ALLOCATION IN CARBON FOOTPRINTING: CONSIDERING BIOGENIC CARBON

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Abstract

Social interest in producing more sustainable products is on the rise. Sophisticated tools are available to assess the environmental performance of products. Among them Life Cycle Assessment is probably one of the most popular in academia, mainly due to its comprehensiveness. Carbon footprinting is based on similar principles, and is considered by many as a simplification – be it convenient or not – of the latter. In the last years it has very much jumped into the spotlight of industry.

Allocation is one of the hottest topics in Life Cycle Assessment. Selecting a particular allocation criterion can outstandingly influence the numerical results, potentially biasing them or even driving towards erroneous conclusions. This can be particularly critical in the case of climate change, most especially after the popularity of carbon footprinting. Some researchers solve this by distinguishing between biogenic and anthropogenic carbon, although this strategy could be incompatible with available information. This study analyzes the use of biogenic carbon under the frameworks of Life Cycle Assessment and carbon footprinting.

Keywords: *life cycle assessment; carbon footprint; allocation; sustainability; biogenic carbon*

Resumen

El interés de la industria por producir productos más sostenibles está en crecimiento. Hoy en día existen sofisticadas herramientas para evaluar los impactos ambientales de los productos. El Análisis de Ciclo de Vida es quizás el más popular en el ámbito científico, dado lo exhaustivo de su metodología. La huella de carbono, basada en principios similares, y considerada por algunos como una simplificación – conveniente o no – del primero, goza en la actualizad quizás de mayor popularidad en el mundo industrial.

En el Análisis de Ciclo de Vida, la asignación de impactos es uno de los temas de mayor discusión. La selección de uno u otro puede influir notoriamente en sus resultados numéricos, con potencial de presentaciones sesgadas de resultados, o incluso conclusiones erróneas. Caso de centrarse en el cambio climático puede resultar especialmente crítico, especialmente dada la popularidad de los estudios de huella de carbono. Algunos investigadores argumentan a favor de la consideración por separado del carbono biogénico y antropogénico para solventar el problema, aunque esta estrategia puede ser incompatible con la información disponible. Este estudio plantea la consideración del carbono biogénico de forma integrada con los marcos del Análisis de Ciclo de Vida y Huella de Carbono.

Palabras clave: *análisis de ciclo de vida; huella de carbono; asignación de impactos; sostenibilidad; carbono biogénico*

1. Introduction

ISO 14040 (2006) defines Life Cycle Assessment (LCA) as a 'compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle'. This definition seems unequivocal at a first glance. It becomes somewhat less clear if a single process has more than one input or output that should be considered in the balance. In these cases, additional variables must be considered, such as additional positive outputs or how much part of a process' impact should be assigned to each one of the products. Allocation of the environmental impacts becomes necessary.

A paradigmatic case of this problem arises when considering recycling. It is a known fact that, in such a process, the extraction of raw materials is avoided. Landfill or incineration is also avoided, even if the inputs and outputs from the recycling process have to be accounted. The question becomes: to which life cycle should we assign the environmental benefit of recycling? Should it be to that of the product that is being recycled? Or should it be to that of the product using the recycled content? It is critical to address this issue at the beginning of any LCA, since the consequences on the model – and not only on the calculation methods – can be considerable. Neglecting to consider this fact can result in lack of coherency and double accounting.

The case of CO2 in particular is rather unusual, and by those means that of carbon footprinting. The most visual particularity shows up on its counter-intuitive inverted values due to carbon sequestration in materials like cardboard or wood. This can influence how environmental impacts are perceived. A greater difference as to the results lies on the statistical differences between recycled content and recycling at the product's end-of-life. This is due to the uniformity of the recycled material, making it feasible to recycle any sort of paper in almost any other sort of paper product. Some sectors, due to strict regulations, might have almost virgin products with high recycling rates, whilst others are almost fully made out of recycled material, and nevertheless fail to go into the recycling stream. Direct consequence of this picture is that results will tend to be highly dependent on decisions regarding recycling allocation (Collado-Ruiz et al., 2008).

One possible solution that has been proposed for this is the accounting of biogenic and antropogenic carbon differently. By those means, carbon sequestrated during a plant's growth – or even an animal's – is accounted in parallel and is not considered along the life cycle. This avoids the appearance of positive impacts (negative values of environmental impact) in the initial stages, and reduces the effect of allocation on the process. This paper seeks to understand up to which point the consideration of biogenic carbon is a feasible alternative. Furthermore, consideration will be given to the effects of using biogenic carbon to draw conclusions, as was done by Collado-Ruiz et al. (2008).

2. Allocation in recycling

LCA practitioners and researchers have come up with a number of options to deal with the problem of allocation, as well as with criteria to decide for one or another. The basic problem as defined by ISO 14044 (AENOR, 2006) is that 'inputs and outputs must be assigned to the different byproducts according to proceedings that are clearly stated' I have to look this up in the ISO. For that, common processes with other product systems must be identified and treated adequately. Several authors (Trinius & Borg, 1999, Borg, 2001) point the different treatment that should be given to processes involved in more than one life cycle. ISO 14044

(AENOR, 2006) has a special chapter (4.3.4.3) in which it deals with recycling in particular, as the most common and representative case of it.

Three possibilities can be regarded: the cycle could be closed, it could be open with the material keeping its properties constant, and it could be open with a material that degrades as cycles go by. Figure 1 shows a schematic of each of these alternatives.

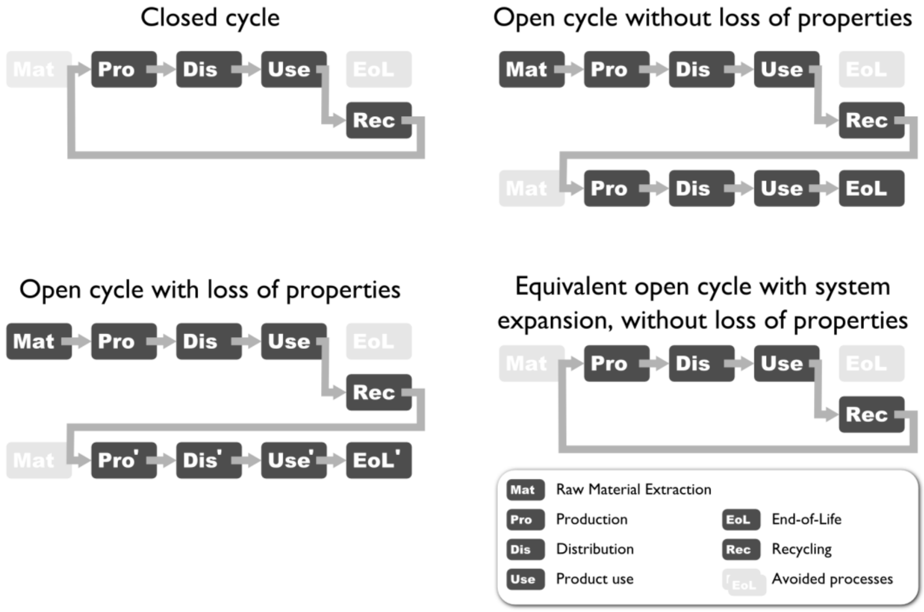


Figure 1.- Possible conflicts when allocating recycling

On the first and second options, system expansion can solve the problem. This way, the whole process is part of the product system, and allocation is avoided. When possible, ISO states that this alternative be chosen. When the cycle is open with material degradation, allocation is unavoidable, and a method must be chosen.

There are two fundamental approaches regarding allocation (Schmidt, 2008): consequential and attributional. Some authors also use synonyms like prospective LCA, in the sense of prevision of consequences, and retrospective LCA, meaning that it is based in past information (Ekvall et al., 2005). Consequential LCA tries to predict the effects of the effects that are being studied. For example, if the prediction is that the consumption is going to entail an increase in energy consumption, and that is going to require of investment on fossil fuels on the midterm, then the environmental impact should be taken as if the 100% if the consumption comes from this type of source. Contrariwise, attributional LCA assigns environmental impacts basing itself on the current – or past – balance. In the previous example, electricity would be taken as a weighted sum based on the current proportions. Ekvall et al. (2005) note the advantages and disadvantages of each alternative from an ethical point of view.

There is strong criticism on both options. The consequential approach can be perceived as unfair in cases where efforts in pro of the environment are being made, whilst the attributional one can lead to decisions that do not count with rebound effects or direct consequences of decisions.

When a system is expanded to include recycled materials, the whole problem becomes a variety of multi-output process (see Figure 2). Weidema and Norris (2002) analyze both problems in the same way, applying a consequential approach based on market fluctuations (Weidema, 2001). For most cases these authors subtract an equivalent product to that byproduct that is generated – in the case of recycling, the recycled material – since it is no longer needed to manufacture that 'raw' material. When the recycled material is used to its uttermost extent, the use of recycled material will not be considered. When excess of recycled material is available, thus lowering its market value, the recycling of the product at its end-of-life will be modeled as inexistent. Then answer, thus, depends on the recycled material's market.

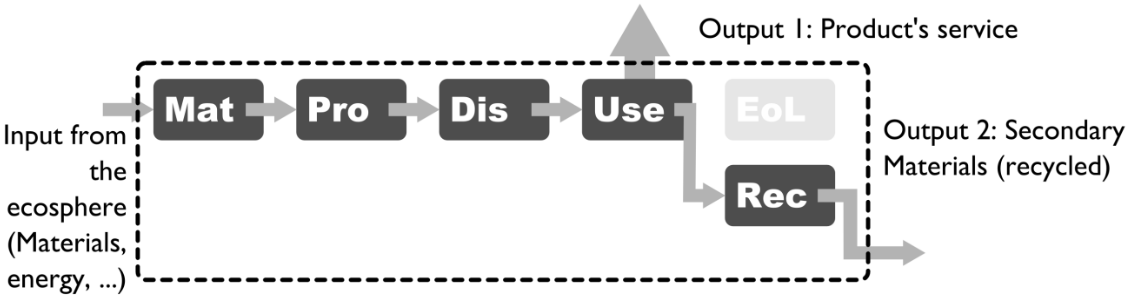


Figure 2.- Recycling seen as a multi-output problem

On the other hand, according to attributional arguments it would seem incoherent to completely ignore the fact that there is some recycling taking place in the end of life, or to include some virtual raw material, even if it does not exist. Therefore, attributional allocation proposes alternatives, some of them very close to the consequential ones, but some of them quite different.

In order to assign the environmental impacts to different cycles (or processes) it seems relevant to compare the original system without recycling to the expanded system including two (or more) cycles. Figure 3 shows the new processes and environmental improvements that need to be allocated. The product in cycle A does not need to be treated any more in its end of life, since it gets recycled instead. A new recycling process appears, nevertheless, and its environmental impact must be attributed to either cycle A or B. Finally, the materials extraction phase of cycle B is avoided, with the correspondent environmental credit.

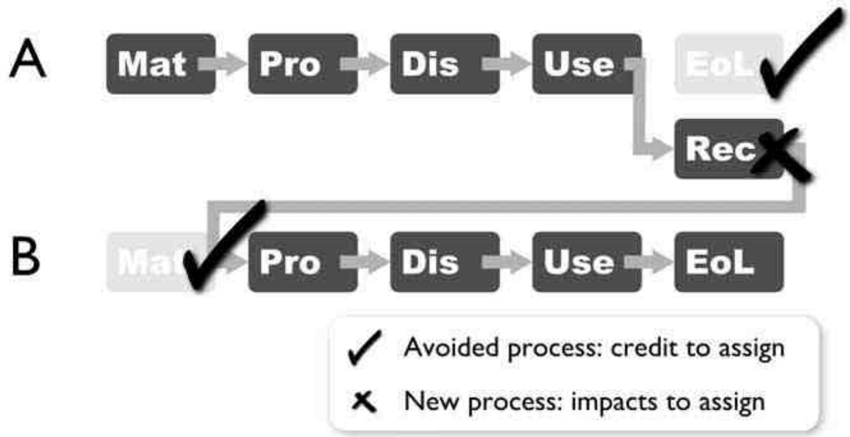


Figure 3.- Changes in product cycles due to recycling

The logical approach may seem clear depending on the particular case that the practitioner has in mind. From a recycling perspective, it makes sense to credit system A for the avoided processes in producing new material, and that it is burdened with the environmental impact of the recycling process. On the other hand, from a material-use point of view, it seems logical to credit products that make use of recycled materials, since they seem to be avoiding the materials production phase, and to burden them with the environmental impact of recycling instead. It seems illogical to attribute the environmental impact of raw materials to a product using recycled material.

If both arguments are considered, then double accounting is being done. The benefits of not manufacturing in cycle B are credited to cycles A and B. This becomes more clear if a cycle is both using recycled material and is recycling the outcome: it would be credited with using recycled content (avoiding materials extraction once) and with the fact of recycling in its end of life (avoiding materials extraction twice). Even if the loop were completely closed as presented in Figure 1 – in which there is no real allocation issue – this approach would deliver an the environmental benefit of an extra credit for the materials extraction.

This reasoning holds true as well for the impacts of the recycling process and the avoided impacts of other end of life processes such as landfilling. The latter is generally not included in the discussion regarding this topic, although some authors include it and allocate it in the same way as the previous. For the purpose of this paper, the main reasoning will be done with the first two: avoidance of raw material extraction and processing, and impact of recycling processes.

Literature presents different approaches to allocation:

- Consequentialist, depending on the market reaction. The impacts and benefits are allocated related to whether the recycled content is fully consumed and of similar price than the raw materials, or if the market for recycled content is a secondary market, in which part of it goes to waste. On the first case, the use of recycled content is disregarded, since the only fact that would change the current conditions of the recycling market is to have more quantity of the material recycled in its end of life. On the second case, recycling more material will not provoke the creation of a market, or rather it will create a market of degraded product that will have to be sold much cheaper to make its way into something useful. In that case, recycling the product at its end of life is not going to affect the market system, so no credit is given to it. Nevertheless, using more quantity of recycled material has a considerable impact on the market, and thus receives the whole credit. Rusell (2002) discusses the dangers of this approach, due to lack of knowledge and to the liability of leaving such a sensitive decision in the hands of the practitioner.
- Cut-off. According to this method, the credit is consistently attributed to the next cycle (Frischknecht et al., 2005). This is shown in Figure 4. In some cases, this is a convenient idea according to consequentialist approaches, and the consistency ensures reliability beyond the practitioner. Recycling the material at its end of life only credits the product with the avoided impacts of the alternative end of life processes, such as landfilling.
- Avoided impacts. This approach is completely opposite to that of cut-off. In this case, the benefits of recycling are completely attributed to the product being recycled, and none to that using recycled material. This approach is also shown in Figure 4.
- Percentage allocation. There are a subset of options regarding this approach:
    - 50%-50% method. Sometimes, an arbitrary percentage of 50% is selected for each cycle. Although there is absolutely no reasoning behind this figure of 50%, it has a very important advantage: it credits recycling and using recycled materials in the same way. Therefore, the social implications of assessing with this method are in overall positive (no environmentally favorable behavior is left uncredited). For this reason, many policy-driven institutions have defended this method as their standard approach. That is the case for the Nordic Guidelines for LCA (Lindfors et al., 1995) or the Umweltbudesamt (UBA) in Germany. Ekvall (2000) presents this approach as a pragmatic way to deal with lack of information (or uncertainty therein) in a consequentialist approach.

- Economic allocation. Werner and Richter (2000) and Howard et al. (1999) defend using the relative prices to define the percentage that is allocated to each cycle. If waste has a value of 80% of the raw materials price, it can be modeled as 80% of the total recovered in that cycle, and the 20% that is left is attributed to the second cycle (the one that uses recycled material). Howard et al. (1999) attributes the end of life credit that is here calculated to the manufacturing phase, defending that it is design for recyclability that constitutes its suitability for recycling, and not the processes in the end of life. A good design would increase the value of the final materials that can be recycled. An interesting point about this allocation approach is that it includes an elevated number of factors into approach, and builds in the complexity of infinity of cycles. If a product can be infinitely recycled, this has an impact in the recycled material's price. Nevertheless, since mass balances are done at an aggregated global level, local mass balances become more difficult to justify. One life cycle will not necessary be balanced in mass.
- Dutch approach. The Dutch norm NEN-EN 8006 (2004) presents a much more elaborate method. It proposed the calculation of the point in which the price of waste goes from negative to positive. The turning point is selected as the limit between both cycles. Environmental impacts before this point are attributed to the first cycle, and those after the process are attributed to the next cycle of the material. The process in which the turning point happens is divided in the same percentage as the ratio between positive and negative values. If this is n not the case, the norm proposes a series of methods to account for the different cycles the product can go through, out of an estimation of how many times it can be recycled. Finally, if none of those is possible, conventional economic allocation is carried out.

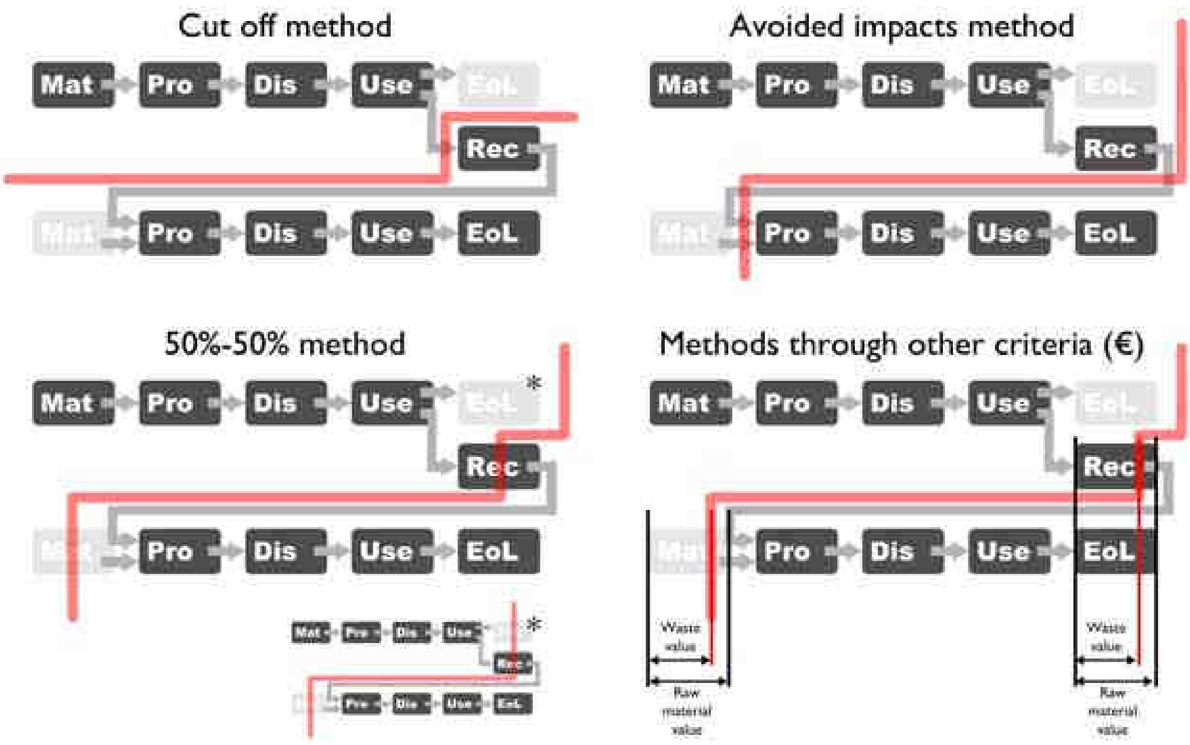


Figure 4.- Different allocation procedures

Literature includes some other alternative methods (Borg, 2001). Most of the time, they consist of prioritizations of when one or another approaches should be used, to avoid leaving this decision open for the practitioners subjectivity. Östermark and Rydberg (1994) in Borg (2001) present a method that inverts how impacts are assigned, crediting the end of life with the materials impact, and burdening the manufacturing with the end of life impacts. Ekvall (2005) and Trinius and Borg (1999) present allocation as a judgment of how things should be, and therefore point out the ethical groundings of selecting one approach or another. It therefore has a teleological and deontological content, and the person's ethics determine the final decision (Ekvall, 2005). A consequentialist approach solves this problem, but the attributional one requires a further subjective reasoning on how the final system should be. This matter is surely of great complexity (Weidema, 2007), and most researchers have a strong standpoint when it comes to their decisions and approaches. Nevertheless, most academics agree in the difficulties of coming up with a rule that will be valid and applicable in a 100% of the cases. Furthermore, most research in this topic comes from the construction and agriculture fields, so further development in other fields may shed new light into the topic.

3. Discussion on allocation in carbon footprinting

Even in the area of LCA, scientists have avoided topics like scope definition or allocation (Finkbeiner, 2009). Discussions about the issue of allocation come mostly out of LCA, with a low reaction when it comes to the field of carbon footprinting. This method of calculating the environmental impacts of products has however gained the attention of industry and the media (Weidema et al., 2008).

Carbon footprinting itself does not have a strict methodology behind it. Its most popular application in its early stages was to calculate the carbon footprint of an institution (Thomas et al., 2000, WBCSD, 2004). Therefore, it diverges from LCA in the sense that it has no life cycle view of the process, but rather a static view of the company or institution. It considers mainly the processes therein. Nevertheless, further evolutions of carbon footprinting stepped into assessing products and services. In most cases, issues like allocation are left to the decision of the practitioner (Carbon Trust, 2007, WBCSD, 2004), whilst in others one particular allocation procedure is provided by the carbon footprinting method or guide (BSI, 2008).

But lack of specification could be compromising to the results. Some of the results can depend – or seem to depend, since conclusions should regard all factors – on the allocation method selected. Particularly, selecting one method or another can compromise the visibility of potential improvements in the system (Collado-Ruiz et al., 2008). Using cut-off allocation in a product that has materials of a high environmental impact will stress this fact out, and point at a change of materials or increase in recycled content, but will leave the recyclability out. If the result intended is to hide the potential of design for recycling – because of the investments to be made – then this method could be selected, and there would be no apparent methodological flaw. On the other hand, if the material is particularly recyclable, but recycled content is expensive, using avoided burdens will stress out the advantages of those alternatives that allow a higher recyclability, ignoring the environmental potential of materials.

As can be seen, leaving the method open is leaving the conclusions partly at the will and ethics of the practitioner, as well as at the understanding of the reader of the LCA. Since most people in the target audience will not be able to spot the difference, this is a potential source of problems. Furthermore, in some products – like cardboard or wood – carbon is sequestrated in the initial stages, when the tree absorbs it from the atmosphere, to turn it into organic matter. This process takes CO2 from the atmosphere, and therefore can be considered to provoke a positive impact in global warming. However, all CO2 that is absorbed by the product can be expected to be emitted along the life of the same, or at least in a longer timeframe, e.g. all the CO2 absorbed by the growing of a tree will be emitted as CO2 or CH4 when the wood or cardboard rots or burns, unlikely to become oil or similar.

When the balance of mass is clear – everything that comes into the system goes out of the system at some point – the problem would only be a matter of accounting it, and of being aware of this issue. However, there are three problems that may arise:

- If accounted in the same way, these counter-intuitive bars may hide more important effects, or may make some relatively important effects look bantam.
- If the scope of the study – most specifically regarding the method to assess the impact – is to consider the effects on the next few years of the process after it has been discarded, landfilling may have not yet discharged all the CO2 out to the atmosphere.
- Some of the proposed allocation methods do not strictly keep a balance of mass, since there is an outflow of matter that is not accounted or credited for. If that mass flow includes physical carbon without considering the original intake, only the environmental benefit of sequestration is considering, passing on the burden to that product which uses recycled material. An example of the ridiculous reasoning that would spawn from this would be that using recycled paper would have a much higher environmental impact than using virgin paper.

The latter is particularly alarming, since it strongly depends on the knowledge of the practitioner, and is highly sensitive to intent.

An attempt to control these flows and understand the environmental impacts somewhat better is the parallel accounting of biogenic CO2. Biogenic CO2 is the one that is gathered naturally by the plant (or the animal), to constitute the raw material. This constitutes an effort when gathering information about a process, since for each case biogenic CO2 must be gather distinctly to anthropogenic CO2. Furthermore, when considering a database, it is critical to study the data collection to ensure it does not negatively impact the results.

The advantage of this approach is that the first disadvantage, that of misguiding graphs, is solved. Graphs become considerably more complicated, but include this factor. Nevertheless, a very precise mass balance must be done to avoid the second effect – it must be ensure that the scope of all processes includes a long enough period so that all the biogenic carbon is liberated. The third problem is partly left unsolved.

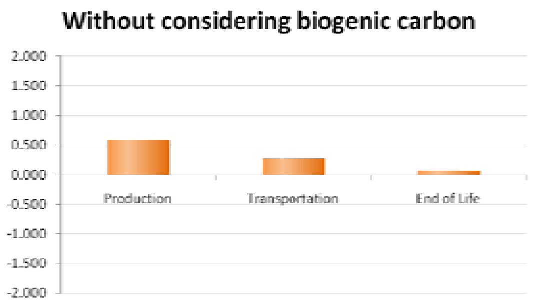
4. Methodological approach and results

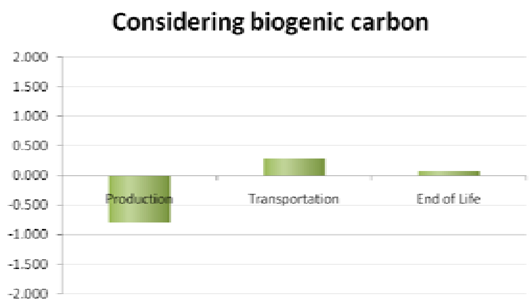
This paper seeks to understand how the separation of biogenic carbon (or even how its lack of analysis) contributes to how environmental impacts are plotted, perceived and considered. To further understand the interrelation between the accounting of biogenic carbon and the different allocation methods, the following steps are followed:

1. Development of a case-study LCA with the different allocation procedures, and with a parallel accounting of biogenic and anthropogenic carbon.
2. Plotting of all the graphs, for each allocation approach and for both approaches regarding biogenic carbon: including it directly in the results, and removing it completely from the results. The allocation approaches considered are cut-off considering no landfill (some approaches completely cut the recycled part away), cut-off considering full landfilling (some approaches completely disregard the recycling, considering it like landfill), avoided burdens, 50%-50% and economic.
3. Comparison of the graphs in terms of variability, highlights and hiding of the issues.

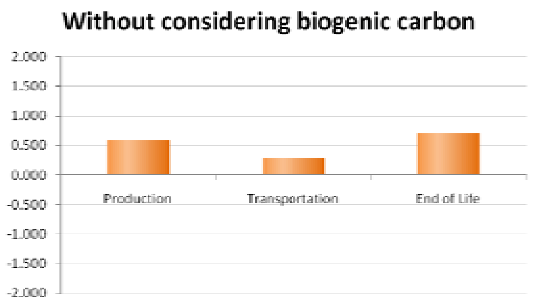
Table 1. Results for different allocation approaches, and of biogenic carbon consideration

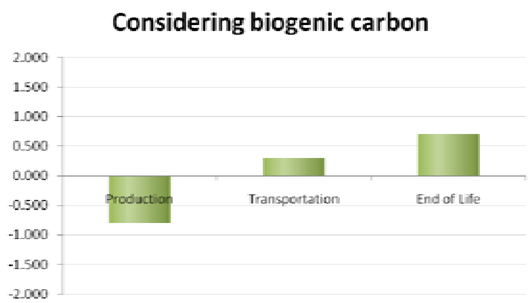
Cut-off (no landfill)



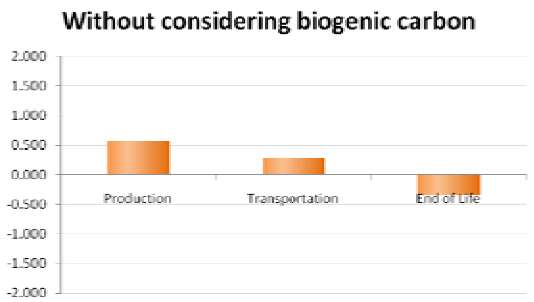


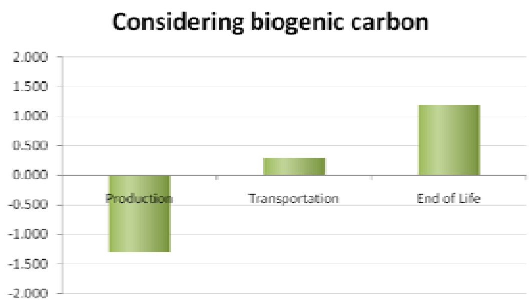
Cut-off (all landfill)



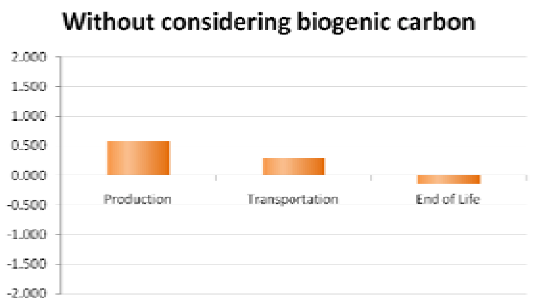


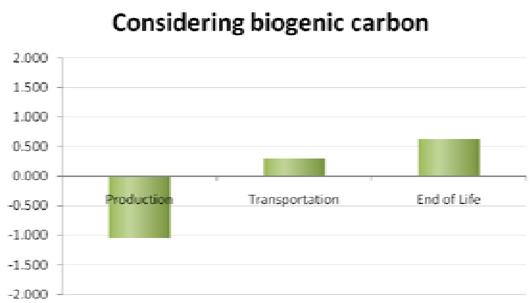
Avoided burdens



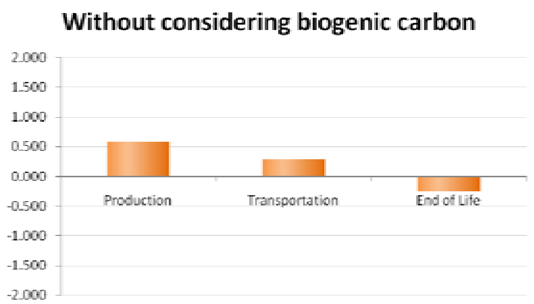


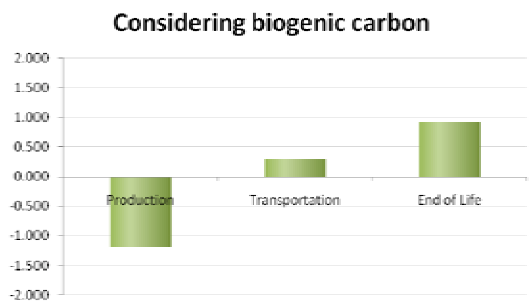
50%-50%





Economic





For the case study, a cardboard box was selected, used for the transportation of 7 Kg of tomatoes across Spain, based on Capuz et al. (2005). This case is very representative, since there is:

- Use of recycled content.
- Recycling of the final product, at a higher rate than the use of recycled content.
- High level of sequestration in the material.
- Considerable impacts beyond the materials (transportation).

On the first column, removing the effect of biogenic carbon from the whole LCA results, it can be seen that the effect of allocation is then limited to the end of life. Since the allocation that is discussed is aimed at processes that happen in this last stage, which is considered an advantage of this approach to considering biogenic carbon. Even when it comes to end of life impacts, the differences are smaller. A strong deviation happens in the case of cut-off considering that 100% of the product goes to landfill. Naturally, this is the least environmentally friendly option, and this method openly disregards the efforts that are put to place in this matter. As it is, the model would be identical to a life cycle in which no recycling happens. Mass balance is kept, but the functional units of future processes are completely neglected, thus lacking a base for comparison.

Cut-off without considering landfill, on the other hand, does not withstand a mass balance. The output is left without credit or burden, although there is a mass flow coming out. However, in this case, since most of that flow is biogenic carbon, which is not accounted for, the interpretation of the results would not diverge notoriously. On the column in the right, where the effect of biogenic carbon is added to the figures, it can be seen that there is an apparent benefit from using the product overall (the overall environmental impact is positive). Therefore, this mass balance does have a considerable effect in the model, and makes it invalid. In this case of considering biogenic carbon in the figures, cut-off (all landfill) withstands this test, since all the biogenic carbon entering comes out in the end of life.

Studying the second column as a whole – those test in which biogenic carbon has been considered in the figures – the differences between allocation procedures are much more notorious, and considerably affect both the raw materials stage and the end of life. In particular, the latter presents all sorts of behavior, although always providing a strongly negative environmental impact. This is because the end of life either:

a) includes the landfill process, with all the emissions of CO2 that have been sequestrated, or

b) includes the subtraction of the environmental impact from the raw materials phase. Since this impact is negative for all cases – carbon is sequestrated for the extraction of raw materials – this effect always has a positive effect on the environment, and the recycling seems – in figures – to have a negative effect on the environment.

Both effects are similar in figures, since the greatest contribution comes from the overall content of sequestrated biogenic carbon in the cardboard box.

Another effect that occurs is that the consideration of biogenic carbon in the figures hides the effect of other environmental impacts. In the case of raw materials extraction, the figures always show a positive environmental impact, which hides the environmental burdens of the crate’s production. Regarding the product’s end of life, impacts are always very high, drawing attention to this stage independently to whether there is potential for improvement here. With a deeper view of the whole process, it can be seen that such a highlight from the model with biogenic carbon is not very relevant, since the percentage of cardboard boxes that get recycled is already very high, and the potential for improvement is limited to a meager percentage of that environmental impact. Additionally, even if 100% of the boxes were recycled – which is a favorable outcome – the environmental impact would still appear high!

This can be seen specially in the graph of environmental burdens considering biogenic carbon. Here, the results respond completely to the allocation approach, and are very far from the real conclusions that can be extracted from a deeper study.

5. Conclusions and outlook

From the results it can be seen that removing biogenic carbon from the figures delivers more detailed information about the real environmental impacts that are occurring in the life cycle of the product. However, end of life impacts become equally indistinguishable. Using more or less recycled content reduces the environmental impact more mildly, but recycling more or less depends precisely on how the impacts are allocated.

All the approaches tested respond to the attributional approach if considered homogeneous for all cases indistinctly. However, it is agreed by many that whichever approach gets closer to the consequential approach is probably the most reliable for decision-making. For that matter, the deviances in the model point out the need for a more reliable allocation system for those cases in which information is missing. Furthermore, homogeneity in the allocation scheme of different studies is crucial for their comparison, up to the point of being potentially misleading if this is not checked.

Regarding reliability of the conclusions, it is very important to know the details about the model under study, and not final or aggregated graphs. This issue points out the dangers of delivering boiled-down graphical information down to a broader public, that can draw conclusions without the knowledge needed to assess those figures. It is clearly visible here that a Kg of CO2 is not an objective measure of environmental impact of an object if the method behind its calculation is not stated.

It is also relevant to point out the importance that this has for datasets. In this case, sequestration has been considered as a first-generation impact and issue, i.e. something that is considered for the life cycle of the product under study. Nevertheless, when carrying out the LCA of a complex system, it is generally accepted to use databases or other LCAs of the elements within that system, e.g. in the LCA (or carbon footprint) of a university, there is bound to be included quantities of paper, out of databases or previous knowledge. It is therefore critical to be able to interpret the information of those figures in what they mean, and to be able to aggregate this into the bigger picture that is the university. This paper has been carried out within the framework of the project entitled "**Propuesta de una metodología para el cálculo de la Huella Ecológica y la Huella de Carbono en una Universidad. Aplicación a la Universidad Politécnica de Valencia**" funded by the Universitat Politécnica de València, and with the purpose of exactly that. Therefore, this paper shall constitute a contribution in the solution of the problems that arise due to carbon-sequestrating products.

This topic opens also potential lines of research regarding the topics of allocation, carbon sequestration and use of biogenic carbon. This approach has been applied to one case study, but other case studies might behave somewhat differently, and provide with insight on how biogenic carbon affects the results in a bigger picture. A study including the whole system, and factoring in the number of times a material can be recycled, is bound to give a greater insight in the reasons for much of what has been presented in this paper.

Furthermore, the issue of allocation is far from closed: none of the presented approaches constitutes the definitive approach. All of them have flaws, and fail in a percentage of the products. This paper has merely shed some light on the matter, but different – and creative – ways of allocating the environmental impacts of recycling. Efforts for closing the loop, or expanding the system beyond the alternatives that have been dealt with , must be explored in order to analyze whether they are suitable for a broader amount of cases than the current approaches.

Another potential point of development is that of selecting the appropriate allocation approach. Intelligent systems that assist the novice user in selecting the best allocation approach, or that even select it automatically to avoid misuses, could constitute a very relevant improvement in LCA software systems, who allow the user to see part of the allocation – in the best cases – but that do not facilitate the process of tracking and modifying these issues while during the process.

In all, this paper has shown the dangers and potential misleads of allocation, and should raise the awareness among practitioners about a topic so sensitive as this one.

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