REDUCING NEW ZEALAND'S AGRICULTURAL GREENHOUSE GASES:

HOW WE MEASURE EMISSIONS

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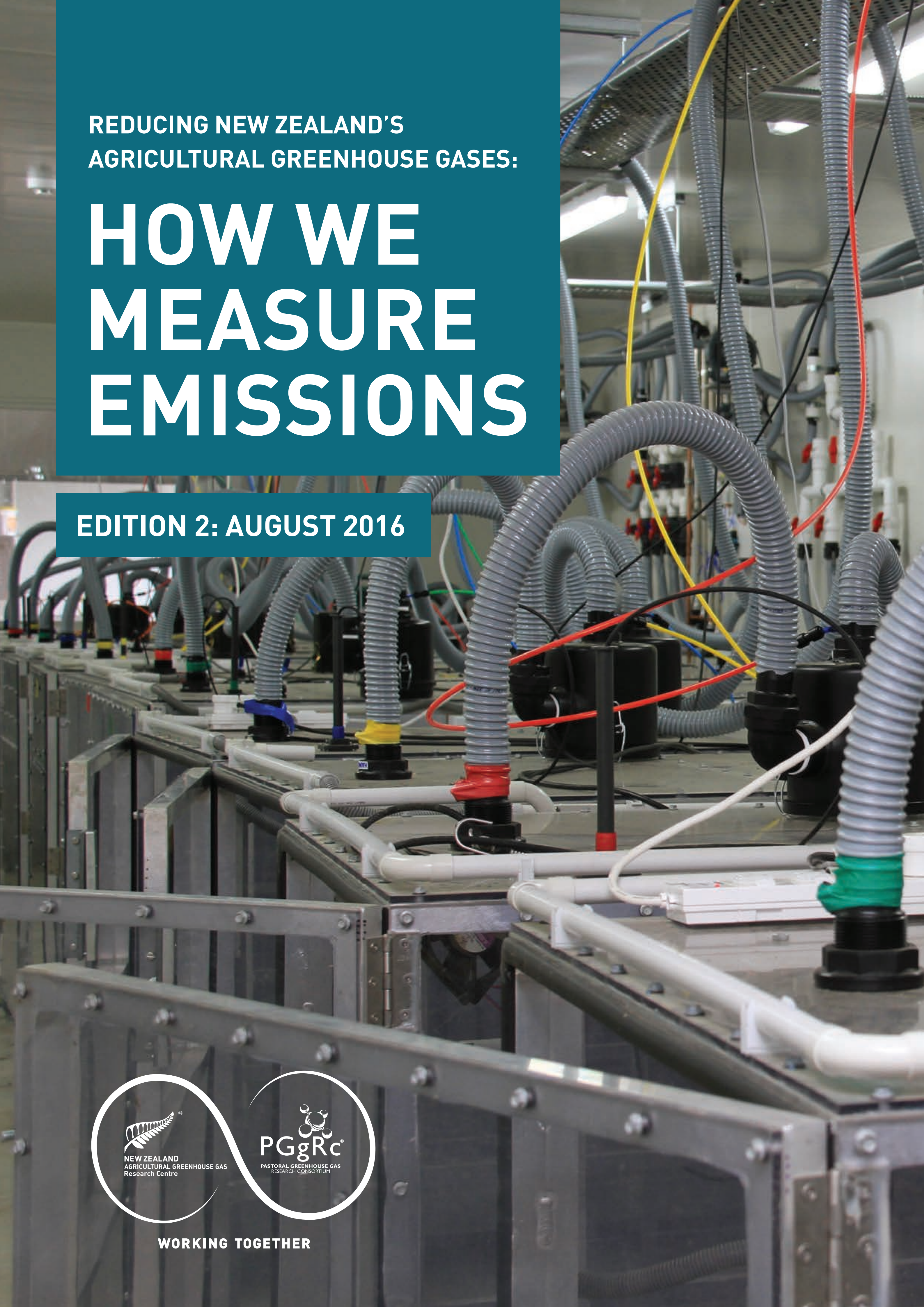

NEW ZEALAND AGRICULTURAL GREENHOUSE GAS Research Centre

PGgRc PASTORAL GREENHOUSE GAS RESEARCH CONSORTIUM

WORKING TOGETHER

MEASURING GREENHOUSE GAS EMISSIONS FROM NEW ZEALAND AGRICULTURE

Agriculture produces greenhouse gas emissions in a number of ways: direct emissions by livestock, emissions from the production of livestock feed, energy use in fertiliser manufacture, farm operations such as milking, refrigeration and housing, and food storage and transport.

Globally, direct emissions from livestock and feed production make up about 80% of total agriculture emissions. This percentage is even higher in New Zealand (97%) because of the dominance of the livestock sector. Most of our animals spend all their time outside grazing on pasture. This poses a stiff challenge for the measurement, quantification and mitigation of agricultural greenhouse gas emissions. New Zealand has invested significantly in the search for cost effective measures to reduce agricultural greenhouse gas emissions, and this has required New Zealand scientists to develop best practice techniques for quantifying these emissions.

WHY WE NEED TO MEASURE

There are five key reasons why measurement matters for New Zealand agriculture:

1. To understand trends and identify how much agriculture contributes to greenhouse gas emissions relative to other sectors both nationally and internationally
2. To develop effective ways to reduce agricultural greenhouse gas emissions, e.g. identifying naturally low-methane emitting animals for breeding programmes
3. To find out whether actions intended to reduce greenhouse gas emissions are effective when they are applied in practice
4. To meet international obligations to monitor progress against commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and subsequent agreements
5. To enable companies to monitor and report on their greenhouse gas footprint.

MEASURING GREENHOUSE GAS EMISSIONS: METHANE

Methane is a powerful but relatively short-lived greenhouse gas. Averaged over 100 years, the global warming potential[1] of one tonne of methane is 25 times that of one tonne of carbon dioxide. In New Zealand, most methane comes from belching by ruminant animals: sheep, beef cattle, dairy cows, and deer, and some from animal manure. Non-ruminants, such as poultry and pigs, also produce methane from their manure but these constitute are a very small source in New Zealand.

RESPIRATION CHAMBERS

HOW THEY WORK

Respiration chambers are animal-friendly closed circuit containers in which animals are contained while their gas output is measured. The New Zealand Animal Ruminant Methane Measurement Centre at AgResearch, part-funded by the NZAGRC, is a dedicated measurement facility, comprising 24 chambers for sheep and four for cattle. Since its opening in April 2011, over 6500 sheep and more than 750 cattle have been measured.

After up to a week of acclimatisation in open-sided crates, the animals enter the respiration chambers which are made of perspex and arranged side-by-side so animals can see each other. Automated systems continuously sample the air entering and leaving the chambers, to measure the amount of methane formed by the animals. Temperature, humidity and air flow are continuously controlled. Technicians top up each animal's food and water at regular intervals, and remove dung and urine. Time spent in the chambers is generally restricted to two days. All animal experiments are subject to strict animal ethics approval procedures, and animals are monitored for their welfare in the chambers; if animals refuse to eat or show signs of distress they are released. If environmental conditions change inside the chambers, the chamber doors open automatically and release the animals.

WHY DO IT

The 'gold standard' in scientific experiments is to keep every element of an experiment the same except for the one factor you are investigating, e.g. the type of feed. In methane research, animal respiration chambers are close to this ideal standard; researchers know exactly what is going into and coming out of an animal and can change the feed, compare the methane emitted from genetically-different animals, or test the effectiveness of a treatment, e.g. a vaccine.

CHALLENGES

Animals can be kept in chambers for only a limited period of time, so measurements essentially provide only a 'snapshot' of emissions. To infer longer-term average emissions, say in different physiological stages e.g. pregnancy or lactation, scientists have to rely on repeat measurements.

The ability to keep things largely constant remains the prime advantage of respiration chambers – but also its main drawback as this does not reflect the real world. For example, in the paddock, different animals might naturally select a different mix of feed, and some may be naturally more active than others. In a chamber, they do not have that choice. Overall, chambers are the most precise measurement method but they are labour and resource intensive, and the number of animals that can be measured is limited by the number of chambers available.

[1]See "Greenhouse Gas Metrics" sidebar on page 15

MEASURING GREENHOUSE GAS EMISSIONS: METHANE

SF_6 tracer technique

HOW THEY WORK

This technique was devised to answer the question 'How much methane does an animal grazing freely in a field produce over a given period (usually one 24-hour feeding cycle)?'

Sulphur hexafluoride (SF_6) is an inert gas that is easy to detect even in minute amounts. In experiments using this technique, a 'permeation tube' containing SF_6 is inserted into an animal's rumen via the mouth. This tube will slowly release SF_6 over time at a predetermined rate and the released gas will be emitted via the mouth.

The animal is fitted with a lightweight 'yoke', which carries an air-evacuated canister that slowly draws air at a steady rate from near the animal's nostrils. When the animal belches, it releases both SF_6 and methane from its nostrils, and some of this is sucked into the canister (along with air surrounding the animal).

Canisters are changed daily so that a series of repeat 24 hour measurements can be obtained. The air accumulated in the canister is analysed later to determine the ratio of SF_6 to methane in the sample.

Since the amount of SF_6 that is released from the permeation tube over a given period is known, scientists can use the measured ratio of SF_6 to methane to calculate how much methane the animal has released over the same period.

WHY DO IT

Measurements are made under realistic conditions and can continue for longer periods of time.

CHALLENGES

Unlike respiration chambers, there is no easy way to measure exactly what the animals are eating while grazing. Feed intake can be inferred from the animal's size and weight gain/milk production, or from dung collection, but these are subject to large errors. The SF_6 tracer technique is also labour intensive: gas collection canisters are generally changed every 24 hours, for about five to eight days. Overall, the technique is not as accurate as respiration chambers.

MEASURING GREENHOUSE GAS EMISSIONS: METHANE

Portable accumulation chambers

HOW THEY WORK

Commonly, these are a sheep-sized transparent polycarbonate box suspended above a race. When a sheep walks into the race, the chamber is lowered over it and the sheep is held inside for about 30 minutes. Air samples are taken during this time and the methane concentration is analysed.

WHY DO IT

Portable chambers may be a useful method for screening a larger number of animals to identify naturally low methane-emitting individuals. They allow large numbers of animals to be screened in a short period of time. This speeds up the animal selection process and provides more low-emitting animals from which to breed the next generation. Keeping the breeding pool large avoids restricting opportunities for general genetic improvements in the herd/flock.

CHALLENGES

Portable chambers are not as accurate as respiration chambers as they only give a brief snapshot of an animal's emissions and are still an artificial environment. It is important to achieve an airtight seal so that all methane produced by the animal can be measured. Intake is also not known accurately if used with grazing animals.

GreenFeed™ and other 'hoods'

HOW THEY WORK

GreenFeed™ is a commercially available system developed by C-lock Inc., USA, to measure methane emissions from non-confined cattle and sheep. The principles of the GreenFeed unit are the similar to that of respiration chambers, with the difference that animals can move freely in and out of the unit and gases are only measured when the animal visits the unit. Small quantities of supplementary feed are made available to attract animals to place their head into a semi-enclosed feed box and simultaneously air is drawn past the nose of the animal. Sensors measure the methane released from the animal's nose and mouth during the several minutes that animal is feeding Daily methane emissions are estimated from multiple short-duration visits to the feed station over 1-2 weeks. Similar systems in dairy sheds are being developed to measure emissions during milking or feeding trials.

WHY DO IT

GreenFeed™ is one response to the search for a lower cost way of measuring methane emissions from free-ranging animals especially from cattle. It is much less labour intensive than SF_6. So far, the resulting estimates appear broadly comparable between GreenFeed and respiration chambers when mean values obtained from groups of animals are compared.

CHALLENGES

This method is still new but rapidly becoming established, although it does require training and expertise to obtain good data. Some animals need training to use the feeder, and individual animal behaviour influences how often animals use the system. The accuracy for individual animals has been found to be influenced by the number and duration of visits to the feeder. Intake is also not known accurately if used with grazing animals as for other field based methods.

MEASURING GREENHOUSE GAS EMISSIONS: METHANE

Paddock-scale micro-meteorological techniques

HOW THEY WORK

All the above measurement techniques provide estimates of emissions from individual animals. This raises the question whether the animals that have been measured are representative of average emissions coming from an entire herd over long periods of time. Micro-meteorological techniques seek to address this question directly, by measuring wind speed, direction and turbulence, as well as the concentration of methane in the air downwind from a flock of sheep or herd of cattle. These data are used to calculate the amount of methane generated by all livestock in a paddock.

WHY DO IT

One challenge for estimating total emissions across the country is the large variability between animals, and the high cost of measuring individual animals. Only a relatively small number of animals can be measured individually, so estimates for an entire flock/herd or for the country as a whole have to make assumptions about typical emission rates per animal. Paddock-scale measurements can be useful in checking whether measurements from individual animals can be multiplied to represent emissions from a group of animals under typical farm management.

CHALLENGES

This research is highly technical and still experimental. Micro-meteorological techniques are labour intensive, mainly in setting up and running the highly specialised equipment. Measurements also depend on favourable wind conditions and suitable paddocks, and for methane, the emissions source (livestock) moves around, which can further reduce the precision of the method. Importantly, intake is also not known accurately, making comparisons between flocks/herds and over time difficult. It is hard to distinguish the methane produced by a single herd of cows or flock of sheep from methane in the air from other sources, and therefore the precision of the method is limited, making it difficult to verify small changes in emissions.

MEASURING GREENHOUSE GAS EMISSIONS: NITROUS OXIDE

Nitrous oxide is a much more powerful greenhouse gas than methane; 298 times more powerful than carbon dioxide over a 100-year timeframe on a per tonne basis[2]. Fortunately, the absolute amount of nitrous oxide emitted from agriculture is lower. In New Zealand, most nitrous oxide is produced by the action of soil bacteria in urine patches in paddocks. Smaller amounts come from dung deposited during grazing, stored manures spread back onto pasture, and from nitrogen fertiliser.

SOIL CHAMBERS

HOW THEY WORK

A closed chamber enables samples of air to be collected for analysis from small patches of soil. A chamber is built from material that does not react with nitrous oxide, such as stainless steel, aluminium, PVC or acrylic.

After the lid on a chamber is closed, gases given off by the soil rapidly accumulate in the volume of air above the soil, and their accumulation over time can be measured to determine the rate at which the gases are released.

Samples may be collected manually or automatically.

Once collected, gas samples can be analysed in a laboratory for nitrous oxide and any other gases of interest.

A key measurement facility in New Zealand is the National Centre for Nitrous Oxide Measurement, developed by Lincoln University with funding from the NZAGRC. The centre can process more than 1000 nitrous oxide samples a day.

ADVANTAGES

With soil chambers, scientists can directly measure nitrous oxide from a point source – the urine patch, but also from soil without (or with different) urine treatment to see the difference.

CHALLENGES

Soil chambers alter the micro-climate above the urine patch. As a result, measurements can only be taken over a short period of time, but can be repeated many times. Attempts to compensate for the microclimate can include insulation and venting the chamber.

Soil chamber measurements on their own are not enough to determine how much nitrous oxide might be coming off an entire paddock, since they only measure emissions from small patches of soil. Other factors include the number of urine patches, variations in urine composition over time, and whether animals repeatedly excrete in the same place, making strategic placement of chambers an important factor in determining overall emissions from a paddock. Soil chambers are very labour intensive, and require a backup infrastructure to measure gas samples once they have been collected in the field.

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[2]See "Greenhouse Gas Metrics" sidebar on page 15

MEASURING GREENHOUSE GAS EMISSIONS: NITROUS OXIDE

Micro-meteorological techniques

HOW THEY WORK

Similar to its application to methane, micro-meteorological techniques are useful to get an estimate of emissions from an entire paddock by measuring wind speed, direction and turbulence, as well as the concentration of nitrous oxide in the air above and downwind from the paddock, and using these data to calculate the total amount of nitrous oxide emitted.

WHY DO IT

Measurements are made under real environmental conditions, averaged over a larger area (at least paddock-scale) and without any soil disturbance. Nitrous oxide emissions are very variable in time and space, especially in grazed pastures where there is patchy deposition of nitrogen in animal excreta. Micrometeorological techniques have the advantage of providing continuous measurements with spatial averaging that can complement small-scale estimates from targeted placement of soil chambers.

CHALLENGES

The amounts of nitrous oxide emitted from an individual paddock are small and emissions fluctuate throughout the day, so equipment must be very sensitive to distinguish the signal above background concentrations. Compared with carbon dioxide for instance, the rates of mass exchange per area of ground are typically 10,000 times smaller. The equipment and site establishment requires a significant up-front cost for a high precision measurement site and analysis of the data is also highly technical. The same limitations apply as for methane, including the reliance on the right wind conditions and suitable paddocks. It is difficult for this technique to measure changes of less than 10% to 20% in cumulative emissions over a few weeks.

MEASURING GREENHOUSE GASES: WHAT WE HAVE FOUND SO FAR

METHANE

Respiration chambers and in-field yokes using the SF_6 tracer technique are the two methods used most in New Zealand research. In combination, they give a consistent picture: average methane emissions are around 21 grams of methane per kilogram of feed (dry matter intake) on pasture based diets.

This means that roughly 6.5% of the energy contained in the feed consumed by New Zealand cattle and sheep is lost in the form of methane. Variations between common feed sources used in New Zealand (such as grass/clover swards, maize silage, or PKE) seem to have only a small influence on the amount of methane produced per kg of dry matter eaten.

Some things do make a difference though. Notably, there is natural variation between animals. Some animals naturally produce less methane than others, without seemingly being any less productive. The use of some brassicas as feeds also results in lower emissions than pasture.

These options, as well as the development of inhibitors and a vaccine to suppress methane generation inside the rumen, are being actively researched to see whether they could be used within New Zealand's pastoral farming systems.

See NZAGRC and PGgRc websites and fact sheet[3] for more information about these emerging mitigation options.

NITROUS OXIDE

The main drivers of nitrous oxide emissions are the amount of nitrogen deposited, and the soil conditions.

Because grazing animals tend to consume a lot more nitrogen then they need for their own maintenance and production of meat or milk, much of the nitrogen they consume is excreted in the form of urine (mostly) and dung, and thus contributes to net greenhouse gas emissions.

Soil moisture is the most important soil factor that influences nitrous oxide emissions, followed by soil type.

The more water-logged the soil, the more nitrous oxide it releases. In one study, a well-drained stony soil converted 80% less of the nitrogen in animal urine to nitrous oxide than a poorly-drained soil.

Research is looking into ways of lowering the amount of nitrogen that animals consume as well as ways of reducing the production of nitrous oxide from a given amount of nitrogen being deposited onto soil.

See NZAGRC and PGgRc websites and fact sheet[3] for more information about these emerging mitigation options.

[3] NZAGRC-PGgRc factsheet: Reducing New Zealand's agricultural greenhouse gases: What we are doing

MEASURING GREENHOUSE GAS EMISSIONS: FARM SCALE & NATIONAL LEVEL

Farm-scale Assessment

In New Zealand, farmers can get a farm-level estimate of their greenhouse gas emissions (methane and nitrous oxide, and in some cases also energy use) using commercially available calculators. These calculators tend to rely on the use of default emissions from specified activities and only take into account a limited number of the factors that influence greenhouse gas emissions in practice. They are, however, useful for assessing how emissions change over time in response to management decisions such as fertiliser use and changes in animal numbers. The most well-known of these calculators is the nutrient budgeting tool OVERSEER®. This uses nitrogen inputs and outputs, as well as the number and productivity of animals, to calculate the unique nutrient budget of a farm, and makes broad inferences from nutrients to greenhouse gases using simplified relationships. OVERSEER® can only provide an approximate farm-level greenhouse gas assessment, since it does not fully reflect all the variables that can affect the unique greenhouse gas budget of a farm (e.g. the specific soil moisture profile and microclimate on the farm).

National Inventories

The Ministry for the Environment defines New Zealand's Greenhouse Gas Inventory as "an annual report of all human-induced emissions and removals of greenhouse gases in New Zealand". The Ministry must produce the inventory every year to support national commitments under the UNFCCC and the Kyoto Protocol.

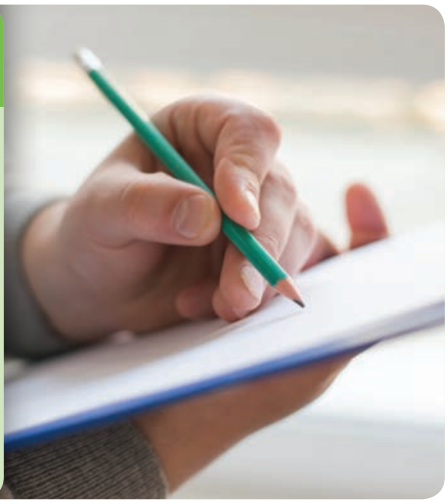
The inventory reports on six direct groups of greenhouse gases across six sectors.

INVENTORY GREENHOUSE GASES

- carbon dioxide
- methane
- nitrous oxide
- hydrofluorocarbons
- perfluorocarbons
- sulphur hexafluoride

INVENTORY SECTORS

- energy
- industrial processes
- solvent and other product use
- waste
- agriculture
- land use, land-use change and forestry



Agriculture sector emissions in the New Zealand inventory include only methane and nitrous oxide; changes in soil carbon stocks currently are not estimated for agriculture as these are considered to be too uncertain at this stage[4].

For the inventory, two key types of information are necessary:

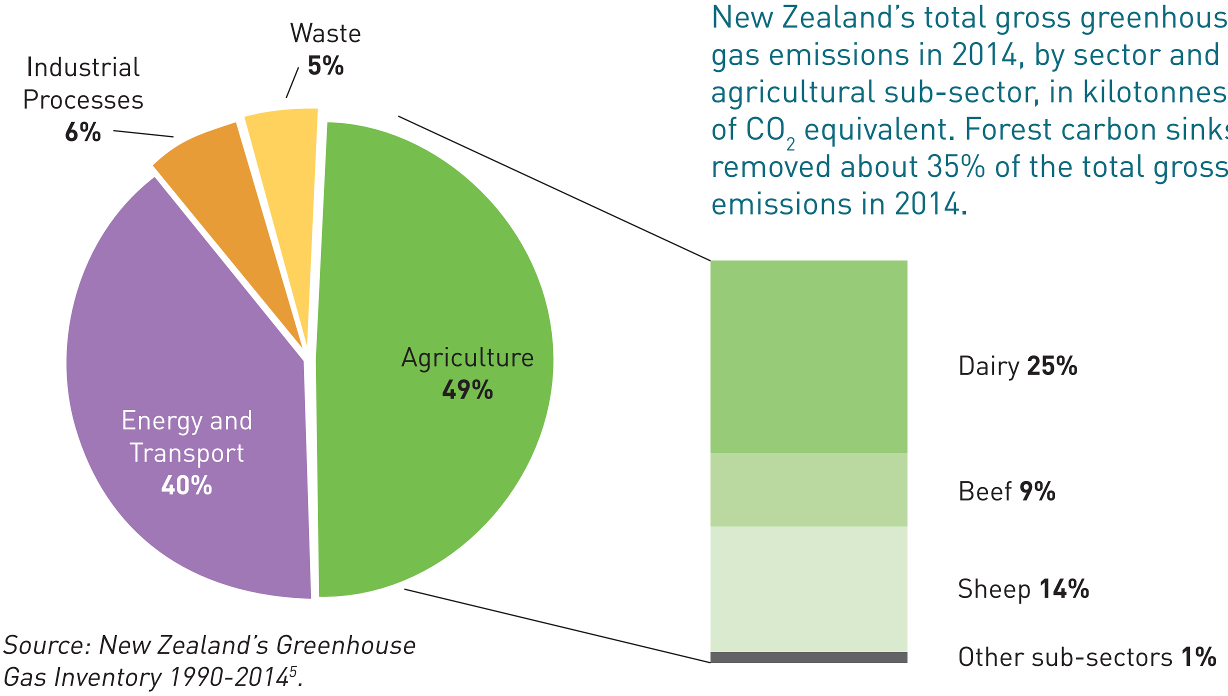
1. Activity Data, such as the total number (and weight and type) of animals, or total amount of oil, gas and coal consumed; and
2. Emission Factors that describe the amount of greenhouse gas emissions associated with an activity, e.g. the emission from the burning of one barrel of oil, the average emissions per adult milking cow, or from one kilogram of nitrogen fertiliser deposited on soil.

Total emissions are then calculated by multiplying the emission factor with activity data. Different levels of complexity are used to describe activities (at national and regional scales), and to differentiate emissions generated by different activities, processes, and animal classes.

[4]NZAGRC-PGgRc fact sheet: Reducing New Zealand's agricultural greenhouse gases: Soil carbon

MEASURING GREENHOUSE GAS EMISSIONS FROM NEW ZEALAND AGRICULTURE

New Zealand's total gross greenhouse gas emissions in 2014, by sector and agricultural sub-sector, in kilotonnes of CO_2 equivalent. Forest carbon sinks removed about 35% of the total gross emissions in 2014.



Source: New Zealand's Greenhouse Gas Inventory 1990-2014[5].

NZ-specific methodology for agriculture

Emissions from an average cow or sheep depend on the animal's productivity and feed input. This makes it important to underpin the national agricultural emissions inventory with actual measurements of New Zealand animals in New Zealand grazing systems.

The Intergovernmental Panel on Climate Change (IPCC) has developed good practice guidelines for national greenhouse gas inventories.

There are different 'tiers' of complexity depending on the sophistication of available data. 'Tier 1' methodologies are for countries that do not have the capacity to collect detailed emissions data. The 'Tier 1' methodology for agriculture, for instance, does not require any knowledge of the sheep population structure (numbers of ewes, rams, lambs, etc) and simply assumes a single emission factor per (average) sheep.

Given the importance of agriculture to the New Zealand economy, we have robust systems for collecting data such as animal numbers, classes and productivity, and hence our inventory can be more sophisticated. In the IPCC guidelines, 'Tier 2' methodologies for agricultural emissions hinge on estimating dry matter intake, which varies during the year with breeding cycles and lactation status. Methane and nitrous oxide emissions are directly linked to the number of animals and the amount they eat to give them the energy they need. New Zealand has devised its own approved Tier 2 methodology for pasture-fed cattle, sheep and deer, to reflect emissions under New Zealand conditions and farming practices, based on the range of measurements outlined in this fact sheet. The detailed methodology and calculations are published by the Ministry for Primary Industries.[6]

EXAMPLES OF DATA USED IN THE NEW ZEALAND AGRICULTURAL INVENTORY METHODOLOGY

- regional productivity
- animal age and breeding status
- differing energy requirements for milk production, conception/gestation and live weight gain
- adjustment of energy requirements for rising one-year-olds (since they spend part of the first year of life being milk-fed)
- specific energy requirements for velvet production in deer
- monthly pasture dry matter digestibility and metabolisable energy content
- amount of nitrogen content in urine relative to the amount of nitrogen content in dung
- proportion of total annual nitrogen excretion in manure management systems (for dairy)

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[5] http://www.mfe.govt.nz/publications/climate-change/new-zealand-greenhouse-gas-inventory-1990-2014
[6] www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/greenhouse-gas-reporting

MEASURING GREENHOUSE GAS EMISSIONS FROM NEW ZEALAND AGRICULTURE

Why do inventory numbers change?

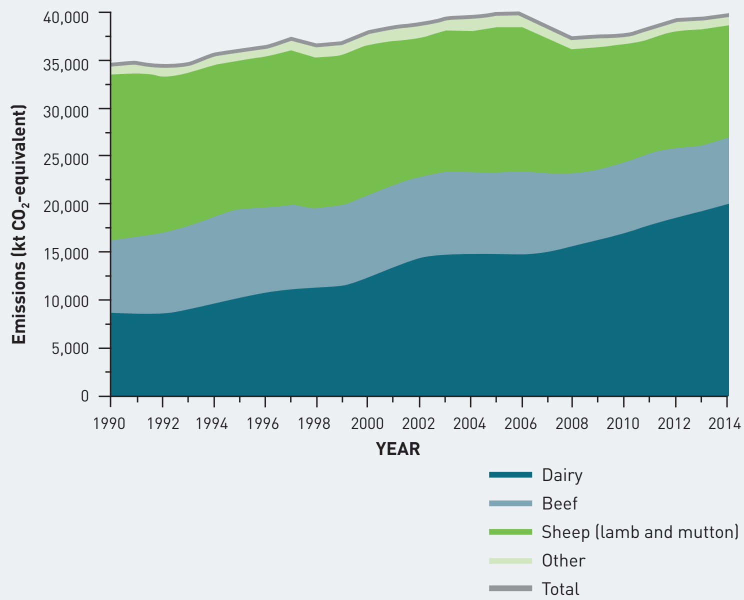
Direct measurement techniques like those described above underpin the development of emissions factors and calculation methods used in inventories. For example, nitrous oxide emissions have been found to vary considerably with soil type and rainfall around New Zealand, but a balance needs to be struck between reflecting this diversity and the difficulty of providing actual and verifiable measurements. Reflecting a diversity of conditions requires far more data, which increases measurement and verification costs. For the time being, a single emissions factor for urine deposits has been applied across the country. As a result, nitrous oxide emissions may be overestimated in some places and underestimated in others.

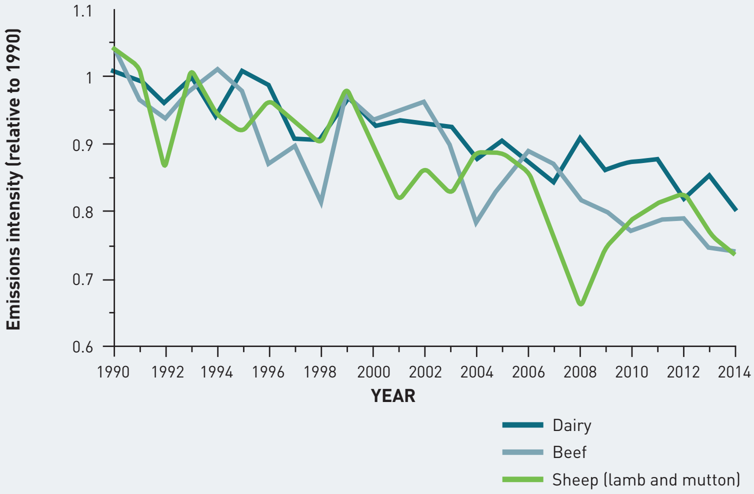
Further research is being conducted to look at this variability, e.g. emissions of nitrous oxide from hill country. As new information emerges, it is fed into refinements of the inventory, with a constant effort to improving the inventory to better reflect this diversity and changes in farm systems over time.

National greenhouse gas inventories are subject to annual international expert review through the UNFCCC.

New research, published in peer-reviewed journals, adds more detail to the overall picture each year and is necessary to justify any changes made to emission factors. The inventory seeks to reflect the real world as closely as possible, so it should be revised as scientists discover more. Revisions must apply all the way back to the start of the accounting period (1990) so that reported long-term trends reflect as well as possible genuine changes in emissions, rather than changes in how emissions are calculated.

Future changes in the inventory are inevitable. These could arise from ongoing improvements in measurement techniques, and growth in the number and types of measurements taken (which will pick up more variability, for instance, between sites and farms), other changes in activity data, emission factors and methodology, or when new emission sources are identified.





New Zealand's total greenhouse gas emissions, and emissions intensity, by agricultural sub-sector including nitrogen fertiliser use (1990-2014).

Source: New Zealand's Greenhouse Gas Inventory 1990-2014.

MEASURING GREENHOUSE GAS EMISSIONS FROM NEW ZEALAND AGRICULTURE

How reliable is the inventory?

Scientists have a good understanding of how emissions increase in line with changes in animal productivity, which affects feed intake (especially important for methane) and the amount of nitrogen excreted (which drives nitrous oxide emissions). This, combined with good quality data on agricultural productivity and animal population changes, means New Zealand's inventory provides clear, reliable evidence of trends in agricultural greenhouse gas emissions.

The inventory is an essential and robust tool to show changes in absolute emissions, and in emissions intensity (i.e. emissions per unit of product). While emissions from agriculture have increased overall, mainly because of increased total production, emissions per litre of milk or kilogram of meat produced have declined, because of the increased productivity of animals and efficiency of farm systems.

While we can be reasonably certain about whether emissions are increasing or decreasing, it is much more difficult to put an accurate number on the absolute amount of emissions from the country as a whole. It is possible to measure emissions of individual animals or at paddock-scale, but it is hard to be certain that these measurements are truly representative of the national herd. When we multiply estimated emissions from a limited number of individual animals to a population of millions of animals, any inaccuracy or lack of representativeness in the original measurements will be reflected in the national total. The absolute level of uncertainty in the national agricultural methane emissions inventory is estimated to be 16%, a value higher than for energy (about 6%), but significantly lower than that for forestry (at 54%).

GREENHOUSE GAS METRICS

Greenhouse gases such as methane, nitrous oxide and carbon dioxide differ in how long they last in the atmosphere and how effective they are in absorbing heat radiation.

To allow emissions of those gases to be compared, emissions are often weighted according to the standards adopted by countries under the UNFCCC, so that emissions of all gases can be expressed in a single unit called "CO_2-equivalent" emissions. For the purpose of national inventories, it is critical that national accounts are consistent with the reporting conventions adopted internationally.

The metric used for reporting under the UNFCCC is called the "Global Warming Potential" (GWP), which is based on the average warming effect of greenhouse gases over 100 years after their emission. This is discussed in more detail in NZAGRC fact sheet titled *Economic and Policy Implications of Alternative GHG Metrics.*

Greenhouse gas metrics are being updated routinely based on new scientific knowledge and as greenhouse gas concentrations and the world's climate continue to change.

This updated fact sheet uses the GWP weighting values that are being used to report greenhouse gas emissions to the UNFCCC from the year 2015 onwards. Compared to values used in earlier emission inventories, this update has increased the weighting given to methane emissions (by 19%) and slightly decreased the weighting of nitrous oxide emissions (by 4%) relative to emissions of carbon dioxide.

These changes do not alter the amount of gases being emitted, but they do affect the reported CO_2-equivalent emissions from agriculture in the national inventory.

Find out more

The government-supported New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) and the joint industry/government Pastoral Greenhouse Gas Research Consortium (PGgRc) are working together to create opportunities for farmers to further reduce emissions. There is more information on our websites, or contact us:

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www.pggrc.co.nz

See also:

www.mfe.govt.nz

For New Zealand's Greenhouse Gas Inventory

www.mpi.govt.nz

For detailed methodologies for agricultural greenhouse gas emission calculation
(MPI Technical Paper No 2013/27)

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