A note on New Zealand's methane emissions from livestock

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Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

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Foreword

New Zealand ratified the Paris Agreement in 2016, and committed to a target of reducing greenhouse gas emissions to 30 per cent below 2005 levels by 2030. The Government is now working to enact a Zero Carbon Bill, which will define a climate target for 2050 and establish a process for setting emission budgets that put the economy on a trajectory to meet that target.

The Government intends its 2050 target to be consistent with the goals of the Paris Agreement. These goals were broadly framed. Countries committed to a long-term global goal of '*holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C …*'. Countries also agreed to aim globally to '*achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century*'.

The three main greenhouse gases are carbon dioxide, methane and nitrous oxide. While most countries are focused on reducing emissions of carbon dioxide, New Zealand is forced to think harder about the contribution of methane and nitrous oxide from agriculture, which together make up a particularly high proportion of our total emissions.

This reflects the large role that agriculture plays in our economy today, and is the legacy of more than a century of pastoral farming. Agriculture's contribution to biological emissions started with the mass release of carbon dioxide from large scale deforestation, as forests were cleared to make way for farming. In the decades that followed, large amounts of methane began to be emitted by a growing livestock industry. In more recent years New Zealand's pastoral agriculture has intensified, relying on more nitrogen-rich feed and fertiliser, which has allowed more animals to be reared and also led to increasing amounts of nitrous oxide being emitted.

There is no easy blueprint to follow for reducing biological emissions from agriculture. For that reason, I decided to provide parliamentarians and their officials with a full report on how biological sources and sinks (e.g. afforestation) might be treated in the context of target setting and policy implementation. The full report is scheduled to be finalised later this year and, in common with all my reports, will rely on a mixture of in-house and commissioned research and analysis.

As part of that research I commissioned some modelling to provide a better understanding of how much warming a given level of methane emissions from livestock causes, and over what timeframe. The results of that modelling are relevant to further defining one of the target options in the Government's Zero Carbon Bill discussion document – namely, 'net zero long-lived gases and stabilised short-lived gases' by 2050.

The Government has provided no indication of the level at which methane emissions might be stabilised under this option, or the amount of warming that might follow from stabilisation. Indeed, the rationale behind such a 'split gas' target was missing.

I have decided to release the results of the modelling prior to the release of my full report, to inform the current debate over how methane should be treated in the context of the proposed Zero Carbon Bill. I hope that providing this modelling will result in a debate that is better grounded in the underlying science. The modelling report is annexed to this note.

I must stress, however, that these results alone cannot answer policy questions about the treatment of methane in target setting or policy implementation. For that reason, I am providing this note to explain the key findings from the modelling, and the limitations of such modelling for policy decisions.

Simon Upton
Parliamentary Commissioner for the Environment

Part 1

New Zealand's methane emissions from livestock

1.1 What questions were asked?

Dr Andy Reisinger of the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGGRC) was commissioned to undertake modelling to answer the following questions:

- If methane emissions from livestock were held steady at current levels, or follow business-as-usual projections, what would be their future contribution to warming?
- What reduction in methane emissions from livestock would be needed to achieve *no additional contribution to warming* from livestock methane above the current level?

To do this, Dr Reisinger needed first to estimate New Zealand's historical emissions of methane from livestock. This is because the current level of methane-induced warming is also affected by past emissions. Those estimates were then combined with data from New Zealand's greenhouse gas inventory and emission projections. This information was fed into a widely-used, relatively simple climate model, which simulated the warming effect resulting from the scenarios outlined above. [1]

These questions were designed to clarify the links between methane emissions, concentrations and global temperature resulting from livestock production in New Zealand. Livestock methane accounts for around 85 per cent of New Zealand's annual methane emissions.

The intention of the first question was to help us understand how much additional warming would be caused if methane emissions continue at or around current levels. Given methane's short life in the atmosphere, there has been conjecture that this is negligible.

The second question was designed to estimate a trajectory for livestock methane that would generate no additional contribution to warming. A baseline year of 2016 was chosen because it is the latest year for which greenhouse gas data is available and is where New Zealand is starting from today.

New Zealand might, of course, consider reducing its warming contribution from livestock methane below this level in the context of its Paris Agreement commitments. That, however, is a matter for policy making; it cannot be answered by science alone.

1.2 A quick recap on methane and the carbon cycle

Greenhouse gases have different chemical and physical properties. The contribution they make to global warming depends on their atmospheric concentrations, lifetimes and decay products.

Carbon dioxide and methane are part of a cycling of carbon on a planetary scale. The carbon cycle is made up of vast reservoirs of carbon that exist in various places – the atmosphere, soil and vegetation, the oceans and fossil fuels – as well as continuous exchanges, or 'fluxes', between these reservoirs. Some of these exchanges operate on very short timeframes, while others are much slower.

Prior to industrialisation, carbon dioxide levels in the atmosphere remained fairly constant over the past few thousand years. Human activity has dramatically increased the release of carbon from land and fossil fuel sources. Processes operating to remove carbon from the atmosphere have not kept up with emissions.

By injecting large quantities of carbon dioxide into the atmosphere, human activities today will continue to perturb the carbon cycle for thousands of years. Describing how long any given emission of carbon dioxide remains in the atmosphere is not easy because it is involved in so many aspects of the carbon cycle. Individual molecules of carbon dioxide are continually being exchanged between the atmosphere, oceans and living things.

But it is still possible to calculate the net effect of adding carbon dioxide to the atmosphere. Carbon dioxide removal is fast initially, as the rate of carbon dioxide absorbed by oceans and living organisms exceeds the rate of re-release to the atmosphere. The remaining carbon dioxide is removed from the atmosphere at a diminishing rate while continuing to cause warming over millennia.

Methane comes from a range of biological processes including the decay of organic material in wetlands and belching from ruminant animals. The biological methane cycle can be considered a loop in the larger carbon cycle, where carbon dioxide from the atmosphere is absorbed by growing plants, converted into methane by microbes, released into the atmosphere, and then oxidised back into carbon dioxide.

The lifetime of methane in the atmosphere is simpler to explain than carbon dioxide. The amount left is reduced by two thirds roughly every 12 years. Almost all of this is broken down through chemical reactions with hydroxyl radicals in the lower atmosphere. [2]

1.3 The warming effect of methane

Methane amplifies the warming associated with the carbon cycle because it is a more potent greenhouse gas than carbon dioxide. Most of the warming caused by methane occurs during the first few decades. One tonne of biological methane traps approximately 33 times more heat than a tonne of carbon dioxide over a 100-year period. However, carbon dioxide causes sustained warming for thousands of years. [3]

The timing of any warming and its strength will depend on the amounts of the two gases in the atmosphere – and all the other greenhouse gases. There is nothing simple about atmospheric chemistry.

The warming caused by methane includes direct warming from methane itself, as well as indirect warming from by-products of methane breakdown. These indirect effects account for about one third of methane's total warming impact. The most significant of these indirect effects are the production of stratospheric water vapour and tropospheric ozone – both powerful greenhouse gases in their own right. [4]

Some methane is emitted to the atmosphere during the extraction of fossil fuels. The warming caused by this methane includes a small additional warming effect from the carbon dioxide produced when fossil methane is oxidised in the atmosphere. This is because the carbon in fossil methane comes from coal, oil and gas deposits that have been buried deep underground for millions of years, so additional carbon is added to the atmosphere when fossil methane oxidises.

This extra warming does not occur with the decay of biological methane, because the carbon is part of the fast biological carbon cycle. Atmospheric carbon dioxide is absorbed by plants, converted into biological methane by microbes, then emitted and converted back into atmospheric carbon dioxide. Hence, the warming caused by this recycled carbon dioxide is not counted towards the warming potential of biological methane.

Although methane emissions are relatively short-lived, some of the warming they cause continues long after the emissions themselves have decayed. This is for two reasons.

First, there is significant inertia in the climate system and this means there is a long lag time between changes in methane emission levels and their full impact on global temperature. Figure 1 shows this in idealised terms using a simple sketch. A constant flow of methane emissions results in a constant methane concentration after around 50 years, but its impact on temperature continues to increase for several centuries. Three hundred years after a constant flow of methane emission has started, the warming effect is more than twice as high as it is after 50 years.

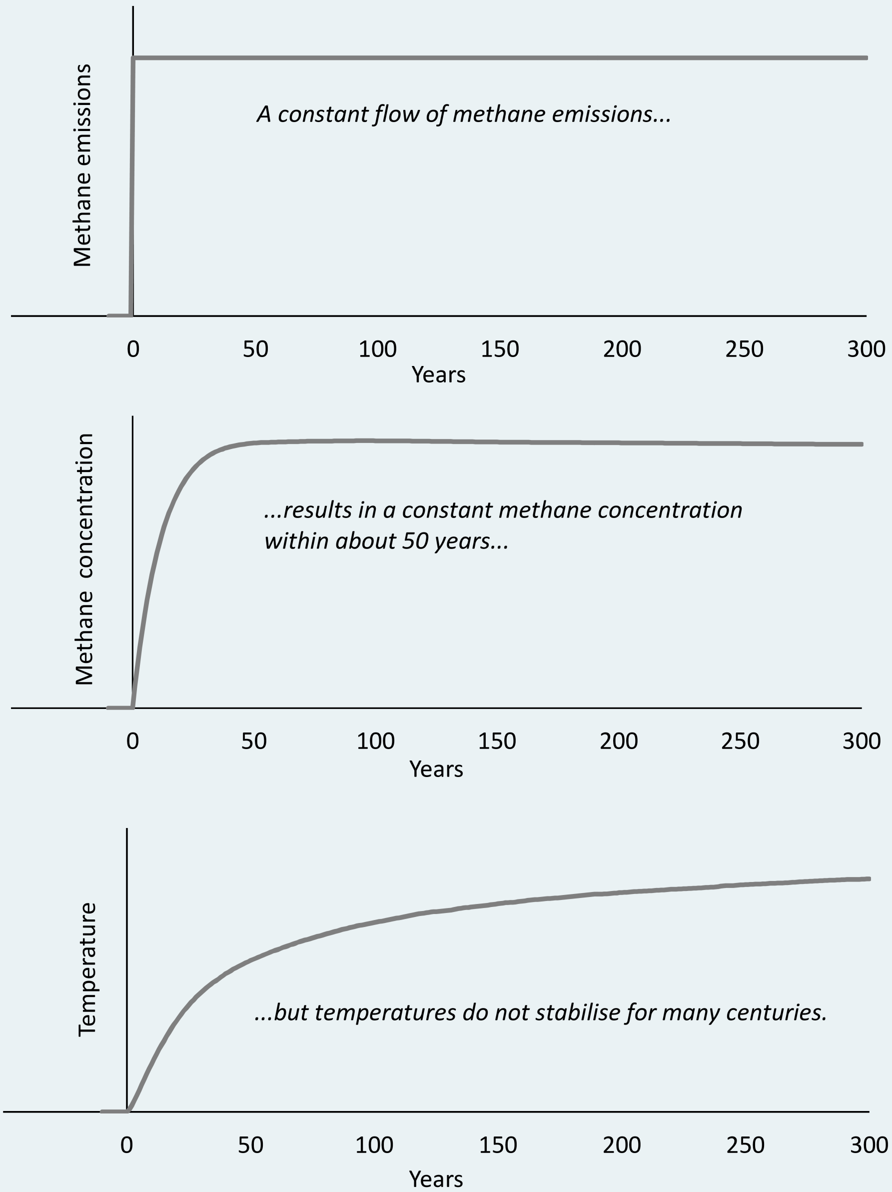

Figure 1: Idealised atmospheric concentration and warming resulting from a constant rate of methane emissions over a 300-year period.

Secondly, higher concentrations and warming effects of methane and other greenhouse gases perturb the global carbon cycle. A warmer climate causes any carbon dioxide already in the atmosphere to remain there for longer, and more carbon dioxide to be released from oceans and the biosphere. These changes amplify and prolong the warming caused directly by the emission of methane (or any other greenhouse gas). While there is uncertainty regarding the magnitude of these feedbacks, there is robust evidence that they result in additional warming, and that this warming can be significant over time.

The lifetimes and potencies of greenhouse gases are not fixed; they respond to the constantly changing background composition of the atmosphere. For instance, the amount of warming a greenhouse gas causes depends on how much of that gas is already in the atmosphere. As a result, emissions of methane gradually become less potent as its concentration in the atmosphere increases, and *vice versa*.

Estimates of the lifetimes and the amount of warming different greenhouse gases cause are published by the Intergovernmental Panel on Climate Change (IPCC). These are regularly updated as scientific understanding develops.

1.4 What the modelling tells us

The key findings from the modelling were as follows. First, if New Zealand's emissions of livestock methane were held steady at 2016 levels, then within about ten years the amount of methane in the atmosphere from that source would level off. However, the warming effect of that methane would continue to increase, at a gradually declining rate, for more than a century. In the year 2050, holding New Zealand's livestock methane steady at 2016 levels would cause additional warming of 10-20 per cent above current levels. This warming would increase to 25-40 per cent by 2100.

Secondly, if New Zealand wished to ensure that methane from livestock caused no additional contribution to warming beyond the current level, emissions would need to be reduced by at least 10-22 per cent below 2016 levels by 2050, and 20-27 per cent by 2100. **[5]**

Further reductions would then be required beyond 2100 to maintain this stable contribution to warming – although the rate of reduction required would get smaller and smaller over time. This is why it is best to think about reducing these emissions as a trajectory.

The 22 per cent level in 2050 reflects a scenario in which other countries take strong action and meet the Paris Agreement goals. The 10 per cent level reflects a scenario in which other countries take some action, but not enough to achieve the Paris Agreement goals.

Figure two shows estimated trajectories of livestock methane emissions from New Zealand that would result in no additional contribution to warming above current levels. The trajectories make different assumptions about global greenhouse gas concentrations, depending on the level of collective action to reduce emissions globally. 'More global action' (RCP 2.6) is a scenario that would limit the increase in global average temperatures to less than 2°C relative to pre-industrial levels. 'Less global action' (RCP 4.5) assumes global action, but not enough to limit warming to under 2°C, as a best estimate. **[6]**

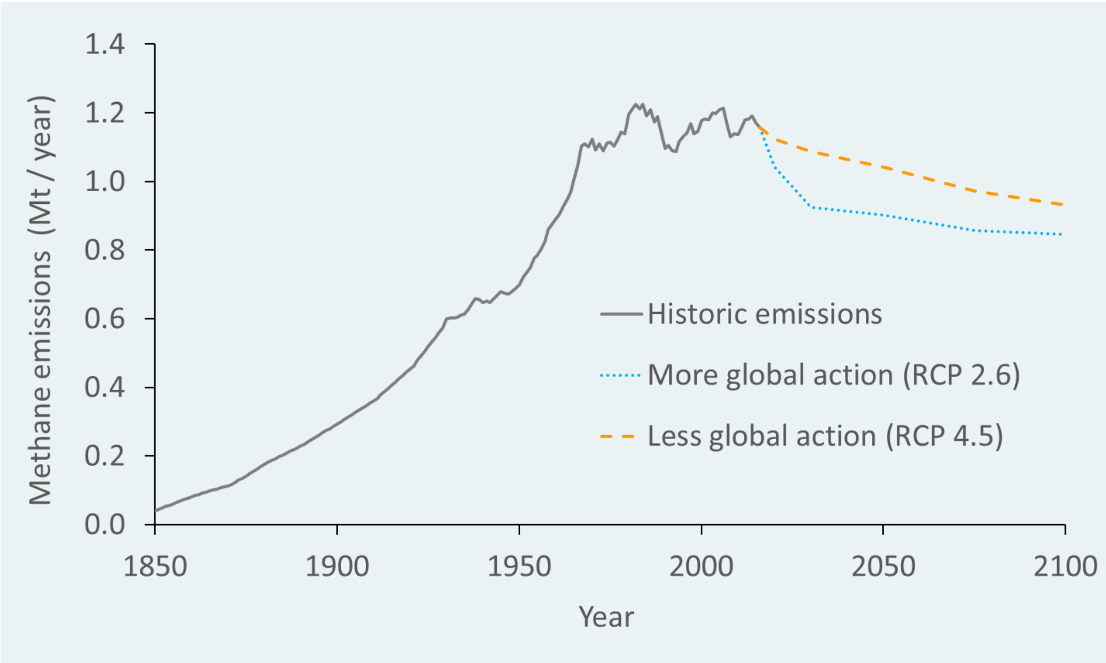

Figure 2: Trajectories for methane from livestock that would result in no additional contribution to warming above current levels.

This modelling tells us that if other countries take strong and rapid action to meet the 'well-below 2°C' goal, New Zealand's emissions of methane from livestock would need to be reduced by about 22 per cent to avoid additional warming. This is because the background concentrations of methane will be lower if other countries take strong action, so the methane emitted by New Zealand causes more warming.

If, on the other hand, we assume that other countries take some action on climate change, but not enough to achieve the well-below 2°C goal, New Zealand's emissions of livestock methane would need to be reduced by about 10 per cent to achieve the same temperature objective.

Part 2

Further implications for policy

The modelling conducted by Dr Reisinger was commissioned to get a better understanding of the relationship between emissions, concentrations and temperature effects for New Zealand's livestock methane. The essential finding is that a continuation of methane emissions from livestock at current levels would result in a constant methane concentration after about a decade. Its impact on temperature would not stabilise for more than a century. While methane emissions from New Zealand's livestock may be short-lived in the atmosphere, they are by no means benign. [7]

If New Zealand wished to ensure that methane from livestock contributes no additional warming beyond the current level, emissions would need to be reduced by at least 10-22 per cent below 2016 levels by 2050 and 20-27 per cent by 2100. These ranges reflect uncertainty in future global emission trends, and apply only to methane from livestock – if a target were to be developed for methane from all sources, the ranges may be different.

In aiming for any given level of methane emissions in 2050, New Zealand cannot avoid making a judgment about the actions of other countries since global action will determine the actual amount of warming our emissions cause. Given that the Zero Carbon Bill is intended to be aligned with the Paris Agreement, an assumption that other countries will act to achieve its goals seems appropriate.

Developing a pathway leading to no additional contribution to warming would need to be economically optimised. The modelling shown in Figure 2 indicates deep initial reductions in methane – 20 per cent by 2030 – for the 'more global action' scenario to ensure no temperature increase in the decades between now and 2050. This proved to be a particularly stringent constraint.

In reality, the trajectory for livestock methane is unlikely to follow this course. If deep reductions early on are not possible, then a steeper reduction to a lower emission level in 2050 would be required – *if* stabilisation of methane's contribution to warming remained the policy objective. Anything less demanding would entail some ongoing contribution to warming.

An objective of no additional contribution to warming from livestock methane is just one possibility. Different objectives could lead to quite different emphasis being placed on reducing methane emissions. One objective, for instance, might be to consider minimising future total warming from all greenhouse gas emissions. The contribution of New Zealand's future livestock methane and fossil carbon dioxide to future total warming under different target scenarios is explored in Appendix II of the modelling report.

Whatever the approach New Zealand decides to take in respect to the treatment of livestock methane, its significance will not be a merely domestic matter. International climate negotiations have not yet focused on methane in the depth that New Zealand has. New Zealand is considering how it will treat livestock methane well ahead of most other countries and what it does is likely to be closely scrutinised.

The Paris Agreement was all about a bottom-up approach to catalysing climate action while maintaining international review of those efforts. Countries will make progress where it makes the best sense for them and where they have particular expertise.

New Zealand is well positioned to take the lead in breaking new ground with biological emissions given its leadership in agriculture and agricultural science. But if it wants other biological methane emitters to adopt its reasoning, it will need to be defensible. The approach taken to target-setting must be transparent and robustly grounded in science, as well as being consistent with our national circumstances and our international commitments.

Notes

1. The model used was the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC). This is a reduced complexity climate model that has been widely used for climate scenario studies and in IPCC assessment reports. The model simulates the basic physics of the climate system, including an upwelling diffusive ocean and a simple carbon cycle model, including CO_2 fertilisation and temperature feedback effects of the terrestrial biosphere and oceanic uptake. The parameters of MAGICC can be calibrated against simulations from more complex Earth System and General Circulation Models, which allows it to emulate the results from much more complex models at global scales.

2. In the context of atmospheric chemistry, a radical is a chemical species containing an unpaired electron. Radicals are often short-lived and highly reactive. A small amount of methane is also removed on longer timescales through other processes, including bacteria uptake by soils, chemical reactions in the stratosphere, and reactions with chlorine radicals in the troposphere.

3. Best estimate calculated using MAGICC and including climate-carbon cycle feedbacks. This is similar to the GWP value stated in the IPCC Fifth Assessment Report of 34.

4. The troposphere is the lowest layer of the atmosphere. It contains most of the atmosphere's mass and water vapour. The stratosphere is located above the troposphere. The direct impact of human activities on water vapour concentrations in the troposphere is negligible. Tropospheric ozone warms the climate, has a negative effect on plant growth and human health, and is therefore considered a pollutant. This is quite distinct from ozone in the stratosphere, which cools the climate and protects the Earth from dangerous solar radiation.

5. This range includes the effect of feedbacks through the climate-carbon cycle.

6. These results include the direct and indirect warming effects of methane, and climate-carbon cycle feedbacks.

7. The lag time between emissions and concentrations in this case is 10 years. In Figure 1 the lag time is 50 years because it depicts a new constant flow with no historic emissions.