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Towards net zero

Practical policies to reduce agricultural emissions

Tony Wood, Alison Reeve, and James Ha

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This report was written by Tony Wood, Alison Reeve, and James Ha.

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Overview

Governments around the world are moving to 'net zero', to limit the impacts of climate change. All Australian state and territory governments have the goal of reaching net-zero carbon emissions by 2050 at the latest, and the Prime Minister says the national target is net zero, preferably by 2050.

Yet Australia is not on track to hit this target. The best way to reduce emissions in an economically efficient manner would be to introduce a single, economy-wide emissions price coupled with well-targeted support for technology development. But the political reality is that carbon pricing is out of reach, at least for now. So Australia should pursue sector-specific policies.

Australian governments can and should act now to create momentum towards the net-zero goal. This report, the third in a series on net zero, recommends policies to reduce emissions in the agriculture and land sectors. These sector are linked because more than half of Australia's land is used for agriculture.

The agriculture sector was responsible for 15 per cent of Australia's emissions in 2019, emitting 76.5 million tonnes. This is down from 86.2 million tonnes in 2005, mainly due to lower livestock numbers: cattle and sheep are responsible for 75 per cent of emissions in the sector. Assuming herd numbers recover from recent years of drought, emissions are projected to rise, reaching 82 million tonnes by 2030.

The land sector includes land-based processes that are not directly related to agricultural production, such as land clearing, forestry, and changes in soil carbon content. It is the only sector that currently removes more carbon from the atmosphere than it emits, reducing Australia's emissions by 26 million tonnes in 2019 (compared to net emissions of 88 million tonnes in 2005).

'Net zero' means reducing emissions and then offsetting the rest by removing carbon from the atmosphere and permanently storing it, possibly in trees or underground. This report focuses mainly on the former: how to *reduce* emissions in the agriculture and land sectors.

The agriculture sector is particularly vulnerable to climate change. Yet it is also a difficult sector in which to cut emissions: there are not yet credible ways to eliminate methane from cattle and sheep (the largest source of emissions); it will take time to implement better manure and fertiliser management across the nation's 50,000 broadacre farms; and electric vehicles and equipment are not yet fully available to substitute for diesel ones. Nonetheless, there are things that can be done now.

The Federal Government should sharpen the incentives for farmers to deploy low-emissions technologies and practices that are available. This will require improving the Emissions Reduction Fund. The Government should also invest more in programs that deliver practical advice to farmers. Governments have a crucial role in supporting R&D of methods that might enable Australia's livestock producers to thrive in a net-zero future. Even with this support, it is likely that the agriculture sector will still be a major source of emissions in 2050 – which must be offset at the expense of taxpayers, farmers, or consumers.

Overall, Australian farmers stand to benefit considerably from actions that reduce emissions and limit climate change. Smarter land management can boost farm productivity and store carbon, creating carbon credits that will be in-demand as the economy approaches net zero. The more that farmers can reduce emissions, the fewer credits they will need to offset their own emissions, and the more they can sell to others – diversifying their revenue stream. Curbing emissions today is the key to maximising this economic opportunity. The next report in this series will cover offsetting – including by farmers – in more detail.

Recommendations

1. Do not exempt agriculture or land from any national net-zero target

- Including agriculture and land in a net-zero target is necessary for the economy to actually reach net zero, and will reduce the risk to Australian exporters of future carbon tariffs from other nations.

2. Do more to encourage deployment of lower-emissions technology and practices today

- The Federal Government should improve the Emissions Reduction Fund by: expanding methods related to agricultural practices; allowing single projects to be registered under multiple methods; providing a fixed-price purchasing desk for proponents of small projects; developing a carbon credit exchange which differentiates between types of credits; and strengthening demand signals for credits. Credits must have integrity; the next report in this series will provide further recommendations on this issue.
- The Federal Government should invest in a multi-decade outreach program to deliver advice to farmers on how to practically reduce farm emissions and secure resilient income streams.
- The Federal Government should consider alternative financing mechanisms to support deployment of lower-emissions practices, such as income-contingent loans, to share the risk with farmers.

3. Spend this decade wisely to allow for more effective technology and policy in future

- The Federal Government should include technologies to reduce animal emissions as a priority in its Low Emissions Technology Statements.
- The Federal Government should expand the remit and increase funding of the Australian Renewable Energy Agency (ARENA) to allow it to support early-stage development of low-emissions agricultural technologies that are not energy-related.
- As technologies to reduce agricultural emissions are developed, all governments should consider what additional policies (subsidies, penalties, or mandates) are needed to ensure deployment of these technologies and to reduce their cost.
- The Federal Government should improve data collection of on-farm emissions-related practices, to ensure farmers receive proper credit for their actions.
- Governments should not limit landholders' opportunities to perform credible carbon dioxide-removing activities.
- Governments should ask Food Standards Australia New Zealand to remove regulatory barriers to alternative protein products entering the market and competing on their merits.

4. Do not weaken existing land clearing laws

- State and territory governments should not weaken existing land clearing laws, and should aim to keep existing stocks of nature-based carbon at or above current levels.

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1 The time is right for practical climate action

Australia has suffered more than a decade of policy uncertainty on climate change. Despite increasing international ambition and increasingly urgent calls for action, political differences between and within Australia's major parties have held back progress.

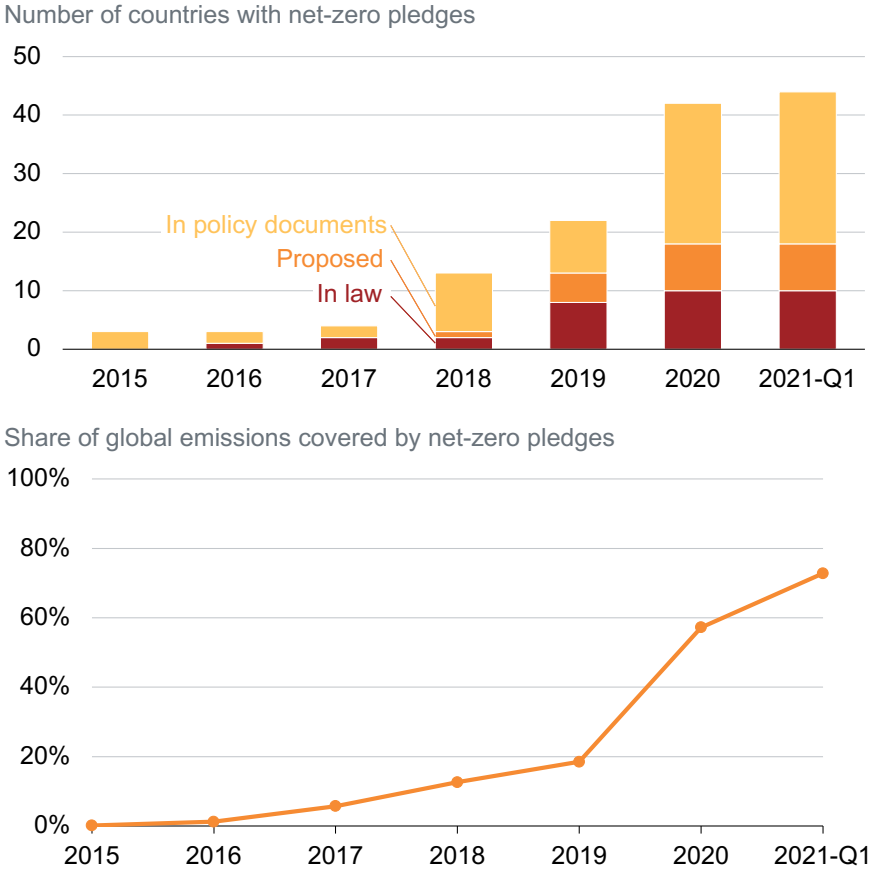
Nevertheless, converging international and domestic political pressures have created a window of opportunity for progress on climate change policy. Political reality means the best policy – a single, economy-wide emissions price – is out of reach in Australia for the foreseeable future. Therefore, the most pragmatic approach is a combination of sector-based, technology-driven policies that will create momentum towards greater ambition at a later date.

In the second half of 2021, Grattan Institute is publishing a series of five reports identifying the practical options for emissions reductions in key sectors. The first two reports covered transport and industrial emissions; these were published in July and August respectively.[1] This report – the third in the series – focuses on emissions from the agriculture and land sectors.

1.1 International and domestic pressure to cut emissions is mounting

The international community has shifted towards greater climate ambition in the past 12 months (Figure 1.1). The US has rejoined the Paris Agreement and committed to reduce emissions to net zero by 2050. The EU, having already made that commitment, is considering imposing carbon costs (equivalent to those from its own emissions trading scheme) on imports from nations with inadequate climate policies.[2] Many of Australia's largest trading partners have

Figure 1.1: The international community is now serious about achieving net-zero emissions



Source: IEA (2021, p. 33).

1. Wood et al (2021b); and Wood et al (2021c).
2. Taylor (2021).

now set net-zero targets, including China, Japan, and South Korea. All Australian states and territories have targets to reach net zero by 2050 or earlier,[3] and the Prime Minister says he wants to achieve that goal as soon as possible, preferably by 2050.[4]

Global action on climate change is overwhelmingly in Australia's national interest.[5] The Federal Government has ratified the Paris Agreement, which means Australia is committed to helping limit global warming to well below 2℃, and ideally to below 1.5℃.[6] To achieve this, there is a limit to how much carbon pollution the world can emit – a 'carbon budget'. Staying within that budget is the real objective.

Achieving net-zero emissions by about 2050 is the bare minimum to have a decent chance of limiting global warming to 1.5℃.[7] But it matters how the world – and Australia – gets there.[8] Continuing to release emissions at the current rate until 2049 – or even until 2035 – would blow the carbon budget.[9] Cutting emissions this decade – but only slowly – would exhaust most of the budget, increasing the pressure on governments to bring their net-zero targets forward, which would require an even faster and more costly transformation of the economy.[10]

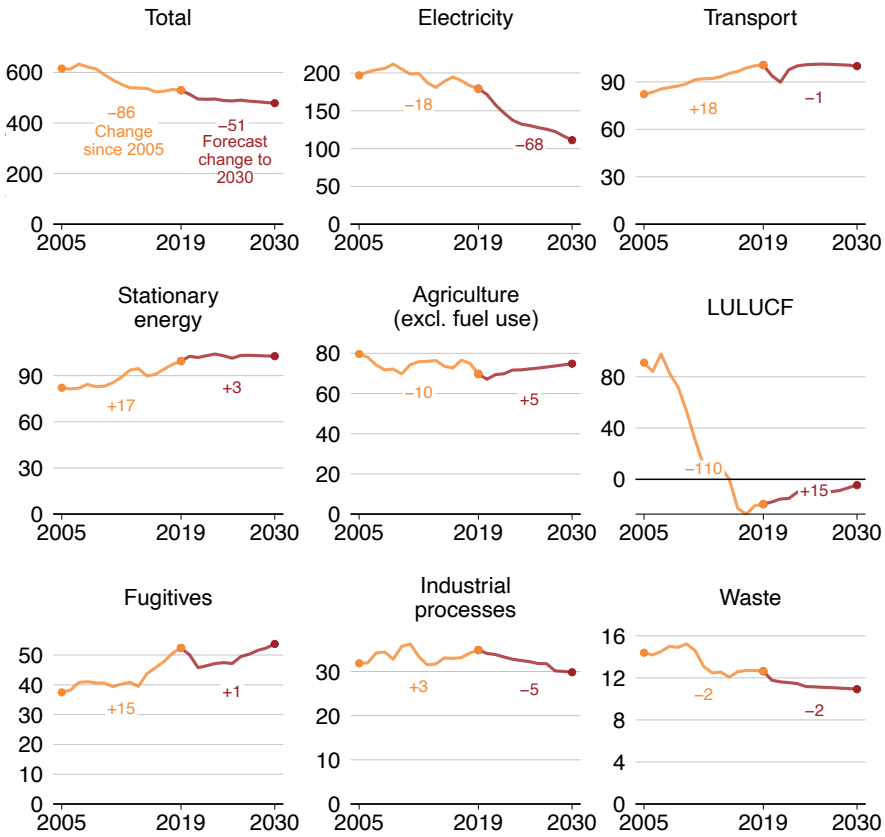
On the other hand, cutting emissions faster today will save more of the budget for the future, buying us time to ensure a smoother transition for our economy and communities. The emissions sources that are cheaper and easier to decarbonise should be targeted first; the harder-to-decarbonise sources should come later. Building momentum, coupled with R&D in low-emissions technologies, will make easier in the future what seems hard now.

The Federal Government's 2020 emissions projections suggest that over the next decade, Australia's electricity emissions will fall substantially, but the next four largest emissions sources in Australia will either grow or plateau at best (Figure 1.2 on the next page).[11] This comes after sustained growth in emissions in several sectors since 2005. There is a market failure here: limiting global warming is in Australia's interest, but current incentives are too weak for companies and individuals to curb their emissions consistent with reaching net zero by 2050.[12]

If government policy does not bend these curves downwards this decade, Australia faces a faster, harder transition to meet this target – it will need to reduce its annual emissions by 24 million tonnes each year for 20 years (Figure 1.3 on the following page). And it will have emitted an extra two billion tonnes by 2050 compared to a trajectory of steady emissions cuts from today.

3. Henry and Chandrashekeran (2021).
4. Morrison (2021).
5. Wood et al (2021a, Chapter 1).
6. UNFCCC (2015).
7. Without achieving net zero, global average temperatures will continue to rise: IPCC (2021, p. 36).
8. Hoegh-Guldberg et al (2018).
9. To have a two-thirds chance of keeping warming at 1.5℃, the world has a carbon budget of about 400 billion tonnes of CO_2 emissions from 2020: IPCC (2021, p. 38). Annual global CO_2 emissions averaged about 40 billion tonnes over the past decade, implying just 10 years of budget remaining at current rates before 1.5℃ could well be breached: IPCC (ibid, p. 6).
10. Vogt-Schilb et al (2018).
11. DISER (2020a).
12. This series of reports focuses on policies to put Australia on the pathway to net zero by 2050 because this is the target to which most of Australia's governments have committed. But international pressure to bring net zero forward is entirely possible as further evidence of climate impacts accumulates. In that case, the recommendations in this series will remain valid, but stronger and more comprehensive policy will be necessary to meet earlier targets.

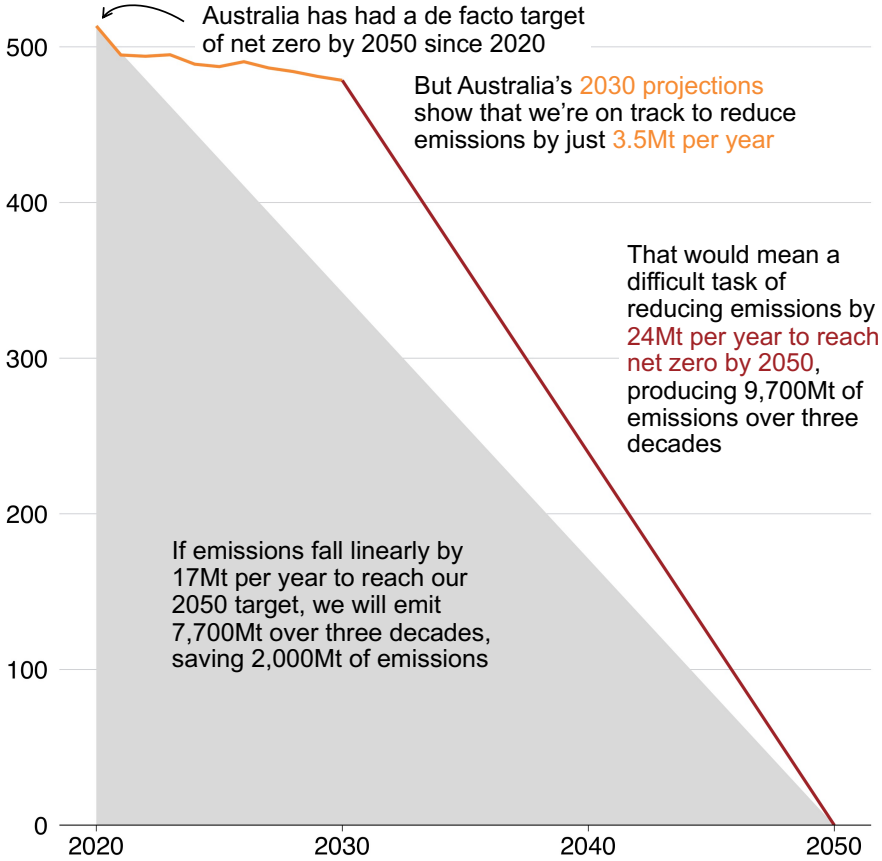
Figure 1.2: Apart from electricity, there's very little emissions reduction expected in Australia over the next decade
Emissions per year (millions of tonnes)



Notes: 'LULUCF' = land use, land use change, and forestry. 'Stationary energy' is the use of fossil fuels for non-electricity, non-transport purposes, and includes burning diesel on farms. 'Fugitives' are non-energy emissions released alongside the extraction of fossil fuels, such as carbon dioxide trapped in gas reservoirs. Emissions are 'carbon-dioxide equivalents'. Data presented here is taken from DISER (2020a), which contains slightly different data to what is reported in DISER (2021a).

Source: Grattan analysis of DISER (2020a), the most recent projections available at time of publication.

Figure 1.3: If there's insufficient progress by 2030, a highly disruptive economic restructuring will be needed in the 2030s and 2040s
Emissions per year (millions of tonnes)



Notes: Emissions are 'carbon-dioxide equivalents'. The two trajectories depicted do not have an equal effect on the climate, despite both reaching net zero by 2050 – it is the total amount of emissions in the atmosphere, not the annual contribution, that drives climate change. Even the straight-line trajectory would exceed Australia's carbon budget for 1.5℃, requiring other nations to cut emissions faster: Reedman et al (2021).

Source: Grattan analysis of DISER (2020a), the most recent projections available at time of publication.

1.2 The best policy is off the table, so Australia needs a practical 'second-best' approach

The most practical approach to reducing emissions for now is a combination of sector-specific policies. While an economy-wide carbon price would be more efficient, the political reality is that Australia is unlikely to re-establish such a price any time soon (Box 1 on the next page).

This agriculture and land use report is the third of a series on sector-based approaches. The first report was on transport, the second on industrial emissions; the remaining two will cover the role of offsetting and the electricity sector. Each analyses emissions sources; pathways and technologies for reductions; technological and economic challenges; and existing government initiatives. Each report provides sector-specific recommendations.

The over-arching theme of these reports is that Australia needs real progress in each sector to achieve net-zero emissions economy-wide by 2050. Each sector has its own challenges and opportunities, but within each are categories of potential actions:

- Those where the costs are understood and either competitive or rapidly becoming so, the emissions abatement impact is clear, and policy is straightforward;
- Those where the costs are understood but expensive, and where there are barriers to implementation beyond cost; and
- Those which seem very difficult to implement and whose costs are unknown or difficult to quantify.

Under a sector-based approach, policy makers rather than the market must decide where to reduce emissions. In this series of reports, we are aiming for the lowest-cost, no-regrets emissions reductions in each sector first, even though this approach will be less efficient than an economy-wide market-based policy.

Generally, we will start from existing policies and orient them towards a common goal, rather than propose wholesale changes. We will prefer policies that are technology-neutral with respect to achieving the net-zero goal, except in the cases where the 'winner' is already obvious. Crucially, we see a role for technology *and* incentives *and* regulation, because a combination of the three will ensure appropriate risk-sharing between the public and private sectors.

It should be possible for major parties to adopt our recommendations – whether for presentation at the international climate conference in Glasgow in November 2021, or for domestic policy platforms – but retain differentiated views on detailed policy design and the best mix.

Much public conversation on setting and achieving a net-zero goal for Australia focuses on activities and changes that are expensive and difficult. This neglects the actions that we can take now, whose successful implementation will build confidence and momentum. This report series focuses on policies that can be implemented now, with some suggestions for the longer term where relevant. None of our recommendations by themselves can deliver the full net-zero outcome, but they will all help orientate the economy in the right direction.

Box 1: Why this report focuses on one sector rather than an economy-wide policy

Australia has 29 years to transform its economy if it is to reach net zero by 2050, and half this if it is to reach net zero within a carbon budget aligned with 1.5°C.[a] As Figure 1.3 on page 8 shows, the slower we progress this decade, the steeper and more disruptive the pathway to net-zero emissions becomes.

It is well-accepted that the most economically efficient way to achieve large emissions reductions across the economy is through a carbon price.[b] Done well, economy-wide carbon pricing ensures that the sectors most able to make cheaper emissions reductions do so; the result is emissions reduction at lowest cost. Carbon pricing is supported by the business community and economists.[c] It should form the bedrock of an effective suite of policies to achieve net zero.[d]

But carbon pricing has a long and difficult history in Australia: a price was taken to election by both parties in 2007, introduced in 2012 (though it was far from perfect, with many compromises to appease political and vested interests), and repealed in 2014 after being successfully labelled a 'tax' by then-Opposition Leader Tony Abbott. A carbon price is now not seen as politically feasible by either major party, and the current Federal Government has ruled out any new policy that resembles a 'tax'.[e]

If Australia is to meet its climate objectives, policy is needed to reduce emissions now, sector by sector. This is a more costly way to reduce emissions than a carbon price because governments, not the market, have to decide where to reduce emissions. Nonetheless, governments should be able to meet their climate targets reasonably efficiently if they target the lowest-cost abatement opportunities in each sector.

Sector-based policies have delivered emissions reductions and survived political battles. For example, the Renewable Energy Target (introduced by the Howard Government in 2001 and reviewed and amended by successive governments since) has been so successful in increasing the renewable share of the electricity sector at reasonable cost[f] that many argue it is no longer necessary.

Starting with sector-based policies does not rule out a future economy-wide policy. But in the meantime, it is better to start bending the emissions curve downwards with sectoral policies. Making sectoral progress would build momentum and confidence that the task of reaching net zero is possible. Once we are moving, it will become easier to move faster.

a. Reedman et al (2021, p. 38).
b. Wood et al (2016, p. 10).
c. BCA (2020); and Wood (2020).
d. A carbon price would need to be complemented by support for low-emissions technologies development and regulation in sectors with barriers to adoption. For example, there is a split-incentive problem in buildings where emissions from gas heating would be paid by tenants, but only the building owners can authorise upgrades to lower-emissions electric heat pumps. In this case, minimum building efficiency standards would probably be a more effective policy.
e. Wood (2021).
f. CCA (2014).

2 Emissions sources and trends in the agriculture and land sectors

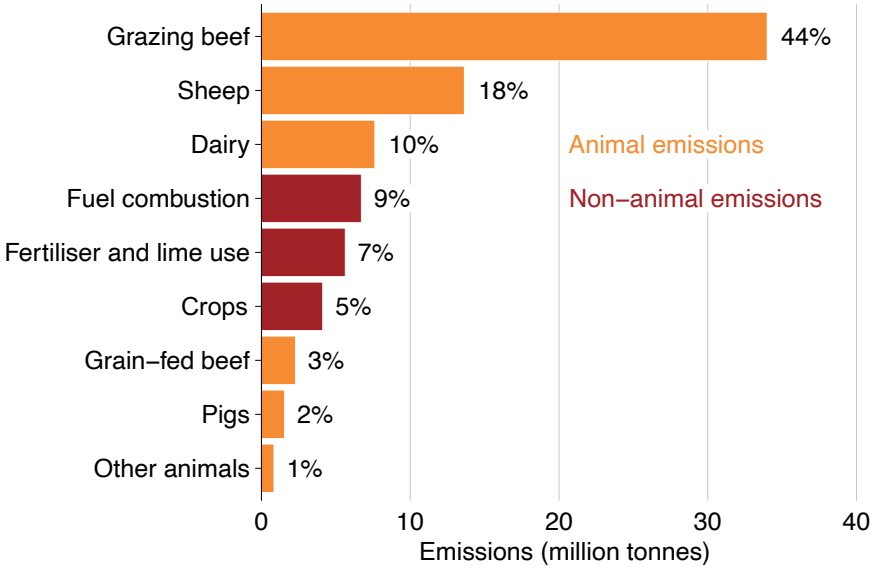
This report considers the agriculture and land sectors together because more than half of Australia's land mass is used for agricultural activities. Agriculture sector emissions mainly come from animals, diesel use, fertiliser use, and crop residues. Land sector emissions are affected by the management of trees, plants, soil, and wetlands.

Agricultural activities were responsible for 15 per cent of Australia's emissions, or 76.5 million tonnes, in 2019. Most of these emissions came directly from livestock (Figure 2.1); emissions in the sector tend to rise and fall with livestock populations. The agriculture sector is not just a source of emissions – it is also uniquely vulnerable to the effects of climate change.

The land sector (often called 'land use, land use change, and forestry' or 'LULUCF') includes processes that both add to and remove emissions from the atmosphere. The net effect is that land sector processes *reduced* Australia's emissions by 26 million tonnes in 2019 (Figure 2.2 on the following page). This was not always the case: in 2005, the sector was responsible for emitting 88 million tonnes of net emissions, mostly due to deforestation to make way for agricultural activities.

Several agricultural industry groups have committed to net zero or carbon neutrality by 2050 or sooner. Yet the Federal Government's 2020 projections suggest that emissions from the agriculture and land sectors will rise this decade. Changing this will require either doing less emissions-intensive activity (e.g. raising fewer cattle) or making activities less emissions-intensive (e.g. feeding cattle supplements that reduce their methane emissions). This chapter examines trends, opportunities, and challenges for each source of emissions.

Figure 2.1: Animal emissions are the dominant source of emissions in the agriculture sector
Emissions sources



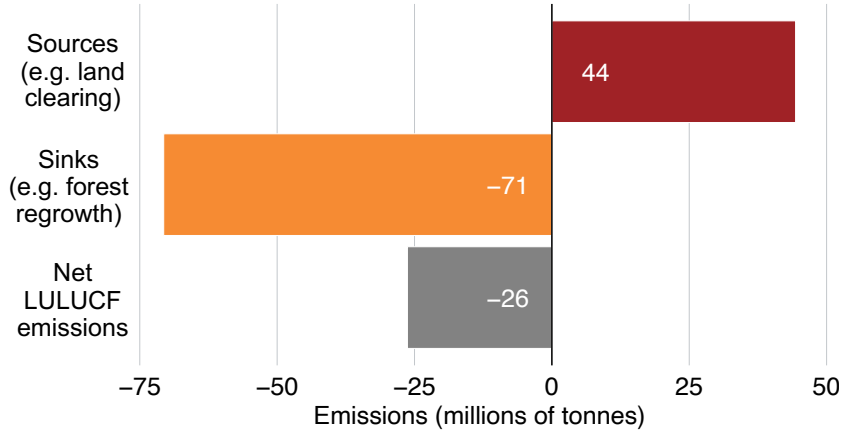
Note: Emissions are 'carbon-dioxide equivalents', estimated using using the 100-year global warming potentials published alongside IPCC (2007).

Source: Grattan analysis of DISER (2020a), the most recent Federal Government projections available at time of publication.

2.1 Trends across the agriculture sector

Agricultural activities were responsible for 76.5 million tonnes of emissions in 2019.[13] Emissions in the sector come from several sources (Figure 2.3). Cattle (for beef and dairy) and sheep are the largest contributors, but there are also non-animal emissions from crops, fuels (used for machinery, heat, and other needs), fertilisers, and lime (used to reduce soil acidity).

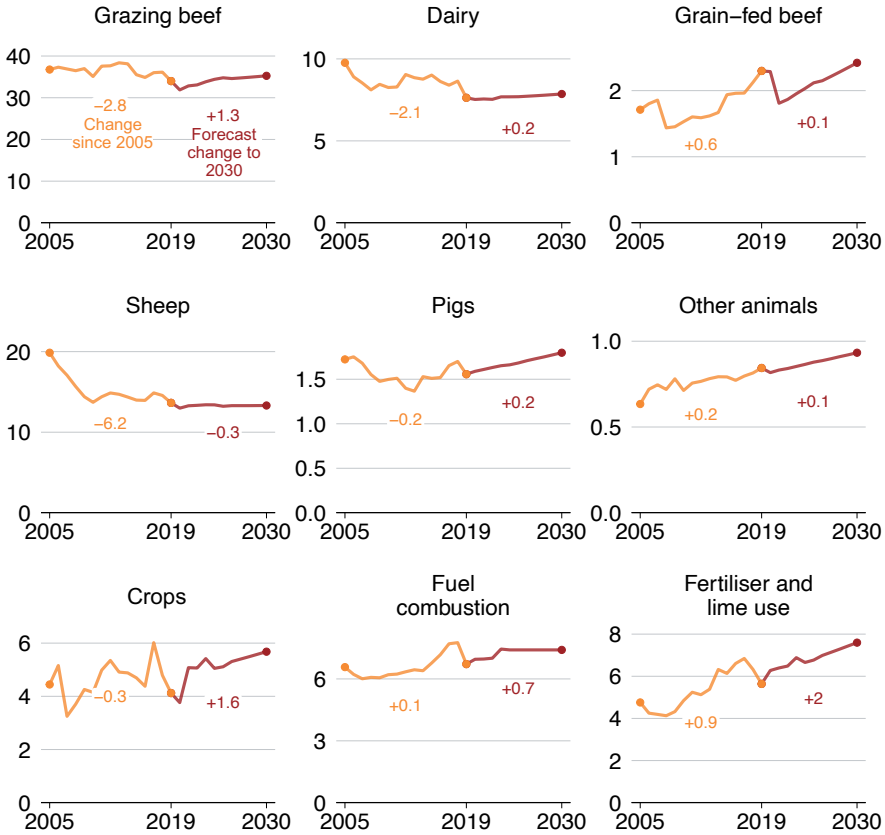
Figure 2.2: Australia's net emissions from land use, land use change, and forestry (LULUCF) were negative in 2019



Notes: 'LULUCF' = 'land use, land use change, and forestry', which collectively are described as the 'land sector' in this report, distinct from agricultural activities. Emissions are 'carbon-dioxide equivalents'.

Source: Grattan analysis of DISER (2021b), which matches with net LULUCF emissions reported in DISER (2021a), but not with those reported in DISER (2020a).

Figure 2.3: The Federal Government's projections show emissions in the agriculture sector either growing or flattening
Emissions per year (millions of tonnes)



Notes: Emissions are 'carbon-dioxide equivalents', estimated using using the 100-year global warming potentials published alongside IPCC (2007). Other animals emissions are not shown, but these were less than 1 million tonnes in 2019.

Source: Grattan analysis of DISER (2020a), the most recent projections available at time of publication.

13. Of these emissions, 69.8 million tonnes came from agricultural processes such as keeping livestock or using fertilisers (Figure 1.2), while 6.7 million came from combustion of fuels in the agriculture, forestry, and fishing sectors: DISER (2021b). Emissions from land clearing or soil carbon loss on agricultural land are counted in the land sector.

Methane is the most significant greenhouse gas in the sector, responsible for 54 million tonnes, compared to 13 million tonnes from nitrous oxide and 9 million from carbon dioxide.[14] Box 2 explains the difference between these greenhouse gases. Unlike some industrial emissions, most methane in the agriculture sector cannot be captured or flared at the source.

Box 2: Comparing different greenhouse gases

Methane and nitrous oxide trap far more heat per tonne than carbon dioxide, but do not persist in the atmosphere for as long. Methane breaks down to carbon dioxide and water vapour after about a decade.[a] To measure the warming effect of different gases, Australia's national emissions reports use a standard conversion factor based on how much warming each gas causes over 100 years – the 'global warming potential' or GWP_{100}. Multiplying the mass of each gas by its GWP_{100} allows each gas to be expressed in tonnes of 'carbon dioxide-equivalents' (CO_2-e). All emissions numbers in this report are based on carbon dioxide-equivalents, matching the national accounts.

There is ongoing discussion about whether a different metric, 'GWP*', should be used in national greenhouse gas accounting, which might better reflect the transient nature of short-lived greenhouse gases.[b] Australia and the international community have not adopted this convention as yet.

a. Nicholls and Baxter (2020).
b. Allen et al (2018) and Lynch et al (2020). The choice of metric matters only for national accounting and targets, not for global climate modelling (which already treats all greenhouse gases differently).

14. DISER (2021a) and DISER (2021b). All greenhouse gas emissions in this report are measured in tonnes of carbon dioxide-equivalents.

The Federal Government projects that annual emissions from the agriculture and land sectors will rise, not fall, over the next decade. The projections assume livestock numbers will increase after drought conditions ease, and that essentially no emissions-reducing technology or practices will be deployed on farms – this would appear to be a conservative estimate, representing a likely upper-bound on the sector's emissions. Yet it also reflects a scarcity of mature decarbonisation options for the agriculture sector. A lack of progress this decade will also make it increasingly difficult to move the economy towards net zero.[15]

If the agriculture sector does not reduce its emissions, Australian producers' export opportunities may be limited.[16] For instance, other countries with carbon prices may impose import tariffs on emissions-intensive goods to protect their domestic industries' competitiveness.[17] Australia's agriculture sector could be particularly vulnerable to these foreign policies because 70 per cent of the sector's products are exported.[18] For red meat, the figure is closer to 75 per cent.

The industry is aware of these headwinds, and recognises the sector's vulnerability to climate change (Box 3 on the next page).[19] For these reasons, the industry is increasingly signing up to net zero by 2050 or earlier:

15. At net zero, any remaining emissions must be completely offset by removing carbon dioxide from the atmosphere. If the land sector absorbs less carbon in future, then Australia will need to rely more on alternative, higher-cost technologies to remove emissions. This risk will be discussed further in the next report in this series.
16. BCA (2021); and Greenville et al (2020).
17. These tariffs are known as 'carbon border adjustment mechanisms', or CBAMs, and the EU is planning to introduce them (but it is unlikely that agricultural commodities would be affected initially): Australian Industry Group (2021, p. 58).
18. ABARES (2021a).
19. National Farmers' Federation (2020).

- The National Farmers' Federation – the peak national body representing Australia's farmers – supports an economy-wide aspiration of net zero by 2050 with some conditions;[20]
- The Red Meat Advisory Council (the federation of Australian red meat and livestock peak bodies), the Cattle Council of Australia (the peak body for cattle producers), and Meat and Livestock Australia (the industry's official marketing and research body) all support the goal of Australia's red meat industry becoming carbon neutral by 2030;[21] and
- Australian Pork Limited (the industry body for pork producers) has a target to be carbon neutral or better by 2025.[22]

Hitting any of these targets will require balancing any remaining emissions from the industry by removing an equivalent amount of emissions from the atmosphere. Removing carbon dioxide from the atmosphere and storing it permanently is a way of offsetting an industry's impact on the climate.

It is very uncertain how many emissions the agriculture sector will be producing in 2050 – and therefore how much offsetting the sector will need. For example, some research indicates that only 10-to-20 per cent of agricultural emissions are cost-effective to cut, and that

20. National Farmers' Federation (2020). The conditions are that 'there are identifiable and economically viable pathways to net neutrality, including impacts from inputs such as energy; and Commonwealth and state legislation is effective, equitable, and helps deliver on-ground programs that benefit agricultural interests and do not create unnecessary regulatory impediments'.
21. RMAC (2019, p. 36), Cattle Council of Australia (2021) and MLA (2020a). 'Carbon neutral' means all emissions are offset by purchasing credits that are created when emissions are reduced elsewhere in the economy. 'Net zero' on the other hand implies reducing emissions as much as is technically and economically feasible first, and then offsetting just the residual emissions: Herbert Smith Freehills (2020).
22. Australian Pork Limited (2020, p. 15).

Box 3: The agriculture sector is particularly vulnerable to climate change

Climate change is already hurting farmers economically. Changes in rainfall patterns over the past 20 years have cut profits across the sector by 23 per cent compared to what could have been achieved in pre-2000 conditions.[a] NSW and Queensland cropping farms have been hardest hit – profits have fallen 36 per cent on average. This trend is expected to continue, with worse warming associated with sharper falls in average farm profits.

The health of farmers themselves is also increasingly at risk. More frequent and intense heatwaves and bushfires threaten the safety and productivity of farm workers, especially those outdoors.[b]

Climate change may lead to structural changes in land use as farmers adapt to new conditions. Land in drier parts of traditional cropping zones is already being switched to livestock or mixed production.[c] But this adaptation may help only temporarily: livestock are also vulnerable to a changing climate. At 3℃ of warming, livestock in the northern third of Australia will suffer heat stress almost daily.[d] As the climate continues to change, the underlying value of some land may fall considerably and some properties may become increasingly expensive to insure.[e]

This report focuses on policies to mitigate climate change and meet climate targets through emissions reduction. It does not focus on other actions the agriculture sector could take to adapt to a changing climate.

a. Hughes and Gooday (2021, pp. 3–4).
b. Australian Academy of Science (2021, p. 44).
c. Hughes and Gooday (2021, p. 10).
d. Australian Academy of Science (2021, p. 46).
e. Steffen et al (2019).

the remaining emissions should be offset by activities that remove carbon dioxide from the atmosphere, such as increasing soil carbon and re-vegetation.[23] In other scenarios, up to two-thirds emissions reduction is possible if there are technological breakthroughs and widespread uptake.[24] Compared with other sectors of the economy, the long-term outcome for the agriculture sector is much less certain. Even the optimistic scenarios still leave tens of millions of tonnes of emissions to offset.

2.2 Animal emissions

Animals were directly responsible for 60 million tonnes of emissions in Australia in 2019.[25] Animal emissions come from two main sources: methane produced in the gut (a process known as 'enteric fermentation'), and methane and nitrous oxide produced from animal wastes (either directly or in soil).[26] Of these, enteric fermentation is the main contributor, responsible for the equivalent of 48 million tonnes of carbon dioxide in 2019 – more than 60 per cent of all agricultural emissions. Cattle and sheep contribute most of these emissions. There are about 64 million sheep and 24 million cattle in Australia.[27]

Most of the remaining animal emissions arise from manure management systems. This is particularly relevant for cattle, sheep, and pigs raised in close proximity (e.g. feedlot beef), where manure is often piled up or stored in settlement ponds. Emissions can be reduced by changing the way manure is stored and treated.[28] If methane emissions from manure are captured (which occurs at several piggeries, for example), they can be burnt and converted to carbon dioxide, reducing overall emissions.[29] There are also nitrous oxide emissions from manure or urine deposited on agricultural soils, which are much harder to reduce.

2.2.1 Future trends and options for action

Emissions from animals are projected to rise by 1.6 million tonnes between 2019 and 2030, mainly from cattle and a return to non-drought conditions.[30]

There are two ways to reduce animal emissions: make the animals less emissions-intensive, or produce fewer emissions-intensive animals.

Making animals less emissions-intensive

To reduce animals' emissions-intensity, cattle and sheep farmers will need to deploy technologies and practices that can limit enteric fermentation, the main source of agricultural emissions. A major co-benefit is improved yields: lowering methane emissions boosts animal productivity because less feed is wasted as methane, meaning more feed is converted to energy for the animal.

There are many potential options to cut methane production in animals, but each remains untested at scale or is a partial solution at best. Possible high-impact technologies include anti-methanogen

23. ClimateWorks (2020, p. 113) and EY (2021).
24. ClimateWorks (2020, p. 113). The Meat and Livestock Association's stretch goal is for 50 million tonnes of annual emissions from the red meat sector to be avoided by 2030, though this includes emissions reductions from savanna burning (which are counted in the land sector): MLA (2020a, p. 16). The CSIRO estimates that between zero and three-quarters of enteric fermentation emissions could be avoided by 2030 depending on technological breakthroughs and their rate of adoption: Mayberry et al (2018, p. 33).
25. DISER (2020a).
26. DISER (2021a, p. 301).
27. ABS (2021).
28. The primary options are aerating and composting to reduce methane emissions, and urease inhibitors to reduce nitrous oxide emissions: DPIRD (2020a).
29. CER (2021a). This can reduce piggery emissions by up to 80 per cent: Australian Pork Limited (2021).
30. DISER (2020a). The projection uses agricultural activity growth rates based on historical growth.

vaccines,[31] and dietary or chemical supplements. Of these, the most effective options appear to be dietary supplements of the red algae *Asparagopsis* or the chemical 3-NOP.[32]

Asparagopsis contains a chemical that disrupts methane production in the stomach and can reduce emissions by more than 90 per cent when incorporated into grain-fed cattle's diet.[33] The supplement 3-NOP also disrupts methane production. Its effectiveness has varied considerably in trials, but it may be able to reduce methane emissions by 40-to-90 per cent.[34] These promising results look difficult to replicate in grazing cattle, where the animals' diet is much less controllable;[35] at any one time, about 96 per cent of the national cattle herd is grazing rather than in feedlots.[36] Shifting this proportion is not straight-forward: much of Australia's grazing land is ill-suited for economic activities other than grazing cattle.[37]

There are also practices that can modestly reduce methane emissions per animal. Three examples are harvesting animals at a younger age, selectively breeding for lower-methane production (which can take several generations before being effective), and planting legumes for grazing cattle.[38]

31. The New Zealand Government is funding research aimed at producing a vaccine that can reduce methane from cattle and sheep by 20 per cent: NZAGRC (2021).
32. 3-NOP is 3-nitrooxypropanol.
33. Kinley et al (2020). Methane reductions of 80 per cent have been demonstrated in sheep; future trials may demonstrate better performance depending on dosage and how the supplement is prepared: Kinley et al (2020) and Li et al (2018).
34. Black et al (2021); Honan et al (2021); and MLA (2021a).
35. Incorporating 3-NOP or dried *Asparagopsis* into lick-blocks (which can be scattered around grazing land) may be possible, and this might help with distribution. But it does not solve the challenge of maintaining the right daily dosage for each animal.
36. Australian Lot Feeders' Association (2021).
37. Laut (1988).
38. Mayberry et al (2018, pp. 18–19, 22). Legumes can reduce enteric fermentation emissions by up to 20 per cent.

Raising fewer emissions-intensive animals

Emissions from animals would also fall if farmers raised fewer emissions-intensive animals. Some farmers may be able to switch to lower-emissions animals – such as switching cattle for chickens – or change from livestock production to another commodity, but for many grazing properties this is not an economic option (if it were, farmers would have already made the switch). In some instances, farmers could also switch to higher-value breeds of animal but keep fewer of them.

Livestock numbers and output could also decline due to policy, technology, markets, and climate.

It is possible, but highly unlikely, that a government might choose to directly regulate livestock numbers to limit emissions.[39] However, policy can also have an indirect effect on herd numbers: policies to cap emissions in other sectors could significantly increase demand for offsetting, pushing up the price of carbon credits. Some farmers would recognise this business opportunity and diversify their income, lower their overall risk, and improve farm profitability by redirecting some effort towards carbon credit generation, especially on under-productive land.

Technology could reduce livestock numbers if ways to synthesise animal meat or dairy ('lab-grown' or 'cultured' products) become economically competitive, and consumers globally develop a preference for these products.[40] However, there are major uncertainties here: firstly, the technology remains in its infancy, with no commercial production in Australia;[41] and secondly, a new low-cost method of

39. This approach is being considered in the Netherlands: Boztas (2021).
40. The emissions impact of these products will depend on their supply chains, feedstocks, and energy sources.
41. FSANZ (2021).

making proteins would probably induce more demand for proteins overall.[42]

Markets and consumer preferences have a key role to play. Decreasing demand for emissions-intensive products, such as red meat, could materially reduce emissions.[43] But since most Australian red meat is exported, the demand from consumers abroad is the main factor affecting Australian production decisions, and this demand is expected to grow as global incomes rise.[44] Unlike Australia's fossil fuel exports – which are likely to decline as other countries reduce emissions[45] – animal products contribute only to Australia's emissions, not the importer's. So overseas demand for emissions-intensive commodities such as red meat could remain strong even in decarbonising nations.[46]

Drought on Australia's east coast was largely responsible for the dip in agricultural emissions in 2020.[47] As the climate changes further, the agriculture sector is especially vulnerable to rising risks of drought, heat waves, and other extreme weather. This could affect livestock numbers, or lead to greater use of feedlot systems, which tend to be less affected than grazing herds by drought.

Animal emissions could either rise or fall over the next three decades depending on livestock numbers, technology, and on-farm practices. But they are very unlikely to fall to zero. To achieve net zero, any remaining emissions will eventually need to be offset; in the worst-case scenario, a total lack of progress in the sector could mean 60 million tonnes of annual demand for offsetting credits by 2050, or more if livestock numbers grow.

2.3 Non-animal emissions

Non-animal sources contributed about 16.5 million tonnes of emissions to the agriculture sector's total in 2019.[48] The main sources are fuel combustion, fertilisers and soil additives, and emissions from crop residues.

Fuel combustion across the agriculture, fishing, and forestry industries contributed about 6.7 million tonnes of emissions, as carbon dioxide. The main fuel is diesel, which is used for equipment and vehicles.[49] Fertiliser use leads to nitrous oxide emissions, while using lime and urea on soils produces carbon dioxide emissions.[50] These emissions sources have grown since 2005.

Crop emissions are more varied, and have fluctuated since 2005. The main source is crop residue (organic material left behind after harvest), which ends up in the soil and contributes mainly nitrous oxide emissions – the equivalent of 3.5 million tonnes of CO_2 emissions in 2019.[51] Smaller sources include methane and nitrous oxide emissions from burning residues, and methane emissions from cultivating rice.

42. AFI (2021).
43. Rivera-Ferre et al (2016).
44. Red meat consumption per capita has fallen over the past 20 years in Australia, the US, and Japan, but risen in China and Indonesia. This trend is expected to continue, with a rising share of Australian red meat destined for export: ABARES (2020).
45. Ha (2021).
46. The top five export markets for Australian meat and dairy products are China, Japan, the US, Korea, and Indonesia, all of which have committed to achieve net zero by 2050 or 2060: DFAT (2021) and Wood et al (2021c, p. 32).
47. DISER (2020a, pp. 48, 62).
48. Ibid.
49. DISER (2021a, p. 115). About 77 per cent of the fuel is used in agriculture, with the rest split between fishing and forestry.
50. Lime is used to reduce soil acidity; urea is another type of fertiliser.
51. DISER (2021b).

2.3.1 Future trends and options for action

Non-animal emissions sources are all expected to grow over the coming decade as agricultural production continues to bounce back after the 2017-2019 drought.[52]

Some non-animal sources of emissions are easier to reduce than others, or will be over coming decades. Diesel use can be partly reduced over time through energy efficiency measures, or substantially reduced by electrifying farm equipment. But this latter option also requires low-carbon sources of electricity, such as on-site renewables with storage, or connection to an electricity grid that is also decarbonising. Electric (or potentially hydrogen-powered) equivalents for many farm vehicles and machines are being developed, but are not yet readily available for all purposes.[53]

Asset life is a key variable affecting the extent to which the sector can electrify by 2050. Replacing a machine in the 2040s with a diesel-powered equivalent that lasts a decade or more will lock in emissions beyond 2050. This problem is not unique to agriculture – the transport and industrial sectors both risk locking in substantial emissions beyond 2050, which will require an equivalent amount of emissions to be removed from the atmosphere to reach net zero.[54]

Fertiliser emissions can be reduced by farmers using the right fertiliser in the right quantity at the right time in the right place.[55] Practices such as precision agriculture can help here, with added economic benefits such as less wasted fertiliser.[56] Alternatively, switching to legume crops or pastures in rotation can help increase nitrogen in the soil and reduce the need for fertilisation.[57] Reducing fertiliser use also has environmental benefits: reducing run-off means less excess nutrients in waterways, lowering the risk of toxic algal blooms.[58]

The main source of crop emissions, nitrous oxide from crop residue in the soil, may also be reduced by removing more residue from the field.[59] But leaving residue has benefits for preventing erosion, improving moisture retention, and increasing soil organic matter.[60]

Similarly to the animal emissions, non-animal emissions will be affected by climate change. Rainfall has declined across the main agricultural regions of eastern Australia, and this is trimming profits for farmers – by $18,600 a year for an average broadacre farm.[61] This could lead to lower agricultural activity over the long run, which may reduce emissions. But falling productivity will also weaken farmers' capacity to take on the additional costs of emissions-reducing activities, unless those activities also boost productivity and profitability.

2.4 Land sector emissions

Net emissions from the land sector have fallen from 88 million tonnes in 2005 to negative-26 million tonnes in 2019.[62] Sources of emissions in the sector include land clearing, soil carbon lost from cleared or poorly-managed land, human-induced burning of fuelwood or other biomass, wetland conversion, and methane emissions from wetlands and decaying organic matter. Bushfires can be a source in some instances (Section 2.4.1 on page 20). The sector also contains sinks: carbon dioxide is stored in vegetation as it grows, and in soil carbon

52. DISER (2020a, p. 47).
53. EEC and NFF (2021); Hutton and O'Connor (2021); and Gorjian et al (2021).
54. Wood et al (2021b); and Wood et al (2021c).
55. Agriculture Victoria (2021).
56. CSIRO (2021a).
57. Stagnari et al (2020); and DPIRD (2020b).
58. Burford (2019).
59. Essich et al (2020).
60. Flower et al (2019).
61. Hughes et al (2019).
62. DISER (2021a, p. 12). Net LULUCF emissions for 2019 were updated in DISER (ibid) from those reported in DISER (2020a).

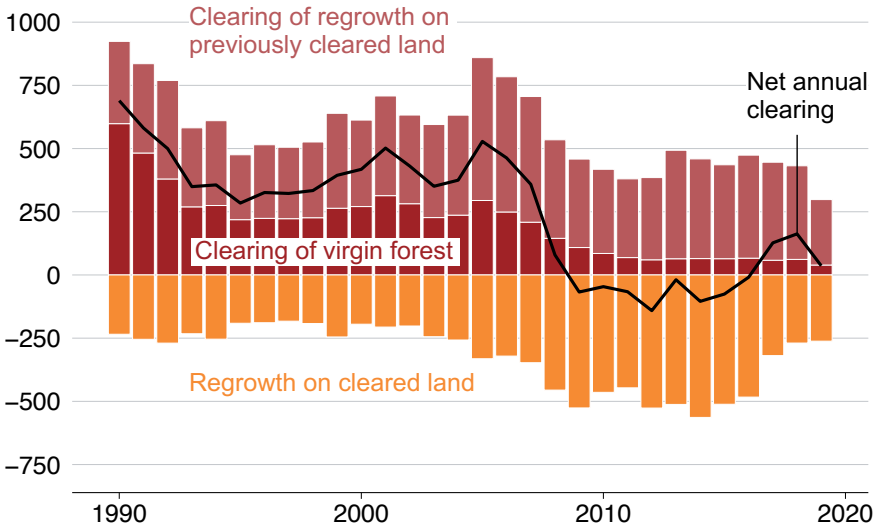
when land is managed well. Since 2016, the sector has been a net sink.

Australia's land sector emissions have declined in recent decades for several reasons. Firstly, an abnormally large amount of forest was converted to pasture or cropland in the early-2000s as landholders in NSW and Queensland rushed to remove vegetation in anticipation of new regulations that would limit future land clearing.[63] This makes 2005 a relatively high baseline year for the land sector. Over the following decade, the NSW and Queensland land-clearing laws, the Millennium Drought, and the 2008-2009 economic slowdown all contributed to much lower levels of clearing. By 2009, the rate of forest clearing had fallen to roughly the rate of forest re-growth (Figure 2.4).[64]

The state land-clearing laws created some controversy, with farm lobbies arguing that farmers had a right to clear their land – and were therefore losing a property right without compensation – despite the environmental costs that their land clearing would impose on society.[65] The Federal and NSW Governments worked together to provide a $436 million funding package to help farmers adjust, but the Queensland Government was unable to negotiate a similar deal, providing just $150 million of assistance from its own balance sheet. This support did not eliminate opposition to the policies.

Today, many emissions reductions associated with land management can earn carbon credits through the Federal Government's Emissions Reduction Fund (ERF). Most of the abatement contracted through the ERF is for vegetation-related projects.[66]

Figure 2.4: There's much less clearing of forests today, and most of it is on land that has previously been cleared
Annual forest clearing (thousands of hectares)



Source: DISER (2021a).

63. Macintosh (2012).
64. DISER (2021c, p. 10).
65. Macintosh (2012).
66. CER (2021b).

2.4.1 Future trends and options for action

Emissions growth from the land sector is projected to outpace emissions removal, making the sector less of a sink across the next decade: compared to the 26 million tonnes of net emissions removed in 2019, less than 5 million tonnes is expected to be removed in 2030.

The land sector is the only sector that has already achieved 'net zero' (and is now 'net negative'), but if its emissions rise then it is less able to offset emissions across the rest of the economy. This will become increasingly important as Australia moves towards net zero: there is likely to be demand for many tens of million of tonnes per year of 'carbon dioxide removal' (CDR) from other sectors in 2050 to offset their remaining emissions.[67] Demand for CDR will depend on how much the rest of the economy has been able to cut emissions, and whether Australia allows the import or export of carbon credits created from CDR.

To prevent emissions rising in the land sector, land clearing in aggregate should remain at or below current levels – clearing in one place should be balanced by reforesting elsewhere. Good soil management on agricultural land can also help to stem the loss of soil carbon. The Federal Government has developed a National Soil Strategy, one of the goals of which is to maintain soil organic carbon.[68] This will be particularly difficult but important in locations where rainfall is projected to decrease due to climate change.[69] Aside from capping emissions, it is also possible to make the sector a better sink: good land management can actively sequester carbon in some instances. This opportunity – and its risks (particularly from a warmer, drier climate) – will be discussed further in the next report in this series, on offsetting.

67. 'Carbon dioxide removal' involves sequestering carbon from the atmosphere and storing it permanently.
68. DAWE (2021a, p. 43).
69. Dooley et al (2020).

Some emissions growth in the land sector may be unavoidable. For example, bushfires are currently not counted towards Australia's national emissions because the carbon lost in a fire should ultimately be re-sequestered as the burnt land regenerates over time. But this will not be the case if the burnt land is either converted to another use,[70] or if climate change means the land can no longer fully regenerate, permanently reducing the carbon stock and creating a new equilibrium.

This is a potential risk that is very difficult to guard against, but could add significantly to land sector emissions. The 2019-20 bushfires released 940 million tonnes of emissions: almost double Australia's reported emissions in 2019.[71] It is expected that eventually those emissions will be fully removed as the forests regrow, but if this is not the case, Australia will need to account for any excess emissions in future emissions reports.[72] This will reduce Australia's remaining carbon budget for the economy unless those excess emissions are offset in another way.

2.5 How the remainder of this report is structured

Chapter 3 identifies immediate steps government can take to promote no-regrets emissions-reducing activities in the agriculture and land sectors. Policies to promote carbon sequestration – removing greenhouse gases from the atmosphere – will be covered in more detail in the next report in this series.

Chapter 4 assesses the impact on other sectors of cutting emissions in the agriculture and land sectors.

70. For example, some forest areas burnt in the 2003 Canberra bushfires were subsequently converted to urban settlements; the emissions impact of this conversion was reflected in Australia's national emissions inventory: DISER (2020b, p. 12).
71. Ibid (p. 9, fn. 4).
72. Ibid (p. 15).

3 What governments should do to help reduce emissions

Net annual emissions from land use are currently negative, but emissions from agriculture total 77 million tonnes and are projected to rise. Achieving deep emissions cuts in the agriculture sector will be technologically and logistically challenging: governments should support emissions-reducing actions that farmers can take today, while co-investing in potential high-impact solutions for the longer term.

Accelerating near-term action means three tasks: encouraging lower-emissions practices through an improved Emissions Reduction Fund; spreading knowledge through a multi-decade farmer outreach program; and determining what financing mechanisms can best assist farmers to manage the risks of deploying new technology and practices.

Improving the long-term emissions outlook for the agriculture sector will require investment in high-impact research, development, and deployment. All governments should consider what combination of subsidies, penalties, and regulations will be necessary to drive the deployment of new technology and bring down its costs. They should also improve data collection on emissions-related activities on farms, and avoid stifling emerging opportunities for farmers such as carbon farming and production of alternative proteins.

For the land sector, the goal should be, at a minimum, to prevent emissions sources from growing larger than emissions sinks. State governments should maintain land clearing laws to prevent a return to the deforestation rates seen in previous decades.

3.1 The agriculture sector must be included in net-zero targets

To achieve net-zero emissions, Australia's annual emissions need to fall as much as is technically and economically feasible, with the remainder offset by removing greenhouse gases from the atmosphere. That means the agriculture sector cannot be excluded from any net-zero target – to have one sector continue emitting without corresponding emissions removals simply means the economy is not at net zero.

Other countries, and previous domestic climate policies, have excluded agriculture from emissions targets on the grounds that it is too challenging, technically, financially, and politically.[73] But until economy-wide net zero is achieved, Australia will continue making climate change worse.

Deep emissions cuts in the agriculture sector do not look easy over the next decade due to a lack of technological options for reducing methane emissions – especially for grazing cattle and sheep.[74] And fully eliminating emissions from the sector is not realistic – even highly-efficient food production will still cause some greenhouse gas production.[75] But even if that means agriculture will cut emissions more slowly than other sectors, there are still immediate actions available (described in Chapter 2) that can both benefit farmers and start contributing to a net-zero goal. Taking these emissions-reducing actions will mean diversified income sources for farmers, improved resilience as the climate and the world economy change, greater productivity, and fewer emissions requiring offsetting in the future.

73. Shankleman (2021); and Collerton (2011).
74. This assumes production of emissions-intensive products such as red meat remains at similar levels – emissions could fall substantially if production also fell, or if farmers switched to commodities that are less emissions-intensive (Section 2.2.1 on page 16).
75. Upton (2019, p. 107). In scenarios where the 2℃ goal of the Paris Agreement is met, there will still be some net methane and nitrous oxide emissions globally, but the world will more than offset these by removing more carbon from the atmosphere than it emits each year (net-negative emissions): IPCC (2021).

Eventually, to reach net zero, *someone* will need to pay for emissions-removing activities to offset the sector's remaining emissions: either the emitting farmers themselves, their consumers, or taxpayers. This situation is not unique to agriculture: in the industrial sector, any emissions remaining after 2050 will require offsetting, either at the expense of the polluting businesses (with pass-through to customers) or taxpayers. Similarly with any vehicle emissions in the transport sector: if the cost of offsetting is not paid by drivers/passengers, then it will fall to the taxpayer to purchase emissions removals.

Deciding who will eventually pay is an urgent priority for businesses that cannot easily and quickly cut emissions – either because long-lived infrastructure is involved, or because changing activities might require new skills. Business decisions that lock in emissions may also lock in liability to offset those emissions.

If agricultural emissions fall only slowly over the next few decades, there will be a large and ongoing offsetting task each year from 2050, which will place a cost somewhere in the economy – possibly on the emitters themselves. This may not be of immediate concern to today's farmers, but it could well leave the legacy of an ongoing financial burden for the next generation of farmers – who will also be the ones to bear the brunt of climate change.

Some of the value of offsetting payments is likely to stay within the sector, because the farmers who remove carbon dioxide from the atmosphere will be able to generate and sell carbon credits. Farmers stand to benefit from the rest of the economy's demand for carbon dioxide removal. As the price of carbon credits rises, more and more farmers will be able to profitably sequester carbon dioxide in trees or soils.[76]

76. CSIRO (2019, pp. 65–67).

Farmers are already earning money from selling carbon dioxide removal credits to businesses in other sectors. By reducing emissions within their own sector, farmers can minimise their own future offsetting liability and maximise the quantity of credits available to sell to the rest of the economy (Box 4 on the next page). This opportunity will be discussed in greater detail in our next report.

To reduce agricultural emissions, governments can use incentives, liabilities, and regulation. Current political realities suggest governments would prefer to use only some incentives to reduce emissions in the near-term. Since the repeal of Australia's carbon price in 2014, the most significant program to encourage lower-emissions activities is the Federal Government's Emissions Reduction Fund.[77] The remainder of this chapter focuses on policies – largely building on existing programs – that governments can implement now to help get the sector moving in the right direction.

3.2 Encourage action today by sharpening incentives, spreading knowledge, and sharing risk

3.2.1 Improve and expand the Emissions Reduction Fund

The Emissions Reduction Fund (ERF) is the Federal Government's main method of securing emissions reductions. It is administered by the Clean Energy Regulator (CER).

Specific emissions-reducing projects can be registered under the ERF. If they succeed in reducing emissions, the project developer (the 'proponent') is awarded Australian Carbon Credit Units (ACCUs) for each tonne of emissions saved.[78]

77. The Large-scale Renewable Energy Target also operated over this period; it imposed a liability within a market structure to drive deployment of renewable energy and reduce electricity sector emissions. It is largely finished now: DISER (2021d).
78. Whether a project succeeds in reducing emissions or not is determined by adherence to the criteria set by the CER. In reality, that means the actual delivered

Unlike an economy-wide carbon price, which would encourage any and all emissions reductions, the ERF can reward only certain types of verifiable emissions-reducing activities.[79] These activities are defined by 'ERF methods'. An example is the 'Animal effluent management method', where carbon credits can be awarded for burning methane from animal waste or treating the waste to reduce methane and nitrous oxide emissions.[80] Methods are designed to ensure abatement activities would not have happened under a business-as-usual scenario (that is, they aim to ensure proponents are rewarded only for 'additional' activities that would not occur without ERF support).[81]

Complexity and the administrative cost of participating in the scheme deters potential proponents of many small projects.[82] Only about 200 projects related to agricultural emissions have been registered, despite there being more than 50,000 broadacre farms in Australia.[83]

Proponents can either bid at auctions to win Federal Government contracts for their abatement, or try to sell their ACCUs to private buyers (who may want them to voluntarily offset their emissions or to meet emissions obligations under the Federal Government's Safeguard

abatement could be lower or higher. There are risks that actual abatement will be lower for some methods – particularly sequestration ones – than the number of ACCUs awarded: Roxburgh et al (2020) and Climate Council (2020).

79. Burke (2016).
80. CER (2021a).
81. This 'additionality' requirement may have been weakened substantially for some project types, in which case ACCUs have been awarded for activity that would have happened anyway. This represents a direct financial transfer from credit purchasers (generally taxpayers via the Federal Government) to project proponents with no emissions benefit: Baxter and Gilligan (2017) and Merzian et al (2021).
82. CCA (2020, p. 45).
83. ABARES (2021b). More land sector projects have been registered: there are about 650 projects related to vegetation, and about 100 related to savanna burning, out of about 1,000 projects in total: CER (2021c).

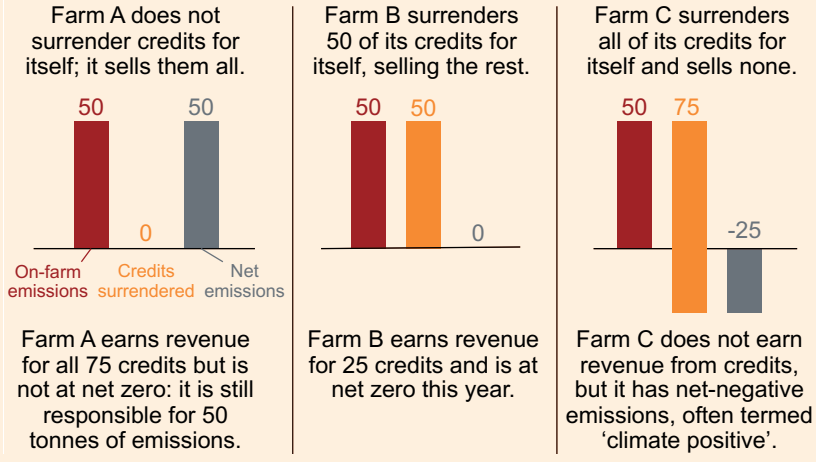
Box 4: Accounting for carbon credits and emissions

Depending on the climate and landscape, some farms will be able to remove carbon dioxide from the atmosphere and store it in vegetation or soil. If the carbon is stored permanently, this should generate a carbon credit for the landholder.

The landholder can then sell the credit to other emitters to offset their emissions – one tonne of carbon dioxide removed from the atmosphere roughly cancels out one tonne of emissions. But if agricultural activities on the farm also produce emissions, then the landholder will need to offset those first to be able to claim that their operations are carbon neutral or that the farm is at 'net zero'. The same logic extends to sectors: the agriculture and land sectors may sell credits to the rest of the economy, but will also need to fully offset their own emissions to achieve net zero.

Figure 3.1: Hypothetical scenario – three identical farms, three different climate credentials

In a year, Farms A, B, and C emit 50 tonnes of emissions and permanently remove 75 tonnes of CO_2 from the atmosphere, receiving 75 carbon credits.



Mechanism).[84] In practice, the vast majority of ACCUs has been bought under contract by the Government.[85] This means taxpayers are funding a number of emissions-reducing activities.

Recent reviews of the ERF have found several ways to unlock additional abatement within the current framework, especially for small, dispersed emitters such as farmers.[86] The Federal Government has agreed to several of the recommendations from the 2020 King Review, and it should implement them quickly.[87] The most relevant for reducing agricultural emissions include:

- Accelerating the creation of new ERF methods to broaden the range of emissions-reducing activities that are encouraged;[88]
- Allowing multiple ERF methods within one project application, to reduce paperwork for small landholders;
- Establishing dedicated small-scale ERF methods with a fixed-price purchasing desk to allow access to the fund for landholders too small to participate in an auction; and
- Developing an ACCU exchange with additional credit details, to allow differential pricing for credits with social or environmental co-benefits.[89]

84. The Safeguard Mechanism is a policy designed to limit emissions from large industrial facilities. It is explained in detail in the previous report in this series: Wood et al (2021c).
85. RepuTex Energy (2021). In 2020-21, the Federal Government was responsible for 89 per cent of ACCU demand, compared to 6 per cent for voluntary buyers, 5 per cent for speculators and liquidity providers, and just 0.5 per cent for Safeguard Mechanism compliance.
86. DISER (2020c); and CCA (2020).
87. Australian Government (2020).
88. For the agriculture sector, this could include additional methods for reducing animal methane emissions, provided any reductions can be reliably verified.
89. The CER is working to develop an exchange by 2023: CER (2021d).

The ERF has a finite budget which it depletes as it pays for abatement projects. It relies on the Federal Government for top-ups. The Government's Climate Change Authority has noted that uncertainty about the quantum and timing of funding for the ERF makes it harder for proponents to develop new abatement projects – it is difficult to predict in advance how much abatement will be purchased and at what price.[90]

Strengthening demand signals for ACCUs would give proponents confidence to do early work and register their projects with the ERF. The Federal Government should provide a clear statement on the future role of the ERF, its desired outcomes, and the level and timing of future funding. Longer term, the Government should step back from being the primary purchaser of abatement through the ERF – this will require policies that effectively drive demand for credits from emitting businesses.

Maintaining the integrity of the ERF is crucial. New and existing methods should be regularly scrutinised, and appropriate discount factors should be applied to all projects depending on how uncertain the actual level of abatement delivered will be.[91]

The next report in this series will outline further reforms to ensure the ERF functions effectively.

3.2.2 Provide long-term support for the extension programs necessary to deploy new tools and practices

Achieving net zero by 2050 will require rapid deployment of existing low-emissions practices and new ones as they become available. Yet farmers may face information gaps and a lack of human resources

90. CCA (2020, pp. 8–9).
91. Some discount factors are already applied to manage the risk that sequestered emissions may in future be lost – these should be updated regularly using the most up-to-date information: CCA (ibid, p. 17).

to concurrently run the farm while implementing emissions-reducing practices. More than 80 per cent of farm businesses are small or medium-sized operations, with annual revenue less than $1 million.[92]

Lowering this barrier is vital: Australia should not just wait for emissions-reducing technology to passively diffuse through the agriculture sector.

Extension programs provide educational outreach services to farmers. They involve experts (extension officers) working with farmers to share knowledge about best practice, plan farm activities, and assist in decision making. Extension programs play a key role in knowledge dissemination.

Extension work is generally labour-intensive, often requiring face-to-face meetings with farmers on-site. There are more than 50,000 broadacre and dairy farms in Australia.[93] Spreading new practices can therefore be a slow process. The degree of success is influenced by the level of trust between farmers and extension officers.[94]

Extension programs are offered by governments, rural research and development corporations (RDCs),[95] regional natural resource management organisations (NRMs),[96] product merchants, independent fee-for-service consultants, processing companies, and others.[97]

The Federal Government has previously contracted for extension programs targeted at reducing emissions. The 'Carbon Farming Futures Extension and Outreach' program funded 24 projects between 2013 and 2017, which were aimed at increasing farmers' and land managers' knowledge of emissions management and the ERF.[98] Grant recipients included RDCs, NRMs, private companies, and an Aboriginal land council. The program supported almost 2,000 face-to-face workshops, presentations, and individual extension activities, reaching tens of thousands of farmers.[99]

The Federal Government should establish a similar program designed to run over at least the next decade, focused on emissions management, carbon credit opportunities, and climate resilience.[100] Bolstering the number of extension officers trained in emissions management could help to lower a key barrier to the uptake of new technology and practices. This will help to accelerate the deployment of new technologies and the enrolment in new ERF methods as they become available.

3.2.3 Consider whether alternative financing mechanisms may be necessary

Changing practice can be risky, and may require an upfront investment (or temporarily foregoing some revenue). For example, electric or hydrogen-powered farm machines (as they become available) are likely to have higher sticker prices than diesel-power equivalents for several years, but lower running costs.[101] Likewise, planting trees on sections of a farm to earn credits through the ERF involves initial capital expenditure, but then generates carbon credits over time as carbon

92. ABARES (2021a).
93. ABARES (2021a) and ABARES (2021b). Broadacre farms include large-scale cropping and grazing farms.
94. Kancans et al (2014, p. 80).
95. These RDCs typically cover a commodity (e.g. Meat and Livestock Australia assists red-meat producers) and are also responsible for marketing and R&D. They are partially funded by industry levies and government contributions.
96. These 56 organisations are responsible for delivering the regional stream of the Federal Government's National Landcare Program: DAWE (2021b).
97. Nettle et al (2018).
98. DAWE (2020a).
99. Grosvenor Management Consulting (2017, pp. 59–69).
100. Climate resilience should be included because the topics of adaptation and productivity are likely to boost engagement with outreach activities: Grosvenor Management Consulting (ibid, p. 5).
101. Gao and Xue (2020) and Gorjian et al (2021). Tractors and combine harvesters make up about two-thirds of total expenditure on farm machinery: ACCC (2021a).

dioxide is gradually absorbed by the growing trees. The gap between when expenses are incurred and when abatement is recognised (and rewarded) can make obtaining finance difficult.[102]

Governments should investigate under what circumstance they may complement commercial lending, such as through providing concessional loans or income-contingent loans for farmers attempting to switch to new, lower-emissions practices. The Federal Government already provides concessional finance for some agricultural investments.[103] Income-contingent loans could function similarly to those in the higher education sector: the loan is provided at low cost (potentially at a zero real interest rate), and repayments are only required once a project achieves a specified revenue.[104] As emissions policy, this could mean the loan is provided specifically to partly or fully fund the upfront cost of an ERF project, with repayment required once the project starts generating ACCUs.

Another possible option for managing the upfront cost of emissions-reducing activities is to award eligible projects with carbon credits before the abatement actually occurs.[105] This is known as 'compressed crediting' and it effectively brings the project's future revenue forward. However, there are substantial risks if the abatement is never delivered – credits may have already been sold and surrendered, despite representing no actual abatement. Concessional financing is a better approach for ensuring the integrity of carbon credits.[106]

102. DISER (2020c, pp. 40–44); and Polglase et al (2011).
103. RIC (2021). A new loan for plantations is being developed.
104. Chapman and Lindenmayer (2019).
105. Some methods already do this to reduce complexity and encourage uptake: DISER (2020c, p. 41).
106. CCA (2020, pp. 54–55).

3.3 Improve the long-term outlook for emissions reduction by supporting new technologies and opportunities

For this decade, it is difficult to see emissions in the agriculture sector falling in line with a net-zero target while output grows. Much like the industrial sector, key emissions-reducing technologies remain immature.[107] Eliminating or substantially reducing methane from grazing cattle and sheep remains an unsolved challenge. Development of electric farm machinery is significantly lagging behind development of electric passenger vehicles.

But unlike the industrial sector, in the agriculture sector there is no handful of mega-emitters to target.[108] So in addition to technological solutions, widespread behaviour changes will be necessary to significantly cut emissions in this sector. These include more efficient fertiliser application, better manure management, protecting soil health, reducing slaughter age, and deploying other emissions-reducing technologies (such as electric vehicles, and supplements and vaccines) as they become available.

In addition to technology investment, comprehensive data on emissions and practices across the sector is required. This will enable accurate accounting of agriculture emissions in Australia's national emissions reporting, and create opportunities for farmers in selling products with certifiable emissions-intensities.

There will be opportunities for some farmers to earn more revenue from sequestering carbon than continuing with their current practices. Governments should not prohibit farmers from discontinuing agricultural

107. Wood et al (2021c).
108. Companies with emissions (scope 1 and 2) greater than 50,000 tonnes per year, or facilities that produce more than 25,000 tonnes per year, must report their annual emissions under the National Greenhouse and Energy Reporting (NGER) scheme: CER (2021e). These large emitters were responsible for less than 1 per cent of all agricultural emissions in 2015-16: CER (2019).

activities in favour of generating carbon credits, provided that the farmers understand the risks and obligations and that these projects (and their impacts on others) are managed well.

There is also a major export opportunity for Australia in producing plant-based and other alternative meat and protein products. The Federal Government should help unlock this opportunity by reducing regulatory barriers for novel products.

3.3.1 Expand government support for emerging low-emissions technologies

The Federal Government has taken a technology-focused approach to emissions reduction.[109] Applying this to agriculture could be fruitful – many of the technologies necessary to make substantial emissions reductions remain immature, and the extent to which they might be feasibly deployed is uncertain (for example, getting feed supplements to grazing cattle and sheep). The Federal Government should elevate technologies to reduce animal emissions to priority status in its Low Emissions Technology Statements.[110]

Government support for technology should be guided by key principles. They should focus on areas of high impact. For instance, technologies that reduce methane from enteric fermentation could significantly cut agricultural emissions, both in Australia and globally. On the other hand, devoting significant resources to improving on-farm diesel generator efficiency may be a poor investment, given that decentralised electricity solutions such as solar panels and batteries are likely to reduce diesel demand anyway.

Governments should use their investments to leverage private-sector involvement. The industries that stand to benefit most from the technology should also contribute to the cost of research and development.

Governments must also complement their investments with policies to actually drive deployment of new technology. This is particularly important for technologies that may not ever be cost-competitive. For example, while new animal feeds may reduce methane emissions and boost animal productivity, the costs of providing the feed might outweigh the productivity benefits. In the absence of a sufficiently high carbon price, there will be very little uptake of this technology. Yet without deployment at scale, it will be difficult to bring the cost of the technology down further.

Governments could take several actions that meet these principles.

- The Federal Government should immediately introduce legislation to expand the remit of the Australian Renewable Energy Agency (ARENA), to allow it to fund emissions-reducing technologies in the agriculture sector. This would also require additional funding for ARENA. To avoid legislation being held hostage to partisan debates (as has happened in the past), the amendment bill should focus only on agriculture.[111] ARENA has a proven history of helping to develop pre-commercial innovations; expanding it could take advantage of institutional knowledge and governance structures, without needing to create a new institution.
- For especially emissions-intensive activities (such as red meat and dairy), the relevant peak bodies should seek industry approval to double their R&D levies.[112] These levies are paid to research and development corporations (RDCs), and largely matched

109. DISER (2020d).
110. Ibid (p. 25).
111. Macdonald-Smith et al (2021).
112. Industry levies can be varied if supported by levy payers: DAWE (2020b, p. 8).

by contributions from the Federal Government.[113] The relevant RDCs – Meat and Livestock Australia (MLA) and Dairy Australia – should be required to spend the additional funding strictly on emissions-reducing R&D and extension. MLA received about $120 million in levies in 2020-21 (mostly in marketing levies rather than R&D levies), with a contribution of $86 million from the Federal Government.[114] Levies represent less than 0.5 per cent of the revenue from red meat and livestock sales.[115] Producers would not bear the full cost of the increased levy; they would pass some of the cost through to the consumers of their higher-emissions products. Even in the absence of higher levies, the RDCs could re-allocate a greater proportion of their spending towards emissions-reducing R&D and extension.[116]

- As technologies to reduce agricultural emissions become available, governments will need to consider what combination of subsidies, penalties, and standards/mandates will drive deployment and bring costs down. Expanding the methods to create carbon credits through the ERF is important, but the Federal Government targets the lowest-cost abatement in its ERF auctions – the price paid for credits may be too low to make new technologies economic to deploy.[117] Deployment policies that target specific technologies will be needed. For example, the Federal Government is trialling a small, $4 million Methane Emissions Reduction in Livestock program to help support early-adopters of new methane-reducing food supplements.[118] Governments could also set aspirational or mandatory targets for deployment of technologies (such as methane-reducing vaccines, if and when they become available). Compliance could be encouraged with soft policy (such as an accreditation scheme) or hard policy (such as financial penalties for failure to meet the target).

113. Federal Government contributions are capped at 0.5 per cent of the industry's gross value product: Department of Agriculture (2019, p. 34). Legislation related to agricultural levies is currently under review, with a draft of new legislation anticipated in 2022: DAWE (2021c).
114. MLA (2021b); and MLA (2021c).
115. MLA (2020b).
116. MLA plans to spend 4-to-6 per cent of its revenue on environmental sustainability R&D and extension over the next five years: MLA (2020c, p. 42).
117. The Federal Government is the majority buyer of ACCUs, and the average price paid per ACCU was $16 at the April 2021 ERF auction: CER (2021b).

3.3.2 Create a framework for collecting and managing emissions data

Better data about on-farm, emissions-reducing practices are necessary so that the agriculture sector's overall emissions can be monitored and not overstated. While national energy emissions can be determined from fuel sales data, and some nitrogen emissions can be estimated from fertiliser sales, animal emissions are harder to estimate. Practices that reduce animal emissions (such as feed supplements) will require reporting and auditing, especially since sales of these technologies do not guarantee an emissions reduction – particularly for grazing animals.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) regulates and tracks agricultural and veterinary chemicals up to point of sale.[119] The Federal Government should require it to also track the sales of emissions-reducing supplements or vaccines, if and when they become available. Sampling audits could then determine how much of the supplement is actually making it into the animals; comparing this number to the APVMA record of sales would enable governments to better estimate animal emissions.

Collecting accurate farm-level data will be necessary if governments decide to implement technology deployment targets as outlined in Section 3.3.1. Any low-emissions certification scheme will similarly

118. DISER (2021e).
119. APVMA (2014).

require farmers to be able to estimate their direct emissions impact with reasonable accuracy. Extension program officers should assist farmers to do this carbon accounting.

3.3.3 Avoid stifling new agricultural opportunities with unnecessary or outdated regulation

There are economic opportunities for farmers in both carbon sequestration and alternative-protein production. But both areas have attracted some community and ministerial criticism.[120] Governments should encourage the responsible uptake of these opportunities; governments should not impose or allow regulatory barriers to limit farmers' abilities to secure diverse revenue streams.

Carbon farming

Some concerns about carbon sequestration on agricultural land are valid. Re-vegetated land that is poorly managed can cause problems such as fire, weeds, and pests, for other farmers. Land used to generate carbon credits should be managed appropriately to minimise these risks.

Governments are already trialling ways to encourage better land management that rewards farmers for more than just the carbon they sequester – examples include the Federal Government's 'Carbon + Biodiversity Pilot', the Queensland Government's Land Restoration Fund, and WA's Carbon Farming and Land Restoration Program.[121] Improving farmers' land management practices is critical even aside from the potential climate benefit: farmers are responsible for managing 56 per cent of Australia's land,[122] and good land management underpins productivity, sustainability, and economic resilience.

There are also concerns that carbon farming may lead to farmers 'locking up' their land (converting all their land to carbon farming) and leaving the region, with knock-on effects for the local community.[123] This is unlikely to be the case except when the farmer's land is so marginal that generating carbon credits is much more economically viable than any other agricultural activity. It is hard to see why some landowners should be forced to live in the same place when the same expectation does not apply to other landowners.

Generally, carbon farming is more likely to co-exist with agricultural activities, because there are productivity benefits associated with many carbon-sequestering measures such as planting shelterbelts or improving soil carbon.[124] Governments should not limit farmers' rights to pursue diversification on their land and create resilient revenue streams.

Alternative proteins

Alternative proteins represent a major economic opportunity for Australia, and a potential lower-carbon food source for the world.[125] Today, these proteins are mainly plant-based meat or dairy products; in the near future, there will also be companies selling identical milk and meat products grown in the laboratory (e.g. meat consisting of animal tissue but not from a slaughtered animal – sometime called 'cultured meat'). To meet growing global demand for protein, the CSIRO is aiming to create new Australian protein products (including

120. McCosker (2021); Le Messurier (2019); Grattan (2021); and Littleproud (2021).
121. DAWE (2021d); Queensland Government (2021); and DPIRD (2021).
122. ABARES (2021c).
123. See, for example, McCosker (2021) and Grattan (2021).
124. For example, EY (2021) estimates that the agriculture sector could offset its own emissions in 2050 primarily through better land management and integrating shelterbelts, with reforestation occurring on just 0.9 per cent of total agricultural land.
125. For this reason, the Clean Energy Finance Corporation has supported an alternative protein start-up, 'All G Foods', through its Innovation Fund: CEFC (2021). The supply chain and land use impacts of these products will determine their effect on emissions.

animal-based, plant-based, and novel proteins) that will earn an additional $10 billion in revenue by 2027.[126]

There is some concern in the agriculture sector that these alternative protein products will shrink the market for traditional proteins. But rising demand for proteins, particularly overseas, is likely to see both industries grow. Some traditional protein producers are already investing in these new technologies.[127] The main challenges for traditional protein producers in Australia are likely to be supply-side issues (rather than changes in consumer demand), such as declining land productivity, water availability, and the need to reduce emissions.[128]

A Senate Inquiry is considering how alternative protein products are labelled, among other issues.[129] The Australian Consumer Law (ACL) protects consumers from misleading information. The ACCC does not consider it very likely that alternative protein products have breached the ACL.[130]

The Federal Government should focus on removing any regulatory roadblocks to innovative food products, so that each product can compete on merit. The Government should ask Food Standards Australia New Zealand to draft new rules to accommodate cultured meat and dairy products.[131] Easing their path into the domestic market will boost consumer choice, and could help Australian companies to develop the capacity needed to capture the substantial alternative-protein export opportunity that is emerging.

126. CSIRO (2021b).
127. Eden Brew is an Australian company formed in 2021 that focuses on non-animal dairy products. It is backed by Norco, a dairy cooperative consisting of 326 dairy farmers: CSIRO (2021c).
128. Admassu et al (2019, p. 64).
129. Senate Standing Committees on Rural and Regional Affairs and Transport (2021).
130. Only a court can determine whether the ACL has been contravened, but the ACCC has not received complaints about alternative protein products that it believes a court would be likely to find in breach of the law: ACCC (2021b).
131. These products are not yet available in Australia. Singapore was the first country to approve them; they have been available there since 2020: Piper (2020).

3.4 State and territory governments should not weaken existing land clearing laws

Regulating land clearing contributed to dramatic reductions in emissions from the land sector over the past few decades (see Section 2.4 on page 18). State governments should protect the remaining nature-based carbon stock, and aim to increase it over time. This does not mean preventing all vegetation clearing – land clearing is necessary to keep some agricultural land productive and to reduce fire risk, and responsible forestry can sequester carbon over time in durable wood products.[132] Instead it means ensuring that clearing or land degradation in one location is offset by regrowth or land restoration elsewhere. The goal should be to ensure that the land sector stays at or below net zero – it should continue to remove more carbon from the atmosphere each year than it emits.

As a first step, states should not weaken existing land clearing laws. If extension programs deliver productivity-enhancing advice (as outlined in Section 3.2.2 on page 24), then agricultural output can increase without requiring additional land, reducing the pressure to clear native forest.[133]

Policies to increase the stock of nature-based carbon by removing greenhouse gases from the atmosphere will be discussed in more detail in the next report in this series.

132. Hepburn et al (2019).
133. This is especially important given that the Federal Government has set a goal to boost the output of the agriculture sector from about $70 billion in 2020-21 to $100 billion by 2030: DAWE (2021e).

4 Implications for other sectors

4.1 The agriculture and land sectors will affect one another

The agriculture and land sectors are closely connected because most of Australia's land mass is used for agricultural activities. Action – or lack thereof – to reduce emissions in the agriculture sector has implications for what the land sector must do to meet a national economy-wide target of net-zero emissions by 2050.

If the agriculture sector does not reduce its emissions substantially by 2050, then tens of millions of tonnes of emissions will require offsetting. This will add to the demand for offsets from other sectors: hard-to-abate activities such as aviation, other heavy transport, some industrial processes, and remaining fugitive emissions from fossil fuels are already expected to need offsetting in 2050.

To meet this demand, only two options are plausible: the land sector will need to sequester much more carbon than it does now, or alternative negative-emissions technologies will need to be deployed.[134]

If the land sector is the primary means of removing emissions, then some farmers will benefit by undertaking emissions-removing activities on their property. The least-productive agricultural land may be able to generate higher revenue from switching to sequestering carbon and generating offsets – carbon would become the primary commodity. If the price of offsets rises substantially, there could be a significant re-allocation of land away from agricultural activities and towards carbon sequestration.[135] Rural landholders may enjoy greater profits than previously, and overall emissions from agricultural activities may fall as a result.

134. An example would be industrial facilities that extract carbon dioxide from the air and store it permanently underground, an expensive process known as 'DACCS'.
135. CSIRO (2019, pp. 65–67).

4.2 Implications for the electricity, transport, and industrial sectors

A decarbonising agriculture sector could affect emissions in each of the electricity, transport, and industrial sectors, but only modestly.

For instance, switching on-farm equipment from diesel to electricity may marginally increase grid demand, but not nearly as significantly as decarbonising the transport sector would. Similarly, demand for electric vehicles on farm properties may modestly increase overall demand for electric vehicles in Australia, spurring deployment of high-capacity electric charging or hydrogen re-fuelling stations in regional areas. More efficient use of fertiliser may reduce overall demand for and therefore production of fertiliser (which is made using an emissions-intensive industrial process). But domestic production of fertiliser is insufficient to meet demand – most fertiliser is imported[136] – so the overall emissions impact in Australia would probably be very modest.

Conversely, decarbonisation of other sectors may also affect agriculture and land emissions. If biomass is used to produce renewable fuels (either for transport or industry), then waste residues from agricultural and forestry activities could become more valuable.[137] Depending on demand for low-emissions fuels, some farmers may produce biomass explicitly for this market.

The next report in this series will focus on the role of offsetting to meet Australia's net-zero goal.

136. Thompson (2021).
137. Wood et al (2021b, p. 33).

Bibliography

ABARES (2020). *Meat consumption*. Australian Bureau of Agricultural, Resource Economics and Sciences. https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/meat-consumption.

_____ (2021a). *Snapshot of Australian Agriculture 2021*. Australian Bureau of Agricultural, Resource Economics and Sciences. https://www.agriculture.gov.au/abares/products/insights/snapshot-of-australian-agriculture-2021#around-70-of-agricultural-output-is-exported.

_____ (2021b). *Farm performance: broadacre and dairy farms, 2018–19 to 2020–21*. Australian Bureau of Agricultural, Resource Economics and Sciences. https://www.agriculture.gov.au/abares/research-topics/surveys/farm-performance.

_____ (2021c). *Catchment scale land use profile dashboard – Natural Resource Management regions*. Australian Bureau of Agricultural, Resource Economics and Sciences. https://www.agriculture.gov.au/abares/aclump/land-use/catchment-scale-land-use-profile-nrm.

ABS (2021). *Agricultural Commodities, Australia: 2019-20*. Australian Bureau of Statistics. https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release#livestock.

ACCC (2021a). *Agricultural machinery market study*. Australian Competition and Consumer Commission. https://www.accc.gov.au/publications/agricultural-machinery-market-study-final-report.

_____ (2021b). *ACCC submission to the Senate Rural and Regional Affairs and Transport Legislation Committee's inquiry into the definitions of meat and other animal products*. Australian Competition and Consumer Commission. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Rural_and_Regional_Affairs_and_Transport/DefinitionsofMeat/Submissions.

Admassu et al (2019). Admassu, S., Fox, T., Heath, R. and McRobert, K. *Alternative proteins in Australian agriculture*. AgriFutures. https://www.agrifutures.com.au/wp-content/uploads/2020/02/20-001.pdf.

AFI (2021). *Protein definition 'wars' benefit none*. Australian Farm Institute. https://www.farminstitute.org.au/publication/protein-definition-wars-benefit-none/.

Agriculture Victoria (2021). *Nitrogen fertilisers — improving efficiency and saving money*. Department of Jobs, Precincts and Regions. https://agriculture.vic.gov.au/climate-and-weather/understanding-carbon-and-emissions/nitrogen-fertilisers-improving-efficiency-and-saving-money.

Allen et al (2018). Allen, M. R., Shine, K. P., Fuglestvedt, J. S., Millar, R. J., Cain, M., Frame, D. J. and Macey, A. H. "A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation". *npj Climate and Atmospheric Science* 1.16. https://doi.org/10.1038/s41612-018-0026-8.

APVMA (2014). *Monitoring*. Australian Pesticides and Veterinary Medicines Authority. https://apvma.gov.au/node/32.

Australian Academy of Science (2021). *The risks to Australia of a 3°C warmer world*. Australian Academy of Science. https://www.science.org.au/supporting-science/science-policy-and-analysis/reports-and-publications/risks-australia-three-degrees-c-warmer-world.

Australian Government (2020). *Australian Government response to the Final Report of the Expert Panel examining additional sources of low-cost abatement ('the King Review')*. https://www.industry.gov.au/data-and-publications/government-response-to-the-expert-panel-report-examining-additional-sources-of-low-cost-abatement.

Australian Industry Group (2021). *Swings and Roundabouts: The unexpected effects of Carbon Border Adjustments on Australia*. Australian Industry Group. https://www.aigroup.com.au/news/policies/2021/swings-and-roundabouts-the-unexpected-effects-of-carbon-border-adjustments-on-australia/.

Australian Lot Feeders' Association (2021). *Frequently asked questions*. Accessed 31 August 2021. Australian Lot Feeders' Association. https://www.feedlots.com.au/faq.

Australian Pork Limited (2020). *Strategic plan 2020-2025*. Australian Pork Limited. https://australianpork.com.au/sites/default/files/2021-06/APL-Strategic-Plan-2020-2025.pdf.

_____ (2021). *Renewable energy (Biogas)*. https://australianpork.com.au/environmental-practices/renewable-energy-biogas.

Baxter, T. and Gilligan, G. (2017). *Australian Journal of Environmental Law* 4, pp. 1–29. ISSN: 2204-1613. https://search.informit.org/doi/10.3316/informit.213968113774497.

BCA (2020). *Scoping Paper - energy and climate change policy*. Business Council of Australia. https://www.bca.com.au/scoping_paper_energy_and_climate_change_policy.

_____ (2021). *Living on borrowed time: Australia's economic future*. Business Council of Australia. https://www.bca.com.au/discussion_paper_living_on_borrowed_time.

Black et al (2021). Black, J. L., Davison, T. M. and Box, I. "Methane Emissions from Ruminants in Australia: Mitigation Potential and Applicability of Mitigation Strategies". *Animals* 11.4. https://www.mdpi.com/2076-2615/11/4/951.

Boztas, S. (2021). "Netherlands proposes radical plans to cut livestock numbers by almost a third". *The Guardian*. 9 September. https://www.theguardian.com/environment/2021/sep/09/netherlands-proposes-radical-plans-to-cut-livestock-numbers-by-almost-a-third.

Burford, M. (2019). "Explainer: what causes algal blooms, and how we can stop them". *The Conversation*. 10 January. https://theconversation.com/explainer-what-causes-algal-blooms-and-how-we-can-stop-them-109646.

Burke, P. J. (2016). "Undermined by Adverse Selection: Australia's Direct Action Abatement Subsidies". *Economic Papers: A journal of applied economics and policy* 35.3, pp. 216–229. https://doi.org/10.1111/1759-3441.12138.

Cattle Council of Australia (2021). *Environment and Sustainability*. Cattle Council of Australia. https://cattlecouncil.com.au/policy-development/environment-and-sustainability.

CCA (2014). *2014 Renewable Energy Target Review – Report*. Climate Change Authority. https://www.climatechangeauthority.gov.au/reviews/2014-renewable-energy-target-review-report.

_____ (2020). *Review of the Emissions Reduction Fund*. Climate Change Authority. https://www.climatechangeauthority.gov.au/sites/default/files/2020-11/ERF%20Review%20Final%20Report%2020201009_2.pdf.

CEFC (2021). *Australian made, low carbon and delicious: the All G Foods recipe for alternative proteins*. 6 September. Clean Energy Finance Corporation. https://www.cefc.com.au/media/media-release/australian-made-low-carbon-and-delicious-the-all-g-foods-recipe-for-alternative-proteins/.

CER (2019). *Australia's scope 1 emissions by industry for NGER reporters*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/a-closer-look-at-emissions-and-energy-data/australia%E2%80%99s-scope-1-emissions-by-industry-for-nger-reporters.

_____ (2021a). *Animal effluent management method*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/ERF/Pages/Choosing%20a%20project%20type/Opportunities%20for%20the%20land%20sector/Agricultural%20methods/Animal-effluent-management-method.aspx.

_____ (2021b). *Auction April 2021*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/ERF/auctions-results/april-2021.

_____ (2021c). *Emissions Reduction Fund project register*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/ERF/project-and-contracts-registers/project-register.

_____ (2021d). *Australian Carbon Exchange*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/Infohub/Markets/australian-carbon-exchange.

_____ (2021e). *Reporting thresholds*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/NGER/Reporting-cycle/Assess-your-obligations/Reporting-thresholds.

Chapman, B. and Lindenmayer, D. B. (2019). "A novel approach to the sustainable financing of the global restoration of degraded agricultural land". *Environmental Research Letters* 14, p. 124084. https://iopscience.iop.org/article/10.1088/1748-9326/ab5deb.

Climate Council (2020). *Submission to Climate Change Authority's 2020 Review of the Emissions Reduction Fund*. Climate Council. https://www.climatecouncil.org.au/wp-content/uploads/2020/06/200601-ERF-Review-clean.pdf.

ClimateWorks (2020). *Decarbonisation Futures: Solutions, actions and benchmarks for a net zero emissions Australia*. ClimateWorks. https://www.climateworksaustralia.org/resource/decarbonisation-futures-solutions-actions-and-benchmarks-for-a-net-zero-emissions-australia/.

Collerton, S. (2011). "Farming and the carbon tax: what's in store?" *ABC News*. 15 July. https://www.abc.net.au/news/2011-07-15/carbon-tax-farmers/2795816.

CSIRO (2019). *Australian National Outlook 2019*. CSIRO. https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/australian-national-outlook.

_____ (2021a). *Precision agriculture*. CSIRO. https://www.csiro.au/en/research/plants/crops/farming-practices/precision-agriculture.

_____ (2021b). *Inquiry into the definitions of meat and other animal products*. CSIRO. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Rural_and_Regional_Affairs_and_Transport/DefinitionsofMeat/Submissions.

_____ (2021c). *Animal-free dairy*. CSIRO. https://www.csiro.au/en/research/production/food/eden-brew.

DAWE (2020a). *Extension and Outreach*. Department of Agriculture, Water and the Environment. https://web.archive.org/web/20210401193543/https://www.agriculture.gov.au/ag-farm-food/climatechange/carbonfarmingfutures/extensionandoutreach.

_____ (2020b). *Levy guidelines: How to establish or amend agricultural levies*. Department of Agriculture, Water and the Environment. https://www.agriculture.gov.au/sites/default/files/documents/levy-guidelines.pdf.

_____ (2021a). *National Soil Strategy*. Department of Agriculture, Water and the Environment. https://www.agriculture.gov.au/ag-farm-food/natural-resources/soils.

_____ (2021b). *Regional NRM organisations*. Department of Agriculture, Water and the Environment. nrm.gov.au/regional/regional-nrm-organisations.

_____ (2021c). *Agricultural levies legislation – Early Assessment Regulation Impact Statement*. Department of Agriculture, Water and the Environment. https://haveyoursay.awe.gov.au/levies-legislation.

_____ (2021d). *Agriculture Stewardship Package*. Department of Agriculture, Water and the Environment. https://www.agriculture.gov.au/ag-farm-food/natural-resources/landcare/sustaining-future-australian-farming.

_____ (2021e). *Delivering Ag2030*. Department of Agriculture, Water and the Environment. https://www.agriculture.gov.au/ag-farm-food/ag2030.

Department of Agriculture (2019). *Streamlining and modernising agricultural levies legislation: Early assessment regulation impact statement*. Department of Agriculture. https://haveyoursay.awe.gov.au/levies-legislation.

DFAT (2021). *Trade statistical pivot tables*. Department of Foreign Affairs and Trade. https://www.dfat.gov.au/about-us/publications/trade-statistical-pivot-tables.

DISER (2020a). *Australia's emissions projections 2020*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/sites/default/files/2020-12/australias-emissions-projections-2020.pdf.

_____ (2020b). *Estimating greenhouse gas emissions from bushfires in Australia's temperate forests: focus on 2019-20*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/data-and-publications/estimating-greenhouse-gas-emissions-from-bushfires-in-australias-temperate-forests-focus-on-2019-20.

_____ (2020c). *Report of the Expert Panel examining additional sources of low cost abatement*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/data-and-publications/examining-additional-sources-of-low-cost-abatement-expert-panel-report.

_____ (2020d). *Technology Investment Roadmap: First Low Emissions Technology Statement*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/data-and-publications/technology-investment-roadmap-first-low-emissions-technology-statement-2020.

_____ (2021a). *National Inventory Report 2019: Australian Government Submission to the United Nations Framework Convention on Climate Change - Volume 1*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/sites/default/files/April%202021/document/national-inventory-report-2019-volume-1.pdf.

_____ (2021b). *National Greenhouse Gas Inventory – UNFCCC classifications*. Data extracted on 14 May 2021. Department of Industry, Science, Energy and Resources. https://ageis.climatechange.gov.au/UNFCCC.aspx.

DISER (2021c). *National Inventory Report 2019: Australian Government Submission to the United Nations Framework Convention on Climate Change - Volume 2*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/sites/default/files/April%202021/document/national-inventory-report-2019-volume-2.pdf.

_____ (2021d). *Renewable Energy Target scheme*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/funding-and-incentives/renewable-energy-target-scheme.

_____ (2021e). *Grants available for livestock feed technology trials*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/news/grants-available-for-livestock-feed-technology-trials.

Dooley et al (2020). Dooley, K., Christoff, P. and Burdon, R. *Land-Based Carbon Dioxide Removal Options for Victoria: Review Paper*. Melbourne Sustainable Society Institute, The University of Melbourne. https://sustainable.unimelb.edu.au/__data/assets/pdf_file/0004/3347194/LBCDR_Options_for_Victoria_Review1.pdf.

DPIRD (2020a). *Managing manure to reduce greenhouse gas emissions*. Department of Primary Industries and Regional Development. https://www.agric.wa.gov.au/climate-change/managing-manure-reduce-greenhouse-gas-emissions.

_____ (2020b). *Reducing nitrous oxide emissions from agricultural soils of Western Australia*. Department of Primary Industries and Regional Development. https://www.agric.wa.gov.au/climate-change/reducing-nitrous-oxide-emissions-agricultural-soils-western-australia.

_____ (2021). *Western Australian Carbon Farming and Land Restoration Program*. Department of Primary Industries and Regional Development. https://www.agric.wa.gov.au/carbon-farming/western-australian-carbon-farming-and-land-restoration-program.

EEC and NFF (2021). *Navigating a dynamic energy landscape: a briefing for farms*. Energy Efficiency Council and National Farmers' Federation. https://www.energybriefing.org.au/sector-spotlights/farms.

Essich et al (2020). Essich, L., Nkebiwe, P. M., Schneider, M. and Ruser, R. "Is Crop Residue Removal to Reduce N_2O Emissions Driven by Quality or Quantity? A Field Study and Meta-Analysis". *Agriculture* 10.11. https://www.mdpi.com/2077-0472/10/11/546.

EY (2021). *How can Australia's agriculture sector capitalise on opportunities in a low emissions future?* Prepared for Farmers For Climate Action. Ernst & Young. https://farmersforclimateaction.org.au/wp-content/uploads/2021/09/FCA-EY-FINAL-Report-Low-emissions-future-for-Agriculture.pdf.

Flower et al (2019). Flower, K., Dang, Y. and Ward, P. "Advances in crop residue management". *Australian Agriculture in 2020: From conservation to automation*. Ed. by J. Pratley and J. Kirkegaard, pp. 137–149.

FSANZ (2021). *Cell based meat*. Accessed 31 August 2021. Food Standards Australia and New Zealand. https://www.foodstandards.gov.au/consumer/generalissues/Pages/Cell-based-meat.aspx.

Gao, H. and Xue, J. (2020). "Modeling and economic assessment of electric transformation of agricultural tractors fueled with diesel". *Sustainable Energy Technologies and Assessments* 39, p. 100697. https://www.sciencedirect.com/science/article/pii/S221313881930548X.

Gorjian et al (2021). Gorjian, S., Ebadi, H., Trommsdorff, M., Sharon, H., Demant, M. and Schindele, S. "The advent of modern solar-powered electric agricultural machinery: A solution for sustainable farm operations". *Journal of Cleaner Production* 292, p. 126030. https://www.sciencedirect.com/science/article/pii/S095965262100250X.

Grattan, M. (2021). "Politics with Michelle Grattan: David Littleproud on The Nationals and net zero". *The Conversation*. 11 February. https://theconversation.com/politics-with-michelle-grattan-david-littleproud-on-the-nationals-and-net-zero-155121.

Greenville et al (2020). Greenville, J., McGilvray, H. and Burns, K. *Global responses to climate change: opportunities for Australian agricultural producers*. Australian Bureau of Agricultural, Resource Economics and Sciences. https://www.agriculture.gov.au/abares/products/insights/global-responses-to-climate-change#as-economies-transition-new-rules-and-preferences-will-emerge.

Grosvenor Management Consulting (2017). *An evalutation of the Carbon Farming Futures programme*. Prepared for the Department of Agriculture and Water Resources. https://web.archive.org/web/20190112075357/http://www.agriculture.gov.au/SiteCollectionDocuments/climate-change/carbon-farming/evaluation-carbon-farming-futures-programme.docx.

Ha, J. (2021). "Australia's coal and gas exports in a net-zero future". *Pearls and Irritations*. 30 May. https://johnmenadue.com/australias-coal-and-gas-exports-in-a-net-zero-future/.

Henry, D. and Chandrashekeran, S. (2021). "State leadership on emissions reduction is crucial". *Pursuit*. 3 May. https://pursuit.unimelb.edu.au/articles/state-leadership-on-emissions-reduction-is-crucial.

Hepburn et al (2019). Hepburn, C., Adlen, E., Beddington, J., Carter, E. A., Fuss, S., Dowell, N. M., Minx, J. C., Smith, P. and Williams, C. K. "The technological and economic prospects for CO2 utilization and removal". *Nature* 575, pp. 87–97. https://doi.org/10.1038/s41586-019-1681-6.

Herbert Smith Freehills (2020). *'Carbon neutral' and 'net-zero carbon': What's the difference – and why does it matter?* https://www.herbertsmithfreehills.com/carbon-neutral-and-net-zero-carbon-whats-the-difference-and-why-does-it-matter.

Hoegh-Guldberg et al (2018). Hoegh-Guldberg, O. et al. *Impacts of 1.5°C Global Warming on Natural and Human Systems*. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/sr15/.

Honan et al (2021). Honan, M., Feng, X., Tricarico, J. and Kebreab, E. "Feed additives as a strategic approach to reduce enteric methane production in cattle: modes of action, effectiveness and safety". *Animal Production Science*. https://www.publish.csiro.au/an/AN20295.

Hughes et al (2019). Hughes, N., Galeano, D. and Hatfield-Dodds, S. *The effects of drought and climate variability on Australian farms*. Australian Bureau of Agricultural and Resource Economics. https://www.agriculture.gov.au/abares/publications/insights/effects-of-drought-and-climate-variability-on-Australian-farms#changes-in-climate-are-affecting-australian-farms.

Hughes, N. and Gooday, P. (2021). *Climate change impacts and adaptation on Australian farms*. Australian Bureau of Agricultural, Resource Economics and Sciences. https://www.agriculture.gov.au/abares/products/insights/climate-change-impacts-and-adaptation.

Hutton, L. and O'Connor, J. (2021). *Energy efficiency and farm vehicles*. NSW Department of Primary Industries. https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/1315286/energy-efficiency-and-farm-vehicles.pdf.

IEA (2021). *Net Zero by 2050: A Roadmap for the Global Energy Sector*. International Energy Agency. https://www.iea.org/data-and-statistics/data-product/net-zero-by-2050-scenario.

IPCC (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar4/syr/.

_____ (2021). *Summary for Policymakers*. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg1/.

Kancans et al (2014). Kancans, R., Ecker, S., Duncan, A., Stenekes, N. and Zobel-Zubrzycka, H. *Drivers of practice change in land management in Australian agriculture: Synthesis report – Stages I, II and III*. Australian Bureau of Agricultural, Resource Economics and Sciences. https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/abares/publications/DrvPracChngLndMan20140626v1.0.0SynthesisReport.pdf.

Kinley et al (2020). Kinley, R. D., Martinez-Fernandez, G., Matthews, M. K., de Nys, R., Magnusson, M. and Tomkins, N. W. "Mitigating the carbon footprint and improving productivity of ruminant livestock agriculture using a red seaweed". *Journal of Cleaner Production* 259, p. 120836. ISSN: 0959-6526. https://www.sciencedirect.com/science/article/pii/S0959652620308830.

Laut, P. (1988). *Year Book Australia, 1988*. Australian Bureau of Statistics. https://www.abs.gov.au/AUSSTATS/abs@.nsf/Previousproducts/1301.0Feature%20Article131988.

Le Messurier, D. (2019). "Country Women's Association calls for milk label changes". *The Daily Telegraph*. 8 May. https://www.dailytelegraph.com.au/news/nsw/country-womens-association-calls-for-milk-label-changes/news-story/c0a3cf353b67c7c94fb5d656004909fb.

Li et al (2018). Li, X., Norman, H. C., Kinley, R. D., Laurence, M., Wilmot, M., Bender, H., Nys, R. de and Tomkins, N. "Asparagopsis taxiformis decreases enteric methane production from sheep". *Animal Production Science* 58, pp. 681–688. https://doi.org/10.1071/AN15883.

Littleproud, D. (2021). *The CSIRO should not be advocating for plant-based foods over genuine meat products in Australia. Expect the CSIRO to provide balanced support for Australian industries. My letter to the CSIRO*. Tweeted 25 August 2021. https://twitter.com/D_LittleproudMP/status/1430379469001293827.

Lynch et al (2020). Lynch, J., Cain, M., Pierrehumbert, R. and Allen, M. "Demonstrating GWP*: a means of reporting warming-equivalent emissions that captures the contrasting impacts of short- and long-lived climate pollutants". *Environmental Research Letters* 15.4, p. 044023. https://doi.org/10.1088/1748-9326/ab6d7e.

Macdonald-Smith et al (2021). Macdonald-Smith, A., Wiggen, J. and Fowler, E. "Clean energy funding setback a 'missed opportunity'". *Australian Financial Review*. 23 June. https://www.afr.com/companies/energy/arena-setback-could-slow-low-carbon-transition-20210623-p583lh.

Macintosh, A. (2012). "The Australia clause and REDD: a cautionary tale". *Climatic Change* 112, pp. 169–188. https://doi.org/10.1007/s10584-011-0210-x.

Mayberry et al (2018). Mayberry, D., Bartlett, H., Moss, J., Wiedemann, S. and Herrero, M. *Greenhouse Gas mitigation potential of the Australian red meat production and processing sectors*. Published by Meat & Livestock Australia. CSIRO. https://www.mla.com.au/contentassets/ec632a5c01ac44b6960fbb5abb038565/b.cch.7714_final_report.pdf.

McCosker, M. (2021). "Corporate carbon farms 'locking up the land' are locking out the people, critics say". *ABC News*. 10 April. https://www.abc.net.au/news/rural/2021-04-10/rural-community-fights-against-corporate-carbon-farning/100048920.

Merzian et al (2021). Merzian, R., Hemming, P. and Schoo, A. *Non-additionality in the Emissions Reduction Fund's Avoided Deforestation Method*. Australian Conservation Foundation and The Australia Institute. https://australiainstitute.org.au/wp-content/uploads/2021/09/ACF-Aust-Institute_integrity-avoided_deforestation_report_FINAL_WEB.pdf.

MLA (2020a). *Carbon Neutral by 2030 Roadmap*. Meat & Livestock Association. https://www.mla.com.au/contentassets/e501cd2919064183b57372897a0e1954/2689-mla-cn30-roadmap_d7.pdf.

_____ (2020b). *The economic significance of Australia's red meat and livestock industry*. Meat & Livestock Association. https://www.mla.com.au/prices-markets/market-news/2020/the-economic-significance-of-australias-red-meat-and-livestock-industry/.

_____ (2020c). *Strategic Plan 2025*. Meat & Livestock Association. https://www.mla.com.au/globalassets/mla-corporate/about-mla/documents/planning--reporting/Strategic-Plan-2025.pdf.

_____ (2021a). *The feed additive reducing methane emissions by up to 90%*. 23 August. Meat & Livestock Association. https://www.mla.com.au/news-and-events/industry-news/the-feed-additive-reducing-methane-emissions-by-up-to-90/.

_____ (2021b). *About your levy*. Meat & Livestock Association. https://www.mla.com.au/about-mla/how-we-are-funded/about-your-levy/.

_____ (2021c). *How we are funded*. Meat & Livestock Association. https://www.mla.com.au/about-mla/how-we-are-funded/.

Morrison, S. (2021). *Address: National Press Club Barton ACT*. 1 February. https://www.pm.gov.au/media/address-national-press-club-barton-act.

National Farmers' Federation (2020). *Climate Change*. 6 August. National Farmers' Federation. https://nff.org.au/key-issue/climate-change/.

Nettle et al (2018). Nettle, R., Ayre, M., King, B., La, N., Paschen, J. A., Reichelt, N. and Smith, E. "The advisory and extension system in Australia: opportunities for strength in pluralism". *13th European International Farming Systems Association (IFSA) Symposium, Farming systems: facing uncertainties and enhancing opportunities, 1-5 July 2018, Chania, Crete, Greece*, pp. 1–15.

Nicholls, Z. and Baxter, T. (2020). "Climate explained: methane is short-lived in the atmosphere but leaves long-term damage". *The Conversation*. 9 September. https://theconversation.com/climate-explained-methane-is-short-lived-in-the-atmosphere-but-leaves-long-term-damage-145040.

NZAGRC (2021). *Methane vaccine*. New Zealand Agricultural Greenhouse Gas Research Centre. https://www.nzagrc.org.nz/domestic/methane-research-programme/methane-vaccine/.

Piper, K. (2020). “Singapore is the first country in the world to approve lab-grown chicken products”. *Vox*. 18 December. https://www.vox.com/future-perfect/2020/12/2/22125518/lab-grown-chicken-meat-singapore-bioreactor-approve.

Polglase et al (2011). Polglase, P. et al. *Opportunities for carbon forestry in Australia: Economic assessment and constraints to implementation*. CSIRO. https://publications.csiro.au/rpr/download?pid=csiro:EP113280&dsid=DS6.

Queensland Government (2021). *About the Land Restoration Fund: Overview, vision and objectives*. https://www.qld.gov.au/environment/climate/climate-change/land-restoration-fund/about/overview.

Reedman et al (2021). Reedman, L., Chew, M. S., Gordon, J., Sue, W., Brinsmead, T., Hayward, J. and Havas, L. *Multi-sector energy modelling*. CSIRO and ClimateWorks. https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/isp/2021/csiro-multi-sector-modelling.pdf?la=en.

RepuTex Energy (2021). *State and trends in the Australian carbon market FY21*. RepuTex Energy. https://www.reputex.com/research-insights/white-paper-the-state-and-trends-of-the-australian-carbon-market-in-fy21/.

RIC (2021). *Our loans*. Regional Investment Corporation. https://www.ric.gov.au/farm-investment.

Rivera-Ferre et al (2016). Rivera-Ferre, M., López-i-Gelats, F., Howden, M., Smith, P., Morton, J. and Herrero, M. “Re-framing the climate change debate in the livestock sector: mitigation and adaptation options”. *WIREs Climate Change* 7.6, pp. 869–892. DOI: https://doi.org/10.1002/wcc.421. https://wires.onlinelibrary.wiley.com/doi/abs/10.1002/wcc.421.

RMAC (2019). *Red Meat 2030*. Red Meat Advisory Council. http://rmac.com.au/wp-content/uploads/2021/05/RedMeat2030.pdf.

Roxburgh et al (2020). Roxburgh, S., Paul, K. and Pinkard, L. *Technical review of physical risks to carbon sequestration under the Emissions Reduction Fund (ERF)*. Final Report to the Climate Change Authority. CSIRO. https://www.climatechangeauthority.gov.au/sites/default/files/2020-10/ERF%20Review%20-%20CSIRO%20Technical%20Report%20on%20Climate%20Risk%20-%20Final%20pdf.pdf.

Senate Standing Committees on Rural and Regional Affairs and Transport (2021). *Definitions of meat and other animal products*. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Rural_and_Regional_Affairs_and_Transport/DefinitionsofMeat.

Shankleman, J. (2021). “Cow cocktails and vaccines join the battle to reach net zero”. *Bloomberg*. 26 April. https://www.bloomberg.com/news/features/2021-04-26/cow-cocktails-and-vaccines-join-the-battle-to-cut-methane-emissions.

Stagnari et al (2020). Stagnari, F., Maggio, A., Galieni, A. and Pisante, M. “Multiple benefits of legumes for agriculture sustainability: an overview”. *Chemical and Biological Technologies in Agriculture* 4. https://doi.org/10.1186/s40538-016-0085-1.

Steffen et al (2019). Steffen, W., Mallon, K., Kompas, T., Dean, A. and Rice, M. *Compound costs: How climate change is damaging Australia’s economy*. Climate Council. https://www.climatecouncil.org.au/resources/compound-costs-how-climate-change-damages-australias-economy/.

Taylor, K. (2021). “LEAK: EU’s carbon border tariff to target steel, cement, power”. *Euractiv*. 4 June. https://www.euractiv.com/section/energy-environment/news/eus-carbon-border-tariff-to-target-steel-cement-power/.

Thompson, B. (2021). “Farmer co-op to ramp up imports as fertiliser prices skyrocket”. *Australian Financial Review*. 21 June. https://www.afr.com/companies/agriculture/farmer-co-op-to-ramp-up-imports-as-fertiliser-prices-skyrocket-20210620-p582ki.

UNFCCC (2015). *Paris Agreement*. United Nations Framework Convention on Climate Change. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

Upton, S. (2019). *Farms, forests and fossil fuels: The next great landscape transformation?* Parliamentary Commissioner for the Environment. https://www.pce.parliament.nz/media/196523/report-farms-forests-and-fossil-fuels.pdf.

Vogt-Schilb et al (2018). Vogt-Schilb, A., Meunier, G. and Hallegatte, S. “When starting with the most expensive option makes sense: Optimal timing, cost and sectoral allocation of abatement investment”. *Journal of Environmental Economics and Management* 88, pp. 210–233. https://www.sciencedirect.com/science/article/pii/S0095069617308392.

Wood, T. (2020). “Carbon pricing: it’s a proven way to reduce emissions but everyone’s too scared to mention it”. *The Conversation*. 26 February. https://theconversation.com/carbon-pricing-its-a-proven-way-to-reduce-emissions-but-everyones-too-scared-to-mention-it-132342.

_____ (2021). “Morrison scores a climate own goal”. *Australian Financial Review*. 8 February. https://www.afr.com/policy/energy-and-climate/morrison-scores-a-climate-own-goal-20210207-p5707z.

Wood et al (2016). Wood, T., Blowers, D., Moran, G. and McCamish, T. *Climate phoenix: a sustainable Australian climate policy*. Report No. 2016-6. Grattan Institute. https://grattan.edu.au/report/climate-phoenix-a-sustainable-australian-climate-policy/.

Wood et al (2021a). Wood, T., Dundas, G. and Ha, J. *Start with steel: A practical plan to support carbon workers and cut emissions*. Report No. 2020-06. Grattan Institute. https://grattan.edu.au/wp-content/uploads/2020/05/2020-06-Start-with-steel.pdf.

Wood et al (2021b). Wood, T., Reeve, A. and Ha, J. *Towards net zero: Practical policies to reduce transport emissions*. Report No. 2021-07. Grattan Institute. https://grattan.edu.au/report/towards-net-zero-practical-policies-to-reduce-transport-emissions/.

Wood et al (2021c) _____ . *Towards net zero: Practical policies to reduce industrial emissions*. Report No. 2021-10. Grattan Institute. https://grattan.edu.au/report/towards-net-zero-practical-policies-to-reduce-industrial-emissions/.