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**ABSTRACT**

I distinguish between reduction offsets and removal offsets, the former generated by a reduction in the rate of greenhouse gas emissions and the latter generated by the removal of greenhouse gases from the atmosphere. I show that only removal offsets make any contribution to mitigating climate change. There is a simple intuitive explanation: a firm buys an offset to compensate for the fact that it is emitting greenhouse gases and plans to continue to do so. What should "compensate" mean in this context?That the purchase of the offset undoes the negative impact of the continuing emissions on the climate. This can only happen by the removal from the atmosphere of a quantity of greenhouse gases equal to that emitted by the purchaser of the offset. So an offset which compensates for the climatic impact of emissions has to remove greenhouse gases from the atmosphere. I also review carbon offsets generated by forest management, as of all currently-traded offsets these are the closest to removal offsets.

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# Greens are Right to be Suspicious of Carbon Offsets

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**Abstract**

I distinguish between reduction offsets and removal offsets, the former generated by a reduction in the rate of greenhouse gas emissions and the latter generated by the removal of greenhouse gases from the atmosphere. I show that only removal offsets make any contribution to mitigating climate change. There is a simple intuitive explanation: a firm buys an offset to compensate for the fact that it is emitting greenhouse gases and plans to continue to do so. What should "compensate" mean in this context? That the purchase of the offset undoes the negative impact of the continuing emissions on the climate. This can only happen by the removal from the atmosphere of a quantity of greenhouse gases equal to that emitted by the purchaser of the offset. So an offset which compensates for the climatic impact of emissions has to remove greenhouse gases from the atmosphere. I also review carbon offsets generated by forest management, as of all currently-traded offsets these are the closest to removal offsets.
**Key words**: carbon offset, carbon credit, greenhouse gas, afforestation, reforestation, reduced deforestation, REDD+

## 1 Introduction

Most corporations that are planning to reduce their emissions of greenhouse gases, are planning to do so by the use of carbon offsets, also known as carbon credits. This means that it is crucial to understand what the use of such offsets can and cannot contribute to the mitigation of climate change. There are actually two distinct questions here, and it is important to keep the difference clear.

One concerns the integrity of offsets: do they really meet the additionality criterion? Are they leakage-free? Are they permanent? There is a widespread and growing recognition that many of the extensively-traded carbon offsets fail on some and possibly all of these criteria, meaning that their contribution to climate change mitigation is limited at best, and negligible at worst (for reviews, see Calel et al. [1], Conte and Kotchen [2] and Gillingham and Stock [3]).

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But this question has been explored and it is not the one that is the focus of this paper (see IPCC [10] ). Here I want to ask a question that is in some ways deeper and simpler. Suppose for the sake of argument that offsets do meet the additionality, no-leakage and permanence conditions, and any others that seem appropriate. In this best of all cases, is their use consistent with meeting the target of a zero-emission world? This, slightly surprisingly, is a question that has not received the same amount of attention as the first. I am going to suggest that to answer this question we need to distinguish between two classes of offsets, which will be called *reduction offsets* and *removal offsets*. Most offsets are in the former category. And I will show that the widespread use of these reduction offsets is incompatible with a world economy with zero net emissions of greenhouse gases, that is with an economy where the atmospheric stock of greenhouse gases is constant or falling. As most of the offsets currently traded are reduction offsets, this finding has important implications. It suggests a need for regulation of offsets traded, with a clear statement of what classes of offsets are acceptable and what are not. Those ruled out will be the great majority of currently-used offsets.

Let me clarify the distinction between reduction offsets and removal offsets. The reduction/removal distinction is one that I first made in Heal [5], and I am developing it and its implications further here. Reduction offsets are generated when an emitting entity reduces its emissions below what they otherwise would have been. Examples would be utilities switching from coal to wind power (see [10]), a landfill capturing methane, a truck fleet switching from internal combustion engines to electric vehicles. Currently in each of these cases there is potential for the reducing entity to sell offsets equal to the amount of the reduction, provided of course that the reduction meets the additionality, no-leakage and other criteria mentioned above. All of these offsets are based on a counterfactual assumption - what would have happened if certain actions had not been taken.

A removal offset, in contrast, is generated when an entity removes a ton of CO2 from the atmosphere. The simplest model here is a direct air capture company removing a ton of CO2 via its proprietary technology - companies such as Carbon Engineering, Climeworks and Heirloom Carbon[1] all offer removal-based offsets. Reforestation and afforestation also remove CO2 from the atmosphere, as to some degree does forest conservation. I will discuss the characteristics of forest conservation in more detail below.

## 1.1 Intuitive Explanation

There is a simple intuitive explanation of why removal offsets should be acceptable and reduction offsets should not. A firm (or other entity) buys an offset to compensate for the fact that it is currently emitting greenhouse gases and plans to continue to do so. What should "compensate" mean in this context? The only reasonable meaning is that the purchase of the offset undoes the negative

[1] carbonengineering.com, climeworks.com and heirloomcarbon.com

impact of the emissions on the climate. This can only happen if it removes from the atmosphere a quantity of greenhouse gases equal to that emitted by the purchaser of the offset. So an offset which compensates for the climatic impact of emissions has to remove greenhouse gases from the atmosphere: reducing the rate of emissions by some other entity in no way compensates and cannot be the basis of an offset.

There is another way of thinking about the problem here, which is that by allowing reduction offsets we are implicitly double counting the reduction in emissions of the entity that sells the offset. It counts as a reduction for the seller, who now has and can claim lower emissions, and it also counts as a reduction for the purchaser who can claim reduced emissions. One way of solving this problem would be to prevent the seller of the offset from claiming a reduction in emissions: the right to claim the reduction now rests with the purchaser of the offset and this excludes the reducer from making this claim. If they sell an offset, then in their carbon accounts they have not reduced emissions. This is in fact a provision of the Paris Agreement of the UNFCCC, whose Article 6 paragraph 2 (page 7 of the English version) states that "Parties .... shall apply robust accounting to ensure, inter alia, the avoidance of double counting, ....". However there is no provision of this type in effect in any country, as emissions reductions are voluntary. Mandatory reductions accompanied by the Paris Agreement's "robust accounting" are a long way off.

Section 2 formalize this in a simple mathematical model. The model proves that the total value (in tons of CO2-e) of reduction offsets[2] traded is a lower bound for the level of CO2-e emissions, so that emissions can never be zero while reduction offsets are used.

## 1.2 A Numerical Example

Before introducing a general model, it is helpful to consider a simple numerical example. Consider a world with two firms, firm A emitting 150 tons of CO2 per year and firm B emitting 100 tons. Firm B reduces its emissions to zero, and sells a 100 ton reduction offset to firm A. Firm A reduces its emissions by 50 tons to 100 tons and buys the offset. So now firm B is producing zero emissions - it is net and gross zero. Firm A is emitting 100 tons but has purchased the 100 ton offset and so can claim to be net zero. Each firm has a claim to producing zero (net) emissions. Total emissions are 100 tons, equal to the offsets traded, and the concentration of CO2 in the atmosphere is rising.

Now suppose that reduction offsets are not allowed, but that there is a market in removal offsets. Firm B again reduces its emissions to zero, and firm A reduces by 50 tons to 100 tons. It pays someone - a direct air capture company or a forestry operation - to remove 100 tons of CO2 tons from the atmosphere, i.e. buys 100 tons of removal offsets. The economy's net atmospheric emissions are now zero, and CO2 concentrations are constant.

The following sections show that this result is general.

[2] Because of a typo, an earlier version of this paper referred here to reduction offsets rather than removal offsets.

## 2 Reduction Offsets

Consider an economy with $I$ firms indexed by $i = 1, 2, ...I$. Each firm initially emits an amount of greenhouse gases[3] $e_i^0 \geq 0$, for a total emission of $E^0 = \sum_i e_i^0$. In a move to combat climate change, all firms reduce emissions to levels $e_i^1 \leq e_i^0$. There is a reduction offset market in which firms that have reduced emissions can sell to others the right to claim their reductions: firm $j$ offers for sale reduction offsets $O_j \geq 0$ where $O_j$ does not exceed the amount by which it has reduced emissions, $O_j \leq e_j^0 - e_j^1$. If firm $i$ buys reduction offsets $B_i \geq 0$ then its net emissions are said to be $e_i^1 - B_i = N_i$.

Suppose firms $i \in Z$ set $e_i^1 = 0$ and are zero emissions firms. These firms can sell offsets $O_i \leq e_i^0$ based on their reductions of emissions. Firm $i$, $i \notin Z$, maintains positive emissions $e_i^1$, with $e_i^0 \geq e_i^1 > 0$ and buys offsets $B_i$. If $B_i = e_i^1$ then firm $i$ is said to be a net zero emission firm: $i \in NZ$.

Total emissions are now $E^1 = \sum e_i^1 = \sum_{i \notin Z} e_i^1$ and the emissions of net zero firms are $E^{NZ} = \sum_{NZ} e_i^1 = \sum_i B_i$.

Clearly as $i \in NZ \Rightarrow i \notin Z$ it must be true that $E^1 = \sum_{i \notin Z} e_i^1 \geq E^{NZ} = \sum_{NZ} e_i^1 = \sum_i B_i$

Thus the following are true:

1. *Total emissions $E^1$ are still at least as high as the total of reduction offsets purchased $\sum_i B_i$. As long as $\sum_i B_i > 0$ and total offsets are positive, emissions are positive and the atmospheric concentration of CO2 is rising.*

2. *Total reduction offsets $\sum_i B_i$ provide a lower bound on emissions.*

3. *We can never attain zero emissions as long as reduction offsets are traded.*

The third point here is the crucial one: *we can never attain zero emissions as long as reduction offsets are traded.*

## 3 Removal Offsets

Assume now the same framework as above, except that reduction offsets are not allowed but an entity or entities dedicated to direct air capture of CO2 (DAC) can sell removal offsets to any firm $i$, in amount $R_i$ . Purchasing a removal offset means paying the DAC entity to remove a ton of CO2 from the atmosphere. A firm $i$ is a net zero firm now if $e_i^0 = R_i$. If every firm is net zero, $\sum_i e_i^0 = \sum_i R_i$, so the economy's total net emissions into the atmosphere are now zero. The same is true if some firms reduce emissions to zero and others purchase removal offsets. Total emissions after offset trades are now $E^1 = \sum_i e_i^1 - \sum_i R_i$ and if each firm is zero emissions or net zero emissions then $\sum_i e_i^1 = \sum_i R_i$ and $E^1 = 0$. *So the use of removal offsets is consistent with the economy having zero net emissions and holding the stock of GHGs in the atmosphere constant.*

[3] Measured in tons of CO2-e

# 4 Forest Offsets

Many offsets traded in voluntary markets are related to the management of forests. I will focus on three different types of forestry offset: those based on *afforestation* (growing a forest where none grew before), *reforestation* (replacing a forest previously cut down) and *avoided deforestation* (reducing the rate at which forests are cleared or degraded, as in the REDD+ system - for a review see [7] ). For a general review of the literature on forest and agricultural offsets see Gonzales-Ramirez et al. [4] and van Kooten et al. [6].

Of these three, the first two are clearly in principle acceptable. By this I mean that they do remove carbon dioxide from the air, and so are removal offsets. Of course, one has to check for additionality and non-leakage, and also for permanence - forests can burn down or be cleared. But in principle one can imagine fully valid removal offsets based on afforestation or reforestation.

Reducing deforestation raises more complex issues (see Coutino et al. [7]). Consider a forest of size $S$ hectares which sequesters from the atmosphere $s$ tons of CO2 per hectare per year, for an annual total of $sS$ tons sequestered. A fraction $c$ of this forest is being cleared each year, and the clearing of one hectare of forest leads to emissions from forest clearance of $e$ tons for a total emissions of $ecS$ tons each year. So the net emissions of this forest are $N = S\,(ec - s)$ tons of CO2 annually. Obviously $N \lesseqqgtr 0$ according as $ec \lesseqqgtr s$: for low values of $c$, low rates of deforestation, the forest is a carbon sink and for high values it may be a carbon source.

Now assume that the rate of deforestation is reduced from $c$ to $\tilde{c} < c$. If $ec > s$ this leads to a reduction in emissions from the forest, and if $ec < s$ it leads to an increase in the removal of CO2 by the forest. So a reduction in the rate of deforestation may generate a reduction offset (if the forest is a net emitter of CO2) or a removal offset (if the forest is a net remover of CO2). If the forest is initially a net emitter, then a big enough reduction in the rate of deforestation will convert it to a net remover of CO2. In such a situation, $e\tilde{c} < s < ec$.

## 4.1 A Numerical Example

To illustrate this point, here are some rough numbers. Consider a moist tropical forest of 100 million hectares (1 million square kilometers - the Amazon rainforest is about 6 million sq. km.) which absorbs in the range of 5 tons of CO2 per hectare per year.[4] Then this forest absorbs roughly 0.5 billion tons of CO2 annually. Assume that 2% is clear cut every year, i.e. 2 million hectares, and that clearcutting a hectare releases 300 tons of CO2.[5] Then the forest releases 0.3bn

[4] Reference [9] estimates that a region of the Amazonian forest absorbs 8.5 moles of CO2 per square meter per year, which translates into 374 tons per square km., while ChatGPT cites figures in the range of 500 to 100 tons.

[5] Reference [10] estimates that plant plus soil carbon in tropical forests is about 900 tons/hectare. I am assuming that about one third of this is released into the atmosphere on clearcutting.

tons $CO_2$ annually, so it is a net absorber of $CO_2$ to the extent of 0.2bn tons per year. In this case a reduction in the rate of deforestation would increase the rate of absorption of $CO_2$, i.e. the rate at which it is removed from the atmosphere, and is removal offset. If the deforestation rate were 4% per year, then the forest would be a source rather than a sink of $CO_2$ and reducing the rate of deforestation marginally would reduce the rate of $CO_2$ emissions and be a reduction offset. Reducing it substantially would tip the forest from being a source to a sink for $CO_2$.

## 5 Conclusions

As the title indicates, those concerned to mitigate climate change are right to be suspicious of the use of carbon offsets. Most of the offsets currently traded are incompatible with the economy achieving zero emissions and constant (or hopefully falling) concentrations of greenhouse gases in the atmosphere. However removal offsets are consistent with this goal, and fortunately the number of entities offering these offsets is increasing. DAC offsets are currently very costly - at least $600 per ton $CO_2$ - and are expected to fall in price. It is worth noting that this figure is below some recent estimate of the social cost of carbon Bilal and Kanzig [8], so that even at these prices it may be socially rational to fund DAC. It is certainly rational to fund appropriate forms of forest conservation and restoration.

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[10] Intergovernmental Panel on Climate Change, "Table 1: Global Carbon Stocks in Vegetation and Carbon Pools Down to a Depth of 1 m," IPCC Special Report on Land Use, Land-Use Change and Forestry: Summary for Policymakers, http://www.ipcc.ch/ipccreports/sres/land_use/003.htm.