Australian Academy of Science

REVIEW OF FOUR METHODS FOR GENERATING AUSTRALIAN CARBON CREDIT UNITS

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Introduction and scope

The Australian Academy of Science (the Academy) is dedicated to maintaining excellence in Australian science, including through the provision of independent scientific advice. In this capacity, we welcome the opportunity to provide a synthesis report to support the Independent Review of Australian Carbon Credit Units (ACCUs).

The Academy has been commissioned by the Department of Climate Change, Energy, Environment and Water (DCCEEW) to provide an independent review of four ACCU generating methods for the independent review panel members. The methods addressed in this report are human-induced regeneration, avoided deforestation, landfill gas, and carbon capture and storage.

In this report we seek to (a) describe the underlying scientific evidence base of each method, (b) list the strengths and limitations of each method. The described strengths and limitations may be from a public policy basis, from a perspective of the limits of scientific verifiability, or from a community or economic co-benefit point of view. Finally, given this synthesis we offer some opportunities for improvement the Panel may wish to consider.

Input has been sought from the Australian research community, enabled by the convening capability of the Academy and other Australian Learned Academies. Details of individuals who have contributed to this report are available at Appendix A.

Advice provided by the Academy seeks to be dispassionate, disinterested, apolitical and founded in expertise, according to the following standards:

- **Excellence**. The Academy draws on the expertise of its Fellowship and other relevant experts.
- **Quality**. All advice is subject to internal and external review to ensure content is appropriate and any advice is compliant with Academy policies and principles.
- **Independence**. The Academy's advice is driven by evidence and will not be influenced by political interference in its drafting or its conclusions.
- **Transparency**. A normal condition of Academy advice is that it is made public. It will be written to be accessible to a non-specialist audience.

This report is structured in six sections as follows:

- Section 1 outlines the key findings
- Sections 2 to 5 describes the scientific basis of the respective methods, their strengths and limitations, and identifies opportunities for improvements
- Section 6 outlines observations and opportunities for scheme-wide improvements

The Academy thanks all those involved in preparing and delivering this report. We particularly thank the contributors and reviewers for their time and expertise. We also thank the Independent Expert Panel and DCCEEW for the opportunity to provide this report.

Glossary of key terms

Abatement in this context refers to both the removal of greenhouse gases already in the atmosphere or the avoidance of greenhouse gas emission.

Australian carbon credit units (ACCUs) represent the quantity of greenhouse gas sequestration or emission avoidance that has occurred by businesses registered under the ERF. One ACCU is the representative of one tonne of carbon dioxide.

Additionality refers to whether a carbon abatement project or activity would have taken place without funding from the Emissions Reduction Fund. Assessments may consider whether a project or activity would have taken place regardless of receiving ACCUs, or if increased carbon sequestration would have occurred without human intervention (such as from increased rainfall).

Avoided deforestation is a method under the Emissions Reduction Fund that credits landholders who hold clearing rights for native forests but agree not to clear the land.

Carbon capture and storage is a method under the Emissions Reduction Fund that uses specialised technology at large stationary sources to capture carbon dioxide before its release into the atmosphere and inject it underground for long-term storage.

CER refers to the Clean Energy Regulator which is established by the *Clean Energy Regulator Act 2011* (the Act) and is responsible for administering schemes legislated by the Australian Government for measuring, managing, reducing or offsetting Australia's carbon emissions.

Carbon Estimation Areas (CEAs) are a specific area of land within a broader property where an ACCU project is established and modelled. The HIR and AD methods specify guidelines on CEA eligibility, management, and reporting.

Carbon sequestration is abatement generated by removing carbon dioxide from the atmosphere and storing it, and in the Act refers specifically to removal and storage that occurs in living biomass, dead organic matter or soil.

Counterfactuals refer to events that would have occurred in an alternate scenario, here typically referring to a scenario without the ERF incentives. Counterfactuals may consider whether forest growth would have occurred without human intervention, or whether projects would be commercially viable without ACCU incentives. It is closely related to assessments of additionality.

ERAC refers to the Emissions Reduction Assurance Committee, an independent expert committee which assesses whether methods meet the requirements of the Emissions Reduction fund and provide advice to the relevant Minister.

ERF refers to the Emissions Reduction Fund, the scheme run by the Australian Government that awards Australian carbon credit units to businesses for abating carbon dioxide equivalents.

Flare describes an activity where gas is combusted rather than released to the atmosphere. Flaring gases that would otherwise have been vented to the atmosphere may result in a lower environmental impact, be performed for safety reasons, and/or dispose of gas that cannot be used commercially.[1]

Forest in this paper refers to a technical definition based on certain thresholds used for carbon accounting. Land is defined as a forest (or as having 'forest cover') if it is at least 0.2 of a hectare in size, and with trees that are 2 metres or more in height which provide crown canopy coverage of at least 20% of the land.[2,3]

GWP refers to the global warming potential of a particular greenhouse gas and can be used to compare warming impacts from different quantities of gas emissions, i.e. one tonne of methane versus one tonne of carbon dioxide. The 100-year and 20-year global warming potentials are denoted as GWP_{100} and GWP_{20} respectively. GWP* is a new measure of GWP that more accurately accounts for atmospheric lifetimes of the different greenhouse gases.

Human-induced regeneration is a method under the ERF that credits landholders who regenerate native forest where it has previously been suppressed. The full name of the method is Human-induced regeneration of a permanent even-aged native forest. The HIR method has been revised multiple times; the analysis in this paper refers to the current method compilation.

Landfill gas refers to methane and other biogases naturally produced from the decomposition of solid waste stored within landfills.

Landfill gas method can refer to either of two methods currently in force. The first (generation) is for crediting emissions reductions achieved through the destruction of methane from decomposing waste at a landfill site as part of the ERF. The method credits emissions reductions from combusting landfill gas in an electricity generator, with or without flaring. It also credits the conversion of landfill gas into biomethane for use as a natural gas substitute within Australia. The second method is for crediting the emissions reductions achieved by upgrading, installing, or reinstating landfill gas collection systems.

Leakage in this paper has two meanings. The first refers to physical leakage, such as gas escaping a landfill without passing through a flaring system. The second refers to the concept of 'carbon leakage'.[4] In this context, leakage is understood as unwanted or unintended emissions, where activities under a certain project lead to emissions occurring outside the project area. For example, emissions cuts to industrial activities in one nation may shift emissions-intensive industries to other nations, resulting in no net decline in emissions.[4] Another example of leakage would be a scenario where emissions are avoided by protecting a forest stand from deforestation, but these emissions are then negated as demand for wood products is met by deforestation of another stand on the property.[5]

Mandatory cancellations are a policy instrument where percentage of carbon credits that are cancelled at issuance. This can either be to provide a buffer for identified risks, such as in the risk of reversal buffer, or to ensure overall carbon mitigation is achieved as in the 'overall mitigation of global emissions' cancellation in the Paris Agreement's Article 6.4 carbon market.[6]

Pools in this paper refers to a concept used to simplify the carbon dynamics and fluxes of forests. It describes what happens to atmospheric carbon after it is taken up by living trees. Carbon not allocated for other processes (such as respiration) is allocated to pools, which include aboveground biomass (i.e., leaves and stems), belowground biomass (i.e., roots), soil carbon, litter, and deadwood.[5]

Risk of reversal buffer is a mechanism within the ERF scheme that reduces issued ACCUs by 5% (for projects that intend to store carbon for 100 years) to counter risks of carbon reversal that may occur from fire or other natural disturbances in sequestration projects.[7]

Stand is a contiguous area within a forest that contains a cohort of trees that have a common set of characteristics.

1. Summary and overall observations

Carbon offsets reduce or remove greenhouse gases (GHGs) in one place to compensate for emissions elsewhere. Since 2011, Australia has had a national carbon market for trading offsets. Many carbon offsets, or Australian Carbon Credit Units (ACCUs), have been purchased through the Emissions Reduction Fund (ERF).

The carbon offsets imperative

Limiting global warming to 1.5°C requires both immediate deep emissions reductions and greenhouse gas removal from the atmosphere. The Australian Government, through the passage of the *Climate Change Act 2022*, is committed to net zero emissions by 2050 and a 43% reduction by 2030.

The latest report from the Intergovernmental Panel on Climate Change (IPCC) highlights the need to remove CO_2 from the atmosphere to limit global warming.[8]

Greenhouse gas removal from the atmosphere is required for several reasons:

- The scale of the abatement task means that mitigation alone (reducing emissions) is not sufficient to achieve net-zero by 2050, or limit warming to 1.5°C.
- Almost all modelled pathways that limit warming to 1.5°C, and most pathways that limit warming to 2°C, require the rapid deployment of greenhouse gas removal methods at greater scale than at present.
- To offset emissions from hard-to-abate sectors such as oil and gas, steel and concrete.
- High carbon dioxide concentration in the atmosphere drives environmental impacts in addition to warming, such as ocean acidification.[8]

High integrity carbon offsets are a part of the policy architecture to reduce emissions

The Australian Government's emission reduction policies require a high integrity and trusted carbon offsetting system for industries and activities that cannot easily reduce emissions. The Australian Government issues ACCUs, authorised by the *Carbon Credits (Carbon Farming Initiative) Act 2011* (the Act), to certify that one tonne equivalent of carbon dioxide has been stored or otherwise not released into the atmosphere.

Eligible offsets projects may only generate ACCUs if they are registered under an approved ERF method, which comply with the offsets integrity standards in Section 133 of the Act, which are:

1. **Additionality**: A method should result in carbon abatement that is unlikely to occur otherwise
2. **Measurable and verifiable:** A method should be able to be measured and capable of being verified
3. **Eligible carbon abatement**: A method should provide abatement that is able to be used to meet Australia's international obligations
4. **Evidence-based**: A method should be supported by clear and convincing evidence

5. **Project emissions**: Material greenhouse gas emissions emitted as a direct result of the project should be deducted
6. **Conservative**: Where a method involves an estimate, projection, or assumptions, it should be conservative.

Review of four methods for earning ACCUs

This report provides a review of four methods—human-induced regeneration (HIR), avoided deforestation (AD), landfill gas and carbon capture and storage (CCS)—for their scientific underpinnings, their strengths and limitations and the extent to which they comply with the offset standards.

Compliance with the offset standards is a contested space. Some of the criticisms levelled at the ACCU scheme assume that each and every standard should be applied and met at the individual project level. At a systems level this may be impractical. Caution needs to be applied in taking such an approach which risks an inappropriate use of scientific tools, such as modelling which may or may not be designed for use at such a granular level.

Hence in conducting this review, we have sought to examine whether the methods meet the offsets integrity standards at a method level, rather than examine individual projects.

Outcomes of the review

The Academy was asked to analyse the underpinning science of the four methods. For each of the methods, **the science is well understood.**

All **methods have different strengths and limitations** in terms of how they respond to the offset integrity standards in the Act. In terms of strengths, all methods have a scientific evidence base. However, the integrity and transparency of the scheme could be strengthened by incorporating a short, plain English statement of the scientific basis of each method.

The methods can offer **co-benefits** for a range of individuals, communities, and environments.

Some limitations of the methods which may raise questions as to their adherence to the offset integrity standards were identified. These include:

- **Challenges with attribution** and confounding influences including climate change, especially for the HIR and AD methods. Similarly, there are challenges around establishing **consistent baseline data** in all locations, especially for the HIR and landfill gas methods (see sections 5.1 and 5.3). Unclear or inconsistently defined baselines can lead to complications when determining additionality.
- Methods that rely on counterfactuals to demonstrate carbon sequestration are inherently vulnerable to questions about their integrity**,** which is a systemic disadvantage for HIR and AD methods against CCS and landfill gas schemes. This represents a risk to investor and community confidence in these methods for generating emissions abatement.
- **Overcomplexity**. Understanding each method requires a complex analysis of legislation, data and measurability, which posed challenges for this report. The subject matter expertise, policy familiarity and industry knowledge necessary for robust verification is very high, such that relatively few individuals possess the combination of expertise required to provide independent assurance. Such complexity creates a barrier to entry to the scheme that runs counter to the object of the Act which seeks to create an incentive for landholders and others to remove or avoid the emission of greenhouse gases. Additionally, the lack of transparency and overcomplexity

can lead to low community confidence, potentially meaning the purchase of ACCUs and participation in the ERF can incur a reputation risk.

Opportunities for improvement

The first objective of the Act is to remove greenhouse gases from the atmosphere. Other objectives revolve around incentives, biodiversity, and climate resilience.[9] Over the decade of operation, the scheme has become less a climate policy instrument, and more an industry policy mechanism. While industrial strategy objectives are not unimportant, **there is a need to reinforce that the ACCU scheme is fundamentally for the removal, and avoidance, of greenhouse gas emissions.**

Other opportunities to improve the overall integrity of the methods include:

- Build **trust in the scientific integrity** of each of the methods by requiring explicit articulation of the scientific basis and intended use cases for each method as a part of the method development process
- **Amend the Act to allow additional levels of transparency** in method operation, data sharing and reporting. Existing confidentiality practices prevent the sufficient release of data that would allow independent assessment of the performance of ACCUs against the integrity standards. Amending the Act to allow greater data release, including through the provisions of the *Data Availability Transparency Act 2022,* would build trust and confidence
- Redesign the scheme to **reduce complexity**, which would simplify method descriptions, regulations, and operations while maintaining scientific integrity
- **Align the ACCU scheme with the operations of carbon markets under the Paris Agreement**, including the recently agreed section 6.4 to build in cancellation provisions. This will build additional protections into the scheme by guaranteeing conservativeness at a system level.
- **Continue investment in R&D and early-stage deployment for improved measurement and verification** technologies and practices. Measures through either as the Clean Energy Regulator (CER) through the *Business Research and Innovation Initiative* or mechanisms such as the Australian Renewable Energy Agency (ARENA) could help mitigate some of the identified limitations.

A functioning, high integrity, transparent and scientifically robust carbon offsets scheme is central to Australia's emerging climate policy architecture. If the Australian Government can capitalise on opportunities to improve the operations of the ACCU scheme, all Australians will benefit from a cleaner environment, as well as the positive social and economic co-benefits that a well-designed scheme can provide.

2. Human-induced regeneration method: science, strengths, limitations, and opportunities

Human-induced regeneration (HIR) credits ACCUs to landholders who regenerate native forest where native forest has been suppressed for at least 10 years. ACCUs are awarded based on changing land management practices that allow a forest to re-grow to a certain international standard.[3] ACCUs are credited based on changes within Carbon Estimation Areas (CEAs), a specific area of land, rather than the property as a whole.

2.1 Underpinning science of human-induced regeneration

The carbon abatement estimated as generated by HIR projects is based on science that links growth in vegetation biomass above ground to carbon sequestration. In general, carbon is stored in 'pools' including within trees, and in dead wood material in a forest stand. The total amount of carbon stored depends on environmental conditions (such as weather), events (such as wildfire), and management activities (such as grazing or prescribed fire). These amounts can be estimated based on measurements in samples of the forest, predictive models, or a combination of the two.[10] Sampling can involve a combination of remotely sensed data and ground plot measurements.

Most HIR projects have been established in low rainfall, semi-arid regions of Australia, and most are in areas without a history of land clearing.[11,12] These areas have 'boom and bust' ecologies dependent upon wet-dry cycles in rainfall patterns.[13] While the semi-arid nature means there is relatively low biomass in these areas, the vast extent of this semi-arid land means there may be significant potential for carbon sequestration if biomass had been reduced due to human-induced factors. However, the dominant influence of wet-dry cycles of rainfall in HIR project areas complicates the attribution of vegetation growth.

The method uses the Full Carbon Accounting Model (FullCAM) to estimate above ground biomass and carbon stocks following the restoration of woody vegetation.[14] FullCAM combines process modelling on biomass change with empirical data on biomass allocation to different pools. The field-based empirical data used in its development is continually expanded. If accurate baseline data are available and accessible, FullCAM enables quick, cost-effective estimations.

FullCAM is flexible: updated calibrations can be incorporated in a transparent fashion. A recent study used 2,340 stand measurements to recalibrate the FullCAM model across a range of stands, finding that FullCAM could predict biomass reasonably well when accounting for stand age, site productivity, and restoration activity (such as excluding grazing livestock).[14]

It is important to note that these estimates are averages over large areas, and that FullCAM estimates and ground measurements for any specific location may vary considerably. If there are no biases (an interpretation which the study referred to above supports), this should not affect the estimations for carbon stock changes at the level of the entire portfolio of HIR projects.

The science of estimating the carbon stock change in HIR projects is well understood. However, HIR requires that carbon stocks be accurately measured *and* that changes in carbon stocks be attributable to human activity. In this respect, there are some uncertainties.

2.2 Strengths and limitations

Almost 28% of ACCUs have been issued under the HIR method.[15] HIR is also one of the methods with significant contestability regarding how projects registered under it are consistent with the offsets standards.

The major strengths of the HIR method are related to its co-benefits, namely economic and environmental:

- **HIR projects offer an alternative revenue stream to farmers**, enhancing socio-economic resilience for individual farming operations and communities more broadly. These bring potential benefits in poverty alleviation and employment. However, it should be noted that the distribution of carbon abatement revenue has the potential to create social divisions, particularly between those whose land is eligible and those land is not.[16]
- **Co-benefits for Indigenous communities**. This method has the potential to support Indigenous communities to meet cultural stewardship obligations.[16] This should not be assumed—revegetated forest may not necessarily match Indigenous stewardship outcomes, but HIR projects may offer an opportunity for the recognition of Indigenous knowledge. This would need to occur on a systematic basis following best practice guidelines for Indigenous engagement.[17]
- **Significant potential environmental benefits beyond carbon sequestration.** Areas of revegetating natural regrowth due to reduced human pressures may (depending upon species mix) promote restoration of biodiversity and conservation of native species, and act as refuges for animal species during droughts and other disturbances. Revegetation can increase soil health. Ground cover may act to mitigate erosion during heavy rainfall. On the other hand, dependent upon the type, extent and growth of vegetation, regrowth may reduce catchment water flows.[16,18]

Nevertheless, several concerns or limitations about the HIR method have been identified:

- **Uncertainty about accurate baseline data**. The method's integration of FullCAM requires baseline information on historical processes to discern the effect of change in human influence on carbon abatement. Project operators must have high-quality documentation of when they ceased processes such as mechanical clearing or controlling grazing, alongside high-quality estimates for the age of vegetation stands. Similarly, the method requires estimates of 'remnant' native vegetation that persists in CEAs at project commencement, which has been legally contentious.[19–21] These estimates require high-quality mapping or records that are often unavailable.
- **Measurement uncertainty**. It is not clear how measurement uncertainty is incorporated into the method. Some under and over-prediction of carbon sequestration by project managers may occur in projects due to changes in site management practices. Uncertainty may be due to the implicit assumption that these variations will cancel each other out over a national scale. For this to be the case, there would need to be no systematic biases towards sites with less additional abatement.
- **Reliance upon counterfactuals, causal inferences, and attribution**. Explicit counterfactual scenarios are always required to estimate the benefit attributed to, or caused by, a particular intervention. Establishing plausible, unbiased counterfactuals for use in related programmes (such as biodiversity offset schemes) has proven very challenging, especially when drivers other than the intervention itself are important factors in a system. [22]
- **Difficulty in determining the carbon sequestration attributable to human activity** (particularly the removal of grazing) as opposed to rainfall in

the regions where most HIR projects occur. Variable patterns in rainfall are the dominant drivers of fluctuations in woody biomass in these systems, with the proportion attributable to human activity small and variable. This triggers the 'evidence based' offset integrity standard, as it is not clear how changes in carbon sequestration in HIR projects can be convincingly differentiated between human and climatic changes.[20,21,23, 24]

- **Climate change presents direct and indirect risks to the future accumulation and maintenance of carbon abatement** because of the weather-driven dynamics in semi-arid and arid systems. By 2050, it is likely that heat stress will limit plant growth, reduce soil water levels, and reduce the availability of suitable conditions for tree regeneration. This risks the survival of young regenerating trees and the growth rate of mature trees (despite potentially increased growth from the CO_2 fertilisation effect).[25] For maintaining sequestered carbon, extreme drought is the main risk. Many HIR projects are regionally concentrated in northwest New South Wales and southwest Queensland; a broad area impacted by regular droughts.[18] This concentration further exacerbates drought risk given the potentially broad area impacted by droughts.[26]
- **Climate change is also affecting attribution.** Changes in temperature, elevated levels of atmospheric carbon dioxide and fluctuations in rainfall influenced by climate change all impact biomass growth and carbon sequestration.[5,25] This may further complicate the 'evidence based' offset integrity standard, because as described above it is not clear how changes in carbon in HIR projects can convincingly differentiate between human and climatic changes.
- **Use of discretion for project variance.** The method's application may differ considerably between projects, challenging the degree to which the method could be considered consistent or comparable. These variants depend on the judgement of project proponents and scheme auditors, leading to variation of forest cover assessment, permitted management activities and sufficiency of regeneration to demonstrate a forest can be supported. When multiple approaches to monitoring are available, there is a risk that whichever provides the most favourable assessment will be selected in any given case, thus creating a systematic tendency towards overestimation, and violating the assumption that overestimation and underestimation will balance out across the portfolio of projects registered under this method.
- **'Carbon leakage' across an entire property.** A farmer may use ACCU revenue generated from CEA areas to fund clearing measures for other parts of their property.[4,27] It may be that this clearing would have occurred anyway: that rights to clear native vegetation are equivalent to property rights with monetary value.[28] The Emissions Reduction Assurance Committee (ERAC) has published statements that appear to indicate it does not interpret the current offsets integrity standards as requiring leakage to be penalised through ACCU deduction, as it can occur as a consequence of non-project factors (in this example, such a factor might include a rise in the price of beef).[29] Regardless, leakage runs counter to the Act's primary object to increase carbon abatement and represents a risk to public confidence in the integrity of the method.

Compounding these limitations is the complexity of method description, hindering comprehension, analysis, and transparency.

Similarly, while there are experts who hold relevant expertise spanning the science underpinning the HIR method and the method itself, the number is less than optimal, pointing to a possible capability deficit. Many Australian experts hold deep expertise relevant to only part of the scientific basis underlying the methods. This points to a lack of capacity to independently assess the overall system and reassure the Australian Government, project operators, investors, and the Australian public of the method's integrity.

2.3 Human-induced regeneration opportunities

Opportunities to improve the operation of the HIR method fall under several broad categories: attribution, documentation, project comparability, addressing carbon leakage, and carbon market operation.

Addressing attribution (additionality)

Separating the impact of management actions from natural variability or climate change remains challenging. It may be possible to address this issue of attribution by restricting new HIR projects to areas with higher rainfall and showing clearer signals of human activity. Alternative methods for generating ACCUs with a relatively clearer anthropogenic intervention could be made available to landholders in areas of lower rainfall.

Documentation

Method documentation should be simplified, and plain-English statements should be introduced to describe the methods used to identify and describe eligible land areas, model tree cover change on those areas, and calculate additional carbon abatement.

While documentation requirements for carbon estimation areas (CEAs) and management actions are a strength of the HIR method, they are not widely available for public or scientific scrutiny. To address concerns around transparency, project operators could be required to provide **detailed reports for each project**. These should include overall management strategies, detailed descriptions of methods and assumptions used to generate carbon abatement estimates, audit reports and any non-conformances, and the response to these non-conformances.

Project Comparability

Several further reforms would enhance the degree to which projects can be compared:

- Standard CEA stratifications and forest cover change products could be developed and provided as standard outputs to all project proponents
- Standardised and conservative estimates of abatement over time for different vegetation types in different regions could be developed to calculate abatement for HIR projects. If project proponents consider their abatement estimates are higher than these standardised estimates, they must provide evidence (statistically accurate and to a specified level of precision) based on field measurements. Alternatively, no upwards revisions of abatements would be permitted, with standardised estimates used only. This would simplify the scheme while preserving the assumption that over- and under-compliance cancel each other out
- The CER should continue to directly support research and development of new remote sensing and technical improvements. These should then be made standard across the scheme, rather than at the developer or project level

These reforms should be overseen and approved by an independent technical committee, which will also provide advice on new technologies in carbon abatement in vegetation. There is potential for this role to be assumed by the Emissions Reduction Assurance Committee, drawing on relevant independent expertise.

Carbon leakages

There is an opportunity to amend the offset integrity standards to address concerns around 'leakage' and maintain community confidence in the integrity of the method. Project proponents should be required to submit a report at regular intervals (such as every five years) on the carbon stock changes across the entire property, not just the CEAs used for the HIR project. Alternatively, the potential for material leakage could be factored in as a further discount on credited ACCUs.

Clarifying the relationship between carbon stock maximisation and co-benefits

Descriptions of the HIR method can imply that increasing carbon stocks to the maximum potential level is a desirable outcome for broader environmental outcomes or broader community values.[30] This is not necessarily the case; project developers could be required to provide reports addressing the environmental and socio-economic benefits from the project.

Carbon market

An opportunity is to reform incentives for project developers from a proportion of generated ACCUs towards a scheduled fee-for-service arrangement. This would reduce the incentive for developers to make assumptions and calculations that maximise estimated carbon abatement to generate the highest level of ACCUs possible from a project.

3. Avoided deforestation method: science, strengths, limitations, and opportunities

Avoided Deforestation (AD) is a method under the ERF that credits emissions reductions to landholders who possess clearing rights for native forests to convert them to cropland or grassland but who agree to refrain from exercising these rights. Projects are eligible if landholders hold a clearing consent issued under certain conditions, limiting the scope of AD to properties in certain regions of NSW.

3.1 Underpinning science of avoided deforestation

The carbon abatement estimated as generated by AD projects is based on science linking vegetation biomass above ground to carbon sequestration and storage.[10] AD's emissions abatement calculation relies on subtracting modelled emissions from field-based measurement. The method relies upon multiple empirical relationships and random sampling.

The techniques and steps to collect necessary data are credible and supported by peer-reviewed assessments.[31] If steps are followed correctly, they should produce estimates of biomass above the ground that is relatively unbiased. Estimates are then converted to carbon stocks using mathematical equations. 'Baseline' emissions are then modelled to estimate the greenhouse gas emissions from activities that the landholder holds rights to conduct, i.e. deforestation. The net abatement is then calculated as the difference between the 'baseline' modelled scenario and the estimated carbon stocks.

3.2 Strengths and limitations

Around 21% of ACCUs have been issued under the Avoided Deforestation (AD) method.[15] Its major strength is that **native vegetation in AD projects is already well-established,** avoiding risks to vegetation growth associated with the initial stage of regeneration or carbon accumulation seen in HIR.

AD also offers significant co-benefits which, while secondary to the primary purpose of the Act, may be desirable for other policy objectives.

- **There are environmental co-benefits.**[18] As vegetation is already established there is greater soil stability and less risk of soil erosion than seen in HIR. Established vegetation improves water quality and reduces leakage from nitrogen, phosphorus, and pesticides. If managed for invasive species (which does not appear to be a requirement under the method determination), AD projects offer potentially significant co-benefits for conservation and as a drought refuge.[16]
- There may be co-benefits for Indigenous communities. The factors for these are identical to those of HIR, described previously.

Limitations and risks associated with the AD method largely concern additionality, measurement and verification:

- **Reliance upon counterfactuals leaves the scheme inherently vulnerable to integrity accusations**.[28,32] AD has been criticised on the basis that landholders have been paid not to clear land they either never intended to clear or had limited capital to support clearing. This raises concerns about the additionality offset standard.

- **Counterfactuals are calculated based on intention**. Critics of the method have extrapolated historical clearing rates and interpreted the area permitted for clearing to claim this land would never have been cleared, with over-crediting as the result.[32,33] The CER argues that historical clearing rates should also include remnant and re-clearing of land, which results in higher peak clearing rates.[34] Industry body GreenCollar has also responded to this criticism, arguing that the area permitted for clearing during the analysed period was lower and the extrapolated rate of clearing should be higher.[35]
- **This raises questions about data sourcing.** Historical analysis by the Australia Institute and Australian Conservation Foundation seems to include both remnant and regrowth clearing, therefore it is unclear how or where the differences in data come from.[32] These arguments are complex and there appears to be information asymmetry as some of the relevant data are not publicly available (including the details of specific clearing consents, which GreenCollar had access to).
- As with HIR, the AD method is vulnerable to accusations of doing little to prevent **carbon leakage.** Hypothetically, a landholder might use revenue from selling ACCUs from an AD project to fund clearing projects elsewhere. Media reporting appears to indicate this has already occurred in at least one instance.[28]
- **Climate change may pose a risk to the maintenance of AD carbon abatements**. Forest death from extreme drought represents the main climate change related risk to AD. As the method involves the protection of existing forests, it avoids the climate change risks to the establishment and early growth from processes seen in HIR.[26]

3.3 Avoided deforestation opportunities

As with HIR projects, offsets integrity standards could be amended to address concerns around 'leakage' and maintain community confidence in the integrity of the method. Project proponents should be required to submit a report at regular intervals (such as every five years) on the carbon stock changes across the entire property, not just the areas used for the AD project.

Some concerns have been raised around AD's limitation when it comes to *intention*: determining whether landholders were actually going to exercise their clearing permits. At dispute is the question of whether ACCUs are being issued under the AD method for landholders agreeing to not clear land that they never intended to disturb. Calculations of historical clearing rates have been advanced to determine whether the system-wide assumption of clearing makes sense.[32]

It may be possible to reform the way in which the counterfactual 'baseline' is calculated to create a more realistic and robust model of intention. The 'baseline' emissions could be calculated using data from rates of clearing on similar properties on recent time scales to help ensure that ACCUs credited are genuinely additional relative to the counterfactual. This would contrast with the current method for modelling a baseline scenario based on rights held by landowners, or by extrapolating historical figures. A similar method is currently used under the biodiversity offsetting scheme administered by the Commonwealth.[22]

However, there are limitations to this approach, as it risks creating further complexity and uncertainty in the method.

4. Landfill gas method: science, strengths, limitations, and opportunities

Landfills store compressed solid waste underground. When filled, landfills are sealed and monitored for fluid and gas leakage. The breakdown of waste products in the landfill generates biogases, including methane. For safe maintenance of a landfill, these gases need to be vented to avoid the build-up of pressure underground.

4.1 Underpinning science of the landfill gas method

Methane is a potent greenhouse gas. One tonne of methane has the 100-year global warming potential of 27 tonnes of carbon dioxide.[36] The scientific integrity of the scheme is based on the conversion of methane to carbon dioxide to reduce global warming impacts. To reduce the climate impact of landfills, biogas from the breakdown of waste products can be combusted in the air (flared), converting methane to carbon dioxide and water. The biogas can also be combusted in a generator to produce energy that can then be sold or refined into biomethane and used as a natural gas substitute.

The landfill gas methods incentivise the capture and combustion of methane with or without energy generation and the capture of biogas for biomethane production. To be eligible for these schemes, methane must be flared with a minimum of 98% destruction efficiency.[37,38] ACCUs are credited for the difference in carbon equivalence between methane and carbon dioxide.

The difference in global warming potential between methane and carbon dioxide is relatively well established, and data needed for the calculations are measurable (for instance: the amount of methane flared, operational costs, the amount of energy created, energy prices, and the regulatory baseline).[36,39]

Questions of landfill gas methods integrity concern whether they generate *additional* carbon abatement, given competing legislative requirements and economic incentives for the activities described.

4.2 Strengths and limitations

The strengths of the landfill gas methods include:

- **Direct greenhouse gas measurement.** Unlike other methods considered here, the measurement of methane destroyed is relatively straightforward and measures the output and conversion of greenhouse gases themselves. As semi-closed systems with a higher degree of human control, landfills are simpler to analyse compared to the other methods under scrutiny. The landfill gas method relies on well-established point-source atmospheric science and energy economics, both of which lend to the method's strengths.[40,41]
- **Energy generation co-benefits.** Landfill gas generation provides a clear co-benefit in the production of energy from waste, which can constitute additional income streams for operators as well. Additional energy also provides broader societal benefits. Non-fossil-based energy sources, especially ones that are packaged alongside other emissions reduction activities, can play a critical role in transitioning away from fossil fuels.

The main limitations of the method concern assessments of additionality:

- **Alternative additionality requirements.** The alternative (*in lieu)* requirements for the landfill gas methods undermine the integrity of the additionality.

  The default measures of additionality as per Section 27 (4A) of the Act are as follows:

  1. Newness**:** Whether a project has already been implemented prior to the Act
  2. Regulatory Additionality: Whether existing regulations already require a project to be implemented
  3. Government program requirement**:** Whether the project would receive other government funding without the ERF. [9]

  The default measures are verifiable and transparent requirements. If a landfill project existed before the Emissions Reduction Fund, was required under another law, or received other government funding for energy production, it would fail the additionality requirements of the Act and would not be eligible for the Emissions Reduction Fund.

  However, landfill gas projects use *in lieu* requirements.[42,43] The alternative requirements are as follows:

  1. Newness: If a project was included in a previous program, like NSW Greenhouse Gas Abatement Scheme or the previous Carbon Farming Initiative, it could transition into the ERF
  2. Regulatory additionality: Whether the project is a landfill gas project
  3. Government program requirement: Whether the project primarily avoids methane emissions.

  How these requirements ensure the additionality of landfill gas projects is unclear, which is a limitation as additionality is currently central to the integrity of ACCUs.[44]

- **Financial additionality.** Financial additionality comes down to assessing whether income from electricity sold and large-scale generation certificates (LGCs) alone provides sufficient profitability to continue generation projects.[33]

  This assessment requires commercially confidential data that is available only to the Regulator reducing the methods' transparency and verifiability. The regulator's assessment approach (using operation costs and future forecasts) differs from that of external analysts (using historical energy data). There is no standardised approach for how to determine financial additionality.

  While some industry actors acknowledge they have been receiving ACCUs for non-additional actions [45], it is unclear to what extent this is due to profitability (financial additionality) or existing regulatory requirements (regulatory additionality).[45] There may be further detail in the industry's letters sent to the review panel, but these are not publicly available. The reliance on confidential commercial data results in a lack of transparency.

- **Baselines**. Baselines look at the proportion of methane destruction that is required by existing legislation, with methane destruction above the baseline being deemed additional and eligible for ACCUs.

  The default baseline is 30%, with the baseline being higher to match the requirements of any specific jurisdiction if necessary.[42,43] A 30% baseline would mean that 70% of the methane destroyed is deemed additional.

  Some landfill operators have a baseline under 30%, carried over from previous government schemes as part of the newness provision that allows project transitions.[44,46] This runs counter to principles of regulatory additionality.

Baseline calculations could be tiered to reflect the economies of scale associated with larger landfills, where energy generation may be profitable enough without ACCUs.[46] ERAC's position is that the size of a landfill project is not the main determinant of its efficiency.[39] Other aspects like the type of gas extraction, purity of biogas extracted, or variable maintenance costs are also key cost factors.

However, the precise nature of these constraints is subject to commercial confidentiality. An appropriate 'mix' of considerations to determine different tiers is therefore difficult to transparently determine or verify. Otherwise, the non-differentiated 30% default (or higher as directed by any jurisdiction) baseline would ensure regulatory additionality, but not necessarily financial additionality.

More well-known issues of landfills revolve around measurement:

- **Total methane measurement is uncertain**. Landfills are only semi-closed systems at best. Methane can leak through surrounding soil or imperfections in landfill infrastructure.[47,48] Improved leakage detection and measurement is needed to better account for fugitive emissions.[47–49]
- The methods use **outdated metrics of methane warming potential**. The current method, as per the 2008 National Greenhouse and Energy Regulations, uses global warming potential for a 100-year period (GWP_{100}).[42,43] However, methane is a short-lived greenhouse gas—it stays in the atmosphere for around 12 years on average. It does not accumulate in the atmosphere long term as carbon dioxide does. GWP_{100} can understate methane's short-term warming (and risks of overshooting emissions and temperature targets) and overstate its long-term warming.[50] Short-term warming is especially important to consider due to short-term emissions targets, short-term temperature goals and overshoot risks.

While these are important considerations of landfills and their climate impact in general, they are tangential to the core issues of the method's integrity (i.e., additionality).

4.3 Landfill gas opportunities

Transparency

A more transparent review of the *in lieu* requirements is a critical first step to improve the integrity of this method. Criticism of the baseline requirements for landfill gas projects stem from these alternative requirements, which do not appear to be fit for purpose. ERAC has previously reviewed the *in lieu* requirements and found them fit for purpose.[39,51] However, details of the analysis are not publicly available. Transparency in the analysis would enable better-informed discussions of proposed improvements to integrity, such as a tiered baseline approach.

Amend in-lieu requirements

Opportunities to amend *in lieu* requirements could involve:

- **Newness**: Projects from previous schemes may transition into the ERF, but this transition should be subject to review and should not allow previous baselines to be carried over. Robust review and verification are not possible if review is only undertaken at project registration
- **Regulatory additionality**: Methane destruction already required under other regulation will be non-additional and not receive ACCUs. This will be enforced via the methods' baselines, which will not allow carryover from previous schemes

- **Government program**: This is the most complex requirement. The issue is whether generation projects would be financially viable with selling energy and LGCs alone. This analysis depends on confidential commercial data and cannot be independently verified, but the analytical approach could be more transparent. Different approaches to these analyses have drawn different conclusions.[39,44,46] A standardised and transparent approach to analysis (potentially one that does not rely as heavily on confidential data) would greatly aid transparency of financial additionality.

  A tiered baseline to reflect financial additionality may depend on confidential commercial data and project level data, like the method of biogas capture, total chemical composition and methane proportion of biogas, in addition to the size of landfill.[39] While they have not indicated explicit public support of this specific policy approach, statements from landfill gas industry operators suggest a willingness towards new approaches to baseline determination.[45]

Improve accuracy of calculations

Opportunities to improve the accuracy of ACCU calculation includes the use of GWP* in place of GWP_{100}. GWP* provides a more accurate short-term assessment of the impact of methane.[50,52–54] This is important for short-term warming goals and understanding overshoot scenarios.[36,50,52–54]

Though promising, GWP* may not be ready for widespread policy use just yet (the IPCC has not yet provided a clear value for methane's GWP*).[36] Once ready, however, GWP* could be integrated into the method via the National Greenhouse and Energy Reporting Regulations yearly amendment cycle which would flow into the calculation of ACCUs within the method.

Improvements in measuring the overall emissions from landfills would also increase the integrity of landfill gas operations as some measurements in the Act are reliant on robust carbon accounting more broadly.

In addition to ground-based methods of methane measurement, satellites can measure (and image) methane emissions directly. This could reduce measurement uncertainties and more effectively identify leak sites from a landfill.

The Committee on Earth Observation Satellites is aiming to implement satellite measurement to create top-down greenhouse gas budgets (including methane) to support the Paris Agreement's Global Stocktake (scheduled for 2023).[55–59] Australia also has the potential to be involved with projects like MethaneSAT, which is planning to launch a high-resolution methane measurement satellite in October 2022.[58]

5. Carbon capture and storage method: science, strengths, limitations and opportunities

Carbon capture and storage (CCS) involves capturing carbon dioxide at large stationary sources and then injecting captured carbon dioxide into the deep surface of the Earth for long-term storage.

5.1 Underpinning science of the carbon capture and storage method

There is extensive industrial experience in the capture and transport, injection and storage of gases like carbon dioxide.[60] Capture is based on industrial chemistry (via either solvents or membranes), with different methods depending on the scale and physical conditions ranging from gas separation to pre-combustion and post-combustion.[61] The common thread across different methods is that separation of carbon dioxide from the air is possible but expensive. Storage is based on the science of fluids behaviour in the deep surface of the Earth, which has been relied upon for groundwater abstraction, oil and gas extraction and natural gas storage for many decades.[62]

This science is calibrated through observations over a vast number of diverse geological settings with different fluid compositions and different temperatures and pressures. It has been relied on in early CCS projects for many years and extensively in the natural gas storage sector.[63] Storage considerations are site-specific and the critical application of this science is in the detailed characterisation, risk evaluation and ultimate selection of sites, as well as the definition of key operating parameters (such as injection pressure) and in containment monitoring.

CCS is primarily targeted at industries that generate greenhouse gases from direct activities such as oil and gas refineries, electricity generation from fossil fuels and steel and cement production (amongst others). The method does not include direct air capture of greenhouse gases from the atmosphere. Similarly, carbon capture, use and storage (CCUS) is not covered by this method and the use of captured carbon for enhanced oil recovery is explicitly excluded. A separate CCUS method is under development by the Clean Energy Regulator.

Geoscience Australia has done considerable work identifying areas in Australia potentially suitable for carbon storage and there is sufficient expertise to effectively characterise, risk assess, develop, operate, decommission and monitor these storage sites for leakage.[64] Reported leakage at operational storage sites has been very low.[65–67]

While scientifically supported as a technology, CCS operations globally are underperforming (though this is contested).[68] For example, Chevron’s carbon capture at its Gorgon plant in WA is falling significantly short of its goal to capture at least 80% of carbon dioxide produced in a 5-year rolling average of operations due to technical delays. Real-world deployment of CCS projects highlights uncertainty around the technology’s maturity to work at the scale needed for reducing global emissions in line with IPCC scenarios.[69,70]

CCS is currently an expensive technology for the amount of carbon it abates and yet it will need to play an essential role in achieving limited warming scenarios. While it is economically sensible to pursue reducing costs of carbon abatement at a decadal level, the significant capital required to install carbon capture and storage equipment raises concerns that it will not be adopted at scale in hard-to-abate industries.[71,72] Globally, there are only 27 fully operational sites.[73]

5.2 Strengths and limitations

The low number of projects registered for ACCUs under the CCS method complicates assessment of the strengths and limitations.

The CCS method has some strengths:

- **It is relatively straightforward to assess the additionality of a CCS project.** Capital outlays for the technology are significant and so there are few incentives to establish a CCS program for carbon abatement without a functioning carbon pricing mechanism.
- **CCS occurs in a stable and controlled system. This improves the integrity of the method's measurability and verifiability.** CCS takes advantage of natural geological settings with large storage capacities that are relatively stable environments. Quantities of gas captured are measurable both at capture point and at injection into storage sites and has the advantage of direct measurement of greenhouse gases themselves, rather than proxy measures applied in other methods. Monitoring requirements in the legislation are long-term and project emissions are included in detail against the abatement.
- **Effective uptake of CCS in hard-to-abate industries can mitigate risk of economic carbon leakage.** The current (short to medium term) alternative to geological carbon storage for many of these stationary sources is venting greenhouse gases into the atmosphere (100% 'leakage') or cessation of industrial activity and imports from other jurisdictions – i.e. economic leakage. Ensuring emissions are reduced in Australia rather than importing them from overseas is the primary argument for incentivising CCS projects in Australia, along with the energy security benefits from this approach.

The limitations of this method are primarily ones of scale, storage and transparency.

- **Storage options for captured carbon are limited**. There is a finite limit to carbon storage space and competing demand for storage sites.[74] Carbon utilisation may reduce demand for storage.
- **CCS eligibility for the ERF may delay emission reductions achieved through oil and gas transitions** or perpetuate a narrative that this is the primary use of the technology. Some have argued that the use of CCS will not result in real and effective carbon abatement to achieve global climate goals if adopted by greenhouse gas emitting industries in its current form. This would arise from the perception that CCS can offset scope 1 emissions while failing to consider the increase in scope 3 emissions from expanding oil and gas projects.
- **CCS is not suitable for completely offset carbon emitting industries.** While an important technology for unavoidable carbon emissions (for example, producing concrete and steel needed to build wind turbines) there is some concern that CCS would also support carbon emitting operations to be expanded in place of prioritising the development of lower carbon alternatives. Given CCS does not operate at 100% efficiency, this would result in overall increase in emissions.
- **Reliance on confidential information.** Approval for CCS projects requires a potential operator to provide evidence that they have yet to make an investment decision. This would presumably be subject to commercial confidentiality, raising difficulties with transparency and verifiability.

Experience of projects overseas requiring greater data openness suggests this could be amended and managed within the scheme.[75,76]

5.3 Carbon capture and storage opportunities

Improvements to the CCS method must strike a balance between the need to incentivise high-emission, hard-to-abate sectors to utilise the CCS method, and the currently limited scale of carbon capture and storage technology.

Perceptions of capture technologies undermine the real and perceived integrity of the application of this method. At time of writing only one project is registered under the CCS method and has not yet accrued ACCUs. It is yet to be seen whether this method will generate significant incentives for the deployment of CCS for hard-to-abate sectors.

There is uncertainty and competing rhetoric as to whether CCS's application in oil and gas sectors supports just transitions into lower carbon economies, or perpetuates continued reliance on fossil fuels over prioritising the development of other energy sources. This goes beyond solely scientific assessment but is important to consider in the context of achieving real carbon abatement essential for meeting global climate targets.

The continuing challenge will be ensuring that future iterations of this method, including the carbon capture, storage and utilisation method under development, adhere strictly to the integrity offset standard relating to the evidence base—particularly for long-term and genuine carbon abatement.

In all cases, CCS technologies and future CCUS technologies considered for generating ACCUs will need to be expanded to achieve the scale required for limited warming scenarios. CCS methods under the ERF could be improved by ensuring flexibility to respond and include these improved technologies as they become market-ready without the need to develop a new method.

6. Other opportunities for improvements to the methods

There are opportunities for improvement in the four methods for generating ACCUs examined. Many of these are operational or method specific as discussed below, but there are some broader opportunities for improvement across the methods.

The first objective of the Act is to remove greenhouse gases from the atmosphere. Other objectives revolve around incentives, biodiversity, and resilience.[9] Over the decade of operation, the scheme has become less a climate policy instrument, and more an industry policy mechanism. While industrial strategy objectives are not unimportant, **there is a need to reinforce that the ACCU scheme is fundamentally for the removal, and avoidance, of greenhouse gas emissions.**

Fundamental reform will be needed to reassert the primary objective of the Act—greenhouse gas removal—as the highest priority.

6.1 Address complexity and improve scientific transparency

Methods could be simplified in their description, regulation, and operation. In many cases, overcomplexity has raised the bar too high for the expertise required to engage and assess the methods.

Furthermore, improved transparency would enhance the overall system. All reports from ERAC should be made publicly available. When methods are amended, if possible, reforms should avoid dependence on confidential commercial information that is not available for public scrutiny.[19–21]

As described above, explicit framing of the scientific principles underpinning the methods would strengthen confidence in the overall system. Similarly, a more proactive, explicit and clear framing of the intent behind each method would ameliorate integrity concerns. For example, the CCS method is not to be used for enhanced oil recovery; it is to be used for hard-to-abate sectors. The AD method is about avoiding the greenhouse gas potential stemming from land clearing permits.

6.2 Mandatory cancellations

Increasing and broadening the scope of mandatory cancellations in the ERF could enable system-level improvements and build in additional conservativeness. Mandatory cancellations mitigate the risk that one ACCU does not represent one tonne of carbon dioxide abated, acknowledging the uncertainties inherent even in the perfect application of scheme methods. When an ACCU is issued, a proportion of it would be cancelled. For example, with a cancellation rate of 10%, if a project operator's abatement results in what would be ten ACCUs, one ACCU would be cancelled at issuance.

The risk of reversal buffer is a form of mandatory cancellation (intended to incorporate the risks that stored carbon can be rereleased), but only applies to sequestration projects and is not applicable scheme wide.[7]

Biodiversity offset schemes have found that 'no net loss' approaches tend to result in loss, and only 'net gain' approaches improve biodiversity outcomes.[22] Applying this understanding to carbon abatement goals and embedding mandatory cancellation across the offsets scheme would increase the chance that the ERF continues to achieve emissions reduction, as well as increasing the conservatism of the scheme in light of integrity concerns.

Furthermore, the lack of a systemwide cancellation would put the ERF behind international standards. The Paris Agreement's carbon market has an "overall mitigation of global emissions" cancellation of 2%, but this is at the low end of possible outcomes, with some analysts considering cancellations up to 30%.[6,77,78] Having cancellation rates lower than the Paris Agreement could pose reputational risks for the ERF.

Additional mandatory cancellations could also bring about co-benefits. Revenue from scheme-wide mandatory cancellation of ACCUs could be distributed to relevant local stakeholders or contribute to funding research for the improvement of monitoring and measurement capabilities, in turn enhancing community confidence in the integrity of the overall system.

Even a relatively simple policy instrument has major complexities. Key considerations that must be made at the outset should include who decides how money is spent, how to decide, how much should be spent for what purpose, and by when. Furthermore, mandatory cancellations should only be implemented *in addition to* and not in place of improving the integrity of the methods.

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Conflicts of interest declaration

This review incorporates input from Australian experts directly involved in research on and related to the topics covered in this report. Many of these contributors and reviewers have worked directly on studies and reports cited in this briefing. Contributors and reviewers are drawn from a range of institutions, initiatives, and fields, and collectively provide an independent and authoritative perspective on this topic.

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