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Towards net zero

Practical policies to offset carbon emissions

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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.

Australian governments can and should act now to create momentum towards the net-zero goal. Strong policies are required to reach net zero, but some sectors and individuals may be able to do more than others at different times. By offsetting over-achievement in one sector against under-achievement in another, effort can be shared across the economy and the goal achieved at lower cost.

This report, the fourth in a series of five on net zero, recommends policies to ensure Australia has access to high-quality offsetting units, both to act as a 'safety valve' if the cost of reducing emissions sector-by-sector is higher than anticipated, and for the ongoing task of offsetting emissions that can't be avoided.

Offsetting is a difficult part of the net-zero conversation. Some see it as an excuse to delay reductions, others as bringing about unacceptable social change, particularly in rural areas. It has been plagued by integrity problems, and there is understandable cynicism about its potential.

None of this changes the reality: in pursuit of net zero, offsetting will be required because there will be emissions we cannot eliminate, and some where we will not be willing to pay the price to do so. The only option to deal with these emissions is to deliberately remove carbon dioxide from the atmosphere to offset them.

Processes to permanently remove carbon dioxide from the atmosphere are uncertain or expensive – or both. Emitting is certain: we know that every tonne of emissions in the atmosphere contributes to global temperature rise. For this reason, offsetting is not a direct substitute for avoiding or reducing emissions in other ways.

Australia has the structures in place to support offsetting. Our governments should be clear about the role of offsetting in each policy they implement in pursuit of net zero. They should also make sure certification for offsetting units maintains high integrity. Otherwise, companies and individuals will bear costs with no corresponding drop in emissions.

As policies begin to drive demand for offsetting units, governments should step back from being the major buyers, and focus on underwriting the development of technologies and practices to remove carbon dioxide from the atmosphere. This includes acting more as a buyer of last resort for high-quality Australian offsetting units; or buying units to offset government emissions.

There is still considerable uncertainty about the costs, permanence, and measurement of many offsetting activities. These are barriers to scaling up the offsetting market. Government should support R&D and early-stage deployment to help lower these barriers.

Imports and exports of offsetting units will become more important as all countries move towards net zero. There is no need to assume Australia must be self-sufficient in offsetting units, but local supply requires our governments to implement strong policies to drive emissions reduction coupled with policies to encourage removal of carbon dioxide from the atmosphere. The Federal Government should introduce rules to support international trade in offsetting units, both for exports and imports.

Recommendations

1. Implement strong policies to reduce emissions consistent with a net-zero pathway

- Previous reports in this series recommended policies for transport, industry, and agriculture.

2. Articulate the role of offsetting in each policy

- For every emissions reduction policy, clarify whether offsetting is allowed as an alternative to reducing emissions, and any limits on the amount of offsetting, the types of units used, and whether these must be produced in Australia or overseas.

3. Bolster the integrity of offsetting units

- The Federal Government should provide extra resources for regular independent expert reviews of methods for creating Australian Carbon Credit Units, and improve methods where necessary.
- Invest in R&D and early-stage deployment for improved measurement and verification technologies and practices.
- Include an ‘upside-downside’ clause in contracts for purchase of Australian Carbon Credit Units and other offsetting units, to share the risk that units have integrity issues and to encourage adoption of amended methods following reviews.
- Place time limits on use of units from outdated methods in policies that allow offsetting.

4. Get ready for an expanded international market in offsetting units

- The Federal Government should introduce rules to prevent double-counting of offsetting activities that take place in Australia but are used to offset emissions overseas.

5. Help create the market but do not dominate it

- Governments should support emergence of a market for offsetting units by acting as buyers of last resort for a limited period.
- Governments should link purchases of offsetting units to their own emissions.
- Over time, where governments purchase offsetting units, they should focus more on supporting projects that remove carbon dioxide from the atmosphere.

6. Support the emergence of negative emissions technologies

- Governments should invest in R&D and early-stage deployment of technologies that remove carbon dioxide from the atmosphere, such as direct air carbon capture and storage, and large-scale mineralisation.

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1 Net zero: why, how, and with what

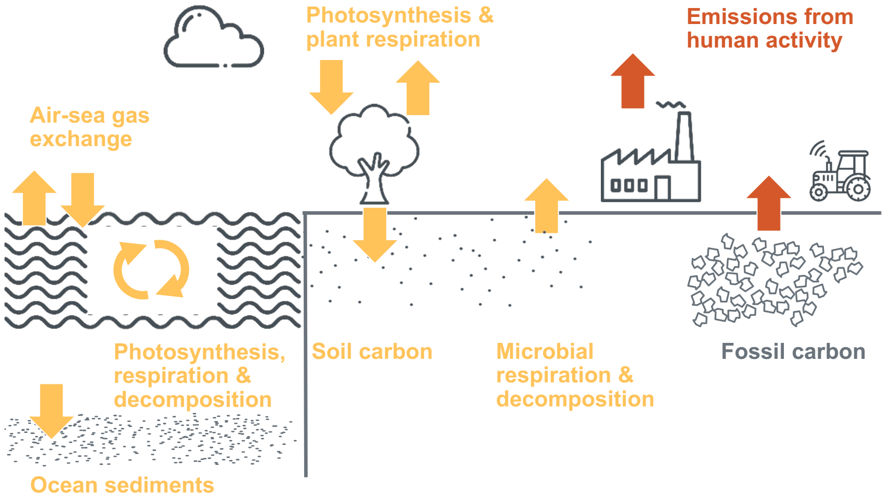
In the second half of 2021, Grattan Institute is publishing a series of five reports identifying practical policies to reduce carbon emissions in key sectors. The first three reports, on transport, the industrial sector, and agriculture, have been published.[1] They identified pragmatic, sector-based policies that will create momentum towards greater ambition at a later date. A fifth report will identify the implications of these policies for national co-ordination and the electricity sector.

This report – the fourth in the series – is different. It focuses on what 'net-zero emissions' really means for the economy, and how two complementary approaches – emissions reductions and removing carbon dioxide from the atmosphere – should work together to achieve net zero.

Net zero means balancing sources of emissions going into the atmosphere with sinks that take them out, with the aim of staying within a carbon budget and limiting global temperature rise. Because there are some emissions that cannot be eliminated (or that we do not want to eliminate), achieving this balance requires 'offsetting': deliberately removing a tonne of carbon dioxide from the atmosphere for each tonne of emissions.

There are many ways to do this, and certifying each offsetting activity makes accounting for sources and sinks easier. Offsetting is not an excuse to delay emissions reduction; rather, it is a necessary part of sharing emissions reduction efforts across sectors, and dealing with emissions that remain once all such opportunities have been adopted.

Figure 1.1: Each natural source of carbon dioxide has a corresponding sink – but human-induced sources do not



Note: Icons from flaticon.com.

Source: Based on NASA (2011).

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

1.1 Restoring the carbon cycle is essential to limiting climate change

Before the industrial revolution, natural sources of carbon dioxide and other greenhouse gases were balanced by natural sinks. This kept the amount of greenhouse gas in the atmosphere fairly constant, which maintained global average temperatures within a narrow band and created a stable climate (Figure 1.1 on the preceding page).

The industrial revolution accelerated the use of fossil fuels. Burning these fuels (and other human activity) releases large amounts of greenhouse gases into the atmosphere. But because there is no corresponding sink, those gases persist in the atmosphere and cause global average temperatures to rise, disrupting the global climate system.

All climate change policy is ultimately concerned with restoring the balance between sources and sinks, in order to hold global average temperature rises to well below 2℃ and ideally below 1.5℃.

To achieve this, there needs to be a limit to how much carbon pollution the world can emit – a 'carbon budget'. Every tonne of carbon pollution that is 'spent' from the budget this year (by putting it into the atmosphere) is one that cannot be spent next year.

Continuing to release emissions at the current rate until 2049 – or even until 2035 – will blow the budget.[2] For countries such as Australia where emissions have been falling slowly, the budget is still likely to be exhausted well before 2050. If we spend our emissions budget at the current rate for the next decade, reaching net zero while staying within the budget will require a very rapid and disruptive change, which will be costly if not technically infeasible.

1.2 What net-zero means

The carbon budget to limit global temperature rise is premised on a stable level of greenhouse gases in the atmosphere. Given there is a stock of gases in the atmosphere already, a stable level means either zero human-induced emissions going into the atmosphere, or net-zero – a balance between what goes in and what comes out.

The Paris Agreement aims to achieve this, by committing signatories to achieving 'a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century'.[3] In practice, this commitment has been interpreted by individual countries as a goal of 'net-zero emissions by 2050 or 2060'. By 2050 or 2060, each country with a net-zero goal will have to account for permanently removing one tonne of greenhouse gas from the atmosphere for every tonne that goes in. This means actual emissions may be above zero, but they will be balanced by removals, so that the 'net' position is zero.

Achieving net-zero emissions by about 2050 is the bare minimum to have a decent chance of limiting global warming to 1.5℃.[4] A commitment to 'net zero' is a commitment to deliberate removal of carbon dioxide from the atmosphere. The alternative – absolute zero – would require giving up all activities and consumption where emissions cannot be eliminated.

2. To have a two-thirds chance of keeping warming to 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).

3. Article 4 of the Paris Agreement.
4. Every additional tonne of emissions contributes to global temperature rise. Limiting human-induced global warming requires limiting cumulative emissions, and reaching at least net-zero carbon dioxide emissions, along with strong reductions in other greenhouse gas emissions: IPCC (2021, p. 36).

The pathway to net zero is as important as the goal itself. If we achieve a balance between sources and sinks in 2050, but overspend our carbon budget on the way there, we will be left with a 'carbon deficit' and will have to remove additional carbon dioxide from the atmosphere in the following decades to balance the carbon budget and stabilise the global climate (Figure 1.2). The risk of this approach is that the world experiences greater warming in the meantime, overshooting temperature goals and potentially locking in irreversible changes to the climate.[5]

1.2.1 The difference between net zero and carbon neutral

The terms 'carbon neutral' and 'net zero' are often used interchangeably, but they are different. To be carbon-neutral, an organisation need only refrain from increasing its emissions, and find sinks to balance out its current emissions. To achieve net-zero, an organisation needs to first reduce its emissions wherever it can, and only use sinks to balance the remainder.[6]

1.3 What is offsetting?

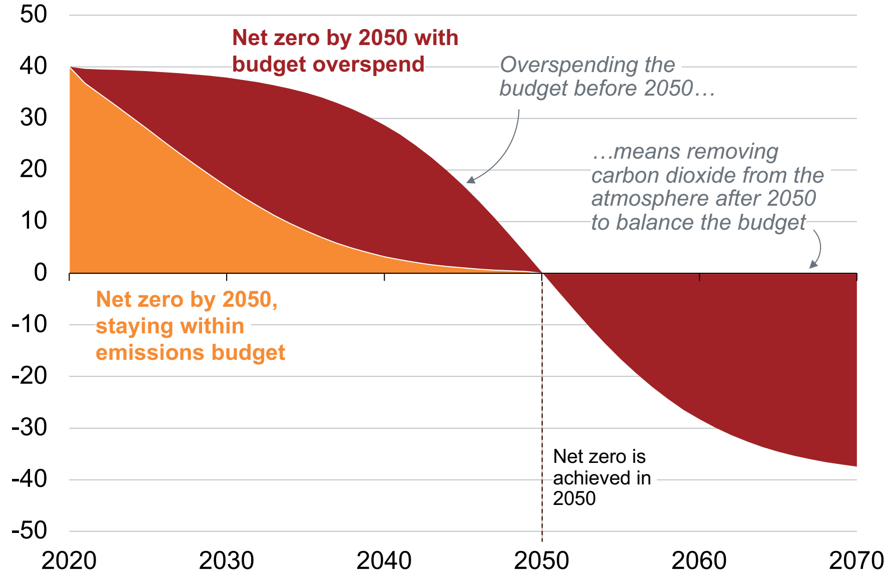
Every nation that has ratified the Paris Agreement keeps a national emissions inventory. This is the ledger for the carbon budget. Over the course of a year, there will be entries on the debit side, as the carbon budget gets spent through economic activity; and on the credit side, where greenhouse gases are removed from the atmosphere through natural processes or human activity. Combining the credit and the debit sides tells us how much of our national carbon budget we have left.

When an emissions constraint is introduced – either through government policy or voluntary action – this restrains the debit side of the ledger. In essence, it restricts how much of the carbon budget can

5. Ibid (p. 18).
6. Herbert Smith Freehills (2020); and Bigg (2021).

Figure 1.2: How to stay within an emissions budget

Global CO_2 emissions (billions of tonnes)



Notes: Both pathways start at 40 billion tonnes in 2020. The total emissions for each pathway (the area under each curve) between 2020 and 2070 is the same – 400 billion tonnes, consistent with keeping warming below 1.5°C: IPCC (2021).

Source: Grattan analysis.

be spent in a given period of time. Staying within that constraint, and continuing to remove emissions at the same pace, leaves more of the carbon budget left to spend in future years.

Sometimes, spending more than the yearly carbon budget can't be avoided. But, as noted in Section 1.2 on page 7, overspending the budget every year quickly exhausts it. To avoid this, the overspend can be 'offset' in two ways:

- by finding someone who emitted less than they expected and offsetting this 'underspend' against the 'overspend'
- by deliberately removing emissions from the atmosphere and offsetting those against the overspend.

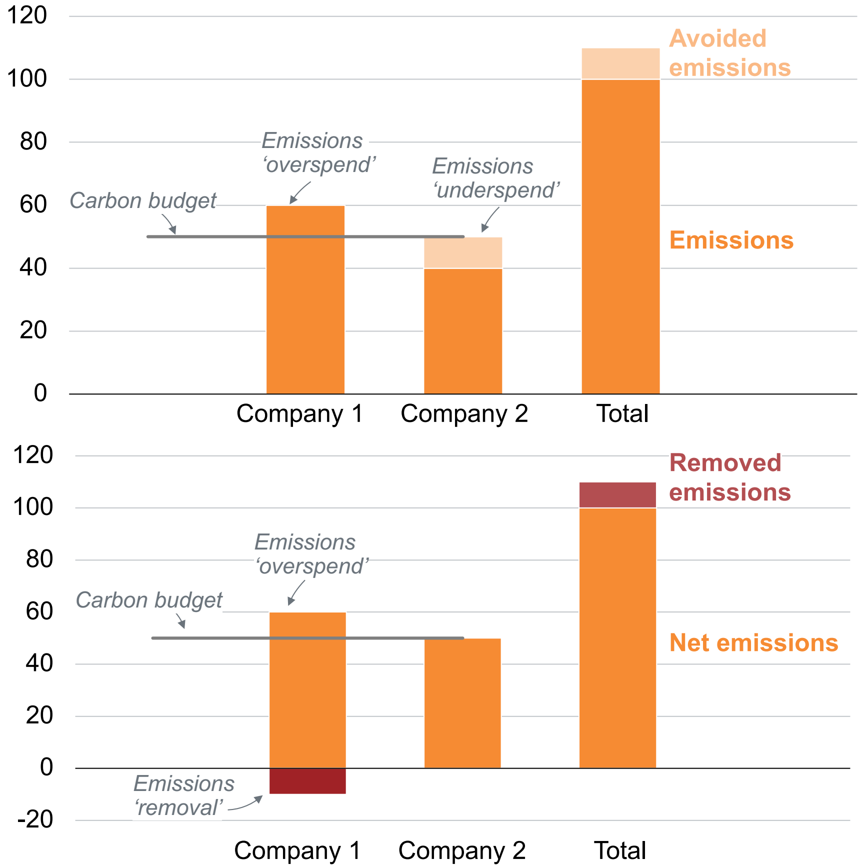
Figure 1.3 shows these two different approaches. Offsetting can take place within a company or entity; between entities in one sector; between entities in different sectors; or between countries.

1.3.1 Offsetting cannot replace the need for emissions reductions

Any entity facing an emissions constraint needs to choose how much of its emissions it wants to reduce, and how much it wants to offset. This choice will be driven by the relative cost of reductions and offsetting activities, as well as the entity's view of the future value of both activities.

In a net-zero world, every tonne of emissions that goes into the atmosphere would be balanced out by immediate equivalent removals. These remaining emissions would come from sources where no viable technological solution, practice, or alternative has been found. The only way to offset them would be to remove carbon dioxide from the atmosphere and store it permanently. This would keep the global concentration of atmospheric greenhouse gases stable, which in turn would stabilise global average temperatures, and limit climate change.

Figure 1.3: Offsetting to stay within a carbon budget
Emissions (tonnes of carbon dioxide equivalent)



Source: Grattan analysis.

But, emitting now and removing later will not help mitigate climate change. While a tonne of greenhouse gas is in the atmosphere, it is contributing to global temperature rise, and may push the global climate system past a 'tipping point' – a sudden and irreversible change in climate. Removing greenhouse gases after a tipping point has been passed will not return the climate to its previous state. For this reason, offsetting is not a substitute for avoiding emissions in the first place.[7]

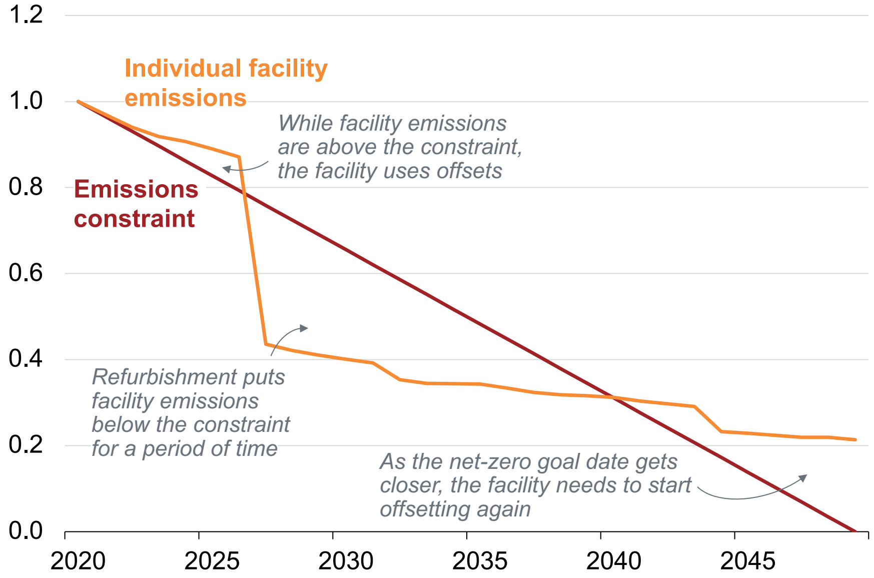
Relying heavily on offsetting slows the rate of adoption of new lower-emissions technologies, because there is no signal to develop and deploy them. This stymies the development of sectors in areas of low-emissions competitive advantage, and slows structural changes in the economy towards low-emissions activities.

Many activities that remove carbon dioxide from the atmosphere and/or avoid emissions have considerable uncertainties around measurement and verification, and others have technical and economic challenges to overcome (discussed in detail in Appendix A). As well, there will be a physical limit to the the amount of offsetting activities that can be done. Delaying emissions reductions on the assumption that these activities will be effective, cheap, and widely available risks overspending the carbon budget and passing a tipping point. We must avoid emissions as a first priority, with offsetting helping but not replacing the need for emissions reduction effort.

In some sectors, the immediate opportunities to reduce or avoid emissions are few. In these sectors, offsetting is a way to limit the damage from emissions that take place while companies wait for new technology to become commercial.[8] Figure 1.4 shows how this might play out.

Figure 1.4: Offsetting and emissions reduction work in concert to reach net zero

Annual emissions (millions of tonnes of carbon dioxide-equivalent)



Note: Stylised example for company with current emissions of 1 million tonnes and a goal of net-zero emissions by 2050.

Source: Grattan analysis.

7. There is scientific debate as to whether offsetting is a one-in-one-out calculation. There is some evidence that large amounts of emissions cause an asymmetric response in the global carbon cycle, and the overall concentration of carbon dioxide in the atmosphere is slightly higher after offsetting than if the emissions had not occurred: Zickfeld (2021). However current international carbon accounting rules, which are used to determine whether countries have met targets, assume a one-in-one-out approach.

8. See BHP (2021) for an example.

1.4 Activities used for offsetting

Offsetting can be done by avoiding or reducing emissions, and also by removing carbon dioxide from the atmosphere.

Avoiding or reducing emissions – for example by switching from fossil to renewable fuels or using energy more efficiently – does not affect current levels of greenhouse gases in the atmosphere, but prevents future levels from being higher. We explored many of the options for these activities in different sectors in earlier reports in this series. In this report, we refer to these activities as ‘avoidance offsetting’ only if the activity is used to offset emissions somewhere else. Otherwise, it is an emissions reduction.

As we approach net zero, avoidance becomes a less common way of offsetting excess emissions, because there are fewer emissions in total, fewer sources that can be reduced, and these remaining emissions are more costly to reduce. Eventually, permanent removal becomes the only way to offset human-induced emissions.[9]

Offsetting by removing atmospheric carbon dioxide reduces current levels of atmospheric greenhouse gas. In this report, we refer to these activities as ‘removal offsetting’ and they come in two broad categories: nature-based removals, and industrial removals.[10]

Nature-based removals

Trees, vegetation, soils, and oceans absorb carbon dioxide as part of their lifecycle, and hold it for a period before releasing it again. Sometimes this cycle is short (for example, a plant that grows and dies within a year); and sometimes the cycle is long (for example, a tree that lives for hundreds of years and takes hundreds more to decay). Natural cycles tend to balance out: the carbon that is absorbed by a plant will be released when the plant dies, but will be reabsorbed by the new plant that grows in its place.

Nature-based removals are limited by land availability and in some cases water availability. Estimating the quantum of carbon removals through nature-based activity is complicated, because there are many variables. Geology, weather, climate, drought, water availability, and land-use patterns all have an impact. In the future, nature-based removals will be affected by a changing climate, which will introduce additional uncertainty.

One advantage of nature-based removals is that they can have many co-benefits (such as increased biodiversity or farm productivity). As well, many involve only changes to practice, rather than inventing and commercialising new technologies. Appendix A explores in more detail the challenges of selected nature-based removals and their applications in Australia.

Industrial removals

Industrial removal systems involve using technology to capture carbon dioxide from industrial processes or from the air, and lock it away in geological formation or through chemical bonds, effectively forever. These systems will be necessary in the future if fossil fuel use is not completely eliminated, because there is no naturally-occurring removal that can remove fossil fuel emissions from the atmosphere at the same rate as they are created.

9. Reducing natural emissions sources, for example through fire management, can be an offsetting activity post-net zero. See Appendix A for details.
10. In general, removal refers only to carbon dioxide, the most abundant and longest-lived greenhouse gas. Methane has a much shorter life than carbon dioxide or nitrous oxide – it lasts only about 12 years in the atmosphere. That means the concentration of methane in the atmosphere will eventually stabilise if methane emissions stop growing (whereas every tonne of carbon dioxide emitted increases its concentration in the atmosphere, and hence traps more heat). A policy intervention that permanently reduces annual methane emissions would therefore be equivalent, in terms of its impact on future temperatures, to active removal of a given amount of CO_2: Allen et al (2018).

Estimating the quantum of carbon removed from such systems is relatively easy compared to nature-based systems. Point-source capture of industrial emissions is relatively well-developed, but still expensive. Direct air capture of carbon dioxide is still an early-stage technology and a long way from being a cost-competitive way to remove carbon dioxide from the atmosphere. Appendix A has more detail on selected industrial removals that are prospective for Australia.

1.5 Offsetting as a policy tool

Policies to reduce emissions generally include rules about offsetting as part of their design. Allowing limited offsetting acts as a 'safety valve' in case governments underestimate the costs their policies impose. It also allows governments to choose more ambitious policies safe in the knowledge that the safety valve is available.

In Australia, the two policies that make use of offsetting as an alternative to emissions reductions are the Safeguard Mechanism and Climate Active. The Safeguard Mechanism requires large industrial facilities to keep emissions below a baseline, and offset any that are above it.[11] Climate Active is a voluntary program to certify organisations, products, services, events, buildings, and precincts as carbon-neutral. It requires organisations to offset emissions where they choose not to reduce them.[12]

1.6 Rules and standards make offsetting more efficient

If an emissions constraint is in place in a sector or across the economy, some entities are likely to choose to offset part of their emissions to meet the constraint, particularly if the cost of reducing their emissions is high.

11. See Wood et al (2021b) for an in-depth discussion of the effectiveness of the Safeguard Mechanism.
12. Climate Active (2021a).

To make this process more efficient, carbon dioxide removal or emissions avoidance can be certified, and the right to count that removal or avoidance against a carbon budget can be turned into a tradeable unit. Anyone who can perform an offsetting activity can create an offsetting unit, and anyone who wants to offset their emissions can buy a unit and retire it.[13]

In this way, a market emerges that allows offsetting to take place at least cost. For offsetting units to contribute to a lowest-cost pathway to net zero, buyers and sellers need to be able find each other and make transactions easily. To facilitate this, the Federal Government is developing an Australian carbon exchange linked to the national registry of emissions units. The Government estimates that by 2030, the exchange will save business up to $100 million in transaction costs.[14]

For an offsetting market to work as an effective policy to constrain emissions, each offsetting unit must have integrity – that is, it must represent genuine removals or avoided emissions. Common criteria for certification include:[15]

- baselining – establishing a realistic and credible baseline against which emissions avoidance is measured
- permanence – assessing the length of time that the carbon dioxide will remain locked up
- additionality – assessing whether the activity would have taken place in the absence of certification. This can include financial additionality, but also policy additionality (ensuring that an offset is not being certified for an activity that is required by law)

13. The unit must be retired in order for the offsetting to show up in the carbon budget. Retirement also prevents anyone else from using the unit.
14. CER (2021a).
15. Taskforce on Scaling Voluntary Carbon Markets (2021).

- avoiding double-counting – establishing assurance that the same activity will not be certified twice or counted in two sets of carbon accounts
- avoiding harm or adverse consequences – ensuring that the activity does not encourage activities that leave society or individuals worse off
- monitoring, reporting, record-keeping, and verification requirements.

Governments that choose to allow offsetting as an alternative to emissions reductions need to decide which units are allowed, and how many. The European Union, for example, allowed limited use of offsetting in its emissions trading scheme from 2013 to 2020, but is proposing to discontinue this practice in the next phase of the scheme.

1.6.1 Australian certification

The most prominent unit used for offsetting in Australia is the Australian Carbon Credit Unit, or ACCU. An ACCU represents one tonne of emissions avoided or removed, by an activity carried out in Australia in accordance with calculation methods and record-keeping and audit requirements established by the Federal Government.[16]

Currently, there are 36 methods through which ACCUs can be created, listed in Table 1.1 on the next page.

As at 17 August 2021, ACCUs could be bought for immediate delivery at $22.40.[17]

ACCUs are the only units that can be used for compliance with the Safeguard Mechanism (see Section 1.5 on the preceding page). They can also be used for achieving carbon-neutral status through Climate Active.

In some cases, other units that represent avoided emissions in Australia are used for offsetting. These include Large Generation Certificates (LGCs) created under the Renewable Energy Target, each representing one megawatt-hour of electricity from a renewable source; and Energy Savings Certificates (ESCs) from the NSW Energy Savings Scheme, each representing one megawatt-hour of energy consumption avoided.[18]

1.6.2 Other certification schemes

Outside Australia, the most significant certification schemes used for offsetting are the Clean Development Mechanism, Gold Standard, Verra, and the American Carbon Registry. Units from these schemes cannot be used in the Safeguard Mechanism, but they can (with some limits) be used for carbon-neutral claims through Climate Active,[19] and are also used by organisations making voluntary efforts to be carbon-neutral or net-zero.

Clean Development Mechanism

The Clean Development Mechanism was originally developed to support the Kyoto Protocol, and certifies projects in less-developed countries.[20] Developed countries could purchase these units (known

16. *Carbon Credits (Carbon Farming) Act 2011*.
17. Reputex (2021).

18. An LGC or an ESC does not offset one tonne, because a megawatt-hour of avoided electricity from the grid does not result in one tonne of avoided emissions.
19. Climate Active allows Certified Emission Reductions except for those associated with nuclear projects, destruction of trifluoromethane, or destruction of nitrous oxide from adipic acid plants or from large-scale hydro-electric projects not consistent with World Commission on Dams guidelines. It allows Verified Emission Reductions and Verified Carbon Units: Climate Active (2021b).
20. Called 'non-Annex One' countries in the context of the Kyoto Protocol. Developed countries are known as 'Annex One' countries.

Table 1.1: Current methods through which Australian Carbon Credit Units can be created for the Emissions Reduction Fund

	Nature-based	Industrial
Avoidance	Vegetation: • Avoided clearing of native regrowth • Avoided deforestation • Designated Verified Carbon Standard projects • Savanna fire management – emissions avoidance Agriculture: • Animal effluent management • Beef cattle herd management • Fertiliser use efficiency in irrigated cotton • Beef cattle: feeding nitrate containing supplements • Milking cows: feeding dietary additives	Waste: • Alternative waste treatment • Landfill gas • Landfill gas (generation) • Source-separated organic waste • Domestic, commercial, and industrial wastewater Other sectors: • Aggregated small energy users • Commercial and public lighting • Commercial building energy efficiency • High-efficiency commercial appliances • Industrial electricity and fuel efficiency • Industrial equipment upgrades • Refrigeration and ventilation fans • Aviation • Land and sea transport • Facilities • Coal mine waste gas • Oil and gas fugitives • Carbon capture and storage
Removal	Vegetation: • Human-induced regeneration of a permanent even-aged native forest • Measurement-based methods for new farm forestry plantations • Native forest from managed regrowth • Plantation forestry • Reforestation and afforestation • Reforestation by environmental or mallee plantings • Savanna fire management – sequestration and emissions avoidance Agriculture: • Measurement of soil carbon sequestration in agricultural systems • Estimating sequestration of carbon in soil using default values	(No methods available yet)

Note: There are also 17 methods that have been revoked (i.e. closed to new projects): CER (2021b). Source: CER (2021c).

as Certified Emission Reductions or CERs) and use them to meet part of their obligations to reduce emissions under the Kyoto Protocol.[21]

The intent of the Clean Development Mechanism was to encourage developed countries to adopt more ambitious targets. In practice, poor project design and monitoring and verification meant that about 85 per cent of CERs came from projects that did not achieve additional emissions reductions.[22] Because developed countries then used CERs as a substitute for reducing their own emissions, overall global emissions were greater than if developed countries had relied only on reducing their own emissions to meet their targets.

Despite the Kyoto Protocol target dates having passed, there are still significant numbers of CERs available, because the projects that create them are still operational. International negotiations are continuing on whether these units can be used to meet national targets under the Paris Agreement. Uncertainty about the future value of CERs means the market is not valuing them highly. CERs were available for US$1.31 in August 2021.[23]

Gold Standard

Gold Standard certifies non-government projects under the Clean Development Mechanism and for voluntary carbon markets. Its rules aim to guarantee carbon reduction projects have high environmental integrity and also contribute to sustainable development.[24] It has certified about 1,900 projects across 80 countries.

There are two types of units available through Gold Standard: Certified Emission Reductions (CERs), which can be used by governments for compliance with Kyoto Protocol targets; and Verified Emission Reductions (VERs), used by non-government groups for voluntary emissions reductions. In 2019, Gold Standard issued 34 million units, of which 28.5 million were VERs.[25]

One Australian project is registered to create Gold Standard units. It is a reforestation project estimated to sequester 25,000 tonnes each year.[26]

Verra

Verra is the world's largest certification scheme for offsetting. It has 1600 projects worldwide, responsible for more than 500 million tonnes of removals and emissions avoided.[27] Verra units have optional additional certification for impacts on biodiversity and communities.[28]

Verra units are used only in the voluntary market. They have been criticised for lacking stringency around additionality criteria, and for inconsistent estimates of sequestration through avoided deforestation.[29]

Four Australian-based projects totalling 266,000 tonnes are registered through Verra. One is a reforestation project, the others are avoided deforestation.[30]

American Carbon Registry

The American Carbon Registry issues units in both regulated and voluntary carbon markets. It oversees units created and used in the California Cap-and-Trade emissions trading scheme, and also issues

21. Kyoto Protocol targets applied to Annex One countries between 2008 and 2020.
22. Carbon Market Watch (2020).
23. Reputex (2021).
24. Gold Standard (2021a).
25. Gold Standard (2021b).
26. Gold Standard (2021c), viewed 6 September 2021.
27. Kaskeala and Salo (2021).
28. Verra (2021).
29. Greenfield (2021).
30. Gold Standard (2021c), viewed 6 September 2021.

VERs for use in voluntary markets.[31] The registry has issued well over 100 million units.[32]

1.7 How the remainder of this report is structured

Chapter 2 analyses where and how offsetting units are being created in Australia, who is buying them, and the factors that influence supply and demand and prices.

Chapter 3 recommends actions Australian governments should take to support a vibrant domestic offset market that maintains integrity and contributes meaningfully to net-zero goals.

Appendix A contains detailed descriptions of selected offsetting activities, and their potential and limits in Australia.

31. American Carbon Registry (2021).
32. American Carbon Registry (2017).

2 The market for offsetting units in Australia

A market for offsetting units is ultimately created by climate change policy. There is little reason to create or purchase offsetting units if there is no current or anticipated obligation or incentive to restrain emissions.

The 'market' for offsetting units in Australia is still emerging, and is dominated by the Federal Government's purchasing program, the Emissions Reduction Fund (ERF). This program purchases Australian Carbon Credit Units (ACCUs) at auction to encourage activity to avoid emissions or remove carbon dioxide from the atmosphere.

Some additional voluntary purchase of offsetting units goes on, mostly by companies that have set their own net-zero targets, but also by speculators. These purchases tend to come from Certified Emission Reductions (CERs) from projects overseas. Purchasing for compliance purposes is negligible.

In future, demand for offsetting units should be driven by strong policies to reduce emissions and achieve net zero. Some sectors have fewer options to reduce emissions than others, and will come to dominate the demand for units as net zero gets closer. International markets for units may also be a source of demand.

The theoretical physical limit for Australian supply of offsetting units is unlikely to be a barrier; but beneath this limit there is considerable uncertainty about costs, measurement, and permanence. Having a good supply of offsetting units by 2050 as part of achieving net zero will require policies that encourage emissions reductions, and considerable effort to deploy removal projects.

Box 1: Regulating the Australian market for offsetting units

As outlined in Section 1.6.1 on page 13, the Australian market for offsetting units is dominated by Australian Carbon Credit Units (ACCUs). ACCUs can be created by registering a project with the Clean Energy Regulator, and carrying out an offsetting activity in accordance with an Emissions Reduction Fund method (see Table 1.1 on page 14 for a list of all current methods). Once eligible activities have been performed, the project owner can create ACCUs and sell them.

The Clean Energy Regulator keeps a registry of all ACCUs created and who owns them. ACCUs can be transferred between owners through the registry and also retired or cancelled – the former is the point at which 'offsetting' occurs. The registry also tracks ownership and status of other units such as Certified Emission Reductions, but Australian owners of these units are not obliged to record this in the registry.

The Clean Energy Regulator also audits projects and administers contracts where the government is the purchaser of ACCUs.

New methods for creating ACCUs are made by the Minister for Energy and Emissions Reductions, acting on the advice of the Emissions Reduction Assurance Committee. The Committee assesses methods to ensure they comply with the Offsets Integrity Standards set out in the Carbon Farming Act. It also reviews existing methods and advises the Minister on whether to vary or revoke them.

The system is underpinned by the *Carbon Credits (Carbon Farming Initiative) Act 2011*.

2.1 Climate change policy creates markets

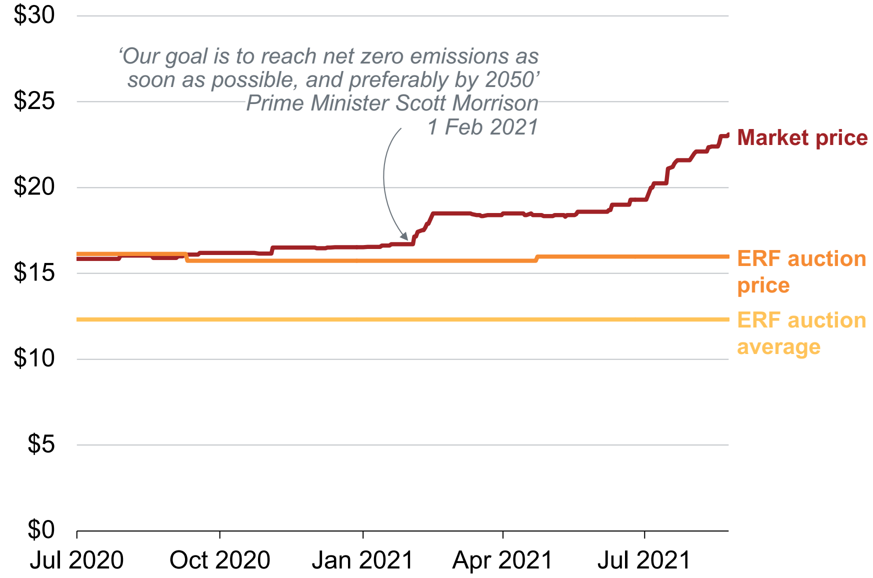
Markets for offsetting units only exist because of pressure to reduce emissions. Some of this pressure may come from consumers, shareholders, and investors, but in most markets it arises because governments have put in place policies to constrain emissions.

When governments put in place emissions constraints, offsetting is often included as a ‘safety valve’ to lower the cost of achieving the constraint, and (in some cases) to allow for a more ambitious policy. Governments may choose to limit the amount of offsetting allowed (as the European Union currently does in its Emissions Trading Scheme) to encourage emissions reductions. Governments may also limit the types of offsetting units that can be used.

Even when emissions constraints are weak, anticipation of a future constraint can drive market activity. Figure 2.1 shows how prices for ACCUs jumped after the Prime Minister’s statement that Australia’s target is to reach net-zero emissions as soon as possible.

Figure 2.1: Anticipation of future emissions constraints can drive demand for offsetting units

Market price of Australian Carbon Credit Units



Note: ERF = Emissions Reduction Fund.

Source: Grattan analysis of CER (2021d) and Reputex (2021).

2.1.1 Government purchasing is the largest single source of offset demand in Australia

Through the Emissions Reduction Fund (ERF), the Federal Government periodically conducts reverse auctions to purchase ACCUs. Projects that win at auction secure a contract to sell ACCUs to the government at a fixed price. Once these ACCUs are delivered to government, the government retires them, and the emissions avoided or removed show up in the national carbon accounts. The project owner can sell any extra ACCUs to someone else.

To date, the Federal Government has entered into contracts totalling $2.5 billion for 205 million ACCUs. About 84 million ACCUs have been created by projects with contracts, of which 66 million have been delivered to government and retired.[33]

In 2020-21, Federal Government purchasing through the ERF represented 89 per cent of ACCU demand.[34] The remainder of the market was made up of voluntary demand (about 6 per cent), compliance with the Safeguard Mechanism (0.5 per cent), and speculators or buyers for other purposes (the remainder).

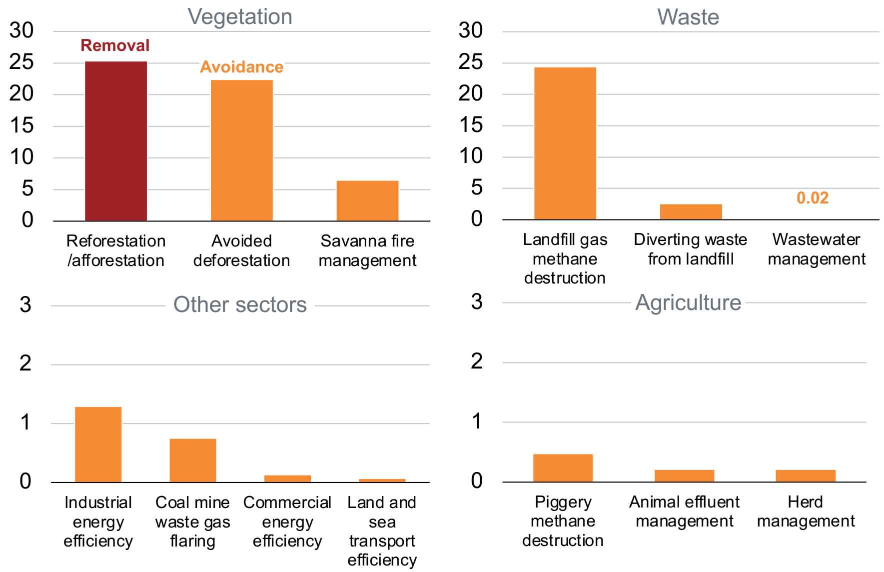
Most ACCUs purchased by the Federal Government are for emissions avoided (Figure 2.2). While details of payments to individuals are confidential, we can get some idea of which sectors have benefited most by applying the average ACCU price achieved across all auctions (Figure 2.3 on the next page).

2.1.2 Private sector demand for offsetting units is small

Companies that have made carbon-neutral or net-zero commitments currently provide some demand for units to offset emissions.[35] Forty-nine companies in the Australian ASX 200 have made net-zero commitments,[36] and 242 Australian companies are certified as carbon neutral through the Climate Active program.[37] The scope and ambition of these goals vary considerably, as do the organisations' activities to date to eliminate or offset emissions.

Figure 2.2: Most Australian Carbon Credit Units that the government has purchased represent emissions avoided

ACCUs (millions)

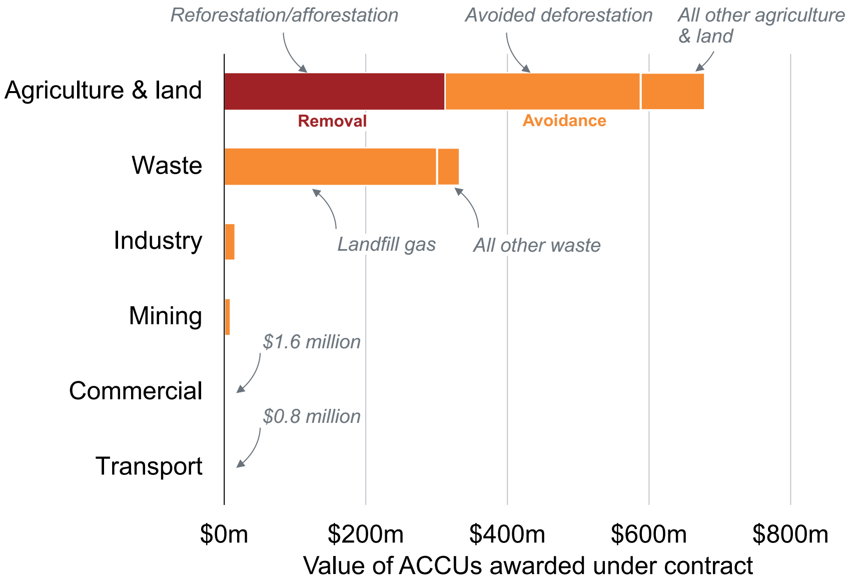


Notes: One ACCU is equivalent to one tonne of emissions offset in carbon dioxide equivalent. Data include all registered Emissions Reduction Fund projects with contracts in place and ACCUs issued as at 1 September 2021. This figure may be higher than the number of ACCUs delivered to government and retired.

Source: Grattan analysis of CER (2021e).

33. CER (2021d) and Grattan analysis of CER (2021e). This report was published before the 13th ERF auction in October 2021.
34. Reputex (2021).
35. A carbon-neutral commitment is a goal of not increasing carbon emissions, and offsetting all those that are produced. A net-zero commitment means reducing carbon emissions wherever possible and offsetting only those that cannot be eliminated: Bigg (2021).
36. Australian Council of Superannuation Investors (2021).
37. Count of companies on the Climate Active website on 6 September 2021. There is some cross-over between these two groups.

Figure 2.3: The land, agriculture, and waste sectors are the biggest beneficiaries of Emissions Reduction Fund purchasing

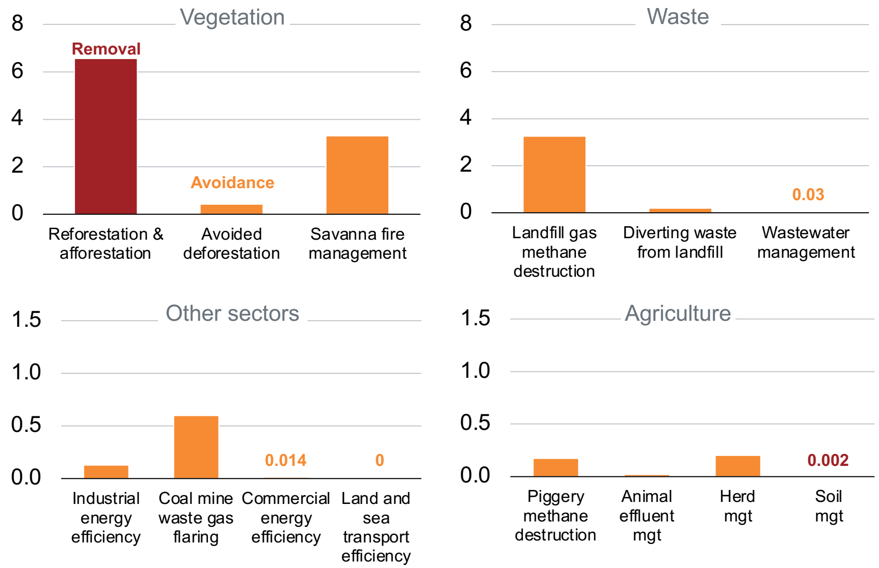


Note: Assumes ACCU price equivalent to the average achieved across all ERF auctions ($12.32) for total ACCUs under government purchasing contracts.

Source: Grattan analysis of CER (2021e).

Figure 2.4: Australian Carbon Credit Units available to purchase outside the Emissions Reduction Fund

ACCUs (millions)



Notes: 'mgt' = management. One ACCU is equivalent to one tonne of emissions offset in carbon dioxide equivalent. Data include all registered ERF projects with contracts in place and ACCUs issued as at 1 September 2021.

Source: Grattan analysis of CER (ibid).

The pattern of ACCUs available for voluntary purchase varies from the pattern seen in ERF purchasing (Figure 2.4). ACCUs from reforestation dominate, and there is almost no demand for avoided deforestation. Methane destruction from landfill gas and coal mine waste gas are also significant sources. There were 923,276 ACCUs traded in the voluntary market in 2020-21,[38] but the sources of these are not published.

However, ACCUs are not the most popular source of offsetting units for voluntary commitments. Certified Emission Reductions (CERs) from overseas projects represented 90 per cent of voluntary offsetting in 2020-21 (8.6 million units).[39] These units are cheap ($1.79 per unit compared to $17.17 for ACCUs in 2020-21)[40] and readily available for immediate retirement to meet current commitments. While ACCUs cost more, it seems the market expects they will have greater future value, particularly for compliance purposes, and as a consequence they are being held rather than being retired.[41]

38. Reputex (2021).

39. Ibid.
40. Ibid.
41. Ibid.

Another source of voluntary demand is companies in other countries with carbon-neutral or net-zero commitments. A prominent recent example is the sale of 40,000 units from Australian soil carbon projects to Microsoft.[42] There is little information available on how much demand for Australian offsetting units comes from overseas, and what certification is preferred by these buyers. The units purchased by Microsoft were certified through a private American certification scheme called Regen, which has been criticised for over-estimating the amount of carbon abated.[43]

ACCUs cannot be exported (that is, an ACCU can't be transferred from the Australian registry to a carbon registry overseas), but overseas companies can hold accounts on the Australian registry, and hold or cancel ACCUs through those accounts. Such transactions show up in Australia's national emissions accounts.

Transactions such as the Microsoft deal are potentially double-counted at present. The emissions reductions that occur here show up in Australia's national carbon accounts, but the purchaser may also report them in another country, and count them towards another country's emissions targets.

2.1.3 Demand for offsetting units for compliance purposes is negligible

The Safeguard Mechanism is a Commonwealth law that applies to all facilities emitting more than 100,000 tonnes annually. It requires facilities to keep their emissions below a 'baseline'. Facilities that exceed their baselines and do not use the allowable administrative provisions to adjust their baseline must surrender ACCUs equivalent to excess emissions or potentially face penalties.[44]

42. Goodwin (2021).
43. Simmons et al (2021).
44. For a detailed description of the Safeguard Mechanism and how it creates demand for ACCUs, see Wood et al (2021b, p. 24).

Compliance demand from the Safeguard Mechanism made up 0.5 per cent of ACCU demand in 2020-21 (88,325 ACCUs).[45] Ideally, compliance demand should be low – this would be a sign that the policy is effective in encouraging industrial facilities to reduce their emissions rather than offset them. However, as we showed in *Towards net zero: Practical policies for the industrial sector*, the Safeguard Mechanism does not place an effective constraint on emissions, and provides considerable headroom for facilities to increase their emissions without penalty.[46]

State government policy is also a potential source of compliance demand. For example, the environmental approvals for the Gorgon LNG project in Western Australia require the facility to capture and store 80 per cent of emissions, and obtain and cancel offsetting units for any shortfall.[47]

2.2 Future demand for offsetting units

In the near term, domestic demand for offsetting units will be driven by a mix of domestic policy, voluntary action, and international market developments. Longer term, demand will come from the 'hard-to-abate' sectors that need removals to reach net zero, including demand from international aviation.

2.2.1 Domestic policy should drive greater investment in projects that create offsetting units

As we showed in the three earlier reports in this series, concerted policy action in every sector is required from federal, state, and territory governments to reach the goal of net-zero emissions, in the absence of a strong economy-wide carbon price.

45. Reputex (2021).
46. Wood et al (2021b, pp. 23–24).
47. Milne (2021a).

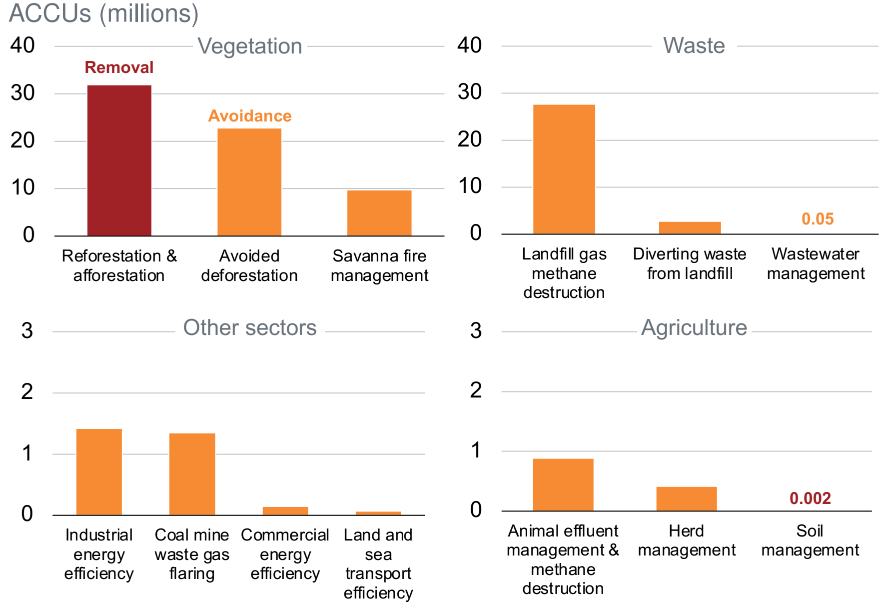
Where offsetting units are created against emissions avoidance, this allows for transfer of effort between sectors similar to a carbon pricing mechanism (albeit by exchanging abatement rather than a permit to emit). The amount of effort exchanged will depend on the cost of emissions reductions in sectors facing constraints, which in turn is a function of technology readiness and other market pressures.

To date, about three-quarters of ACCUs have been created for emissions avoided (Figure 2.5). While Australia is still moving towards net zero, policy should encourage emissions avoidance over emissions removals. This is not just because (as outlined in Section 1.3.1 on page 9) removals are an imperfect substitute for avoidance. It is also because some sectors will have greater need for removal units to reach net zero, and so where possible, others who have more options to reduce or eliminate emissions should do so rather than offset.

In *Towards net zero: Practical policies for the industrial sector*, we suggested declining Safeguard Mechanism baselines so that, over time, all industrial facilities were required to reduce their emissions. If implemented, this could increase future demand for ACCUs.[48]

The other reports in this series make recommendations for policies to bend the national emissions curve towards net zero. If adopted, and depending on design parameters chosen for each policy, these could increase demand for ACCUs or other units for offsetting, if offsetting was used as a 'safety valve' in policy design.

Figure 2.5: Avoided emissions have dominated Australian Carbon Credit Unit creation



Notes: One ACCU is equivalent to one tonne of emissions offset in carbon dioxide equivalent. Data include all registered ERF projects with contracts in place and ACCUs issued as at 1 September 2021. This figure may be higher than the number of ACCUs delivered to government and retired.

Source: Grattan analysis of CER (2021e).

48. The Federal Government has committed to implement an additional type of offsetting unit called a 'below-baseline credit' for Safeguard facilities: DISER (2021a). The rules around creating and using these units will affect demand for ACCUs from Safeguard facilities.

2.2.2 Future demand from voluntary action

The global voluntary market for offsetting units will need to grow by up to 15 times by 2030 to support the investment required to deliver emissions reductions consistent with limiting global warming to 1.5℃.[49]

Voluntary action to reduce emissions can be effective in helping companies and individuals identify successful emissions reductions approaches and understand their costs. Its critical weakness is that, in the absence of strong policies, achievements by a handful of well-meaning companies or individuals can be swamped by the emissions of those who don't act.[50]

About one-quarter of the top 200 companies in the ASX are covered by a net-zero or carbon-neutral commitment.[51] Emissions in 2019-20 from these companies totalled at least 100 million tonnes,[52] or slightly less than one-fifth of Australia's 2019 emissions. Detail is scarce on how many of these companies plan to meet these goals, and the extent to which they plan to offset. But if global trends are a guide, we can expect that less than 10 per cent plan to meet their net-zero goals solely through emissions reductions.[53]

However, this does not mean there is a potential market of 90 million offset units. As governments put in place policies to constrain emissions and achieve net-zero goals, and as shareholder and international pressure changes, companies with net-zero targets will change their preferred mix of emissions reductions, offsets, and divestment.[54]

Companies will need to balance their duties to shareholders, their compliance with emissions regulation, and a desire to stay ahead of competitors.

2.2.3 Longer-term demand for offsetting units

In the three earlier reports in this series, we identified some 'hard-to-abate' sectors where offsetting currently seems the best way to reach net zero by 2050. These are sectors that are likely to have significant need for removal offsetting units, and include:

- Aviation;
- Some long-distance heavy transport, if electric and fuel-cell vehicles are slow to achieve full market penetration;
- Some industrial process emissions, such as cement and chemicals manufacturing; and
- Beef and dairy cattle, and sheep.

Figure 2.6 on the next page shows a possible order-of-magnitude demand for offsetting units in 2050 across the economy. If the hardest-to-abate sectors are able to reduce emissions by only 20 per cent by 2050, then they will be responsible for about 62 million tonnes of emissions per year. That means these sectors will need 62 million tonnes of annual offsetting units to reach net zero. Changes

49. Taskforce on Scaling Voluntary Carbon Markets (2021, p. 10).
50. Riggs (2002, pp. 65–67).
51. Australian Council of Superannuation Investors (2021).
52. Grattan analysis of CER (2021f) and Australian Council of Superannuation Investors (2021). 100 million tonnes is the sum of Scope 1 emissions of all ASX-200 entities with a net-zero target that also report their emissions through the National Greenhouse and Energy Reporting Scheme.
53. Energy & Climate Intelligence Unit (2021).
54. Divestment refers to companies selling high-emissions facilities in order to meet emissions targets. Unless the purchaser closes the facility, divestment makes no change to overall emissions, just a change in who is responsible for the emissions. Companies that have adopted the Science Based Targets initiative commit to establishing their own carbon budget and to reducing emissions as much as possible before turning to carbon dioxide removal for offsetting: SBTi (2020, p. 33).

in technology and market demand for these products could mean emissions fall faster or slower, or even rise – the outlook is very uncertain.

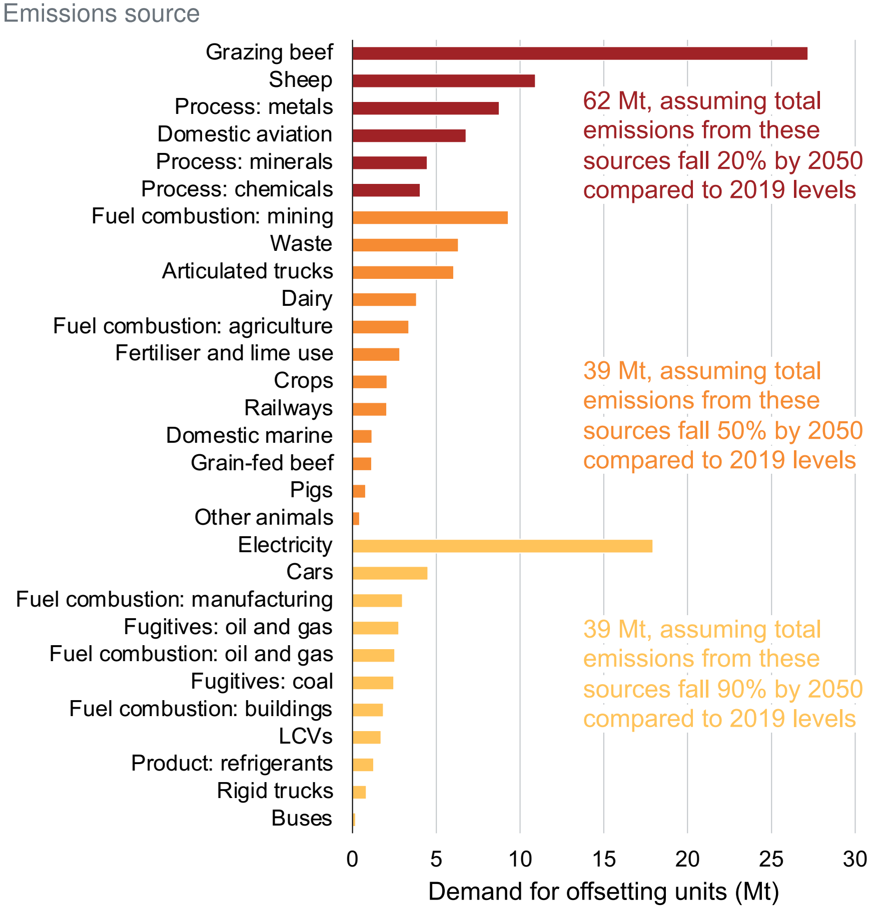
There are moderately-hard-to-abate sectors with better prospects for reducing (but not eliminating) emissions. For example, in 2050 there may be many articulated trucks (e.g. semi-trailers) powered by batteries or hydrogen, but unless sales of diesel-fuelled trucks cease in the 2030s there will still be many diesel trucks on the road in 2050. These sectors could emit 39 million tonnes in 2050, assuming that their emissions fall by half.

Lastly there are sectors where either an obvious solution exists to eliminate emissions (e.g. electricity), or the activity may largely cease by 2050 (e.g. coal mining). But even these sectors may still have some residual emissions that require offsetting to achieve net zero by the deadline of 2050. There are significant economic and technical challenges in trying to run a reliable electricity system on 100 per cent renewable energy.[55] For the foreseeable future, a small amount of gas-powered generation looks to be the cheapest way to maintain reliability in a mostly-renewable system. In addition, demand for electricity will rise as people switch from gas to electric appliances and from petrol/diesel vehicles to electric vehicles. As for coal mining, even if demand for coal collapses, abandoned mines continue to emit some fugitive emissions. Assuming total emissions from these sectors fall 90 per cent, that would still leave about 39 million tonnes of emissions in 2050.

All sectors have at least some options to reduce emissions – the estimates shown in Figure 2.6 are only the residual emissions – and that is where their efforts should focus first. Even with an emissions constraint, some emitters might offset for a while before reducing emissions, then return to offsetting later for residual emissions.

55. Wood and Ha (2021).

Figure 2.6: All sectors are likely to have some demand for offsetting units in 2050



Notes: Mt = million tonnes. LCVs = Light Commercial Vehicles. Chart shows possible demand for offset units if emissions fall from current level by the percentages shown in 2050. Emissions from some very small sources (e.g. motorcycles and military fuel use) are not included. Note that some sectors may offset from within their own sector (for example, beef-cattle farmers undertaking soil carbon management).

Source: Grattan analysis of DISER (2020).

International aviation

Another emerging source of international demand for offsetting units is the Carbon Offset and Reduction Scheme for International Aviation (CORSIA). Emissions from international aviation make up 65 per cent of all aviation emissions, but are not counted on any one country's greenhouse gas accounts. International aviation is a significant and growing source of emissions: 1.3 per cent of all global emissions, and (pre-COVID) growing at 5 per cent per year.[56]

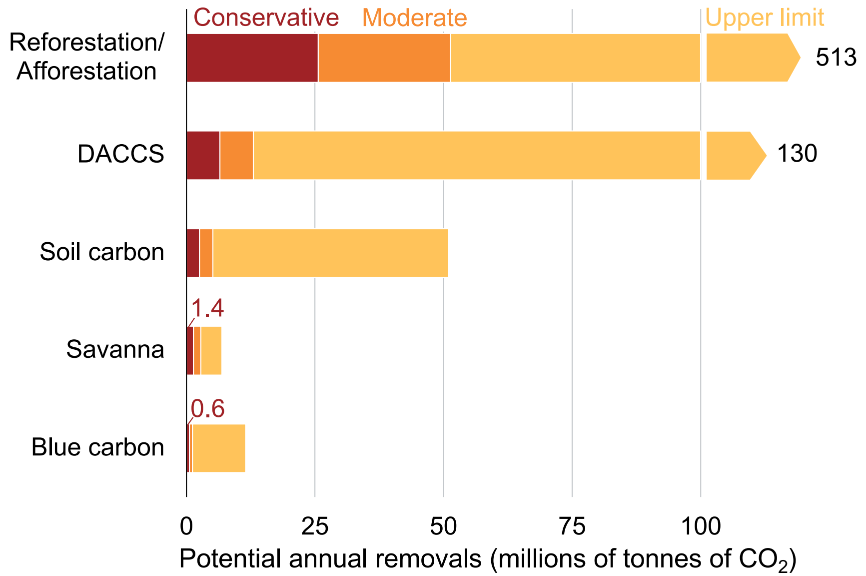
CORSIA is a voluntary agreement through the International Civil Aviation Organisation to prevent any growth in international aviation emissions after 2020, through using offsetting units and lower-emissions fuels. This could provide demand for 7.8 billion offsetting units between 2020 and 2040.[57]

2.3 Will there be sufficient units to meet likely demand?

If emissions reductions follow the pattern in Figure 2.6 on the previous page, long-term offsetting requirements for holding national emissions at net zero would be more than 100 million units each year.[58]

If the most optimistic estimates in Appendix A came to fruition, Australia's capacity to create offsetting units from removal activities would be at least 700 million tonnes each year (Figure 2.7).[59] But achieving this would involve massive change in the economy and in patterns of land and water use, away from agriculture and towards creating nature-based units. It would involve setting aside most available geological carbon storage sites for potential direct air capture use. And, it would involve doubling or tripling current electricity generation and network capacity. This estimate does not account for relative costs of each option, or for the fact that some options are

Figure 2.7: Physical limits to Australia's potential to remove carbon from the atmosphere are well above economic and technical limits



Notes: DACCS = direct air capture with carbon storage. A full explanation of assumptions and sources can be found in Table B.1 on page 46.

56. Timperley (2019).
57. Ecosphere (2021). Note this estimate was made before the COVID-19 pandemic.
58. Figure 2.6 shows demand for 140 million offsetting units in 2050. Land use, land use change, and forestry (LULUCF) already removes about 25 million tonnes of emissions each year; if this is maintained, then an additional 115 million offsetting units will be needed: DISER (2021b). If technology for reducing emissions improved faster than currently projected or if some emitting activities cease, the need for offsetting may be lower than shown here. If sustained large-scale atmospheric removal of carbon dioxide is necessary to stabilise or decrease global temperatures, the need for offsetting may be higher than shown here.
59. This figure includes some avoidance units from savanna burning. Savanna burning is the only source of avoidance offsetting available once net zero is reached, because it involves avoiding naturally occurring emissions. See Appendix A.1.2 on page 39 for more detail.

subject to considerable uncertainties and may be affected by climate change. These issues are explored in more depth in Appendix A.

To achieve the ‘conservative’ level of removals shown in Figure 2.7 on the previous page (37 million tonnes per year) will require reforesting 5 per cent of suitable land (much of which is currently used for agriculture). It will require direct air carbon capture and storage at double the rate of Australia’s only CCS facility. It will require 5 per cent of farmland to include soil management for carbon; 20 per cent of savanna to undergo fire management; and restoration of 5 per cent of Australia’s degraded coastal ecosystems. Even this conservative estimate requires producing more removal ACCUs every year than have been created in the five years of the ERF’s operations.[60] A moderate level of removals would double all these figures.

At present, it is unclear in which direction the market will evolve. There is a physical upper limit to how many offsetting units Australia can produce, but beneath that limit there is a cost curve of different options, each with their own uncertainties around measurement, permanence, and cost.

There is no need to assume Australia must meet all its offsetting requirements from Australian offsetting units. If units with equivalent or greater integrity are available from elsewhere at a cheaper price or lower social or environmental impact, then we should use those.[61]

If Australia wants to be able to use international offsetting units as part of achieving net zero, schemes such as CORSIA will create stiff competition (to say nothing of competition from other, larger countries that also need to offset to keep their emissions at net zero). However, if we can produce high-integrity offsetting units at a cheaper price than other countries, and those units are valued more highly in international markets than Australian markets, international demand represents an opportunity. In the long term, offset units may become like any other commodity: we will produce some here for our own use, export some, and import where it makes sense to do so.

60. To date, about one-quarter of ACCUs (32 million) have come from nature-based removals; the balance are avoided emissions (Figure 2.5 on page 22).
61. The Clean Energy Future emissions trading scheme in place between 2012 and 2013 envisaged using international units for compliance once a floating price was in place: DCCEE (2011, p. 107).

2.4 The cost of offsetting

2.4.1 Cost drivers for producing offsetting units

The costs of producing offsetting units vary widely with the type of project undertaken. Australian costs currently appear to be well below $30 per unit, based on dominance of vegetation management and landfill gas management. But the cost of permanent industrial removal through direct air capture and storage is estimated at between US$100 and US$1,000 per tonne of carbon dioxide captured.[62]

The relative cost of creating offsetting units in Australia will depend on whether the inputs (land, renewable energy) deliver more value if used to create offset units than other economic outputs, and whether the social and environmental impacts are acceptable. Common to all types of offsetting units, however, is that compliance with the rules for creating units forms a significant part of set-up and ongoing costs.[63] There is a trade-off between keeping these costs low, and maintaining integrity, discussed further in Section 3.2.1 on page 31.

2.4.2 Prices for purchasing offsetting units

As the dominant purchaser of offsetting units to date, the Federal Government has been the Australian market price-setter. Since the Government started buying ACCUs in 2015, the price has varied

62. Realmonte et al (2019).
63. CCA (2020, p. 45), Dormady and Englander (2015, p. 144).

between $10.23 and $15.99, with an average across the period of $12.32 (Figure 2.8).

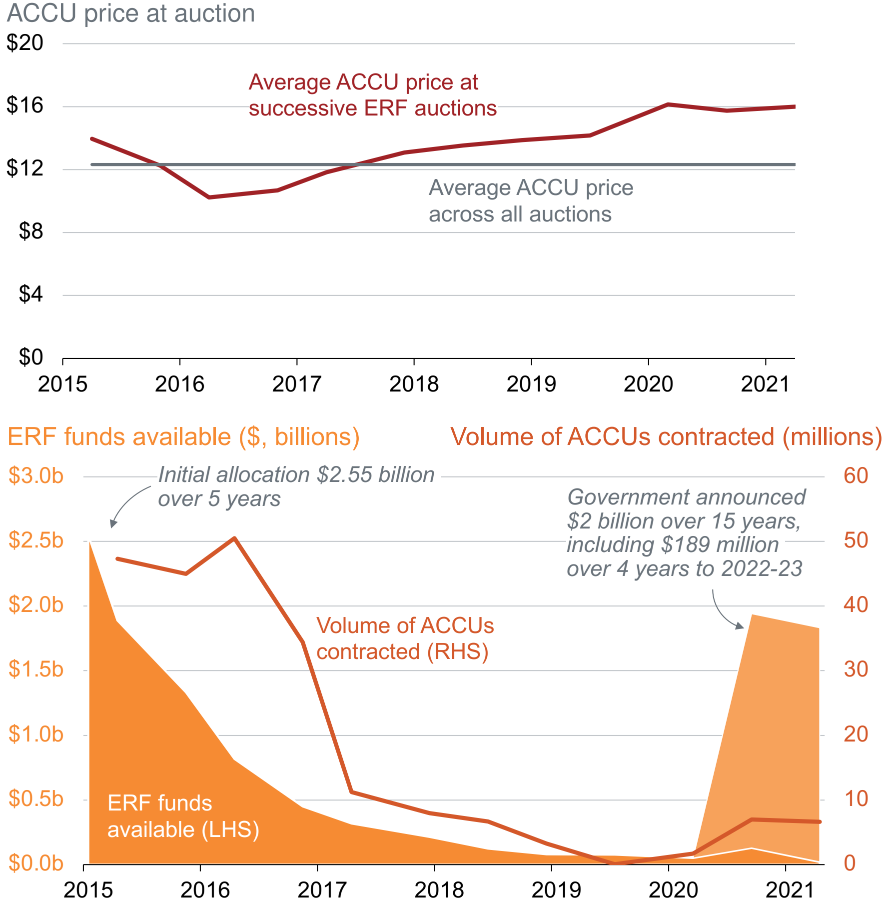
The Federal Government seeks to purchase ACCUs at least cost, and maximise the amount that it can purchase.[64] Volumes of ACCUs purchased were very high at the first few auctions, but soon dropped off as potential creators realised that the funds allocated were being used up (Figure 2.8). The average price per ACCU contracted at each auction has been creeping up, presumably because potential creators are asking higher prices. A government announcement in 2019 of an additional $2 billion over 15 years has not led to a rebound in ERF interest: creators remain wary of the these funds being reallocated to other government priorities.[65]

Because the non-government market is small, its prices can be volatile. In recent months there has been a significant divergence between the government and non-government price (Figure 2.1 on page 18). On 1 October 2021, the non-government price reached $28.75.[66] Some attribute diverging prices to anticipation of limits on emissions following the Prime Minister's statement that Australia wants to achieve net zero as soon as possible and preferably by 2050.[67]

Future prices of offsetting units will be affected by the relative costs of reducing emissions; how large the emissions reductions are; and expectations about the stringency of future emissions constraints, and future costs of emissions reductions and units, particularly if units can be held indefinitely.

Higher prices for offsetting units will encourage more emissions reductions and less offsetting; conversely, a low unit price will

Figure 2.8: Australian Carbon Credit Unit volumes at auction fell as the market anticipated lower demand



Note: Does not include results from the 13th ERF auction scheduled for mid-October 2021.

Source: Grattan analysis of CER (2021d), Treasury (2014) and Treasury (2019).

64. *Carbon Credits (Carbon Farming) Act 2011, s20G(3).*
65. CCA (2020, pp. 7, 35).
66. Demand Manager (2021).
67. Reputex (2021).

encourage firms subject to an emissions constraint to use offsetting rather than make changes to their operations that reduce emissions.

As noted in Section 1.3.1 on page 9, emissions reductions are preferable to offsetting, because of the uncertainty about permanence, and because relying too strongly on offsetting risks pushing the global climate past a tipping point. Governments therefore should not be afraid of high prices for offsetting units if these are coupled with strong policies to reduce emissions.

3 What governments should do

Policies that create momentum towards net-zero emissions in Australia by 2050 can be more ambitious and achieved at lower cost if they include offsetting. And offsetting will be essential for some sub-sectors where reducing emissions is technically or economically out of reach.

Once emissions reduction policies are in place, there are four further actions governments should take so that offsetting can play its part in achieving net zero.

First, offsetting units must have integrity – each unit must represent a genuine additional emissions reduction or removal that would not have happened otherwise. Over time, most emissions reductions will be part of normal practice in every sector, and offsetting will become dominated by genuine carbon dioxide removals.

Second, units need to be tracked, to avoid double-counting and assist in verification, and to allow price information to emerge.

Third, governments have a role as early market-makers to help build a functioning market. But, they should step back from market participation over time.

And finally, governments should invest in R&D and early-stage deployment for industrial emissions removals, to ensure these technologies can play their part in reaching net zero and holding atmospheric carbon levels stable.

3.1 Stronger policies to reduce emissions will underpin a vibrant offsetting market

In this report series, we have recommended several policies that governments in Australia should enact now to put emissions on the path to net zero. Of these polices, the following could include offsetting to lower costs and increase ambition:

- Introduce an emissions standard for light vehicles.[68]
- Introduce a renewable fuel standard for diesel and aviation fuel.[69]
- Strengthen the Safeguard Mechanism so that facility baselines put downward pressure on emissions, including linking baselines to national targets and making all baselines decline.[70]
- Expand or introduce state-based energy efficiency schemes to drive emissions reductions in small industrial facilities.[71]
- Expand the number of Emissions Reduction Fund methods available for agriculture, and make it easier for farmers to participate in the fund.[72]

In an earlier report, *Go for net zero: A practical plan for reliable, affordable, low-emissions electricity*, we showed that achieving net zero in the electricity sector is likely to require a small amount of gas-fired generation, unless other affordable solutions for seasonal electricity storage can be found.[73] Emissions from this gas generation would also need to be offset. The amount of units required will depend on several factors, including how much electricity demand grows as other sectors switch to electrification to reduce their emissions.

68. Wood et al (2021a).
69. Ibid.
70. Wood et al (2021b).
71. Ibid.
72. Wood et al (2021c).
73. Wood and Ha (2021).

The policies outlined in our *Towards net zero* series will not be enough to achieve net zero by themselves – additional policies will be needed. But they will begin bending the emissions curve downwards. Incorporating emissions avoidance offsetting (from activities that go beyond compliance) into the design of these policies will allow for transfer of effort between sectors, so that all reduce their emissions at lower costs. And it will allow governments to be more ambitious when scoping these policies.

Offsetting is a necessary part of achieving net zero by 2050. Governments need to set clear parameters around the role offsets will play in each policy that contributes to net zero. In general, it would be better to design these policies with an expectation that offsetting is a 'safety valve' in the event that costs are higher than anticipated, rather than expecting substantial offsetting.

Governments in Australia will also have to decide what role, if any, international offsetting units can play. Allowing more international units may help keep costs down, but too many may slow the pace of uptake of new technologies by encouraging firms to offset instead of reduce emissions.

Emissions reductions are only one part of the net-zero story. Removing emissions from the atmosphere will be necessary, because there is a net-zero deadline and not every source of emissions can be eliminated by that deadline at reasonable cost (or in some cases, eliminated at all without ceasing that activity). While emissions are declining towards net zero, governments should focus on improving the measurement, verification, permanence, and cost of removals. As net zero gets closer, governments will need to adjust policies so that offsetting only unavoidable emissions becomes the norm.

For offsetting to play its full part, government should step back from being a large market participant and focus instead on the market underpinnings: creating and maintaining a strong policy framework to drive down emissions and create demand for offsetting units; making sure offsetting units are credible and have integrity; and removing barriers to efficient trading.

3.2 Integrity is essential for an effective market

Confidence in the integrity of offsetting units is a fundamental underpinning of an effective market for offsetting units. For an offsetting unit to have integrity, it has to represent actual emissions reductions or sequestration that would not have taken place in the absence of demand for an offsetting unit. It must be able to be accurately monitored and verified, and it must only be counted once.[74]

Poor integrity increases costs

Additionality – judging whether an activity would have taken place in the absence of an offsetting unit being offered – can be fraught.

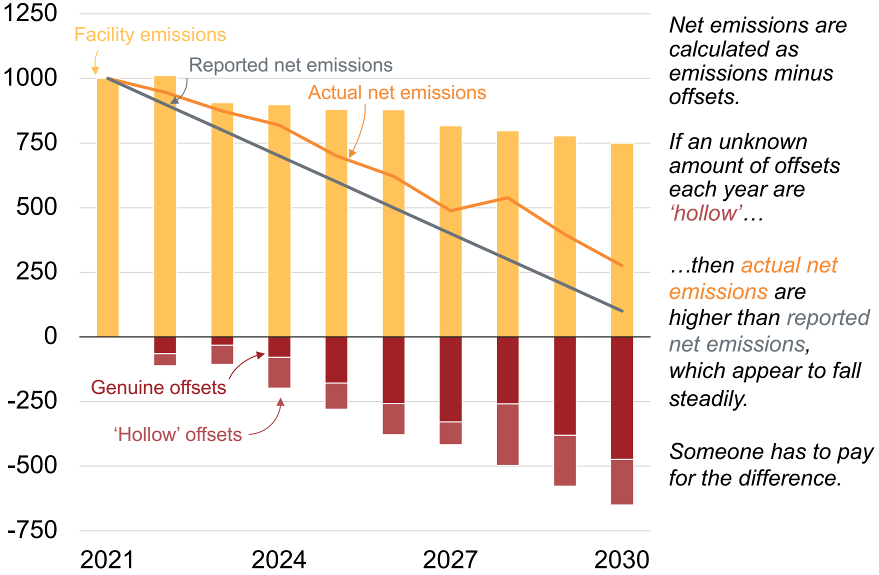
If the additionality test is complex, very little activity will be encouraged. Make it too simple, and there will be large volumes of activity bought and paid for, but much of this will be 'hollow': units that do not offset as many tonnes of greenhouse gas as they say they do. Hollow units may be offset against emissions in an accounting sense, but the outcome will not be a reduced impact on global temperatures.

If some of the units in the market are hollow, the real cost to the economy of emissions reductions will be higher than the market price of units suggests. As well, a bottom-up aggregation of reported emissions (which would include offsetting) will diverge from top-down calculations, making it difficult to assess overall progress towards net zero (Figure 3.1 on the following page).

74. Taskforce on Scaling Voluntary Carbon Markets (2021).

Figure 3.1: Poor integrity makes the cost of emissions reduction higher

Emissions (thousand of tonnes of carbon dioxide equivalent)



Notes: Stylised example. Percentage of 'hollow' offsetting units varies between 20 per cent and 70 per cent in any year. In this example, the gap between emissions reported and actual emissions is 1.2 million tonnes. At a cost per unit of $12, the cost of abatement achieved is $18.76 per tonne.

Source: Grattan analysis.

New data and technology will come to light

Methods for calculating and creating offsetting units should include some allowance for uncertainty in measurement and verification. Measurement and verification practices and technologies are improving all the time, and methods should keep up with these changes.

At the same time, many nature-based offsetting activities are at risk from climate impacts,[75] and these risks will change the basis on which emissions avoided or removals are calculated.

Methods therefore cannot be 'set-and-forget': they need to be regularly reassessed both for improvements in measurement and verification and advances in their underpinning science; and also for the impacts of a changing climate on previous assumptions. Otherwise, these could become a further source of hollow units.

Double-counting could be an issue as demand increases

Double-counting happens when rules do not prevent the same offsetting activity from being claimed more than once (see Figure 3.2 on the next page). Similar to poor additionality, it creates a disconnect between carbon accounts and actual emissions, making it more difficult to assess progress towards net zero.

3.2.1 Questions about integrity undermine effectiveness

As noted in Section 3.2 on the preceding page, additionality refers to testing whether an offsetting activity would take place if no offsetting units were awarded for it. It includes regulatory additionality (does the activity go beyond what is required by law?) and financial additionally (is the project economic without an additional income stream from selling offsetting units?). Both these have been called into question for two of the largest sources of Australian Carbon Credit Units (ACCUs).

75. Roxburgh et al (2020), discussed further in Appendix A.

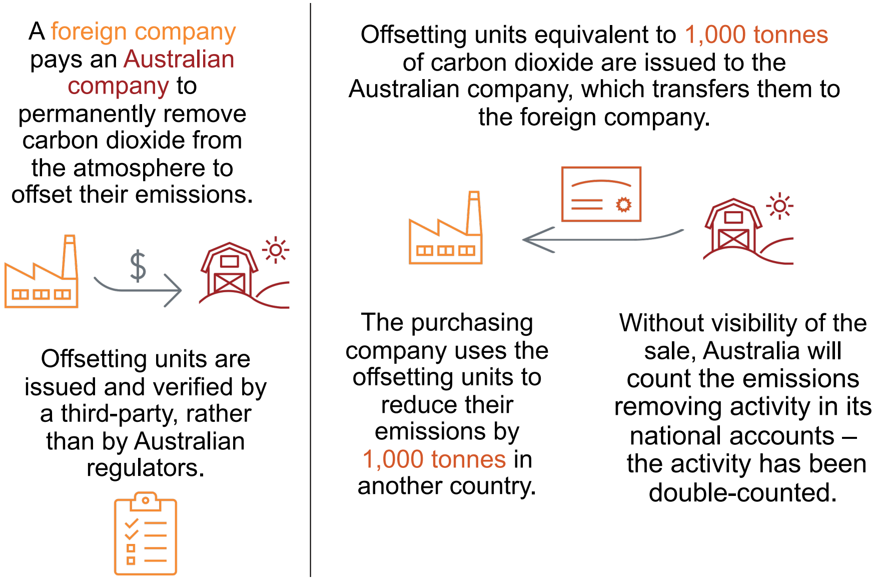
Flaring and using methane from landfill is a major source of ACCUs created by projects with a government contract to date – 24.4 million out of a total of 84.4 million ACCUs created.[76] State environmental protection laws require landfill operators to manage methane emissions, and often the most cost-effective way to do so is flaring. Or, methane can be used to generate electricity. When this is done, landfill operators can claim LGCs (large-scale generation certificates) and on-sell the electricity for an income stream. Some have cited this as a failure of financial additionality.[77]

About 22.4 million ACCUs have been created by projects with government contracts for avoided deforestation.[78] The underpinning calculations rely on an assumption that landholders intended to clear vegetation from land and only refrained from doing so because ACCUs were available. But state laws restrict land-clearing. Some critics see this as failing the regulatory additionally test, because it is not clear whether deforestation is avoided because ACCUs have 'valued' the activity, or because the laws have delivered their intended outcome.[79]

Contested additionality is not an issue confined to ACCUs. As discussed in Section 1.6.2 on page 13, Certified Emission Reductions (CERs) notoriously had problems with additionality, which severely affected their value. CERs are used extensively in voluntary offsetting in Australia, much more so than ACCUs.

Issues such as the above (regardless of how material or true they are) contribute to offsetting's poor reputation. It is notable that very few avoided deforestation ACCUs are available for voluntary purchasers (see Figure 2.4 on page 20), although this may also be a case of voluntary purchasers preferring ACCUs with greater co-benefits, such

Figure 3.2: How international double-counting of offsetting units might happen



76. Grattan analysis of CER (2021e). See also Figure 2.5 on page 22.
77. Baxter and Gilligan (2017).
78. Grattan analysis of CER (2021e). See also Figure 2.5 on page 22.
79. Slezak and Timms (2021).

as those from Indigenous-led savanna burning projects, and those associated with tree-planting.

3.2.2 Designing for integrity

Offsetting already has a poor reputation because of integrity issues (see Box 2). Integrity needs to be maintained (and be seen to be maintained) at a high level if offsetting is to be an effective policy instrument.

Additionality is a vexed question for all public policy interventions. Governments do not have perfect foresight, nor can they reasonably audit every single offsetting project. The best approach is to be as rigorous as possible where additionality is clear-cut (for example on regulatory additionality), while accepting that inevitably some activity may not be additional, and design policies to keep such activity at a minimum.

Similarly, the technology for measurement and verification, and the science underpinning calculations, is changing day by day. Governments must find a balance between staying up-to-date, and minimising the transaction costs that arise from constantly changing the rules. Methods that are based on outdated science or technology may result in creation of ACCUs that do not represent the true emissions avoided or removed (either on the upside or the downside). If technology or practice has advanced since the method was created, it is possible that potential sources of ACCUs based on newer approaches cannot be accessed if methods do not allow them.

Every method for creating offsetting units should be reviewed regularly, assessed against evidence from projects that use that method, and adjusted to minimise non-additional activity. Creators of offsetting units should switch to the updated method as soon as possible.

Box 2: Improving confidence in offsetting

Offsetting is a difficult part of the net-zero conversation, because it has a poor reputation. Offsetting is often regarded as delaying action to reduce emissions,[a] or taking the easy way out.[b]

Nature-based offsetting, particularly tree-planting, has been characterised as destructive of rural communities, because they could 'lock up' land and result in depopulation.[c]

Successive offsetting programs have been plagued by integrity problems, and there is understandable cynicism about offsetting's potential.[d]

None of this changes the reality: we have passed the point where just reducing emissions to a lower level would be sufficient to limit global warming. The acceptable level of emissions is rapidly becoming zero. Absolute zero emissions is not possible, because there will be emissions we cannot eliminate, and some where we will not be willing to pay the price to do so.

Governments planning to use offsetting as part of a net-zero strategy need to confront not just the integrity issues we outlined above, but also the image problem. They can do this by taking an 'avoid emissions first' approach in their policies, setting clear rules, having high standards, and by being clear about why offsetting is necessary.

a. Milne (2021b).
b. Greenpeace (2021).
c. Murphy (2021).
d. Schwartzman (2018).

The Federal Government should improve the reviews of ACCU methods

The *Carbon Credits (Carbon Farming Initiative) Act 2011* underpins the creation of ACCUs, establishes standards for ACCU integrity and provides for ACCU creation methods to be reviewed regularly. The Federal Government's original intention was for every method to be reviewed at least every four years.[80] There is currently no formal schedule for method reviews.[81] While reviews of methods may result in changes, projects that were established under the old methods are not required to adopt the changes.

Currently reviews are done by the Emissions Reduction Assurance Committee (see Box 1 on page 17). As the number of methods expands and covers more areas of the economy, it is unlikely that the Committee will have the depth of experience and knowledge required for every review. It would be better to use independent expert reviewers with deep knowledge of the underpinning science, and measurement and verification technologies, for each method.

The Federal Government should return to its original commitment to review every method every four years, use independent expert reviewers, and set aside the resources to do this. These reviews should include assessing the impacts of climate change on emissions avoided or removed.

Invest in better, cheaper, more accurate measurement

Uncertainty is reduced, and integrity improved, by better measurement. Many land management offsetting activities will have limited capacity to scale up unless cheaper and more accurate ways to establish baselines and measure emissions reductions and removals can be found. The Federal Government is already investing in improving technology for soil carbon measurement;[82] it should expand this investment to other offsetting opportunities, informed by regular reviews of ERF methods as outlined above.

80. Australian Government (2014).
81. CCA (2020, p. 65).

Provide incentives to use the most up-to-date method

Currently, there is no requirement for ACCU creators to switch to an updated method if it becomes available. It would be reasonable to assume that ACCU creators only do so if the revised method allows them to create more ACCUs. If they don't switch, a long-duration project will be an ongoing source of hollow credits, blunting the efficacy of offsetting as a tool to reach net zero, and increasing the cost.

Project owners reasonably assume that if they follow the rules set out in an ACCU creation method, their ACCUs will be valid. They do not have access to the full range of information that underpins the integrity of the method, and so cannot assess the risk that the rules may change in the future. They would have a reasonable objection if, following a method review and change, they were forced to use a new version that meant they could create fewer ACCUs. However, from the position of overall integrity and market confidence, allowing these projects to continue increases the number of hollow units in the market.

One solution would be to add an 'upside/downside' clause to government contracts, which would be invoked in the event of a method change that reduced the number of eligible units. The clause would allow the government to pay a reduced price if the project owner continued to use the old method, but a higher price if they moved to the new method. This would share the risk between both parties, but would place a higher value on ACCUs from updated methods, providing an incentive to switch. Private purchasers could also consider a similar approach.

82. ARENA (2021).

If stronger emissions constraints were in place, and these (rather than government purchasing) were driving ACCU demand, governments could place limits on how long units from outdated methods would be accepted for compliance purposes. This would ensure such units 'wash out' of the system quickly, because they would need to be purchased and surrendered quickly or become valueless.

Greater transparency around uncertainties in data and assumptions that underpin methods would also assist project proponents to assess the risk of future method changes before they enter into projects.

The Federal Government should do more to insure against international double-counting

Evidence is emerging of overseas demand for Australian offsetting activity – for example the deal between an Australian pastoral company and Microsoft referred to in Section 2.1.2 on page 19. Currently there is nothing to stop such activity being counted twice by being certified under multiple certification schemes. Further potential for double counting arises because the emissions reductions from this activity will show up in Australia's national greenhouse accounts, but also in another country's accounts if the purchaser uses them to reduce their reported emissions in that country (Figure 3.2 on page 32).

If international units like CERs were allowed to be used for compliance purposes in Australia – in a revised Safeguard Mechanism, for instance – the same problem could arise in reverse if there are not stringent criteria on which units can be used. The Federal Government's investment in setting up a high-integrity carbon offset scheme for Australia and countries in the Indo-Pacific will (if well-designed) help insure against this, at least for some countries.

Article 6 of the Paris Agreement is meant to settle the rules for such transactions, but is still under negotiation in the lead-up to the COP26 international climate change conference in Glasgow in November 2021.

As a potential exporter and importer of offsetting units, Australia has an interest in clear, transparent rules that support trade while maintaining integrity. The Federal Government should move quickly after COP26 to implement provisions in Article 6 of the Paris Agreement that support international trade in units. If the Article 6 negotiations do not conclude in November, the Federal Government should consider putting rules in place around offsetting activities whose impacts are sold to overseas buyers.

More information on who is creating ACCUs, and where, would also enable ACCU buyers to assess the risk of double-counting for themselves. For example, the Clean Energy Regulator could publish project locations and more detail about activities for each project.

3.3 Market making

Successive federal governments have underpinned the early development of an offsetting market in Australia. But that market has now grown to the size where it is time to reconsider the role of government. In particular, for the market to function well, government demand needs to shrink to a level commensurate with government emissions. This would allow private sector demand and policies to constrain emissions to drive the market.

3.3.1 Underwrite supply

Given the large role government purchasing plays in markets at present, withdrawing suddenly would collapse demand, leading to reduced confidence.

One way governments can support the market as it withdraws demand is by being a buyer of last resort. Currently, the Federal Government enters into two types of contracts after Emissions Reduction Fund auctions: fixed delivery contracts, where the government agrees to buy a fixed amount of ACCUs delivered on an agreed date at an agreed price, with penalties for the counter-party if delivery is not achieved; and optional delivery contracts, where the government agrees to buy ACCUs if the counter-party does not find another buyer, with no penalties for failing to deliver.

In effect, optional delivery contracts underwrite offset projects by guaranteeing a buyer, but allow for the counter-party to sell the ACCUs elsewhere. Once ACCUs are delivered to the federal government and payment is made, the ACCUs are retired. Federal and state governments should make greater use of these optional delivery or buyer-of-last-resort contracts, to effectively provide a floor price and encourage ample supply, rather than buying large amounts of ACCUs. This should allow governments to be more ambitious with policies to drive emissions reductions, because it would make the 'safety valve' of offsetting more certain.

In Section 2.2.2 on page 23 we outlined how quickly the market for removal offsetting units needs to scale up to meet likely demand. It is not feasible for governments to fully underwrite this scale-up. Over time, governments should reduce the amount of buyer-of-last-resort contracts they offer, and limit their use to newer, less mature ACCU methods where projects are riskier.

3.3.2 Link purchases to government emissions

Where governments do want to enter the offsetting market as buyers, they should link their purchases to a source of emissions from government activity. In a net-zero world, governments, just like any other part of the economy, will face the cost of offsetting residual emissions from their activities. By establishing contracts to offset emissions from flights, for example, governments could underpin supply while also building their own capability in sourcing offsetting units for their own emissions.

Federal Government flights were responsible for about 1.5 per cent of domestic aviation emissions in 2015-16 (130,000 tonnes), and in that year the Federal Government spent $223 million on domestic airfares.[83]

Airlines currently offer to offset flight emissions at a cost of about 0.3-to-1 per cent of the 'best fare of the day'.[84] This offsetting is mostly done using international offsetting units.[85]

If the Federal Government took up this offer for each flight it booked, it could offset all its domestic aviation emissions for just a few million dollars. However, if the government wanted to encourage this offsetting to come from Australian projects with high levels of integrity, it could include a requirement to offset using ACCUs in the next tender for whole-of-Australian-government travel arrangements.

Flights are just one area of government operations where emissions are hard to abate. Others may include (for the federal government) fuel use for defence, and Antarctic bases; and (for state governments) state-owned long-distance transport, such as trains.

Shift focus over time to removals

When more effective policy to constrain emissions begins to drive more demand for offsetting units, governments should shift their focus to helping develop more projects that remove carbon dioxide from the atmosphere.

It is imperative that high-integrity removal offsetting units are plentiful as the net-zero goal gets closer, because they will become more important as reductions become harder.

83. Grattan analysis based on DIRD (2017) and Department of Finance (2018).
84. Grattan analysis based on BITRE (2021) and Qantas (2021a).
85. Qantas uses Gold Standard or Verra units for offsetting customer flights: Qantas (2021b). Virgin Australia uses a Climate Active methodology: Virgin Australia (2021). Climate Active allows CERs to be used as offsetting units: Climate Active (2021b).

Governments could support the development of more removal projects by choosing to purchase removal offsetting units rather than those from projects that avoid emissions. This also applies to buyer-of-last-resort contracts. Once nascent removal technologies are better understood, the Federal Government could make more ERF methods available for removals, and phase out or close methods for avoided emissions to encourage removal projects.

3.4 Invest in developing removal technologies

Achieving net zero requires a suite of removal options, because all are subject to constraints and uncertainties. Nature-based removals may dominate availability in the short term (not least because we already know how to implement them), but they come with uncertainties around measurement and verification, permanence, and the impacts of climate change. Industrial removals are currently expensive and unproven at scale, and because (in the absence of a high carbon price) they generate no revenue, they have trouble attracting private investment. A process of price and cost discovery is required.[86]

To ensure a full range of options are available, governments should invest in supporting R&D and demonstration of industrial removal technologies, similar to some of the projects funded through the *Carbon Capture, Use and Storage Development Fund*.[87] It may be that some technologies turn out to be less promising than currently thought – it is better to find this out sooner rather than later so that other policies can be adjusted accordingly.

At present, industrial removals such as direct air carbon capture are not recognised in the *Carbon Credits (Carbon Farming Initiative) Act 2011* and cannot claim ACCUs. Once the potential for industrial removals is better understood, this should be changed.

86. The Royal Society (2018).
87. Taylor (2021).

Appendix A: Offsetting activities

Offsetting activities are as diverse as the sources of emissions. But some are more likely to succeed than others. Cost, climate, geography, geology, and land management practices all affect success.

Offsetting activities can be be based in natural processes or industrial processes, and can involve avoiding emissions or removing carbon dioxide from the atmosphere. Table A.1 summarises major activities, and this appendix discusses activities that seem most likely to succeed in Australia. For detail on activities to avoid transport, industrial, and agricultural emissions, see the three earlier reports in this series.

A.1 Nature-based activities

Nature-based offsetting takes advantage of natural processes that absorb carbon dioxide from the atmosphere.

A.1.1 Vegetation

This includes avoided deforestation, forest management, afforestation (creating forests on land that has never been forested before), and reforestation (restoring forests to land that has been cleared).

Avoided deforestation refers to an agreement to preserve vegetation that would otherwise have been cleared. Because the trees are likely to be already mature, the amount of additional carbon sequestered is likely to be small, although forest management can increase it somewhat.

Afforestation and reforestation capture carbon dioxide from the air as trees grow. As trees reach maturity, this capture rate slows, though forest management practices can in some cases reduce this decline.

Table A.1: Matrix of offsetting activities

	Nature-based	Industrial
Avoidance	Vegetation: • Forest management • Avoided deforestation Agriculture: • Manure management • Herd management • Fertiliser management • Soil management Fire management Mangrove, sea grass, and tidal marsh preservation	Avoided fossil fuel consumption: • Fuel-switching • Energy efficiency Fugitive emissions management Industrial process improvement Carbon capture and storage
Removals	Vegetation: • Reforestation • Afforestation Agriculture: • Soil carbon Fire management Mangrove, sea grass, and tidal marsh restoration	Direct air carbon capture and storage Mineralisation Enhanced weathering Bioenergy with carbon capture and storage

Notes: Items shown in grey are not discussed in this appendix. For a summary of industrial emissions avoidance, see Wood et al (2021b), and for avoided agricultural emissions, see Wood et al (2021c).

If the forest is harvested, sequestered carbon is either stored long term in wood products such as buildings; or released to the atmosphere if the wood is burned or decays in landfill. Replanting the forest captures equivalent carbon dioxide from the atmosphere over time.

In all cases, the amount of carbon captured and locked away varies depending on plant species, climate, water availability, and weather; as does the length of time the carbon spends out of the atmosphere.

Avoided deforestation measurement has two parts: how much would have been emitted had the trees been cut down; and how much will be absorbed by leaving them in place. The first can be modelled based on known emissions generated from deforestation, but also requires making a judgment about how likely the forest owner was to cut it down. The second is measured and verified in a similar way to afforestation and reforestation.

Emissions sequestration through afforestation and reforestation can be measured by field sampling over small areas, or can be estimated using carbon cycle models and satellite data for larger areas.

Potential and limits in Australia

The CSIRO estimates that Australia could offset up to 513 million tonnes each year between 2031 and 2050 using afforestation and reforestation, in scenarios where strong global action to mitigate climate change prevails.[88] However, it also notes that this would require considerable switching from other forms of agriculture (particularly away from grazing livestock) and, if fully exploited, would mean devoting between 25 per cent and 50 per cent of national water use to these activities, and between 22 million and 63 million hectares of land.[89] Reaching this maximum would require a global carbon price in 2050 of $285 per tonne to make offsetting five times more valuable than maintaining current agricultural production patterns on the same land.[90] It would also favour fast-growing single-species plantings, which would reduce biodiversity.

Afforestation and reforestation offsetting projects are also at risk from the impacts of climate change. Increased heat and water stress stunts tree growth, leading to slower accumulation of carbon. More fires, increased fire intensities, more pests, and more diseases also have an impact. Drought also increases tree mortality in existing forests, reducing carbon stored through avoided deforestation.[91]

A.1.2 Fire management

Savanna areas in northern Australia burn predominantly in the late dry season, resulting in large, hot, and intense fires. These fires produce more emissions and burn a greater proportion of dead organic matter than fires that occur under cooler, moister conditions in the early dry season.[92]

Managing fires to reduce the frequency and extent of late dry season fires creates two potential offsetting activities: avoided emissions from fires; and removing carbon dioxide from the atmosphere as organic matter in the soil absorbs more carbon. Avoided emissions are not carbon dioxide (which is re-absorbed from the air as vegetation regrows after fire) but methane and nitrous oxide, which are also released when vegetation burns but are not taken up through regrowth.[93]

88. Bryan et al (2015, pp. 29, 31). In this modelling, a global carbon price is used as a proxy for the strength of international action to reduce emissions. This price drives afforestation and reforestation activities. Encouraging this level of offsetting unit creation requires a global carbon price trajectory beginning at about $47 per tonne in 2015 and rising to $285 per tonne in 2050.
89. Ibid (pp. 3, 17).
90. Ibid (pp. 18, 29).
91. Roxburgh et al (2020, p. x).
92. CER (2021g).
93. *Carbon Credits (Carbon Farming Initiative-Savanna Fire Management-Sequestration and Emissions Avoidance) Methodology Determination 2018.*

Managing fires can involve planned burning earlier in the season, and also activities such as firebreaks and fire suppression on unplanned late-season fires. Timing and type of fire management depend on weather conditions, the landscape and vegetation in the area. Much activity is based on traditional knowledge and practices of Indigenous communities.

The emissions avoided through fire management are the only source of avoidance offsetting discussed in this report that will continue to be available in a net-zero world. This is because the reduction in emissions is made against an emissions source that is not human-induced.

Emissions avoidance and atmospheric removals through fire management are estimated using modelled approaches and satellite data. Abatement through improved soil carbon levels is subject to the same uncertainties as other soil carbon estimates (see Appendix A.1.3).

Potential and limits in Australia

One estimate for northern Australia suggests 6.9 million tonnes could be offset each year using fire management in 1.5 million square kilometres of suitable savanna areas. However, this estimate assumes the total area of suitable land is managed, which in practice would be unlikely.[94]

Savanna burning is less relevant in southern Australia because unplanned fires are less frequent, and burnable fuel loads are smaller.[95]

Methane has an impact on global temperature rise 28 times larger than that of carbon dioxide. Nitrous oxide has an impact 298 times larger (DISER (2021c)).

94. Lipsett-Moore et al (2018). Note this estimate also includes a negligible area of land in Papua New Guinea.
95. Maraseni et al (2016).

Climate change will reduce the potential for offsetting through savanna burning. Reduced rainfall and higher temperatures will reduce plant growth, which in turn reduces fuel load. As well, increased fire danger and decreased landscape moisture content could shorten the seasonal window for planned burning, and increase the physical risk of burning activities.[96]

A.1.3 Soil carbon

Carbon stored in soil takes the form of decaying plant matter, soil organisms, and microbes, as well as products from plant root, microbe and other organisms, and those from chemical reactions.[97] The amount of carbon stored in soil is ultimately determined by soil type, water availability, climate, and solar radiation, but within these limits can be increased through land management practices and crop selection. In most of Australia, water availability has the greatest influence on soil carbon levels.[98]

Practices that improve soil carbon levels include no-till agriculture, crop rotation, and stubble retention on cropping land; and fertilisation, liming, irrigation, and sowing of more productive grass varieties on grazing land.[99] Converting cropping land and cultivated pasture to permanent (uncultivated) pasture also raises soil carbon levels, though by much less than converting these lands to forest.[100] Sequestration rates tend to diminish over time, with largest gains in the first 5-to-10 years of changed practices, diminishing to near zero after 40 years.[101]

96. Roxburgh et al (2020, p. x).
97. Inorganic carbon also occurs in soil, but levels are relatively stable.
98. Badgery et al (2020).
99. Some of these practices also produce emissions – for example, stubble retention increases nitrous oxide emissions.
100. Wilson (2021).
101. Sanderman et al (2010).

Soil carbon is measured by taking samples, measuring soil density, and then measuring the carbon contained in the sample. The process can be labour-intensive and time consuming, and therefore expensive.[102] Soil carbon can also vary considerably over small geographical areas, even within one paddock, which means a large number of samples is needed to establish a baseline and to measure improvement. Because levels can vary with climate patterns (for example between drought years and good years), establishing a baseline also requires establishing a 'control' – an area not subject to improvements, with similar soil type, land use, and climactic conditions – to determine the underlying rate of change.[103] There is also uncertainty over the permanence of soil carbon improvements.[104]

Some advances are being made in using spectroscopy to rapidly measure soil carbon.[105] Modelled approaches and satellite data can also be used, but as yet these do not square with values obtained from sampling, and are likely to overestimate carbon by at least a factor of 10.[106]

Potential and limits in Australia

The CSIRO estimates that the average carbon levels in Australian soil are about 29.7 tonnes per hectare, with higher levels in cool temperate regions with high rainfall and significant forest cover, and lower levels elsewhere. Roughly half the national stock of soil carbon is found in agricultural areas.[107]

Improvements of between 0.2 and 0.3 tonnes of carbon per hectare per year could be achieved through improved management of cropland, however much of this is likely to be returning soil to its original state, rather than sequestering additional atmospheric carbon.[108] Improvements of between 0.1 and 0.3 tonnes of carbon per hectare per year are possible on grazing land.[109]

Very few areas of the Australian landmass have the right climatic conditions and soil types to sequester large amounts of carbon.

Of all the nature-based offsetting options, soil carbon is the most vulnerable to the impacts of climate change. A hotter and drier climate will inhibit plant growth, which in turn reduces the amount of organic matter returned to the soil. Climate change will also effect soil respiration and microbial processes, reducing the rate at which organic matter is returned to soil carbon.[110]

A.1.4 Mangroves, sea grasses, and tidal marshes

Blue carbon refers collectively to the carbon stored in mangroves, sea grasses, and tidal marshes. These habitats take up atmospheric carbon dioxide at a greater rate than land-based vegetation.[111] Similar to land-based vegetation, disturbance of mangroves, sea grasses, and tidal marshes releases stored carbon to the atmosphere, and so avoiding disturbance avoids emissions.

Unlike land-based vegetation, the rate of carbon uptake by mangroves, sea grasses, and tidal marshes does not slow over time. This is because, in addition to storing carbon in their leaves and stems, they also store it in soil beneath the plants. As well, mangroves, sea grasses, and tidal marshes are very efficient at capturing and sequestering carbon from other biomass floating in the water. This efficiency, and the lack of an upper limit, means that per unit of area, a

102. DAWE (2021).
103. Badgery et al (2020).
104. Ibid.
105. Kusumo et al (2017).
106. Simmons et al (2021).
107. CSIRO (2014).
108. Sanderman et al (2010).
109. Ibid.
110. Roxburgh et al (2020, p. x).
111. CSIRO (2021a).

blue carbon zone is about twice as efficient in storing carbon compared to the same area of land.[112]

Blue carbon is stored in above-ground biomass (such as in mangroves), and in soil beneath the plants. In Australian blue carbon stocks, mangroves dominate above-ground biomass sequestration, and sea grass dominates soil carbon storage.[113]

To date, blue carbon stocks have been estimated using sampling regimes, and extrapolated using satellite data.[114]

Potential and limits in Australia

Estimates of Australia's blue carbon stock and potential to increase it are still preliminary. One recent study estimated Australia's mangrove, sea grass, and tidal marsh habitats at 11-to-15 million hectares, or between 9 per cent and 32 per cent of global stock. This equates to between 70 million and 185 million tonnes of carbon in above-ground biomass, and 1,055-to-1,540 million tonnes in soil.[115]

Offsetting via blue carbon could come from restoring degraded mangroves. However, this is a time-consuming and expensive solution, that requires restoring water flows across tidal flats.[116] Avoided destruction or degradation has greater potential. One estimate puts Australia's potential to offset emissions this way at 2-to-3 million tonnes per year;[117] others suggest Australia's current stock absorbs about 10 million tonnes each year.[118] This demonstrates the considerable uncertainty around measurement and verification.

112. Mcleod et al (2011).
113. Serrano et al (2019).
114. Ibid.
115. Ibid.
116. Waters (2016).
117. Serrano et al (2019).
118. Rickells and Quaas (2021).

Awarding offsetting units for avoided destruction has the same problems with additionality as avoided deforestation.

Potential habitat for mangroves may expand with climate change.[119] Increased coastal storm surges also have implications for existing mangroves and stability of soil carbon storage.[120] More frequent heatwaves are likely to damage sea grasses, leading them to release carbon to the atmosphere. One estimate for the Shark Bay sea grass area in Western Australia suggests it released between 2 million and 9 million tonnes of emissions over three years after a marine heatwave.[121]

A.2 Industrial removals

A.2.1 Direct air carbon capture and storage

Direct air carbon capture and storage (DACCS) units use chemical sorbents, amines or other processes to extract ambient carbon dioxide from the air and capture it. Once captured, carbon dioxide can be liquefied, and transported by truck or pipeline to a storage site where it is pumped into porous rock formations below the surface, as for conventional carbon capture and storage. Depleted gas and oil fields are often used for storage, because their geology is well-understood.

Alternatively, carbon dioxide can be dissolved in water and pumped underground, where it reacts with and becomes part of underground rock.[122] Or, it can be reacted with mineral feedstocks to form industrial products (see Appendix A.2.2 on page 44 below).

One advantage of DACCS units is that they can be co-located with storage sites, avoiding transport of carbon dioxide which can be a considerable technical and financial challenge to CCS projects.

119. Dunn (2018).
120. Roxburgh et al (2020, p. x).
121. Arias-Ortiz et al (2018).
122. Carbfix (2021).

DACCS units can be large or modular. Because DACCS is still an emerging technology, cost estimates vary greatly, between US$100 and US$1,000 per tonne of carbon dioxide captured depending on unit design and the purity of the carbon dioxide captured.[123] The global cost of transport and storage of carbon dioxide is estimated to be between US$2 and US$14 per tonne.[124]

DACCS consumes considerable amounts of energy – between 5 gigajoules (GJ) and 9.9 GJ per tonnes captured[125] – because of the low carbon dioxide concentration in ambient air. Compression and injection energy consumption is similar to CCS: 80 kWh and 120 kWh per tonne captured.[126]

Deploying DACCS at scale would require major refocusing of existing manufacturing and chemical industries for sorbent and amine production. As well, alternative (non-fossil fuel) feedstock would be required for amine production.[127] Other materials for capturing carbon dioxide, such as metal organic framework nano-materials, may provide alternatives that are cheaper to manufacture at scale.[128]

There is still no established way of measuring and verifying removals via DACCS. It is likely to be similar to that for CCS: using gas chromatography to sample the relative concentrations of carbon dioxide in gas streams before and after capture.[129]

123. Realmonte et al (2019).
124. Baylin-Stern and Berghout (2021).
125. Realmonte et al (2019). This is equivalent to 1389 kWh and 2750 kWh respectively, or about 10 times that required for CCS.
126. Jackson and Brodal (2019).
127. Realmonte et al (2019).
128. Southern Green Gas (2021).
129. *National greenhouse and energy reporting measurement determination s1.19J*.

Some carbon dioxide will escape to the atmosphere at each stage of compression, liquefaction, transport, and injection. Current practice is to estimate this using standard factors.[130]

Leakage after storage can be detected using sensors, providing a baseline of background atmospheric carbon dioxide concentrations at the site is established before injection, and any natural variability is understood.[131]

Potential and limits in Australia

The limiting factor on geological carbon storage in Australia is not volume (there is estimated capacity available for 100 million tonnes of carbon dioxide per year for 1600 years)[132] but rather financial and technology risk.

Given the high energy consumption of DACCS, Australia may be able to deploy DACCS more cheaply than other countries because of our abundant and cheap renewable energy resources.

Sorbents and amines are toxic and require careful controls and handling to protect the surrounding environment and human health.

Some DACCS technologies consume considerable amounts of water, which will be a constraint in areas of Australia.

Like CCS, financial risk for DACCS projects is acute because, in the absence of a strong carbon price, they generate no economic return. Because they are capital intensive with uncertain revenue, they are an unattractive asset class for investors.[133]

130. *National greenhouse and energy reporting measurement determination part 3.4*.
131. CSIRO (2021b).
132. Australian Government (2007).
133. Wang et al (2021).

A.2.2 Mineralisation

Mineralisation refers to reacting captured carbon dioxide with minerals to form a carbonate, which can then be used in range of industrial applications, such as concrete and cement, plastics, and paints and inks. This method can also be used to treat waste materials such as mine tailings, slag, and kiln dust.[134]

Mineralisation is yet to be demonstrated at scale. Scale (and therefore cost) will be driven by the demand for and price of carbonates (excluding the cost of capture, which is similar to CCS or DACCS), as well as the avoided cost of otherwise disposing of mine tailings and other industrial waste.

Potential and limits in Australia

Australia has capacity to produce and use large volumes of carbonation feedstocks, where they come from mined ores and mine tailings. Slag and ash are less available.[135] As well, logistics may place limits on deploying mineralisation on mine waste, because many mines are in remote locations.

Australia's excellent solar resources may be an advantage if concentrated solar thermal energy can be used to provide heat to mineralisation processes.[136]

A.2.3 Enhanced weathering and bioenergy with carbon capture and storage

Neither enhanced weathering nor bioenergy with carbon capture and storage have good prospects in Australia for large-scale removals of carbon dioxide from the atmosphere.

134. Srinivasan et al (2021, p. 46).
135. Ibid (p. 47).
136. Ibid (p. 48).

Enhanced weathering refers to accelerating the natural process of silicate rock weathering (which removes carbon dioxide from the atmosphere) by milling rock to increase the surface area and spreading the resulting rock dust on land.[137] Enhanced weathering works best in areas of high rainfall, and takes a long time to absorb significant amounts of carbon dioxide. There are also health hazards associated with handling milled rock dust.[138]

Bioenergy with carbon capture and storage is sometimes cited as removal offsetting but is more accurately thought of as a combination of two avoided emissions activities: switching from fossil fuels to bioenergy, and then capturing the emissions from burning bioenergy and storing them using CCS. Australia's capacity to produce bioenergy is limited by poor soil, long distances, water availability, and competing land use. Any bioenergy production is likely to be in the form of drop-in fuels for transport[139] – but transport uses are not conducive to carbon capture.

137. The Royal Society (2018, p. 49).
138. Peter Cook Centre for Carbon Capture and Storage Research (2019, p. 31).
139. Campey et al (2017, p. 87).

Appendix B: Estimating Australia's capacity to produce offsetting units

This appendix sets out three estimates – optimistic, moderate, and conservative – of Australia's capacity to produce offsetting units, based on the literature summarised in Appendix A. The estimates are not forecasts; they are intended to provide context for the policy recommendations in this report.

The optimistic case represents the technologically possible maximum number of offsetting units from each source. However, as Appendix A makes clear, reaching this maximum will require far-reaching technological and social changes, high carbon prices, overcoming logistical hurdles, or all of the above. As well, reaching the maximum of some options precludes reaching the maximum in others: for example, afforesting all suitable land means less land is available for soil carbon removals; and high uptake of direct air carbon capture and storage uses water, which is then unavailable for afforestation.

To make more realistic assessments, we consider a conservative case, where 5 per cent of the theoretical maximum is achieved, and a moderate case, where 10 per cent is achieved (except for savanna burning, see Table B.1 on the next page for details). These seem very low until we consider what would be required to achieve them. Five per cent of the maximum afforestation estimate, for example, would equate to average annual removals of 25.6 million tonnes every year between 2030 and 2050, approximately five times that currently achieved through the Emissions Reduction Fund. Ten per cent of the maximum direct air carbon capture and storage (DACCS) estimate is 18 million tonnes of removals per year: six times that currently achieved through Australia's only carbon capture and storage facility.

Table B.1: Assumptions and sources for estimates of offsetting capacity

Method	Offsetting capacity (Mt/y) by scenario: Upper limit	Moderate	Conservative	Sources	Notes
Reforestation/Afforestation	513	51.3	25.7	Bryan et al (2015)	
Direct air carbon capture and storage	130	13	6.5	Australian Government (2007)	Assumes storage capacity of 180 Mt/y, of which 50 Mt/y (about a quarter) is assumed to be taken up by point-source carbon capture and storage.
Soil carbon	51	5.1	2.6	Sanderman et al (2010), Lam et al (2013)	Upper limit is calculated as the average of the source values.
Fire management	6.9	1.8	1.4	Lipsett-Moore et al (2018)	Savanna burning in Australia is already claiming ACCUs at about 20 per cent of the upper limit value. The conservative case assumes this is maintained; the moderate case assumes this is doubled.
Blue carbon	11.5	1.2	0.6	Serrano et al (2019)	
Total	712	73	37		

Note: Mt/y = million tonnes of carbon dioxide per year. For each method (other than fire management) the conservative limit is assumed to be equal to 5 per cent of the upper limit; the moderate limit is assumed to be twice the conservative limit.

Bibliography

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.

American Carbon Registry (2017). *ACR Reaches Milestone Issuance of 100 Million Tonnes of Greenhouse Gas Emissions Reductions*. https://americancarbonregistry.org/news-events/program-announcements/acr-reaches-milestone-issuance-of-100-million-tonnes-of-greenhouse-gas-emissions-reductions.

——— (2021). *What we do*. https://americancarbonregistry.org/how-it-works/what-we-do.

ARENA (2021). *Investment priorities*. Australian Renewable Energy Agency. https://arena.gov.au/about/strategic-priorities/.

Arias-Ortiz et al (2018). Arias-Ortiz, A. et al. “A marine heatwave drives massive losses from the world’s largest seagrass carbon stocks”. *Nature Climate Change* 8, pp. 338–344. https://www.nature.com/articles/s41558-018-0096-y.

Australian Council of Superannuation Investors (2021). *Promises, pathways & performance - Climate change disclosure in the ASX200*. Australian Council of Superannuation Investors. https://acsi.org.au/wp-content/uploads/2021/08/Climate-Change-Disclosure-in-ASX200.Aug21.pdf.

Australian Government (2007). *Australian Government submission to the House of Representatives Inquiry on Geosequestration*. Australian Government. https://www.aph.gov.au/parliamentary_business/committees/house_of_representatives_committees?url=scin/geosequestration/subs/sub41.pdf.

——— (2014). *Emissions Reduction Fund White Paper*. Australian Government. https://webarchive.nla.gov.au/awa/20190324022947/http://environment.gov.au/climate-change/government/emissions-reduction-fund/publications/erf-white-paper.

Badgery et al (2020). Badgery, W. B., Mwendwa, J. M., Anwar, M. R., Simmons, A. T., Broadfoot, K. M., Rohan, M. and Singh, B. P. “Unexpected increases in soil carbon eventually fell in low rainfall farming systems”. *Journal of Environmental Management* 261, p. 110192. https://www.sciencedirect.com/science/article/pii/S0301479720301286?via%3Dihub.

Baxter, T. and Gilligan, G. (2017). “Verification and Australia’s emissions reduction fund: integrity undermined through the landfill gas method?” *Australian Journal of Environmental Law*. https://search.informit.org/doi/10.3316/agispt.20190311007553.

Baylin-Stern, A. and Berghout, N. (2021). *Is carbon capture too expensive*. https://www.iea.org/commentaries/is-carbon-capture-too-expensive.

BHP (2021). *Carbon offsets*. https://www.bhp.com/sustainability/climate-change/carbon-offsets.

Bigg, T. (2021). “What’s the difference between net-zero and carbon-neutral policies?” *Renewable Energy World*. https://www.renewableenergyworld.com/policy-regulation/difference-between-net-zero-and-carbon-neutral-policies/.

BITRE (2021). *Domestic airfares*. Bureau of Infrastructure and Transport Research Economics. https://www.bitre.gov.au/statistics/aviation/air_fares.

Bryan et al (2015). Bryan, B. A., Hatfield-Dodds, S., Nolan, M., McKellar, L., Grundy, M. J. and McCallum, R. *Potential for Australian land-sector carbon sequestration and implications for land use, food, water and biodiversity*. CSIRO. https://www.csiro.au/-/media/Major-initiatives/Australian-National-Outlook/Tech-reports/REPORT_ANO_Land_sector_sequestration_2015.pdf.

Campey et al (2017). Campey, T., Bruce, S., Yankos, T., Hayward, J., Graham, P., Reedman, L., Brinsmead, T. and Deverell, J. *Low emissions technology roadmap*. CSIRO. https://www.csiro.au/-/media/EF/Files/LowEmissionsTechnologyRoadmap-Technical-Report.pdf.

Carbfix (2021). *Direct air capture*. https://www.carbfix.com/direct-air-capture.

Carbon Market Watch (2020). *Carbon markets 101 - The ultimate guide to global offsetting mechanisms*. Carbon Market Watch. https://www.industry.gov.au/sites/default/files/2020-09/climate-active-technical-guidance-manual.pdf.

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

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

——— (2021b). *Closed Emissions Reduction Fund methods*. Clean Energy Regulator. https://www.industry.gov.au/regulations-and-standards/methods-for-the-emissions-reduction-fund/closed-emissions-reduction-fund-methods.

——— (2021c). *Methods for the Emissions Reduction Fund*. Clean Energy Regulator. https://www.industry.gov.au/regulations-and-standards/methods-for-the-emissions-reduction-fund.

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

——— (2021e). *Carbon abatement contract register*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/ERF/project-and-contracts-registers/carbon-abatement-contract-register.

——— (2021f). *Safeguard facility reported emissions 2019–20*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/safeguard-facility-reported-emissions/safeguard-facility-emissions-2019%E2%80%9320.

——— (2021g). *Savanna fire management methods*. Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/ERF/Choosing-a-project-type/Opportunities-for-the-land-sector/Savanna-burning-methods/.

Climate Active (2021a). *Certification*. https://www.climateactive.org.au/be-climate-active/certification.

——— (2021b). *Climate Active - technical guidance manual*. Department of Industry, Science, Energy & Resources. https://www.industry.gov.au/sites/default/files/2020-09/climate-active-technical-guidance-manual.pdf.

CSIRO (2014). *Australian soil carbon map sets a baseline for future gains*. https://www.csiro.au/en/news/news-releases/2014/australian-soil-carbon-map.

——— (2021a). *Estimating Australia's 'blue carbon' potential*. https://www.csiro.au/en/news/news-releases/2021/estimating-australias-blue-carbon-potential.

——— (2021b). *Validating monitoring technologies for CCS in coastal waters*. https://www.csiro.au/-/media/OnA/Files/CSIRO_CCS_Capability_Factsheet_200901.pdf.

DAWE (2021). *Soil carbon*. Department of Agriculture, Water and the Environment. https://webarchive.nla.gov.au/awa/20210605084048/https://www.agriculture.gov.au/ag-farm-food/climatechange/australias-farming-future/soil-carbon.

DCCEE (2011). *Securing a clean energy future*. Department of Climate Change and Energy Efficiency. https://webarchive.nla.gov.au/awa/20120327185133/http://www.cleanenergyfuture.gov.au/clean-energy-future/securing-a-clean-energy-future/f.

Demand Manager (2021). *Certificate prices*. https://www.demandmanager.com.au/certificate-prices/.

Department of Finance (2018). *Travel Services Statistics*. https://webarchive.nla.gov.au/awa/20210121033058/https://www.finance.gov.au/government/travel-arrangements/travel-services-statistics.

DIRD (2017). *Managing the Carbon Footprint of Australian Aviation*. Department of Infrastructure and Regional Development. https://www.infrastructure.gov.au/sites/default/files/migrated/aviation/environmental/emissions/files/Managing-the-Carbon-Footprint-of-Australian-Aviation.pdf.

DISER (2020). *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.

——— (2021a). *Safeguard Crediting Mechanism: discussion paper*. Department of Industry, Science, Energy and Resources. https://consult.industry.gov.au/safeguard-crediting-mechanism.

——— (2021b). *National Greenhouse Gas Inventory – UNFCCC classifications*. Department of Industry, Science, Energy and Resources. https://ageis.climatechange.gov.au/.

DISER (2021c). *National Greenhouse Accounts Factors*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-factors-2021.

Dormady, N. and Englander, A. (2015). "Drivers of demand for carbon offsets: a comprehensive assessment of imperfect substitutes". *Journal of Public Policy*. https://www.cambridge.org/core/journals/journal-of-public-policy/article/carbon-allowances-and-the-demand-for-offsets-a-comprehensive-assessment-of-imperfect-substitutes/17334B0209CFF211A8C9643847E1C3EA.

Dunn, C. (2018). "Mangrove forests can rebound thanks to climate change – it's an opportunity we must take". *The Conversation*. https://theconversation.com/mangrove-forests-can-rebound-thanks-to-climate-change-its-an-opportunity-we-must-take-102823.

Ecosphere (2021). *CORSIA: Airlines Offsetting Scheme*. https://ecosphere.plus/corsia-airlines-offsetting-scheme/.

Energy & Climate Intelligence Unit (2021). *Taking stock: A global assessment of net zero targets*. Energy & Climate Intelligence Unit. https://eciu.net/analysis/reports/2021/taking-stock-assessment-net-zero-targets.

Gold Standard (2021a). *Vision and impacts - Gold Standard*. https://www.goldstandard.org/about-us/vision-and-mission.

——— (2021b). *Gold Standard market report 2020*. Gold Standard. https://www.goldstandard.org/sites/default/files/gold_standard_market_report_2020.pdf.

——— (2021c). *Impact registry - the Gold Standard*. https://www.goldstandard.org/resources/impact-registry.

Goodwin, S. (2021). "Microsoft buys carbon credits from NSW cattle operation". *Farm Online*. https://www.farmonline.com.au/story/7105542/microsoft-buys-carbon-credits-from-nsw-cattle-operation/.

Greenfield, P. (2021). "Carbon offsets used by major airlines based on flawed system, warn experts". *The Guardian*. https://www.theguardian.com/environment/2021/may/04/carbon-offsets-used-by-major-airlines-based-on-flawed-system-warn-experts.

Greenpeace (2021). *We're living in a golden age of greenwash*. https://www.greenpeace.org.uk/news/golden-age-of-greenwash/.

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.

IPCC (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/ar4/syr/.

Jackson, S. and Brodal, E. (2019). "Optimization of the Energy Consumption of a Carbon Capture and Sequestration Related Carbon Dioxide Compression Processes". *Energies* 12.1603 (9). https://www.mdpi.com/1996-1073/12/9/1603.

Kaskeala, N. and Salo, E. (2021). *Reforming the voluntary carbon market*. Compensate. https://www.compensate.com/reforming-the-voluntary-carbon-market#download-white-paper.

Kusumo et al (2017). Kusumo, B., Sukartono, S. and Bustan, B. "The rapid measurement of soil carbon stock using near-infrared technology". *Earth and Environmental Science* 129, p. 012023. https://iopscience.iop.org/article/10.1088/1755-1315/129/1/012023.

Lam et al (2013). Lam, S. K., Chen, D., Mosier, A. R. and Roush, R. "The potential for carbon sequestration in Australian agricultural soils is technically and economically limited". *Science Reports* 3.2179. https://www.nature.com/articles/srep02179.

Lipsett-Moore et al (2018). Lipsett-Moore, G. J., Wolff, N. H. and Game, E. T. "Emissions mitigation opportunities for savanna countries from early dry season fire management". *Nature Communications* 9.2247. https://www.nature.com/articles/s41467-018-04687-7.

Maraseni et al (2016). Maraseni, T. N., Reardon-Smith, K., Griffiths, G. and Apan, A. "Savanna burning methodology for fire management and emissions reduction: a critical review of influencing factors". *Carbon Balance and Management* 11 (25). https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-016-0067-4.

Mcleod et al (2011). Mcleod, E., Chmura, G. L., Bouillon, S., Salm, R., Björk, M., Duarte, C. M., Lovelock, C. E., Schlesinger, W. H. and Silliman, B. R. "A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2". *Frontiers in ecology and the environment* 9 (10), pp. 552–560. https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/110004.

Milne, P. (2021a). "Time's up on Gorgon's five years of carbon storage failure". *Boiling Cold*. https://www.boilingcold.com.au/times-up-on-gorgons-five-years-of-carbon-storage-failure/.

——— (2021b). "Woodside's real plan for Pluto LNG: delay action, not reduce emissions". *Boiling Cold*. https://www.boilingcold.com.au/woodsides-fudged-pluto-net-zero-plan-is-much-less-than-it-appears/.

Murphy, J. (2021). "Senior National admits farmers are not party's core constituency". *Farm Online*. https://www.farmonline.com.au/story/7326181/senior-national-admits-farmers-are-not-partys-core-constituency/.

NASA (2011). *The carbon cycle*. https://earthobservatory.nasa.gov/features/CarbonCycle.

Peter Cook Centre for Carbon Capture and Storage Research (2019). *Negative emission technologies in Australia*. University of Melbourne. https://petercook.unimelb.edu.au/__data/assets/file/0007/3454927/NETs-report.pdf.

Qantas (2021a). *Book a flight*. Offset prices extracted 1 October 2021. https://www.qantas.com/au/en/book-a-trip/flights.html.

——— (2021b). *Carbon offsetting - FAQs*. https://freight.qantas.com/help/carbon-offsetting-faqs.html.

Realmonte et al (2019). Realmonte, G., Drouet, L., Gambhir, A., Glynn, J., Hawkes, A., C.Köberle, A. and Tavoni, M. "An inter-model assessment of the role of direct air capture in deep mitigation pathways". *Nature communications*. https://www.nature.com/articles/s41467-019-10842-5.

Reputex (2021). *State and trends in the Australian carbon market FY2021*. Reputex. https://www.reputex.com/wp-content/uploads/2021/08/REPUTEX_The-State-of-the-Australian-Carbon-Market-FY21_0821.pdf.

Rickells, W. and Quaas, M. (2021). "Mapping 'blue-carbon wealth' around the world". *Carbon Brief*. https://www.carbonbrief.org/guest-post-mapping-blue-carbon-wealth-around-the-world.

Riggs, J. A. (2002). *U.S. Policy on Climate Change: What Next?* Washington DC: The Aspen Institute.

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

Sanderman et al (2010). Sanderman, J., Farquharson, R. and Baldockm, J. *Soil Carbon Sequestration Potential: A review for Australian agriculture.* CSIRO. https://publications.csiro.au/rpr/download?pid=csiro:EP10121&dsid=DS8f.

SBTi (2020). *Foundations for science-based net-zero target setting in the corporate sector*. Science Based Targets initiative. https://sciencebasedtargets.org/resources/legacy/2020/09/foundations-for-net-zero-full-paper.pdf.

Schwartzman, S. (2018). "Carbon Credit Shell Game: the Clean Development Mechanism in New Climate Accords". *Environmental Defense Fund*. http://blogs.edf.org/climatetalks/2018/03/21/.

Serrano et al (2019). Serrano, O. et al. "Australian vegetated coastal ecosystems as global hotspots for climate change mitigation". *Nature Communications* 10.4313. https://www.nature.com/articles/s41467-019-12176-8.

Simmons et al (2021). Simmons, A., Cowie, A., Wilson, B., Farrell, M., Harrison, M. T., Grace, P., Eckard, R., Wong, V. and Badgery, W. "US scheme used by Australian farmers reveals the dangers of trading soil carbon to tackle climate change". *The Conversation*. https://theconversation.com/us-scheme-used-by-australian-farmers-reveals-the-dangers-of-trading-soil-carbon-to-tackle-climate-change-161358.

Slezak, M. and Timms, P. (2021). "Many carbon credits for deforestation could be 'nothing more than hot air', report finds". *ABC News*. https://www.abc.net.au/news/2021-09-22/deforestation-carbon-emissions-credits-questioned-by-report/100479212.

Southern Green Gas (2021). *Southern Green Gas and Swiss Re to collaborate on Carbon Removal*. https://www.southerngreengas.com.au/news/southern-green-gas-and-swiss-re-to-collaborate-on-carbon-removal2332872.

Srinivasan et al (2021). Srinivasan, V., Temminghoff, M., Charnock, S., Moisi, A., Palfreyman, D., Patel, J. and Hortle, C. H. A. *CO2 Utilisation Roadmap*. CSIRO. https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/futures-reports/co2-utilisation-roadmap.

Taskforce on Scaling Voluntary Carbon Markets (2021). *Phase II report*. Taskforce on Scaling Voluntary Carbon Markets. https://www.iif.com/Portals/1/Files/TSVCM_Phase_2_Report.pdf.

Taylor, A. (2021). *Media release: $412 million of new investment in carbon capture projects*. 18 June. https://www.minister.industry.gov.au/ministers/taylor/media-releases/412-million-new-investment-carbon-capture-projects.

The Royal Society (2018). *Greenhouse gas removal*. The Royal Society. https://royalsociety.org/-/media/policy/projects/greenhouse-gas-removal/royal-society-greenhouse-gas-removal-report-2018.pdf.

Timperley, J. (2019). “Corsia: The UN’s plan to ‘offset’ growth in aviation emissions”. *Carbon Brief*. https://www.carbonbrief.org/corsia-un-plan-to-offset-growth-in-aviation-emissions-after-2020.

Treasury (2014). *Budget 2014-15: Budget overview*. https://archive.budget.gov.au/2014-15/overview/Budget_Overview.pdf.

——— (2019). *Budget 2019-20: Budget paper 2*. https://archive.budget.gov.au/2019-20/bp2/download/bp2.pdf.

Verra (2021). *Linked standards and programs*. https://verra.org/project/linked-standards-programs/.

Virgin Australia (2021). *Celebrating 10 Years of our Carbon Offset program*. https://travel.virginaustralia.com/au/blog/celebrating-10-years-our-carbon-offset-program.

Wang et al (2021). Wang, N., Akimoto, K. and Nemet, G. F. “What went wrong? Learning from three decades of carbon capture, utilization and sequestration (CCUS) pilot and demonstration projects”. *Energy Policy*. https://www.sciencedirect.com/science/article/pii/S030142152100416X.

Waters, H. (2016). “Mangrove Restoration: Letting Mother Nature Do The Work”. *Ocean Smithsonian*. https://ocean.si.edu/ocean-life/plants-algae/mangrove-restoration-letting-mother-nature-do-work.

Wilson, B. (2021). “Setting expectations, measuring, estimating and modelling soil organic carbon”. *Soil Organic Carbon: Realities and science for policy advisers and decision-makers*. National Press Club, Canberra. https://www.pmc.gov.au/resource-centre/domestic-policy/part-3b-setting-expectations-measuring-estimating-and-modelling-soc-associate-professor-brian-wilson-university-new-england.

Wood, T. and Ha, J. (2021). *Go for net zero: A practical plan for reliable, affordable, low-emissions electricity*. Report No. 2021-02. Grattan Institute. https://grattan.edu.au/report/go-for-net-zero/.

Wood et al (2021a). 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 (2021b) ———. *Towards net zero: Practical policies to reduce industrial emissions*. Report No. 2021-10. Grattan Institute. https://grattan.edu.au/wp-content/uploads/2021/08/Towards-net-zero-Practical-policies-to-reduce-industrial-emissions-Grattan-report.pdf.

Wood et al (2021c) ———. *Towards net zero: Practical policies to reduce agricultural emissions*. Report No. 2021-12. Grattan Institute. https://grattan.edu.au/report/towards-net-zero-practical-policies-to-reduce-agricultural-emissions/.

Zickfeld, K. (2021). “Why CO2 removal is not equal and opposite to reducing emissions”. *Carbon Brief*. https://www.carbonbrief.org/guest-post-why-co2-removal-is-not-equal-and-opposite-to-reducing-emissions.