How much forestry would be needed to offset warming from agricultural methane?

October 2022

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

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- Andy Reisinger
- Dave Frame
- Keith Woodford.

Contents

1 Introduction

New Zealand's emissions reduction targets for 2050 were enshrined in legislation in 2019. When setting these targets, the Government decided that forestry offsets would be counted towards the target for fossil carbon dioxide and other long-lived greenhouse gases (net zero by 2050), but not the emissions reduction targets for biogenic methane (a 10% reduction by 2030 and a 24–47% reduction by 2050, relative to the 2017 level).

The rationale behind the important and far-reaching decision to have a net target for long-lived greenhouse gases but a gross target for biogenic methane was never satisfactorily explained.[1] Why should emitters of carbon dioxide in the fossil-fuel-based economy have access to New Zealand's limited supply of forestry offsets to assist them in meeting their emissions reduction target, but not emitters of livestock methane in the land-based economy?

Obviously, forests remove carbon dioxide from the atmosphere, not methane. But if forest offsetting works by creating a cooling effect to compensate for warming from emissions occurring elsewhere, then it should be possible – at least in theory – to use forestry to offset the warming from any greenhouse gas. This includes methane.

As I explained at length in my Farms, forests and fossil fuels report, I do not see planting more and more trees to offset fossil carbon dioxide emissions as a credible long-run solution. As long as fossil carbon dioxide emissions continue, they will require ever-increasing areas of forest land to offset them. The sequestered carbon must remain safely stored for as long as the emissions being offset continue to cause warming, which in the case of carbon dioxide emissions is centuries to thousands of years. Mechanisms are therefore needed to guarantee that future losses will be compensated for through new plantings or other forms of carbon dioxide removal. Meanwhile, future losses through extreme weather events, fires and disease are likely to become more frequent as the climate changes, making forests increasingly expensive to insure.[2]

The Climate Change Response Act 2002 requires a reduction in biogenic methane emissions of 24–47% by 2050 relative to the 2017 level. Once the opportunities for reducing livestock emissions at source have been exhausted and gross emissions have been reduced to somewhere within this range, forests could be used to offset part or all of the warming that remains from ongoing emissions. Using forestry offsets for this purpose offers two key advantages: it does not require ever-increasing areas of forest land to be planted, and it does not necessarily lock up land permanently in forest.

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[1] The term 'gross target' is used here to mean a target that excludes emissions and removals from land use, land use change and forestry. In the Climate Change Response Act 2002, the term 'gross' is not actually used in the context of the target for biogenic methane. The term 'biogenic methane' is defined in the Climate Change Response Act 2002 as "all methane greenhouse gases produced from the agriculture and waste sectors (as reported in the New Zealand Greenhouse Gas Inventory)". 'Gross emissions' are defined in the Act as "New Zealand's total emissions from the agriculture, energy, industrial processes and product use, and waste sectors (as reported in the New Zealand Greenhouse Gas Inventory)". Biogenic methane emissions can therefore be considered a subset of gross methane emissions.

[2] PCE, 2019. See chapter four for a discussion of the relative risks of using forests to offset gross carbon dioxide emissions and biogenic greenhouse gases.

In theory, it should be possible to reach some form of long-run equilibrium between the area of land used for pastoral agriculture and the area of forest land. The warming effect of annual livestock methane emissions from the pastoral land could be counterbalanced by the cooling effect of the carbon dioxide removed by the forest land.

I was curious to know what combination of gross reductions in livestock methane emissions and new forest planting would be required to achieve such a balance for New Zealand's national herds of ruminants. I therefore commissioned Professor Dave Frame from the University of Canterbury (formerly of Victoria University of Wellington) and Dr Nathanael Melia (Victoria University of Wellington) to calculate what area of forest would be required to offset livestock methane emissions using a warming-based approach.[3] Their results and some worked examples at the national level are outlined in this note.

The emissions reduction targets for biogenic methane were set in 2019 and are now embedded in the Climate Change Response Act 2002. But many in the primary sector remain concerned about the potential social, cultural and economic consequences of meeting the 2050 target – particularly the upper end, a 47% gross reduction. It is likely that debate over how we can achieve the upper end of the methane target or go beyond it will continue.

There are no recommendations in this note. My aim in publishing it is simply to lay out what can and cannot be credibly claimed with respect to offsetting livestock methane, in the hope that this will help foster a better-informed debate about New Zealand's 2050 target for biogenic methane.

The next section of this note provides an explanation of how the climate responds to emissions and removals of different greenhouse gases. This is followed by an overview of the warming caused by emissions to date and a discussion of the extent to which reducing emissions could reduce warming in the future. The subsequent section considers how tree planting, in combination with minimum gross emissions reductions, could be used to offset some or all of the warming from future livestock methane emissions. Some illustrative examples are provided of the reductions in warming from New Zealand's national emissions of livestock methane that could be achieved by reducing gross emissions and planting forests. The note concludes with a discussion of the opportunities, challenges and limitations of this approach.

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[3] Frame and Melia, 2022. A copy of this report is available on the Parliamentary Commissioner for the Environment (PCE) website (www.pce.parliament.nz).

2 Warming and cooling: a quick recap

There remains a lot of genuine confusion about how much warming is being caused by New Zealand's biogenic methane emissions – among both those advocating for more stringent cuts to biogenic methane emissions and those advocating the opposite. It is easy for people to talk past each other when debating this topic. This is partly because there are different possible interpretations of commonly used terms such as 'warming' and 'cooling'.

What follows is a quick recap of the basics.

Warming from a one-off emission or a one-off removal

Every kilogram of methane emitted from human activities makes the atmosphere a little warmer than it would otherwise have been if that methane had not been emitted. A one-off emission of methane has a strong but short-lived warming effect because methane decays rapidly in the atmosphere.

While most of the warming from a one-off emission of methane occurs within the first few decades, there is also a small but long-lived tail of lingering warming (Figure 1a and Figure 1c). This is due to inertia in the transfer of heat between the atmosphere and oceans, as well as interactions between the climate and the carbon cycle (known as climate–carbon cycle feedbacks). These mechanisms continue to cause a small warming effect even after the methane itself has been removed from the atmosphere.[4]

By contrast, a one-off emission of carbon dioxide has a relatively weak but very long-lived warming effect (Figure 1b and Figure 1d). This is because carbon dioxide does not break down rapidly in the atmosphere as methane does. As a result, a fraction of each pulse of carbon dioxide emitted remains in the atmosphere causing warming for centuries to millennia.

Trees remove carbon dioxide from the atmosphere as they grow.[5] Figure 1b and Figure 1d illustrate the temperature response for a one-off removal of carbon dioxide from the atmosphere, which is assumed to be more or less the inverse of the warming caused by a one-off emission of carbon dioxide.[6]

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[4] Fossil methane causes slightly more warming than methane of biogenic origin. This is because when fossil methane decays, it adds carbon dioxide to the atmosphere that was not previously there, while biogenic methane does not. The Intergovernmental Panel on Climate Change (IPCC) sixth assessment report estimates that the 100-year global warming potential (GWP100) value for fossil methane is 29.8, which is approximately 10% higher than the value for biogenic methane of 27.0. See Forster et al., 2021, p.1017.

[5] While photosynthesis removes carbon dioxide from the atmosphere, trees also emit carbon dioxide through respiration, particularly at night. For a newly established forest, more carbon dioxide is removed than emitted, so the net effect is carbon dioxide removal. However, in a mature forest, carbon dioxide emissions and removals become closer in magnitude, resulting in a stabilisation in the amount of carbon stored in the forest. How climate change may impact the exchanges of carbon dioxide between forests and the atmosphere in the future is an area of active research.

[6] In reality, there is some asymmetry in the response of the climate to carbon dioxide emissions and carbon dioxide removals. Modelling by Zickfeld et al., 2021, p.613, found that "a CO2 emission into the atmosphere is more effective at raising atmospheric CO2 than an equivalent CO2 removal is at lowering it, with the asymmetry increasing with the magnitude of the emission/removal."

Warming from sustained emissions or removals

Figure 1a and Figure 1c show the warming caused by a one-off emission of methane. But a herd of cattle or sheep doesn't just release a one-off emission of methane. It emits a sustained series of methane emissions, one after another, every time one of the animals in the herd exhales or burps.

The warming effect of sustained emissions can be thought of as a successive stacking of the individual temperature responses for one-off annual emissions shown in Figure 1. For methane, the result is rapidly rising warming for the first few decades, followed by a more gradual increase until the warming eventually stabilises after more than a century.[7] This eventual stabilisation of the warming effect from constant methane emissions is due to the relatively short lifetime of methane in the atmosphere.[8]

The warming effect of sustained carbon dioxide emissions continues to increase over time and does not stabilise – at least not for many thousands of years. This is due to the very long lifetime of carbon dioxide, which means it readily accumulates in the atmosphere.

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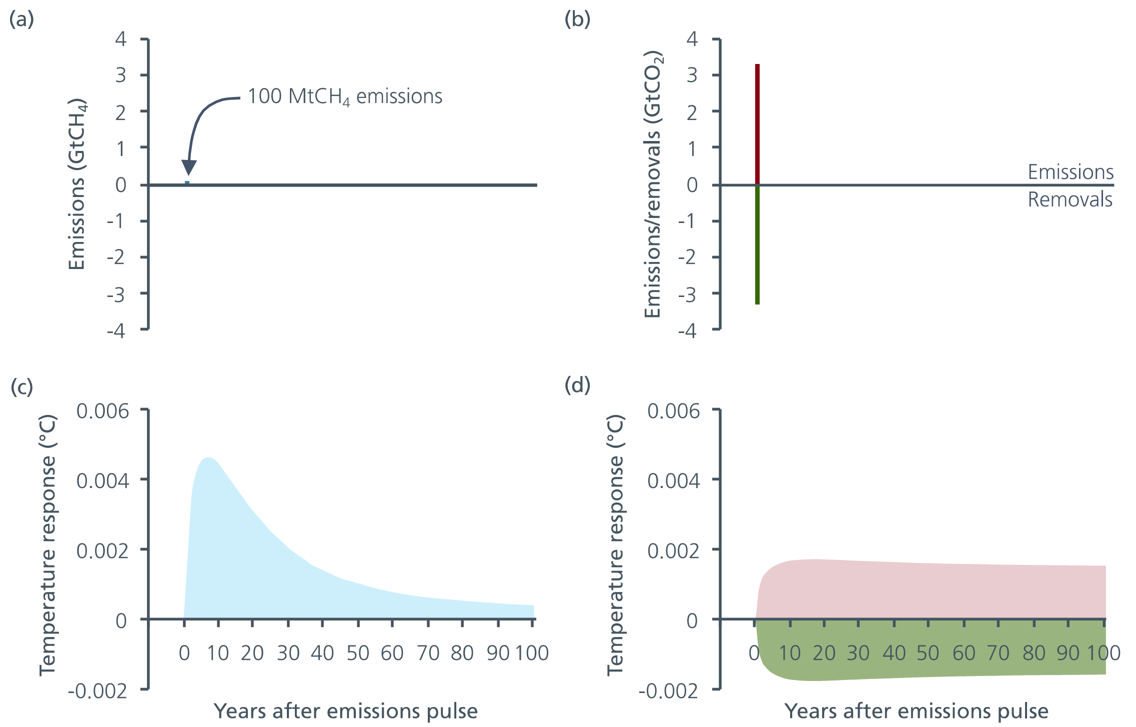
[7] The time frame over which temperature stabilisation occurs depends on the climate model used and whether climate–carbon cycle feedbacks are included or excluded. Using the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) and including climate–carbon cycle feedbacks, the warming would take more than two centuries to stabilise. See Reisinger, 2018, p.22.

[8] In reality, the temperature response to sustained emissions is slightly more complicated than a simple stacking of the individual temperature responses for one-off annual emissions. For one thing, the temperature response for one tonne of methane emitted today is not exactly the same as for one tonne of methane emitted in the past or in the future. This is because how the climate responds to an emission of methane depends in part on the concentration of methane and other compounds in the atmosphere, which itself is changing over time. But for the purpose of the temperature charts in this note, stacking the temperature responses for one-off emissions is a reasonable approximation of the temperature response.



Source: Based on Reisinger, 2018

Figure 1: Warming caused by a one-off emission of 100 million tonnes of methane (a and c) and a one-off emission or removal of 3.3 billion tonnes of carbon dioxide (b and d).[9] These quantities of methane and carbon dioxide are used for illustrative purposes because they trap approximately the same amount of heat over a 100-year period.[10] They are not related to New Zealand's national emissions. The temperature response for methane includes climate–carbon cycle feedbacks.[11]

[9] In the temperature charts in this note, positive temperature responses represent warming and negative temperature responses represent cooling.

[10] The quantity of methane that traps the same amount of heat over a 100-year period as one tonne of carbon dioxide is called the 100-year global warming potential (GWP100). This value is subject to scientific uncertainties and updated estimates are published periodically by the IPCC. The quantities in this figure are based on a GWP100 value for methane of 33 (Reisinger, 2018, p.19). The IPCC sixth assessment report gives a value of 27 for the GWP100 of non-fossil methane. See Forster et al., 2021, p.1017.

[11] Climate–carbon cycle feedbacks amplify and prolong the warming caused directly by emissions of methane (or any other greenhouse gas). For example, a warmer climate causes carbon dioxide to remain in the atmosphere for longer, and causes more carbon dioxide to be released from oceans and the biosphere. The shape of the 'tail' of warming for methane partly depends on these feedbacks, and there will be minor differences in the thickness of the tail depending on which climate model is used. The climate model used to generate the temperature responses shown in this figure was MAGICC. See Meinshausen et al., 2011.

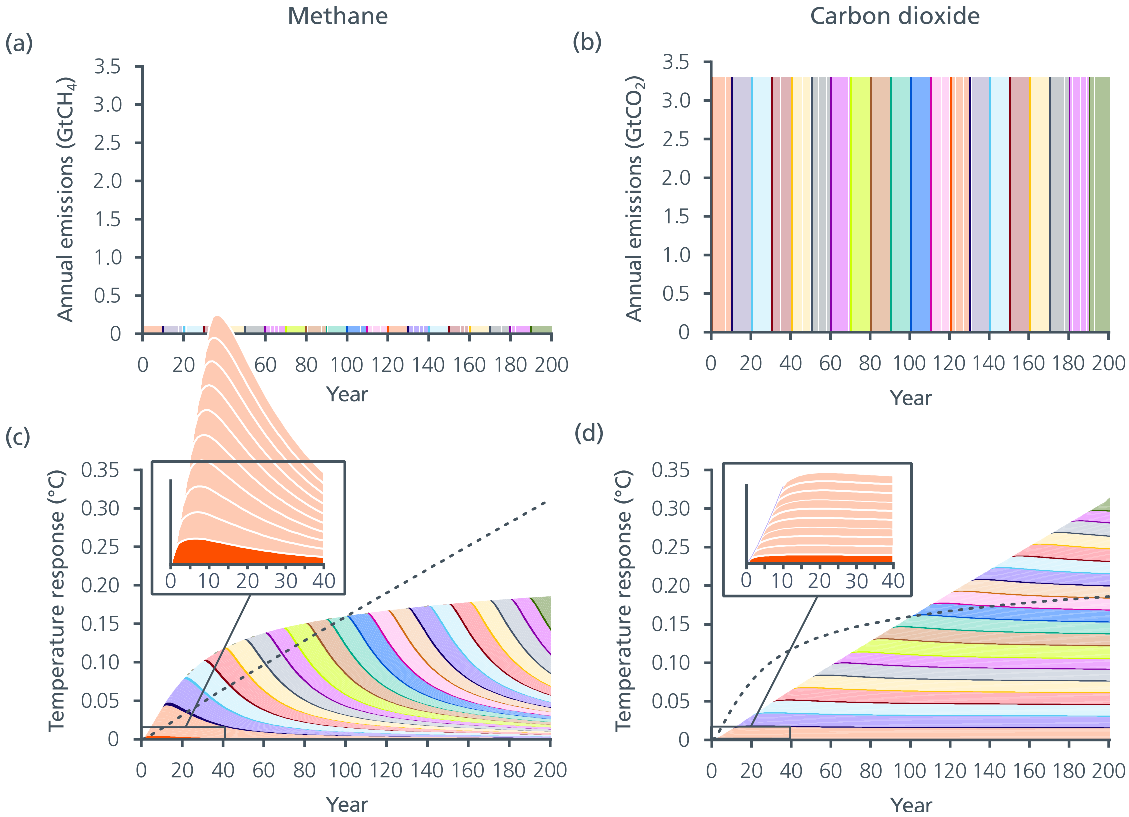


Figure 2: Warming caused by sustained emissions of 100 million tonnes of methane per year and 3.3 billion tonnes of carbon dioxide per year.[12] These sustained emissions of methane and carbon dioxide are used for illustrative purposes because they trap the same amount of heat in year 100. They are not related to New Zealand's national emissions. The temperature responses in this figure were calculated by simply stacking the temperature responses for one-off emissions from Figure 1.[13] The dotted black line in (c) is the temperature response for carbon dioxide (d) superimposed on the temperature response for methane for easy comparison, and vice versa.

[12] The rate at which warming from sustained methane emissions continues to increase after the first century depends on the thickness of the 'tail' of warming for a one-off emission of methane, which will vary depending on the climate model used. As for Figure 1, this figure is based on the temperature response function for a one-off emission of methane in Reisinger, 2018, which was calculated using MAGICC.

[13] The purpose of the temperature response charts in this note is to illustrate and compare the general shapes and relative magnitudes of the temperature responses for sustained emissions of methane, carbon dioxide and nitrous oxide. If precise quantitative estimates of temperature responses are required, the exercises would need to be undertaken using a detailed climate model.

Figure 3 illustrates the temperature response for sustained removals of carbon dioxide. In this example, sustained removals of 3.3 billion tonnes of carbon dioxide per year begin in year zero, and the same amount of carbon dioxide is removed every year thereafter. The value of 3.3 billion tonnes of carbon dioxide per year was chosen for consistency with Figure 2.

This example is for illustrative purposes only and is not analogous to the cooling caused by planting a forest. The temperature response for a newly established forest is more complicated than this because a forest does not sequester the same quantity of carbon dioxide every year. The temperature effect of planting a forest will be discussed in more detail later in this note.

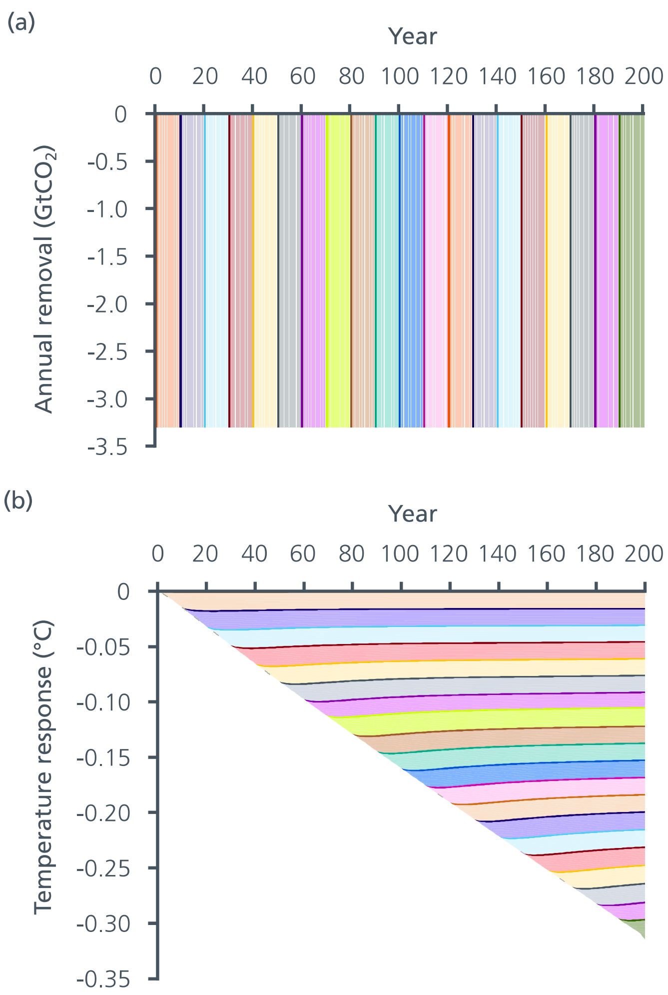


Figure 3: Cooling caused by sustained removals of 3.3 billion tonnes of carbon dioxide per year. The temperature responses in this figure were calculated by stacking the temperature responses for one-off removals from Figure 1.

Marginal warming and additional warming

The abstract examples above illustrate how much warming is caused by one-off or sustained emissions or removals relative to the temperature of a world in which those emissions or removals had not occurred. This is the way the term 'warming' is most commonly used within the international climate science and climate policy communities, and it is how the outputs of climate models are typically communicated for the purpose of assessing different options for climate change mitigation.[14] For example, it is the definition of 'warming' used by the He Pou a Rangi – Climate Change Commission in its advice to the Government.[15] It is referred to as "the marginal effect of each emission relative to the absence of that emission" in the Intergovernmental Panel on Climate Change sixth assessment report.[16]

All herds of ruminants cause a marginal warming effect – even herds that are decreasing in size over time – in the sense that they are keeping the planet warmer than it would otherwise be if the herds did not exist.

Another term that is increasingly being used in debates about methane targets is 'additional warming'. Additional warming refers to the change in warming relative to a reference point (typically a base year level such as the 1990 level). For example, in my previous methane note, I outlined what reductions in livestock methane emissions would be required to achieve no additional warming (i.e. no change in warming) relative to the 2016 level.[17]

In the rest of this note, the term 'warming' is used to describe the marginal warming effect of a series of emissions relative to the absence of that series of emissions, unless otherwise stated. Likewise, the term 'cooling' is used to describe the cooling effect of a series of carbon dioxide removals relative to the absence of that series of removals.

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[14] Marginal warming cannot be measured directly – it can only be estimated using climate models. First, the model is used to simulate how the global average temperature would change over time for a world in which the emissions occur. The virtual experiment is then repeated for a world in which the emissions did not occur. The difference between the two model runs is the marginal warming that can be attributed to the emissions in question.

[15] Climate Change Commission, 2022, p.189.

[16] Dhakal et al., 2022, pp.2–18. (Note: This is the accepted version of this IPCC chapter subject to final editing, available on the IPCC website as of 24 August 2022. Page numbers and wording may be different in the final version.)

[17] PCE, 2018.

Box 1: The difference between marginal warming and additional warming

To understand the difference between marginal warming and additional warming, consider a heater in a room.

Without the heater, the temperature in the room is a constant 10 °C all day.

The heater is turned on first thing in the morning and turned to a high setting. The temperature of the room reaches 20 °C by lunchtime. The heater is now causing 10 °C of marginal warming. In other words, by lunchtime the room is 10 °C warmer than it would have been in the absence of the heater.

By the afternoon, the temperature of the room reaches 24 °C. The marginal warming from the heater is now 14 °C. The additional warming relative to the lunchtime level is the difference between 20 °C and 24 °C, which is 4 °C.

The heater is turned down to a lower setting. By the evening, the temperature of the room has decreased to 18 °C. Now the room is only 8 °C warmer than it would have been in the absence of the heater, so the marginal warming is 8 °C. The change in warming relative to the lunchtime level is the difference between 20 °C and 18 °C, which is –2 °C.

In other words, in the evening the room is cooler than it was at lunchtime. But the heater is still having a marginal warming effect on the room, in the sense that the room is still warmer than it would otherwise have been without the heater.

Figure 4 provides a graphic representation of this illustrative example.

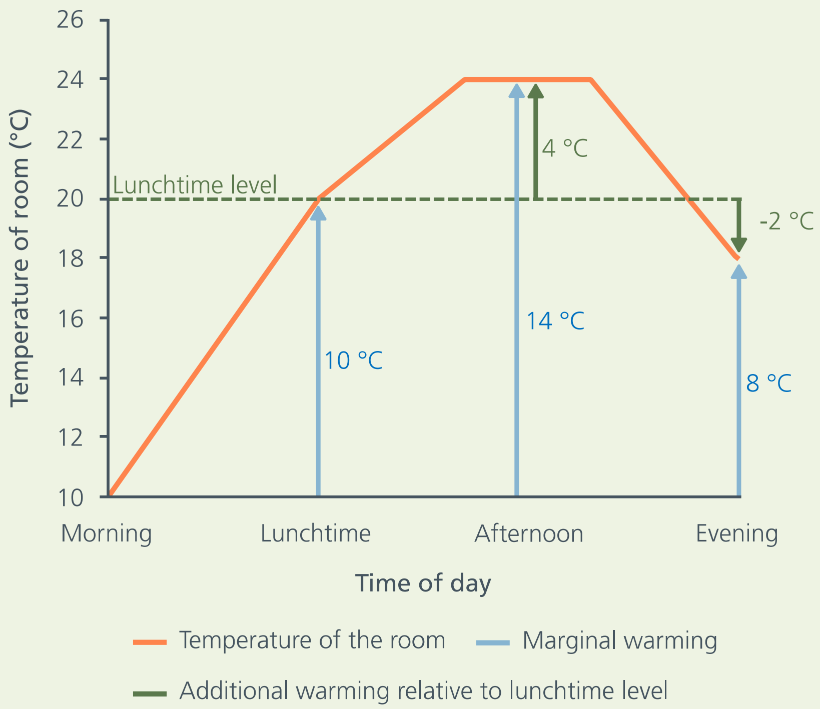

Figure 4: Illustrative example of marginal warming and additional warming for a heater in a room.

3 Warming from past emissions

Livestock methane emissions to date

National livestock methane emissions rose steeply during the 1950s and 1960s, mainly driven by increases in sheep and beef cattle numbers (Figure 5a).[18] Since the early 1990s, methane emissions from dairy cattle have risen while emissions from sheep have declined. The overall result is that total livestock methane emissions have been roughly stable (Figure 5b).

National livestock methane emissions were 1.2 million tonnes of biogenic methane in 2020. Of this, 95% came from enteric fermentation (ruminants burping and breathing out methane) and 5% came from manure management. Livestock methane accounted for 89% of New Zealand's total methane emissions in 2020, with the rest coming from waste (9%) and fugitive emissions from oil and fossil gas infrastructure (2%).[19]

Current contributions to warming from past emissions

New Zealand's livestock methane emissions to date are currently keeping the planet around 0.0015 °C warmer than it would otherwise have been in the absence of these emissions.[20] While total livestock emissions have been roughly constant over the past two decades, the warming caused by these emissions is still increasing (Figure 5c).

Because methane is short lived, most of the current warming is being caused by methane emitted since around 1990.

As explained in the previous section, the marginal warming from livestock methane emitted since 1990 is not the same thing as additional warming relative to the 1990 level. For the national dairy cattle and beef cattle herds, additional warming relative to the 1990 level is only a subset of the marginal warming from methane emitted after 1990.

For the national sheep herd, the decline in methane emissions since 1990 means that additional warming relative to the 1990 level is negative – that is, the current warming contribution is lower than the 1990 level. By contrast, marginal warming from methane emitted from the sheep herd since 1990 is positive and is in fact larger than the marginal warming from methane emitted from the dairy herd since 1990. However, the warming contribution of the national dairy herd is rising more rapidly – based on current trends it is likely to exceed the warming from the national sheep herd within a few decades (Figure 6).

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[18] Ruminants have been farmed in New Zealand since at least the mid-nineteenth century, but 1950 is the first year for which disaggregated livestock statistics for dairy cattle and beef cattle are available. That is why the charts in Figure 5 begin in 1950.

[19] MfE, 2022, p.46.

[20] Reisinger and Leahy, 2019, p.9.

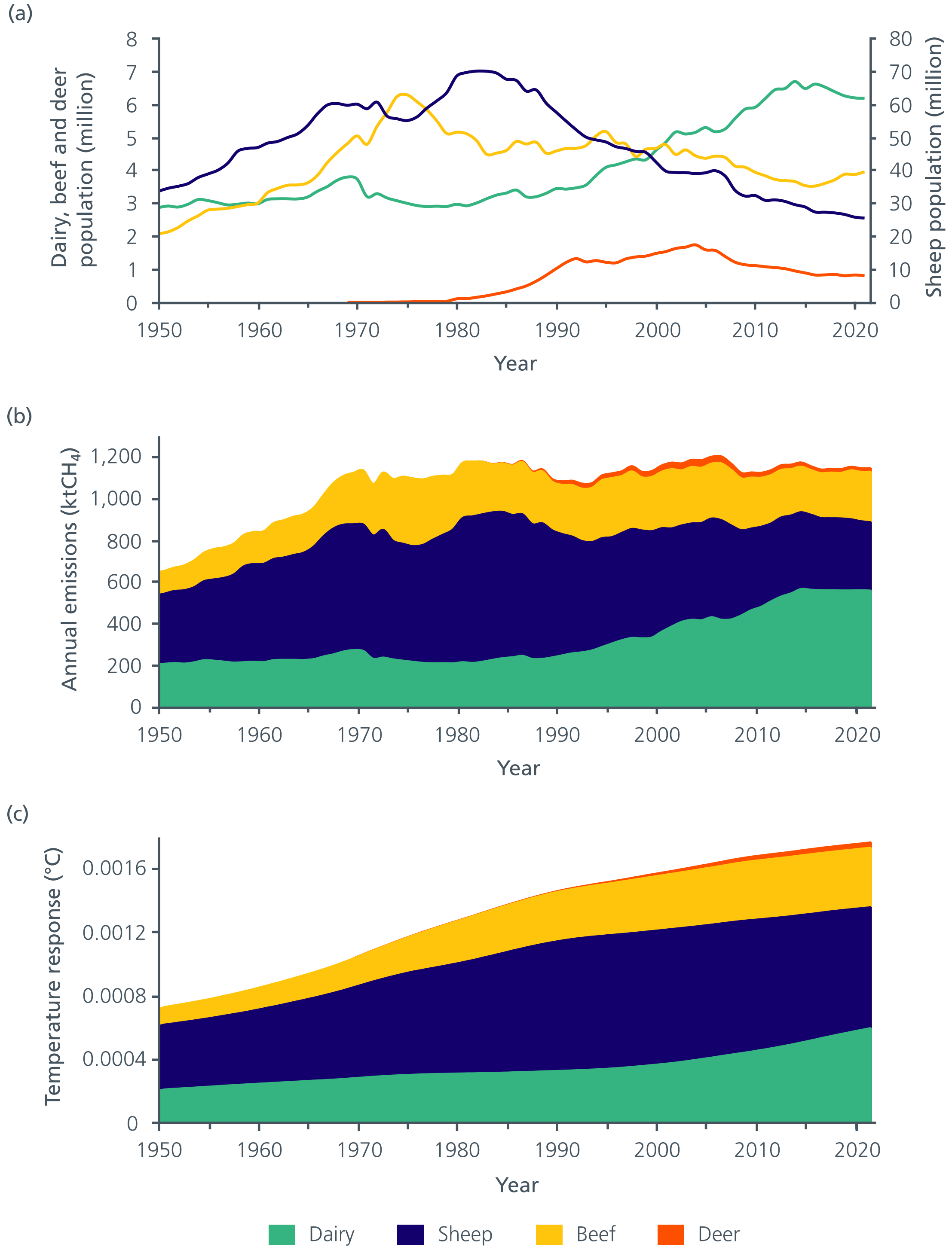

Figure 5: Livestock numbers (a), livestock methane emissions (b) and warming caused by livestock methane emissions (c) between 1950 and 2021. The charts begin in 1950 because this is the first year for which disaggregated statistics for dairy cattle and beef cattle are available. The temperature responses were calculated by stacking the temperature responses for one-off emissions from Figure 1.

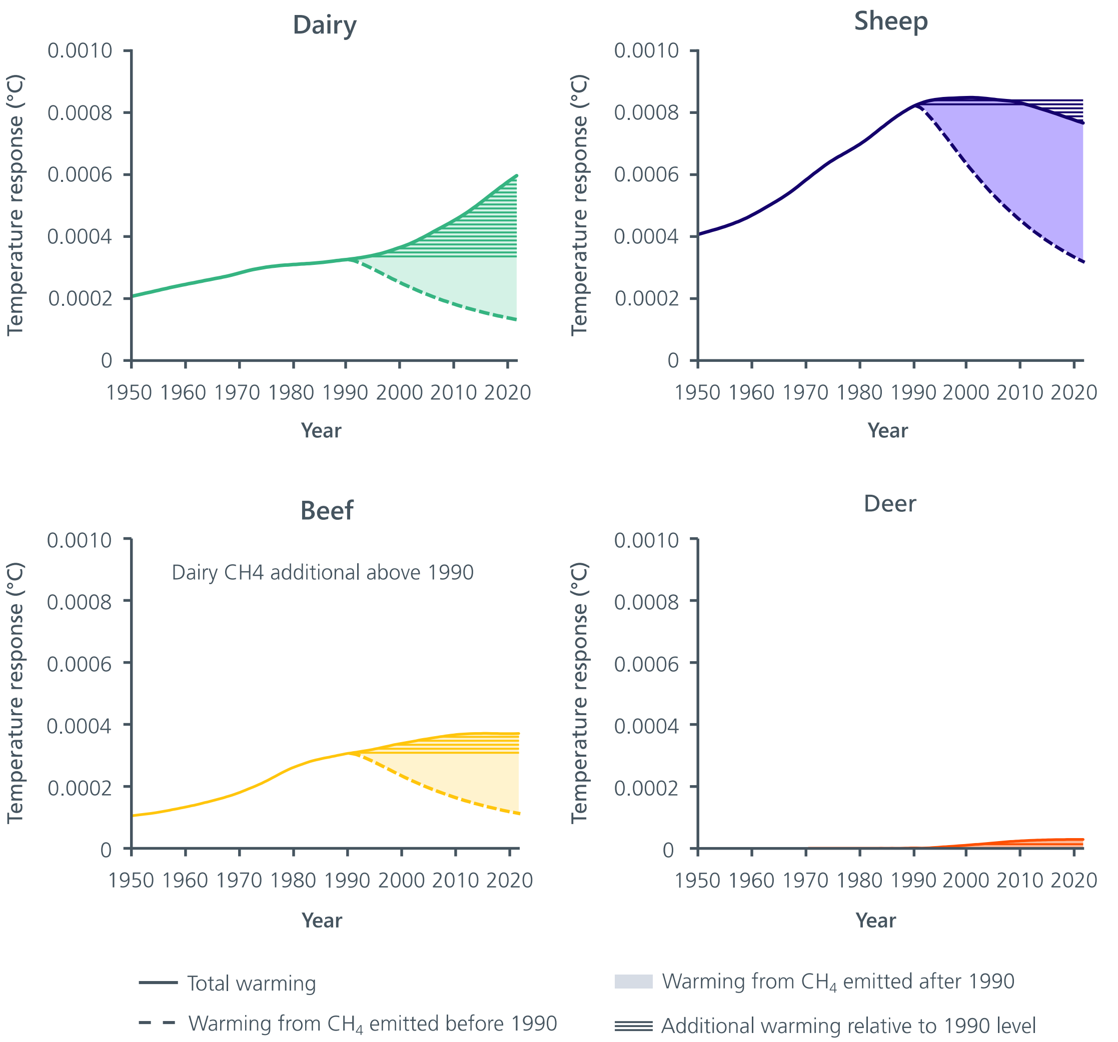

Figure 6: Contribution to warming of methane emissions from New Zealand's national herds of dairy cattle, beef cattle, sheep and deer between 1950 and 2021. The temperature responses were calculated by stacking the temperature responses for one-off emissions from Figure 1.

In most industrialised countries, the current contribution to warming from the use of fossil fuels in the energy, transport and industry sectors is larger than the contribution from the agriculture sector.

New Zealand is different. The current contribution to warming from New Zealand's livestock methane emissions to date is significantly greater than the warming contribution from all of the fossil carbon dioxide emitted since 1850.

The additional warming from fossil carbon dioxide emissions relative to the 1990 level is larger than the additional warming from livestock methane emissions. However, the marginal warming of livestock methane emitted since 1990 (the solid blue shaded area in Figure 7) is still significantly larger than the marginal warming of fossil carbon dioxide emitted since 1990 (the solid red shaded area in Figure 7).

The solid blue shaded area in Figure 7 shows what the current warming contribution of livestock methane could have been if livestock methane emissions had been reduced by between 0% and 100% since 1990.

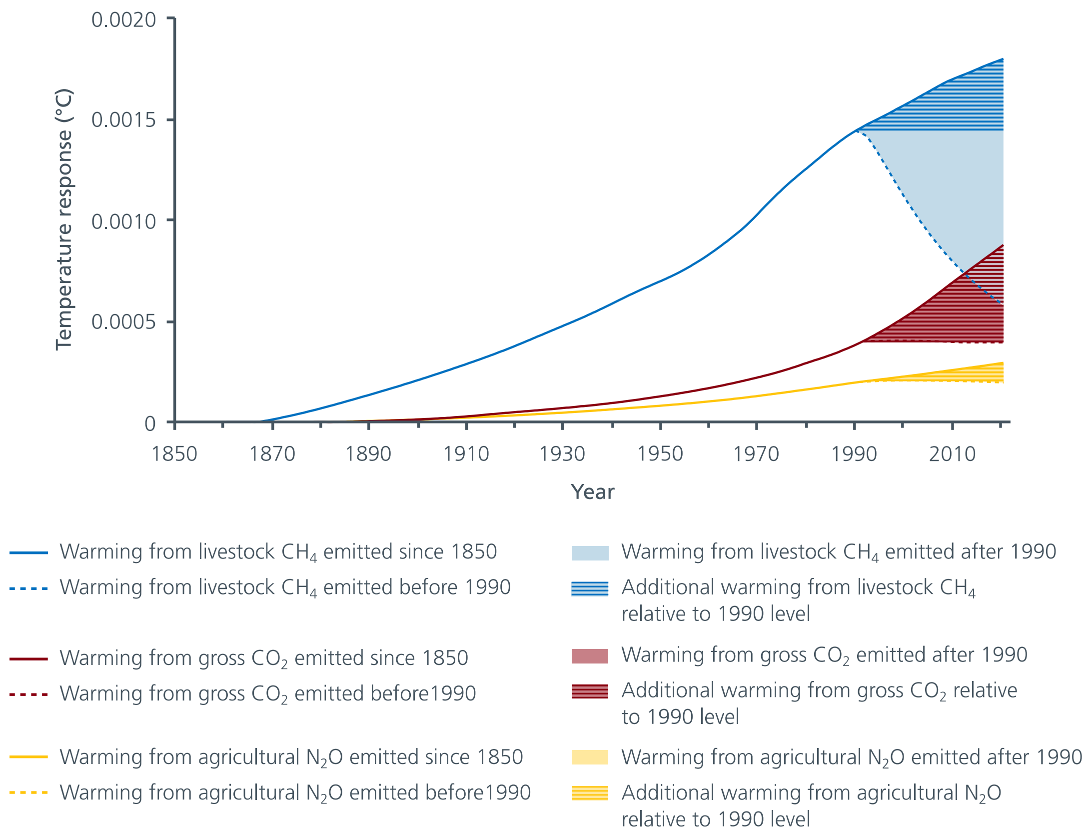

Figure 7: Warming from New Zealand's emissions to date of livestock methane, fossil carbon dioxide and agricultural nitrous oxide. The solid lines show warming from emissions since 1850. The solid shaded areas show warming from emissions since 1990. The hatched areas show additional warming relative to the 1990 level, which for livestock methane is a subset of warming from emissions since 1990. The temperature responses were calculated by stacking the temperature responses for one-off emissions from Figure 1.

Future warming from past emissions

The carbon dioxide, nitrous oxide and methane that has already been emitted to date will continue to have a warming effect in the future. The future warming that is already 'locked in' is sometimes called 'legacy warming from past emissions'.[21]

The time frame over which past emissions continue to have a lingering warming effect depends in part on the atmospheric lifetime of each gas. Past emissions of long-lived gases such as carbon dioxide and nitrous oxide will continue to cause warming for centuries or even thousands of years into the future. By contrast, most of the warming from livestock methane emitted before 2020 will be gone by the second half of this century (Figure 8).

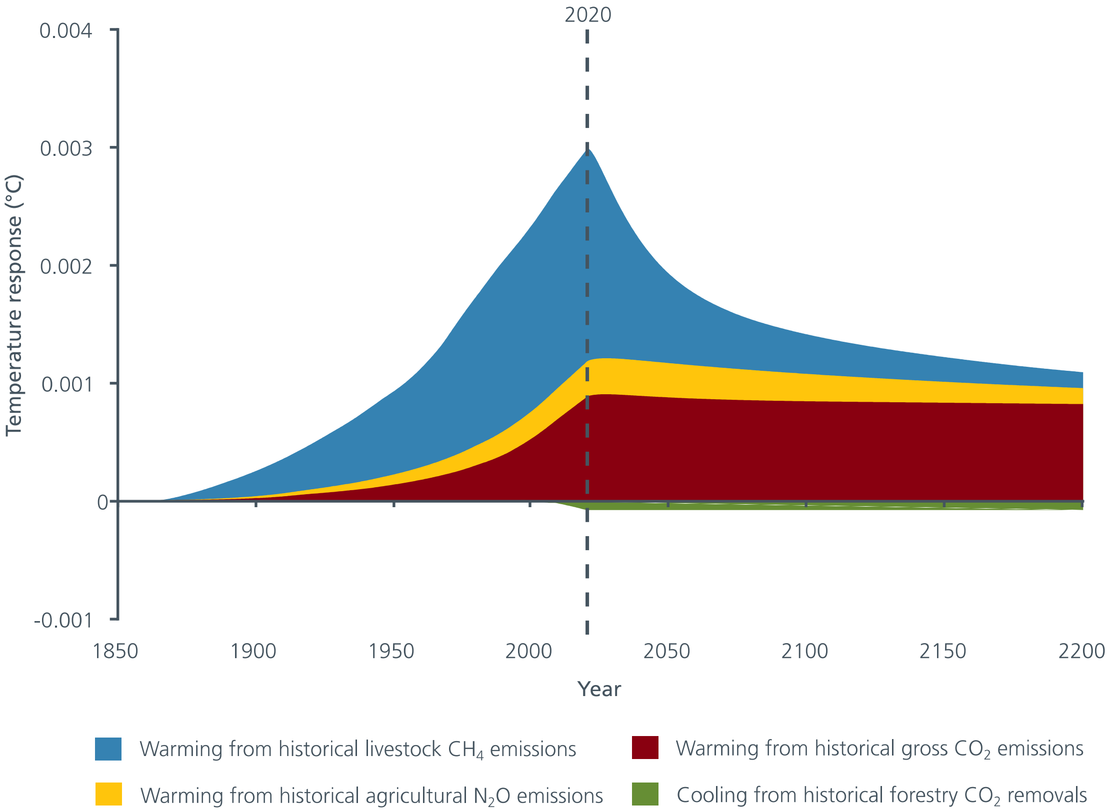

Figure 8: Warming from past emissions of gross carbon dioxide, agricultural nitrous oxide and livestock methane, and cooling from past carbon dioxide removals from forestry. Past emissions refer to emissions between 1850 and 2020. Past removals refer to removals between 1990 and 2020. The temperature response for emissions and removals from forestry prior to 1990 is not shown. The warming contributions from emissions since 1850 are the same as the warming contributions shown in Figure 7, but in this figure they are stacked. The warming that continues after 2020 is legacy warming from past emissions. The temperature responses were calculated by stacking the temperature responses for one-off emissions and removals from Figure 1.

[21] Reisinger et al., 2021, p.5.

4 Warming from future emissions

Warming from different pathways for future emissions

The Paris Agreement set a global goal to hold the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit it to 1.5 °C.[22] The global average temperature has already risen by 1.1 °C relative to the average over the period 1850–1900.[23]

Achieving the global temperature goal of the Paris Agreement will require all countries and all sectors to do as much as they can to minimise the marginal warming effect of their future emissions.

New Zealand is a relatively efficient producer of red meat and dairy products. But, as a developed country, New Zealand has a responsibility to take a leading role in mitigating climate change. It is therefore difficult to sustain the argument that the ambition of the agriculture sector should be to maintain the warming from its biogenic methane emissions at the current level.

New Zealand's emissions reduction targets for 2050 were established in an amendment to the Climate Change Response Act 2002 in 2019. The target for greenhouse gases other than biogenic methane is net zero emissions by 2050. The target for biogenic methane emissions is a 10% reduction by 2030 and a 24–47% reduction by 2050 relative to the 2017 level.

The Government did not provide quantitative information on the change in New Zealand's contribution to warming that was expected to result from these emissions reduction targets. Independent modelling of the expected change in contribution to warming broken down by gas was published by the New Zealand Agricultural Greenhouse Gas Research Centre.[24]

The warming caused by gross carbon dioxide emissions will continue to increase so long as gross emissions remain above zero. This is because carbon dioxide is a very long-lived greenhouse gas and accumulates in the atmosphere. The only way that the warming contribution from non-zero gross carbon dioxide emissions can be stabilised or reduced domestically is by employing the countervailing cooling effect of carbon dioxide removals.

In the Climate Change Commission's 'demonstration path', gross carbon dioxide emissions are reduced by 27% by 2030 and 78% by 2050 relative to the 2019 level.[25] Net zero emissions of long-lived gases are achieved in the early 2040s. If this path were achieved and further reductions in gross carbon dioxide emissions made after 2050, the warming from future gross emissions of carbon dioxide would add approximately 0.0004 °C by 2100 on top of the 0.0009 °C already 'locked in' from past carbon dioxide emissions (Figure 9 and Figure 10).

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[22] Paris Agreement, Article 2.1(a), December 2015.

[23] Gulev et al., 2021, p.326.

[24] Reisinger and Leahy, 2019, pp.8–10.

[25] Calculated from the datasets available from Climate Change Commission, 2021.

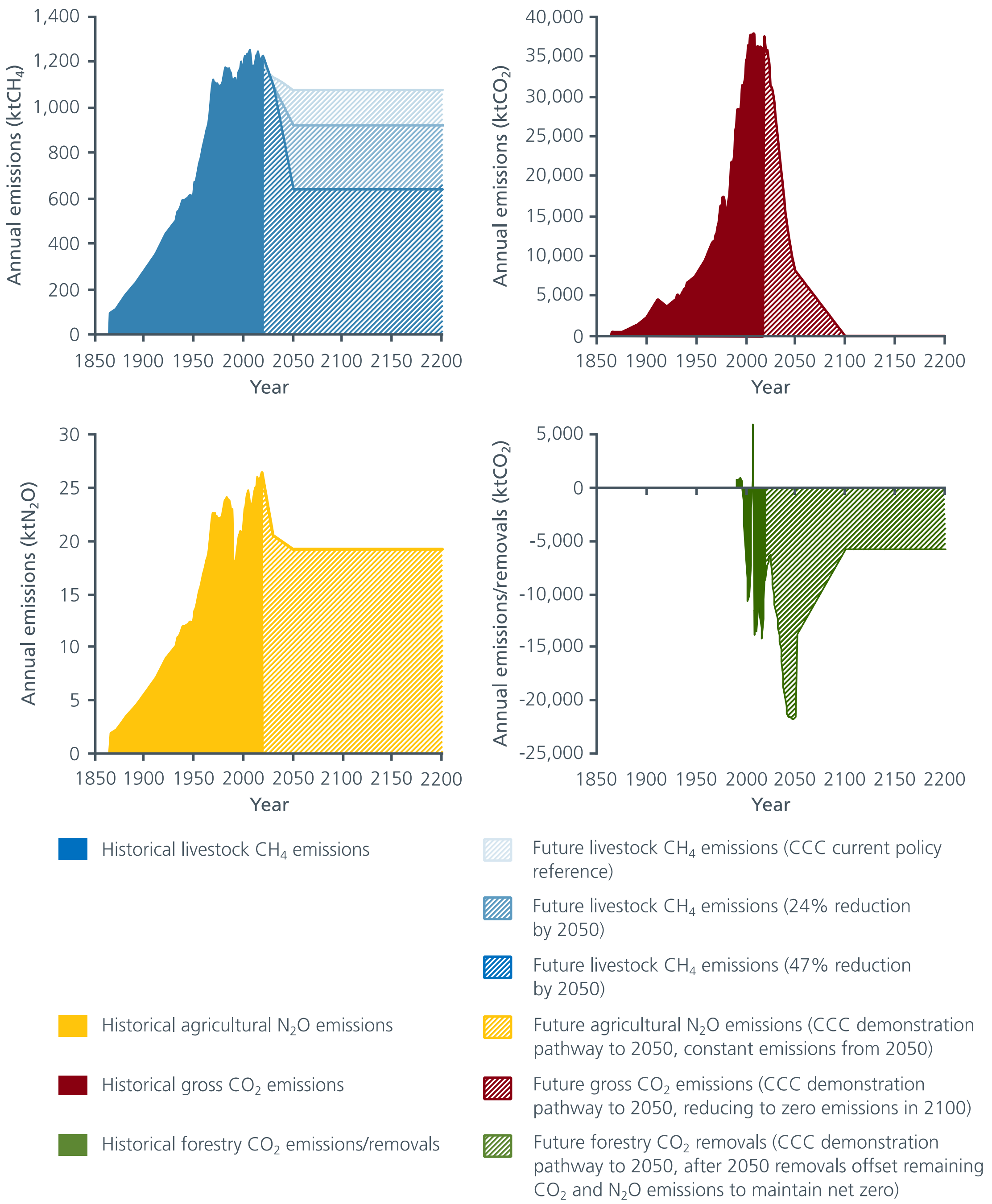

Figure 9: Past emissions and removals and illustrative pathways for future emissions and removals. The illustrative pathways for future emissions of livestock methane are based on straight-line trajectories to the 2030 and 2050 targets and the Climate Change Commission's 'current policy reference' scenario.[26] The illustrative pathways for future gross emissions of carbon dioxide and agricultural nitrous oxide and future carbon dioxide removals from forestry are based on the Climate Change Commission's 'demonstration path'.[27] Emissions and removals from forestry prior to 1990 are not shown.

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[26] Climate Change Commission, 2021, pp.89–90.

[27] Climate Change Commission, 2021, pp.98–122.

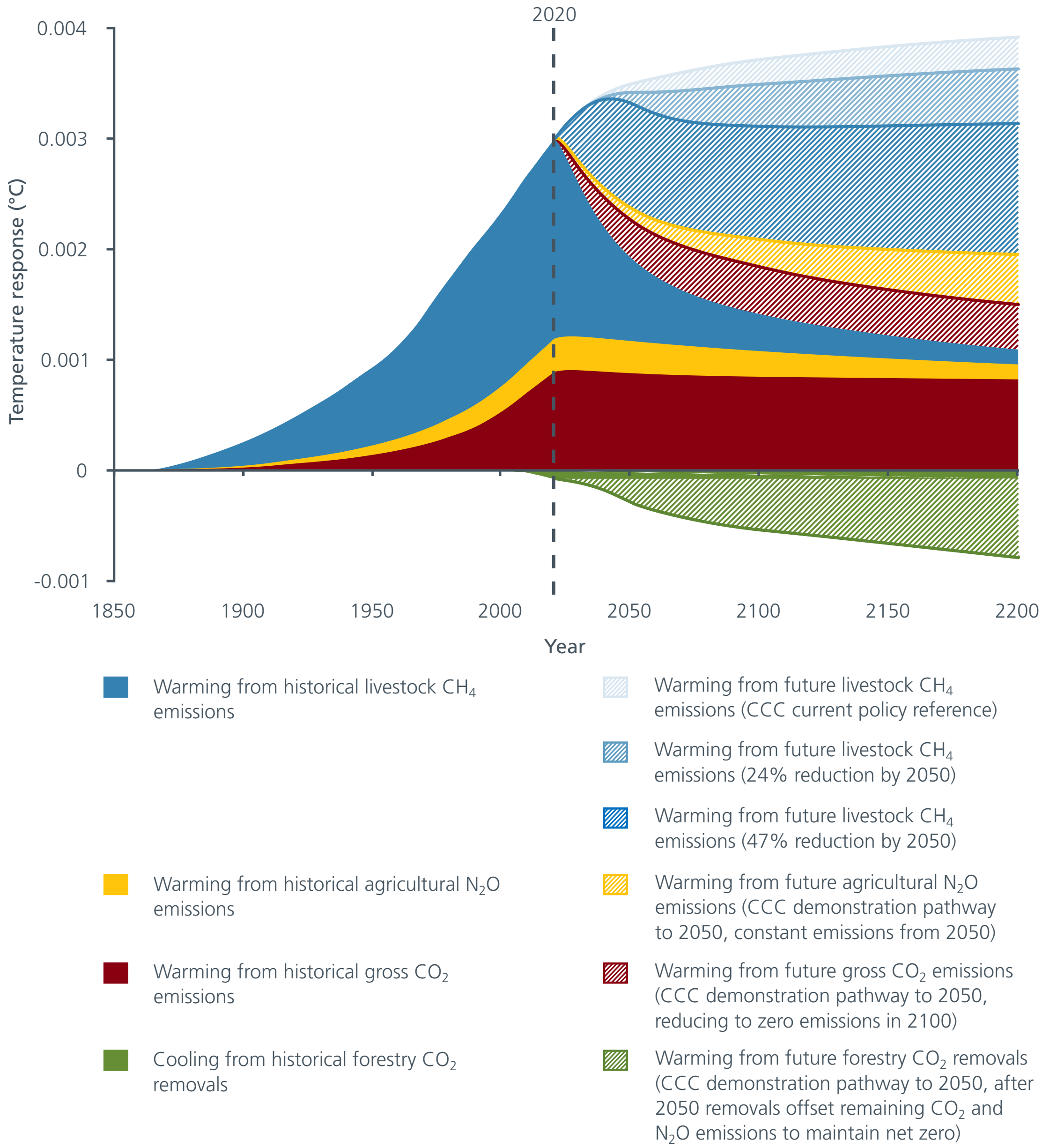

Figure 10: Warming from past emissions and illustrative pathways for future emissions. The solid shaded areas show the warming from past emissions – this warming is already 'locked in'. The hatched areas show the warming from future emissions that can potentially be avoided by reducing emissions. Deep, rapid and sustained reductions in gross emissions of livestock methane, fossil carbon dioxide and agricultural nitrous oxide will be needed – as well as enhanced carbon dioxide removals from forests – to minimise the warming from New Zealand's future emissions. The temperature response from emissions and removals from forestry prior to 1990 is not shown. The temperature responses were calculated by stacking the temperature responses for one-off emissions and removals from Figure 1.

In the Climate Change Commission's 'current policy reference' scenario, gross carbon dioxide emissions are reduced by 11% by 2030 and 37% by 2050.[28] A comparison of the warming from future gross carbon dioxide emissions in this scenario and the 'demonstration path' is shown in Figure 11.

The short-lived nature of methane means that almost all of the warming from methane by the end of the century will be from emissions that have yet to occur. In other words, it is warming in the future we can do something about – if we choose to.

Reducing livestock methane emissions by 24–47% by 2050 (with further reductions beyond 2050) would reduce the warming from livestock methane emissions to below its current level by the second half of this century.

Even if livestock methane emissions were reduced by 47% by 2050, most of the warming from future emissions would still come from livestock methane. If livestock methane emissions were reduced by 47% by 2050 then kept at that level and gross emissions of carbon dioxide and nitrous oxide followed the Climate Change Commission's 'demonstration path', the warming from livestock methane emitted from 2020 onwards would account for around three quarters of the warming from all future emissions by the end of the century (Figure 9 and Figure 10).

If livestock methane emissions were only reduced by 24% by 2050, their share of warming from future emissions would increase even further to roughly 80% by the end of the century. The warming avoided in 2100 by reducing livestock emissions by 47% by 2050 instead of 24% is roughly similar in magnitude to the warming from all future gross carbon dioxide emissions under the Climate Change Commission's 'demonstration path'.

A significant reduction in biogenic methane emissions from agriculture will come at a cost. This is no different to any other sector. Climate change mitigation will cost money. It will be a political, economic and value judgement as to how far and how fast biogenic methane emissions can be reduced. For the moment, that judgement for biogenic methane has been legislated as a 24–47% reduction by 2050 relative to the 2017 level.[29]

A comparison of marginal warming from future livestock emissions and additional warming relative to the 2020 level for two illustrative future emissions pathways (the Climate Change Commission's 'current policy reference' scenario and a 47% gross emissions reduction by 2050) is shown in Figure 11.

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[28] Calculated from the datasets available from Climate Change Commission, 2021.

[29] A 24–47% decrease in livestock methane emissions from the 2017 level is equivalent to an 18–43% reduction from the 1990 level. Note that the 24–47% target in the Climate Change Response Act 2002 is for all biogenic methane, not only livestock methane.

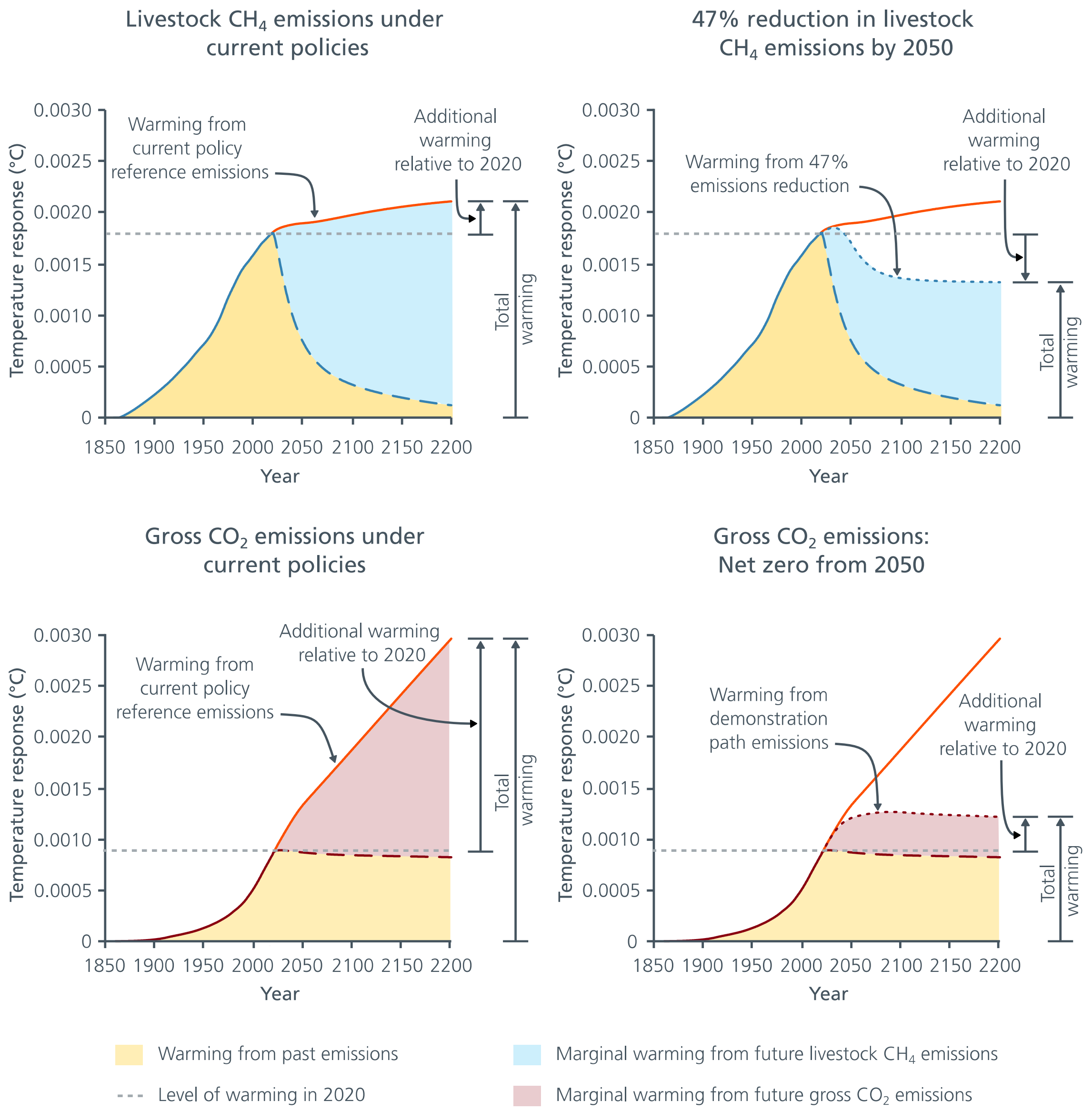

Figure 11: A comparison of marginal warming and additional warming under illustrative pathways for future gross emissions of carbon dioxide and livestock methane. The temperature responses were calculated by stacking the temperature responses for one-off emissions from Figure 1.

Options for reducing the warming from future emissions

Livestock methane emissions are roughly proportional to dry matter intake.[30] Farmers can therefore reduce their methane emissions by reducing livestock numbers and by improving the efficiency with which feed is converted into product. The economic impact of these actions is highly place-specific. For some farms, reducing stock numbers while improving performance per animal can improve profitability.[31] For other farms, this will be very challenging, and simply reducing stock numbers without improving animal performance will often have the opposite effect.

Apart from reducing livestock numbers and improving farm efficiency, there are currently limited options commercially available to make more than incremental reductions in livestock methane emissions. The most advanced on-farm options include low-methane sheep, low-methane feeds and methane inhibitors. These options are likely to become commercially available in New Zealand within the next five years. Other new on-farm mitigation options with greater potential to reduce emissions are being actively researched, such as low-methane cattle and a methane vaccine. However, these options are likely to take longer to bring to market.[32]

Once gross emissions of livestock methane have been reduced as far as practicable, all or part of the remaining warming from ongoing emissions could be offset by planting trees. Unlike fossil fuel-based sectors, it would be possible – at least in theory – to offset a sustained level of warming from livestock methane emissions by planting a finite area of forest.

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[30] This applies to methane from enteric fermentation in the rumen, which accounts for 95% of livestock methane emissions. The remaining 5% comes from manure management (i.e. effluent ponds).

[31] Reisinger et al., 2017, pp.6–7, 35–37.

[32] NZAGRC, 2021, p.41.

5 Offsetting livestock methane by planting trees

If a national emissions reduction target were set for biogenic methane that allowed forest offsetting, the next question would be how to do it. The area of forest that needs to be planted and the timing of the planting varies depending on the approach used. The conventional approach to offsetting long-lived greenhouse gases is based on the 100-year global warming potential (GWP_{100}) metric. However, this metric was not designed to be used for the purpose of offsetting methane with trees. An alternative warming-based approach to offsetting methane with trees is therefore outlined below.

Offsetting livestock methane using the conventional approach

The conventional way to calculate what area of forest would need to be planted to offset livestock methane emissions would be to use the GWP_{100} metric (see Box 2).

Box 2: Greenhouse gas metrics

Greenhouse gas metrics provide a method for converting emissions and removals of two or more greenhouse gases into a common unit so they can be added or subtracted together for accounting purposes. The most widely used metric is the GWP_{100} metric. This metric compares greenhouse gases based on how much heat a single emissions pulse traps over a 100-year period relative to a single pulse of one tonne of carbon dioxide. It is currently the default metric for international reporting and accounting of greenhouse gases, and is used for domestic climate policy in New Zealand. GWP_{100} emissions are reported in tonnes of carbon dioxide equivalent.

For long-lived greenhouse gases that accumulate in the atmosphere, such as carbon dioxide, cumulative GWP_{100} emissions are approximately proportional to warming. However, this relationship does not hold for short-lived greenhouse gases such as methane, since GWP_{100} approximates the average warming from a single emissions pulse over the next 100 years, but not the warming at any given point in time within this period.

GWP* is an alternative use of GWP_{100} that equates an increase or decrease in the annual emission rate of a short-lived greenhouse gas with a one-off emission or removal of carbon dioxide. By doing so, it ensures that cumulative GWP* emissions are approximately proportional to the additional warming from a time series of methane emissions relative to the warming at the start of the time series. Cumulative GWP* emissions give similar results to using a climate model to assess additional warming from a time series of methane emissions. GWP* emissions are reported in tonnes of carbon dioxide warming equivalent.[33]

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[33] Allen et al., 2018; Cain et al., 2019; Lynch et al., 2020; Forster et al., 2021, pp. 927–928, 1015–1019.

Consider the warming from methane emitted from 2020 onwards from a herd of 6.2 million dairy cattle. If each beast emits 95 kilograms of methane per year, the whole herd emits around 590,000 tonnes of methane annually. Using a GWP_{100} value of 28 for methane, this corresponds to annual livestock methane emissions of 16.4 million tonnes of carbon dioxide equivalent per year.[34]

If the herd size stays constant and the goal is to offset 100% of the emissions, the conventional approach would suggest that annual removals of 16.4 million tonnes of carbon dioxide per year would be needed from 2020 onwards. Note that in this simple illustrative example, it is assumed that no gross emissions reductions occur; in reality, a minimum level of gross emissions reductions would be required in addition to forest offsetting.

Average annual removals of 16.4 million tonnes of carbon dioxide per year could be achieved by planting around 706,000 hectares (7,060 square kilometres) of new pine plantation forest every 16 years indefinitely.[35] The significance of 16 years is that this is the age at which the long-term average carbon stock is reached for a new radiata pine forest (assuming a 28-year rotation). For longer rotations, the age at which the long-term average carbon stock is reached would increase.

Initially, though annual GWP_{100} emissions would be net zero on average, the net temperature effect would be warming. This is because the cooling from planting 706,000 hectares of pine plantation forest would be insufficient to offset the warming effect of the 590,000 tonnes of methane being emitted annually by the dairy herd.

By the year 2120 (100 years after planting started), around 4 million hectares of new forest would have been planted and the cooling from the forest would finally balance out the warming from the herd. After 2120, the net temperature effect would be cooling, because more and more forest would continue to be planted every 16 years – even though the warming from the herd would be roughly stable by then (Figure 14).

In other words, using the conventional approach based on GWP_{100} means that although annual emissions would appear to be net zero from 2020 onwards, the combined temperature effect of the warming from methane emissions and the cooling from carbon dioxide removals would only actually be zero in the year 2120. Before this point, the area of forest planted would be insufficient to offset the warming effect of the herd and the net effect would be warming. After 2120, more forest than necessary to compensate for the herd's warming would be planted, resulting in a net cooling effect.[36]

Achieving a closer match over time with the warming from a herd of livestock requires taking a closer look at the cooling effect of forest planting.

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[34] This GWP100 value for methane is from the IPCC fifth assessment report and excludes climate–carbon cycle feedbacks. See Myhre et al., 2013, p.731.

[35] This calculation assumes a value of 396 tCO2 per hectare by the age of 16 years for the cumulative quantity of carbon sequestered by a pine plantation forest. This is the value for the Auckland region from the carbon look-up tables for the New Zealand Emissions Trading Scheme (MPI, 2017, p.39). The Auckland region was chosen to align with calculations in Frame and Melia, 2022, p.11, Table 2. Under averaging accounting in the New Zealand Emissions Trading Scheme , a new radiata pine forest on its first rotation earns credits up until the age of 16 years.

[36] The temperature implications of using the GWP100 metric to offset methane with carbon dioxide removals are studied in more detail in Brazzola et al., 2021.

The cooling effect of forest planting

Forests remove carbon dioxide from the atmosphere, which causes cooling. However, the cooling caused by a forest does not increase linearly over time like the example shown in Figure 3 because the amount of carbon sequestered varies from year to year. How much carbon dioxide is removed from or emitted to the atmosphere by a forest in any given year depends on the tree species, age of the forest and forest management regime.

When pasture is first converted into a pine plantation forest, a small amount of carbon dioxide is emitted due to the clearing of biomass from the site and loss of soil carbon over a 20-year period. Once the new trees are established, they begin to remove carbon dioxide from the atmosphere. Some carbon is lost when the forest is pruned and thinned.

Once harvested, most of the carbon within the harvested trees is likely to be lost to the atmosphere but the time horizon over which that happens can vary enormously depending on how the wood is used. Burning the wood will release the carbon back into the atmosphere almost immediately. By contrast, using the wood for furniture or as a structural building material can keep the carbon locked up for very lengthy periods. Replanting after harvest restarts the cycle and the forest begins to remove carbon dioxide from the atmosphere again. This cycle results in the characteristic 'sawtooth' carbon storage function depicted in Figure 12a.

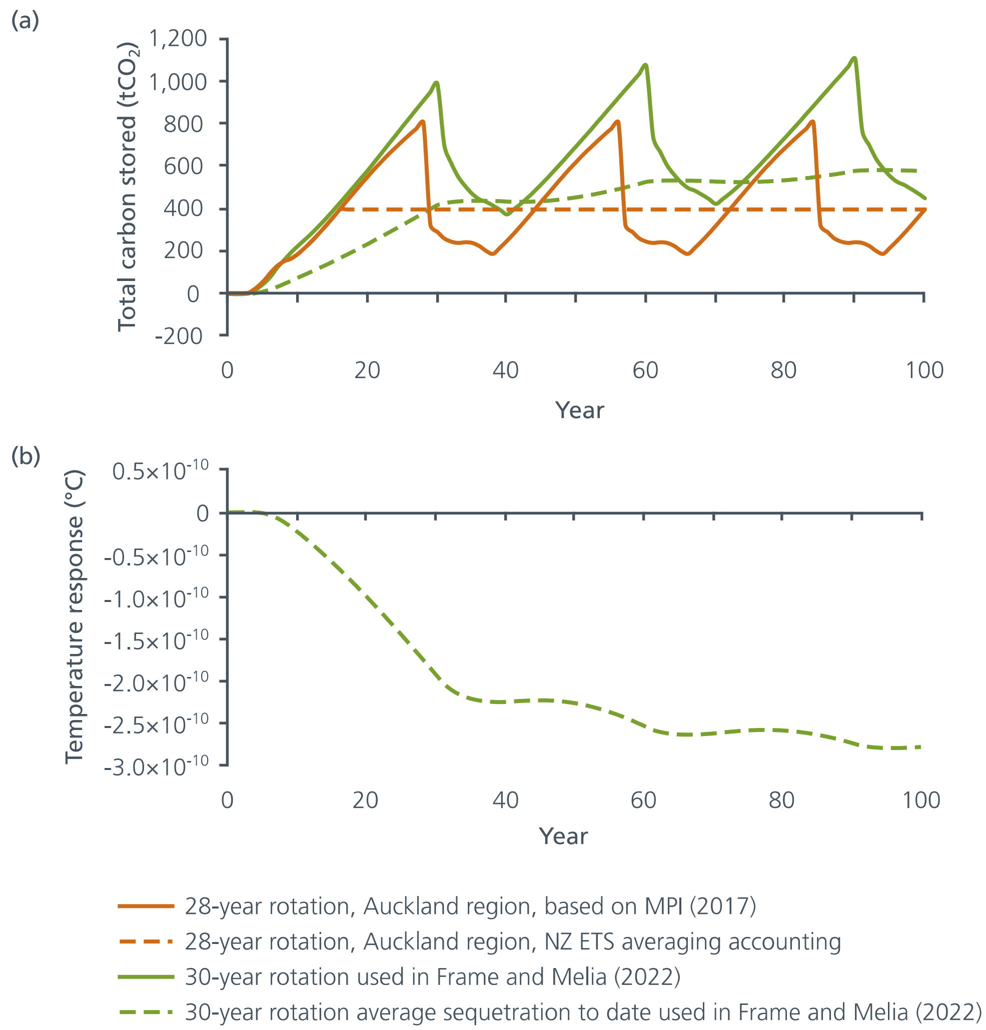
Unharvested native forests sequester carbon more slowly than pine plantation forests. As a result, most unharvested native forests store less carbon within the first century of being planted. However, an unharvested native forest is likely to continue sequestering carbon for centuries, while the amount of carbon stored in a pine plantation forest roughly stabilises after the first few rotations. In the long run, unharvested native forests generally store more carbon per hectare than pine plantation forests that are periodically harvested, though carbon sequestration rates are highly variable for different native species. Research is underway to get better data on carbon sequestration rates of native tree species.

The temperature response for a pine plantation forest (Figure 12b) has a similar shape to the cumulative carbon storage function (Figure 12a).[37] However, it is inverted because removing carbon dioxide from the atmosphere has a cooling effect.

The average cooling over time caused by planting a fixed area of new pine plantation forest in 2016 is roughly the mirror image of the warming caused by methane emitted from 2020 onwards from a herd of livestock (Figure 13).[38]

[37] The cumulative carbon storage function depicts carbon dioxide removals as positive values. It is therefore the inverse of cumulative carbon dioxide removals.

[38] If the objective is to offset 100% of the warming from 2020 onwards, the forest needs to be planted four years in advance (i.e. in 2016 in this example) due to a small disparity between the two temperature response curves.



Source: Based on MPI, 2017, and Frame and Melia, 2022

Figure 12: Cumulative carbon dioxide storage (a) and associated temperature response (b) for one hectare of pine plantation forest. The illustrative examples of the 'conventional approach' in this note are based on a 28-year rotation forest in the Auckland region with averaging accounting under the New Zealand Emissions Trading Scheme.[39] The calculations in Frame and Melia, 2022, used a 30-year rotation forest derived from Paul et al., 2019, which was based on plots around the country and included carbon stored in biomass above and below ground, dead wood litter and fine litter. Harvest residuals and harvested wood products were included by Frame and Melia after the first rotation. The temperature response was calculated by stacking the temperature responses for one-off removals from Figure 1.

[39] MPI, 2017, p.39.

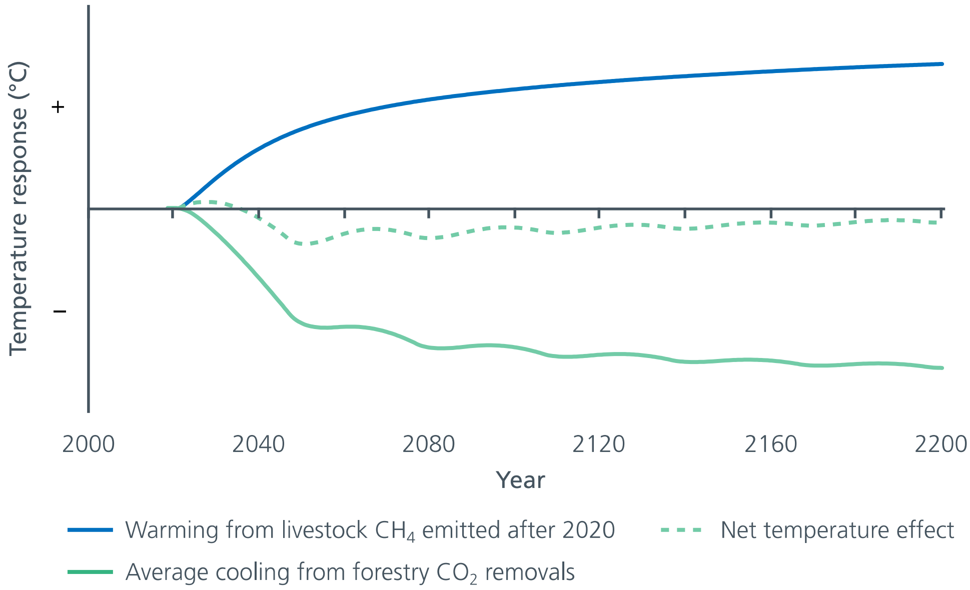


Figure 13: Illustration of the warming caused by methane emitted after 2020 from a herd of livestock, the cooling caused by planting a new pine plantation forest in 2016 with a 30-year rotation, and the net temperature effect (i.e. the combined temperature effect of the warming from methane emissions and the cooling from carbon dioxide removals). The temperature response was calculated by stacking the temperature responses for one-off emissions and removals from Figure 1.

Offsetting livestock methane using a warming-based approach

The work I commissioned from Frame and Melia demonstrates how a closer match over time between the warming effect of a herd of livestock and the cooling effect of a forest can be achieved by planting a one-off fixed area of forest. The method they developed used the GWP* metric instead of the GWP_{100} metric to represent livestock methane emissions.

Table 1 shows the one-off area of new pine plantation forest that needs to be planted to achieve approximately the same temperature effect as decreasing the size of a herd of ruminants by one animal in 2020. If multiplied by the total number of animals in the herd, these values show the area of new pine plantation forest required to offset 100% of the warming from methane emitted after 2020 from a herd of ruminants using a warming-based approach.

The reason for the range of values for each livestock type is that pine plantation forests grow at different rates in different regions of New Zealand. Gisborne has the highest forestry growth rates in the country, and Canterbury the lowest.

The approach does not require the forest to be planted in the same paddock as the livestock being offset. The forest can be planted anywhere. Nor does the approach assume that planting the forest causes any indirect reduction in livestock numbers or gross livestock methane emissions due to land use change from pastoral agriculture to forestry.

If the objective is to mimic the temperature effect of a less than 100% reduction in livestock methane emissions, the numbers in Table 1 can be scaled down accordingly. For further details about the method used to derive these numbers, see the accompanying technical report by Frame and Melia.[40]

Table 1: One-off areas of new pine plantation forest that need to be planted to achieve approximately the same temperature effect as decreasing the size of a herd of ruminants by one animal.

	Dairy cattle	Beef cattle	Deer	Sheep
Hectares of new pine plantation forest per animal (national average values with minimum and maximum values in brackets)	0.6 (0.5–0.8)	0.4 (0.3–0.5)	0.2 (0.1–0.2)	0.08 (0.07–0.10)

Returning to the illustrative example of 6.2 million dairy cattle from earlier in the note, the numbers in Table 1 indicate that using a warming-based approach to offset 100% of the warming caused by emissions after 2020 from the same herd would require a one-off planting of around 3.9 million hectares of new pine plantation forest (in the absence of any gross emissions reductions).

Over the first 100 years, the total area of new pine plantation forest that needs to be planted is similar to when the conventional approach based on GWP_{100} is used. The main difference is the timing of the planting. In the warming-based approach, the total area is planted upfront (note that if 2050 is the target year, the planting can be spread out between now and 2050). By contrast, when GWP_{100} is used, the planting is spread out over a century (Figure 14).

The area of forest that needs to be planted upfront in the warming-based approach is around five to six times greater than in the conventional approach. However, no further expansion of the forest area is required after the initial planting. This enables some form of steady state to be reached in terms of land area because it is no longer necessary to plant an additional new area of forest every 16 years.

[40] Frame and Melia, 2022.

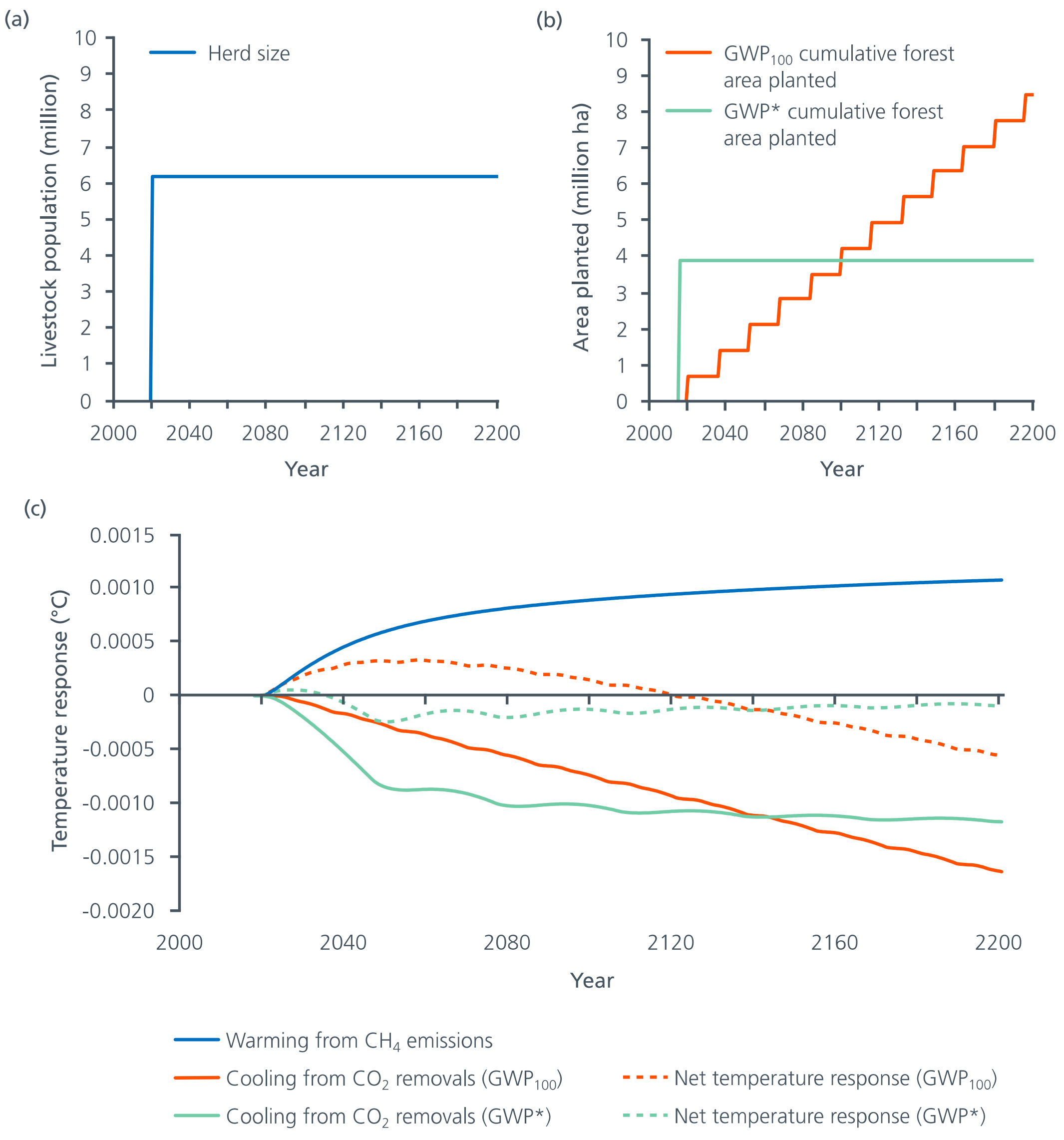


Figure 14: Offsetting the warming from methane emitted after 2020 from a herd of 6.2 million dairy cattle by planting pine plantation forest using the conventional approach based on the GWP100 metric and a warming-based approach based on the GWP* metric.

Offsetting livestock methane from New Zealand's national herds of ruminants

The approach outlined in this note can be used in different ways depending on the purpose of the exercise and the level of ambition desired. The focus of this note is on the potential use of forests for offsetting livestock methane emissions at the national level, not at the farm or processor level.

The area of new pine plantation forest that would need to be planted to offset national livestock emissions depends on by how much gross emissions are reduced and the total net reduction sought by combining gross emissions reductions with forestry offsets.

In addition to reducing national livestock methane emissions by 24–47% by 2050, a similar temperature effect to decreasing livestock methane emissions by a further 10% could be achieved by planting around 770,000 hectares of new pine plantation forest between now and 2050 (equivalent to an average annual planting rate of around 26,000 hectares per year). These numbers can be scaled up depending on the total net reduction sought: a further 20% would require 1.5 million hectares (51,000 hectares per year), a further 30% would require 2.3 million hectares (77,000 hectares per year) and so on.[41]

Assuming that national livestock methane emissions are reduced by 24–47% by 2050, a summary of the range of options is shown in Figure 15. Broken-down figures for the national herds of dairy cattle, beef cattle, sheep and deer are shown in Appendix 1.

Very large areas of forest would be required if the objective were to reduce national livestock methane emissions by 24–47% by 2050 plus use forestry offsets to achieve the same temperature response as reducing livestock methane emissions to zero by 2050. If national livestock methane emissions were reduced by 47% by 2050, this would require 4.1 million hectares of pine plantation forest to be planted between now and 2050 (136,000 hectares per year over 30 years). If national livestock methane emissions were reduced by only 24%, the area of forest required to achieve the same objective would increase to 5.8 million hectares (194,000 hectares per year over 30 years).

[41] Here, the term 'total net reduction' is used to refer to the hypothetical reduction in livestock methane emissions by 2050 that would have roughly the same temperature impact as the combined effect of the actual gross emissions reduction and forest planting. For example, reducing livestock methane emissions by 24% by 2050 and planting around 1.5 million hectares of pine plantation forest would have roughly the same temperature impact as reducing livestock methane emissions by 44% by 2050. In this example, the gross emissions reduction would be 24%, forestry would contribute a 'further' 20%, and the total 'net reduction' would be 44%. A net reduction of 100% by 2050 would have roughly the same temperature response as reducing livestock methane emissions to zero by 2050.

To put these numbers into perspective, there is currently around 9 million hectares of land being used for pastoral farming in Aotearoa (2.2 million hectares of dairy cattle land, 2.7 million hectares of beef cattle land and 4.1 million hectares of sheep land).[42] There is currently around 2.1 million hectares of plantation forest, of which around 1.7 million hectares is productive.[43] In terms of annual planting rates, 34,000 hectares of new exotic production forest was planted in 2020 and the highest annual planting rate since records began was 98,000 hectares in 1998.[44]

These extraordinary numbers show that even if national livestock methane emissions were reduced by 24–47% by 2050, offsetting all of the warming remaining from future ongoing livestock methane emissions would require land use change from livestock farming to pine plantation forest on a scale that has not been experienced to date.

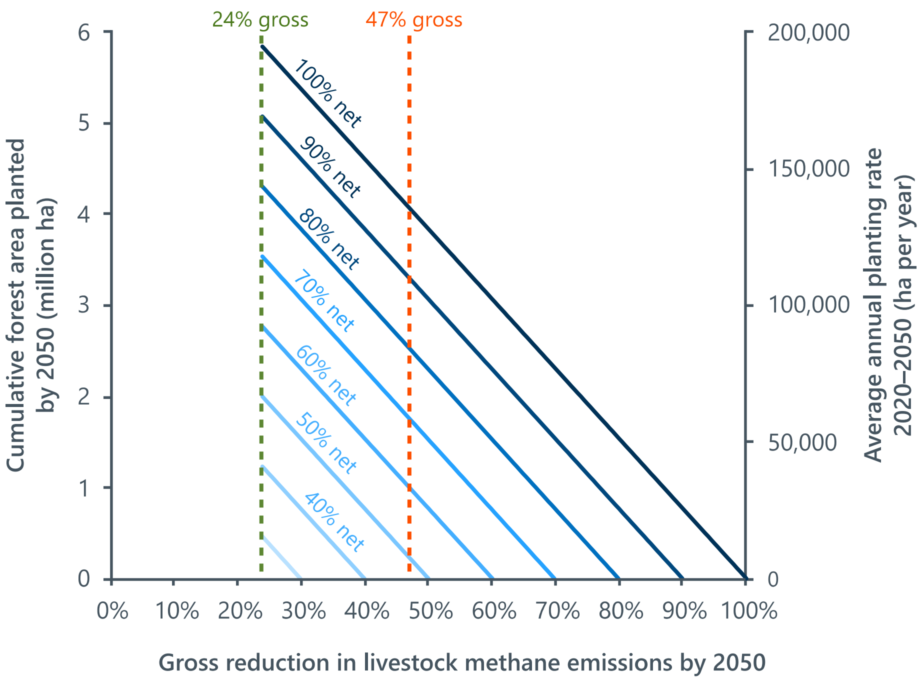


Figure 15: Area of new pine plantation forest that would need to be planted between 2020 and 2050 to offset New Zealand's national livestock methane emissions (all herds combined). Cumulative forest area is shown on the left axis. The corresponding average annual planting rates for 2020–2050 are shown on the right axis. The diagonal lines show how the area of forestry required depends on the total net reduction sought through the combination of gross emissions reductions and forestry offsets. The minimum gross reduction in livestock methane emissions shown is a 24% reduction by 2050.

[42] Stats NZ, 2021.

[43] MPI, 2022. Ninety per cent of this productive forest is radiata pine. See NZFFA, NZFOA and Te Uru Rākau, 2021, p.2.

[44] NZFFA, NZFOA and Te Uru Rākau, 2021, p.15.

Figure 16 shows what would happen to national livestock methane emissions, cumulative forest area planted, cumulative carbon dioxide removals and temperature response using the following illustrative examples:

- national livestock methane emissions reduced by 24% by 2050, no forest planting
- national livestock methane emissions reduced by 47% by 2050, no forest planting
- national livestock methane emissions reduced by 24% by 2050, forest planting used to achieve a further 76% reduction (100% total net reduction)
- national livestock methane emissions reduced by 47% by 2050, forest planting used to achieve a further 53% reduction (100% total net reduction).

Similar illustrative examples for the national herds of dairy cattle, beef cattle, sheep and deer are provided in Appendix 2.

These illustrative examples assume that all gross emissions reductions are achieved through reductions in livestock numbers. If other on-farm mitigation options became available and were successful at reducing emissions, the same gross emissions reductions could be achieved with smaller reductions in livestock numbers.

Straight-line reductions in livestock methane emissions are assumed between 2020 and 2050. Similarly, these illustrative examples assume that equal areas of forest are planted each year between 2020 and 2050, after which planting ceases. As a result, the cumulative forest area increases linearly between 2020 and 2050, then levels off.

If a 100% total net reduction by 2050 is achieved through a combination of gross emissions reductions and forest planting, zero warming from livestock methane emitted since 2020 would be achieved by around the end of the century.

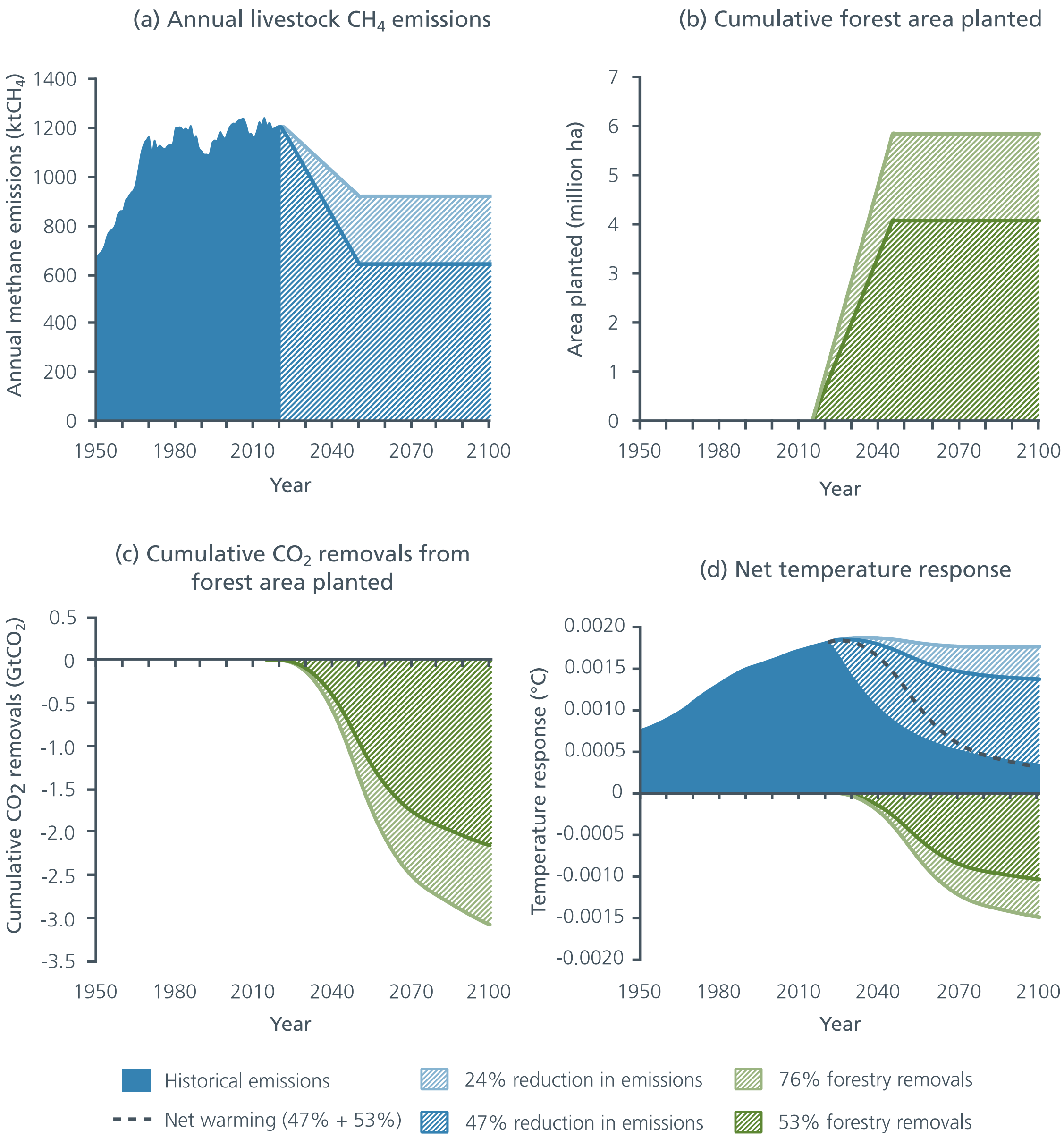


Figure 16: Illustrative scenarios for offsetting national livestock methane emissions using a warming-based approach.

6 Opportunities, challenges and limitations

This note has outlined how the warming from livestock methane emissions can be offset by forest planting and has illustrated how this approach could be used to offset the warming from methane for New Zealand's national dairy cattle, beef cattle, sheep and deer herds.

The warming-based approach outlined in this note would place a greater focus on matching warming and cooling over time than the conventional approach using GWP100, which only matches warming and cooling on average over a 100-year period. Using GWP100 underestimates the forestry removals needed in the first century and overestimates them in the second century. By contrast, a warming-based approach would provide a closer alignment over time between the warming from the herd and the cooling from the forest. It does this by front-loading the forest planting. Averaged over around two centuries, the warming outcomes of both approaches would be similar.

In the conventional approach, a new area of pine plantation forest must be planted every 16 years indefinitely to offset ongoing livestock methane emissions. Clearly, planting more and more land in forest over time is not sustainable in the long run. The warming-based approach requires a significantly larger area of pine plantation forest to be planted upfront, but this planting is a one-off (or can be spread over, for example, 30 years) and no further planting is subsequently required.

The warming-based approach therefore provides an opportunity to achieve some form of long-run equilibrium in terms of land area between livestock farming and pine plantation forestry. Though even if such an equilibrium were eventually reached, pressure may remain on livestock methane emitters to further reduce their gross emissions in the future.

The net zero emissions target for long-lived greenhouse gases means that a combination of gross emissions and forestry offsets will be used to achieve roughly the same temperature response as a 100% reduction in gross emissions of long-lived gases by 2050. The temperature outcome of achieving this would be no further increase in warming from 2050 onwards.

For livestock methane, it would be very challenging indeed to use forestry offsets in combination with gross emissions reductions to achieve roughly the same temperature response as a 100% reduction in gross emissions by 2050. If gross emissions were reduced by 47% by 2050, it would require 4.1 million hectares of new pine plantation forest to be planted over the next 30 years to achieve the same temperature response as reducing gross emissions to zero. By the end of the century, that would mean zero warming in perpetuity from future emissions. This area is equivalent to roughly 45% of the land currently being used for pastoral farming in Aotearoa. If gross emissions were reduced by 24% by 2050, this would increase to 5.8 million hectares.

By contrast, if the objective were only to achieve no additional warming from livestock methane above the current level, then gross emissions would only need to be reduced by 10–22% by 2050 relative to the 2016 level and forest offsetting would probably not be required.[45] An ambitious but achievable policy goal lies somewhere between these two extremes.

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[45] PCE, 2018. Note that a reduction in biogenic methane emissions of 10–22% by 2050 relative to the 2016 level is not compatible with the 2050 target in the Climate Change Response Act 2002, which requires a 24–47% reduction by 2050 relative to the 2017 level.

The illustrative examples in this note focus on pine plantation forest. Offsetting national livestock methane emissions using native forest alone is unlikely to be feasible due to the very large areas of native forest that would be required. However, it is possible that a mix of fast-growing exotic tree species and slower-growing natives could be used to offset livestock methane. Some preliminary analysis of the mixed forest option is provided by Frame and Melia.[46]

The illustrative examples provided in this note are for New Zealand's national herds of ruminants. But if an individual farm or business (or a collective of farms) wanted to set itself a voluntary temperature objective for its livestock methane emissions, the method could also be applied at smaller scales. The only input data required are current livestock numbers and the forest planting factors in Table 1. Farmers do not need to calculate their GWP* emissions to use this method, so historical emissions data are not required.

If the Government were to enable livestock methane emitters to offset their emissions by planting forests, changes would need to be made to the architecture of the Climate Change Response Act 2002 as well as the policy mechanisms in place to tackle biogenic emissions. The architecture of the Climate Change Response Act would need to evolve from the current split-gas approach, which hermetically seals off biogenic methane from the rest of the land-based economy, to a split-sector approach with separate targets for the fossil-based and the land-based sectors. This would not be a trivial change.

Emissions pricing for agriculture will be introduced in 2025, either by introducing surrender obligations for agriculture under the New Zealand Emissions Trading Scheme or by establishing a new split-gas levy on biogenic emissions, as proposed by He Waka Eke Noa.[47] Either of these approaches, with modification, could enable livestock methane emitters to offset their emissions by planting trees themselves or by paying others to do so.

Whatever approach to emissions pricing is taken, the policy mechanism would need to be carefully designed to ensure that the 24–47% gross reduction in livestock methane emissions is achieved. Given that in most cases forest planting is likely to be a cheaper option than reducing livestock methane emissions, the absence of a minimum level of gross emissions reductions would likely incentivise an even higher level of land use change. The current rates of land use change from pastoral land to forestry are already causing concern in some rural communities.

Given the scale of new forest planting that would be required to offset part of New Zealand's livestock methane emissions, the approach outlined in this note is unlikely to be compatible with the continued unlimited use of forests to offset emissions from the energy, transport and industry sectors through the New Zealand Emissions Trading Scheme.

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[46] Frame and Melia, 2022.

[47] For more on the proposed scheme, see He Waka Eke Noa, 2022.

Since publishing my *Farms, forests and fossil fuels* report, I remain of the view that reliance on forests to offset fossil carbon dioxide emissions should be reduced and there should be a target for gross carbon dioxide emissions. If the approach to offsetting livestock methane outlined in this note were taken up by the Government, it would therefore need to be accompanied by a progressive reduction in the use of forestry removals as offsets for long-lived greenhouse gases in the New Zealand Emissions Trading Scheme. Doing so would clearly shift more of the burden of New Zealand's climate change mitigation policy onto the fossil-fuel-based segments of the economy and would likely expose them to higher emissions prices.

This work shows that very large areas of forest would need to be planted to make any significant dent in the marginal warming effect of New Zealand's livestock methane emissions. For that reason, if forest planting were to be used to offset livestock methane, it would have to be in addition to – not instead of – reducing national gross emissions of biogenic methane by 24–47% by 2050. We cannot simply plant our way out of this problem.

Appendices

Appendix 1: Areas of new pine plantation forest that would need to be planted to offset livestock methane emissions for the national herds of dairy cattle, beef cattle, sheep and deer

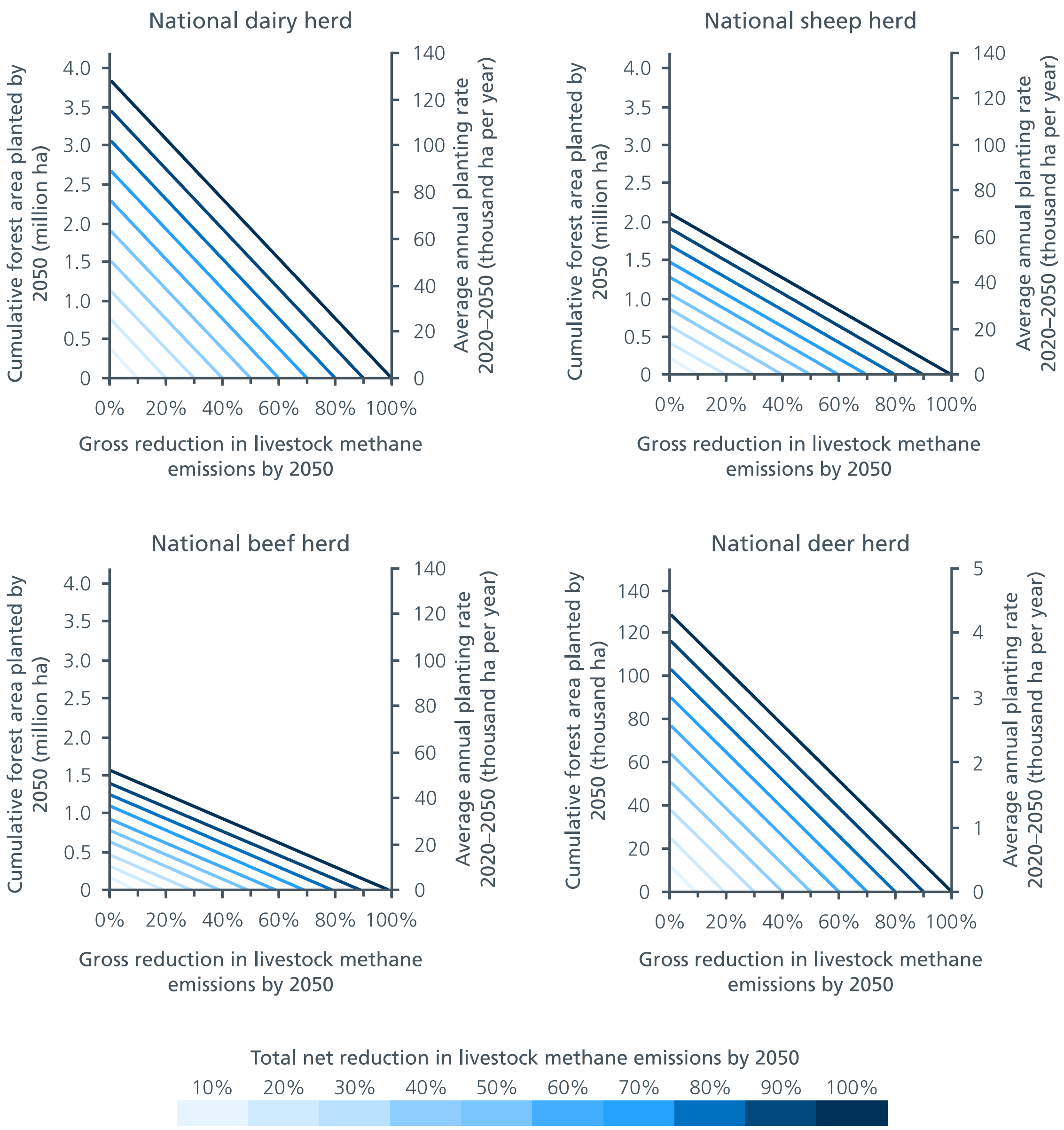

Figure A1.1: Area of new pine plantation forest that would need to be planted between 2020 and 2050 to offset livestock methane emissions for the national herds of dairy cattle, beef cattle, sheep and deer. Diagonal lines show how the area of forestry required depends on the total net reduction sought through the combination of gross emissions reductions and forestry offsets. On aggregate, gross emissions of biogenic methane must be reduced by 24–47% by 2050.

Appendix 2: Illustrative scenarios for offsetting warming from livestock methane emissions for the national dairy cattle, beef cattle, sheep and deer herds using GWP*

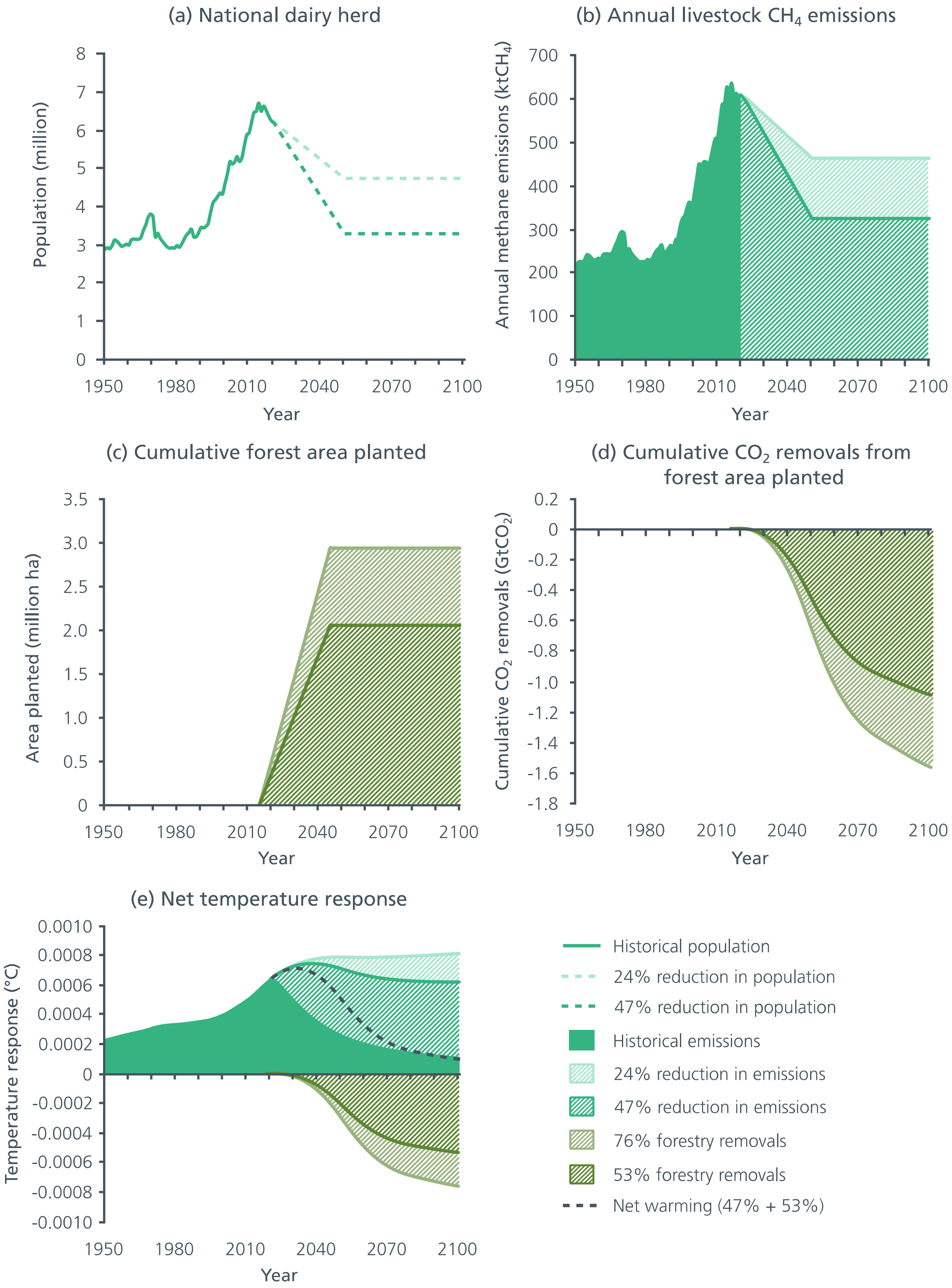

Figure A2.1: Illustrative scenarios for offsetting warming from livestock methane emissions for the national dairy cattle herd using GWP*.

Figure A2.2: Illustrative scenarios for offsetting warming from livestock methane emissions for the national beef cattle herd using GWP*.

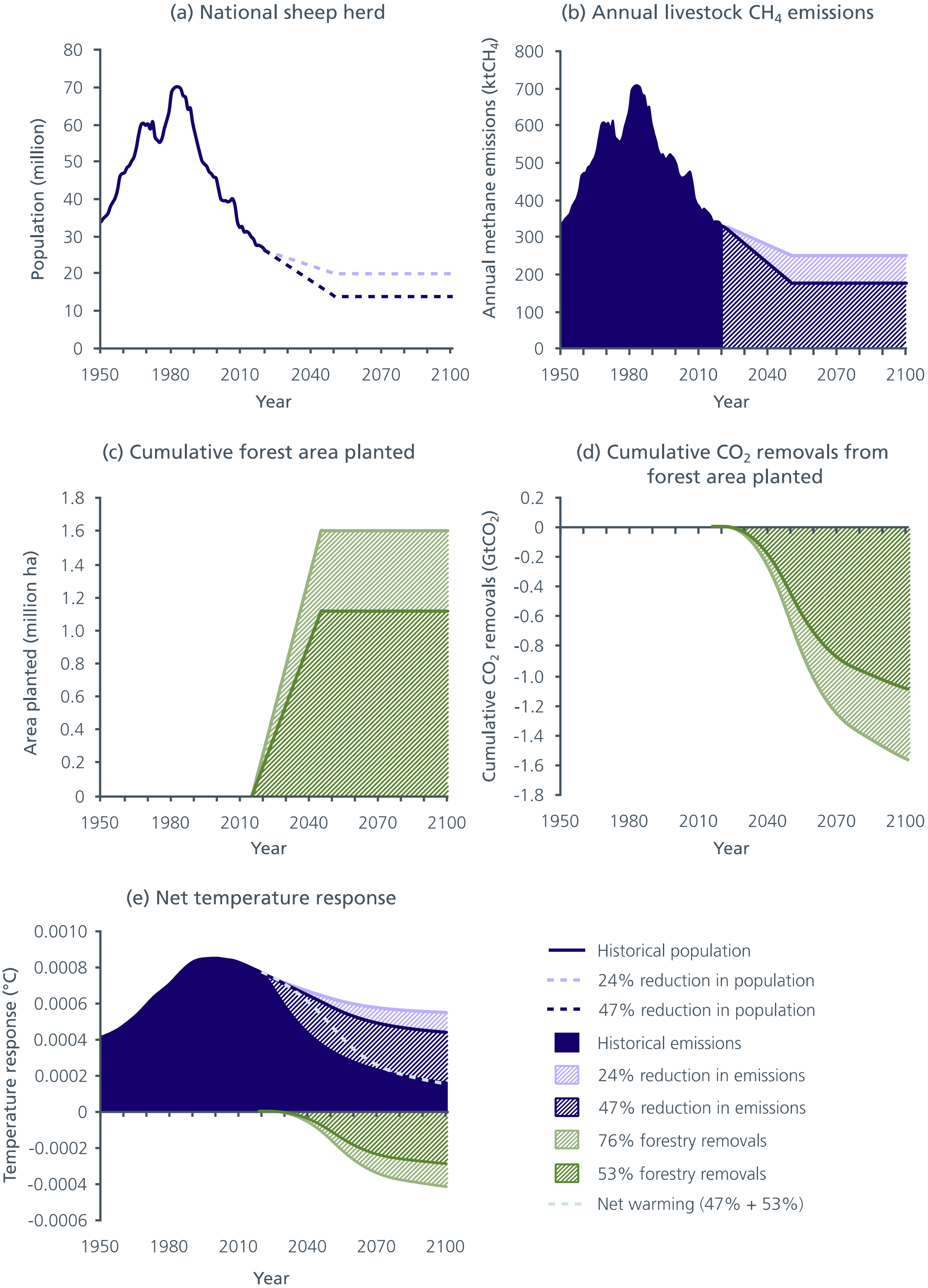

Figure A2.3: Illustrative scenarios for offsetting warming from livestock methane emissions for the national sheep herd using GWP*.

Figure A2.4: Illustrative scenarios for offsetting warming from livestock methane emissions for the national deer herd using GWP*.

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