



Why offsets are not a viable alternative to cutting emissions

February, 2023

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This report was commissioned by Solutions for Climate Australia and the Australian Conservation Foundation to look at the scientific issues surrounding the application of offsets in the Australian policy context, specifically in relation to the safeguard mechanism review.

CITATION

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This document may be cited as:

Climate Analytics (2023). Why offsets are not a viable alternative to cutting emissions



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Executive summary

The steady increase in corporate and national net zero targets in recent years raises critically important questions as to what role, if any, offsets should play in achieving them, and to what extent they are legitimate substitutes for direct emission reductions at source.

The Australian government is in the midst of formulating what could be the most important climate policy of this term of government, one that sets rules for our most energy-intensive facilities, covered by the Safeguard Mechanism (SGM), which accounted for 27% of national emissions in 2021.

The Government's proposed changes to the Safeguard Mechanism (SGM) include an unlimited use of domestically generated offsets, called Australian carbon credit units (ACCUs), for the country's industrial emitters. The government has also left open for subsequent review the ability to use international carbon credit units post-2025.

As we move further into the critical decade for climate action, and ever closer to 2050, the year that many countries and companies have set as their net zero emissions target, policy makers need to confront the fundamental shortcomings of offsets in achieving real emission reductions – notably from fossil fuel sources.

In this report we set out an assessment of the state of global science around offsets, and, considering that, examine the impact of the Australian Government's proposed changes for the country's industrial emitters.

Concerns related to this proposed unlimited use of offsets are made worse by ongoing fears about the integrity of many of the offsets that have already been generated – or will be generated – in the Australian carbon market. A recent government-sponsored review of Australia's carbon credit scheme has effectively ignored well-grounded criticism on its key methodologies from prominent experts and scientists.

We find that unless key issues with the use of offsets are addressed, Australia's ability to achieve real emission reductions consistent with its 2030 reduction target, as well as its net zero 2050 emissions target, is likely to be at grave risk of failure. Such issues include the need for permanence and whether offset carbon storage is additional to what would otherwise have happened.

This report outlines the key issues with carbon offsets, why they are not a viable alternative to direct emissions reductions, and why their use in Australia should be significantly constrained.

We show that unfettered use of offsets under the Safeguard mechanism will likely allow real emission increases (as opposed to reductions) in Australia, and their use will have adverse implications for global emissions:

- We calculate that for every Australian carbon credit unit (ACCU) generated to offset one tonne of CO₂ equivalent (tCO₂e) emissions (meaning CO₂, methane, and other greenhouse gas (GHG) emissions) from liquefied natural gas (LNG) production in Australia – about 8.4 tCO₂e lifecycle emissions are emitted globally (see Appendix).
- For coal, the equivalent figure – i.e., for every ACCU generated to offset one tonne of coal production emissions – is 58-67 tCO₂e. This neatly demonstrates the real-world impact of enabling fossil fuel companies to offset their emissions and continue, or even expand, production, rather than reduce their emissions over time.

Offsetting fossil fuel extraction leads to significant downstream emissions

The CO₂ offsetted for the production and processing of LNG or coal is only a fraction of these fuels' CO₂ equivalent lifecycle emissions

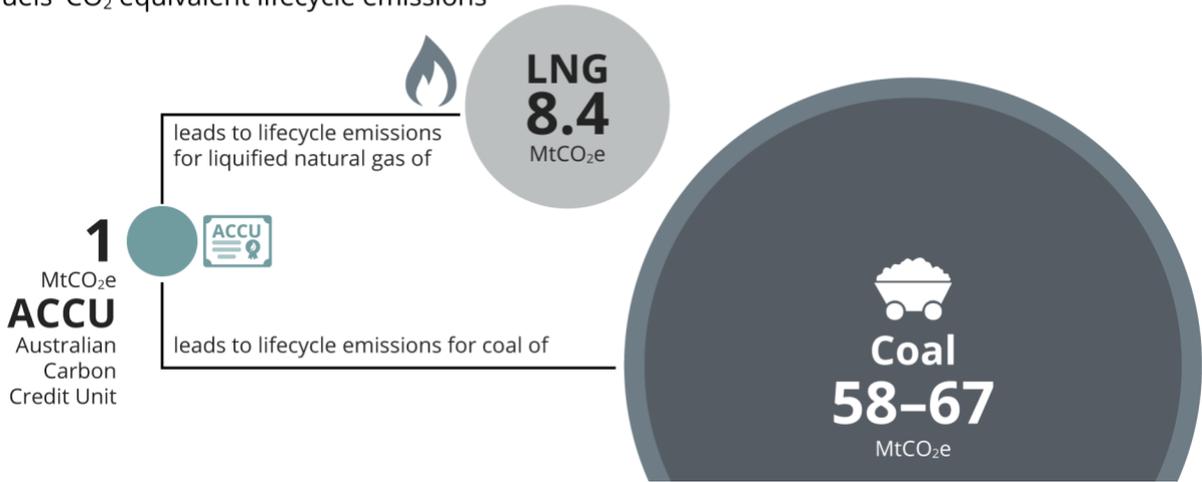


Figure ES1: Lifecycle Greenhouse gas emissions resulting from offsetting one million tonnes of emissions in Australia (MtCO₂e) from fossil fuel production of liquefied natural gas and coal. Present emissions from LNG production in Australia are about 36 million tonnes of GHG emissions (MtCO₂e) and coal mining around 32 MtCO₂e in 2022. Offsetting one million tonnes of LNG production emissions in Australia could effectively produce 8.4 million tonnes of emissions globally taking into account transport and final use of the gas - 8.4 MtCO₂e is equivalent to about 2% of Australia's 2022 emissions. Similarly for coal mining, offsetting one million tonnes of emissions from an average mine in Australia could lead to 58-67 MtCO₂e emissions globally, equivalent to about 12-14% of Australia's 2022 emissions.

The science

The scientific evidence makes it clear that *not all offsets are the same*. Forests and other natural ecosystems and soils, in both Australia and globally, provide vital carbon stores that need to be protected for their biodiversity ecosystem services values and to ensure their carbon stores are not released to the atmosphere.

However, offsets generated from activities in the land sector are known to be reversible and are particularly susceptible to integrity issues, specifically regarding the genuineness of purported emission reductions, their additionality, and their permanence. Therefore, using them to offset fossil fuel emissions is risky.

The first half of this report addresses the latest science on these issues. To summarise:

- Carbon sequestered in forests and soil can be lost back to the atmosphere for several reasons. For forests this includes fire, disease, adverse weather events, and damage from wildlife in their early stages of growth. For soil, this includes a cessation of sequestration practices, fire, erosion, and dust storms.
- The ability of land to take up carbon is limited. It is ultimately determined by climate and local soil and topographic considerations, is limited to the amount previously depleted by land use, and appears likely to be reduced as a consequence of climate change.
- Worsening drought and extreme fire conditions are already affecting forests in Australia and are likely to reduce the ability of forests and soil in Australia – and in other parts of the world – to uptake, store and hold carbon. Hotter, and drier Australian landscapes will absorb less carbon in trees and soil.
- Fossil fuel emissions have a very long lifetime in the atmosphere. Each tonne of carbon released into the atmosphere is long-lived, with around 40 percent remaining after 100 years, 20-25% remaining after 1,000 years, and up to 20% after 10,000 years. Land-based offsets do not and cannot guarantee such long-term sequestration.

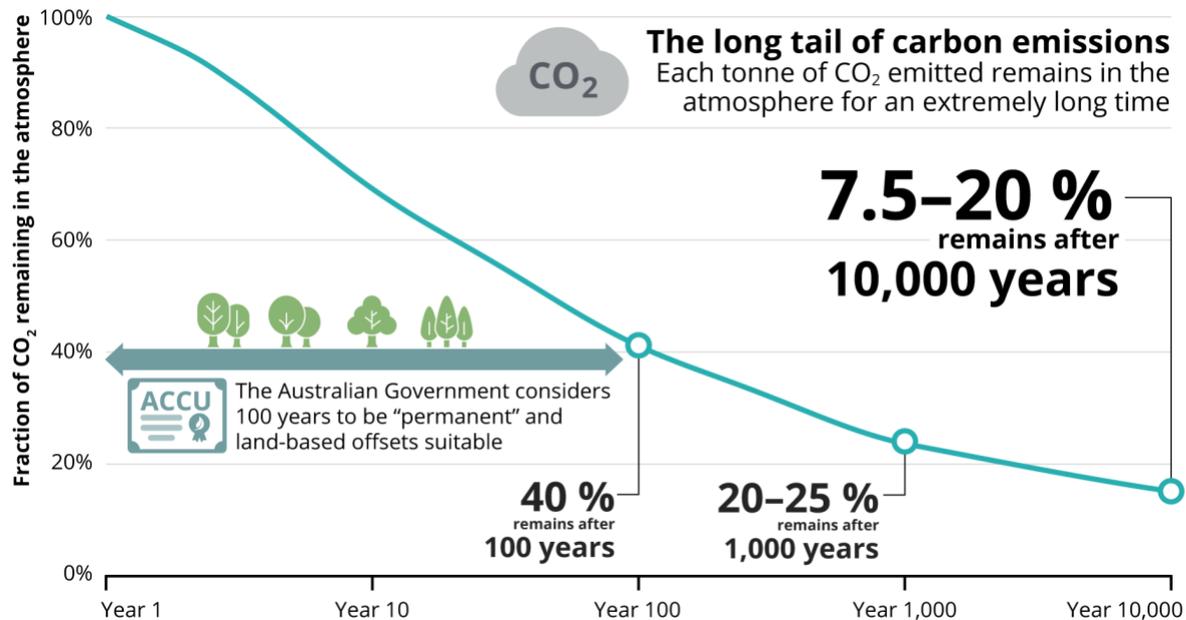


Figure ES2: Fraction of emitted CO₂ remaining in the atmosphere in years after emission up to 10,000 years

Given these issues, CO₂ emissions from the extraction and combustion of fossil fuels, which make up roughly two thirds of global annual greenhouse gas emissions, are the most acute threat exacerbating global warming, and those least able to be addressed through impermanent land-based offsets.

While there are some measures that can be taken to increase the integrity of offsetting schemes, offsets remain a risky bet, and can often be intentionally manipulated, or doomed to fail due to inadequate tools, implementation, monitoring or long-term regulation.

A critical issue overlooked in Australia is the need for offset permanence. So that even if an offset over 25 or 100 years perfectly offsets the CO₂ climate effect of fossil CO₂ emissions, there is no requirement that stored carbon be held longer than the 25 or 100 years established by the Clean Energy Regulator. There is also no requirement to replace carbon from these projects should they be subsequently lost after this 'permanence' period.

This means that if after the end of the permanence period set under the Australian regulatory system, when carbon is ultimately lost from ACCU projects, as is likely over longer timeframes, the atmospheric CO₂ concentration would be higher than if the offset scheme had not been used in the first place, and an emission reduction was made at its source instead. A lack of additionality, or only partial additionality, would simply exacerbate this problem, meaning that there would be little or no benefit even during the Australian 25-to-100-year permanence period.

There are also several other major problems with offsets, including their potential to negatively impact water and food security, ecosystem biodiversity, and the wellbeing and livelihoods of traditional landowners and agricultural producers. These problems can be particularly acute in developing countries, where the necessary levels of resourcing, governance, and land management capacities are often not present.

Australia's carbon credit scheme, and credit use in its proposed Safeguard Mechanism reforms

By allowing the facilities covered by its Safeguard Mechanism policy an unlimited use of offsets¹ to meet their emissions reduction obligations, the Australian Government is very likely sanctioning a large-scale continuation and expansion in fossil fuel production and its associated emissions.

The likely result of the proposal for an unlimited use of offsets is to provide a green light for new coal and gas production, while allowing existing producers to continue polluting unchecked.

In addition to broader concerns about using offsets to replace genuine on-site emissions reductions, several critical flaws in the Australian carbon credit scheme remain unaddressed by the recently released Government sponsored Chubb review into its overall integrity, particularly in relation to the heavily used human induced regeneration method.

This method, which accounts for almost 30% of issued ACCUs, and almost 50% of carbon credits contracted for sale to the Australian Government, was singled out by the former chair of the Emissions Reduction Assurance Committee (the scheme's regulatory body) as [leading to a large number of offsets that do not represent genuine emission reductions.](#)

1 Australian Carbon Credit Units or ACCUs, each ACCU = 1 tonne of carbon dioxide equivalent sequestered from the atmosphere or avoided being emitted



Australia's offset program

Breakdown of Australian Carbon Credit Units (ACCUs) produced by method up to 2021

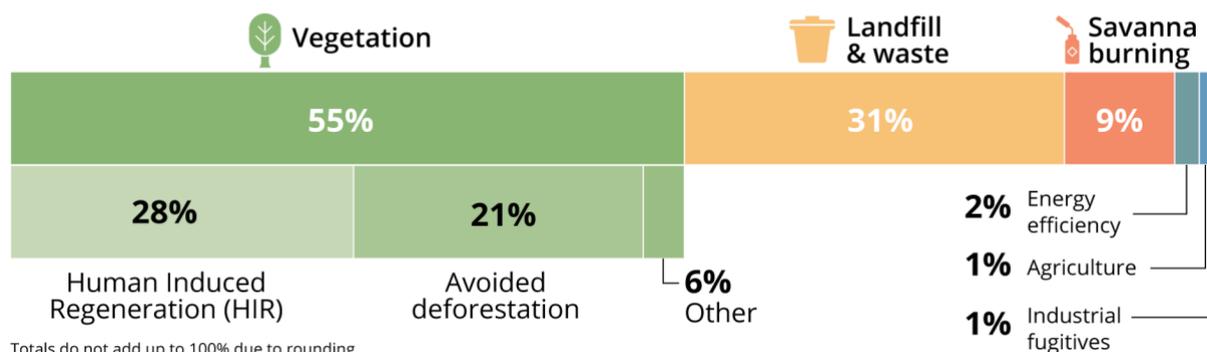


Figure ES3: Existing ACCU breakdown by method as of 2021

Under the Australian Carbon Credit scheme, the government regards carbon sequestration as permanent if it is maintained as a net sink for 100 years. The government also offers a much shorter permanence period of 25 years with just a 20 percent reduction, a discount rate in the number of ACCUs - in an attempt to account for the greater risk of this much shorter permanence period. This discount rate does not appear to be based on any scientific criteria. Given the demonstrated longevity of CO₂ emissions in the atmosphere, the assumption of a 20% discount as an adequate against loss after a 25-year permanence period expires is critically inadequate.

A wholesale expansion of the Australian carbon credit scheme triggered by a large increase in demand for offsets from Safeguard Mechanism covered facilities, if allowed unfettered use of offsets, would very likely fail to reduce emissions. Given the impermanence concerns in the longer-term, large-scale use of offsets would lead to higher levels of CO₂ concentration than would otherwise have occurred - and with that, greater warming.

Apart from the failure to address climate change, this would represent hundreds of millions of dollars that could otherwise have been used to reduce emissions at source and/or invest in transforming industry processes. This scenario must be avoided at all costs, by strictly limiting, or ideally preventing facilities - particularly fossil fuel facilities - covered by the Safeguard Mechanism from purchasing Australian carbon credits.

We find the proposal to allow all facilities covered by the Safeguard Mechanism, including new entrants to the scheme, a continued unlimited use of Australian carbon credits, would only serve to enable the continued extraction and burning of fossil fuels. Instead of reducing emissions as is urgently needed, this proposal would provide an avenue for fossil fuel companies to continue polluting at the expense of Australians - and indeed the world facing worsening climate change impacts.

Within the Safeguard Mechanism, new fossil fuel facilities with no limitations on the use of offsets will be able to bring significant new emissions into the scheme and force the cost of their emissions burden onto other industries. This cost transfer is a like an effective subsidy for which all others will pay to keep the total emissions under the Safeguard Mechanism within its committed carbon budget.

Widespread use of carbon offsets has the potential to lock in polluting technologies for years.

The United Nation's High Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities recently called for non-state actors to only use carbon credits beyond their own activities. The International Organisation of Standardisation (ISO) has also released corporate net zero guidelines stating that offsets should only be used when there are no available alternatives. Where a company chooses to offset emissions stemming from its activities and processes, this leaves its polluting equipment in place, and in the instance where the offset facilitates a like for like replacement, would lock in those future emissions for the equipment's lifetime.

Internationally, there is a strong and growing opposition to the use of offsets, particularly from within the climate and environmental not-for profit sector. Climate Action Network International, a coalition of over 1,900 civil society organisations from 130 countries, has recently published its position that strongly opposes offsets, arguing they do not protect biodiversity, and echoing the issues outlined in this document about the steep growth in the use of offsets, and instead, demands concerted global action to limit it.

Given the scale of emissions the offset market could soon represent if left to grow unencumbered, the stakes for getting this right are enormous. Limiting global warming to safe levels and avoiding the worst of projected potential climate impacts is not consistent with such growth in the use of offsets, and instead, demands concerted global action to limit it.

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Introduction

The number of countries and corporations that have set net zero greenhouse gas (GHG) emissions targets has been increasing in recent years. This is a positive trend, but not all net zero targets are created equal: the greater the use of carbon offsets to achieve net zero emissions, the more likely it is that some portions of these emissions reductions are not real, nor permanent, nor additional to what would have happened anyway.

Carbon offsets can be created in many ways, but land sector-based offsets, including those generated from reforestation, avoided deforestation, and improving soil carbon, have proven to be most susceptible to failing to represent genuine, permanent, or additional emission reductions. For this reason, this report will primarily focus on carbon offsets generated from the land sector.

In practice, genuineness and additionality can be hard to achieve, or even ascertain, depending on the method by which the offsets are generated. Indeed, no offset generated from the land sector's carbon storage can truly achieve permanence as this storage is inherently reversible through human activities, and disturbances including climate change (IPCC, 2000). This renders offsets fundamentally inferior to reducing actual emissions at their source.

In terms of permanence, each tonne of carbon released into the atmosphere is long lived, with a substantial proportion remaining after thousands of years, whereas no land-based offset can ensure such long-term sequestration. For example, stored carbon in the form of a tree will be released back to the atmosphere in the event of its death and decomposition, while no product made from its wood is likely to last for millennia.

This issue of offset integrity is particularly relevant in the context of Australian climate policy, as the Australian Government is proposing to allow essentially unfettered use of offsets through its proposed reforms to one of Australia's key climate policies, the Safeguard Mechanism (SGM). The SGM covers Australia's top 215 emitting facilities covering 27% of national emissions in 2021, and the government proposes an unlimited use of carbon offsets to meet their soon-to-be-more-stringent emissions baselines. This would provide a green light for new coal and gas production, while giving existing producers potentially inexpensive means of avoiding taking action to reduce emissions at source, allowing them to continue polluting unchecked.

In 2022, the Labor government ordered a review of Australia’s carbon offset scheme, but its report released in early 2023 failed to address some of the most consequential criticisms of the scheme levelled by the former chair of its regulatory body. Among others, these included a call to deal with the large share of existing Australian carbon credit units (ACCUs) with questionable integrity, and deep concerns over the methodology behind the most popular method of ACCU generation, human induced forest regeneration.

A failure to address these criticisms will greatly hinder Australia’s ability to achieve its 2030 and 2050 emissions targets, as millions of questionable ACCUs will be bought by Australian companies to achieve their mandated emissions reductions. This report will outline the key issues with carbon offsets, why they aren’t a viable alternative to cutting emissions, and why their use in Australia should be significantly constrained.

The urgency of real emissions reductions

Figure 2.1 illustrates the global emissions gap between governments’ current policies and the GHG emission reductions needed to align with a 1.5°C compatible pathway (Climate Action Tracker 2022b). Policies and actions need steep improvement globally, as there is currently an implementation gap of 23-27 GtCO₂e in 2030 between current policies and 1.5°C compatible emissions pathways. Even if policies were aligned with current targets, the world would be 19-22 GtCO₂e above a 1.5°C pathway in 2030. Australia is part of this global gap in climate ambition, and needs to play its part in aligning with 1.5°C.

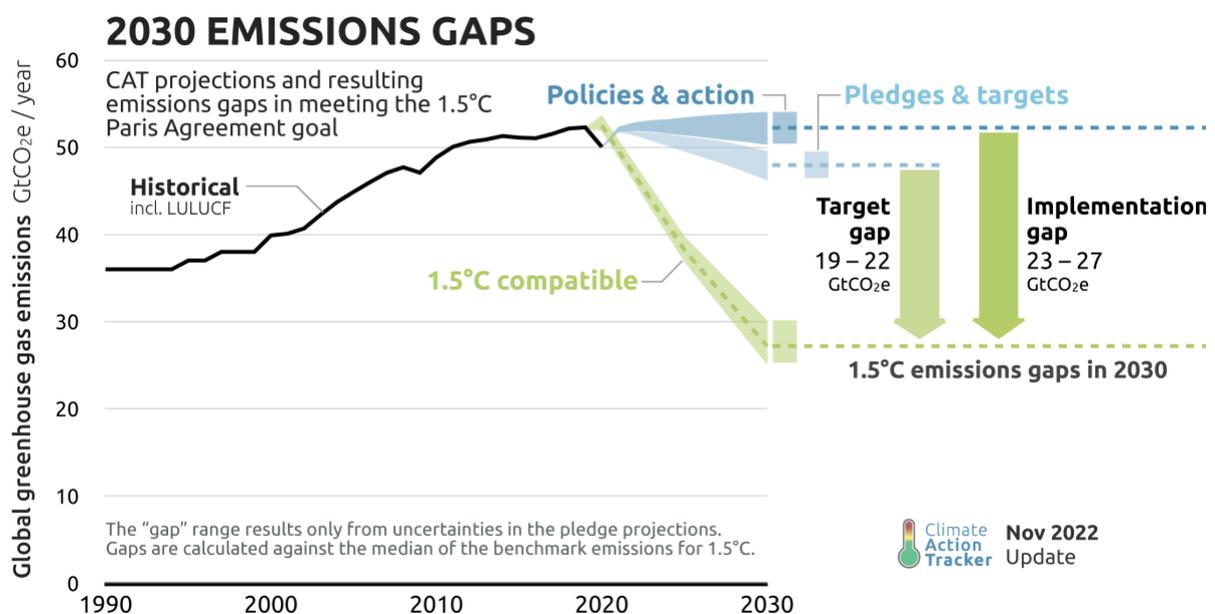


Figure 2.1 Global emissions gaps for 2030 (Climate Action Tracker 2022b).

Australia's current policies and targets are not consistent with a 1.5°C pathway. In June 2022, the Australian government updated and improved its 2030 GHG emissions reduction target from a 26-28% reduction below 2005 emission levels to a 43% reduction below 2005 levels. Both targets include emissions from the land-use sector. The 43% target is in line with a 2°C pathway, whereas current policies are compatible with 3°C of warming, indicating that both require considerable strengthening (Climate Action Tracker 2022a). To align with the Paris Agreement's 1.5°C long-term temperature goal, Australia would need to set a much stronger 2030 target to at least a 57% reduction below 2005 levels.

Following COP27 in Egypt the UN Secretary General has indicated that he will convene an ambition summit in September 2023 to provide an opportunity for countries who have yet to align their 2030 commitments with the Paris Agreement's long term temperature goal to do so before December's COP28 meeting in Dubai.

Under the Paris Agreement's "ratchet up mechanism" a Global Stocktake is underway to provide the basis for countries to put forward 2035 targets in 2025. Following the conclusion of the Global Stocktake and with the input of the IPCC 6th Assessment Report, to be concluded in the first quarter of 2023, governments will be expected to begin considering their 2035 targets in 2024 ready for submission by COP30 in 2025.

Given that Australia's 2030 target is not aligned with 1.5°C pathway trajectory to net zero by 2050, it will be important for the government to improve this so it can put forward a sufficient 1.5°C-aligned 2035 target. Emission reductions that are too slow ahead of 2030 will make it more difficult to make the deeper reductions required by 2035. Ensuring that climate policies like the Safeguard Mechanism are set to enable stronger action, including a much stronger 2035 target, will be critical.

While Australia has a net zero GHG emissions target for 2050, the government has no realistic plan to achieve this target. The Long-term Emission Reductions Plan set under the previous government presents scenarios that reduce emissions 66-85% below 2005 emissions levels by 2050, and relies on carbon offsets, global technology trends, and unspecified "technology breakthroughs" to achieve the remaining necessary abatement to reach net zero (Climate Action Tracker 2022a).

One of Australia's key climate policies, the Safeguard Mechanism currently allows an unlimited use of carbon offsets, called Australian Carbon Credit Units (ACCUs). The SGM is currently under a review and reform process. Getting the details of the SGM reforms right is important, given it covers Australia's top 215 emitting facilities.

Under the government's proposed reforms, the baselines and decline rates dictating each facility's required emissions reduction until 2030 are significantly strengthened but can still be achieved with an unlimited use of ACCUs.

Given the many documented issues with carbon offsets, below we set out the reasons for why achieving real and direct emissions reductions is critical.

Issues with using land-based carbon removal to offset fossil fuel CO₂ emissions

To offset an emission of fossil CO₂ to the atmosphere, any mechanism needs to account for the carbon cycle and climate effects of these emissions over all relevant timeframes. This means that a credible offset mechanism needs to be:

1. Essentially permanent in duration, removing and storing CO₂ over a timescale of centuries to millennia.
2. Removing CO₂ rapidly from the atmosphere over a similar timescale to that of emissions.
3. In addition to stringent emissions reductions, as defined by the latest evidence on 1.5°C compatible pathways with sustainable levels of carbon dioxide removal.

The following section explores some of the key scientific issues and problems that relate to offsetting fossil CO₂ emissions, considering both the short-term and long-term aspects of climate action.

The long lifetime of fossil CO₂ emissions and need for permanence

CO₂ emissions from the combustion of fossil fuels and their extraction make up roughly two thirds of total global GHG emissions (Gütschow and Pflüger 2022). Once emitted, this CO₂ spends an extremely long time in the atmosphere, up to thousands of years, before being fully removed by natural processes (IPCC 2018). In the first 100-200 years after an emission of CO₂, about 60% is taken up by the land biosphere and ocean, and about 40% remains in the atmosphere.

Over the following thousands of years, the remaining part of the emitted carbon is taken up in part by the oceans, so that after 1,000 years approximately 20 to 25% remains in the atmosphere. Over longer timeframes much of the CO₂ emitted from fossil fuel combustion is further absorbed by the land and ocean sinks, but a significant portion remains (Archer et al. 2009; Eby et al. 2009; Lord et al. 2015). Some 7.5 to 20% could remain after 10,000 years and is removed much more slowly via weathering processes and deposition of calcium carbonate that can take up to hundreds of thousands of years, or even longer (see Figure 3.1) (IPCC 2013).

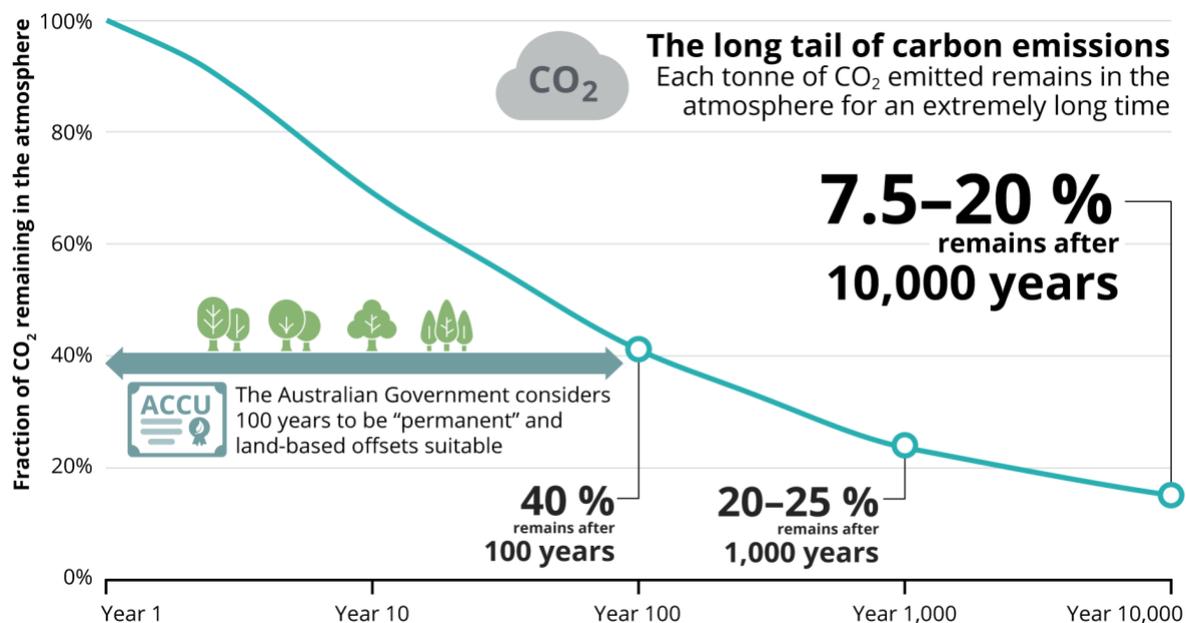


Figure 3.1: Fraction of emitted CO₂ remaining in the atmosphere in years after emission up to 10,000 years
Calculation uses impulse response function of (Joos et al 2013) to 1,000 years and range from (Archer et al 2009) and (Lord et al 2016) up to 10,000 years. See also (IPCC 2013)

While the peak warming effect of a CO₂ emission is felt within the first 20 years following emission, this only slowly declines so that after about 1,000 years, all other factors being equal, a substantial part of this atmospheric warming remains (Joos et al. 2013). The warming from emitted CO₂ is very long-lived, with a single pulse of emissions increasing global average surface temperature by an amount that remains constant for centuries (Matthews and Caldeira 2008). There is evidence that the warming effect of a CO₂ emission will be felt for thousands of years since the residual CO₂ emissions in the atmosphere continue to warm the planet over a very extended time frame (Eby et al. 2009).

This means that for practical purposes, the warming produced by an emission of CO₂ is “forever”, which some authors have referred to as the ‘fossil fuel hangover’ (Inman 2008; Tyrell, Shepherd, and Castle 2007). To fully compensate for the warming impact of CO₂, any offset would also need to store CO₂ over millennial timeframes.

What is also important to recognise is that the residual CO₂ in the atmosphere continues to contribute to the planetary energy imbalance, warming the oceans and contributing to sea level rise over this and longer periods of time (Joos et al. 2013). This CO₂ also contributes to ongoing ocean acidification, itself a very serious problem, including to coral reef systems such as the Great Barrier Reef, exacerbating the effects of marine heatwaves and ocean warming (Cornwall et al. 2021; Klein et al. 2022; Mongin et al. 2016).

The majority of land-based CO₂ removal has permanence timescales of decades to a century, which substantially undermines the validity of offsetting fossil CO₂ emissions by these methods (Canadell, Monteiro, et al. 2021). There is therefore a fundamental difference between directly reducing a source of CO₂ emissions by one tonne, and offsetting that same tonne of CO₂ emissions through sequestration in trees or soil. The direct reduction of emissions does so permanently, whereas the CO₂ that is captured and stored in trees or newly sequestered soil carbon will at some point be released back into the atmosphere, adding to the extant emissions that the tree or soil sequestration was meant to offset. In this way, forest and soil sequestration of CO₂ emissions is fundamentally less effective at reducing emissions compared to a direct reduction at its source.

If CO₂ storage is impermanent, then in the long-term, fossil CO₂ emissions will still be in the atmosphere after the carbon storage has ended. In such a situation, long-term CO₂ concentrations and warming would be higher in the emissions plus offset scheme case, than they would have been if the emission was simply avoided in the first place (Kirschbaum 2006).

There is a wide range of reasons why land-based CO₂ removals are an impermanent form of carbon storage:

- Trees are susceptible to drought, heat extremes, fire, disease, adverse weather events – phenomena which will be exacerbated by climate change, and – in their early stage of growth – damage from wildlife. When trees die or are damaged by the above factors, the carbon that they have stored will be released back into the atmosphere. However, offset programs often only require projects to last a few decades, with no requirements to replace any lost carbon in the project area after its completion.

- Sequestered soil carbon can also be lost back to the atmosphere for several reasons, including a cessation of the carbon sequestering practice, or the occurrence of natural events such as fire. This volatility of sequestered soil carbon has led to the imposition of steep permanence 'discount rates' of up to 50% on some soil carbon-based offsets (Kim, McCarl, and Murray 2008).

Another way to deal with this volatility is the leasing, rather than selling, of soil carbon-based offsets, which places a termination date on the permit, at which point it would need to be replaced. The ease with which soil carbon can be lost to the atmosphere if a project owner decides to discontinue the sequestering practices is the reason such instruments have been deemed necessary (Murray, Sohngen, and Ross 2007).

- The issue of forest and soil carbon impermanence will also be exacerbated by climate change, with increasing risk of forest fires a well-established consequence of global warming, as is the loss of soil carbon through microbial respiration (IPCC 2019).

This is particularly the case for Australia, which has warmed at a faster rate than the global average to date, and for which the intensity, frequency, and duration of fire weather events are projected to increase throughout the country (IPCC 2021b).

These impacts are already being felt, with the historically destructive Australian bushfires in 2019/20 confirming projections made more than a decade ago that increases in climate-driven fire risk would be detectable by 2020 (Abram et al. 2021; Canadell, Meyer, et al. 2021). Total ecosystem carbon losses in bushfire affected areas over this period were shown to significantly exceed interannual variations in net carbon uptake over 2010-2019 and exceeded Australia's fossil fuel emissions in that year (Byrne et al. 2021).

- The frequency of dust storms, which, combined with wind erosion, has also led to the loss of about 1.6 million tonnes of carbon from Australian soils each year, and is projected to increase throughout Australia due to climate change (Wright 2013).
- Human societal and economic factors also affect the permanence of carbon storage from reforestation or revegetation. If reforestation projects are halted and forests re-cleared, then the carbon stored temporarily will be released back into the atmosphere.

There is significant evidence that such reforestation reversal is occurring at a large scale, with up to 75% of the initial carbon stored re-released to the atmosphere due to land cover changes (Schwartz et al. 2020). This is particularly relevant when considering the timescales required to guarantee the permanence of carbon storage to offset against the very long-term effects of fossil CO₂ emissions.

Mature forests, carbon storage, and limiting warming to 1.5°C

Mature forests store a large amount of carbon and it's critical that they are protected from disturbance (Luyssaert et al. 2008). In the absence of disturbance, the carbon stored in these forests both above and below ground can be considered quite permanent.

However, as we are seeing old growth forests are also susceptible to climate change and related disturbances. Declining fog in Northern California since the mid-twentieth century, for example, appears to be causing the ancient coast redwood to be increasingly drought stressed (Johnstone 2010).

In Australia we have already seen some devastating examples of old growth forest, which historically have experienced few fires, burning, leading to large releases of carbon. The mega fires of 2019 and 2020 burnt about 7 million hectares of Eucalypt Forest and woodland releasing approximately 700 Mt of CO₂ emissions (Bowman et al. 2021). Assessments of this event indicate that the combination of drought and frequent fires is reducing the capacity of these forests to recover, meaning they may store less carbon in the future (Bowman et al 2021).

Quite apart from the loss of carbon, the biological conservation impacts of these fires are far-reaching and adverse on both fauna and flora (Godfree et al. 2021; Ward et al. 2020). These events point to the need for massively upgraded efforts to protect the integrity of Australia's mature forests and woodlands to provide the best prospects for them to be able to cope with the climate changes that are happening and that will continue to happen, even if global warming is limited to 1.5°C. Proper legislative and management protection of these forests for their biodiversity and other values would also maintain the vital carbon stocks, and provide the best buffer available against climate change.

Events and observations such as these, globally and in Australia, have led to assessments that climate-driven risks could fundamentally compromise forest carbon sinks in this century, including substantial risk to forest stability (Anderegg et al. 2020, 2022).

The carbon stored in regenerating forests and soils is well acknowledged as likely to be temporary and subject to reversal due to a variety of factors, including human activities, changes in political, regulatory, and economic circumstances as well as the effects of climate-related impacts, including extreme heat, drought wildfire and related risks.

This situation means that it is unsafe to rely upon the assumed historical permanence of carbon stocks in mature forests as an analogue for the future. It does point to the need to ensure that mature forests are protected, and adverse human induced stresses that can be managed are reduced, removed, or stopped in order to provide the best basis for these ecosystems to be resilient to the increased risk of heat extremes, drought and wildfire stresses that they are projected to experience.

Inclusion of mature forests and woodlands in offsetting schemes that include an avoided deforestation method, however, would open any such offsets to the same methodological difficulties that led to a rejection of this method by an independent review into Australia's carbon offsetting scheme (see Section 5.2.3). Efforts to protect these critically important ecosystems and storers of carbon must be separate from those designed to mitigate climate change such as the generation of carbon offsets.

It is also apparent that the observed increase in forest stocks globally may be transient, due to a range of different factors, including CO₂ fertilisation (increased plant growth rates stemming from higher atmospheric CO₂ concentration), previous disturbance, and recovery regimes (Pugh et al. 2019). There are rising concerns in the scientific community that we could be approaching a tipping point for the terrestrial biosphere – including forests – where the effects of warming outweigh the effects of CO₂ fertilisation, leading to a major reduction of the carbon uptake capacity of the biosphere (Duffy et al. 2021).

In relation to CO₂ fertilisation, if global policies to limit warming to 1.5°C degrees are successful, then CO₂ concentration will likely peak in the next few decades and begin to decline. This would limit the CO₂ fertilisation effect and start to reduce it, at the same time that significant warming effects are beginning to become dominant in terrestrial ecosystems, leading at best to a declining land uptake of carbon before mid-century (Canadell, Monteiro, et al. 2021)² or worse, a halving of this uptake by 2040 (Duffy et al. 2021).

2 See figure 5.25 in (Canadell, Monteiro, et al. 2021)

Reversibility of land-based carbon storage

The IPCC has long-recognised the potential reversibility of land-based carbon storage and consequential implications for permanence. Its Special Report on Land Use, Land Use Change and Forestry (LULUCF) in 2000 (IPCC 2000) noted in particular that:

“Enhancement of carbon stocks resulting from land use, land-use change, and forestry activities is potentially reversible through human activities, disturbances, or environmental change, including climate change. This potential reversibility is a characteristic feature of LULUCF activities in contrast to activities in other sectors. This potential reversibility and non-permanence of stocks may require attention with respect to accounting, for example, by ensuring that any credit for enhanced carbon stocks is balanced by accounting for any subsequent reductions in those carbon stocks, regardless of the cause”.

The Summary for Policy Makers further noted specifically in relation to LULUCF:

“LULUCF projects raise a particular issue with respect to permanence (see paragraph 40). Different approaches have been proposed to address the duration of projects in relation to their ability to increase carbon stocks and decrease greenhouse gas emissions, inter alia: (i) They should be maintained in perpetuity because their “reversal” at any point in time could invalidate a project; and (ii) they should be maintained until they counteract the effect of an equivalent amount of greenhouse gases emitted to the atmosphere”

These IPCC findings remain relevant today, and in particular to the construction of offsetting systems. In the more than 20 years since this report we have seen the proliferation of climate-related disturbances which have disrupted forest soils and ecosystems across the world, including notably within Australia, and affected their carbon storage capabilities. We also know that human activities have accelerated, and have contributed to vegetation loss globally, and that in Australia we are often unable to manage these risks.

CO₂ removal should be additional to, rather than a substitute for, ambitious emission reductions

Reducing carbon loss from forests and other ecosystems and expanding carbon sequestration in natural systems is an important element of any strategy to limit warming to 1.5°C. However, the benefits of such nature-based CO₂ removal can only be achieved when combined with policies that rapidly reduce fossil fuel CO₂ emissions to zero (Matthews et al. 2022). Otherwise, temporary carbon sequestration will only delay the inevitable temperature rise by a matter of years, with temperatures rebounding as soon as the CO₂ is re-released.

Pathways that limit warming to 1.5°C follow this logic, substantially increasing carbon sequestration in the terrestrial biosphere while also reducing CO₂ emissions from fossil fuels very rapidly towards zero. In the IPCC 6th Assessment Report, CO₂ emissions excluding negative emissions from CO₂ removal still fall 45% from 2020 to 2030 in 1.5°C compatible pathways that meet sustainability constraints.³ Carbon removal in these pathways is therefore in addition to ambitious CO₂ emissions reductions. Most of the mitigation in these pathways is emissions reduction rather than emissions removal.

In other words, in a country trying to bring its emissions down to align with 1.5°C, fossil CO₂ emissions need to be reduced and land sector carbon storage needs to be increased. However, many policy frameworks allow offsets in the form of carbon storage units to be generated, and these offsets then enable additional fossil fuel emissions above those consistent with a 1.5°C compatible pathway.

Where this is the case, it is likely that total net emissions will then exceed levels consistent with limiting warming to 1.5°C. The large-scale, unfettered deployment of carbon offsets enabling ongoing exploitation of fossil fuels severely jeopardises the 1.5°C temperature limit.

In summary, to be a credible offset for fossil CO₂ emissions, a scheme would need to provide permanent carbon storage with the offsetting occurring contemporaneously with the CO₂ emission itself. The benefits of such a scheme would only be achieved if offsets take place alongside reducing fossil CO₂ emissions to zero (Matthews et al. 2022). It is clear that a large proportion of current and proposed offsetting plans do not meet these criteria, and as such, risk exacerbating, not addressing, the challenge of climate change. We now go on to explore a range of further issues related to offsets in more detail. The first of these is the relationship between offsetting and carbon cycle dynamics.

Carbon cycle, CO₂ fertilisation and fossil fuel emissions

Adding CO₂ to the atmosphere leads to an increased CO₂ fertilisation effect, which in turn leads to additional carbon storage in the terrestrial biosphere (Keenan et al. 2021; Walker et al. 2021).

3 This is a subset of pathways with sustainable levels of AR and BECCS, based on the latest assessment of the sustainable potential for their deployment (Reference: (Fuss et al. 2018; Grant et al. 2021).

This is the natural “land sink”, which, along with the ocean sink, ensures that not all the CO₂ emitted remains in the atmosphere. The most recent global carbon budget assessment indicates that much of the increased carbon storage in the terrestrial biosphere since 1960 has come from the addition of CO₂ to the atmosphere attributable to the CO₂ fertilisation effect.

In this context, it is interesting to note that, of the cumulative CO₂ emissions from fossil fuels and land use change to 2021, the terrestrial biosphere has taken up about 30%, the oceans about 25%, leaving about 44% in the atmosphere.

There has also been a small negative effect on land uptake of CO₂ due to climate change, mainly in South America, Central America, the southwestern US, Central Europe, western Sahel, southern Africa, Southeast Asia, southern China, and eastern Australia (Friedlingstein et al. 2022). Overall, the evidence indicates that fossil fuel emissions have driven increased land carbon storage in the land sink over much of the last century (Schwalm et al. 2020).

However, in ambitious mitigation scenarios that align with 1.5°C, CO₂ emissions must fall to zero around mid-century and often become negative in the second half of the century (Byers et al. 2022). In a world where CO₂ emissions are net-negative, carbon removal is not 100% effective (Canadell, Monteiro, et al. 2021). This is because the land and oceans, which have been absorbing CO₂ from the atmosphere, would instead become sources and begin releasing CO₂ into the atmosphere.

This means that a tonne of carbon removal does not necessarily result in a tonne of CO₂ removal from the atmosphere. One recent estimate in the context of a pathway to limit warming below 2 °C indicates that the likely effectiveness is in the range of 63 to 69% (Matthews et al. 2022). This means that, in a pathway where CO₂ emissions become net-negative, for every tonne of CO₂ stored in the biosphere over a century timeframe only about 630 to 690 kg is withdrawn from the atmosphere.

The impact of positive emissions on atmospheric CO₂ concentrations and global temperatures is not equal and opposite to the impact of negative emissions (Zickfeld et al. 2021). This asymmetry in the effect of CO₂ emissions and removals on the climate system remains poorly constrained (Canadell, Monteiro, et al. 2021), but highlights the risk of treating emissions and removals as direct substitutes, as occurs in offsetting schemes.

Limited carbon storage in the biosphere

As already seen, offsets which are non-permanent, non-instantaneous and non-additional to ambitious emissions reductions, are no substitute for rapid reductions in fossil CO₂ emissions. However, another issue facing the offsetting industry is that the scale of envisaged offsets far exceeds the ability of land-based systems to sequester carbon.

The ability of the biosphere to store carbon is much more limited than many assume. The generation of land-based offsets is limited by several key factors, including the availability of suitable land, and the technological feasibility and cost-effectiveness of such activities. It is limited very much by the amount that was previously depleted due to land use change and other activities (House, Prentice, and le Quéré 2002; Mackey et al. 2013; Smith et al. 2013).

Future climate impacts may also substantially reduce the potential for land-based carbon storage. Given the prevalence of offsets generated from afforestation and reforestation (AR) efforts, this section will focus primarily on limits to AR efforts.

There is a considerable body of scientific literature that estimates the global and regional limitations to AR efforts (Austin et al. 2020; Dooley, Nicholls, and Meinshausen 2022; Fuss et al. 2018; Grant et al. 2021; IPCC 2019; Nabuurs et al. 2022).

The IPCC's 6th Assessment Report collates many of these estimates and identifies a technical potential for AR in the range of 0.5 to 10.1 GtCO₂/y in 2050 (Nabuurs et al. 2022). The upper bound of this potential would require over 670 Mha of land for AR (Nabuurs et al. 2022). However, the sustainable potential is likely to be much smaller. Recent estimates of the sustainable potential for AR in 2050 gave estimates in the range 0.5-3.6 GtCO₂/y, with the scope for limited growth in AR sequestration post-2050 (Fuss et al. 2018; Grant et al. 2021).

The cost-effective potential of AR may be smaller still. Recent cost-effective mitigation potential estimates, which often assume a maximum cost of mitigation of \$100/tCO₂e, yield a range of 0.5-3.0 GtCO₂/y with a central estimate of around 1.6 GtCO₂ per year between 2020-2050, with a much smaller associated area of suitable land of roughly 200 Mha (Austin et al. 2020; Nabuurs et al. 2022; Roe et al. 2021).⁴

4 This figure also includes peatland restoration and coastal wetland restoration.

The literature suggests that the land available for AR is in the range of 200-500 Mha. In comparison, the AR included in current national pledges would require over 550 Mha of land by 2050, an area larger than the EU – exceeding this level by up to 2.5 times (Dooley, Keith, et al. 2022).

Climate change risks to carbon storage

Another issue relating to the use of land-based offsets is their vulnerability to climate impacts. Climate impacts threaten both the scale of sequestration that could be achieved by land-based removals and exacerbate the issue of forest and soil carbon impermanence.

As reported above, CO₂ fertilisation forced by fossil CO₂ emissions has tended to dominate the terrestrial carbon cycle. This has pushed an increased uptake of carbon into forest and soils over the last century. It appears likely that in the coming decades there will be a transition from this CO₂ fertilisation dominated system to one that is dominated by the effects of climate warming, thereby reducing the total uptake potential of the land biosphere. There are already signs of this beginning to happen in different parts of the world (Peñuelas et al. 2017). Forests are likely to feel the effects of climate change due to heat, drought and more extreme fire conditions (Anderegg et al. 2020, 2022).

These effects are certainly now prevalent in Australia, which has warmed at a faster rate than the global average to date, and where the intensity, frequency, and duration of fire weather events are projected to increase across the country (IPCC 2021b).

The impacts of climate change can already be seen with large areas of forest burnt under extreme heat, during droughts, and in fire conditions (Abram et al. 2021; Canadell, Meyer, et al. 2021; Ma et al. 2016; Squire et al. 2021). Extreme heat, drought, and fire in 2019/2020 led to a significant net loss of carbon from ecosystems in South-eastern Australia – a loss that exceeded fossil fuel emissions (Byrne et al. 2021).

It can be expected that the projected increase in extreme heat, drought, and fire conditions will lead to more such events, reducing the recovery time for ecosystems and potentially leading to loss of carbon on multi-year timescales.

In Western Australia, significant parts of the Northern Jarrah Forest experienced collapse due to extreme heat and drought (Brouwers et al. 2013; Matusick et al. 2013, 2018) with subsequent implications for carbon storage (Walden et al. 2019). This further highlights the inadequacy of replacing emissions reductions with offsets based on temporary carbon removal – removal which is itself threatened by climate impacts.

Wider impacts of land-based offsets

Nature-based offsets can have wider impacts on temperatures beyond the (temporary) temperature reduction afforded by CO₂ sequestration. Land-based offsets can have wider impacts on surface albedo and the water cycle. These additional non-CO₂ impacts on temperature would need to be small, if the effectiveness of the offset is not to be compromised.

The IPCC Sixth Assessment notes that there can be different biogeochemical, and climate affects from different approaches to carbon storage that can “decrease carbon uptake and/or change local and regional climate, and in turn limit the CO₂ sequestration and cooling potential of specific methods” (Canadell, Meyer, et al. 2021; Canadell, Monteiro, et al. 2021). One recent analysis found that the biophysical impacts of nature-based offsets could only offset up to 45% of their total sequestration impact (Matthews et al. 2022).

The important corollary of this is that when nature-based offsets are used to licence fossil fuel emissions that would otherwise not have happened, they may not 100% compensate for the heating effect of the fossil emissions due to other biophysical side-effects. If this is the case, then the subsequent release of carbon to the atmosphere from the impermanent terrestrial carbon storage would exacerbate warming, compared to a situation in which the emission was avoided instead of being offset.

Methane emissions

The previous sections have highlighted the substantial flaws in relying on land-based offsetting methods to enable continued fossil CO₂ emissions. We now turn our attention to other greenhouse gas emissions, exploring the limitations of offsetting short-lived greenhouse gases such as methane.

Methane is particularly potent over the first two decades after it is emitted, when it is approximately 80 times more powerful than CO₂ (IPCC 2021a). This leads to two key flaws in using CO₂ offsets to facilitate continued methane emissions.

The first is that, in general, 100-year global warming potentials (GWPs) are used to convert methane emissions into an equivalent amount of CO₂. However, on shorter timescales than 100 years, the warming impact of the methane emissions will be greater than the cooling impact of the calculated offset (even if the sequestration is achieved instantaneously). This means that the net warming impact of the methane emission plus offset will be positive for 100 years, which is arguably incompatible with the urgent need to limit peak warming in the coming decades.

Secondly, even if a more stringent twenty-year GWP is used to estimate the amount of offsets required, if these offsets do not lead to instantaneous sequestration, there will again be a time-lag where initially global temperatures are elevated by the methane emissions, while the cooling impact of the nature-based offsets grows slowly. The offset is arguably therefore not “climate neutral”, as near-term temperatures are higher than they would otherwise be had the emission been avoided.

It is crucial to note that methane emissions have been increasing rapidly over recent years, roughly due in equal part to fossil fuel sources and agricultural and waste sources combined (Jackson et al. 2020). This recent rapid increase is not expected to reverse before 2050 under current policies, with emissions instead projected to increase by 30% compared to 2015 levels by then (Höglund-Isaksson et al. 2020).

In contrast, in 1.5°C compatible pathways in the IPCC AR6 database which meet sustainability criterion, total methane emissions fall by 35% from 2020 to 2030. This reduction is particularly driven by reductions in methane from the energy sector, which fall 63% from 2020 to 2030, underscoring the need for rapid methane emissions reductions, rather than a reliance on offsetting which could exacerbate warming.

Reducing methane emissions is an important part of limiting warming to 1.5°C, as rapid reductions in methane will reduce the rate of warming and are needed to compensate for the reduction in aerosol emissions due to reductions in fossil CO₂ emissions (IPCC 2021a).⁵

Stringent methane emission reductions are an integral part of, and to a significant extent, driven by, the deep reductions of CO₂ needed by 2030 in 1.5°C compatible pathways. In these pathways, CO₂ is reduced by half between 2020 and 2030. Carbon emission reductions form the largest component of total mitigation in these pathways and drive substantial methane emission reductions as part of an overall cost-effective mitigation strategy.

With very substantial emissions from gas extraction and coal mining in Australia, it is important that policy focuses on measures that actually achieve real methane emission reductions. The offsetting approaches proposed under the safeguard mechanism would likely not achieve this.

5 The [IPCC AR6 Summary for Policymakers](#) found with high confidence that: “In the low and very low GHG emissions scenarios, assumed reductions in anthropogenic aerosol emissions lead to a net warming, while reductions in CH₄ and other ozone precursor emissions lead to a net cooling. Because of the short lifetime of both CH₄ and aerosols, these climate effects partially counterbalance each other and reductions in CH₄ emissions also contribute to improved air quality by reducing global surface ozone”

Nature based solutions as a complement to emissions reductions at source

The storage of carbon in ecosystems, both natural and managed, is sometimes termed “nature-based solutions” (NbS). Maintaining the storage of carbon in ecosystems and soils is well acknowledged as important for efforts to limit warming to 1.5 °C, and measures to achieve this include stopping deforestation and land clearance, reducing degradation of ecosystems, restoring ecosystems, building up soils in agricultural and pastoral areas and a range of other activities.

What appears to be less well understood is that this needs to be a complement to emission reductions at source, not as an alternative. Seddon et al (2021) provide a very useful guide to principles for policy makers that can enable nature-based solutions to provide sustainable benefits to society at large.

- NbS are not a substitute for the rapid phase out of fossil fuels;
- NbS involve a wide range of ecosystems on land and in the sea, not just forests;
- NbS are implemented with the full engagement and consent of Indigenous Peoples and local communities in a way that respects their cultural and ecological rights; and
- NbS should be explicitly designed to provide measurable benefits for biodiversity.

The first of these principles raises a red flag in relation to using offsets generated from the land sector to enable further fossil fuel emissions, and thereby contradict the objective of a rapid phasing out of fossil fuels.

Direct Air Capture as a route for permanent and rapid carbon removal

This report focuses on the flaws in using nature-based, non-permanent, non-rapid carbon removal as a replacement for direct emissions reductions at source, as the majority of the current offset market relies on these methods of carbon sequestration. However, in the future it is possible that new carbon removal methods will emerge, in particular direct air carbon capture and storage, or DACCS.

DACCS does not present the same set of risks as nature-based offsets and could represent a more credible offset option. However, the following issues must still be noted about reliance on DACCS as an offsetting scheme:

- The potential for DACCS, particularly pre-2050, is most likely limited by technological readiness (Grant et al. 2021), access to geological storage (Grant et al. 2022; Lane, Greig, and Garnett 2021) and the current high energy requirements for DACCS (Realmonte et al. 2019).
- At the same time, the costs of DACCS are likely to remain high. This means that the scope to use DACCS to offset fossil CO₂ emissions on the road to net-zero CO₂ by 2050 is very limited and will only be cost-effective for use against emissions which are truly “hard-to-abate”, with very high mitigation costs.
- DACCS only represents a “rapid” source of CO₂ removal if the carbon is sequestered in the same time frame as the emissions. Therefore, continuing fossil emissions in the present, with the aim of offsetting these emissions via future direct air capture deployment does not represent a robust offsetting strategy.

The need for permanence also arises in the context of considering the timeframe needed for geological storage of CO₂, including via DACCS, when using carbon capture and storage (CCS) technologies. In carbon capture and storage, CO₂ emissions are avoided by capturing CO₂ from power, industrial production or from natural gas reservoirs, and storing the CO₂ in geologically secure underground storage repositories.

Alcalde et al. (2018) has argued towards maximum loss rates from geological storage of around 0.001% per year - a 1% loss over a century in order to ensure the climatic effectiveness of each CCS unit. Others have argued that a leakage rate of 1% or less per century is needed to “maintain conditions close to those of a low-emission projection with no sequestration” (Shaffer 2010).

Without drawing conclusions here, it is quite apparent that these kind of loss rates, if required to ensure that a CCS unit is an effective offset against an emission reduction in a climatic sense the same must also be true for land-based carbon storage.

It is also interesting to note that in the Australian context, the CCS methodology adopted (Lee et al. 2021) recently also places only a 100-year time frame on storage with no ongoing monitoring or liability.

In Australia, the Clean Energy Regulator (CER) considers 100 years to be permanent, and that, by implication, should the carbon be lost after 100 years, it is of no consequence, as at present there is no regulatory or other requirement for ongoing replacement of lost carbon from credited projects. It should be recalled that at year 100 after an emission about 40% of the original emission remains in the atmosphere, and if the carbon that's offset is released, CO₂ levels will be higher in the subsequent centuries than they would have been in the absence of the offsetting system in the first place (Kirschbaum 2006).

Carbon lock-in and undue substitution

The use of land-based carbon offsets has long attracted criticism that it is a way for companies and governments to circumvent necessary mitigation actions (Carton et al. 2020; Dooley and Gupta 2017). The relatively low cost of many land-based carbon removal projects makes purchasing offsets generated from such projects an attractive option for emitters to meet their climate targets. However, their widespread availability and low prices absolve emitters from the need to invest resources into emissions reductions activities. This has led to high level concern internationally about the role of offsets including expressions of concern about greenwashing and proposals to avoid this by strictly limiting offset use (Anon 2022; UN HLEG 2022).

The decision of how an emissions reduction target can and should be met is influenced by a number of factors, including the prevailing carbon price if it exists, the short run marginal cost of abatement options, the longer run question of optimal transformational investments, and the need to avoid locking in carbon intensive practises, industries and infrastructure.

Making the choice to replace polluting technology with a more expensive, but lower emissions alternative, is far less likely if government regulation makes it cheaper to simply purchase inexpensive land-based offsets. This can lead companies to plan the achievement of net zero targets largely using offsets, leaving their polluting assets in place and increasing the risk of operational, technological, or capital 'lock-in' (Pineda and Faria 2019).

A company's choice to utilise cheap land-based offsets over investing in actual emissions reductions can be thought of as a kind of 'undue substitution' of offsets for cutting emissions, in that such a choice can result in harmful unintended consequences (Asayama 2021). One example could be an increased risk of a company becoming less competitive in a decarbonising economy, while the failure to recognise the social, ethical, and environmental impacts of continuing to emit is another.

A growing number of proposals are arising for how to reduce the prevalence of, and harm caused by, these undue substitutions, including setting separate targets for emissions reduction and carbon removal rather than a single net zero target.

The UK Climate Change Committee (UK Climate Change Committee 2022) found in its report on offsets that:

“Relying on a carbon credit to ‘offset’ emissions could mean a business then invests in high-carbon technology that becomes ‘locked’ in for many years. This would in the long run lead to higher emissions than if funds used for ‘offsetting’ were used to invest in low-carbon technology. Therefore, businesses should also prioritise available funds to invest in longer-term decarbonisation before considering relying on ‘offsetting’”

This issue has also been raised in the Australian context by researchers looking at specific questions about offset methods, such as soil carbon. Their conclusions, however, are of broader applicability, raising the point that the widespread use of offsets “could have the most undesirable effect of diverting businesses in the mining, manufacturing and transport industries from taking real measures to reduce their own emissions” (White 2022).

Unfortunately, this is exactly what the unfettered use of offsets in a safeguard mechanism could lead to - lock in of high carbon industries, practises, and activities at the expense of investment in reducing emissions at source that would help the Australian economy become more competitive in a world working to achieve the Paris Agreement's 1.5°C limit.

Land sector offsets often do not represent genuine or ‘additional’ emissions reductions, and can result in leakage

There are several ways in which land-based carbon offsets can fail to represent a genuine emissions reduction, or an emissions reduction that is additional to that which would have happened without the credited intervention. Failure to generate genuine emissions reductions can result from methodological shortfalls like inappropriate or deficient measurement techniques, while leakage can mean a project or set of projects fails to achieve net emissions reductions.

A recent nine-month investigation by journalists at SourceMaterial, The Guardian and Die Zeit newspapers found that more than 90% of rainforest carbon offsets created by the world's largest provider, Verra, do not represent genuine emissions reductions (Greenfield 2023; SourceMaterial 2023).

The investigation was based on new analysis of scientific studies of Verra's rainforest schemes as well as dozens of interviews with relevant scientists, industry insiders and indigenous communities. A large number of companies rely on these carbon offsets, representing tens of millions of tonnes of CO₂ equivalent emissions reductions, which are purported to be mostly worthless. This raises serious questions around the integrity of land-based carbon offsets globally, given the similarities in methodological requirements in other locations.

Serious methodological issues relating to carbon credits generated from the land sector in Australia have been highlighted recently. As of early 2023, approximately 81 million ACCUs, or roughly two thirds of the total number of ACCUs issued, were for projects in the land sector, including vegetation (55%), agriculture (1%), and savanna burning (9%) related projects (Clean Energy Regulator 2022).

In 2022, Professor Andrew Macintosh, an environmental law and policy expert and the former chair of the ACCU scheme's regulatory body, the Emissions Reduction Assurance Committee (ERAC), estimated that a majority of ACCUs issued using two of the most popular methods, avoided deforestation, and human-induced regeneration of native forests, and representing over a third of total ACCUs issued, did not represent genuine emissions abatement (ANU 2022; Macintosh 2022).

Inadequate methodological issues highlight the fundamental risks of relying on an offsetting scheme like the ACCU scheme that leans so heavily on abatement from the land sector to achieve emissions reductions. It is a neat demonstration of the riskiness of such schemes, that, even when heavily regulated and independently reviewed by a panel of experts, as occurred with the Australian Government's 2022 Chubb Review, they can fail to achieve consensus among key experts as to their ability to achieve genuine emissions reductions (Australian Government 2022c; Macintosh and Butler 2023).

Measurement

One key methodological shortfall highlighted in the Australian context is the way that emissions reductions are measured.

The measurement of changes that occur in a particular area of land can be obscured by a lack of precision in measuring a baseline of existing stored emissions either through deficient equipment, poor quality data, or inappropriate methods, such as a reliance on modelling in lieu of direct measurements. The use of modelling in lieu of direct measurement to ascertain the level of abatement that has occurred from a project can also lead to inaccurate results.

Often it is highly complicated to ascertain the amount of carbon per hectare in forests, given the wide variation in land productivity, species, and land management practices (Mendelsohn, Sedjo, and Sohgen 2012). Accurate verification may require a manual inspection process that can be costly and resource intensive, providing an incentive to minimise the extent to which this approach is utilised. Instead, various region-specific modelling approaches have been developed to estimate the initial level of existing carbon content and how it will change over time with the proposed regeneration activities.

This approach has been strongly criticised by independent experts in the Australian context, with the use of the Australian Government's Full Carbon Accounting Model (FullCAM) and a simplified version of it, the Reforestation Modelling Tool (RMT) have been shown to have significant shortcomings for accurately measuring the level of actual abatement occurring on each site (see Section 5.2.4) (Macintosh, Butler, Evans, et al. 2022b, 2022a; Macintosh, Butler, and Ansell 2022).

Soil carbon-based offsets suffer from complex measurement requirements, making them particularly susceptible to lacking integrity. Measuring soil carbon is both time intensive and expensive, limiting the area of land that can feasibly be tested; in 2019 it was estimated at USD 32 per hectare, compared to the prices announced by many emerging carbon crediting firms at the time of between USD 10-15 per hectare (Paul et al. 2019). This is particularly an issue given the high degree of spatial variability embodied by soil carbon projects. The use of models to address this issue is similarly problematic given the quality and quantity of data needed to ensure their accuracy, not to mention the complexity of the most accurate models, which require a high degree of skill to operate (Environmental Defense Fund 2019).

Leakage

To be a viable method of reducing emissions, carbon abatement projects must lead to a *net* emissions reduction. Unfortunately, for several reasons, engaging in reforestation or avoided deforestation projects often leads to what is known as leakage, whereby these types of projects can result in deforestation activity elsewhere, cancelling out the emissions reductions achieved through the original project.

This is particularly relevant in relation to the trade-off between forestland and agricultural land, given the tendency for reforestation projects to occur on formerly agricultural land. Assessing the issue from a systems perspective, if reforestation on agricultural land creates scarcity and raises the price of goods formerly produced on that land, it may lead to land clearing in another location if the consequent price increase creates a sufficient financial incentive to establish greenfield agricultural land.

This process could occur within a particular country, but given the highly globalised nature of commodity markets, could also occur across one or more countries internationally, which often makes it costly and difficult to prove. Given the projected competition of carbon offset-related reforestation projects in Australia with agricultural land (see Section 5.4), this is particularly salient for the Australian context (Australian Government 2011).

Additionality

Establishing whether emission reductions achieved through land sector projects used to generate offsets are 'additional' to those that would have occurred regardless of whether the offset was generated can prove difficult.

For example, the activity that generated the emissions reduction may have occurred without needing the incentive provided by the price of the offset(s) generated from the activity. There are claims from both academia and within industry that this was the case for offsets generated with the avoided deforestation method in several projects in Australia, as well as in the landfill gas combustion and capture sector (see Section 5.2.2 & 5.2.3) (Macintosh 2022; Slezak 2022).

The Emissions Reduction Assurance Committee (ERAC), the government regulatory body overseeing the integrity of Australia's ACCU scheme, has also conceded that the subjective nature of necessarily establishing a counterfactual scenario during the assessment process means there is no way to truly identify the degree of additionality of a particular project (Australian Government 2022b).

To the extent that additionality is not guaranteed, then even if all other aspects of an offsetting system are perfect, including monitoring reporting and verification, the offsetting system would lead to more CO₂ being emitted from a controlled source than what otherwise would have been the case, contributing to greater warming than what otherwise would have happened in the absence of the offsetting system itself.

The Australian Context

The Emissions Reduction Fund (ERF) and Australian Carbon Credit Units (ACCUs)

The Emissions Reduction Fund (ERF) is one of the main GHG emissions reduction policies in Australia. It was introduced in 2015 and provides funding to businesses, households, and communities to invest in emissions reduction activities.

The ERF awards Australian Carbon Credit Units (ACCUs) that can be used to offset GHG emissions in Australia. One ACCU corresponds to one tonne of carbon dioxide equivalent emission reduced, removed, or avoided. The ACCUs can be traded to the State or on the secondary market. To this day, the Australian government remains by far the main buyer of ACCUs. According to Minister for Climate Change and Energy Chris Bowen, “carbon credits will play a vital role in [the] government’s climate action plan” (Chris Bowen 2022). However, the integrity of these carbon offsets has been called into question.

On July 1, the government appointed Professor Ian Chubb to review the carbon credit scheme and address its shortcomings (Morton and Murphy 2022). His subsequent report, released in early January 2023, claims that the ACCU scheme was “fundamentally well designed when introduced” (Australian Government 2022c).

However, the evidence supporting the position that levels of abatement resulting from the scheme have been overstated was ignored in favour of evidence that purportedly showed the opposite, but no such contradictory evidence was produced.

Prior to the release of the Chubb Review, the Australian Conservation Foundation called for the government to reform the Clean Energy Regulator (CER), increase data transparency, adjust existing or issue new methodologies to ensure offset integrity, encourage emission reduction instead of offsets and incentivise co-benefits (Australian Conservation Foundation 2022).

In relation to these issues, while the Chubb Review did acknowledge that the responsibility for Australian Government purchasing of ACCUs should be moved away from the CER, due to the perception of a conflict of interest, it did not advocate for CER reforms.

A key finding was that current restrictions on data availability are undermining transparency, trust, and confidence in the scheme, and recommended amendments to provisions relating to data access and sharing.

The report recommended leaving unchanged the most contentious methodologies used to calculate emissions reduction additionality or integrity, particularly those relating to human induced regeneration (HIR). It rejected criticism of the current model-based estimation of aggregate carbon storage in native vegetation.

In 2022 the Australian Government commissioned the Australian Academy of Sciences to review the four most contentious ACCU generation methods, their scientific underpinnings, and the extent to which they comply with the offset standards.

The review identified limitations of these methods which “may raise questions as to their adherence to the offset integrity standards” (Brack et al. 2022). These include challenges with attribution of emissions reductions and confounding influences including climate change, challenges with establishing consistent emissions baseline data, and questions of integrity for methods that rely on counterfactuals to demonstrate carbon sequestration. It states that the overcomplexity of all the methods require a prohibitively high level of subject matter expertise, policy familiarity, and industry knowledge to ensure robust verification, so that relatively few individuals can provide independent assurance.

While several methods suffered from more than one of these limitations, the only method that was singled out as suffering from all of them, was human induced regeneration, which makes up a large proportion of all ACCUs generated to date. The Chubb review made no mention of these methodological limitations in its findings or recommendations.

Highlighted methodological issues with the ACCU scheme

Lack of genuineness and additionality in the Human Induced Regeneration (HIR) method

As of the end of 2022, 29% of ACCUs issued as part of the Emissions Reduction Fund program came from forest regeneration initiatives, to incentivise regrowth in native forests. Almost all such human-induced regeneration (HIR) projects are taking place in arid or semi-arid areas, where vegetation regeneration has been shown to correlate strongly with rainfall (Macintosh, Larraondo, et al. 2022).

One set of comparisons of woody cover inside and just outside of areas covered by human-induced regeneration projects found that the projects' activities have a limited impact on woody regeneration (Macintosh, Larraondo, et al. 2022). These results obtained by Andrew Macintosh et al suggest that such projects have therefore had limited additionality, as the progress observed in their areas would have happened anyway.

In particular, the management of livestock grazing on these projects, a method which underpins the generation of many ACCUs using the HIR method, was found to have limited impact on woody regeneration in project areas, particularly in arid and semi-arid areas (Macintosh, Larraondo, et al. 2022).

In a response that these findings were incorrect, the Emissions Reduction Assurance Committee (ERAC), until mid-2022 chaired by a former CEO of the Australian Petroleum Production & Exploration Association (APPEA), relied on a single study that it had commissioned. The Macintosh et al counter response was that this had invalidating methodological deficiencies (Macintosh, Butler, Evans, et al. 2022a).

The ERAC report also ignored the findings in its commissioned study that 23% of all projects analysed, and 37% of the analysed Queensland projects, have had either no, negative, or almost no impact on sparse woody and forest cover relative to what would have occurred otherwise (Macintosh, Butler, Evans, et al. 2022a).

The findings of the Chubb Review fail to acknowledge several of the key methodological deficiencies highlighted by Macintosh et al, including a contended misapplication of measurement requirements in the method, and crediting of ineligible areas (Macintosh, Butler, Evans, et al. 2022a). No recommendations have been made to amend or replace the methodologies in contention. Instead, it makes sweeping statements such as "the HIR method is sound", and "the Panel does not accept that a correlation between rainfall and vegetation growth undermines the method", without dealing with any specific criticisms (Australian Government 2022c).

The Macintosh et al contention that the CER and ERAC public defence of the HIR method is deeply flawed is also not addressed by the Chubb Review. This implies the HIR method will remain fundamentally unchanged moving forward, leaving grave doubts as to the genuineness and additionality of future ACCUs generated through this method, and likely ensuring the approval of a large number of future projects that fail to significantly reduce emissions as required.

After publication of the Chubb Review, Professor Chubb indicated that his panel relied on evidence presented by the ERAC when evaluating the robustness of the methodologies under question, but did not elaborate on exactly what that evidence was, and whether that evidence was produced under the leadership of the former oil and gas executive (ABC Radio National 2023a). It is noteworthy that one of the recommendations made by the Chubb Review was to abolish the ERAC and replace it with an entirely new regulatory body with new membership but provided no specific reasons for doing so (Australian Government 2022c).

Lack of additionality in landfill gas use and capture

As of the end of 2022, landfill gas use and capture activities accounted for over a quarter of ACCUs generated. A study led by Andrew Macintosh shows that up to two thirds of these abatements are not additional, as power generation due to landfill methane and the sale of the associated renewable energy certificates are profitable before the issuance of carbon credits (Macintosh 2022).

The concentration of ACCU emissions among a few facilities – the largest 20 projects represent 70% of the ACCUs issued with this method – is likely to be a contributing factor to the non-additional nature of these offsets because of economies of scale.

In September 2022, several industry leaders benefitting from landfill related ACCUs called on the government to review the method to improve its integrity (Michael Slezak 2022). They argue that the current lack of integrity of landfill gas offsets undermines the carbon market's credibility as a whole.

The Chubb Review found the baselines of methane destruction at participating landfills required under existing legislation are often too low, and do not accurately reflect state and territory requirements, or “do not create a financial incentive for project operators to go beyond the regulatory minimum, and also to innovate” (Australian Government 2022c). In response, the Review recommended a change to upward sloping baselines for future projects, while a shift to such upward sloping baselines for existing projects should be voluntary. This is unlikely to solve the additionality issue for existing projects and was criticised by Andrew Macintosh in an interview after publication of the Chubb Review (ABC Radio National 2023b).

Additionality and Avoided deforestation

Avoided deforestation is another opportunity to participate in the ERF. This activity represents 21% of issued ACCUs (Australian Academy of Science 2022). It targets landowners in possession of the right to clear their estates. The avoided deforestation offsets methodology assumes that all areas where avoided deforestation projects are undertaken would otherwise be cleared within 15 years.

In addition to not being conservative (one of the criteria for offset integrity under the ERF method), this assumption has been found by the Australian Conservation Foundation to be implausible, as it would imply a clearing rate several orders of magnitude higher than the historical one (Australian Conservation Foundation 2021). Similarly, to human-induced regeneration projects, avoided deforestation projects are sensitive to carbon leakage, where an entity benefitting from ACCUs funds deforestation elsewhere.

The Chubb Review found the existing method for awarding ACCUs for avoided deforestation makes it difficult to establish additionality of a registered project's emissions reductions and recommends that no new projects be allowed under this method. However, it followed this up with a recommendation to develop new methods that "incentivise the maintenance of native vegetation that has the potential to become a forest, as well as maintaining existing forests at risk of land-use conversion" (Australian Government 2022c).

Such amended methods are unlikely to address concerns over the additionality of emissions reductions achieved by these kinds of projects.

Further methodological issues

Other ACCU methodologies such as the plantation method (Macintosh and Waschka 2022) have attracted further criticism. While the government plans to increase the supply of ACCUs with the release of guidelines for carbon capture and storage (CCS) and soil carbon, according to the Australia Institute, there are limited signs that these new methodologies will guarantee offset integrity (Hemming, Armistead, and Venketasubramanian 2022).

With regards to the new CCS method, the proportion of total emissions from any fossil fuel project captured by CCS is only ever minor, meaning that net emissions from any such new project would increase. The ACCU scheme's regulatory body, the Clean Energy Regulator, has prioritised the development of a method for carbon capture, utilisation, and storage (CCUS), which is generally utilised to maximise output from declining oil and gas reservoirs, leading to a net increase in fossil fuels, not a decrease.

The CER has not, however, required ongoing and permanent responsibility from those that deploy CCS. The need for permanence for geological storage of CO₂ is well recognised in the scientific community. In carbon capture and storage CO₂ emissions are avoided by capturing CO₂ from power, industrial production or from natural gas reservoirs, and storing the CO₂ in geologically secure underground storage repositories. Alcalde et al. (2018) has argued towards maximum loss rates from geological storage of around 0.001% per year - a 1% loss over a century to ensure the climatic effectiveness of a CCS unit.

Others have argued that a leakage rate of 1% or less per century is needed to “maintain conditions close to those of a low-emission projection with no sequestration” (Shaffer 2010).

Without drawing conclusions here, it is quite apparent that if these kinds of loss rates are required to ensure that a CCS unit is an effective offset against an emission reduction in a climate sense, the same must also be true for land-based carbon storage.

Additionality, permanence, and viability of climate benefits concerns also exist with the **“blue carbon” method**. The wider benefits of restoration of coastal blue carbon ecosystems for biodiversity conservation, marine ecosystem protection, food security and other values are clear however there are massive uncertainties around whether it is feasible to secure long-term carbon removal through these methods. At the very least this is highly uncertain and is subject also to the effects of climate change itself creating risks for coastal mangroves, seagrass and coral reef ecosystems (Fyson, Schleußner, and Hare 2019; Williamson and Gattuso 2022).

In relation to the **soil carbon method**, there are well documented issues with the complexity and resource intensiveness related to measuring soil carbon increases, and with maintaining soil carbon after activities have been credited (see Section 5.1). ACCUs are generated with the goal of achieving the ‘lowest cost abatement’ which creates an incentive to minimise these measurement costs and increases the risk of poor-quality offset generation (White, Davidson, and Eckard 2021).

Ensuring the veracity of **land use-generated carbon offsets** also requires an accurate estimate of changing vegetation cover, something that has long been contested in the Australian context. Researchers involved in the State-wide Landcover and Trees Study (SLATS) in Queensland, have pointed to significant discrepancies between what is treated as cleared land by SLATS versus by Australia’s National Carbon Accounting System (NCAS) used by the federal government to calculate GHG emissions from Australia’s land sector. In 2018/19 alone, land clearing reported by SLATS was found to be 1.9 times higher than the officially reported total submitted to Australia’s National Greenhouse Gas Inventory (NGGI), a difference of roughly 230,000 hectares (Taylor 2022). If the true size of emissions and abatement from the land sector is not being measured accurately, this will provide a misleading picture of Australia’s net emissions.

This has implications for the success or failure of Australia’s GHG emissions reduction targets, but also carries reputational risk within the international climate community if it were to be revealed that there are significant discrepancies between Australia’s reported, and actual, land sector emissions.

Doubts have also been raised relating to the calculated area of **regrowth on previously cleared land**, which relates directly to the creation of ACCUs, a large share of which are generated by this method. Criticism has been levelled at the heavy reliance on the Australian Government's FullCAM (or Full Carbon Accounting Model), and a simplified version of FullCAM, the Reforestation Modelling Tool (RMT), for calculating abatement levels from projects relating to Human Induced Regeneration (HIR) (Macintosh, Butler, Evans, et al. 2022a, 2022b; Macintosh, Butler, and Ansell 2022).

Specifically, the extent to which mature trees exist on project sites greatly affects the tree yield function that is used to calculate the carbon stored in HIR projects, and the presence of such mature trees in these projects indicates that the modelled rates of carbon abatement are likely over-estimated. This is because mature trees do not sequester carbon to the same extent as growing trees and that mature trees will generally compete with these growing trees, reducing the growth rates of new regrowth (ANU Institute for Climate Energy & Disaster Solutions 2022).

It has long been recognised that there is a need to factor out the CO₂ fertilisation effect from estimates of increased CO₂ storage in the biosphere, but this has not been done (Canadell et al. 2007). This means there's a substantial likelihood that a significant part of the additional carbon storage counted in national emission inventories in the biosphere could be attributable to CO₂ concentration increases but are themselves due to fossil fuel emissions.

ACCUs and the Redesigned Safeguard Mechanism

In January 2023, the Australian Government released its proposed reforms to the Safeguard Mechanism (SGM) policy that targets GHG emissions from 215 large industrial facilities (Australian Government 2023).

Facilities are required to reduce their emissions over time below an established baseline. Under the original design of the policy, the ability for companies to purchase ACCUs in lieu of reducing their own emissions was unlimited, meaning there was no obligation for any facilities to achieve actual emissions reductions. This remains the case under the proposed reforms, with no limitations placed on the number of ACCUs purchased.

Under the latest government projections, the total required abatement under the SGM in 2030 will include 9 million ACCUs, representing 20% of the total 36 MtCO_{2e} of abatement required by SGM-covered facilities in that year (Australian Government 2022). Under a conservative assumption that 20% of the cumulative required abatement to 2030 will also be achieved with the use of ACCUs, this represents 41 MtCO_{2e} or 41 million ACCUs required in total.

The total number of flawed ACCUs called out by Macintosh et al as unlikely to represent genuine or additional emissions reductions is in the order of 60 million (Macintosh and Butler 2023). This means that it's possible, that all, or at the very least, a large share of ACCUs purchased by SGM facilities to 2030 could fail to reduce emissions at all.

One proposed change to the SGM was the inability for facilities covered by it to *create* ACCUs for new projects, though existing projects that are already registered and reduce emissions at a facility covered by the SGM can continue to generate and sell ACCUs for their existing crediting period. Importantly, however, both existing and new entrant facilities will have unlimited access to *purchase* ACCUs to achieve their required emissions reduction.

This effectively grants facilities under the SGM permission to continue emitting indefinitely, so long as they purchase enough ACCUs (or safeguard mechanism credits (SMCs) that are proposed to now be generated when companies reduce actual emissions to below their set baseline).

Similarly, new facilities, including coal, gas, and oil extraction, will be permitted to emit GHGs without limit, so long as they purchase sufficient ACCUs (or SMCs) to achieve their assigned baselines. Given the well-documented issues with ACCUs and their veracity or additionality, including in this report, this would amount to permission for current, and future new and expanded fossil fuel production facilities to significantly increase Australia's actual GHG emissions.

This issue could be avoided entirely, if permission to purchase credits was limited to SMCs, which represent actual emissions reductions by SGM participants. This would also increase demand for SMCs, pushing their price up, and increasing the incentive for SGM participants to reduce actual emissions below their respective baselines. A closed SMC trading system could link up with other international systems like the EU-ETS.

A key rationale for allowing SGM participants unlimited ACCU purchases is the notion that emissions from some sectors are 'hard to abate', and that offsets represent the only realistic option for achieving their respective emissions baselines (Australian Government 2023).

The emergence of new technologies across these 'hard to abate' industries like steel, cement, and fertilisation production, and heavy duty transport means that this argument is rapidly losing credence.

Box 1: Emerging options to decarbonise 'hard to abate' sectors

Green Hydrogen and Ammonia

Steep reductions in the cost of solar PV and wind power has led to a boom in demand for green hydrogen and ammonia, made by electrolysing water using renewable electricity. Further solar and wind cost reductions, combined with falling electrolyser prices that will eventuate as production ramps up, will make these fuels viable alternatives for steel and fertiliser production respectively.

Several firms are already investing in production facility upgrades to accommodate these zero carbon inputs. Green hydrogen can also be used to power fuel cell electric long-haul heavy duty trucks, and to produce zero carbon synthetic fuels, likely to be pivotal in decarbonising long-haul aviation and shipping.

Synthetic Fuels

Carbon neutral synthetic fuels are possible through the use of captured CO₂ from the atmosphere and green hydrogen. As direct air carbon capture technology improves and begins to scale up, the economics of such fuels will improve in tandem. In 2022, the airline EasyJet decided to scrap its carbon offset program in favour of reducing actual emissions, in part through direct air carbon capture and storage (easyJet 2022). Long distance aviation and shipping are increasingly looking to develop synthetic fuel technology as a means to achieve decarbonisation.

Low-carbon cements and process efficiency gains

The addition of supplementary cementitious materials (SCM) like calcined clays can significantly reduce the carbon intensity of cement production, and is currently being trialled in several countries (Srinivasan and Elliott 2022). The cost of limestone calcined clay cement (LC3), a leading alternative, is cheaper to produce than Portland Cement (Scrivener, Martirena, and Bishnoi 2021).

Carbon capture (utilisation) and storage (CCS/CCUS)

The extraction of fossil fuels produces considerable quantities of emissions, which can be captured and stored underground permanently. This technology has yet to become cost effective, and technical challenges remain, but is being trialled in several locations around the world. With its Longship project, Norway aims to "realise a cost effective solution for full-scale CCS". The country has been storing CO₂ underground in the North Sea since 1996, largely due to its longstanding carbon tax (CCS Norway 2023).

How permanence is handled

The Australian government recognises that carbon offsets need to be permanent to represent a genuine emissions reduction, but the chosen method for ensuring permanence is critically insufficient. Under the ACCU scheme, carbon sequestration is regarded as permanent if it is “maintained on a net basis for 100 years” (Australian Government 2020).

Participating landholders are given the option to nominate a permanence period of either 25 or 100 years, with those choosing the 25-year period subject to a 20% reduction in the number of ACCUs to “cover the potential cost to the Government of replacing carbon stores after the project ends” (Australian Government 2020). A further 5% reduction in the number of ACCUs issued is imposed as a “risk of reversal buffer”, which notionally accounts for the possibility of carbon sequestered in the project being lost back to the atmosphere.

Once the chosen permanence period of a particular project expires, the obligation to maintain the sequestered carbon is removed (Australian Government n.d.). A failure to comply with a carbon maintenance obligation may result in pecuniary penalties up to AUD 2.2 million for corporations, or AUD 444,000 for individuals.

As has been highlighted in previous sections of this report, a significant proportion of CO₂ emissions remains in the atmosphere for thousands of years, with around 40% remaining after 100 years; the period considered “permanent” by the Australian government (IPCC 2018). Given the likely transient and reversible nature of land-based carbon offsets, it is not possible to ensure they generate permanent sequestration. This discrepancy between the known lifetime of emitted CO₂ and the ascribed 100-year permanence period highlights a critical shortcoming of the ACCU scheme.

Land implications for Australia of largescale ACCU generation

The current makeup of ACCUs generated under the ERF scheme is split between projects from the following categories: vegetation (55%), landfill and waste (31%), savanna burning (9%), energy efficiency (2%), agriculture (1%), industrial fugitives (1%) and transport (0.1%) (Clean Energy Regulator 2022). Given the large share of vegetation based ACCU generating projects, the land implications for Australia of a continuation and ramping up of ACCU generation warrant investigation.



Australia's offset program

Breakdown of Australian Carbon Credit Units (ACCUs) produced by method up to 2021

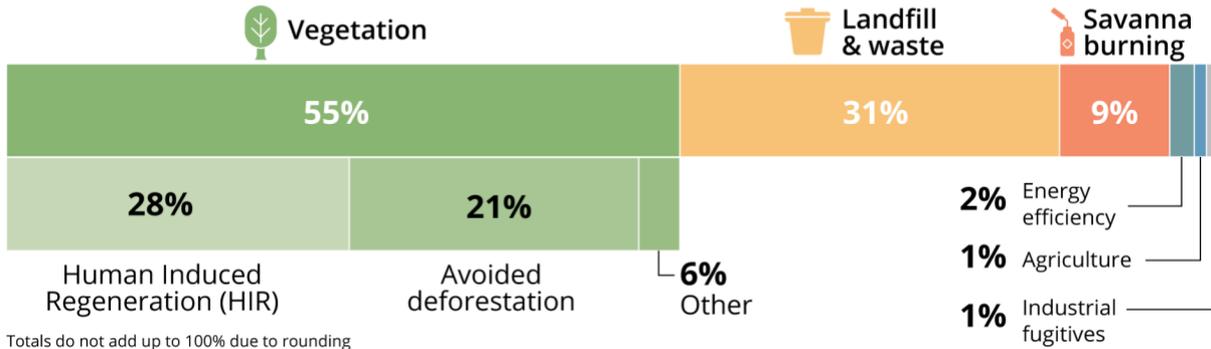


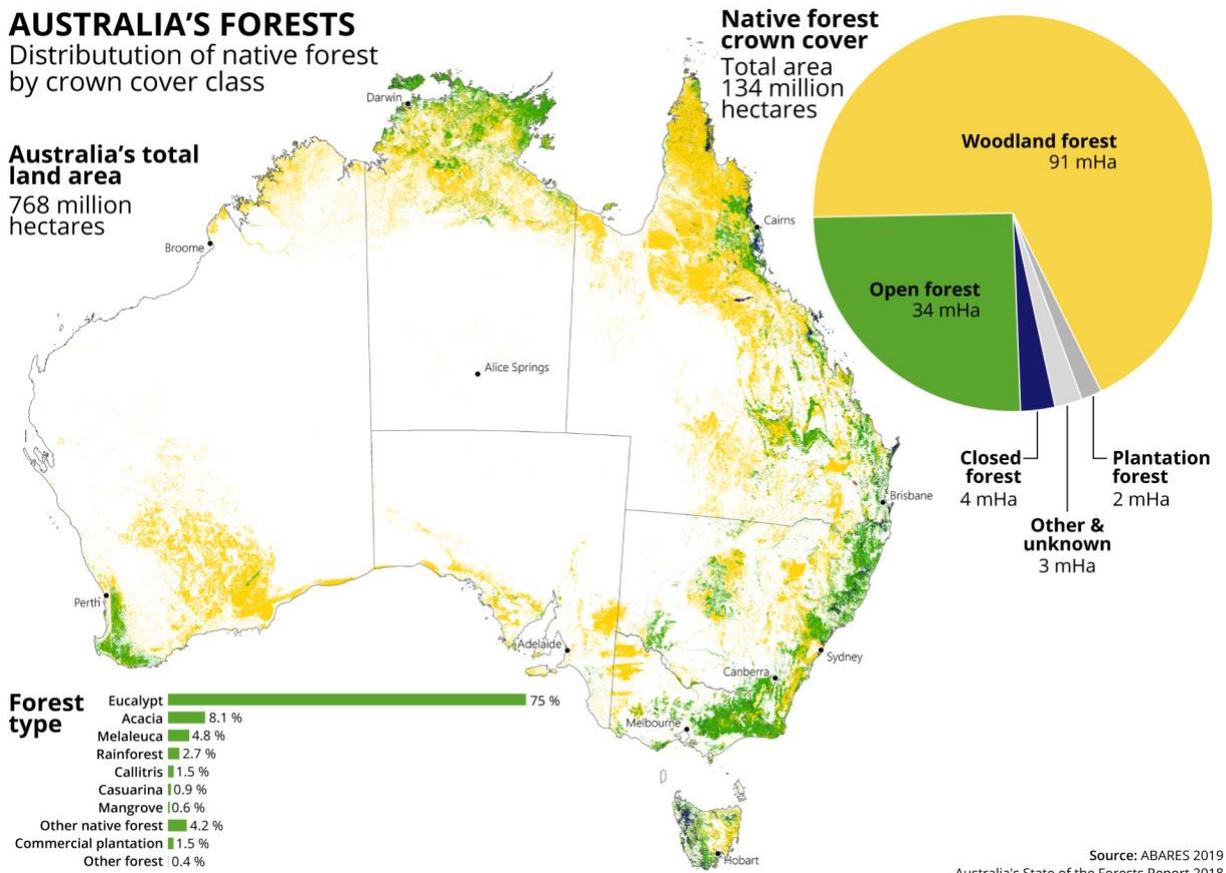
Figure 5.1 Breakdown of Australian Carbon Credit Units (ACCUs) by method, as of 2021

The current total area of Australia's forests is roughly 134 Mha, with 98% of this being native forest, three quarters made up of eucalypt forest, and 69% being woodland forest with 20-50% crown cover (ABARES 2019).

AUSTRALIA'S FORESTS

Distribution of native forest by crown cover class

Australia's total land area
768 million hectares



Source: ABARES 2019
Australia's State of the Forests Report 2018

Figure 5.2: Distribution of Australia's forest types, 2018 (Source: ABARES 2019)

A CSIRO report that modelled the annual Australian carbon sequestration potential of various offset generation methods showed the Human Induced Regeneration (HIR) method has an average potential of 47 MtCO₂e per year at year 25 after areas deemed too small to be viable projects are removed (Roxburgh et al. 2020).⁶ This corresponds to a total feasible area for potential future HIR activity of 28.3 Mha, or almost a fifth of the total current area of Australia's forests.

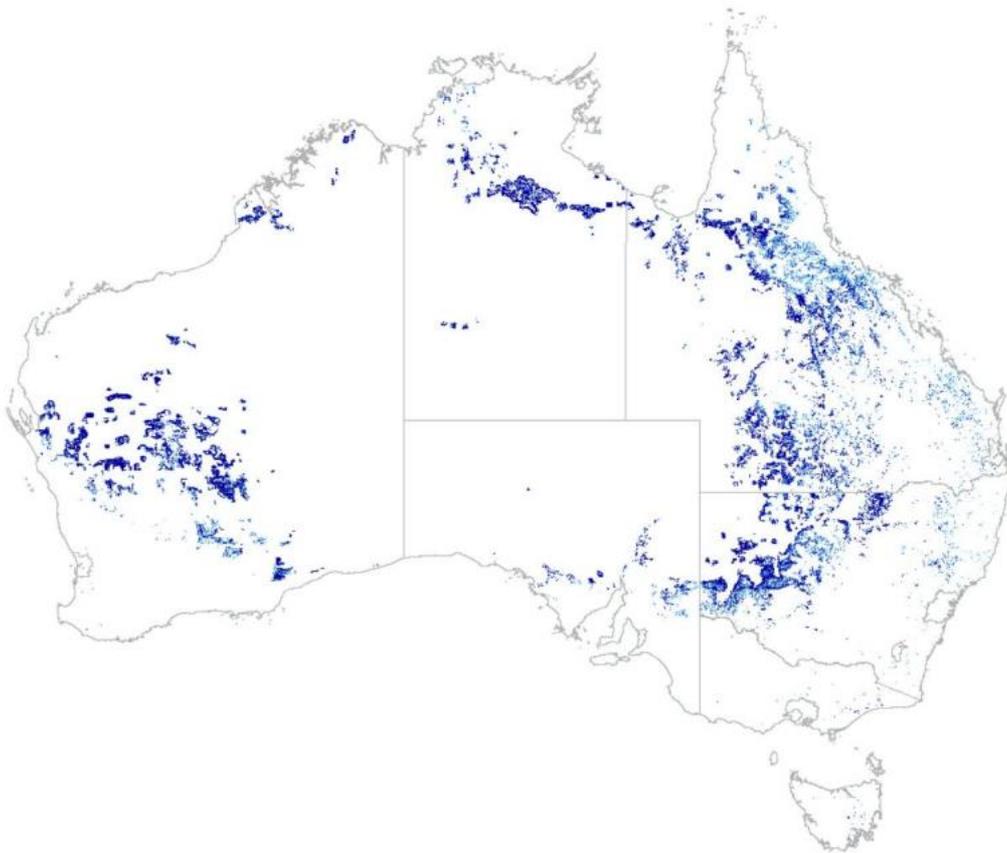


Figure 5.3: Extent of potential HIR project activity after removal of areas deemed too small to support viable projects (Source: Roxburgh et al 2020)

6 This modelled sequestration potential is derived using the same modelling software (FullCAM) that has been criticised by Macintosh et al (2022, 2022b) for its inaccuracy in calculating sequestration resulting from HIR projects.

Potential of Human Induced Regeneration (HIR)

Land area deemed feasible for HIR projects to generate Australian Carbon Credit Units (ACCUs)

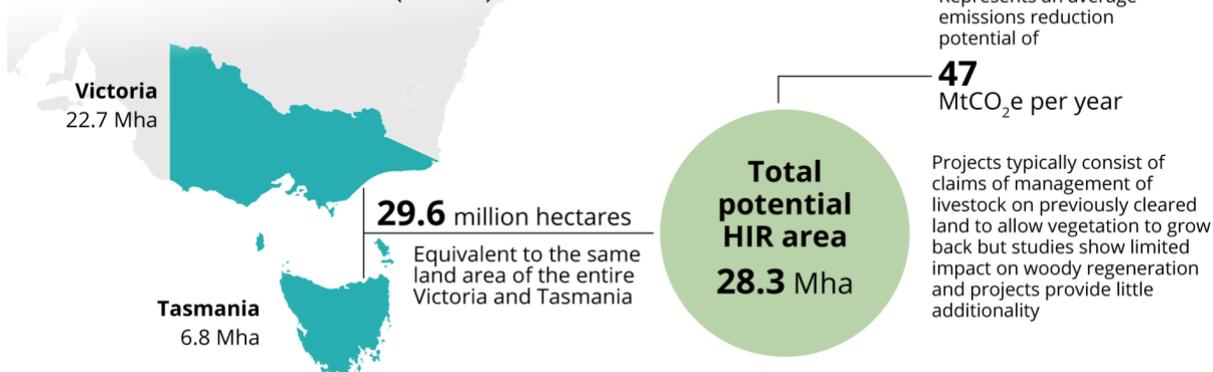


Figure 5.4: Extent of potential Australian land area utilised by HIR projects (own adaptation of data from Roxburgh et al 2020)

With respect to Australian afforestation and reforestation (AR) potential, Roxburgh et al (2020) assert that an average annual sequestration of 53.4 to 75.5 MtCO₂e is achieved with a carbon price of AUD 50/ tCO₂e, displacing between 2.0 and 3.1 Mha of land. This represents between 3.1 and 4.9% of identified viable agricultural land in Australia.

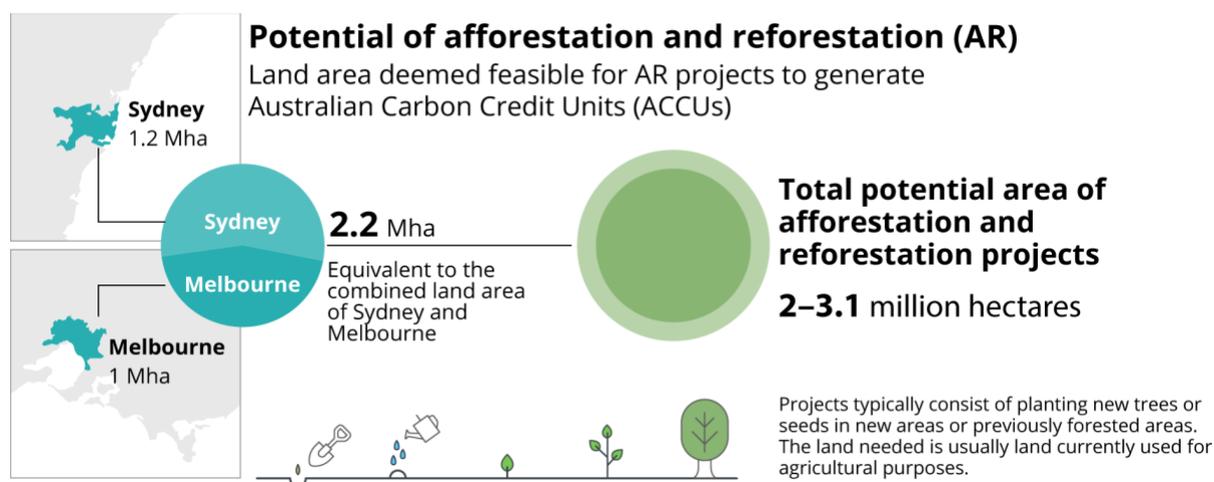


Figure 5.5: Extent of potential Australian land area utilised by AR projects (own adaptation of data from Roxburgh et al 2020)

A 2011 report completed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) estimated areas of reforestation and associated tonnes of carbon dioxide equivalent (tCO₂e) resulting from carbon credit generation under medium and ambitious global action scenarios (Australian Government 2011).⁷ The report presented modelling of the ability to sell Australian carbon credits at a global carbon price reflected by these two respective scenarios.

⁷ The 'medium' and 'ambitious' global action scenarios correspond to the stabilisation of atmospheric GHGs at 550 ppm and 450 ppm, respectively, by around 2100.

Under the modelled ambitious global action scenario, with a starting carbon price of AUD 47/tCO₂e, the area of viable land for reforestation reached 4.9 Mha, representing an estimated 865 MtCO₂e in cumulative carbon sequestration to 2050.⁸ This equates to a far lower level of annual mitigation potential of around 23 MtCO₂e, less than half of the mitigation potential estimated by Roxburgh et al (2020), but using around twice the land area. Whether Roxburgh et al (2020) or ABARES (2011) are closer to reality, the impact on Australian agriculture of extensive AR carbon offset generation is considerable.

The total number of ACCUs issued to date for vegetation-related projects (largely HIR) is over 68 million, representing roughly 68 MtCO₂e in expected sequestration from these projects. The proposed SGM reforms target a cumulative abatement from covered facilities of 205 MtCO₂e to 2030 below current trends (Australian Government 2023). Of this 205 MtCO₂e, an estimated 20% is to be achieved with the use of ACCUs, but given the large, modelled capacity for vegetation-based offsets in Australia at relatively low carbon prices, and assuming their unlimited use will ultimately be allowed, this could well be understating the actual future SGM-related demand.

The targeted 205 MtCO₂e in cumulative emissions reductions is made up of a 166 MtCO₂e reduction by existing facilities, with the remainder projected to be achieved by new entrants (Australian Government 2023). This projection of cumulative emissions reductions required by new entrants is, however, just an estimate of the number and size of emitting new facilities coming online prior to 2030. The actual level of required emissions reductions by new entrants could therefore ultimately significantly exceed the projected 39 MtCO₂e if there are a greater than expected number of new facilities operating by 2030. This would in turn entail an even larger reliance on ACCUs.

Under the current settings of the SGM, with very generous facility emissions baselines, a total of 1.27 million ACCUs were surrendered⁹ by facilities covered by the scheme between the commencement of the SGM in mid-2016, to mid 2021 (Australian Government 2018, 2019, 2020, 2021, 2022a). Given the proposed SGM reforms greatly tighten these baselines, a steep increase in ACCU demand from SGM facilities can be expected, pushing up their price, and therefore increasing the viability of a much greater number of ACCU-generating projects, with a large share of these inevitably coming from vegetation projects.

8 The carbon price in both scenarios was assumed to increase at an average rate of 5% per year until 2049-50.

9 Surrendered ACCUs in this context refers to those purchased by SGM facilities to meet their set emissions baselines.

Global policy context for offsets

A large and growing number of governments and international organisations are warning of the shortcomings of corporate offset purchases in place of achieving actual emissions reductions at their source, and consequently advocate either to avoid them completely, or to limit their use as much as possible. There are significant concerns that businesses are, and will increasingly, use offset purchases to greenwash unsustainable corporate practices, masking a lack of effort to directly reduce emissions created within their value chain.

Several organisations created by the United Nations have cautioned against unfettered use of offsets, including the UN Environment Program, which states that at most, offsets should be a temporary measure until 2030 and can lead to complacency towards achieving actual emissions reductions (UNEP 2019). The IPCC, the world's preeminent scientific body studying climate change, its impacts, and mitigation options, among other climate-related topics, warns that land-based removals "cannot compensate for delayed emissions reductions in other sectors" (IPCC 2022).

Much of the discussion around the use, or avoidance, of offsets, is in the context of national and corporate net zero targets. The UN High Level Expert Group (HLEG) on the Net-Zero Emissions Commitments of Non-State Entities, published a series of recommendations relating to the key elements of achieving net zero emissions in 2022. One such recommendation was the prioritisation of urgent and deep emissions reductions across non-state entities' own activities and processes, with carbon credits to be used only *beyond* their own activities and processes, and not to be counted towards any interim emissions reduction targets (UN HLEG 2022).

Building on this HLEG work, the International Organisation for Standardisation (ISO) released its own net zero guidelines in late 2022, stating that leadership of an organisation should be "directly accountable for ensuring it prioritises the organisation's own GHG emissions reductions and removals over the use of credits and offsets" (ISO 2022).

The ISO guidelines also state that organisational leadership should be directly accountable for establishing quality criteria for the use of "removals, credits, or offsets", and that offsets should only be used when there are no alternatives available. The guidelines are also in alignment with the HLEG recommendation that organisations should not use offsets towards any interim emissions targets.

The Science Based Targets initiative (SBTi), a partnership between several organisations including CDP, the UN Global Compact, the World Resources Institute (WRI), and the World Wildlife Fund (WWF), has also produced a corporate Net-Zero Standard. This standard utilises modelled 1.5°C pathways to derive corporate emissions reduction targets aligned with the 1.5°C long-term temperature goal of the Paris Agreement. The standard asserts that net zero targets should be set by 2050, and at least 90% of the target should be achieved with actual emissions reductions within their value chain, leaving a maximum of 10% that could be addressed through the purchase of offsets.

Restoring and protecting forest ecosystems will be critical to limiting warming to 1.5°C. Achieving this will require large financial flows, potentially in excess of USD 300bn per year (Austin et al. 2020). It is therefore essential to mobilise funding for forest protection, which could come from a range of sources, including a global financial transactions tax (Thomä and Schoenauer 2021), taxes on aviation and increased climate finance from developed nations in the global North.

Regulation to mandate deforestation-free supply chains will also be critical to protect forest ecosystems (HLEG, 2022). A much more stringently regulated offset market, where offset schemes of high integrity are only used to compensate emissions beyond company activities and processes, and in limited numbers, could also contribute much needed funds towards nature restoration. However, with climate change representing a critical threat to the health of forest ecosystems, offsetting schemes that provide funds for forest restoration but have a net-negative impact on global warming represent a false solution to the challenges of climate change and ecosystem degradation.

In addition to the rising number of international organisations calling for a limited corporate use of carbon offsets, governments are beginning to limit their use in achieving targeted emissions reductions. The most consequential example is that of the European Union (EU), which has proposed discontinuing the use of international emissions credits for compliance in the EU Emissions Trading System's current fourth phase of operation (European Commission 2021). These international credits were largely generated through reforestation projects in developing countries.

In October 2022, the influential Climate Action Network International, a coalition of over 1,900 civil society organisations from 130 countries, published its position that strongly opposes offsets, arguing they do not protect biodiversity, and echoing the issues outlined in this document about their lack of permanence (CAN International 2022).

“Experience, observations and scientific analysis tell us that offsetting, with its wider implications on the carbon cycle and political impacts on effective GHG reduction policies, is at large counter-productive,” the paper says.

Another well-documented and roundly criticised aspect of carbon offsets generated through the land sector is their tendency to create negative outcomes across a broad range of domains. These include food and water security, ecosystem biodiversity, and the wellbeing and livelihoods of traditional landowners and agricultural producers (Dooley, Keith, et al. 2022).

While offset schemes in developed countries with well-resourced regulatory bodies can avoid many of these issues and can even represent a financial boon for agricultural producers on marginally productive land, they can create devastating consequences for individuals and communities in developing countries where strict regulation and enforcement are lacking.

That said, even in developed countries, the complexity of offset program design, measurement, and enforcement can lead to a large overallocation of carbon offsets. For example, in California, it is estimated that 30 MtCO₂e worth of carbon offsets generated in its carbon offsets program, valued at USD 410m, did not represent real climate benefits (Badgley et al. 2022). A buffer pool was established in the California scheme to protect against various risks to forest carbon, and to ensure that forest carbon is stored for a 100-year permanence period. However, Badgley et al estimate that over-crediting in the scheme likely exceeds the size of the buffer pool, which contained 24.6 MtCO₂e worth of carbon offsets as of October 2020.

A growing number of international organisations and academics have raised the profile of these concerns over consequences for individuals and communities in developing countries, with recent studies highlighting an array of examples where nature-based offsets or the activities that underpin them have caused unintended harm (Barletti and Larson 2017; Cavanagh and Benjaminsen 2014; Fleischman et al. 2020; Veldman et al. 2015).

Tree planting in unsuitable locations, be that due to existing functional biomes, the superior ability of land to naturally regenerate, or the need to remove local populations from their land, can lead to negative outcomes like net declines in carbon sequestration, or human rights abuses. Similarly, the failure of regulatory regimes to ensure there is no mistreatment of local populations, or to ensure adequate monitoring of projects, can produce negative outcomes that may go unreported.

References

- Australian Government. 2018. *2016-17 Safeguard Facility Data*.
- Australian Government. 2019. *2017-18 Safeguard Facility Data*.
- Australian Government. 2020. *2018-19 Safeguard Facility Data*.
- Australian Government. 2021. *2019-20 Safeguard Facility Data*.
- Australian Government. 2022. *Australia's Emissions Projections 2022*.
- ABARES. 2019. *Forests of Australia (2018)*.
- ABC Radio National. 2023a. "Carbon Credit Scheme Review Dismisses Claims It Lacks Integrity." Retrieved (<https://www.abc.net.au/radionational/programs/breakfast/carbon-credit-scheme-review-dismisses-claims-it-lacks-integrity/101839390>).
- ABC Radio National. 2023b. "Whistleblower Critical of Carbon Credit Scheme Review." Retrieved (<https://www.abc.net.au/radionational/programs/breakfast/whistleblower-critical-of-carbon-credit-scheme-review-/101839322>).
- Abram, Nerilie J., Benjamin J. Henley, Alex sen Gupta, Tanya J. R. Lippmann, Hamish Clarke, Andrew J. Dowdy, Jason J. Sharples, Rachael H. Nolan, Tianran Zhang, Martin J. Wooster, Jennifer B. Wurtzel, Katrin J. Meissner, Andrew J. Pitman, Anna M. Ukkola, Brett P. Murphy, Nigel J. Tapper, and Matthias M. Boer. 2021. "Connections of Climate Change and Variability to Large and Extreme Forest Fires in Southeast Australia." *Communications Earth & Environment* 2(1). doi: 10.1038/s43247-020-00065-8.
- Alcalde, J., S. Flude, M. Wilkinson, G. Johnson, K. Edlmann, C. E. Bond, V. Scott, S. M. Gilfillan, X. Ogaya, and R. S. Haszeldine. 2018. "Estimating Geological CO₂ Storage Security to Deliver on Climate Mitigation." *Nature Communications* (2018). doi: 10.1038/s41467-018-04423-1.
- Anderegg, William R. L., Oriana S. Chegwiddden, Grayson Badgley, Anna T. Trugman, Danny Cullenward, John T. Abatzoglou, Jeffrey A. Hicke, Jeremy Freeman, and Joseph J. Hamman. 2022. "Future Climate Risks from Stress, Insects and Fire across US Forests." *Ecology Letters*. doi: 10.1111/ELE.14018.
- Anderegg, William R. L., Anna T. Trugman, Grayson Badgley, Christa M. Anderson, Ann Bartuska, Philippe Ciais, Danny Cullenward, Christopher B. Field, Jeremy Freeman, Scott J. Goetz, Jeffrey A. Hicke, Deborah Huntzinger, Robert B. Jackson, John Nickerson, Stephen Pacala, and James T. Randerson. 2020. "Climate-Driven Risks to the Climate Mitigation Potential of Forests." *Science* 368(6497). doi: 10.1126/SCIENCE.AAZ7005.

Anon. 2022. "Carney, Kyte Oversee Carbon Offset Rules to Address Greenwashing Concerns." *Climate Home News*.

ANU. 2022. "Australia's Carbon Market a 'fraud on the Environment' | ANU College of Law." Retrieved June 9, 2022 (<https://law.anu.edu.au/news-and-events/news/australia%E2%80%99s-carbon-market-fraud-environment>).

ANU Institute for Climate Energy & Disaster Solutions. 2022. Submission to the Independent Review of Australian Carbon Credit Units.

Archer, David, Michael Eby, Victor Brovkin, Andy Ridgwell, Long Cao, Uwe Mikolajewicz, Ken Caldeira, Katsumi Matsumoto, Guy Munhoven, Alvaro Montenegro, and Kathy Tokos. 2009. "Atmospheric Lifetime of Fossil-Fuel Carbon Dioxide." *Annual Review of Earth and Planetary Sciences* 37:117–34. doi: <https://doi.org/10.1146/annurev.earth.031208.100206>.

Asayama, Shinichiro. 2021. "The Oxymoron of Carbon Dioxide Removal: Escaping Carbon Lock-In and yet Perpetuating the Fossil Status Quo?" *Frontiers in Climate* 3. doi: <https://doi.org/10.3389/fclim.2021.673515>.

Austin, K. G., J. S. Baker, B. L. Sohngen, C. M. Wade, A. Daigneault, S. B. Ohrel, S. Ragnauth, and A. Bean. 2020. "The Economic Costs of Planting, Preserving, and Managing the World's Forests to Mitigate Climate Change." *Nature Communications* 11(1):1–9. doi: 10.1038/s41467-020-19578-z.

Australian Academy of Science. 2022. "Review of Four Methods for Generating Australian Carbon Credit Units."

Australian Conservation Foundation. 2021. Questionable Integrity: Non-Additionality in the Emissions Reduction Fund's Avoided Deforestation Method.

Australian Conservation Foundation. 2022. Submission to the Independent Review of Australian Carbon Credit Units.

Australian Government. 2011. Abatement Potential from Reforestation Under Selected Carbon Price Scenarios.

Australian Government. 2020. "Permanence Obligations." *Clean Energy Regulator*. Retrieved (<https://www.cleanenergyregulator.gov.au/ERF/Choosing-a-project-type/Opportunities-for-the-land-sector/Permanence-obligations>).

Australian Government. 2021. National Greenhouse Accounts Factors.

Australian Government. 2022a. *2020-21 Safeguard Facility Data*.

Australian Government. 2022b. Emissions Reduction Assurance Committee Findings on the Emissions Reduction Fund's Human Induced Regeneration Method.

Australian Government. 2022c. Independent Review of ACCUs Final Report.

Australian Government. 2023. Safeguard Mechanism Reforms: Position Paper.

Australian Government. n.d. The Emissions Reduction Fund and Permanence on the Land.

Badgley, Grayson, Jeremy Freeman, Joseph J. Hamman, Barbara Haya, Anna T. Trugman, William R. L. Anderegg, and Danny Cullenward. 2022. "Systematic Over-Crediting in California's Forest Carbon Offsets Program." *Global Change Biology* 28(4):1433–45. doi: 10.1111/gcb.15943.

Barletti, Juan Pablo Sarmiento, and Anne M. Larson. 2017. "Rights Abuse Allegations in the Context of REDD+ Readiness and Implementation: A Preliminary Review and Proposal for Moving Forward." *CIFOR Infobrief* 190.

Bowman, David M. J. S., Grant J. Williamson, Owen F. Price, Mercy N. Ndalila, and Ross A. Bradstock. 2021. "Australian Forests, Megafires and the Risk of Dwindling Carbon Stocks." *Plant, Cell & Environment* 44(2):347–55. doi: <https://doi.org/10.1111/pce.13916>.

Brack, Christopher, Rodney Keenan, Martine Maron, Ian Mackenzie, John Zhou, and Peter Rayner. 2022. *Review of Four Methods for Generating Australian Carbon Credit Units*.

Brouwers, Niels, George Matusick, Katinka Ruthrof, Thomas Lyons, and Giles Hardy. 2013. "Landscape-Scale Assessment of Tree Crown Dieback Following Extreme Drought and Heat in a Mediterranean Eucalypt Forest Ecosystem." *Landscape Ecology* 28(1):69–80. doi: 10.1007/s10980-012-9815-3.

Byers, E., V. Krey, K. Kriegler, K. Riahi, R. Schaeffer, J. Kikstra, R. Lamboll, Z. Nicholls, M. Sanstad, C. Smith, K. van der Wijst, F. Lecocq, J. Portugal-Pereira, U. Saheb, A. Strømman, H. Wi, and A. al Khourdajie. 2022. "AR6 Scenario Database Hosted by IIASA."

Byrne, B., J. Liu, M. Lee, Y. Yin, K. W. Bowman, K. Miyazaki, A. J. Norton, J. Joiner, D. F. Pollard, D. W. T. Griffith, V. A. Velazco, N. M. Deutscher, N. B. Jones, and C. Paton-Walsh. 2021. "The Carbon Cycle of Southeast Australia During 2019–2020: Drought, Fires, and Subsequent Recovery." *AGU Advances* 2(4):e2021AV000469. doi: <https://doi.org/10.1029/2021AV000469>.

CAN International. 2022. CAN International Position on Carbon Offsetting.

Canadell, Josep G., Miko U. F. F. Kirschbaum, Werner A. Kurz, María José Maria-Jose Sanz, Bernhard Schlamadinger, and Yoshiki Yamagata. 2007. "Factoring out Natural and Indirect Human Effects on Terrestrial Carbon Sources and Sinks." *Environmental Science & Policy In Press*,(4):370–84. doi: 10.1016/j.envsci.2007.01.009.

Canadell, Josep G., C. P. (Mick) Meyer, Garry D. Cook, Andrew Dowdy, Peter R. Briggs, Jürgen Knauer, Acacia Pepler, and Vanessa Haverd. 2021. "Multi-Decadal Increase of Forest Burned Area in Australia Is Linked to Climate Change." *Nature Communications* 12(1):6921. doi: 10.1038/s41467-021-27225-4.

Canadell, Josep G., P. M. S. Monteiro, M. H. Costa, L. Cotrim da Cunha, P. M. Cox, A. V. Eliseev, S. Henson, M. Ishii, S. Jaccard, C. Koven, A. Lohila, P. K. Patra, S. Piao, J. Rogelj, S. Syampungani, S. Zaehle, and K. Zickfeld. 2021. "Global Carbon and Other Biogeochemical Cycles and Feedbacks." Pp. 673–816 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*, edited by V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou. Cambridge: Cambridge University Press.

Carton, Wim, Adeniyi Asiyani, Silke Beck, Holly J. Buck, and Jens F. Lund. 2020. "Negative Emissions and the Long History of Carbon Removal." *WIREs Climate Change* 11(6).

Cavanagh, Connor, and Tor A. Benjaminsen. 2014. "Virtual Nature, Violent Accumulation: The 'Spectacular Failure' of Carbon Offsetting at a Ugandan National Park." *Geoforum* 56:55–65.

CCS Norway. 2023. "Knowledge from the CCS Project Longship." Retrieved (<https://ccsnorway.com/reports/>).

Chris Bowen. 2022. Keynote Address to Carbon Market Institute Symposium.

Clean Energy Regulator. 2022. "ERF Projects Map."

Climate Action Tracker. 2022a. "Australia (August 2022 Update)." *Climate Action Tracker*. Retrieved December 20, 2022 (<https://climateactiontracker.org/countries/australia/>).

Climate Action Tracker. 2022b. Global Update, Gas Expansion Overtakes Climate.

Cornwall, Christopher E., Steeve Comeau, Niklas A. Kornder, Chris T. Perry, Ruben van Hoodonk, Thomas M. DeCarlo, Morgan S. Pratchett, Kristen D. Anderson, Nicola Browne, Robert Carpenter, Guillermo Diaz-Pulido, Juan P. D'Olivo, Steve S. Doo, Joana Figueiredo, Sofia A. V. Fortunato, Emma Kennedy, Coulson A. Lantz, Malcolm T. McCulloch, Manuel González-Rivero, Verena Schoepf, Scott G. Smithers, and Ryan J. Lowe. 2021. "Global Declines in Coral Reef Calcium Carbonate Production under Ocean Acidification and Warming." *Proceedings of the National Academy of Sciences of the United States of America* 118(21). doi: 10.1073/pnas.2015265118.

DEE. 2018. Australian Energy Update 2018.

Dooley, Kate, and Aarti Gupta. 2017. "Governing by Expertise: The Contested Politics of (Accounting for) Land-Based Mitigation in a New Climate Agreement." *International Environmental Agreements: Politics, Law and Economics* 17:483–500.

Dooley, Kate, Heather Keith, Anne Larson, Georgina Catacora-Vargas, Wim Carton, Kirstine Lund Christiansen, Ojong Enokenwa Baa, Alain Frechette, Sonia Hugh,

Nathan Ivetic, Li Ching Lim, Jens Friis Lund, Muhammad Luqman, Brendan Mackey, Iliana Monterroso, Hemant Ojha, Ivette Perfecto, Kimaren Riamit, Yann Robiou Du Pont, and Virginia Young. 2022. *The Land Gap Report 2022*.

Dooley, Kate, Zebedee Nicholls, and Malte Meinshausen. 2022. "Carbon Removals from Nature Restoration Are No Substitute for Steep Emission Reductions." *One Earth* 5:812–24.

Duffy, Katharyn A., Christopher R. Schwalm, Vickery L. Arcus, George W. Koch, Liyin L. Liang, and Louis A. Schipper. 2021. "How Close Are We to the Temperature Tipping Point of the Terrestrial Biosphere?" *Science Advances* 7(3). doi: 10.1126/SCIADV.AAY1052.

easyJet. 2022. "Net Zero by 2050." Retrieved (<https://www.easyjet.com/en/sustainability>).

Eby, M., K. Zickfeld, A. Montenegro, D. Archer, K. J. Meissner, and A. J. Weaver. 2009. "Lifetime of Anthropogenic Climate Change: Millennial Time Scales of Potential CO₂ and Surface Temperature Perturbations." *Journal of Climate* 22(10):2501–11. doi: 10.1175/2008JCLI2554.1.

Environmental Defense Fund. 2019. *Agricultural Soil Carbon Credits: Making Sense of Protocols for Carbon Sequestration and Net Greenhouse Gas Removals*.

European Commission. 2021. "Proposal for a Directive of the European Parliament and of the Council Amending Directive 2003/87/EC Establishing a System for Greenhouse Gas Emission Allowance Trading within the Union." Retrieved (https://ec.europa.eu/info/sites/default/files/revision-eu-ets_with-annex_en_0.pdf).

Fleischman, Forrest, Shishir Basant, Ashwini Chhatre, Eric A. Coleman, Harry W. Fischer, Divya Gupta, Burak Guneralp, Prakash Kashwan, Dil Khatri, Robert Muscarella, Jennifer S. Powers, Vijay Ramprasad, Pushpendra Rana, Claudia Rodriguez Solorzano, and Joseph W. Veldman. 2020. "Pitfalls of Tree Planting Show Why We Need People-Centered Natural Climate Solutions." *Bioscience* 70(11):947–50.

Friedlingstein, Pierre, Matthew W. Jones, Michael O'Sullivan, Robbie M. Andrew, Dorothee C. E. Bakker, Judith Hauck, Corinne le Quéré, Glen P. Peters, Wouter Peters, Julia Pongratz, Stephen Sitch, Josep G. Canadell, Philippe Ciais, Rob B. Jackson, Simone R. Alin, Peter Anthony, Nicholas R. Bates, Meike Becker, Nicolas Bellouin, Laurent Bopp, Thi Tuyet Trang Chau, Frédéric Chevallier, Louise P. Chini, Margot Cronin, Kim I. Currie, Bertrand Decharme, Laique M. Djeutchouang, Xinyu Dou, Wiley Evans, Richard A. Feely, Liang Feng, Thomas Gasser, Dennis Gilfillan, Thanos Gkritzalis, Giacomo Grassi, Luke Gregor, Nicolas Gruber, Özgür Gürses, Ian Harris, Richard A. Houghton, George C. Hurtt, Yosuke Iida, Tatiana Ilyina, Ingrid T. Lujckx, Atul Jain, Steve D. Jones, Etsushi Kato, Daniel Kennedy, Kees Klein Goldewijk, Jürgen Knauer, Jan Ivar Korsbakken, Arne Körtzinger, Peter Landschützer, Siv K. Lauvset, Nathalie Lefèvre, Sebastian Lienert, Junjie Liu, Gregg Marland, Patrick C.

McGuire, Joe R. Melton, David R. Munro, Julia E. M. S. Nabel, Shin Ichiro Nakaoka, Yosuke Niwa, Tsuneo Ono, Denis Pierrot, Benjamin Poulter, Gregor Rehder, Laure Resplandy, Eddy Robertson, Christian Rödenbeck, Thais M. Rosan, Jörg Schwinger, Clemens Schwingshackl, Roland Séférian, Adrienne J. Sutton, Colm Sweeney, Toste Tanhua, Pieter P. Tans, Hanqin Tian, Bronte Tilbrook, Francesco Tubiello, Guido R. van der Werf, Nicolas Vuichard, Chisato Wada, Rik Wanninkhof, Andrew J. Watson, David Willis, Andrew J. Wiltshire, Wenping Yuan, Chao Yue, Xu Yue, Sönke Zaehle, and Jiye Zeng. 2022. "Global Carbon Budget 2021." *Earth System Science Data* 14(4):1917–2005. doi: 10.5194/ESSD-14-1917-2022.

Fuss, Sabine, William F. Lamb, Max W. Callaghan, Jerome Hilaire, Felix Creutzig, T. Amann, Tim Beringer, Jan C. Minx, G. Luderer, and Gregory F. Nemet. 2018. "Negative Emissions — Part 2 : Costs , Potentials and Side Effects."

Fyson, Claire, Carl-Friedrich Schleußner, and William L. Hare. 2019. *The Dangers of Blue Carbon Offsets: From Hot Air to Hot Water?*

Gan, Yu, Hassan M. El-Houjeiri, Alhassan Badahdah, Zifeng Lu, Hao Cai, Steven Przesmitzki, and Michael Wang. 2020. "Carbon Footprint of Global Natural Gas Supplies to China." *Nature Communications* 11(1):1–9. doi: 10.1038/s41467-020-14606-4.

Godfree, Robert C., Nunzio Knerr, Francisco Encinas-Viso, David Albrecht, David Bush, D. Christine Cargill, Mark Clements, Cécile Gueidan, Lydia K. Guja, Tom Harwood, Leo Joseph, Brendan Lepschi, Katharina Nargar, Alexander Schmidt-Lebuhn, and Linda M. Broadhurst. 2021. "Implications of the 2019–2020 Megafires for the Biogeography and Conservation of Australian Vegetation." *Nature Communications* 12(1):1–13. doi: 10.1038/s41467-021-21266-5.

Grant, Neil, Ajay Gambhir, Shivika Mittal, Chris Greig, and Alexandre C. Köberle. 2022. "Enhancing the Realism of Decarbonisation Scenarios with Practicable Regional Constraints on CO₂ Storage Capacity." *International Journal of Greenhouse Gas Control* 120(July):103766. doi: 10.1016/j.ijggc.2022.103766.

Grant, Neil, Adam Hawkes, Shivika Mittal, and Ajay Gambhir. 2021. "The Policy Implications of an Uncertain Carbon Dioxide Removal Potential." *Joule* 5:2593–2605.

Greenfield, Patrick. 2023. "Revealed: More than 90% of Rainforest Carbon Offsets by Biggest Provider Are Worthless, Analysis Shows." *The Guardian*.

Gütschow, Johannes, and Mika Pflüger. 2022. "The PRIMAP-Hist National Historical Emissions Time Series v2.4 (1750-2021)." *Zenodo*. Retrieved (doi:10.5281/zenodo.7179775).

Hemming, Polly, Alia Armistead, and Sumithri Venketasubramanian. 2022. An Environmental Fig Leaf? Restoring Integrity to the Emissions Reduction Fund.

Höglund-Isaksson, Lena, Adriana Gomez-Sabriana, Zbigniew Klimont, Peter Rafaj, and Wolfgang Schöpp. 2020. "Technical Potentials and Costs for Reducing Global

Anthropogenic Methane Emissions in the 2050 Timeframe –Results from the GAINS Model." *Environmental Research Communications* 2.

House, Joanna I., I. Colin Prentice, and C. Corinne le Quéré. 2002. "Maximum Impacts of Future Reforestation or Deforestation on Atmospheric CO₂." *Global Change Biology* 8(11):1047–52. doi: 10.1046/j.1365-2486.2002.00536.x.

Inman, Mason. 2008. "Carbon Is Forever." *Nature Climate Change* 1:156–58.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2018. Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways. edited by T. W. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor. Switzerland: Intergovernmental Panel on Climate Change.

IPCC. 2019. An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems Edited. doi: 10.4337/9781784710644.

IPCC. 2021a. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC. 2021b. Sixth Assessment Report: Regional Fact Sheet - Australasia.

IPCC. 2022. "Summary for Policymakers." in Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, edited by P. R. Shukla, J. Skea, R. Slade, A. al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, and J. Malley. Cambridge, UK and New York, NY, USA: Cambridge University Press.

ISO. 2022. IWA 42:2022 Net Zero Guidelines.

Jackson, R. B., M. Saunio, P. Bousquet, J. G. Canadell, B. Poulter, A. R. Stavert, P. Bergamaschi, Y. Niwa, A. Segers, and A. Tsuruta. 2020. "Increasing Anthropogenic Methane Emissions Arise Equally from Agricultural and Fossil Fuel Sources." *Environmental Research Letters* 15(7). doi: 10.1088/1748-9326/ab9ed2.

Johnstone, James. 2010. "Climatic Context and Ecological Implications of Summer Fog Decline in the Coast Redwood Region." *PNAS* 107(10).

Joos, F., R. Roth, J. S. Fuglestedt, G. P. Peters, I. G. Enting, W. von Bloh, V. Brovkin, E. J. Burke, M. Eby, N. R. Edwards, T. Friedrich, T. L. Frölicher, P. R. Halloran, P. B. Holden, C. Jones, T. Kleinen, F. T. Mackenzie, K. Matsumoto, M. Meinshausen, G. K.

- Plattner, A. Reisinger, J. Segschneider, G. Shaffer, M. Steinacher, K. Strassmann, K. Tanaka, A. Timmermann, and A. J. Weaver. 2013. "Carbon Dioxide and Climate Impulse Response Functions for the Computation of Greenhouse Gas Metrics: A Multi-Model Analysis." *Atmospheric Chemistry and Physics* 13(5):2793–2825. doi: 10.5194/ACP-13-2793-2013.
- Keenan, T. F., X. Luo, M. G. de Kauwe, B. E. Medlyn, I. C. Prentice, B. D. Stocker, N. G. Smith, C. Terrer, H. Wang, Y. Zhang, and S. Zhou. 2021. "A Constraint on Historic Growth in Global Photosynthesis Due to Increasing CO₂." *Nature* 600(7888):253–58. doi: 10.1038/s41586-021-04096-9.
- Kim, Man-Keun, Bruce A. McCarl, and Brian C. Murray. 2008. "Permanence Discounting for Land-Based Carbon Sequestration." *Ecological Economics* 64(4):763–69.
- Kirschbaum, Miko U. F. 2006. "Temporary Carbon Sequestration Cannot Prevent Climate Change." *Mitigation and Adaptation Strategies for Global Change* 11(5–6):1151–64. doi: 10.1007/S11027-006-9027-8.
- Klein, Shannon G., Nathan R. Geraldi, Andrea Anton, Sebastian Schmidt-Roach, Maren Ziegler, Maha J. Cziesielski, Cecilia Martin, Nils Rådecker, Thomas L. Frölicher, Peter J. Mumby, John M. Pandolfi, David J. Suggett, Christian R. Voolstra, Manuel Aranda, and Carlos M. Duarte. 2022. "Projecting Coral Responses to Intensifying Marine Heatwaves under Ocean Acidification." *Global Change Biology* 28(5):1753–65. doi: 10.1111/gcb.15818.
- Lane, Joe, Chris Greig, and Andrew Garnett. 2021. "Uncertain Storage Prospects Create a Conundrum for Carbon Capture and Storage Ambitions." *Nature Climate Change* 11:925–36.
- Lee, Juhwan, Raphael A. Viscarra Rossel, Mingxi Zhang, Zhongkui Luo, and Ying Ping Wang. 2021. "Assessing the Response of Soil Carbon in Australia to Changing Inputs and Climate Using a Consistent Modelling Framework." *Biogeosciences* 18(18):5185–5202. doi: 10.5194/bg-18-5185-2021.
- Lord, N. S., A. Ridgwell, M. C. Thorne, and D. J. Lunt. 2015. "The 'Long Tail' of Anthropogenic CO₂ Decline in the Atmosphere and Its Consequences for Post-Closure Performance Assessments for Disposal of Radioactive Wastes." *Mineralogical Magazine* 79(6):1613–23. doi: 10.1180/MINMAG.2015.079.6.37.
- Ma, Xuanlong, Alfredo Huete, C. James, Derek Eamus, Frédéric Ch, Joanna Joiner, Benjamin Poulter, Yongguang Zhang, Luis Guanter, and Wayne Meyer. 2016. "Drought Rapidly Diminishes the Large Net CO₂ Uptake in 2011 over Semi-Arid Australia." *Scientific Reports* (July):1–9. doi: 10.1038/srep37747.
- Macintosh, Andrew. 2022. The Emissions Reduction Fund's Landfill Gas Method: An Assessment of Its Integrity.

Macintosh, Andrew, and Don Butler. 2023. "Chubb Review of Australia's Carbon Credit Scheme Falls Short – and Problems Will Continue to Fester." *The Conversation*. Retrieved (<https://theconversation.com/chubb-review-of-australias-carbon-credit-scheme-falls-short-and-problems-will-continue-to-fester-197401>).

Macintosh, Andrew, Don Butler, and Dean Ansell. 2022. Measurement Error in the Emissions Reduction Fund's Human-Induced Regeneration (HIR) Method.

Macintosh, Andrew, Don Butler, Megan C. Evans, Pablo R. Larraondo, Dean Ansell, and Philip Gibbons. 2022a. The ERF's Human-Induced Regeneration (HIR): What the Beare and Chambers Report Really Found and a Critique of Its Method.

Macintosh, Andrew, Don Butler, Megan C. Evans, Pablo R. Larraondo, Dean Ansell, and Marie Waschka. 2022b. *Integrity and the ERF's Human-Induced Regeneration Method: The Measurement Problem Explained*.

Macintosh, Andrew, Pablo R. Larraondo, Don Butler, Dean Ansell, Marie Waschka, and Megan C. Evans. 2022. Trends in Forest and Sparse Woody Cover inside ERF HIR Project Areas Relative to Those in Surrounding Areas.

Macintosh, Andrew, and Marie Waschka. 2022. "Integrity Problems with the ERF's 2022 Plantation Forestry Method."

Mackey, Brendan, I. Colin Prentice, Will Steffen, Joanna I. House, David Lindenmayer, Heather Keith, and Sandra Berry. 2013. "Untangling the Confusion around Land Carbon Science and Climate Change Mitigation Policy." *Nature Climate Change* 2013 3:6 3(6):552–57. doi: 10.1038/nclimate1804.

Matthews, Damon, and Ken Caldeira. 2008. "Stabilizing Climate Requires Near-Zero Emissions." *Geophysical Research Letters* 35(4). doi: doi.org/10.1029/2007GL032388.

Matthews, H. Damon, Kirsten Zickfeld, Mitchell Dickau, Alexander J. MacIsaac, Sabine Mathesius, Claude-Michel Nzotungicimpaye, and Amy Luers. 2022. "Temporary Nature-Based Carbon Removal Can Lower Peak Warming in a Well-below 2 °C Scenario." *Communications Earth & Environment* 3(1):1–8. doi: 10.1038/s43247-022-00391-z.

Matusick, George, Katinka X. Ruthrof, Niels C. Brouwers, Bernard Dell, and Giles St. J. Hardy. 2013. "Sudden Forest Canopy Collapse Corresponding with Extreme Drought and Heat in a Mediterranean-Type Eucalypt Forest in Southwestern Australia." *European Journal of Forest Research* 132(3):497–510. doi: 10.1007/s10342-013-0690-5.

Matusick, George, Katinka X. Ruthrof, Jatin Kala, Niels C. Brouwers, David D. Breshears, and Giles E. St J. Hardy. 2018. "Chronic Historical Drought Legacy Exacerbates Tree Mortality and Crown Dieback during Acute Heatwave-Compounded Drought." *Environmental Research Letters* 13(9). doi: 10.1088/1748-9326/aad8cb.

- Mendelsohn, Robert, Roger Sedjo, and Brent Sohgen. 2012. "Forest Carbon Sequestration." in *Fiscal Policy to Mitigate Climate Change: A Guide for Policymakers*. International Monetary Fund.
- Michael Slezak. 2022. "Industry Bosses Making Money from Carbon Credits Say System Needs to Change." *ABC News*, September 5.
- Mongin, Mathieu, Mark E. Baird, Bronte Tilbrook, Richard J. Matear, Andrew Lenton, Mike Herzfeld, Karen Wild-Allen, Jenny Skerratt, Nugzar Margvelashvili, Barbara J. Robson, Carlos M. Duarte, Malin S. M. M. Gustafsson, Peter J. Ralph, and Andrew D. L. L. Steven. 2016. "The Exposure of the Great Barrier Reef to Ocean Acidification." *Nature Communications* 7:1–8. doi: 10.1038/ncomms10732.
- Morton, Adam, and Katharine Murphy. 2022. "Former Australian Chief Scientist to Head Review of Carbon Credit Scheme after Whistleblower Revelations." *The Guardian*, July 1.
- Murray, Brian C., Brent Sohngen, and Martin T. Ross. 2007. "Economic Consequences of Consideration of Permanence, Leakage and Additionality for Soil Carbon Sequestration Projects." *Climatic Change* 80:127–43.
- Nabuurs, Gert-jan, Rachid Mrabet, Assem Abu Hatab, Mercedes Bustamante, Harry Clark, Petr Havlík, Joanna I. House, Cheikh Mbow, Karachepone N. Ninan, Alexander Popp, Stephanie Roe, Brent Sohngen, Sirintornthep, and Towprayoon. 2022. *IPCC Sixth Assessment Report Working Group III Chapter 7: Agriculture, Forestry and Other Land Uses (AFOLU)*.
- Paul, S. S., N. C. Coops, M. S. Johnson, M. Krzic, and S. M. Smukler. 2019. "Evaluating Sampling Efforts of Standard Laboratory Analysis and Mid-Infrared Spectroscopy for Cost Effective Digital Soil Mapping at Field Scale." *Geoderma*.
- Peñuelas, Josep, Philippe Ciais, Josep G. Canadell, Ivan A. Janssens, Marcos Fernández-Martínez, Jofre Carnicer, Michael Obersteiner, Shilong Piao, Robert Vautard, and Jordi Sardans. 2017. "Shifting from a Fertilization-Dominated to a Warming-Dominated Period." *Nature Ecology & Evolution* 1(October). doi: 10.1038/s41559-017-0274-8.
- Pineda, Alberto Carrillo, and Pedro Faria. 2019. Towards a Science-Based Approach to Climate Neutrality in the Corporate Sector.
- Realmonte, Giulia, Laurent Drouet, Ajay Gambhir, James Glynn, Adam Hawkes, Alexandre C. Köberle, and Massimo Tavoni. 2019. "An Inter-Model Assessment of the Role of Direct Air Capture in Deep Mitigation Pathways." *Nature Communications* 10(1):1–12. doi: 10.1038/s41467-019-10842-5.
- Roe, Stephanie, Charlotte Streck, Robert Beach, Jonah Busch, Melissa Chapman, Vassilis Daioglou, Andre Deppermann, Jonathan Doelman, Jeremy Emmet-Booth, Jens Engelmann, Oliver Fricko, Chad Frischmann, Jason Funk, Giacomo Grassi, Bronson Griscom, Petr Havlik, Steef Hanssen, Florian Humpenöder, David

- Landholm, Guy Lomax, Johannes Lehmann, Leah Mesnildrey, Gert Jan Nabuurs, Alexander Popp, Charlotte Rivard, Jonathan Sanderman, Brent Sohngen, Pete Smith, Elke Stehfest, Dominic Woolf, and Deborah Lawrence. 2021. "Land-Based Measures to Mitigate Climate Change: Potential and Feasibility by Country." *Global Change Biology* 27(23):6025–58. doi: 10.1111/GCB.15873.
- Roxburgh, Stephen, Jacqui England, David Evans, Martin Nolan, Kimberley Opie, Keryn Paul, Andrew Reeson, Garry Cook, and Dean Thomas. 2020. *Potential Future Supply of Carbon Offsets in the Land Sector in Australia*.
- Schwalm, Christopher R., Deborah N. Huntinzger, Anna M. Michalak, Kevin Schaefer, Joshua B. Fisher, Yuanyuan Fang, and Yaxing Wei. 2020. "Modeling Suggests Fossil Fuel Emissions Have Been Driving Increased Land Carbon Uptake since the Turn of the 20th Century." *Scientific Reports* 10(1). doi: 10.1038/S41598-020-66103-9.
- Schwartz, Naomi B., T. Mitchell Aide, Jordan Graesser, H. Ricardo Grau, and María Uriarte. 2020. "Reversals of Reforestation Across Latin America Limit Climate Mitigation Potential of Tropical Forests." *Frontiers in Forests and Global Change* 3:85. doi: 10.3389/ffgc.2020.00085.
- Scrivener, Karen, Fernando Martirena, and Shashank Bishnoi. 2021. "Implementation of LC3 in the Field." *American Concrete Institute*. Retrieved (<https://www.concrete.org/education/freewebsessions/completelisting/coursepreviews.aspx?ID=51734580>).
- Seddon, Nathalie, Alison Smith, Pete Smith, Isabel Key, Alexandre Chausson, Cécile Girardin, Jo House, Shilpi Srivastava, and Beth Turner. 2021. "Getting the Message Right on Nature-Based Solutions to Climate Change." *Global Change Biology* 27(8):1518–46. doi: 10.1111/gcb.15513.
- Shaffer, Gary. 2010. "Long-Term Effectiveness and Consequences of Carbon Dioxide Sequestration." *Nature Geoscience* 3(7):464–67. doi: 10.1038/ngeo896.
- Slezak, Michael. 2022. "Industry Bosses Making Money from Carbon Credits Say System Needs to Change." *ABC News*. Retrieved (<https://www.abc.net.au/news/2022-09-06/companies-making-money-from-carbon-credits-speak-out/101400566>).
- Smith, Pete, Helmut Haberl, Alexander Popp, Karl-heinz Karlheinz Erb, Christian Lauk, Richard Harper, Francesco N. Tubiello, Alexandre de Siqueira Pinto, Mostafa Jafari, Saran Sohi, Omar Masera, Hannes Böttcher, Göran Berndes, Mercedes Bustamante, Helal Ahammad, Harry Clark, Hongmin Dong, Elnour a. Elsidig, Cheikh Mbow, Nijavalli H. Ravindranath, Charles W. Rice, Carmenza Robledo Abad, Anna Romanovskaya, Frank Sperling, Mario Herrero, Joanna I. House, Steven Rose, Carmenza Robledo-Abad, Anna Romanovskaya, Frank Sperling, Mario Herrero, Joanna I. House, and Steven Rose. 2013. "How Much Land Based Greenhouse Gas Mitigation Can Be Achieved without Compromising Food Security and Environmental Goals?" *Global Change Biology* 19(8):2285–2302. doi: 10.1111/gcb.12160.

SourceMaterial. 2023. "The Carbon Con." *SourceMaterial*.

Squire, Dougal T., Doug Richardson, James S. Risbey, Amanda S. Black, Vassili Kitsios, Richard J. Matear, Didier Monselesan, Thomas S. Moore, and Carly R. Tozer. 2021. "Likelihood of Unprecedented Drought and Fire Weather during Australia's 2019 Megafires." *Npj Climate and Atmospheric Science* 4(1). doi: 10.1038/s41612-021-00220-8.

Srinivasan, Pavitra, and Neal Elliott. 2022. "Low-Carbon Cement Could Be Sped to Market with Climate Law Funds." *ACEEE*. Retrieved (<https://www.aceee.org/blog-post/2022/12/low-carbon-cement-could-be-spiced-market-climate-law-funds>).

Taylor, Martin. 2022. Deforestation in Queensland 2018/19 Nearly Double What Australian Government Reports to the UN.

Thomä, Jakob, and Anne Schoenauer. 2021. How Can Financial Sector Taxes Contribute to Climate Goals?

Tyrell, Toby, John G. Shepherd, and Stephanie Castle. 2007. "The Long-Term Legacy of Fossil Fuels." *Tellus B* 59(4):664–72.

UK Climate Change Committee. 2022. Voluntary Carbon Markets and Offsetting.

UN HLEG. 2022. Integrity Matters: Net Zero Commitments by Businesses, Financial Institutions, Cities and Regions.

UNEP. 2019. "Carbon Offsets Are Not Our Get-out-of-Jail Free Card." Retrieved (<https://www.unep.org/news-and-stories/story/carbon-offsets-are-not-our-get-out-jail-free-card>).

Veldman, Joseph W., Gerhard E. Overbeck, Daniel Negreiros, Gregory Mahy, Solzige Stradic, G. Wilson Fernandes, Giselda Durigan, Elise Buisson, Francis E. Putz, and William J. Bond. 2015. "Where Tree Planting and Forest Expansion Are Bad for Biodiversity and Ecosystem Services." *Bioscience* 65(10):1011–18.

Walden, Lewis L., Joseph B. Fontaine, Katinka X. Ruthrof, George Matusick, Richard J. Harper, and Giles E. St. J. Hardy. 2019. "Carbon Consequences of Drought Differ in Forests That Resprout." *Global Change Biology* 25(5):1653–64. doi: <https://doi.org/10.1111/gcb.14589>.

Walker, Anthony P., Martin G. de Kauwe, Ana Bastos, Soumaya Belmecheri, Katerina Georgiou, Ralph F. Keeling, Sean M. McMahon, Belinda E. Medlyn, David J. P. Moore, Richard J. Norby, Sönke Zaehle, Kristina J. Anderson-Teixeira, Giovanna Battipaglia, Roel J. W. Brienen, Kristine G. Cabugao, Maxime Cailleret, Elliott Campbell, Josep G. Canadell, Philippe Ciais, Matthew E. Craig, David S. Ellsworth, Graham D. Farquhar, Simone Fatichi, Joshua B. Fisher, David C. Frank, Heather Graven, Lianhong Gu, Vanessa Haverd, Kelly Heilman, Martin Heimann, Bruce A. Hungate, Colleen M. Iversen, Fortunat Joos, Mingkai Jiang, Trevor F. Keenan, Jürgen Knauer, Christian Körner, Victor O. Leshyk, Sebastian Leuzinger, Yao Liu, Natasha MacBean, Yadvinder

Malhi, Tim R. McVicar, Josep Penuelas, Julia Pongratz, A. Shafer Powell, Terhi Riutta, Manon E. B. Sabot, Juergen Schleucher, Stephen Sitch, William K. Smith, Benjamin Sulman, Benton Taylor, César Terrer, Margaret S. Torn, Kathleen K. Treseder, Anna T. Trugman, Susan E. Trumbore, Phillip J. van Mantgem, Steve L. Voelker, Mary E. Whelan, and Pieter A. Zuidema. 2021. "Integrating the Evidence for a Terrestrial Carbon Sink Caused by Increasing Atmospheric CO₂." *New Phytologist* 229(5):2413–45. doi: 10.1111/nph.16866.

Ward, Michelle, Ayesha I. T. Tulloch, James Q. Radford, Brooke A. Williams, April E. Reside, Stewart L. Macdonald, Helen J. Mayfield, Martine Maron, Hugh P. Possingham, Samantha J. Vine, James L. O'Connor, Emily J. Massingham, Aaron C. Greenville, John C. Z. Woinarski, Stephen T. Garnett, Mark Lintermans, Ben C. Scheele, Josie Carwardine, Dale G. Nimmo, David B. Lindenmayer, Robert M. Kooyman, Jeremy S. Simmonds, Laura J. Sonter, and James E. M. Watson. 2020. "Impact of 2019–2020 Mega-Fires on Australian Fauna Habitat." *Nature Ecology & Evolution* 4(10):1321–26. doi: 10.1038/s41559-020-1251-1.

White, Robert E. 2022. "The Role of Soil Carbon Sequestration as a Climate Change Mitigation Strategy: An Australian Case Study." *Soil Systems* 6(2).

White, Robert E., Brian Davidson, and Richard Eckard. 2021. A Landholder's Guide to Participate in Soil Carbon Farming in Australia.

Williamson, Phillip, and Jean-Pierre Gattuso. 2022. "Carbon Removal Using Coastal Blue Carbon Ecosystems Is Uncertain and Unreliable, With Questionable Climatic Cost-Effectiveness." *Frontiers in Climate* 0:130. doi: 10.3389/FCLIM.2022.853666.

Wright, Andrew. 2013. "Soil Carbon 'Blowing in the Wind.'" *CSIRO*. Retrieved (<https://csiropedia.csiro.au/soil-carbon-blowing-in-the-wind/>).

Appendix

The total emission intensity of LNG includes the production emissions in Australia, shipping, regasification and final combustion.

Production emissions in Australia, as reported in 2022 amounted to 0.44 tCO₂e/tLNG shipped.

Transport emissions as reported by (Gan et al. 2020) amount to about 0.18 tCO₂e/tLNG. With transport emissions from the West Coast of Australia and the NT being lower than Queensland we have weighted these estimates by production capacity.

We have ignored regasification emissions for this calculation given other uncertainties

Greenhouse gas emissions from final use/combustion estimated to be 3.09 tCO₂e/tLNG based on Australian (DEE 2018)¹⁰ and IEA emission and energy intensity numbers (IEA 2020).¹¹ The full range is 2.5-3.5 tCO₂e/tLNG.

The total lifecycle emissions are estimated to be 3.7 tCO₂e/tLNG with about 0.44 tCO₂e/tLNG occurring in Australia in 2022, with about 3.3 tCO₂e/tLNG occurring offshore in the form of transport emissions and final use.

What this means is 1 tonne of domestic LNG emissions covers about 2.3 tonnes of LNG production in 2022. Hence if an ACCU unit is used to offset 1 tonne of domestic LNG emissions the 2.3 tonnes of LNG production covered produces around 7.4 tonnes of GHG emissions abroad (Scope 3 emissions) for a total of 8.4 tonnes of GHG emissions globally per ACCU unit.

Hence there is substantial risk that 1 tonne of ACCU offsetting 1 tonne of LNG emissions would have a Scope 3 emission multiplier of 7.4 tonnes, in addition to the domestic emissions at one tonne if the ACCU enables ongoing production of LNG.

ACCUs as Coal emissions multiplier

10 Figure 2.3 in this report presents the Sankey diagram of natural gas flows in Australia in 2016 including LNG sector. Energy intensity from Australian LNG inferred from LNG production and Australia energy balance numbers.

11 IEA 2020 CO₂ emissions from fuel combustion 2020 edition database documentation
https://iea.blob.core.windows.net/assets/474cf91a-636b-4fde-b416-56064e0c7042/WorldCO2_Documentation.pdf

The total emission intensity of coal mining ultimately includes the mine production emissions in Australia as well as coal shipping and final combustion or use (eg in iron smelting).

Black Coal mining emissions in Australia, as reported in 2022 amounted to 0.07 tCO₂e/tonne coal production. However, there's a wide emissions gap between open cut and underground mining. In 2020, coal mining carbon intensity was 0.025 tCO₂e/tcoal for open cut mining, and 0.25 tCO₂e/tcoal for underground mining.¹²

We have ignored transport and shipping emissions in this calculation.

Greenhouse gas emissions from final use/combustion estimated to be 3.9-4.4 tCO₂e/tonne of black coal based on Australian emission and energy intensity numbers (Australian Government 2021)¹³ and AR5 GWPs.¹⁴

The total lifecycle emissions are estimated to be 3.9-4.4 tCO₂e/ tonne of black coal. About 0.25 or 0.025 tCO₂e/tonne of black coal emissions are occurring in Australia in 2020/21 depending on the extraction mode.

In the case of an open cut mine, 1 tonne ACCU offsets 50 tonnes of black coal, which leads to 195 to 220 tonne CO₂e, of which 193.8 to 218.7 would be scope 3 emissions.

In the case of an underground mine, 1 tonne ACCU offsets 4 tonnes of black coal, which leads to 16 to 18 tonne CO₂, of which 15 to 17 tonnes would be scope 3 emissions.

Hence there is substantial risk that 1 tonne of ACCU offsetting 1 tonne of emissions from a black coal mine in Australia would have a Scope 3 emission multiplier of 15 to 220, in addition to the domestic emissions of one tonne that the ACCU offset enables.

12 Emissions statistics from the Emission Projections 2022 (<https://www.dcceew.gov.au/climate-change/publications/australias-emissions-projections-2022>), production statistics from the Energy Update 2022 (<https://www.energy.gov.au/publications/australian-energy-update-2022>)

13 Table 1, <https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-accounts-factors-2021.pdf>

14 <https://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme/global-warming-potentials>