeting the second and vice versa. The convenient notion that all greenhouse gases and other forcings can be converted using the current Kyoto conversion factors to CO_2-equivalents (CO_2^{eq}) for the purposes of a trading system obscures the separate nature of the two problems and increases the risk of failing to meet one or both goals.

We will explain the details below, but consider first a plausible example of what could happen in a global ETS. In so far as global measures to reduce CO_2^{eq} are successful, then either coal fired power stations will be closed or carbon capture and storage will be attached. This will allow equivalent amounts of emissions to be released from other activities (with a gradual overall decline). A company could, for example close a coal station, open a wind farm and sell leftover permits. Global meat consumption is increasing, so imagine if permits to emit 210 mega tonnes annually of CO_2 flowed from coal to cattle. Cattle produce methane and using the Kyoto conversion factor of 21, we could swap 210 mega tonnes of CO_2 for 10 mega tonnes of methane. For grass fed cattle, this would equate to about 90 million animals and would involve substantial deforestation for which we would also need permits — thus reducing the allowed methane to possibly 9 mega tonnes. The deforestation would create Black Carbon which is a potent but short lived positive climate forcing not easily measurable and not covered by any ETS. The closing of the power stations would remove a substantial negative climate forcing (sulphate aerosols) — also not covered by any ETS. The immediate forcing reduction from reduced CO_2 emissions would actually be almost 4 times smaller than the increased forcings due to the added methane. As a result, climate forcings would rise and the planet would get hotter[1]. This is far from a zero sum transaction as assumed by the simplified ETS science model.

[1] Please note, Professor Tom Wigley confirms that the U.S. National Center for Atmospheric Research has done work using the MAGICC modelling tool which predicts that a couple of decades of increased warming is exactly what would happen if all the coal power plants were shut off tomorrow — even without additional methane.

Methane forcing

What does one of the world's top climate scientists think caused the global warming trend that began in the 1960s?

> **"Thus I suggest that the sharp global warming trend that began in the 1960s was primarily a consequence of the activities producing the trace gases, mainly CFCs and methane (CH_4), as these gases produce only warming."**
>
> NASA Climate Scientist, James Hansen[1]

This quote from James Hansen will be presented with more context later, but it is intended, for now, as a jolt for people who believe that global warming is *all* about CO_2 — it isn't. To understand why this is so, we need to understand the scientific concept of *forcing*, as applied, to greenhouse gases of differing lifetimes, in some detail. The simplification of the science for non-scientists by substituting the concept of carbon dioxide equivalents ($CO_2^{\mathbf{eq}}$) has obscured issues which are crucial to the effectiveness of any actions intended to reduce global warming.

The *forcing* of a greenhouse gas is a measure of the degree to which the gas makes it easier or harder for energy to arrive at or leave the planet's surface. Here is a summary of the current forcings[2]:

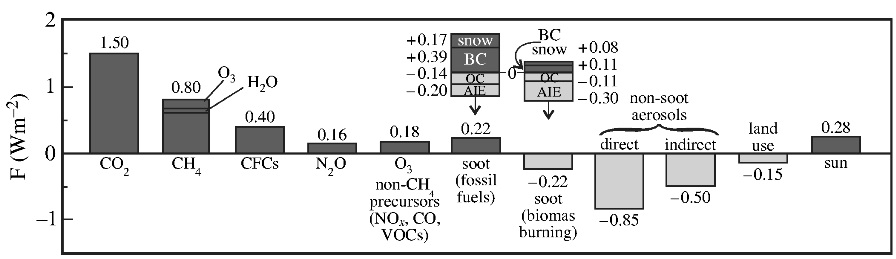


Figure 8. Estimated effective climate forcings for the industrial era, 1750–2000, with primary indirect effects grouped with the sources of direct forcing (Hansen *et al.* 2005*a*). BC, black carbon; OC, organic carbon; AIE, aerosol indirect effect; CFCs, chlorofluorocarbons; VOCs, volatile organic compounds.

When we say that CO_2 has a forcing of 1.5 w/m^2 (watts per square meter), we mean that as a result of the accumulated CO_2 in the atmosphere there is now 1.5 watts more energy arriving at each square meter of the planet's surface than leaving. The figure caption (reproduced from the original source) makes it clear that the 1.5 w/m^2 imbalance due to CO_2 has been accumulating, first slowly, but now quickly, for 250 years. On the other hand, what isn't stated, and it isn't obvious, is that the methane which is creating the 0.8 w/m^2 imbalance was almost all put into the atmosphere during the past 20 years. This is because CO_2 has a very long atmospheric lifetime. About 25% of every tonne emitted will still be in the atmosphere 500 years later. Methane, on the other hand, has a very short atmospheric lifetime. About 66% of every tonne emitted is gone in 10 years and 90% is gone by 20. Some of the CO_2 now in our atmosphere was put there during the burning of trees during deforestation 500 years ago, but almost none of the methane is older than 20 years.

Methane which leaks from fossil fuel mining will have its huge warming for 10–20 years and then break down into CO_2 to become just another CO_2 emission. Methane from livestock (or other biological sources) effectively takes CO_2 from the carbon cycle, and puts it on warming "steroids" for 10–20 years.

What heats the planet up, of course, isn't forcing, but *net* forcing. Net forcing is known with reasonable directness from satellite measurements which measure energy arriving and energy leaving the planet. However, there is considerable uncertainty in some of the component estimates in the above figure. Recent work[2] indicates that the forcing from Black Carbon (0.39 w/m^2 in our figure and the result of biomass burning and diesel exhausts) may be much higher than previously estimated – perhaps even 0.9 w/m^2. If this is confirmed, it means, firstly, that some other forcing has been overestimated and secondly, that Black Carbon joins the ranks of major climate forcers. It is also of great significance, because Black Carbon has an even shorter atmospheric lifetime than methane, which means reductions have a quick beneficial impact on net forcings.

NASA climate scientist James Hansen makes an absolutely crucial observation about the different roles of forcing and net forcing in the quote with which we began this submission. Here it is again with more context[1]:

> *"The distinction between CO_2 and the trace gases is important, because the same activities that produce most of the CO_2, burning of fossil fuels and land conversion, also produce aerosols. The net climate forcing by aerosols, direct plus indirect, is almost certainly one of cooling, which would tend to at least partially obscure globally warming due to increasing CO_2. Thus I suggest that the sharp global warming trend that began in the 1960s was primarily a consequence of the activities producing the trace gases, mainly CFCs and methane (CH_4), as these gases produce only warming."*

The concentration of methane in the atmosphere is 1.77 parts per million compared with 385 parts per million of CO_2. Yet this tiny amount of methane has, according to the above figure, a forcing of 0.8 w/m^2, a little over half the forcing of CO_2.

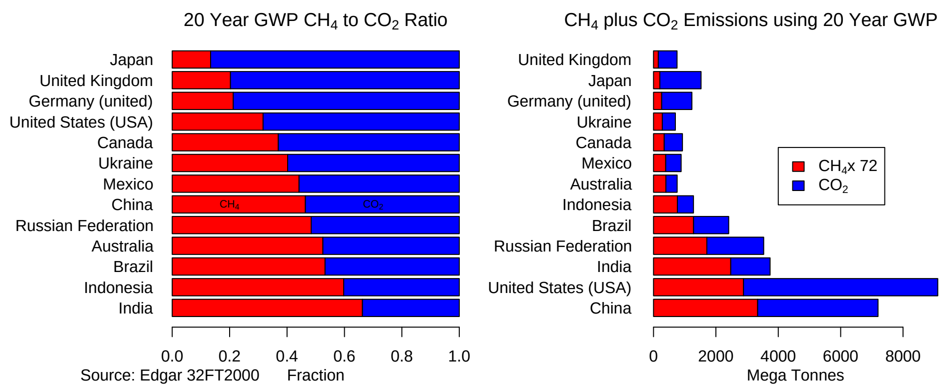
If you think about these numbers, the steady stream of reports and newspaper ar-

[2] Forthcoming in *Nature Geoscience* by Ramanathan and Carmichael.

ticles which tell people that methane has 21 times the potency of CO_2 don't make sense. Multiplying a tonne of methane by 21 to get an "equivalent" amount of CO_2 simply doesn't give you an equivalent forcing. The figure of 21 is what you get when you average methane's forcing relative to CO_2 over 100 years — which is hardly relevant since methane doesn't last that long.

Is there a factor which can be used to multiply a tonne of methane emissions to find its approximate forcing relative to a tonne of CO_2 emissions? Yes — according to the IPCC Fourth Assessment report[3], one tonne of methane will have an impact on warming during the 20 years after its release which is equivalent to 72 tonnes of CO_2. If you are interested in methane's forcing (its warming), then multiplying by 72 is a reasonable estimate.

The following graphs show the relationship of methane and CO_2 forcings for the major methane emitting countries when the proper forcing factor of 72 is used. On the left is the ratio of forcings and on the right are the mega tonnes of the two gases when $CO_2^{\mathbf{eq}}$ is calculated with a factor of 72.



Note that in Australia, methane and CO_2 forcings are very similar.

Australia's livestock produce about 3.1 mega tonnes of methane annually (out of our total of 5.4), mostly through enteric fermentation in the guts of our sheep and cattle, but also via manure and savanna burning. This has a warming impact bigger than all of our coal fired power stations. These power stations produce about 180 megatonnes of CO_2[4]. The 3.1 mega tonnes of methane generates a warming equivalent to $3.1 \times 72 = 223$ tonnes of CO_2. This calculation hasn't even taken into account any of the cooling aerosols produced by those power stations. In addition to providing a more powerful incentive to reduce livestock numbers, a conversion factor of 72 would provide a powerful incentive to flare the methane produced from underground coal mining. Currently, about 0.5 mega tonnes of methane is produced from underground coal mines which produces warming similar to about

80% of Australia's passenger vehicles[4].

Globally and locally, livestock are not only the biggest single source of methane, they are also the biggest driving force behind deforestation[5] which is a major generator of Black Carbon. The red meat industries are a double problem: they generate huge quantities of methane and drive the production of large amounts of black carbon.

If the goal of an ETS is to reduce warming — to cool the planet — then the appropriate factor which should be used to convert methane to CO_2^{eq} is not 21, but 72. If your aim is to protect and foster methane producing industries, then use 21.

Hansen[6] makes it clear just how valuable methane reduction can be to buy time to allow CO_2 emission reductions to take effect:

> *"We posit that feasible reversal of the growth of atmospheric CH_4 and other trace gases would provide a vital contribution toward averting dangerous anthropogenic interference with global climate. Such trace gas reductions may allow stabilization of atmospheric CO_2 at an achievable level of anthropogenic CO_2 emissions, even if the added global warming constituting dangerous anthropogenic interference is as small as 1°C. A 1°C limit on global warming, with canonical climate sensitivity, requires peak CO_2 440 ppm if further non-CO_2 forcing is 0.5 w/m^2, but peak CO_2 520 ppm if further non-CO_2 forcing is 0.5 w/m^2. The practical result is that a decline of non-CO_2 forcings allows climate forcing to be stabilized with a significantly higher transient level of CO_2 emissions."*

Since livestock is the largest source of anthropogenic methane on the planet[5], it shouldn't be surprising that IPCC Chairman, Rajendra Pachauri, has recently urged people to eat less meat, saying:

> **"Please eat less meat – meat is a very carbon intensive commodity . . . this is something that the IPCC was afraid to say earlier, but now we have said it."** IPCC Chair Rajendra Pachauri, Jan 15th 2008[3]

Hansen echoed this call in an email to me on 17th of February. Here is the email in its entirety — reproduced with his permission.

> *"Geoff,*
>
> *I say that the single most effective action that a person can take to curb*

[3] `http://www.abc.net.au/news/stories/2008/01/16/2139349.htm?section=world`

global warming is support a moratorium, and eventual phase-out, of coal-fired power plants.

However, in our personal life styles, the most effective action is to begin to alter our diet more toward vegetarian. I do not believe it is realistic to exhort everybody to become vegetarian, but we can greatly reduce the stress on the planet, including global warming, with realistic changes by a large number of people. I have become 80-90% vegetarian. For the sake of nutrition and because of available choices, becoming 100% vegetarian is not easy, and not essential, in my opinion. But a change in that direction is one of the best things we can do – probably more effective than buying a Prius.

Jim"

Note that this submission shouldn't be interpreted as a plea to forget CO_2 and focus on methane and Black Carbon. It is an attempt to redress an Australian and global imbalance that has seen all attention shift to CO_2 while other major forcings pretty much get a free ride. If you think we are exaggerating, consider carefully that the CSIRO, our major public research body is advocating a diet high in red meat[7, 8] — produced by an army of 28 million methane belching cattle and 100 million sheep. This makes the CSIRO a major obstacle to reducing Australia's climate forcings.

Two problems — one set of factors

In the introduction we defined two *major* problems. Cutting emissions of CO_2 dramatically *now* is absolutely essential and will help future generations because a substantial fraction of CO_2 emissions stay aloft for hundreds of years. This is problem number one and it dominates public discussion and understanding of global warming.

But problem two is to cut *net* climate forcing — and this concept is totally missing from public discussion. Note the word *net* carefully. Unfortunately the two problems don't have the same solution and we can't afford to ignore either problem.

We saw in the Introduction that mass closure of coal fired power stations has positive and negative impacts. As our earlier quote from Hansen implies, the levels of sulphate aerosols these power stations create would drop quickly — within days. The level of atmospheric CO_2 wouldn't drop at all for decades. So we would be removing some negative forcing quickly without a similarly rapid reduction in the positive forcing. Depending on the precise mix of coal types and aerosol types, net forcing could even go up. The planet could get temporarily hotter! Reducing methane, on the other hand, achieves quick reductions in net forcing with no such risk. Without net forcing reductions, we run the real risk of crossing critical climate tipping points.

A pure ETS converts emissions to the single currency of $CO_2^{\mathbf{eq}}$ using a set of factors for methane, Black Carbon and so on $(f_{ch4},\ f_{bc},\ \ldots)$ but provides no additional legislative tools to ensure that the market tackles both problems with appropriate zeal.

The choice of factors in such a scheme is critical. For example, if f_{ch4} was 1000, then to produce 1 tonne of methane you would need a permit for 1000 tonnes of CO_2 and it is likely that no cattle farmers would obtain permits. This would be good for forcings, but unfair on cattle farmers. On the other hand, if the methane factor was too low, then some power companies might decide that building power stations was too much like hard work and that they could make more money out of cattle — so they could take their permits and enter the cattle business instead. This could drive methane emissions up instead of down.

If a goal is to reduce cattle methane for the good of the planet, then a high methane factor will do it, but another option, which may be considered fairer, would be to announce this as clear policy up front and then use public money to reduce the industry in a controlled fashion over a reasonable time period. This was done with Australia's tobacco industry some years back.

An alternative to a single ETS with a set of factors driving policy, would be to have separate cap and trade systems for different forcings. This would give finer control to maximise the chance of that both major problems were adequately addressed.

It may seem that it is possible to choose a set of conversion factors which will lead to a simultaneous solution of both major problems. One of the authors (Russell) has spent nearly 30 years in the mathematical optimisation industry and knows that choosing a set of factors to achieve multiple desired outcomes is rarely as simple as it sounds. Optimisation of a function using a set of weightings is easy to understand and implement, but in the real world, such methods are dismal. For example, in his field of transit scheduling, the best software simultaneously solves all the specified problems. If there is no solution simultaneously solving all problems then the software will discover this. Some software does use the "magic factor" method and is useless in all but the simplest of cases. If your choice of factors doesn't yield the desired results, you try another set and fail in a different and generally unpredictable manner. Like a gambler, you can flounder about endlessly chasing that perfect set of factors which will solve all problems.

In an ETS, the choice of factors is far less flexible than in a computer scheduling system. If you change, for example, the methane factor, then what will be the response of the people who hold permits obtained with the previous factor set? Will they demand compensation?

A second difficulty for any ETS

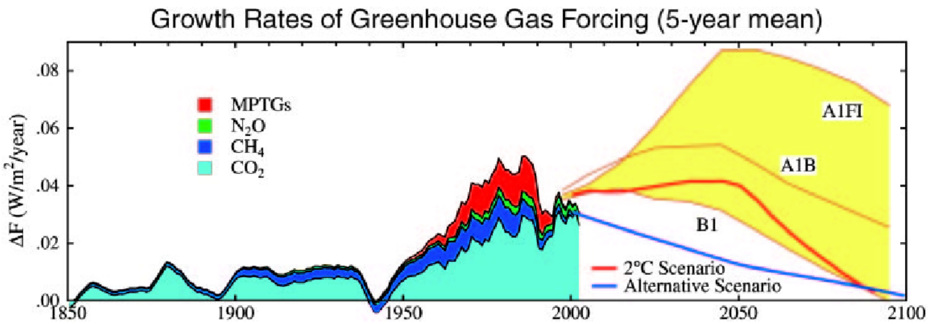
For a pure cap and trade ETS to be successful, it is desirable, and perhaps necessary for a tonne of emissions from one source to be equal to a tonne from any other source. Papers by James Hansen and others[2, 9] explain why this isn't the case with coal and oil CO_2 emissions.

> *"Estimated oil and gas reservoirs . . . with only modest further use of coal, are sufficient to bring atmospheric CO_2 to [the] approximately 450–475 ppm limit of the alternative scenario [see [9]]. Given the convenience of liquid and gas fuels, it seems likely that readily available oil and gas reservoirs will be exploited. Thus, attainment of the alternative scenario implies the need to phase out coal use, except where the CO_2 is captured and sequestered, and to impose the same constraint on development of unconventional fossil fuels. In practice, achievement of these goals surely requires a price (tax) on CO_2 emissions sufficient to discourage extraction of remote oil and gas resources as well as unconventional fossil fuels. Furthermore, the time required to develop fossil-free energy sources implies a need to stretch supplies of conventional oil and gas. In turn, this implies a need for near-term emphasis on energy efficiency[2]."*

In summary, any coal we use now will reduce the gas and oil we can use in the future and that it is unrealistic to expect people to forego use of such convenient fuels. Hence any ETS must be enhanced with additional legislative tools to force a coal phase out.

Health impacts of forcing agents

The destruction of stratospheric ozone by various gases was successfully halted by the 1987 Montreal protocol. This was implemented primarily because of health concerns, particularly skin cancer. But the guilty gases are also greenhouse gases. The chart below (from [6]) shows, in red, the growth of forcings due to these gases. Unlike CO_2, these gases, by chance, have a very short life time, and once we stopped production, their forcings dropped rapidly.



If we hadn't implemented the Montreal protocol, these gases would have been the dominant greenhouse gases now and CO_2 would have been relegated to the category of "just another greenhouse gas". The Montreal protocol has been spectacularly successful because people agreed that the gases constituted a clear and present health danger worth taking action on. As a byproduct, it has recently been estimated[10] that the radiative forcing saved by the Montreal protocol amount to between 9 and 12 giga tonnes of CO_2. If all countries reach their Kyoto targets by 2012, the total savings will amount to about 2 giga tonnes.

Other greenhouse forcings have important health implications also. Black Carbon, mentioned earlier, isn't just a climate forcing but a potent pollutant which kills an estimated 400,000 people (mainly women and children) annually in low income countries due to smoke inhalation from indoor cooking. Reducing Black Carbon production therefore is doubly valuable.

A 2005 paper titled "Management of Trophospheric Ozone by Reducing Methane Emissions" estimates that there would be net monetized global benefit to agriculture, forestry, and human health of reducing anthropogenic methane emissions by some 17%[11]. The health benefits assessed related to improved air quality and a subsequent decline in respiratory problems. Trophospheric ozone is the culprit and methane is a precursor.

A recent *Lancet* paper by Australian Professor Tony McMichael discussed the emissions reduction implications of reduced global average meat consumption. He suggested steep cuts in meat intake in high-income countries and modest increases in meat intake in low-income countries. The health benefits in high-income countries would mainly be in reduced heart disease and colorectal cancer — some of which would be transfered to low-income countries[12]. McMichael didn't attempt to quantify the various health gains but Professor Graham Giles of Cancer Council Victoria estimates that cutting red meat back to one serve per week would cut new cases of colorectal cancer in Australia by about 48%, meaning a reduction of 6,000 new cases annually[13].

Practical implementation difficulties

We assume during this section that there is a separate cap and trade system for methane and consider how to apply such a system to livestock.

A cap and trade system works by internalising the costs that are imposed on others by any economic activity that produces $CO_2^{\mathbf{eq}}$. This may encourage consumers to switch their purchases to other goods that can be produced without, or with less, $CO_2^{\mathbf{eq}}$. Or it may encourage purchasers of permits to implement efficiencies which then allow them to produce more cheaply, or to produce more with the same permit, or to sell part of that permit. For example if a company has a permit to emit 100 tonnes of CO_2 and then finds a way of saving 10% of those emissions, they can sell somebody else a 10 tonne permit. Because such permits have substantial value, an auditing scheme is required to check that efficiencies have been fully realised.

In the case of livestock, a person or company could bid for a license to run some number of animals. The license would be tradeable with a fixed term. The cost of the licence would be reflected in the price of the product, and hence would provide consumers with an incentive to switch to products that can be produced without emitting so much $CO_2^{\mathbf{eq}}$.

The successful implementation of such a scheme faces two challenges. Firstly, there is an auditing challenge. Cattle farmers, for example, are spread across a huge part of the continent. Who will check if a Kimberley cattle farmer claims to be using magic feed supplement X which has been demonstrated to reduce methane emissions by 20% on a CSIRO research station? Secondly, no or few cattle farms are big enough to undertake methane reduction research, so this has to be done by industry bodies like Meat and Livestock Australia or Government.

Research into reducing methane production from cattle predates concern over global warming. For example a 1982 paper[14] discusses a series of methane inhibitors and cites other work going back to the early 1970s. A substantial amount of energy is "wasted" by ruminants during the production of methane and researchers have long wanted to harness this wasted energy to increase growth. This isn't the place to go into too much detail except to say that the field is littered with failures for a variety of reasons. We consider that current research into using kangaroo gut microbes in ruminants will similarly fail for the simple reason that sheep and cattle are more efficient at converting good (energy dense) pasture into body mass than kangaroos — which are excellent at converting bad (energy poor) pasture into body mass. Hence we speculate that if the projects successfully manage to populate cattle rumens with kangaroo microbes, ruminant efficiency will drop and no ruminant farmer will be very interested.

It is clear that an ETS based around using trading to encourage efficiencies to drive down methane production faces serious difficulties. Counting sheep and cattle, on the other hand is simple and easily verifiable as the animals are brought to market in towns and cities[4]. Hence a planned reduction in total herd numbers would be easy to implement with a cap and trade system based on livestock numbers rather than methane emissions. A person or company could bid for a permit to run some number of animals. Either the permit or a part thereof would be tradeable with a fixed term. The cap would gradually be lowered.

Conclusion

In summary, we need to reduce CO_2 emissions to give future generations a reasonable chance of keeping climate relatively benign. Furthermore, we can't just reduce it by any available means, we have to favour technologies that leave as much coal in the ground as possible. We also need to reduce net forcings to keep from crossing dangerous tipping points and to reduce current warming. We can't afford to violate any of these constraints in our approach to climate change.

The major point that we hope this submission has demonstrated is this: in order to reduce *net* forcings an ETS needs to use a methane conversion factor that converts methane tonnages to $CO_2^{\mathbf{eq}}$ tonnages in a way that reflects relative forcings. A factor of at least 72 is warranted.

In addition, we have raised some questions about whether a *pure* ETS will achieve the desired results, given that generating a tonne of CO_2 from coal has a different impact on the climate due to aerosol production compared with generating a tonne of CO_2 from oil, and given also that it is virtually certain that all easily accessible supplies of oil and gas will be used. For that reason, for an ETS to have any chance of success, we are likely to need additional regulation to phase out coal use (other than with full CCS) by, say, 2030.

Geoff Russell Peter Singer Barry Brook
April 2008

[4] In the language of the ETS discussion paper, there is a clear point of obligation.

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