Incentivising and accounting for negative emission technologies

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Abstract

Unlike conventional greenhouse gas abatement technologies, which generally only eliminate or reduce emissions towards zero, negative emission technologies are able to remove CO\textsubscript{2} from the atmosphere. One such technology is the application of carbon capture and storage (CCS) to biogenic CO\textsubscript{2} sources (bio-CCS), such as those arising from biomass combustion (e.g. heat and electricity generation) or biomass decay (e.g. during fermentation processes in the production of bioethanol). This paper considers various greenhouse gas emission accounting frameworks as to how they record negative emissions, and whether this creates an incentive for their use.

1. Introduction

Unlike conventional greenhouse gas emissions abatement technologies, which generally only eliminate or reduce emissions towards zero or add carbon to the less permanent biological pool, negative emission technologies are able to achieve long-term removal of CO\textsubscript{2} from the atmosphere. One such technology is the application of carbon capture and storage (CCS) to biogenic CO\textsubscript{2} sources (bio-CCS; also widely referred to as ‘BECCS’), such as those arising from biomass combustion (e.g. in generating heat and electricity) or biomass decay (e.g. during fermentation processes in the production of bioethanol). As plants grow, they absorb (or ‘remove’) CO\textsubscript{2} from the atmosphere, which is typically re-released back to the atmosphere upon combustion or biological decay of the harvested biomass.

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Using CCS to capture and store the CO₂ from such sources can remove carbon from the short-term biological cycle and lock it up for long periods of time in the geological carbon pool, leading to a net reduction in atmospheric CO₂.

Interest in negative emission technologies, in particular bio-CCS, has grown over recent years because of their potential benefits when compared to conventional emissions abatement measures. These include:

- The capacity to accelerate reductions in atmospheric concentrations of CO₂ compared to just reducing the rate of addition to the atmospheric pool;
- The capacity to remove or compensate for historical emissions by removing their legacy from the atmosphere (these two aspects are important if action to mitigate greenhouse gas emissions is delayed in the first part of this century, as is becoming increasingly likely [1]); and,
- The ability to reduce the overall costs of climate change mitigation by offsetting more difficult to abate – or ‘recalcitrant’ – emission sources (e.g. emissions from aviation) [2, 3, 4, 5].

These benefits have recently been highlighted by several influential international institutions, including: the United Nations Environment Programme [6, 7], the Intergovernmental Panel on Climate Change [8], the International Energy Agency [9, 10, 11], and the United Nations Industrial Development Organisation [12]. Notwithstanding the growth in international recognition of the benefits, recent literature has highlighted that certain low carbon policies and measures – and associated greenhouse gas accounting rules – do not adequately recognize, attribute and reward negative emissions [2, 5, 12, 13]. As such, the policy incentives for deploying bio-CCS are uncertain, thereby hampering its development. The accounting rules and their link to incentivizing bio-CCS is the focus of this paper.

Nomenclature

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>2006GLs</td>
<td>2006 IPCC Guidelines for National Greenhouse Gas Inventories</td>
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<tr>
<td>bio-CCS</td>
<td>Biomass energy with carbon capture and storage (also widely referred to as ‘BECCS’)</td>
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<td>CDM</td>
<td>Clean development mechanism</td>
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<td>C-LCFS</td>
<td>California Low Carbon Fuel Standard</td>
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<tr>
<td>ETS</td>
<td>Emissions trading scheme</td>
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<td>EU ETS</td>
<td>European Union emissions trading scheme</td>
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<td>EU MMR</td>
<td>EU ETS Monitoring and Reporting Regulation</td>
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<td>FQD</td>
<td>EU Fuel Quality Directive</td>
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<tr>
<td>GHGRP</td>
<td>US Mandatory Greenhouse Gas Reporting Program</td>
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<td>LUC</td>
<td>Land use change</td>
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<tr>
<td>NGER</td>
<td>Australia National Greenhouse and Energy Reporting (Measurement) Determination</td>
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<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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2. Basis for negative emissions accounting

The scientific basis for negative emissions was highlighted in the introduction. When applying this theory in the context of greenhouse gas emissions accounting, the approach is as follows:

1. That when biomass grows, it is assumed to remove carbon from the atmosphere and convert it into organic carbon in the form of plant matter. The mass of carbon absorbed by the biomass is recorded in an accounting scheme as a CO₂ emissions removal (from the atmospheric carbon pool).
2. When biomass is harvested, its carbon content is released as an emission through combustion, fermentation or natural decay processes. For accounting purposes, this is assumed to be an instantaneous process that leads to full oxidation of the carbon in the biomass, and is recorded in an accounting scheme as a CO₂ emission (back to the
atmospheric carbon pool). The emissions offset the removal achieved during growth, leading to a zero net sum when considering carbon stock changes in the biogenic carbon pool;

3. When CO₂ is captured and stored in geological formations, it is not emitted to the atmosphere. This is recorded as an emission reduction.

4. When CO₂ from biomass combustion or decay is captured and geologically stored, the zero net emissions from growth and harvesting needs to be subtracted as an emission reduction, resulting in ‘negative emissions’ equal to the amount of CO₂ captured and stored.

On a lifecycle basis, other emissions would need to be included such as emissions from biomass harvesting machinery, and the energy penalty associated with capturing, transporting and injecting the CO₂, as summarized below (Fig. 1). Other factors may also need to be considered such as land-use change effects (LUC) in the growth and harvesting cycle, which can lead to overall changes in emissions (discussed further below).

3. Negative emissions accounting in practice

Various greenhouse gas emissions accounting rules are in place around the world, each with slight variations in purpose and scope depending on the scheme under which they are applied. These include:

- **International accounting rules** – namely those available for national governments to use in preparing their country’s greenhouse gas inventory reports under the United Nations Framework Convention on Climate Change (UNFCCC). The most recent edition is the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (2006 GLs; [14]) which are likely to be in force from 2015, at least for developed country Parties to the UNFCCC. The approach taken is economy-wide and includes accounting rules for both CO₂ emissions and removals by greenhouse gas sinks such as forests and other types of land use;

- **Project-based scheme accounting rules** – project-based greenhouse gas offset schemes can provide useful guidance on accounting rules. The main scheme in this context is the Kyoto Protocol’s clean development mechanism (CDM), although other project-based ‘offset schemes exit in the US and Canada. Whilst specific issues relating to bio-CCS activities have not been addressed, analogues within the schemes highlight options for negative emissions accounting;

![Fig. 1. Greenhouse gas emissions accounting for bio-CCS with negative emissions (adapted from [2])](image-url)
Regional, national and sub-national accounting rules – these cover policy measures in place to control greenhouse gas emissions in various jurisdictions, such as cap-and-trade based emissions trading schemes, and the attendant monitoring and reporting rules in force thereunder, and mandatory emission reporting programmes. Key amongst these are the European Union’s emissions trading scheme (EU ETS) Monitoring and Reporting Regulation (EU MRR; [15]), AB32 Mandatory Greenhouse Gas Reporting Rule (applied under California’s emissions trading scheme (ETS); [16]), the US Environmental Protection Agency’s Greenhouse Gas Reporting Program (GHGRP; [17]), and Australia’s National Greenhouse and Energy Reporting (Measurement) Determination, 2008 (NGER; [18]). These schemes are focussed on sectors of the economy with the highest point source greenhouse gas emissions, such as power generation and industry. The schemes’ general architecture and boundaries can create issues for recognising negative emissions;

Product-based schemes – this includes approaches such portfolio standards for the greenhouse gas intensity of fuels sold and used in certain market. These include California’s Low Carbon Fuel Standard (C-LCFS; [19]) and the EU Fuel Quality Directive (FQD; [20]) and primarily the rules for calculating biofuel greenhouse gas emissions intensity and managing sustainability thereunder. These policy instruments adopt a portfolio standards/mandates approach on operators to limit the emissions associated with the supply of energy products – namely liquid transport fuels – into markets.

There are a number of factors affecting the capacity of the account rules applicable under the various schemes to recognize, attribute and reward negative emissions, including:

- Whether emission removals and CCS are included within the scheme – of those highlighted above, only the UNFCCC reporting requirements and those applicable under the C-LCFS and the FQD take account of land use and forestry removals. With the exception of the California ETS, all of the schemes reviewed include CCS within their rules;
- How the schemes’ baseline mechanism operates – for example, under cap-and-trade schemes, a qualifying entity or facility is only required to surrender emission rights equal to the amount of emissions occurring for a given period, usually a calendar year. If no emissions occur, the entity does not face any penalties under the scheme (i.e. the baseline is zero). This means that ‘negative emissions’ are not implicitly recognized within a scheme unless it includes a mechanism for providing ‘credits’ to an entity going beyond the baseline of zero (i.e. through negative emissions). On the other hand, under a project-based scheme, negative emissions can be recognized as these usually always involve the issuance of ‘credits’ against a baseline minus actual emission irrespective if these are negative;
- What the scheme compliance entity is – this affects the capacity to ‘net-back’ any negative emissions against positive emissions occurring elsewhere across a portfolio of emissions. This can work on a country level where there is a broad portfolio of emissions sources, but most cap-and-trade schemes operate on single a facility compliance level, and do not generally allow pooling across multiple facilities to allow them to act as a single compliance entity.

A diagrammatic representation of these differences is presented below (Fig. 2), and the result of analysis of different schemes is set out in the next section.

3.1. Status of negative emissions under various schemes

International accounting rules in the 2006 GLs allow for negative emissions from bio-CCS to be recorded and recognised in national greenhouse gas inventories for Parties to the UNFCCC. Similarly, project-based schemes such as the CDM, the C-LCFS and the EU FQD all potentially allow for negative emissions achieved using bio-CCS to be recognised within the ambit of their respective accounting rules.
This occurs for two reasons:

- Either the scheme compliance operates at a portfolio level, allowing negative emissions to be ‘netted back’ against positive emissions elsewhere in the portfolio (e.g. against other emissions in a county; or other emissions in a fuel suppliers portfolio); or,
- It allows “credits” to be generated (as in the CDM).

For the latter, credits can be generated based on the emissions for an alternative scenario (the baseline), minus the emissions for the actual activity (which in the case of bio-CCS could be negative), giving rise to net positive credits (Fig. 2).

On the other hand, GHG accounting rules under regional cap-and-trade schemes do not generally recognise and attribute negative emissions should they arise. Under the EU ETS, only the mass of ‘fossil carbon’ transferred for geological storage may be deducted from an installation’s greenhouse gas inventory, which prevents negative emissions from bio-CCS being recognized (including in the case of co-firing of biomass with coal). Further, installations exclusively using biomass are exempted from the scheme, thereby excluding the recognition and rewarding of bio-CCS at plants exclusively burning biomass. Several options to address these shortfalls are available, as outlined below. Notwithstanding these barriers and options to address them, any amendment to the EU ETS rules would need to be accompanied by an approach to reward negative emissions. Presently, whilst the scheme’s architecture potentially allows for pooling (i.e. ‘netting-back’ at a portfolio level) and the use of domestic offsets (i.e. crediting), these elements of the legislation are largely defunct. Also, mechanisms to allocate ‘EU Allowances’ (EUAs) – the emission rights units employed under EU ETS – to an installation that accounts for and reports negative emissions do not exist.

Consultations are currently underway on revisions to Australia’s NGER to clarify the treatment of CCS, although this does not include consideration of bio-CCS and negative emissions [20]. However, since large emitters are not required to report emissions from biomass combustion, the scheme is not able to recognise negative emissions in its current format.
The California ETS does not allow for negative emissions to be recognised because an appropriate ‘quantification methodology’ for CCS does not yet exist under the scheme [16]. A summary of various schemes’ capacity to recognise and attribute negative emissions is outlined below (Table 1).

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Inclusion of removals</th>
<th>Inclusion of CCS</th>
<th>Compliance entity</th>
<th>Recognition of negative emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNFCCC, Kyoto Protocol 2006 GLs</td>
<td>Yes</td>
<td>Yes</td>
<td>Country</td>
<td>Yes</td>
<td>Explicitly acknowledged for bio-CCS in 2006 GLs (Vol. 2 Ch. 2)</td>
</tr>
<tr>
<td>CDM</td>
<td>Yes</td>
<td>Yes</td>
<td>Project-based</td>
<td>Yes</td>
<td>In theory, although never applied to date</td>
</tr>
<tr>
<td>EU ETS</td>
<td>No</td>
<td>Yes</td>
<td>Installation</td>
<td>No</td>
<td>Operators may only record transfers of ‘fossil’ CO$_2$ for CCS as emission reductions [14]</td>
</tr>
<tr>
<td>GHGRP</td>
<td>No</td>
<td>Yes</td>
<td>Facility</td>
<td>No</td>
<td>Biomass entities excluded from reporting requirement</td>
</tr>
<tr>
<td>NGER</td>
<td>No</td>
<td>Partial</td>
<td>Large emitters</td>
<td>No</td>
<td>Biomass entities excluded from reporting requirement</td>
</tr>
<tr>
<td>California ETS</td>
<td>No</td>
<td>No</td>
<td>Facility</td>
<td>Possible – subject to inclusion of CCS within the scheme</td>
<td>A methodology for CCS is yet to be recognized by the Air Resources Board (see Article 5, §95852(g) in [16])</td>
</tr>
</tbody>
</table>

Source: Based on [2]

The current status means there is a disconnect between the benefits available to countries employing bio-CCS and claiming negative emissions under the UNFCCC, and the incentive mechanisms in place to promote private sector uptake of the technology in order to contribute to this outcome. For example, in the EU, whilst a country could potentially meet emission reduction targets in place under the second commitment period of the Kyoto Protocol using negative emissions from bio-CCS, private operators (of e.g. power plants) are not incentivized to deploy the technology. This is because it is not recognized under the EU ETS, despite this being the primary policy instrument in Europe for member states’ to regulate emissions from large point sources in order to meet their international commitments. Similar sentiments also apply in the other jurisdictions reviewed. However, it seems logical to utilize every policy tool possible to meet international emission reduction commitments. As such, further consideration of the role of bio-CCS – and related incentives – should be made. For example, in the EU, by changing the CO$_2$ transfer provisions of the MRR to allow inclusion of ‘biogenic carbon’, and consideration of ‘crediting’ options such as the use of an ‘Allowance reserve’ from which to allocate EUAs to operators in the event of negative emissions being reported.

4. Other issues for bio-CCS and negative emissions

There are two other important issues to take into account when considering incentivizing widespread take-up of bio-CCS in the coming years, namely:
• Whether, given the additional benefits offered by bio-CCS relative to more conventional ‘fossil’ CCS, additional incentives or rewards should be made available to bio-CCS activities; and,
• The potential LUC effects that could arise from deploying bio-CCS, particularly on a large scale that is potentially required to meet ambitious emission reductions targets in the middle to later part of this century (see e.g. [1, 6, 7, 8, 11])

These two items are considered further below.

4.1. Setting an appropriate level of incentive

Offering additional incentives for bio-CCS relative to other types of CCS applications may be warranted on the basis of the potential double dividend offered by the technology in (i) reducing emissions from fossil fuel combustion through the substitution of e.g. coal with biomass, and (ii) reducing emissions below zero by applying CCS. Problematically, the benefits from substitution of fossil fuel for biomass is typically forgone under schemes such as regional cap-and-trade programmes as it is inherently included within a scheme’s ‘baseline’ (see Fig. 2). Consequently, only the negative quotient of emission reductions could be recognised, which means that bio-CCS effectively competes on a per tCO₂ reduction basis with other mitigation options including substituting coal for biomass, or applying CCS to fossil CO₂ sources. For example, emissions from a power plant combusting biomass are typically exempted under cap-and-trade rules; therefore, credits could only be theoretically generated equal to amounts of CO₂ captured and stored, and would not include the coal substitution effect. This means that the use of CCS at fossil fuel fired power plant, or the substitution of fossil fuel for biomass, would therefore actually receive the same level of reward, resulting in bio-CCS having to compete for investment on a tCO₂ for tCO₂ reduction basis with coal substitution or CCS at fossil-fuel fired power plants. Arguably, this is correct since the level of actual emission reductions achieved is comparable. But on the other hand, it offers no additional incentives for undertaking bio-CCS compared to fuel switching or fossil-CCS as the net effect is to recognise CCS on a fossil and a biogenic CO₂ stream on the same per tCO₂ stored basis. Project-based schemes can overcome this problem if the fuel substitution abatement effect is included within the baseline (i.e. if the baseline is for an equivalent fossil fuel source; Fig. 2).

Taking this challenge into account, when designing policies to support bio-CCS, two potential schools of thoughts are possible: (i) a centrally-planned view, taking the position that the benefits of bio-CCS need to be prioritised whilst also phasing out fossil fuels. On this basis, bio-CCS should be given additional incentives compared to only biomass substitution or CCS on fossil CO₂ sources. This could be take a variety of forms, including through emissions trading type approaches (e.g. tradable ‘credits’), or other measures such as feed-in tariffs or ‘green certificates’; and, (ii) the economic purist view that carbon markets can drive innovation, and that, aside from certain niche circumstances where it is advantageous to do so, ultimately bio-CCS might only be deployed as and when only more recalcitrant emission sources/more costly abatement options remain to be tackled (see also [4] for a discussion in this context). The latter school of thought suggests the existence of negative emission technologies should in principle allow policy-makers to be more ambitious in establishing greenhouse gas emission reduction targets in the next few years.

4.2. Managing potential land use effects

The assumption that the combustion or decay of biomass leads to zero emissions provides the basis for calculating negative emissions from bio-CCS where such sources are captured and stored. However, the zero emissions assumption is predicated on the growth and harvesting of biomass being in equilibrium (i.e. growth and harvesting lead to equal removals and emissions of CO₂ on a carbon stock basis in forests). However, this is not necessarily always the case. Significant controversy has arisen regarding the promotion of biofuels in jurisdictions such as the US and EU, and the effects of energy crop cultivation on land degradation and loss of biological carbon stocks as a result of LUC when converting forests to cropland or plantations. Assessing the extent to which this is occurring and being accounted for is dependent on establishing a robust monitoring system for Land Use, Land Use
Change, and Forestry (LULUCF) and effects of Reducing Emissions from Deforestation and Forest Degradation (REDD) activities under e.g. the UNFCCC. However, at present such monitoring schemes are generally patchy and poorly implemented across many parts of the world, especially in developing countries. Consequently, bioenergy can be imported into regulated jurisdictions, and greenhouse gas emission reduction benefits accrued upon its use (e.g. under the EU ETS), absent of consideration of the LUC effects and associated greenhouse gas emissions – as well as more general sustainability impacts – occurring upstream in the fuel supply chain.

In order to tackle this issue, policies such as low carbon fuel standards include detailed greenhouse gas removal and emission accounting rules for calculating the upstream emissions from biomass growth, harvesting, transport, processing and, to some extent, LUC effects. These effects are then taken into account in the emissions at the point of use. Such quantitative approaches – although not without controversy – do set out to address the issues presented by inadequate LULUCF and REDD monitoring and reporting around the world.

On the other hand, regional cap and trade programmes aimed at regulating emissions in electricity and heat production and industrial activities do not generally include such considerations. Exceptions are the California ETS, which restricts the application of a zero-emissions factor to only a few specific biomass types. In an attempt to address this concern, the EU recently clarified the sustainability requirements for zero-rating biomass used in the EU ETS, including for it to be compliant with national and voluntary sustainability schemes that demonstrate good practice in land use [22]. The US EPA has also considered the scope for introducing measures to take account of the upstream effects of biomass use in the GHGRP by using ‘biogenic adjustment factors’, although it has not yet implemented such measures [23]. Notwithstanding these recent developments, there still remains significant latitude for LUC effects to go unrecorded when applying a zero-emission assumption approach to biomass combustion.

5. Conclusions and recommendations

The analysis presented suggests that are several issues to address in incentivising the uptake of bio-CCS technologies and accounting for the negative emissions that they can generate. The biggest issue is that whilst countries can account for negative emissions within national greenhouse gas emissions inventories submitted under the UNFCCC and Kyoto Protocol, the incentive cannot be readily passed onto private developers through existing cap-and-trade schemes and/or greenhouse gas reporting programmes. On the other hand, project- and product-based schemes can recognize negative emissions. Options to overcome the issues for cap-and-trade programmes include allowing pooling of compliance entities to allow ‘net-back’ accounting between positive and negative emitting facilities, or the use of ‘credits’ to reward negative emissions (either from a dedicated allowance reserve or through the use of project-based mechanisms within the scheme).

A further challenge is how to effectively incentivize negative emission technologies. As often the benefits of substituting fossil fuel (e.g. coal) for biomass are foregone under a cap-and-trade scheme, the benefits rewarded to a bio-CCS project are the same as applying CCS to a fossil-fuel CO₂ source on a tonne for tonne reduction basis. There are options to overcome this through creation of additional incentives for negative emission technologies, such as through complimentary measures such as feed-in tariffs or crediting approaches.

Any future discussions regarding support measures for bio-CCS should include consideration of requirements to address greenhouse gas emissions from LUC, as well as other sustainability concerns associated with biomass supply. Without addressing such concerns, the creditability of negative emission claims could be placed under scrutiny as the zero-emission assumption on which it is predicated may not be correct.

Several actions are possible to address these issues:

- The undertaking of further consultation with the European Commission – DG Climate Action, the Australian Clean Energy Regulator, and the California Air Resources Board (CARB) by interested stakeholders to clarify the status of bio-CCS and to discuss potential options to recognise and reward negative emissions;
• Further analysis should be made with respect to the potential level of reward offered to bio-CCS projects relative to other types of CCS projects. There are potentially two approaches based on either direct action to incentivize the technology, or reliance on the use of market-based instruments (e.g. the EU ETS) to bring forward investment into the technology. There are merits to both approaches that should to be taken into account;

• In making considerations of the ‘upstream’ LUC effects potentially driven by bio-CCS, it is important to be mindful of the parity of treatment of biomass fuels compared to fossil fuels. The latter do not need to account for ‘upstream’ emissions in their supply chain under most of the accounting rules reviewed, the exception being project- and product-based approaches. However, the scope for opening up this broader discussion is likely to make for a complex political process; experiences in Europe in implementing Article 7(a)(5) of the FQD (relating to the calculation of life cycle greenhouse gas emissions from fossil fuels) – that continues to be debated with the European Commission more than four years after adoption of the Directive – suggests the challenges of such an approach could be considerable.

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[16] CCR, Title 17 (Public Health), Division 3 (Air Resources), Chapter 1 (Air Resources Board), Subchapter 10. Climate Change - Regulation for the mandatory reporting of greenhouse gas emissions.


