NEW ZEALAND
AGRICULTURAL GREENHOUSE GAS
Research Centre

Economic and Policy Implications of Alternative GHG Metrics

Greenhouse gas 'metrics' aim to convert the properties and implications of different greenhouse gases into a single currency, often called 'carbon dioxide equivalence'. Inconveniently, there are different ways of establishing that equivalence, as it really is a case of comparing apples and oranges: science alone cannot determine which is the best way.

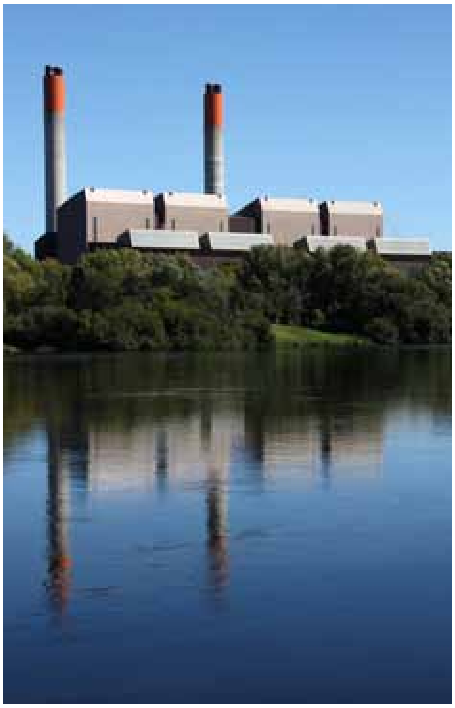
This fact sheet describes the most common equivalence metric, the Global Warming Potential, used by the UNFCCC and in the Kyoto Protocol, and other alternative metrics. It also highlights the potential implications of those metrics – globally, and for New Zealand – for our collective efforts to limit greenhouse gas emissions and projected climate change at least cost.

What are greenhouse gas metrics?

Increasing concentrations of greenhouse gases in Earth's atmosphere are now widely understood to result in rising average temperatures and other associated climate changes. Carbon dioxide (CO_2) is the most important greenhouse gas produced by human activities, but other gases, such as methane (CH_4), and nitrous oxide (N_2O), also contribute substantially to the overall warming effect. The more we reduce emissions of all of these gases, the more we would expect to reduce the rate and magnitude of future climate change.

Mitigation strategies that tackle a number of greenhouse gases simultaneously are generally considered more effective, and less costly than strategies focussed only on a single gas, such as carbon dioxide. Consistent with this, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol don't prescribe emissions targets for individual gases, but instead set aggregate targets for a group of greenhouse gases. This gives countries the flexibility to reduce emissions of this mix of gases in the most cost-effective way, including through international and domestic emissions trading.

The New Zealand emissions trading scheme (NZ-ETS) includes all greenhouse gases, which means emissions in one industry sector can be traded against emissions reductions of another gas in a different sector. Agricultural emissions of methane and nitrous oxide, mainly from sheep, beef and dairy, are in principle included in the NZ-ETS, although the Government recently announced its intent to delay the entry of agriculture into the scheme.



Any such trading scheme critically relies on a 'common currency', or 'exchange rate' that sets the relative value of reducing emissions of one gas compared to another. This is fundamental to allow emissions of different gases to be compared and traded in a common market. The common currency used to compare greenhouse gas emissions is also referred to as a greenhouse gas 'metric'.

Metrics help answer important questions: how much weight should we give to reducing methane emissions, compared to nitrous oxide or carbon dioxide? If a company or individual were to decrease carbon dioxide emissions by one tonne, by how much could methane emissions increase for net emissions to remain the same? If it costs the same money to reduce one tonne of methane, or 20 tonnes of carbon dioxide, which would be 'better' for the climate? Do products that result in emission of mainly methane have a higher or lower carbon footprint than products that result in emissions of carbon dioxide?

Answers to these questions depend on the relative contribution each gas makes to the greenhouse effect, and the consequent warming of our climate. Some gases are more effective at trapping heat than others, and each has a different lifetime in the atmosphere: in some cases, that lifetime depends on how warm the atmosphere is. Scientists recognise those different properties, and have developed metrics that give emissions of each gas a simple weighting factor and thus allow the costs of mitigating different gases to be compared in a straightforward way.

Due to the wide use of greenhouse gas metrics in government and private decision making, metrics that change the weight placed on short-lived gases could affect many aspects of how society responds to climate change.

The Global Warming Potential and alternative metrics

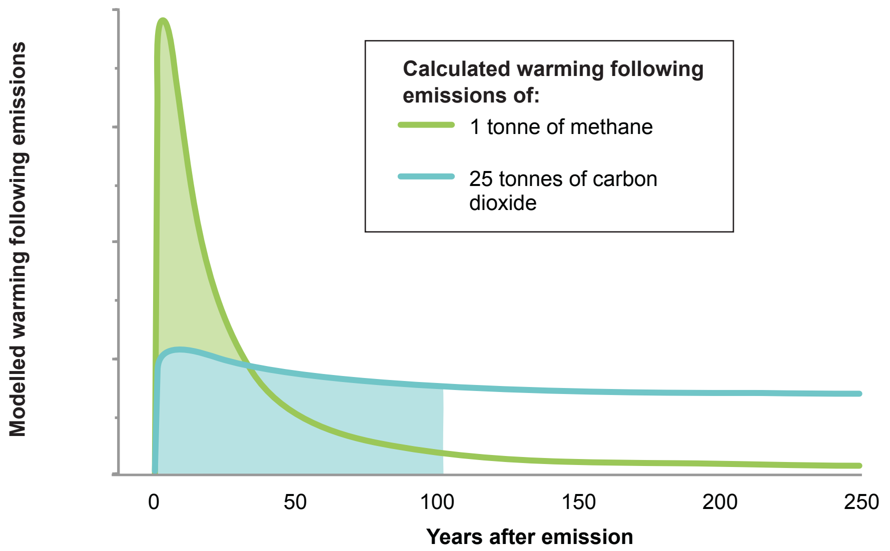
The UNFCCC has adopted the Global Warming Potential (GWP) as the universal metric for reporting GHG emissions, and for measuring the success of mitigation. The agreement reached in Durban in 2011 for countries' emissions out to 2020 – along with most domestic climate policies and corporate programmes – continues to use GWPs to compare emissions from different sectors, set overall targets, and inform emissions trading.

The GWP uses carbon dioxide (the most important greenhouse gas) as a reference, against which the warming effect of other gases can be compared. Emissions of each gas are calculated by multiplying its weight by its GWP, which is then reported as a 'carbon dioxide equivalent' emission (sometimes abbreviated as 'CO_2-eq').

The GWP is based on the amount of carbon dioxide that would have produced the same cumulative warming effect (technically known as 'radiative forcing') over a given period as the gas being emitted. For instance, over the course of a century, emitting one tonne of methane is estimated, based on measurements and climate model calculations, to have an approximately 25 times greater warming effect than one tonne of carbon dioxide, while nitrous oxide has an effect 298 times greater. So methane's 100-year GWP is 25, while nitrous oxide's is 298; and the emission of one tonne of methane is reported as 25 tonnes of CO_2-eq.

However, GWPs have their shortcomings. Methane is a much more powerful greenhouse gas than carbon dioxide, but has a short lifetime in the atmosphere:

Modelled warming following emissions of methane and carbon dioxide



Calculated warming resulting from emission of either 1 tonne of methane or 25 tonnes of carbon dioxide. Over 100 years, the cumulative warming from 1 tonne of methane is approximately the same as from one tonne of carbon dioxide.

most of the warming from methane occurs within 50 years after its emission. By contrast, emitting carbon dioxide produces a warming effect that lasts for many centuries. Hence, the longer into the future we chose to look, the greater carbon dioxide's cumulative warming effect appears compared to methane.

The UNFCCC adopted a 100-year time horizon to calculate GWPs, but this may not necessarily be the optimum time horizon. Some suggest we should focus on the next 20 years, which is a time frame more relevant to business and policy decisions, and better reflects the rate of warming we could expect. A contrary view contends that a metric should look at least 500 years

“There is no simple scientific answer as to which is the ‘correct’ metric, because answers to these questions depend not just on science, but on the choices society wishes to make.”

ahead, given the long lifetime of carbon dioxide, and the essentially irreversible changes to the climate system that current emissions of carbon dioxide could cause.

What's more, looking at the cumulative warming effect is not the only way to compare greenhouse gas emissions. Some people argue that we should instead concentrate on the warming that might result at a specified time in the future, perhaps when warming might cross some critical thresholds. To address this view, an alternative metric, called the Global Temperature Change Potential (GTP), has been developed, which compares the warming predicted to occur in a given future year resulting from today's emissions. The 100-year GTP gives lower weight to methane emissions than the 100-year GWP, because it focuses only on the more distant future and 'forgets' the warming that has occurred in between (see graph below).

The GTP has been proposed in two variants: a fixed and a time-dependent one. The fixed GTP looks at warming a fixed time interval ahead (e.g. 100 years), no matter when the emission occurs. The time-dependent GTP looks at warming in a given future year (e.g. the year 2100). In the latter case, an emission in 2012 is weighted by the warming it is expected to produce 88 years ahead, whereas an emission in 2090 would be weighted by the warming only 10 years ahead. Such time-dependent GTPs would give a steadily increasing weight to methane emissions as the target year is approached. If the chosen target year is 2100, this would mean an initial weight of less than 10 in the first two decades of the 21st century, but more than 100 towards the end of the century.

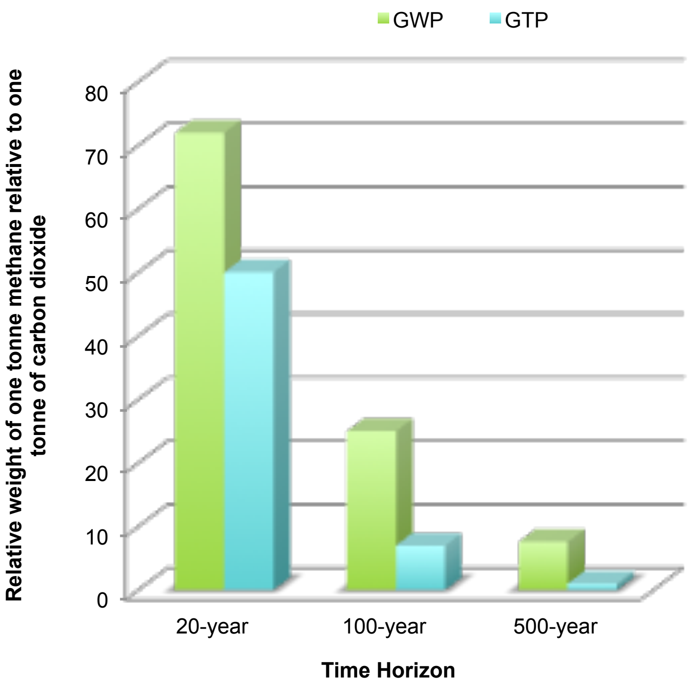
Either metric has to answer several key questions though: how far into the future do we wish to look? When are the most significant impacts from climate change expected to occur? Do we wish to give the same weight to impacts that might occur from warming hundreds of years into the future, as we would to impacts that might arise in the next two decades? And what about impacts expected to occur soon in one part of the world, but only later (or never) in another part?

Given the very different lifetime of methane and carbon dioxide in the atmosphere, the weighting given to methane differs significantly, depending on whether we wish to look 20, 100 or 500 years ahead, or whether we want to focus specifically on the year 2030, 2100, or 2500.

There is no simple scientific answer as to which is the 'correct' metric, because answers to these questions depend not just on science, but on the choices society wishes to make.

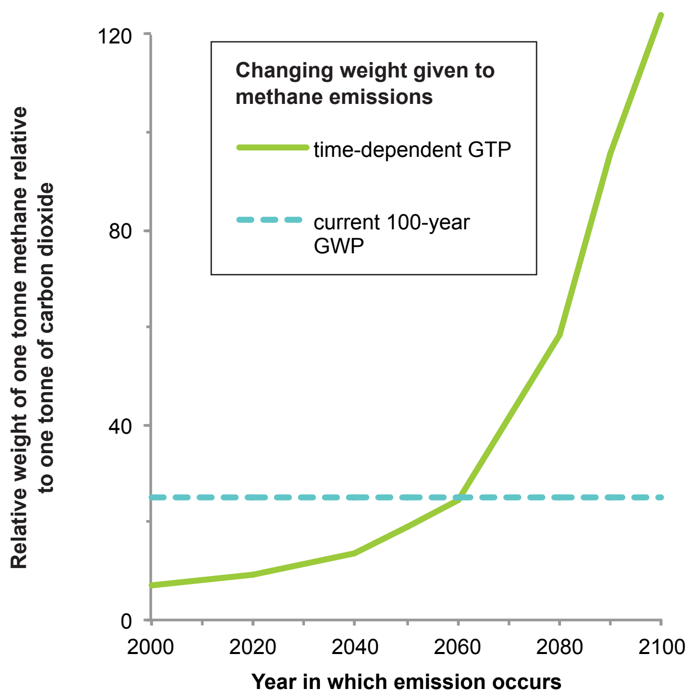
Alternative metrics change the CO_2-equivalence of methane

Fixed GWPs and GTPs



The weight assigned to the emission of one tonne of methane, relative to one tonne of carbon dioxide, by alternative metrics and time horizons. The 100-year Global Warming Potential (GWP) metric, already widely adopted for emission targets to 2020, gives each tonne of methane 25 times the weight of a tonne of carbon dioxide.

Time-dependent GTP



If a time-dependent GTP metric is used, the weight given to the methane emissions would increase steadily over time, from currently less than 10 to eventually more than 100. The weight given by the current 100-year GWP is shown for comparison.

Implications of alternative metrics

Different choices of metric and time horizon could result in significantly different weights being assigned to non-CO_2 gases – particularly methane – which in turn could shift the balance of mitigation efforts. Science alone can't tell us what metric to use.

So how might the choice of metric we make affect the overall cost and efficacy of mitigation efforts, both globally, and for New Zealand? Changing the metric could affect not only overall emissions targets and abatement costs, but also the distribution of emissions costs between sectors. Agriculture will be particularly interested in the effect of different metrics on the weight accorded to methane and nitrous oxide relative to carbon dioxide, and their implications for the cost of livestock and food production. Different metrics would also change carbon footprints and could thus affect consumer preferences for livestock versus other agricultural products, and might modify priorities for further research into developing cost-effective mitigation options.

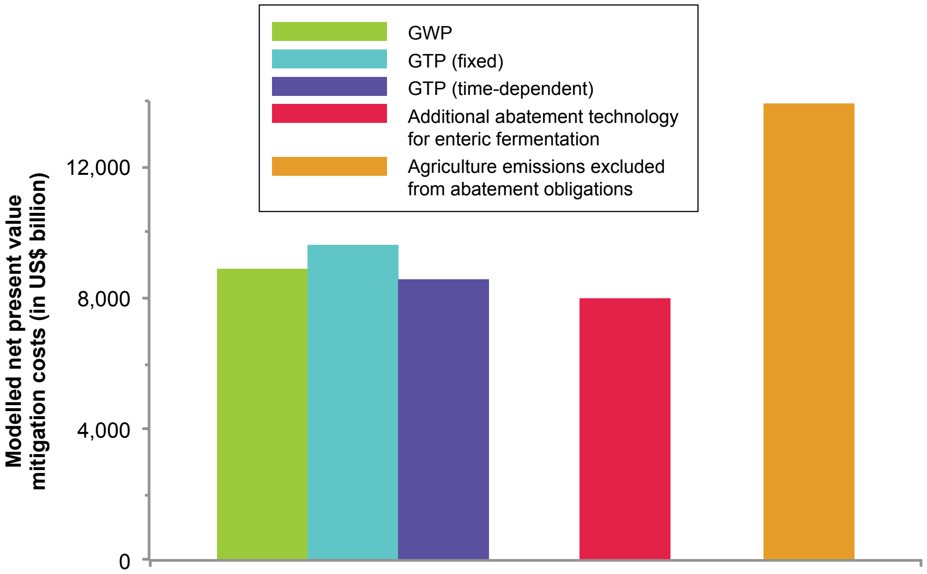
Countries are now in broad agreement that they wish to limit global warming to 2°C. There is strong consensus among scientists that, regardless of metric, achieving this goal requires reducing global carbon dioxide emissions to near zero before the end of the 21st century. But there is some flexibility as to how quickly those reductions have to occur. The overall cost of mitigation to meet the 2°C goal depends in part on how much we reduce emissions of other gases in addition to carbon dioxide.

Economic and technology models suggest that using 100-year GWPs would result in lower global mitigation costs than if we adopt a metric that gives a consistently lower weight to methane, such as a fixed 100-year GTP. This is because carbon dioxide is the dominant greenhouse gas, and most mitigation costs globally will arise from efforts to reduce net carbon dioxide emissions. If that pressure on carbon dioxide mitigation can be relieved by reducing the additional warming effect from other gases, overall mitigation costs will tend to be lower.

If our main goal, however, is to limit long-term warming by the end of the 21st century, then reducing methane now contributes only little to that goal. This is because the warming effect from current methane emissions would have mostly (though not entirely) worn off by 2100. Placing too much weight on methane in the immediate future would therefore increase costs, without delivering long-term benefits.

For this reason, economic models indicate that the lowest mitigation costs overall are achieved using time-dependent GTPs: they give a low weight to methane now, but steadily increase it until, by the end of the 21st century, its weight becomes more than four times greater than under GWPs.

Global Mitigation Costs Across all Sectors



Global mitigation costs to limit warming to 2 degrees, based on an integrated assessment model with a detailed representation of the global energy sector. The model assumes global cooperation and participation of all sectors, and a steady improvement of agricultural abatement options over time. The detailed results are from modelling work recently completed by the New Zealand Agricultural Greenhouse Gas Research Centre (see Reisinger and Stroombergen, 2011)

"The choice of metric [...] appears to make little difference to overall mitigation costs, as long as the world takes stringent, collective action to reduce greenhouse gas emissions."

Do we need metrics at all?

Some scientists argue that we should not use metrics at all. This is because, if we are to limit global warming to no more than two degrees, the most important task is to reduce global emissions of carbon dioxide to near zero before the end of the 21st century. By contrast, reducing emissions of short-lived gases such as methane is not absolutely necessary to achieve that two-degree goal: it helps to reduce costs, but is not absolutely necessary. Mixing different gases via metrics, some scientists contend, only distracts from the central task of global climate policy.

The overriding need to significantly reduce carbon dioxide emissions, if the world is to limit warming to two degrees, is scientifically uncontentious. It is clear, however, that the cost of mitigation to meet the two degree goal would be lowered if we were able to also reduce emissions of other greenhouse gases at the same time. So the question remains: how much mitigation of other greenhouse gases is scientifically justified, and economically reasonable, in addition to stringent carbon dioxide reductions?

Metrics can be seen as a way to help inform this broader question, even amid reservations against unrestricted trading amongst gases with very different physical properties. Given that emissions trading is widely seen as a cornerstone of climate policy, it seems very likely that some form of metrics will be employed in future climate agreements, and therefore in domestic policy.

Whether such escalating weights on methane could be reliably and consistently applied in climate policies is another question, as it essentially shifts the cost of dealing with methane emissions onto future generations, and it could give mixed messages about mitigation research priorities now and in future.

Despite these differences, the economic consequences of choosing different metrics appear to be relatively small. Modelling studies suggest that if our main goal is to limit long-term warming, and if there is global cooperation towards that goal, using 100-year GTPs instead of GWPs would increase global mitigation costs by between around five and 10 per cent. Using time-dependent GTPs would lower costs by some five to six per cent.

These cost differences are minor compared with the implications of other assumptions. For example, the development and global implementation of new technologies to reduce methane from enteric fermentation could reduce global mitigation costs by 10 to 20 per cent, as it could reduce global methane concentrations significantly more than currently seems feasible. These additional methane reductions could allow us to delay carbon dioxide reductions by just a few more years, hence reducing overall mitigation costs. By contrast, not mitigating agricultural emissions at all would increase global mitigation costs by some 25 to 50 per cent, because carbon dioxide emissions – mainly from energy production and transport – would then need to be reduced even more rapidly.

The choice of metric, then, based on studies available to date, appears to make little difference to overall mitigation costs, so long as the world takes stringent, collective action to reduce greenhouse gas emissions. Widespread participation of countries and different industries, along with the development and refinement of mitigation options, appear to be far more important.

"New technologies to reduce enteric fermentation, even if they came at a considerable expense, could reduce global mitigation costs by 10 to 20 per cent."

These conclusions are based on idealised assumptions though: no studies have yet been done on the role of metrics in scenarios where global action on climate change is piecemeal and fragmented. It is also an open question whether different countries, businesses and consumers would change the way they engage with climate change if methane were assigned a different weight compared to carbon dioxide.

Issues for New Zealand

Existing model studies suggest that, provided there is global collaboration towards a long-term goal, the choice of metrics makes little difference to mitigation costs globally. But this may not hold for individual countries like New Zealand that have a large fraction of agricultural non-CO_2 emissions.

If emissions are weighted by GWPs, agriculture is New Zealand's largest greenhouse gas emitter, accounting for about 47 per cent of New Zealand's total gross emissions in 2010. By contrast, if fixed 100-year GTPs were used, agriculture's current contribution to total greenhouse gas emissions drops to about 35 per cent, and power generation and transport would instead comprise a greater share than agriculture, at almost 60 per cent.

"If all countries were to include agriculture in their mitigation efforts, [...] New Zealand would benefit more if the world used GWPs to weigh agricultural emissions than if it used GTPs."

Given the current scarcity of technologies to significantly and reliably reduce emissions of methane from livestock, these different proportions matter, particularly with regard to the government's long-term goal of reducing gross emissions by 50 per cent, relative to 1990, by 2050.

Intuitively, then, it seems that the metric which gives the lowest possible weight to methane – or perhaps even excludes agricultural emissions entirely – should result in the lowest costs to New Zealand to meet its long-term mitigation goals.

However, New Zealand's future economic fortunes in relation to climate change are determined not only by its domestic emissions target, but also by the global prices of carbon and commodities. Modelling studies suggest that these two factors can play at least as important a role in determining New Zealand's economic fortunes as the direct cost to from its methane emissions.

If the world adopts a metric that gives a consistently lower weight to methane than GWPs, this would require more stringent global reductions of carbon dioxide, which would drive up global carbon prices. Because New Zealand will probably need to buy carbon credits on the international market to help meet its 2050 emissions target, it would then have to pay a higher price for those credits than it would under GWPs.

"A global agreement to price all emissions – agricultural and otherwise – appears by far the cheapest way to curb greenhouse gas emissions, while offering New Zealand farmers more opportunities to capitalise on their greater efficiency."

More importantly, global mitigation measures will also influence agricultural commodity prices. These influences can be direct – if agricultural production faces additional costs from its greenhouse gas emissions – and indirect, through measures to stem deforestation and promote biofuels, which compete with livestock production for available land. If all countries were to include agriculture in their mitigation efforts, this would raise commodity prices globally. Economic and trade models suggest that the resulting hike in export returns would more than compensate for the costs of our own greenhouse gas emissions. In such a scenario, New Zealand would benefit more if the world used GWPs to weigh agricultural emissions than if it used GTPs.

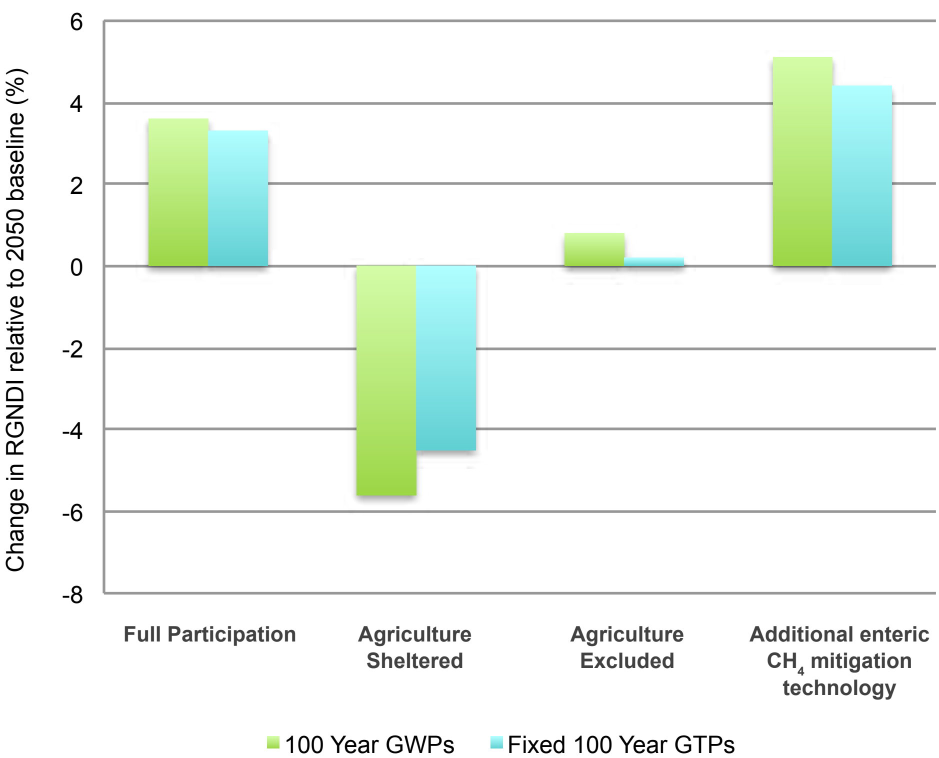
These benefits would be amplified if additional technologies to mitigate livestock methane came on stream, because they would further enhance New Zealand's competitive advantage.

On the other hand, if New Zealand were the only country, even in the long term, to put a price on its agricultural emissions, then it would incur economic losses. Those losses would be lower if its emissions were weighed using GTPs, rather than GWPs.

On balance, choices around long-term stabilisation targets, the inclusion or exclusion of agriculture globally, and the availability of further technologies to reduce agricultural GHG emissions seem to be more important for New Zealand than any plausible choice of metric. A global agreement to price all emissions – agricultural and otherwise – appears by far the cheapest way to curb greenhouse gas emissions, while offering New Zealand farmers more opportunities to capitalise on their greater efficiency.

The choice between GWPs and GTPs can modify, but does not fundamentally alter, the implications of those wider issues.

Modelled Economic Implications for New Zealand by 2050



Modelled economic implications of New Zealand meeting its 2050 goal of reducing gross emissions by 50 per cent below 1990 levels, under alternative policy scenarios. The economic implications are expressed as Real Gross National Disposable Income (RGNDI), relative to a baseline scenario of no climate change action taken anywhere in the world. "Full participation" means agriculture is fully included in mitigation actions everywhere. "Agriculture sheltered" assumes that even though countries are responsible for their agriculture emissions, New Zealand is the only country to expose the sector to the full price of carbon. "Agriculture excluded" assumes that agriculture is excluded in all countries from any abatement obligations. "Additional abatement technology" assumes that, over and above a steady progress in reducing emissions intensity of agriculture, a novel technology is developed that can reduce methane from enteric fermentation by 30% by 2030. All scenarios assume that countries take collective action to reduce emissions from all other sectors. Note that impacts of climate change have not been included in either the baseline or any of the specific scenarios; these model estimates do not represent the full cost of climate change.

Further Reading

Allen, M.R., D.J. Frame, C. Huntingford, C.D. Jones, J.A. Lowe, M. Meinshausen, N. Meinshausen, 2009: Warming caused by cumulative carbon emissions towards the trillionth tonne. *Nature*. **458(7242)**, 1163-1166.

Azar, C., D.J.A. Johansson, 2012: On the relationship between metrics to compare greenhouse gases – the case of IGTP, GWP and SGTP. *Earth Syst. Dynam. Discuss.* **3(1)**, 113-141.

Fuglestvedt, J.S., T.K. Berntsen, O. Godal, R. Sausen, K.P. Shine, T. Skodvin, 2003: Metrics of climate change: assessing radiative forcing and emission indices. *Climatic Change*. **58**, 267-331.

Hertwich, E.G., G.P. Peters, 2009: Carbon Footprint of Nations: A Global, Trade-Linked Analysis. *Environmental Science & Technology.* **43(16)**, 6414–6420.

Johansson, D., U. Persson, C. Azar, 2006: The Cost of Using Global Warming Potentials: Analysing the Trade off Between CO_2, CH_4 and N_2O. *Climatic Change*. **77(3)**, 291-309.

Johansson, D., 2011: Economics- and physical-based metrics for comparing greenhouse gases. *Climatic Change*. **110,** 123–141.

Manne, A.S., R.G. Richels, 2001: An alternative approach to establishing trade-offs among greenhouse gases. *Nature*. **410(6829)**, 675-677.

Peters, G.P., B. Aamaas, M. Lund, C. Solli, J. Fuglestvedt, 2011: Alternative "global warming" metrics in life cycle assessment: a case study with existing transportation data. *Environmenal Science and Technology.* **45(20)**, 8633-8641.

Rao, S., K. Riahi, 2006: The role of non-CO_2 greenhouse gases in climate change mitigation: Long-term scenarios for the 21st century. *Energy Journal*. **27 (Special Issue November 2006)**, 177-200.

Reisinger, A., A. Stroombergen (2011) Implications of alternative metrics to account for non-CO_2 GHG emissions. Ministry of Agriculture and Forestry, Wellington, NZ. pp88.

Shine, K., T. Berntsen, J. Fuglestvedt, R.B. Skeie, N. Stuber, 2007: Comparing the climate effect of emissions of short- and long-lived climate agents. *Philosophical Transactions of the Royal Society A*. **365(1856)**, 1903-1914.

Shine, K., 2009: The global warming potential—the need for an interdisciplinary retrial. *Climatic Change*. **96(4)**, 467-472.

Tanaka, K., G.P. Peters, J.S. Fuglestvedt, 2010: Policy Update: Multicomponent climate policy: why do emission metrics matter? *Carbon Management*. **1(2)**, 191-197.

van Vuuren, D., J. Weyant, F. de la Chesnaye, 2006: Multi-gas scenarios to stabilize radiative forcing. *Energy Economics*. **28(1)**, 102-120.

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