Greener farming
protecting the environment

mla
MEAT & LIVESTOCK AUSTRALIA

Study guide

RESPONSIBLE FARMING

We're all aware of the concerns about global warming and the damage that greenhouse gases can cause. Burning fossil fuels and other industrial processes are the primary culprits. But some farming operations, also emit greenhouse gases. Can anything be done about this?

The answer is a resounding 'yes'. Australian cattle and sheep farmers are tackling greenhouse gas emissions in many innovative ways. Farmers and the wider industry are monitoring and researching how emissions are produced and the best ways to reduce them. An example of this is selective breeding to produce cattle and sheep whose digestive processes emit less methane. Another is research into different types or combinations of feeds, which result in fewer emissions.

Australian cattle and sheep farmers are also trying to find better and more efficient ways of powering farms, and finding ways in which farming operations can contribute to energy efficiency. This includes increased emphasis on wind and solar energy (including siting wind farms on farming land), finding ways to reduce energy consumption, and converting waste products into energy.

It's a very positive picture. Meat & Livestock Australia's goals are ensuring that the production of beef and lamb is accomplished in the most sustainable and environmentally responsible manner possible.

MEAT & LIVESTOCK AUSTRALIA FOR A SUSTAINABLE FUTURE

Meat & Livestock Australia is an initiative by Australian cattle and sheep farmers, along with the broader industry, to deliver sustainable farming by 2020. It's a commitment to take positive action, both big and small, to continually improve the way farmers operate, and to improve sustainability throughout the red meat supply chain.

Sustainability isn't a new thing – the whole Australian cattle and sheep industry has been investing in environmental research and development for many years. It continues to invest more than $13 million every year in research and development to reduce the industry's environmental impact through improved farming practices.

As caretakers of the land, farmers are committed to leaving it in better shape than when they found it by improving efficiency and reducing resources used. Apart from harnessing the latest technology and science to reduce farming's footprint, Meat & Livestock Australia is also about sharing ideas, celebrating successes and providing a focal point for environmental, social and ethical farming action to ensure we all enjoy a sustainable food supply into the future.

HOW TO USE THE GUIDE

The notes in this study guide offer both variety and flexibility of use for the differentiated classroom. You and your students can choose to use all or any of the five sections – although it is recommended to use them in sequence, along with all or a few of the activities within each section.

THE 'FIVE Es' MODEL

This guide employs the 'Five Es' instructional model designed by Biological Sciences Curriculum Study, an educational research group in Colorado. It has been found to be extremely effective in engaging students in learning science and technology. It follows a constructivist or inquiry-based approach to learning, in which students build new ideas on top of the information they have acquired through previous experience. Its components are:

Engage Students are asked to make connections between past and present learning experiences and become fully engaged in the topic to be learned.

Explore Students actively explore the concept or topic being taught. It is an informal process where the students should have fun manipulating ideas or equipment and discovering things about the topic.

Explain This is a more formal phase where the theory behind the concept is taught. Terms are defined and explanations given to models and theories.

Elaborate Students develop a deeper understanding of sections of the topic.

Evaluate Teacher and students evaluate what they have learned in each section.

![MLA - Meat & Livestock Australia logo]

Greenhouse gases, climate change and livestock

Australia's cattle and sheep farmers are developing innovative ways to reduce greenhouse gas emissions.

MEAT & LIVESTOCK AUSTRALIA

The potential implications of climate variability for cattle and sheep farmers vary, depending on which part of Australia they are farming in. However, it is clear that they will need to prepare for more variable conditions.

It's crucial to equip farmers with the ability to adapt to climate change and manage climate variability through research and development initiatives, and to develop practical resources and tools that help farmers manage risks and new opportunities.

The Australian cattle and sheep industry is actively working to reduce greenhouse gas emissions at every stage of beef and lamb production, with a major focus on research to reduce cattle and sheep methane emissions.

Through good management of soil and vegetation, the cattle and sheep industry also plays an important role in removing carbon from the atmosphere.

Cattle and sheep farmers face the following expected challenges as a result of climate variability:

- increased risks to productivity due to an increase in extreme weather events
- a decline in pasture quality and growth
- reduced stream flow and quality of water supply across southern Australia
- greater exposure of stock and crops to heat-related stress and disease
- southern migration of some pests
- a likely increase in the distribution and abundance of some exotic weeds.

These challenges are being addressed through investment by cattle and sheep farmers and the Australian Government, aimed at reducing emissions from cattle and sheep farming and processing, and helping farmers plan for the impacts of climate change.

EMISSIONS

To understand why cattle and sheep naturally produce methane, it's important to understand how they eat. Known as 'ruminant' animals, they have a digestive system that allows them to eat otherwise indigestible foods, such as grass (with the key ingredient of cellulose), by regurgitating it as cud and re-chewing it. To aid digestion, their stomachs are filled with bacteria that break down the cud, producing methane in the process.

RUMEN

OMASUM

ABOMASUM

RETICULUM

123RF

REFRACTION MEDIA
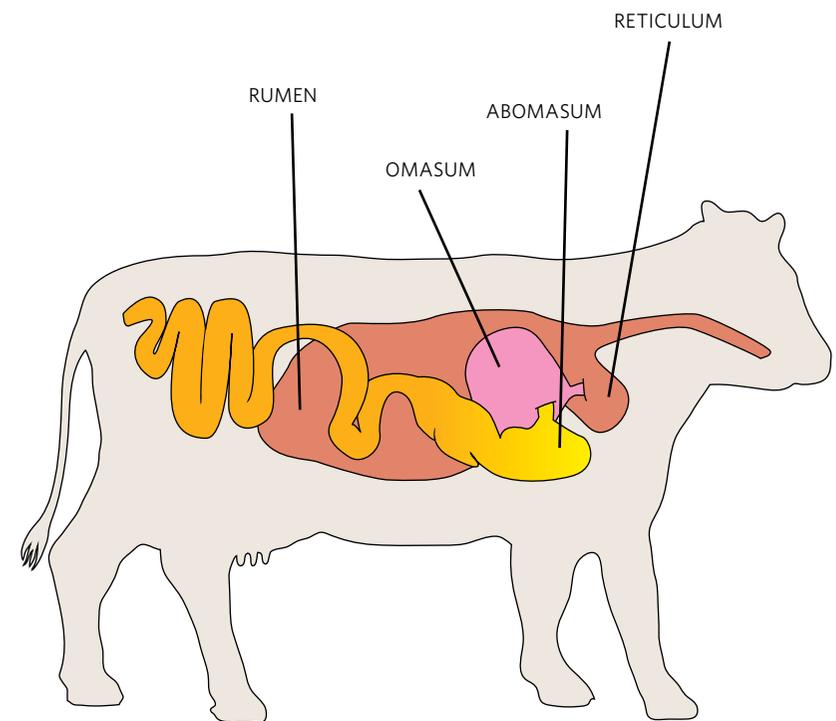
THE CARBON CYCLE

The Australian cattle and sheep industry's contribution to greenhouse gas emissions is best understood within the context of the carbon cycle. It is not just about emissions, but also about transfers between carbon stores.

The carbon stored in plants is consumed by cattle and sheep when they graze. Most of it is then released into the atmosphere as carbon dioxide (CO_2) when the animals breathe out, and as methane when they digest their feed. Methane in the atmosphere is eventually transformed to CO_2 and water. CO_2 is then re-absorbed by plants as they grow... and so the cycle continues.

The process of absorbing CO_2 from the atmosphere via photosynthesis and storing carbon in plants and soil is called 'sequestration'. Some of this carbon is stored in the stems and roots of plants and some is stored in the soil, improving soil health.

GRAZING LANDS CAN STORE MORE CARBON THAN FORESTS

Australia's cattle and sheep farmers spend considerable time and effort managing not only their cattle and sheep, but also all other living organisms on their property. The health of the soil, trees, micro-organisms, native animals and vegetation are all essential to cattle and sheep farmers' livelihoods. This is also important
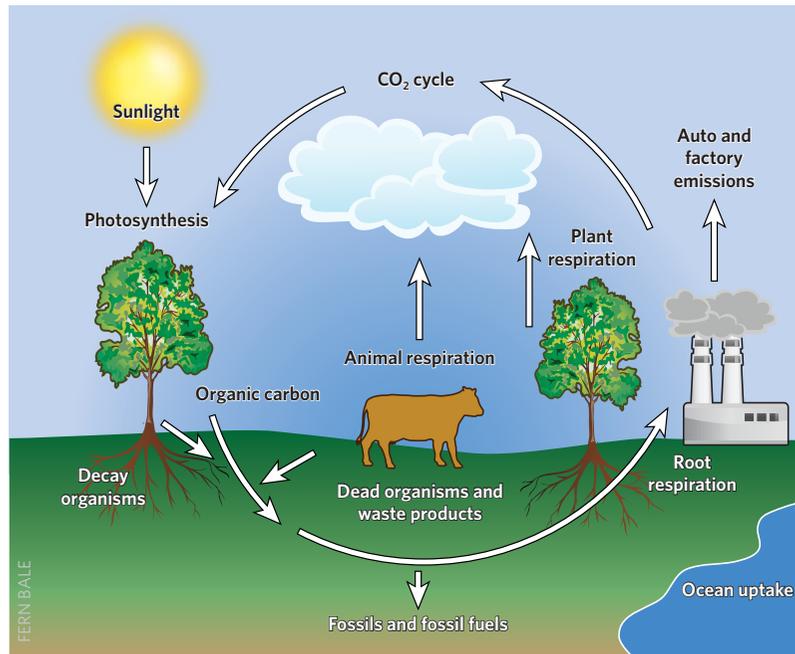
for Australia's overall emissions profile. A worldwide analysis of the effects of land management on soil carbon showed there is, on average, about 8% more soil carbon under well-managed pasture than under native forests.

International greenhouse accounting rules currently account for carbon released into the atmosphere as methane and as CO_2 after land clearing, but they do not fully account for the capacity of trees, grass and soil to store carbon as part of the carbon cycle. A recent report by the Queensland Government found

that if all carbon sinks were taken into consideration, the Queensland beef industry (which comprises 47% of Australia's cattle) would be close to carbon neutral.

Beef production is becoming more and more efficient thanks to research and development in the industry.

Figure 2. The carbon cycle.

FERN BALE

REDUCING EMISSIONS

Australia's livestock industry produces approximately 10% of Australia's total greenhouse gas emissions. Most of these emissions come from methane, which is produced by the natural digestion process of cattle and sheep.

Since 1990, emissions from producing beef in Australia have decreased by 5.3% per kilogram (calculated using 2010 beef production data from Meat and Livestock Australia and from the 2009 National Greenhouse Gas Inventory). Due to improved productivity, the age to market of animals is decreasing. At the same time, the average amount of meat being produced from each animal is increasing due to more efficient farming methods.

The first life-cycle assessment

undertaken on Australian beef and lamb production systems showed that Australia has one of the lowest carbon emission profiles of any major meat-producing country. This research was undertaken by the University of New South Wales in 2009. Research released in 2011 by the CSIRO found the amount of methane emitted from cattle fed on tropical grasses in northern Australia is up to 30% less than the figures currently used to calculate the northern cattle industry's contribution to Australia's greenhouse gas accounts. If this methodology were endorsed by the National Greenhouse Gas Inventory, the industry's overall contribution would be significantly reduced.

123RF

REFRACTION
MEDIA

REDUCING EMISSIONS IN THE PADDOCK

Sheep and cattle play a very important role in the human food chain. They convert low-quality grass to high-quality, nutrient dense protein, a role that other species, such as pigs and chickens, cannot perform.

In Australia, most beef and lamb production occurs in extensive rangeland areas where few other food products could be viably grown, meaning there are few, if any, realistic alternatives for producing food on this land.

FARMLAND ABSORBS CARBON
By holistically managing their properties, Australia's cattle and sheep farmers play an important role in boosting the carbon stored in their soil as part of the carbon cycle. By maximising soil carbon stocks, cattle and sheep farmers help to ensure a healthier environment and contribute to a reduction in Australia's greenhouse gas emissions profile.

WORKING TOWARDS FURTHER REDUCTIONS
Research and development are key to understanding emissions from cattle and sheep, and developing strategies to reduce those emissions. That is why cattle and sheep farmers, through levies they pay, invest in collaborative research efforts to reduce the industry's emissions at each stage of production. This research includes:

MEASURING METHANE
The development of a practical, reliable, repeatable individual methane measurement and data-collection system, suitable for measuring the methane generated from sheep and cattle herds, is an important step in tackling emissions reduction. The device must be precise enough to measure differences in methane production as a result of strategies that attempt to lower methane levels.

BREEDING LOW-METHANE PRODUCING SHEEP
This research is investigating whether some sheep breeds produce less methane than others. It aims to establish

With careful genetic analysis and breeding methods, farmers may be able to breed sheep that produce less methane.

preliminary estimates of genetic correlations between methane emissions and production traits.

UNDERSTANDING SOIL CARBON IN RANGELANDS
This project aims to provide information to farmers who are interested in the potential to build soil carbon levels. A tool is being developed to credibly estimate soil carbon stocks and measure the results of different grazing practices in northern Australia. This tool will provide reliable information for farmers considering entering a voluntary offsets market, and will be linked to the national soil carbon datasets being developed by CSIRO. This information will also assist the industry to develop a policy position on agricultural soil carbon.

### PARTNERING WITH INDUSTRY AND GOVERNMENT
The cattle and sheep industry and the Australian Government are co-investing in reducing greenhouse gas emissions through the National Livestock Methane Program (NLMP). The NLMP is being coordinated by Meat and Livestock Australia, with 16 projects being undertaken by major research organisations to:

- develop practical on-farm options to achieve a significant reduction in methane emissions from cattle and sheep
- quantify the level of abatement achievable while increasing productivity.

This research is being done to refine the key outcomes of the Reducing Emissions from Livestock Research Program (RELRP) to further explore methane reduction options.

The key outcomes of the RELRP relating to cattle and sheep production are:

- preliminary results indicate that it will be possible to identify bulls whose calves will produce less methane
- several forages have been identified as having immediate, persistent and maintained methane reduction impact when included as part of a mixed diet
- nitrate supplements have consistently and rapidly reduced methane production; however, further understanding of its potential toxicity impact is required
- an online calculator, FarmGAS, has been developed and launched to allow producers to explore abatement options
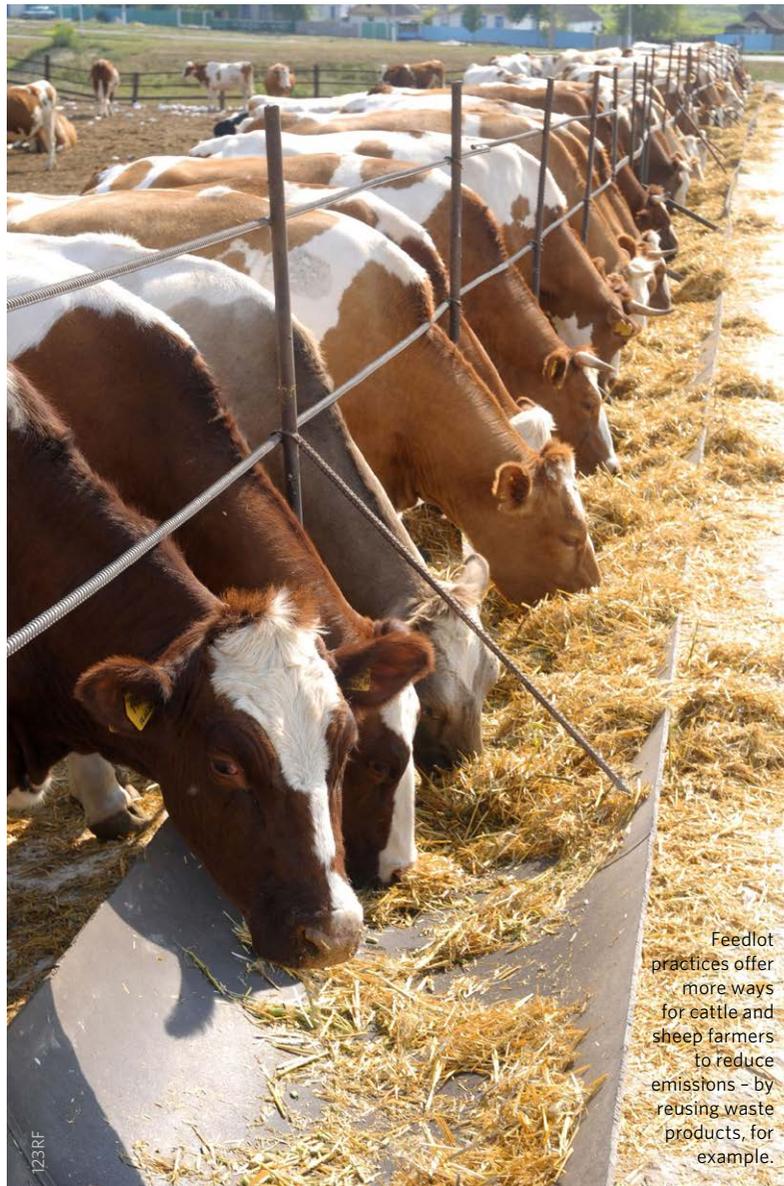
REFRACTION MEDIA

REDUCING EMISSIONS IN THE FEEDLOT

At any one time, around 3% of Australia's cattle population is located in feedlots – managed facilities where cattle are provided a balanced and nutritious diet for the purpose of producing beef of a consistent quality and quantity.

Australian feedlot cattle spend most of their lives in an open range, grass-fed environment before entering a feedlot for an average of 50–120 days, or around 10%–15% of their lifespan.

Grain-fed beef operations are well-placed to manage emissions, particularly through the provision of high-quality feed, resulting in reduced emissions per kilogram of beef produced.

Reducing energy consumption is another means of reducing greenhouse emissions. Energy consumption on cattle and sheep farms and feedlots mainly relates to power for the homestead and office, to pump water to watering points, and to run machinery and vehicles.

There is also potential to reuse methane as a renewable energy source. Recycling manure enables the industry not only to reduce emissions, but also to create a resource from a waste product.

WORKING TOWARDS FURTHER EMISSION REDUCTIONS

Reducing greenhouse gas emissions is a high priority for the grain-fed cattle industry. The sector has several research priorities to reduce greenhouse gas:

- Improving nutrition and production efficiency to improve feed conversion rates. This can be achieved by superior diets, nutritional supplements, genetics, animal health and best management practices.
- Reusing and recycling carbon; for example, using cattle manure as an organic fertiliser, or capturing and reusing methane as a renewable energy source.
- Reducing manure and nitrous oxide emissions from manure and effluent by altering pen cleaning frequency and turning compost piles.
- Applying other energy efficiencies in relation to feed processing, feed delivery and cattle and commodity transportation.

Cattle farmers and lot feeders, through the levies they pay, also invest in collaborative research efforts to reduce the industry's emissions.

This research includes:

FEEDLOT POND METHANE EMISSIONS

This project has been initiated to measure greenhouse gas emissions – principally methane – from an anaerobic feedlot pond and will provide industry with the data required to assess both the contribution of ponds to greenhouse gas emissions and the potential for use of methane harvested from ponds as an energy source.

FEEDLOT MANURE GREENHOUSE EMISSIONS

This project is being undertaken by the Queensland Department of Agriculture, Fisheries and Forestry, to quantify and mitigate greenhouse gas emissions associated with manure management at feedlots. The project is complementary to the above work, and will focus on understanding and mitigating emissions from the manure pad, manure stockpiles, manure application areas and secondary emissions.

Feedlot practices offer more ways for cattle and sheep farmers to reduce emissions – by reusing waste products, for example.

123RF

REDUCING EMISSIONS IN PROCESSING

Beef and lamb processing plants produce greenhouse gases from energy use and waste treatment. Electricity and thermal energy (from gas or coal) account for most of the energy consumption in processing. Electricity runs refrigeration, compressors, electrical motors, air compressors and lighting, while thermal energy is consumed by on-site treatment of waste products and hot water heating.

The amount of fossil fuel energy consumed in processing plants varies between sites and is dependent on a range of factors, including the age and condition of equipment, percentage of the product that is frozen and the type of fuel used in the boiler.

The industry has a major focus on reducing electricity usage. Examples of this include:

■ implementing new energy smart technologies;
■ installing ceiling fans and wall liners in freezer rooms;
■ recycling of heat from on-site electricity generation for heating, using cogeneration; and
■ using alternative energy sources, such as solar, to generate electricity.

CONVERTING WASTE TO ENERGY
In addition to traditional energy-saving approaches, another option available to the processing sector in reducing emissions lies in methane capture and use. Beef and lamb processing plants generate large quantities of effluent that is rich in organic compounds and nutrients and could be used in other industries. Research into converting organic by-products into energy is advancing rapidly, with new facilities opening in Australia and overseas.

Managing waste is a major priority for meat processing plants. While more than 90% of solid waste produced is reused, mainly as compost, the industry is working to improve this figure by converting waste into energy through:

■ using solid waste streams as alternative boiler fuels
■ using pyrolysis technology (see wikipedia.org/wiki/Pyrolysis) to produce renewable energy in the form of syngas (biofuel.org.uk/what-is-syngas.html), which can be used in place of fossil fuels, from organic solid waste streams, as well as creating biochar (a stable form of charcoal that can be used to store carbon, improve soil health and increase crop yields)
■ processing organic solid waste streams to create biogas for use in boilers or to generate electricity.

Waste from the processing sector can be converted to tallow, a source of glycerine normally used in the manufacture of soap and synthetic rubber. However, recent trials found that tallow biodiesel, made from the 600,000 tonnes of tallow produced in Australia each year, could produce a superior fuel to ethanol.

WORKING TOWARDS FURTHER EMISSION REDUCTIONS
Beef and lamb processors, through the levies they pay, also invest in collaborative research efforts to reduce the industry's emissions. This research includes:

COVERING ANAEROBIC PONDS FOR ENVIRONMENTAL BENEFITS
Most wastewater from meat processing plants goes into anaerobic ponds where the wastewater is treated. Covering of the ponds solves two of the industry's key issues, odour and greenhouse gas emissions. Covering ponds also allow for methane capture and use as bio-energy to produce heat and electricity. A project by the University of Southern Queensland is underway at a processing facility to underpin a more extensive study of pond behaviour, including the development of a monitoring protocol and improved pond cover design.

NEW WASTEWATER TREATMENT TECHNOLOGIES
Developing new and alternative wastewater treatment methods for the processing sector is important to reduce footprint, odour and greenhouse gas emissions. Two new reactor-based methods are under lab-scale development by the University of Queensland and if successful will be piloted in 2013.

MEASURING CARBON EMISSIONS IN THE PROCESSING SECTOR
This research project involves investigating measurement, calculation and reporting methods available to the Australian meat processing industry to meet requirements of the National Greenhouse and Energy Reporting Scheme.

ENERGY CONSUMPTION
Reducing the amount of energy consumed by the sheep and cattle industry is an important means of reducing its greenhouse gas emissions. There are many initiatives industry is implementing to save on energy and convert waste into energy, several of which are outlined above. In addition, renewable energy is used on many Australian farms.

Australia's farmers have used windmills to harness wind energy for over a hundred years, and today windmills continue to be an important source of renewable and cost efficient energy. Some farmers are also contributing to the generation of renewable energy for Australia through leasing areas of their properties to wind farms.

A growing number of cattle and sheep farmers are also investing in solar panels as a more efficient power source to pump water, power the homestead and even sell back to the grid as a supplementary form of income. The wide, open spaces and abundant sunshine in rural areas make farms ideal to take best advantage of this technology.

■ For more information about what the cattle and sheep industry is doing to reduce energy, go to *goodmeat.com.au/education*

Name: Richard Eckard
Location: Primary Industries Climate Challenges Centre

Green solutions

Scientists are working to find ways to reduce livestock greenhouse gas emissions, but without jeopardising farmers' livelihoods.

RICHARD ECKARD'S RURAL upbringing, in Swaziland in Africa, instilled in him a lifelong love for animals. "My dad was an entomologist. He was always bringing home all sorts of weird bugs and things. We'd go out in the field with him, and while he was collecting bugs we'd be collecting snakes," says Eckard. "I had a whole menagerie of animals at home that I used to rescue and rear."

By his early high school years, he had already decided on a career in agriculture. His university studies covered animal science, grassland management and soil science. "I figured everything has to eat – the animals, the grass and the soil," he says.

And food is still high on his agenda. "We know we need to feed a world that's going to have an extra 3.5 billion people by 2050. The opportunity for Australian farmers lies with the portion of those extra 3.5 billion people who will be middle and upper class, and who will want to consume Australian beef and lamb," Eckard says.

Eckard moved to Tasmania in 1995, making the switch from tropical to temperate zone research. "I wanted to learn how temperate zone production systems worked, and I don't think you can truly understand an agricultural system until you live in it."

Now at the Primary Industries Climate Challenges Centre, a joint venture between the University of Melbourne and the Victorian Department of Environment and Primary Industries, Eckard and his team are helping farmers face the challenge of climate change and the need to reduce emissions of greenhouse gases.

"In Australia, about 10% of all greenhouse emissions come from livestock, the majority of which is methane that comes from cows and sheep belching," Eckard says. The methane is produced by bacteria that live in the animals' digestive systems.

There are several possibilities for reducing those emissions. The first is to carefully manage herds and flocks so that there are fewer unproductive animals. The second is to selectively breed animals that produce less methane, which is not necessarily easy, as there are many other factors farmers have to take into account when undertaking breeding programs.

A third way is to alter the food the animals eat. Eckard and his team have found that if livestock is fed an industry byproduct that has high oil or fat content in it, methane is reduced quite substantially. "If you think of canola oil that has been cold pressed to remove the oil for biodiesel, there's still enough oil left in the canola seed that, if you feed it to cattle, you reduce methane further," he says.

A longer-term project, and potentially the most effective one, is to modify the microbe mix inside the stomachs of cattle and sheep, some of which are responsible for producing the methane the animals belch out. If scientists can selectively remove those microbes, it could solve the problem. "If you want to have a sustained reduction in methane production from animals, that's the way to do it – find some way to permanently change the microbial composition. But you can't just do that without being sure you're not going to have an adverse impact," Eckard says. "It's a 20-year project."

But he's hopeful these approaches will work. "We have a long history in agriculture of coming up with solutions; we are very confident that we'll come up with solutions in this area as well," he says. "I sleep better at night, because I know that what I do is actually essential for the future of the planet, both from an environmental point of view and a food point of view." – *Jonathan Nally*

Eat less, grow more

One Australian farming family is finding out that reducing greenhouse gas emissions can pay dividends.

MATTHEW AND SARAH Arkinstall's cattle farm is located at Rathdowney in southeast Queensland, about one hour south of Brisbane and an hour from the Gold Coast. They run about 180 stud and commercial Blonde d'Aquitaine beef cattle, and are active members of the local Beaudesert Landcare Group.

The Arkinstalls have several initiatives underway with a view to making the farm more sustainable. These include setting up a test station in 2010 (in conjunction with Warren Drynan of Glenapp farm, also in Rathdowney), which tests beef cattle for feed efficiency with the ultimate aim of reducing methane emissions from livestock.

"We're measuring feed conversion ratios," says Matthew. "So how many kilograms of dry matter can animals eat compared to how much 'live weight gain' an animal will put on."

Lower feed consumption would mean fewer greenhouse gases emitted in the production of that feed, and less methane produced in the cattle's stomachs.

"We've had some pretty good results," Matthew says. "It shows that there's a big variation not only between breeds, but even within an individual farmer's herd." That is, some breeds are more efficient than others at converting food into weight gain, and even within herds of the same breed, some cows might be more efficient than others. A typical cow might need 6 kg of feed to produce a one kilogram increase in 'live weight gain'. But the Arkinstalls have found that some of their cattle need only 3 kg of feed to produce one kilogram of live weight gain.

Name: Matthew and Sarah Arkinstall
Location: Rathdowney Farm, southeast Queensland

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This kind of knowledge is gold for farmers wanting to improve the feed efficiency of their whole herds. "If you weren't selecting for it, you could be inadvertently breeding poor inefficiency into your herd," says Matthew. "But by having that ability to select for it through testing, you can cull out the inefficient ones and you'll get a more efficient herd as a result."

Under the new Carbon Farming Initiative, producers are able to claim credits for reductions in emissions or for storage of carbon in the ground and vegetation. These credits can then be purchased by companies and individuals who want to 'offset' their own emissions. For farms with large herds, and with continued use of efficient sires, these credits can equate to an extra source of income.

The Arkinstall's test station won the 2011 Queensland Landcare award for Innovations in Sustainable Farming Practices. – *Meat & Livestock Australia*

Greenhouse gases and climate change – what do you think?

Climate change is one of the greatest challenges of our time, scientists and world leaders agree. It is also generally agreed that human activities are driving climate change. Many of the things we do, as a society on a daily basis all over the world, produce greenhouse gases (also called emissions), and too much of greenhouse gases is a bad thing, because they trap heat. The international Intergovernmental Panel on Climate Change, in its Fourth Assessment Report 2007, says that "greenhouse gas forcing has very likely been the dominant cause of the observed global warming over the last 50 years" (here, 'forcing' means some something that exerts an extra influence on a system; in this case it human-produced increase in greenhouse gases). Over-heating of the Earth is leading to global warming, and this warming effect is changing our climate.

PART A
In small groups:

1. Brainstorm the term 'global warming'. What does it mean to you? Write the group's thoughts on the outside section of the graphic provided.

_____
_____
_____

2. Next, brainstorm what you know about greenhouse gas emissions. What are the main greenhouse gases, and what human activities are adding more of these gases into the atmosphere? Record your thoughts in the middle section of the graphic.

_____
_____
_____

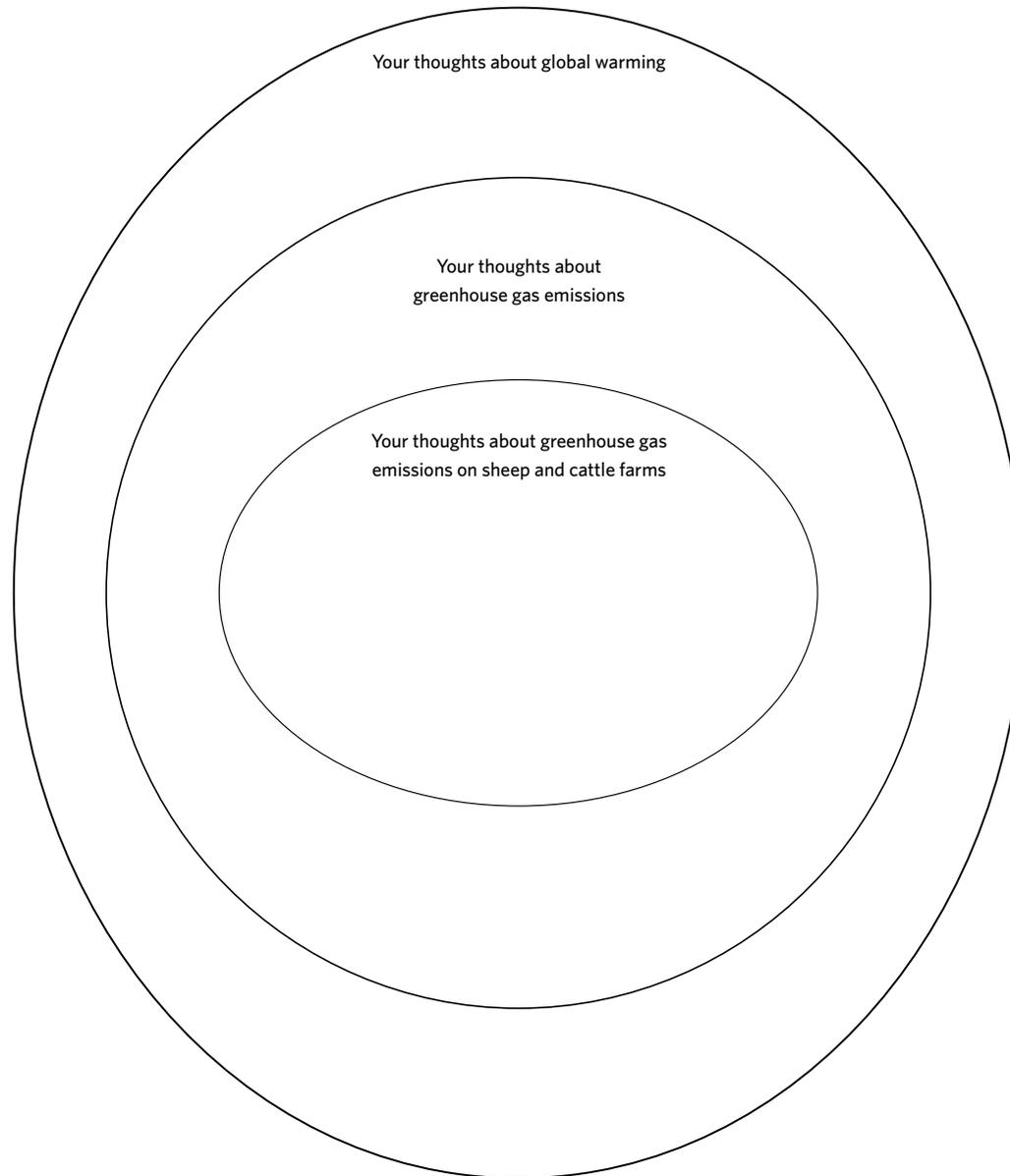**3.** Lastly, focus specifically on the livestock industry. How do you think the farming of animals such as sheep and cattle might produce greenhouse gas emissions? Jot down your thoughts in the smallest oval on the graphic.

_____
_____
_____

Your thoughts about global warming

Your thoughts about
greenhouse gas emissions

Your thoughts about greenhouse gas
emissions on sheep and cattle farms

PART B

Imagine you are a cattle or sheep farmer, and the government requires you to reduce the greenhouse emissions on your farm. What can you do to meet these requirements? Use the information in the rest of this guide, and your own research, to write a list of all the things you can think of that might help reduce the farm's emissions.

Teacher's information

The aim of the Explore section is for the students to investigate some of the ideas and issues about greenhouse gas emissions as they apply to the cattle and sheep industry. It is intended that the students make their own discoveries as they work around the stations in the room.

The equipment table below lists the equipment and preparation required.

Station no.	Station activity	Materials list
1	Modelling emission gases	Molymod kits; key to identify which colours represent the different atoms
2	Measuring emissions	Computer to access ABC *Catalyst* video (6 minutes): *abc.net.au/catalyst/stories/3685323.htm*
3	Exhaling emissions	Clean drinking straws; limewater
4	Reducing emissions	Computer to access the website: *www.csiro.au/en/News/News-releases/2016/Greenhouse-gas-mitigation-potential-of-the-global-livestock-sector-revealed*
5	Your ecological footprint	Computer to access the website: *www.epa.vic.gov.au/~/media/Publications/1216.pdf*
6	The carbon cycle game	Computer to access the website: *windows2universe.org/earth/climate/carbon_cycle.html*
7	Carbon sinks and sources	Images of carbon sources and sinks – provided (plus any other photos or posters you have at your school that the students could use)
8	The Virtual Farm	Computer to access the website: *virtualfarm.mla.com.au*

Station 1

[Task] Modelling emission gases

1. Use the molymod kits and the key provided to build some greenhouse gases.

2. In the space below, draw your model of carbon dioxide – CO_2

3. Now have a go at building methane – CH_4. Draw your model.

4. Water vapour also is a greenhouse gas. Build a molecule of H_2O and draw it here.

5. Finally, have a go at building nitrous oxide – N_2O – and draw it here.

Station 2

[Task] Measuring emissions

1. Go to *abc.net.au/catalyst/stories/3685323.htm* and watch the video called 'Future Farm' (from the ABC archives; broadcast on Thursday, 7 February 2013).

2. How many sheep are there in Australia?
_____
_____

3. How many tonnes of methane do they collectively release into the atmosphere each year?
_____
_____

4. Describe the tent experiment that measures the amount of methane the sheep produce.
_____
_____

5. What are the benefits of working in the field like this, rather than try to conduct these experiments in the laboratory?
_____
_____
_____

6. Why do agricultural scientists want to measure the amount of methane sheep produce?
_____
_____
_____

Station 3

[Task] Exhaling emissions

1. Pour 20mL of limewater into a small beaker.

2. Observe the limewater and describe your observations here.
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_____
_____
_____

3. Use a straw to exhale some of your own breath into the limewater for 1 minute (breathing in through your nose when you need to).

4. Observe the changes that take place in the limewater and record them here.
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_____
_____
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5. Limewater goes cloudy in the presence of carbon dioxide. If your limewater went cloudy, explain where the carbon dioxide came from.
_____
_____
_____
_____

Station 4

[Task] Reducing emissions

1. Read the blog at www.csiro.au/en/News/News-releases/2016/Greenhouse-gas-mitigation-potential-of-the-global-livestock-sector-revealed

2. Produce your own brief written summary of the blog (bullet points are fine to use).

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Station 5

[Task] Your ecological footprint

1. Go to *www.epa.vic.gov.au/~/media/Publications/1216.pdf*

2. Follow the instructions and respond as best you can about your lifestyle

3. When you have finished, record your results here:

How many Earths does it take to support your lifestyle?	
How many global hectares do you need to support your life choices?	
List the areas of life that have the least impact (smallest section of the pie chart) to the most impact.	

4. Suggest ways you could reduce your global footprint. You can test out your ideas with the calculator you have just used.

_____

_____

_____

_____

Station 6

[Task] The carbon cycle game

1. Go to _windows2universe.org/earth/climate/carbon_cycle.html_ and click on the carbon cycle game.

2. Work your way around to visit the six carbon reservoirs and answer the questions along the way.

3. List the six carbon reservoirs:

_____

_____

_____

_____

_____

_____

4. Which reservoirs are relevant to farmers?

_____

_____

_____

_____

Station 7

[Task] Carbon sinks and sources

1. Look at the images provided (p19).

2. Sort the images into two groups: one group for sources of carbon, and another for sinks of carbon, adding them to the table below.

Notes: A sink absorbs more carbon than it gives off (eg, the ocean). A source emits more carbon than it absorbs (eg, burning wood). The amount of carbon in the atmosphere at any one time depends on the balance that exists between the sinks and sources. This system of sinks and sources operates all over the planet and is known as the carbon cycle.

Sources of carbon	Carbon sinks

Carbon sinks and sources: images to sort

Station 8

[Task] The Virtual Farm

1. Go to the Virtual Farm at *virtualfarm.mla.com.au*

2. Click on the Kalyeeda station in the Kimberley.

3. Click on 'Let's go' on the right hand side.

4. Click on the blue sky to the left of the helicopter. When the circle appears, click on 'Sustainable Futures'.

5. Click on the video 'Climate variability' and listen to what James has to say about the decisions that need to be made about the farm depending on the climate.

6. What kinds of decisions does James have to make about the number of cattle raised, in relation to the amount of rain and heat the property gets?

_____

_____

_____

_____

7. If weather conditions were to become more extreme or unpredictable, suggest how it could affect James.

_____

_____

_____

8. Click on 'back to farm' on the top right, and then click on the solar panel on the right. Now click on 'Science' and then the 'Energy needs' video.

9. What sources of energy does Kalyeeda farm use?

_____

_____

10. What does Kalyeeda farm use solar energy for?

_____

_____

11. Now go back to the map of Australia and go to the Malabar farm in Gippsland.

12. Click on 'Let's go' on the right hand side.

13. Click on the solar panel on the right and then on 'Science'. Watch the video called 'Using solar energy'.

_____

_____

14. What do they use solar panels for on the Malabar farm?

_____

_____

15. What does Paul identify as the benefits of using solar panels on his farm?

_____

_____

Going green

Student literacy activities

In this section, we delve into the issues associated with greenhouse gas emissions and the cattle and sheep industry, and explain some of the science involved. Students read a series of articles and complete a number of linked discussion topics and literacy activities. These include:

- Brainstorm.

- Glossary.

- Comprehension and summary questions.

- Questioning toolkit.

ARTICLES

1. The rise and rise of greenhouse gases
Levels of the worst greenhouse gases – carbon dioxide, methane and nitrous oxide – all reached new highs last year, says the United Nations.

2. Carbon hoofprints
The term 'carbon footprint' is often used when discussing climate change, but what exactly is a 'carbon hoofprint'?

3. Reducing livestock methane emissions
In Australia, methane emissions from cows and sheep are thought to account for about 10% of our total greenhouse gas emissions. The CSIRO is involved in several research projects aimed at reducing these emissions.

Brainstorm

[Task] How much do you know about greenhouse gas emissions? Take this quiz to find out.

1. Which greenhouse gas is the most abundant in the Earth's atmosphere?

2. Which of these was not present in the atmosphere in pre-industrial times: methane, nitrous oxide, or halogen-containing gases such as chlorofluorocarbons?

3. Which country has the highest per-capita carbon dioxide (CO_2) emissions: the US or Australia?

4. Fossil fuel combustion contributes what percentage of human-caused CO_2 emissions: 25%, 50% or 75%?

5. After CO_2, which gas contributes most to our total greenhouse emissions?

6. Australia emits about 24 tonnes of greenhouse gases each year.... in total, or per person?

7. True or false: The greenhouse effect is caused by humans.

8. Which of these contributes most to Australia's greenhouse gas emissions: the energy sector or the agricultural sector?

9. When did Australia sign the Kyoto Protocol, agreeing to stabilise its greenhouse gas emissions?

Brainstorm answers

1. carbon dioxide
2. halogen-containing gases, such as chlorofluorcarbons
3. Australia
4. 75%
5. methane
6. per person
7. false (it is the enhanced greenhouse effect that humans are causing)
8. Energy sector
9. 2007

The rise and rise of greenhouse gases

THE VOLUME OF greenhouse gases causing global warming has risen to new highs, the UN World Meteorological Organisation (WMO) says, warning it is becoming increasingly unlikely the world can limit rising temperatures to UN-backed targets.

Pointing out that the worst warming gases – carbon dioxide (CO_2), methane and nitrous oxide – had all reached new highs in recent years, the agency's Secretary-General Michel Jarraud said "it is getting increasingly unlikely" that a UN-backed pledge to limit global warming to 2°C (3.6° Fahrenheit) could be achieved.

"Between 1990 and 2011, there was a 30% increase in radiative forcing – the warming effect on our climate – because of carbon dioxide and other heat-trapping long-lived gases," the WMO said.

Carbon dioxide
Levels of CO_2 – the single most important human-made contributor to climate change – rose to 390.9 parts per million (ppm) in 2011, which is 2.0 ppm higher than in 2010, reported the WMO. In April 2012, CO_2 levels were recorded as reaching almost 400 ppm (399.72), the first time they have reached this level in three million years.

CO_2 levels are at more than 140% of the pre-industrial level (before 1750), with about 375 billion tonnes of carbon released into the atmosphere as CO_2 in the past 260 years.

"These billions of tonnes of additional CO_2 in our atmosphere will remain there for centuries, causing our planet to warm further and impacting on all aspects of life on earth," Jarraud said in a statement. "Future emissions will only compound the situation," he added.

Taking the long view on data to smooth out year-on-year anomalies, the WMO showed that while CO_2 in the atmosphere increased on average 1.5 ppm during the 1990s, the average annual hike from 2000 to 2010 stood at 2.0 ppm. "So it's not just increasing, it's increasing exponentially," WMO scientific officer Oksana Tarasova told reporters.

Jarraud, meanwhile, pointed out that so-called 'carbon sinks', including oceans, have until now absorbed nearly half of the CO_2 emitted by humans, but stressed that "this will not necessarily continue in the future."

Methane
The level of atmospheric methane (CH_4), the second most important greenhouse gas after CO_2, has also reached new highs at 1,813 parts per billion (ppb). This is 259% of the pre-industrial level, the WMO said, blaming mainly human activities like fossil fuel exploitation, cattle breeding, rice agriculture, landfills and biomass burning.

As a greenhouse gas, methane is estimated by the Intergovernmental Panel on Climate Change to be between 21–23 times the potency of CO_2.

Nitrous oxide
Also worrying was the increase in nitrous oxide (N_2O) levels, the WMO said, since its impact on climate is almost 300 times greater than that of carbon dioxide.

The gas, emitted into the atmosphere from natural and artificial sources, also plays an important role in the destruction of the ozone layer, which protects the Earth from harmful ultraviolet rays.

According to the WMO, the atmospheric concentration of nitrous oxide in 2011 was about 324.2 ppb, which is up 1.0 ppb from 2010, and at 120% of pre-industrial levels.
– *AFP*

The Australian picture

AUSTRALIA ONLY CONTRIBUTES about 1.5% of the world's greenhouse gas emissions. However, on a per-capita basis, Australia is one of the world's worst polluters. Our emissions are about 24.4 tonnes carbon dioxide equivalent (CO_2e) per person – that's more than four times the world average.

Australia's greenhouse gases contributions mostly come in the form of CO_2. This gas accounts for about 74% of our emissions, most of which are generated by the energy sector. Methane accounts for a further 20% of our emissions, with nitrous oxide making up most of the remainder.
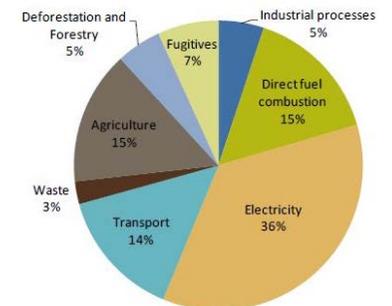
The main human activities increasing the amount of carbon dioxide in the atmosphere are:
- electricity production (involving the combustion of fossil fuels, which releases CO_2)
- transport (motor vehicles, trains and planes all burn fuel, which releases CO_2)
- land clearing (when forests are cleared, there are fewer trees to store carbon and to convert CO_2 during the process of photosynthesis).

For methane emissions, the main contributing activities are livestock production (since livestock, such as cattle and sheep, produce methane during their digestion process) and mining for fossil fuels, which releases methane. Nitrous oxide, the third major greenhouse gas, mainly comes from the production and application of nitrogen fertilisers, which are used to help crops grow.

Deforestation and Forestry 5%
Fugitives 7%
Industrial processes 5%
Direct fuel combustion 15%
Agriculture 15%
Electricity 36%
Waste 3%
Transport 14%

Source: Department of Climate Change and Energy Efficiency Australia's Emission Projections 2010[2]

D.C.CEEA

Activity 1 – Glossary

[Task] Define some of the scientific terms used in the article, using the table provided.

Term	Definition
Greenhouse gases	
Global warming	
Parts per million	
Pre-industrial	
Anomalies	
Exponentially	
Carbon sinks	
Biomass burning	
Potency	

Activity 2 – Summarise

[Task] Answer the following questions relating to the article.

1. Why does the UN believe is it becoming less likely that the world can limit global warming to the target of 2°C?

_____

_____

2. Why is it a problem having too many greenhouse gases in the atmosphere – what do these gases do?

_____

_____

3. Why are methane and nitrous oxide considered a problem as greenhouse gases, even though the levels of these gases in the atmosphere are far lower than CO_2 levels?

_____

_____

4. Draw a simple line graph to show how carbon dioxide levels have risen over the years. (Put Time on the _x_ axis; ppm on the _y_ axis. Include data for 2000, 2010, 2011 and 2012.)

5. Convert the pie chart in 'The Australian Picture' text box to a data table, showing the main sources of Australia's greenhouse gas emissions and the percentages each contribute.

MEAT & LIVESTOCK AUSTRALIA

Activity 3 – Questioning Toolkit

[Task] Write your ideas and opinions relating to each of the different types of questions.

Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits:
McKenzie, Jamie (2000)
Beyond Technology, FNO Press, Bellingham, Washington, USA. fno.org/nov97/toolkit.html

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. **Questions** What are greenhouse gases? What role do they play in global warming? How do human activities contribute to the problem? What are the major contributors to the problem?	
Subsidiary questions These questions help us manage our information by finding the most relevant details. **Questions** Which are the most damaging greenhouse gases? What can be done to reduce the levels of these gases being produced and released into the atmosphere? How can we, as individuals, help reduce greenhouse gas levels?	

Type of question	Your ideas and opinions
Hypothetical questions Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches. **Questions** If greenhouse gas levels keep going up at the rate they are now, what will be the consequences? What if we had taken action sooner to reduce greenhouse gas levels? What if we don't take action now?	
Provocative questions Questions to challenge convention. **Questions** Do we take global warming seriously enough? Are we doing enough to reduce greenhouse gas levels? Who is responsible for reducing these levels?	

Carbon hoofprints

THE TERM 'CARBON FOOTPRINT' is often used when discussing our current climate crisis. But what exactly is a 'carbon hoofprint'?

Livestock takes up an estimated one-third of the world's land that isn't covered in ice. In Australia, there are more cattle than people, and both have an impact on global warming.

A 'carbon hoofprint' refers to the contribution livestock make to total greenhouse gas emissions. This livestock greenhouse gas contribution mainly takes the form of methane, which cattle and sheep burp out (it is a common misconception that the methane comes primarily from the rear end) and release into the atmosphere. Methane is a potent greenhouse gas, 23 times stronger than carbon dioxide (CO_2).

To enable the calculation and comparison of carbon footprints, whether they are from an individual, organisation or industry, greenhouse gases are generally converted into units of carbon dioxide. In the case of Australian livestock, three megatonnes (Mt) of methane is produced annually, which equates to 63 Mt of CO_2.

Reducing emissions

One way to reduce methane emissions is to increase the efficiency of farm animals (ie, increase the amount of milk or meat produced 'per day'). Mitigating carbon emissions in this way is something that farmers are happy to do. As CSIRO researcher Ed Charmley, from the livestock and environmental systems program, explains, "it's a positive thing from an economics point of view and it's also positive for the environment."

The methane is produced by bacteria living in the animals' digestive systems. Cattle and sheep need these bacteria to digest their food, so they can't be removed, but there are still some avenues to reduce emissions. For example, adding fat to the cattle's diet can help, as it slows the activities of bacteria in their stomachs, lessening methane production, says Charmley.

Researchers are looking at even more innovative solutions for the future. Research underway ranges from manipulating the animals' genes so they require fewer methane-producing bacteria, to identifying the genetic makeup of the bacteria themselves, to develop targeted modifications of them.

One of the biggest challenges is coming up with strategies that are practical for livestock farmers to adopt, as well as good for the environment. Creating a win-win situation is important, says Charmley. For example, the Carbon Farming Initiative, introduced by the Australian Government, allows farmers to earn carbon credits if they can prove that they've reduced their greenhouse emissions. They can then sell those credits to companies wishing to offset their emissions, thereby making a profit. "That's a tool that I think will allow farmers to realise that they're not going to be penalised financially by doing these things. There is a mechanism in place that allows it to be worth their while," said Charmley.

Research into livestock-produced methane

There are many research projects under way throughout Australia, to tackle the issue of greenhouse gas emissions in the livestock industry. A few of these projects are outlined here.

Reducing methane emissions through breeding

■ The Sheep Cooperative Research Centre is looking at breeding low-methane-producing sheep, so the number of animals with a genetic predisposition to produce less methane can be increased in the population.
■ The University of New England is working on producing a genetic variety of Angus cattle that produces less methane.

Reducing methane emissions through feed types or supplements

■ The CSIRO is collaborating with the University of Western Australia to investigate whether some types of fodder plants have the ability to reduce the methane produced from grazing livestock. These plants are known as 'anti-methanogenic plants'.

Accurately measuring methane emissions

■ The CSIRO is developing reliable methods for measuring methane emissions from Australia's northern beef herd, which accounts for about 5% of our total greenhouse emissions.
■ The University of Wollongong is testing how effectively laser and infrared 'open path techniques' can measure greenhouse gas emissions. This involves sending beams of light across paddocks containing grazing animals, and then analysing the reflected light for greenhouse gas concentrations.
■ The National Livestock Methane Program, funded by cattle and sheep farmers and the Australian Government Department of Agriculture, Fisheries and Forestry, is focused on improving the measurement of livestock methane emissions, as well as mitigation using genetic, feed and microbial approaches (see daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research/livestock-methane-research).

– based on an article by Cherese Sonkkila

Activity 1 – Glossary

[Task] Define some of the terms used in the article, using the table provided.

Term	Definition
Carbon footprint	
Mitigating carbon emissions	
Genetic makeup	
Carbon credits	
Offset	
Genetic predisposition	
Genetic variety	
Angus cattle	
Fodder	
Anti-methanogenic plants	
Laser	
Infrared	

Activity 2 – Summarise

[Task] Answer the following questions relating to the article.

1. Explain in your own words what a carbon hoofprint is.

_____

_____

_____

_____

_____

2. Is the contribution Australia's livestock industry makes to greenhouse emissions significant? Give at least two reasons for your answer.

_____

_____

_____

_____

3. Draw a sketch or cartoon that depicts the main source of greenhouse gas emissions by the livestock industry.

4. Why is creating a 'win-win' situation important when coming up with strategies to reduce livestock emissions?

_____

_____

_____

_____

5. Fill in the table below to show some of the research being done to reduce livestock methane emissions, and who is doing the research.

Research organisation(s)	Research project

Activity 3 – Questioning Toolkit

[Task] Write your ideas and opinions relating to each of the different types of questions.

Further reading on questioning toolkits: McKenzie, Jamie (2000) *Beyond Technology*, FNO Press, Bellingham, Washington, USA. *fno.org/nov97/toolkit.html*

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. **Questions** What is a carbon hoofprint? How does the cattle and sheep industry contribute to the issue of greenhouse emissions? What emissions are produced, and in what amount?	
Subsidiary questions These questions help us manage our information by finding the most relevant details. **Questions** What can the cattle and sheep industry do to reduce its greenhouse emissions? What is already being done? What might be possible in the future?	

Type of question	Your ideas and opinions
Hypothetical questions Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches. **Questions** If cattle and sheep farmers cut down on the number of animals on their land to reduce emissions, what consequences would that have? If Australia can't find a way to reduce its emissions while still producing enough food, what might be the consequences?	
Provocative questions Questions to challenge convention. **Questions** Who should take responsibility for reducing cattle and sheep emissions: industry, individual farmers, the government? Does each of us have a responsibility to try to reduce our own greenhouse emissions?	

Reducing livestock methane emissions

THE COMMONWEALTH SCIENTIFIC and Industrial Research Organisation (CSIRO) has an extensive research program devoted to reducing the methane emissions of Australia's livestock.

Ruminants, such as cattle and sheep, produce methane as a by-product of digesting plant material in the rumen – one of the four chambers of their stomachs. This methane is released from the gut by belching.

In Australia, methane emissions from ruminants are estimated to account for approximately 10% of total greenhouse gas emissions (National Greenhouse Gas Inventory, May 2010).

The CSIRO is taking three separate but related approaches to reducing livestock methane emissions:

■ microbiological research to understand methane production in the rumen, and to develop biological methods for reducing this;

■ systems-based research to understand management and dietary factors that affect methane emissions from cattle;

■ investigation of plant foods (forage) that could reduce methane production in ruminants, and the incorporation of these plants into Australian livestock production systems.

Project 1 – Managing methane-producing microbes

In a ruminant, certain microbes in the gut produce methane as a by-product during the process of breaking down plant material and producing energy, which the animal needs to live and grow.

CSIRO researchers are investigating the genetics of these methane-producing microbes, to better understand how they influence gut function and digestion in ruminants. The aim is to find a way of changing the breakdown of plant material, to reduce the amount of methane produced by gut microbes, without reducing the energy animals get from their feed.

Learning from Australian wallabies

The digestive systems of Australian macropods (kangaroos and wallabies) are often compared to those of ruminants – especially sheep and cattle. Both groups of animals have evolved to live on grasses and shrubs, relying on specialised gut microbes to break down this cellulose-rich plant food.

However, the two types of animals have key differences in their digestive anatomy and digestive processes, and macropods generate less methane during digestion.

With support from the U.S. Department of Energy, CSIRO scientists are decoding the 'microbiome' from the Australian Tammar wallaby's foregut and comparing it with the microbiomes of the rumen in cattle and sheep.

Researchers have identified several unique microbes involved in the digestion process in the Tammar wallaby's gut. Some of these microbes use different enzymes for breaking down complex carbohydrates than the microbes in the rumen of cattle and sheep, resulting in less methane production.

Through this research, the scientists are attempting to find new ways of using microbiology and gene-based technologies to improve the digestion process in livestock so that they produce less methane.

Project 2 – The northern beef herd

Estimating methane emissions in Australia's extensive grazing systems is challenging. To address this, CSIRO scientists are developing state-of-the-art technologies to measure and model cattle methane emissions and the conditions that produce them.

Measuring cattle methane emissions

This project is looking to provide quantifiable estimates of methane emissions under the wide range of environmental and management conditions that face

Agriculture researchers use poly tunnels to capture the methane that cattle and sheep produce, so it can be measured.

the Australian beef industry. Three key research areas include:

■ assessing methane emissions from cattle fed tropical forages, using the method of respiration chambers for measuring methane

■ developing and deploying new techniques for measuring methane emissions from cattle in the field, validated against the respiration chambers

■ modelling cattle methane emissions under northern Australian conditions.

Using open circuit gas-exchange respiration chambers at the Lansdown Research Station in North Queensland, CSIRO scientists can accurately measure the uptake of oxygen and the release of carbon dioxide and methane from individual animals as they feed on a range of diets, including tropical forages and legumes.

Tropical pastures are highly varied, and livestock are very selective when grazing. Accordingly, the diet of

To identify which plant species have promise, the scientists measure the breakdown of the plant material and the amount of methane produced.

Plants that reduce methane production – known as 'anti-methanogenic plants' – are then tested further to see if their effects are variable or relatively consistent:
- over time;
- during different stages of plant maturity (eg, vegetative growth or flowering);
- across different locations;
- in response to the plants being grazed by livestock.

In a final step, anti-methanogenic plants will be fed to animals, under controlled conditions and eventually under field conditions, to confirm if the beneficial effects seen in the laboratory also occur in the real world.

Getting the mixture right

Another part of this research is aimed at improving our understanding of the impact of different doses and mixtures of plants on methane production in the gut of livestock. This is very important, since the plants will most likely be used as one part of a diverse diet offered to grazing livestock.

Scientists are aiming to find practical ways to include alternative plants in the diet of grazing animals to achieve multiple benefits, including:
- whole-farm profitability;
- animal productivity;
- environmental sustainability.

Part of this research involves understanding which plants animals choose to eat when presented with many different plants, and developing management strategies for encouraging livestock to include anti-methanogenic plants in their diet.

grazing cattle is very different from the average pasture composition. Selective grazing also varies across the season, making it impossible to replicate the grazing animal diet by feeding harvested forages in a respiration chamber.

Using lasers and wireless sensor networks, CSIRO scientists are measuring methane emissions from grazing cattle in their natural environment.

To extend the data to include field-based measurements, CSIRO has developed open-path laser methods that can be used to assign a methane value to grazing cattle and the type of pasture they have been grazing. The open-path laser is a gas detection device that uses an infrared laser beam to detect methane from cattle in a field.

The researchers are also trialling a poly tunnel that aims to replicate the respiration chambers in the field. The tunnel can be placed in different pasture types with a small number of cattle or other animals grazing inside.

Project 3 – Using forage to reduce methane emissions

In this project, scientists are investigating which plant foods reduce methane production in sheep and cattle, and how these plants may be used in Australian livestock production systems.

The anti-microbial properties of plants

All plants contain natural chemicals. Some of these chemicals protect the plants against pests, or limit the extent to which they are eaten by herbivores (including insects and larger animals).

Because some of these plant chemicals have anti-microbial properties, they may be used to reduce the number of methane-producing microbes in the gut of ruminants, thereby reducing methane emissions from livestock.

The first step is to screen a large number of plants in laboratory tests that simulate the foregut of sheep or cattle.

REFRACTION
MEDIA

Activity 1 – Glossary

[Task] Define some of the scientific terms used in the article, using the table provided.

Term	Definition
Ruminants	
By-product	
Microbiological research	
Systems-based research	
Livestock production systems	
Methane-producing microbes	
Microbiome	
Gene-based technologies	
Tropical forages	

Term	Definition
Grazing systems	
Quantifiable estimates	
Respiration chambers	
Pasture composition	
Selective grazing	
Field-based measurements	
Anti-microbial properties	
Animal productivity	
Environmental sustainability	

Activity 2 – Summarise

[Task] Answer the following questions relating to the article.

1. What percentage of Australia's total greenhouse emissions is estimated to be contributed by the livestock industry?

_____

2. a) Why do you think the CSIRO has an 'extensive research program' devoted to reducing the methane emissions of Australia's livestock?

_____

_____

b) Why do you think the CSIRO is taking more than one approach to reducing methane emissions?

_____

_____

3. Project 1
a) Use your own words to explain why wallabies are being studied. (What do scientists think they can learn from them?)

_____

_____

b) List one important similarity, and one important difference, between digestion in macropods and digestion in ruminants.
Similarity:

_____

Difference:

_____

4. Project 2
a) What do the respiration chambers allow scientists to do, and why is this useful?

_____

_____

_____

b) Explain why scientists are not only studying cattle using respiration chambers, but also 'within their natural environment'.

_____

_____

c) What technology is being used to study cattle methane emissions as the cattle graze in a field?

_____

_____

5. Project 3
a) Explain why some plants, when digested by cattle, produce less methane than others.

_____

_____

b) List the three steps (in simple terms) that researchers are taking to study these anti-methanogenic plants.
Step 1:

_____

Step 2:

_____

Step 3:

_____

c) Why do you think scientists are trying to understand the influence of different doses and mixtures of plants on methane production in livestock?

_____

_____

![mla - MEAT & LIVESTOCK AUSTRALIA]

Activity 3 – Questioning Toolkit

[Task] Write your ideas and opinions relating to each of the different types of questions.

Further reading on questioning toolkits: McKenzie, Jamie (2000) *Beyond Technology*, FNO Press, Bellingham, Washington, USA. *fno.org/nov97/toolkit.html*

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. **Questions** Why are scientists trying to reduce cattle and sheep methane emissions? Is it practical to achieve this 'in the field' (rather than just in the lab)? Is it possible to reduce emissions enough to bring about significant change? Can research find the answers?	
Subsidiary questions These questions help us manage our information by finding the most relevant details. **Questions** What sorts of things are being done by researchers to try to reduce methane emissions from cattle and sheep? What is their chance of success? Which strategy is likely to be most successful?	

Type of question	Your ideas and opinions
Hypothetical questions Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches. **Questions** What if none of this research finds a way to effectively reduce cattle and sheep methane emissions? What if it is successful and cattle and sheep methane emissions are virtually eliminated? (What direction do you think research might take then? e.g. are there other emissions that could be reduced in the cattle and sheep industry?)	
Provocative questions Questions to challenge convention. **Questions** Who should have to pay for the changes needed to reduce greenhouse emissions from farms? If you owned cattle and sheep, would you try to reduce their greenhouse gas emissions? Why or why not?	

REFRACTION MEDIA

Activity 4 – Bringing it all together

1. Create a mind map to show the main topics the three articles address, and how the articles are related to one another.

1. List five issues you have learned about from reading the articles.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

2. List three questions you have after reading the articles.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

About the Refraction Science Matrix

What is the Refraction Science Matrix?
A learning matrix such as the Refraction Science Matrix is a flexible classroom tool designed to meet the needs of a variety of different learning styles across different levels of capabilities. Students learn in many different ways; some are suited to hands-on activities, others are strong visual learners, some enjoy intellectually challenging, independent, hands-off activities, while others need more guidance. The matrix provides a smorgasbord of science learning activities from which teachers and/or students can choose.

Can I use the matrix for one or two lessons, or for a whole unit of study?
Either! The matrix is designed to be time flexible as well as educationally flexible. A time frame for each activity is suggested on the matrix. Choose to complete one activity, or as many as you like.

Is there room for student negotiation?
Yes! Students can be given a copy of the matrix and choose their own activities, or design their own activities in consultation with their classroom teacher.

Can I use the matrix for a class assessment?
Yes! You can set up a point system – perhaps one lesson equals one point. Students can be given a number of points to complete. If they choose less demanding activities, they will have to complete more of them.

What do the column headings mean?

1. Read and revise

Designed to enhance student comprehension of information.

2. Read and relate

Gives the student the opportunity to apply or transfer their learning into a unique format.

3. Read and review

Requires the more challenging tasks of analysing and/or assessing information to create and express new ideas and opinions.

What do the row headings mean?

Row heading	Description of activity
Scientific procedure	Hands-on activities that follow scientific method. Includes experiments and surveys. Great for kinaesthetic and logical learners, as well as budding scientists.
Science philosophy	Thinking about science and its role in society. Includes discussion of ethical issues, debates and hypothetical situations. An important part of science in the 21st century.
Being creative with science	For all those imaginative students with a creative flair. Great for visual and musical learners and those who like to be innovative with the written word.
Science time travel	Here we consider scientific and technological development as a linear process by looking back in time or travelling creatively into the future.
'Me' the scientist	Personalising the science experience in order to engage students more deeply.
Communicating with graphics	Using images to communicate complex science ideas.
ICT	Exploring the topic using computers and the Internet.

MLA MEAT & LIVESTOCK AUSTRALIA

	1. Read and revise	2. Read and relate	3. Read and review
Scientific procedure	How are gases produced? Use Linked Activity 1 to investigate the production of an important greenhouse gas.	Investigate the ability of plants to take up carbon dioxide during the process of photosynthesis. See Linked Activity 2.	Design and build two identical mini greenhouses that a thermometer can fit inside. You could use glass or clear Perspex, with cardboard for a roof and cling wrap for windows, or just recycle a large, clear plastic bottle. Now design and conduct an experiment where you manipulate one variable to either increase or decrease the temperature inside your greenhouse, compared to the other greenhouse under 'normal' conditions. Try using different gases inside the greenhouse, or different thermal conditions outside the greenhouse. Write this up as a full scientific report.
Science philosophy	Do you think it is environmentally irresponsible, or even immoral, for humans to keep on producing greenhouse gas emissions at the current rate? Why or why not?	Are humans totally dependent on the activities that produce greenhouse gases? Could we ever stop producing these emissions? What are the benefits and drawbacks of producing greenhouse gases as individuals and a community, now and in the future?	Explore the ethics of greenhouse gas emissions and the cattle and sheep industry. Do some further research, and then prepare a report that includes your recommendations about what should/should not be required of Australia's sheep and cattle farms. Make sure you justify your recommendations.
Being creative with science	Design a poster or a mural to show how methane and nitrous oxide are formed on sheep and cattle farms, and why these gases are a problem in excess in our atmosphere.	Produce a model of a cow's digestive system to show how they digest their food, and where and how methane is produced.	You have been invited to demonstrate to a group of farmers an invention you have designed, that reduces greenhouse gas emissions from cattle and sheep farms. Draw or build a prototype of your idea, and provide a full description of how it works.
Science time travel	Think about what you have read about greenhouse emissions by the cattle and sheep industry and all the research being done to reduce emissions, and use your imagination to write a short description of how the situation might be different in the next century. (You might like to put this in the form of a short story.)	Collect data showing temperature and carbon dioxide levels such as those found at *daviesand.com/Choices/Precautionary_Planning/Closer_Look/index.html* Use at least 2 other sources and compare the results. Combine these results and write a short report of how temperature and atmospheric carbon dioxide have changed over time.	Go to *ipcc.ch/graphics/2001syr/large/05.24.jpg* and examine the graph showing possible future scenarios with regard to global temperature increases. Which case scenario do you think is most likely and why? Research other reliable sources of climate science predictions, and use this information to write a report that includes your own predictions of average global temperatures in the year 2100. What will some of the consequences be if your prediction becomes reality?
'Me' the scientist	Keep a diary for a day, and record every activity you do that contributes to the level of greenhouse gases in the atmosphere. (Make sure you include any use of power – electricity and gas – and motorised transport.) Allocate points for each activity, then calculate your total.	If you were a scientist studying greenhouse gas emissions by the cattle and sheep industry, what would you choose to study, and why? What question(s) would you investigate? How might you go about doing this?	Create a classroom activity for your peers, in which they investigate and report on: 1. how the school contributes to greenhouse emissions 2. changes the school could make to reduce its emissions 3. a realistic goal that could be set (in terms of reducing emissions) and the time frame for achieving it.
Communicating with graphics	Create a storyboard for a short video about greenhouse emissions on cattle and sheep farms, and the work being done to reduce these emissions. The video needs to be suitable for a high school audience.	Create a graphic that shows which greenhouse gases are produced by cattle and sheep farms, the relative proportions of these, and the main activities or sources of these emissions.	Imagine you are an atom of carbon. Create a fun flowchart or other graphic to show how you can travel around the carbon cycle, moving in and out of the biosphere, atmosphere, and hydrosphere.
ICT	Design a quiz in 'Survey Monkey' or any equivalent software, to test a fellow student's knowledge of the carbon cycle.	Produce an animation of a cow's digestive system that shows how they digest their food and produce methane.	Design an app, or the features of an app, that farmers could use on their farms in the future to help them monitor the amount of methane their farms are producing.

REFRACTION MEDIA

Activity 1
INVESTIGATING GAS PRODUCTION

MATERIALS
- Dilute HCl (hydrochloric acid) or vinegar
- Marble chips (calcium carbonate)
- Limewater
- Test tube with feeder arm and cork or rubber stopper
- Test tube without feeder arm
- Test tube rack

METHODS
1. Put the two test tubes in the test tube rack.
2. Place two fingers' width of marble chips into the bottom of the test tube with the feeder arm.
3. Place the feeder arm into the second test tube.
4. Pour limewater into the second test tube until the end of the feeder tube of the feeder arm is submerged.
5. Pour the acid (HCl or vinegar) over the marble chips until the test tube is half full. Immediately place the cork or rubber stopper on the test tube with the acid and marble chips.
6. The gas produced will bubble into the limewater.
7. Note the change in the limewater in Table 1.

RESULTS
Table 1 – Colour of limewater before and after bubbling

Colour of limewater before bubbling	Colour of limewater after bubbling

DISCUSSION
1. Which gas do you think was produced when the acid was added to the marble chips?
_____
_____
_____

2. Why do you think this? (Explain your answer to Question 1)
_____
_____
_____

3. Is there anything you could do to test the gas, to prove it is what you think it is?
_____
_____
_____

4. Identify any difficulties you had with this experiment, and state how you overcame them.
_____
_____
_____

Activity 2

SOAKING UP CARBON DIOXIDE

Note: Bromothymol blue turns green in the presence of carbon dioxide, and blue when there is either no carbon dioxide or very little.

AIM

To investigate the ability of plants to take up carbon dioxide during photosynthesis

MATERIALS

- Two small containers with lids, or two small beakers with glad wrap to seal the top
- A sprig from an elodea plant (a type of waterplant)
- Bromothymol blue
- Straw

METHODS

1. Place 50 mL of water in each container/beaker with five drops of bromothymol blue.
2. Using the straw, blow into the bromothymol blue until it turns green.
3. Add the sprig of elodea into one of the containers/beakers.
4. Seal both containers and label the one without the elodea 'control' and the one with the elodea 'experiment'.
5. Wait a few hours, or overnight, and then record the colour changes in Table 2.

RESULTS

Table 2 – Colour of bromothymol blue with and without elodea

	Original colour (after blowing)	Colour after a few hours
Control (without elodea)	Green	
Experiment (with elodea)	Green	

DISCUSSION

1. Why do you think you were asked to blow into the bromothymol blue at the beginning of the experiment?

_____

_____

_____

_____

_____

_____

_____

_____

2. Identify any difficulties you had with this experiment, and state how you overcame them.

_____

_____

_____

_____

_____

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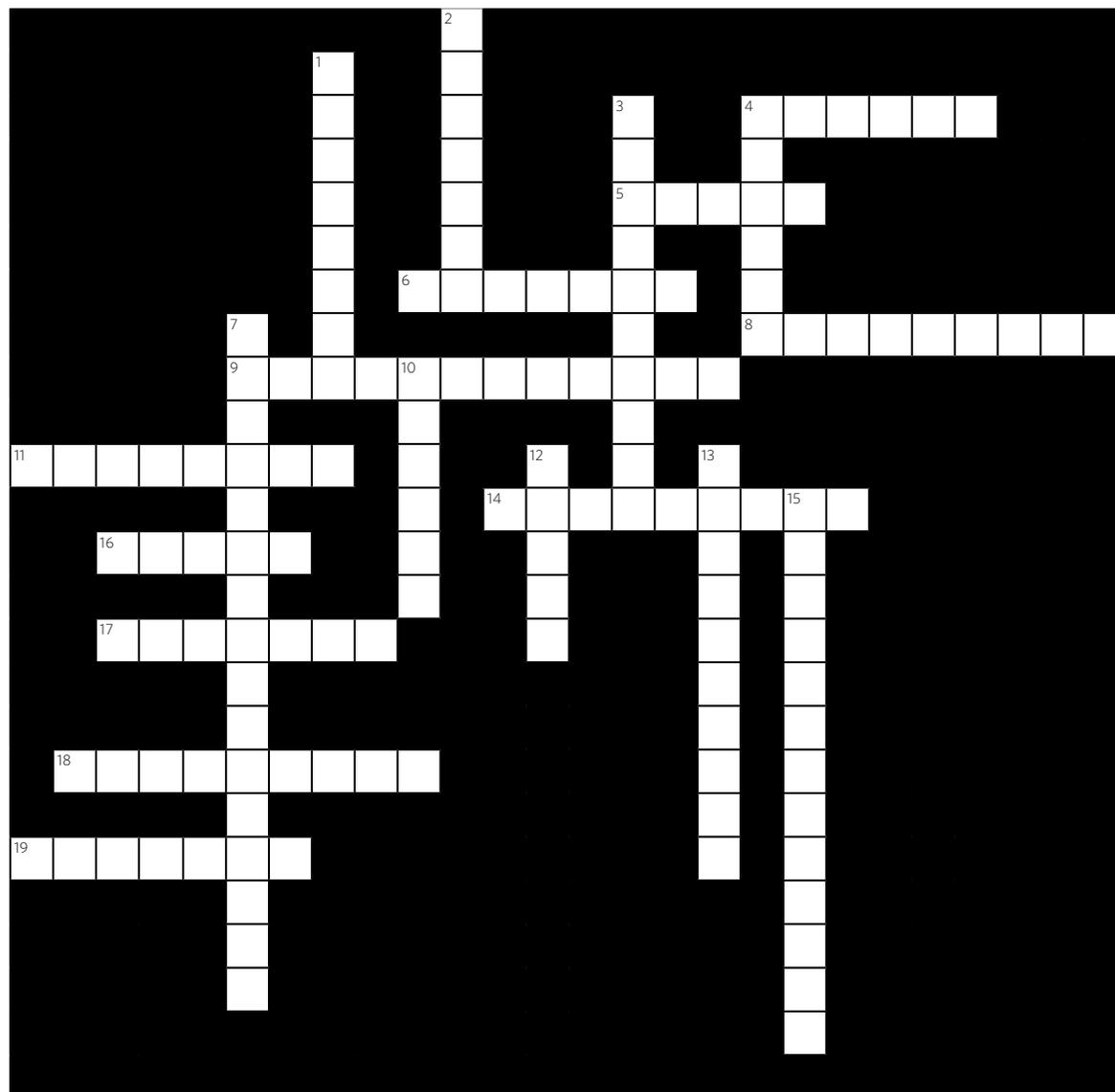
Crossword

Activities to allow students to show what they know about greenhouse gas emissions in the cattle and sheep industries, and evaluate their learning.

Across

4. Food given to cattle and sheep to eat
5. Australia's scientific and industrial research organisation
6. Managed facility where cattle are provided a balanced diet for the purpose of producing beef of a consistent quality and quantity
8. Gases given off into the air (eg, when fossil fuels are burned)
9. The third most abundant greenhouse gas
11. The action of a cow or sheep that releases methane into the air
14. Animals raised on a farm for food
16. One of the compartments of a ruminant's stomach
17. A greenhouse gas produced by cattle and sheep
18. Wallabies and kangaroos
19. Activities that produce carbon

Down

1. A cud-chewing hoofed mammal with a four-chambered stomach
2. Land covered with grass and other plants suitable for grazing animals
3. The collection of microbes that live within an organism
4. Plant foods grazed on by cows and sheep
7. Plants that reduce methane production
10. To cancel out, counteract, or compensate for something
12. Places or objects that soak up and store carbon
13. Where the greenhouse gases we produce end up
15. The most abundant greenhouse gas

Answers on page 47

DIY quiz

1. Ask each student to call out a word or term that relates to the topic (eg, methane). Record these on the board.

2. Each student is to pick three terms from the board and write a definition for each.

3. Each student is to pick another three terms from the board, and write a paragraph about the cattle and sheep industry that uses each of these words.

4. Students create their own concept map, or some other type of diagram, to show what they have learnt about emissions and farming. They are to use as many words/terms from the board as possible, and show the connections between these.

Class debate

1. Choose one of the following questions to use as the topic for a class debate:

   a) Although Australia's cattle and sheep industry makes only a small contribution to global greenhouse gas emissions, it is still worthwhile to try and reduce it.

   b) We should focus our efforts on reducing carbon dioxide emissions, since there is more of this greenhouse gas produced than any other.

   c) Everyone has a role to play in reducing greenhouse gas emissions.

2. Divide the class into two groups. Group 1 will debate the affirmative and Group 2 will debate the opposing view.

3. Appoint an adjudicator, or an adjudicating team to decide which debating team presented the most compelling argument.

Group presentations

1. Place students into small groups, within which they will work to prepare and give a short presentation to the class. (Members should have a few minutes each to talk).

2. Allocate a topic to each group, or have them choose their own, based on the activities they have been doing in this unit. Examples include: greenhouse gas emissions from Australian farms; reducing cattle and sheep methane emissions; research into greenhouse gas emissions in the cattle and sheep industry.

3. Give each group a mark for their overall presentation, and each group member an individual mark for their part of the talk.

Personal review of unit

Personal summary	Where to now?
Make a dot point summary of all the things you learnt during this unit of work. Highlight the things you found the most interesting.	Write five questions that have come up for you during this unit, which you would like to know the answers to.

Something ethical	Something political
Think of two ethical issues that came up during this unit, and propose some ideas about how these issues might be addressed.	If you were a leader in Australia today, what would you do to help reduce global greenhouse emissions?

Crossword answers