Braskem

I'm green BIO-BASED

UPDATING CARBON ACCOUNTING RULES

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Net Zero
CIRCULAR ECONOMY FOR PLASTICS

The atmosphere's carbon concentration is regulated by a complex system that involves geological and biological mechanisms. There is an equilibrium between the carbon from the atmosphere, the oceans, and the land. **This equilibrium is called the natural carbon cycle.**

The carbon in fossil resources was once biogenic, but that was hundreds of millions of years ago. This means that the natural carbon cycles of today are **not prepared to deal with them.** Human activity is responsible for disrupting this balance by releasing carbon stored in geological reservoirs to the atmosphere at a rate far greater than what the natural cycles can cope with.

We need to rethink the usage of fossil resources if we want to deal with the climate change crisis. The energy sector is switching to renewable sources, such as wind, solar, photo-voltaic, geothermal, etc. Many other industrial sectors are also trying to decarbonise their business models.

Unlike other industrial sectors, the production of materials like paper, textiles and plastics cannot be decarbonised. These materials are made of carbon molecules, and the goal here is not only to reduce the emissions related to production process, but also to de-fossilise the products themselves. Meaning, we need to produce materials without using fossil carbon and use renewable carbon instead.

The circular economy will help maximise the time resources spend in use, which will maximise the value of our products. Circular systems, however, are not 100% efficient and so losses will occur and will need to be replenished. Also, plastics consumption is not at its peak with global consumption projected to double by 2050. The Circular Economy cannot cope with this increase in consumption as the amount of carbon available for tomorrow is at most what exists today.

This means that at least until 2050 (and possibly till 2100 when global population is expected to peak) we will need to add carbon to the economy.

SO, HOW DO WE KEEP PRODUCING PLASTICS WITHOUT INCREASING GHG EMISSIONS?

To solve this, we need to use carbon sources available above the ground. But using above-ground carbon that has been locked in land-based carbon pools, such as old-growth forests, would also end up increasing atmospheric CO2 concentrations. So, our only viable source of carbon atoms is the atmosphere. We can use that carbon by growing biomass or through technologically capturing carbon from the atmosphere (which is usually called Carbon Capture and Use – CCU).

growing *sustainable biomass*

Growing biomass requires land which is also used for food and feed production, so safeguards must be put in place to avoid disrupting food supply. **Biomass that does not cause a depletion of existing land-based carbon pools and do not disrupt the food and feed supply is called sustainably sourced biomass.**[1]

CCU

CCU technologies are currently very energy intensive and would only reduce GHG emissions if renewable energy is used – and this is still a scarce resource in the world.

The challenge ahead of us is immense, and all measures below must be deployed and scaled up.

The Roadmap for the transition to a Net Zero Circular Economy would need several solutions, from circularity to renewable resources, such as

1. Responsible consumption (reduction, reuse, redesign)
2. Energy efficient processes and technologies
3. Recycling in all its forms
4. Use sustainably sourced bio-based and recyclable materials
5. Use CCU based recyclable materials
6. Use technologies to permanently remove CO2 from the atmosphere (Carbon Capture and Storage – CCS).

[1] there are many other environmental aspects and impacts that should be considered in a complete sustainability assessment, but they are not directly related to carbon accounting", so any lengthy discussion on these additional sustainability criteria would deviate from the main topic of this paper.

CARBON FOOTPRINT OF FOSSIL PLASTICS

Emissions are currently accounted for when and if they happen. When oil, natural gas, or coal is extracted from the ground **only emissions associated with the extraction process are accounted for. The carbon present in crude oil, gas, or coal (embedded carbon) is not accounted for as an emission.** This same approach is used throughout the life cycle and the embedded carbon is considered as emitted only when it is released to the atmosphere as CO_2 or CH_4. Consequently, the carbon footprint of intermediate products, such as polymers, consider only the emissions that have already happened until the outbound gate of the production stage (cradle-to-gate).

In the case of **fossil plastics**, the cradle-to-gate carbon footprint is the sum of the emissions from extraction, refining, steam cracking, and polymerisation (including emissions due to transport between the stages). The carbon that constitutes plastic, however, is not accounted for as an emission.

For those **materials that do not contain significant amounts of carbon**, such as glass, metal and concrete[2], the emissions happen mostly at the beginning of their life or in the use phase, and virtually no emissions happen at **EoL (End of Life). Materials formed by carbon** such as wood, paper, textiles, and plastics can have significant emissions in all life cycle stages. **Plastics can have 50% to 60% of their life cycle emissions at EoL, which can happen many years in the future[3] and therefore an accurate depiction of their footprint is dependent on their EoL scenario.**

The full life cycle carbon footprint of a plastic product will also include emissions from the conversion, use and EoL. When a plastic is recycled, the carbon contained in the plastic is considered as fully transferred to the next life cycle and so no emissions of the embedded carbon are assigned to the first life cycle. When a plastic is incinerated, most of the embedded carbon is released to the atmosphere as CO_2, and a much smaller part becomes CH_4, ashes or char. All emissions are then accounted for. Landfilling does however present a challenge. The datasets for landfilling consider only the first 100 years and less than 1% of the plastic mass landfilled is degraded in those first 100 years, so virtually no emissions from landfilling of plastics are visible.

The explicit difference in impact in each stage of the life cycle is key. It helps to identify pain points and enables the deployment of adequate measures to minimise them. They are essential to the designing of products with better environmental performance.

[2] Although concrete does not contain CO2,it can absorb CO2 from the atmosphere in a process known as recarbonation which is a natural process, occurring when concrete reacts with CO2 in the air. The exact amount of CO2 that concrete can reabsorb has a maximum of 100% of that emitted during the calcination of limestone in the cement manufacturing process. (These are known as process CO2 emissions and are the cause of approximately 60% of the embodied CO2 of concrete.) The actual amount of carbon uptake will depend on a range of parameters including the resistance class, exposure conditions, thickness of the concrete element, recycling scenario and secondary use. A practical estimate of the global carbon sink provided by all concrete is 25% of the process CO2 emissions released during cement production. (https://gccassociation.org/essential-concrete/carbon-uptake/#:~:text=The%20exact%20amount%20of%20CO2,the%20embodied%20CO2%20of%20concrete.)

[3] See 'Time Distribution of Emissions, page four

The problem with the **TIME DISTRIBUTION OF EMISSIONS IN CLIMATE CHANGE IMPACT**

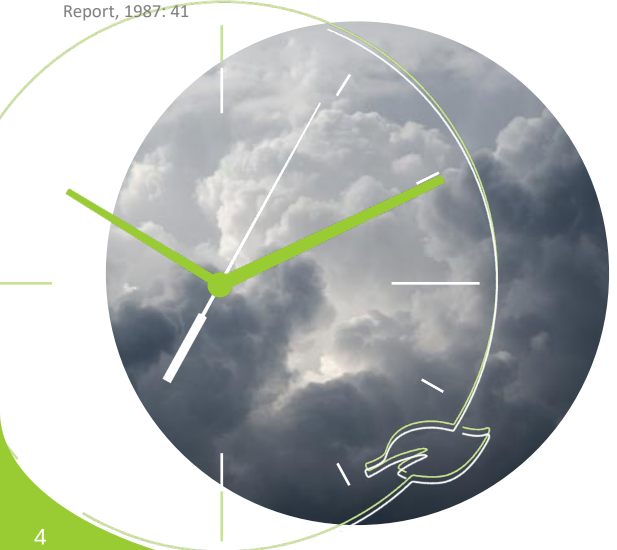
Before going to the bioplastic section, let us talk about the time distribution of emissions in Climate Change.

Time appears in GHG accounting in two different ways. The first is what emissions (today and/or future) should be considered in our carbon footprint or corporate inventory. This is the time horizon at the inventory level. Another way is the time horizon for impact assessment, that is, for how long should we consider the impacts after an emission happens and that is the time horizon for the impact assessment. For example, when we use the GWP_{100} methodology, it considers 100 years as the limit. GWP calculates the contribution of a gas to climate change over a chosen period. The longer the period chosen, the less importance is given to short-lived gases like CH_4, and more importance given to CO_2, and N_2O (and for CFCs, HCFCs, and HFCs). Virtually, all assessments today are made using GWP_{100}, so that is a methodological choice adopted without considering the philosophical or policy implications.

The **time horizon** at the inventory level **depends on the relative importance we give to present and future emissions**. When we consider that there is no time horizon (or an infinite time horizon), all future emissions should be accounted for as if they had happened when the product was put on the market (GHG Protocol, ISO 14067). This means that all emissions, present and future, are equally important which is justified by the inter-generational equity principle of the sustainable development definition[4]. On the other hand, when we establish a time horizon after which no emissions are considered (PAS 2050 which uses a 100-year time horizon) we are placing greater value on present emissions over those of the future. **One possible reason for this approach is that we need to solve the climate crisis now and if we do not then there would be no future. If we succeed in addressing that today, it means future generations will be better prepared to deal with those future emissions.**

Ultimately, **the methodological choices we adopt to measure emissions depend on a value judgment, and we should not impose either option.**

[4] "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" The Brundtland Report, 1987: 41



There are at least **three different impacts related to Climate Change and time influences all of them.** A detailed discussion exists in the **Climate-change impact potentials – CCIP as an alternative to global warming potentials (Kirschbaum, 2014):**

1. Impact related directly to elevated temperature: heat waves and other extreme weather events, coral bleaching is unambiguously correlated to increased temperatures. The Global Temperature Potential (GTP) is the best metric for this impact which measures the expected temperature in the future because of an emission.

2. Impact related to the rate of warming: warm is not inherently worse than cooler conditions but change itself will cause problems for both natural and socio-economic systems. A slow rate of change will allow time for migration or other adjustments, but faster rates may give insufficient time for such adjustments. The rate of warming will strongly influence whether species can migrate to newly suitable habitats, or whether they will be driven to extinction in their old habitats.

3. Impact related to cumulative warming includes impacts such as sea-level rise which is quantified by including both the magnitude of warming and the length of time over which oceans and glaciers are exposed to increased temperatures.

Regardless of the metric chosen (GWP, GTP, or CCIP) time horizons at inventory level **play a decisive role in assessing the impacts of products on the climate.**

Using the infinite time horizon, mixing present emissions with future emissions obscures the assessment of the rate of change and may overestimate cumulative warming effects. On the other hand, using short-term time horizons may obscure and underestimate the temperature increase in the future, and underestimate the cumulative warming effects. **Both views are necessary for a complete picture of the climate change impacts caused by products and corporations. The methodology chosen to measure emissions (and removals) should allow both perspectives to be shown.** The UNEP Life Cycle Initiative in 2016 recommended the use of different metrics for short-term impacts (GWP100) and long-term impacts (GTP100) but no recommendation for a time horizon at inventory level was given.

CARBON FOOTPRINT OF BIO-BASED PLASTICS

Calculating the carbon footprint (CFP) of emissions associated with the production of bio-based plastics does not require any change from the current approach used for all plastics. However, **accounting for the carbon contained within the plastic does**. **The discussion below is restricted to this embedded carbon.**

For bio-based plastics, the initial removal of carbon from the atmosphere through photosynthesis **reduces the concentration of CO_2 in the atmosphere**. **Later emissions at EoL**, if they happen, may counterbalance that initial removal and **return the carbon concentration to the initial values.**

A methodological approach for bio-based plastics that ignores the initial removal because it will be neutralised by later EoL emission (the so-called 0/0 approach) is assigning EoL emissions already at the cradle-to-gate CFP. Methodological consistency requires that the embedded carbon in fossil plastics is also considered as already emitted at cradle-to-gate. **This approach would obscure the benefits of EoL scenarios that prevent the release of the embedded carbon, such as recycling.** All EoL scenarios would have the same zero emissions (as it happens with bio-based plastics using this approach). It also makes it impossible to show the difference in time between cradle-to-gate emissions and future EoL emissions forcing the infinite time horizon approach upon users of the CFP regardless of their value judgement. This is the methodological approach used in European Product Environmental Footprint (PEF) for bio-based plastics, but not for fossil plastics, creating an asymmetry in methodological approach.

The **alternative approach is usually called the -1/+1 approach** which considers that when biogenic CO_2 is absorbed from the atmosphere it should be characterised using -1. When biogenic CO_2 is released, it should be considered as +1. Since this release will happen only at EoL, cradle-to-gate CFP of bio-based products may be negative if process emissions are lower than atmospheric CO_2 uptake. This approach is used in most CFP standards such as ISO 14067, GHG Protocol Product Standard, and PAS 2050, (but not in Corporate Inventory Standards such as GHG Protocol). All standards also require that biogenic emissions, non-biogenic emissions, and emissions due to variations in land-based carbon stocks are shown separately.

The use of the -1/+1 approach explicitly shows the difference between bio-based plastics and fossil plastics already at the cradle-to-gate stage. It also allows the users to include EoL emissions according to their value judgment using or not a time horizon at the inventory level. It also incentivises recycling as the absence of EoL emissions preserves the initial benefit of CO_2 uptake[5]. It has also the advantage that no changes in the calculation methodology for fossil plastics are needed.

[5] It provides incentives to recycling at EoL but there is still a problem with incentivising the use of recycled content and whether there should be a difference if this recycled content originated from fossil plastics or from bio-based plastics. This problem is currently being discussed at the Biogenic Carbon Project from the UNEP Life Cycle Initiative and it is not discussed in this document.

GHG PROTOCOL CORPORATE STANDARD AND SCIENCE-BASED TARGETS INITIATIVE (SBTi)

Both these organisations adopt an infinite time horizon approach at the inventory level, but the philosophical and political implications of this choice are not explicit.

There are some inconsistencies between the documents published. The Product Life Cycle Accounting and Reporting Standard follows the -1/+1 approach, so CFPs of intermediate products may have a negative total CO_2 value, although each component should also be reported separately.

The following components make up the total inventory results:

$$\frac{\text{Total } CO_2e}{\text{unit of analysis}} = \frac{CO_2e \text{ Emissions (Biogenic)}}{\text{reference flow}} - \frac{CO_2e \text{ Removals (Biogenic)}}{\text{reference flow}} + \frac{CO_2e \text{ Emissions (Non-Biogenic)}}{\text{reference flow}} - \frac{CO_2e \text{ Removals (Non-Biogenic)}}{\text{reference flow}} + \frac{CO_2e \text{ Land Use Change Impacts}}{\text{reference flow}}$$

The CFP of I'm green^{TM} bio-based HDPE calculated using the Product Life Cycle Accounting and Reporting Standard would be -2.12 kgCO2e/kg[6] while the CFP of fossil HDPE +3.10 kgCO2e/kg[7]. As stated previously the only differences between bio-based PE and fossil PE are at the cradle-to-gate level, the downstream stages are the same for both plastics. Therefore, we expect the difference between them to be always 5.22 kgCO2e/kg regardless of the EoL scenario.

However, in the Corporate Value Chain (Scope 3) Accounting and Reporting Standard no biogenic carbon removal upstream is considered nor is the EoL emission, thus the 0/0 approach is followed.

A paper manufacturer purchases wood pulp from suppliers and sells finished paper products to consumers. The company accounts for GHG emissions from the production of wood pulp in Scope 3, category 1 (Purchased goods and services). The company does not account for upstream CO_2 removals from biological carbon sequestration that occurs in trees in Scope 3 but instead may report CO_2 removals separately. The company also does not account for downstream biogenic CO_2 emissions from the incineration of sold paper products at the end of their life in Scope 3, but instead reports those emissions separately.

Different approaches are used for CFP calculation and Corporate Inventory Scope 3, but both have an explicit life-cycle perspective. In the Scope 3 category 1, the declared value for fossil HDPE is still +3.10 kgCO2e/kg, and the declared value for bio-based HDPE, without the carbon uptake, is +1.02 kgCO2e/kg. So the difference between them is only 2.08 kgCO2e/kg, or roughly 40% of the difference in CFP.

[6] Braskem I'm green™ bio-based polyethylene Life Cycle assessment 2023
[7] HDPE (GLO) EcoInvent 3.10

When the EoL is incineration, the emission for fossil plastics (under Scope 3 category 12) would be around 3.14 $kgCO_2e/kg$[8]. For bio-based plastics, the emission would be zero. The benefits of using bio-based plastics would be fully captured in this way, but incineration does not foster material circularity.

When plastics are landfilled there is another inconsistency since the GHG Protocol uses an infinite time horizon, but the value reported in Scope 3 category 12 for fossil plastics is close to zero because of the limitations in the datasets for landfilling, as discussed previously. The emissions for bio-based plastics in landfill are assumed to be zero, as only biogenic carbon is released.

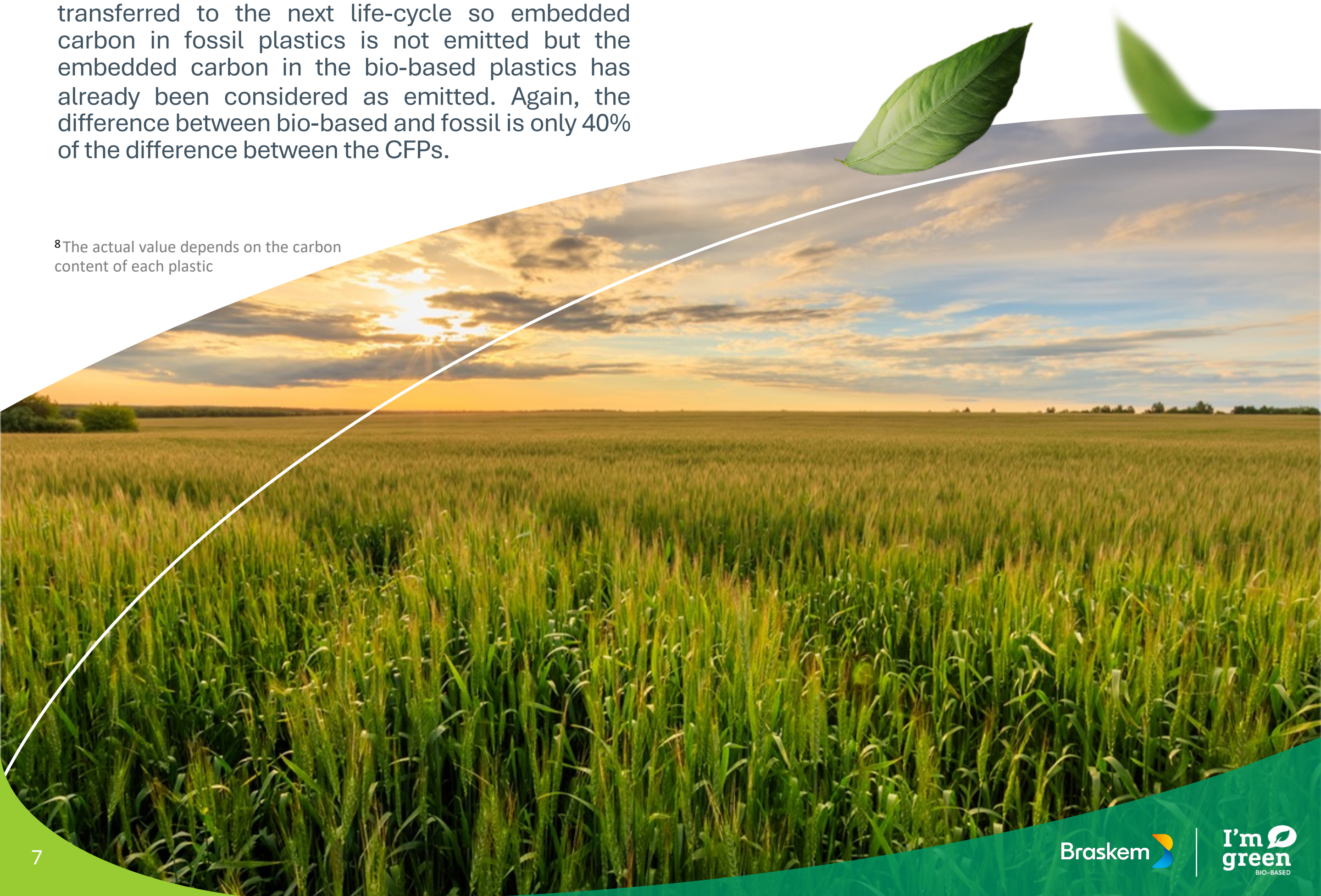
Once more, **the difference between bio-based and fossil is only 40% of the difference between the CFPs.** Although disagreeing with the infinite time horizon at inventory level approach, if this approach is to be applied consistently for plastics, the emissions from landfilling in category 12 must be corrected and consider that when a plastic is landfilled the embedded carbon in plastics is fully emitted. **This would have a massive impact in corporate Scope 3 inventories and could double the inventories depending on how much plastic is used in the value chain.**

When fossil plastics or bio-based plastics are recycled only the emissions associated with the recycling process itself are reported, something around 0.4 $kgCO_2e/kg$ for collection, sorting and recycling, which should be reported in category 1 (recycling) or categories 5 and 12 (collection and sorting). The embedded carbon is considered as transferred to the next life-cycle so embedded carbon in fossil plastics is not emitted but the embedded carbon in the bio-based plastics has already been considered as emitted. Again, the difference between bio-based and fossil is only 40% of the difference between the CFPs.

This is deeply troubling as this is the preferred EoL method in a circular economy but the differences in methodology between bio-based and fossil-based plastics reduces significantly the benefits in corporate inventories.

The way in which current guidelines and protocols are stated today, a company can be reducing their package CFP by using bio-based plastics up to **5.22 $kgCO_2e/kg$**, but the same benefit cannot be fully reported at the Corporate Inventory Scope 3.

Biogenic carbon and removals were the main topics in the still-to-be-published GHG Protocol Land Sector and Removal Guidance (LSRG). Since the final phrasing of this document is still unknown, our analysis is limited to the discussion in the Technical Working Groups. Among the modifications proposed was the inclusion of an additional category "Product Storage" that would account for these removals into products. **The new structure proposed creates three distinct categories:** emissions, removals, and product storage, each subdivided into biogenic, non-biogenic, and land-based. All these subcategories would not be fungible, meaning that companies should have specific targets for each category. Although it partially addresses some of the issues raised here the proposed format would only have a significant effect on long-lived products, so the problems and inconsistencies would persist for fast-moving consumer goods.



[8] The actual value depends on the carbon content of each plastic

DROP IN BIO-BASED PLASTICS

DROP IN BIO-BASED PLASTICS ARE A NECESSARY SOLUTION FOR A NET ZERO CIRCULAR ECONOMY

These are materials that are chemically identical to existing, fossil fuel-based plastics. They have the same physico-chemical properties, they are processed in the same machines, they are used in the same applications, and they are recycled in the same existing streams. **The only difference is that the molecules of those plastics are formed by carbon that was already above the ground instead of fossil carbon stored underground.**

Due to differences in scale and market maturity between fossil-based and bio-based plastics, the latter tend to be more expensive. **As their performance is the same, the value proposition of these products relies heavily on their sustainability attributes**, especially their reduced carbon footprint. These benefits, however, are not always visible using the current accounting practices both at product level and at the corporate carbon accounting level.

Firstly, **drop-in bio-based plastics are not competing with recycled plastic** (or any other way to reduce plastic consumption). **Bio-based materials in general, and bio-based plastics in particular, should be seen as an additional carbon pool that expands the current land-based carbon pool** that works in synergy with the natural carbon cycles; removing carbon from the atmosphere, transferring that carbon to the product carbon pool, and then releasing it back to the atmosphere when they degrade. With more carbon circulating in these pools, instead of the atmosphere, there is less carbon contributing to climate change. **Human activity caused the climate crisis, but human activity could also reduce the problem.** This does not work while we keep pumping carbon from fossil fuels to the atmosphere and **bio-based plastics are key to decoupling the plastics industry from fossil resources.**

Using biogenic carbon to produce plastics reduces climate change while using fossil carbon will ultimately increase climate change. The methodological approach for calculating carbon footprint must reflect this difference. For drop-in bio-based plastics, cradle-to-gate carbon footprint is essential because it reflects this core difference between them, and fossil-based plastics.

LAND-RELATED EMISSIONS AND REMOVALS

The existing standards require the inclusion of impacts related to Land Use Change (LUC) so losses in land-based carbon stocks must be reported but if an LUC promotes an increase in carbon stocks this cannot be included in the CFP. This creates difficulties for companies that want to improve their practices and regenerate land instead of simply not degrading it.

Improvements in land management (without changing the land use category) that lead to increased carbon stocks in the soil cannot be captured in CFPs either and disincentivise companies to adopt such practices.

The land-related emissions and removals will introduce an approach that includes removals in corporate inventories, but not in CFP.

Proposed changes in CFP, CORPORATE ACCOUNTING, AND TARGET SETTING

Adoption of the -1/+1 approach

CFP and corporate accounting should present results using both an infinite time horizon and using a 100-year[9] time horizon with appropriate metrics

Companies and Organisations should be stimulated to set targets to reduce their corporate emissions but also to reduce the CFP of their products

Develop datasets for EoL that consider an infinite time horizon

Inclusion of removals and emissions coming from LUC and land management both in CFP and Corporate accounting

Accounting for biogenic carbon in recycling needs further research to ensure it is effectively integrated into life-cycle CFP accounting

[9] There is no scientific data that supports the choice of 100 years as time horizon instead of other time frames. The choice was simply to minimise disruption since the boundary between short term and long term in LCA has been traditionally 100 years.