THE METHOD'S INFLUENCE ON CLIMATE IMPACT ASSESSMENT OF BIOFUELS AND OTHER USES OF FOREST BIOMASS

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Towards a bio-economy: the role of the forest

Biomass has an increasingly important role in replacing fossil and mineral resources, and it is central in environmental impact-reduction strategies in companies and governments, locally, nationally and internationally. The European Union has recently taken action to strengthen the bio-economy, defined as "*…the sustainable production and conversion of biomass into a range of food, health, fibre and industrial products and energy*".

Two thirds of the land area in Sweden is covered by forests, and forestry has been an important industry for centuries. Increased and/or more efficient use of forest biomass thus has a great potential for replacing the use of fossil and mineral resources in Sweden.

There are two main reasons for why forest- and other bio-based products are seen as environmentally beneficial. Biomass is (most often) a renewable resource, in contrast to finite fossil and mineral resources, and there is often a balance between CO_2 captured when the biomass grows, and CO_2 released when the bio-based product is incinerated.

The challenge: calculate carbon footprints

Moving towards a bio-economy means replacing non-renewable fuels and materials with bio-based fuels and materials. This is a transition on many levels: technology, business models, infrastructure, political priorities, etc. To guide such a grand transition, there is a need to understand the environmental implications of new bio-based products. This includes assessing their climate impact, so-called carbon footprinting.

Carbon footprinting of forest products is not as simple as saying that forest products are carbon and climate neutral by definition. Fossil energy used for producing and transporting the products has a carbon footprint. Also, the carbon balance can differ between forest products, which can influence their carbon footprint. For example, carbon stored in products, while CO_2 is captured in the re-growing forest, can mitigate climate change. The modelling of the carbon balance is influenced by the study's geographical system boundaries – national, regional, landscape and single-stand perspectives often yield different results. Forestry can also lead to positive or negative changes in the levels of carbon stored in the soil, the levels of aerosols emitted by the trees (influencing cloud formation), and the albedo (surface reflectivity) of the forest land. An indirect effect of forestry can be increased competition for land, with expanding or intensified land use elsewhere, with positive or negative climate effects. All these factors are potentially important when calculating carbon footprints.

There is limited knowledge about how and to which extent the aforementioned factors influence the carbon footprint of forest products. Also, there is a lack of methods for assessing some of these factors. In light of this, can the carbon footprints of today be trusted? And can we ensure that they provide relevant and robust decision support?

Our approach: Testing three different carbon footprint methods in five case studies

In this study, we have:

1. Identified different carbon footprint methods.
2. Used the identified methods to calculate the carbon footprint of different forest products and non-forest benchmarks (using life cycle assessment, LCA).
3. Compared the results to find out how and why they differ.

We identified three main categories of carbon footprint methods: (i) the common practice in LCA, (ii) recommendations in standards and directives (we tested the EU sustainability criteria for biofuels and bioliquids and the Product Environmental Footprint (PEF) guide), and (iii) more advanced methods proposed in the scientific literature (we tested dynamic LCA). For dynamic LCA, we tested different time horizons (20 and 100 years) and different geographical system boundaries, based on (a) the national level, assuming a net annual growth of biomass (which is the case in Sweden); (b) the landscape level, assuming a balance between the annual harvesting and growth (the level at which forests are often managed); and (c) the stand level (a stand is the part of a landscape that is harvested in one year, a level often used by researchers developing new methods for modelling the dynamics of forest carbon flows).

These methods were applied to five forest products: two automotive fuels (a lignin-based fuel produced from black liquor and butanol), a textile fibre (viscose), a timber structure building, and a chemical (methanol, used for different end products).

Our findings

We found that different carbon footprint methods can give different results, as shown for the biofuel case studies in **Figure** 1. The common practice is close to the recommendation in the EU sustainability criteria and the PEF guide. Results from dynamic LCA differ considerably, as it accounts for the timing of (fossil and biogenic) greenhouse gas (GHG) emissions and CO_2 capture, which is ignored by the other methods. The results of dynamic LCA depend primarily on the geographical system boundaries, but also on the time horizon.

When applying dynamic LCA with a stand perspective, we assumed that the CO_2 uptake occurs *after* harvest. Alternatively, one could assume that the CO_2 uptake occurs *before* harvest, which would give different (lower) results.

When comparing the carbon footprints of the forest products with products they could be expected to replace, we see that the results for the forest products could range from being definitely favourable to worse (see **Figure** 2).

More results can be found in the full report. Results were produced to answer the research questions of this study, and should not be used out of context.

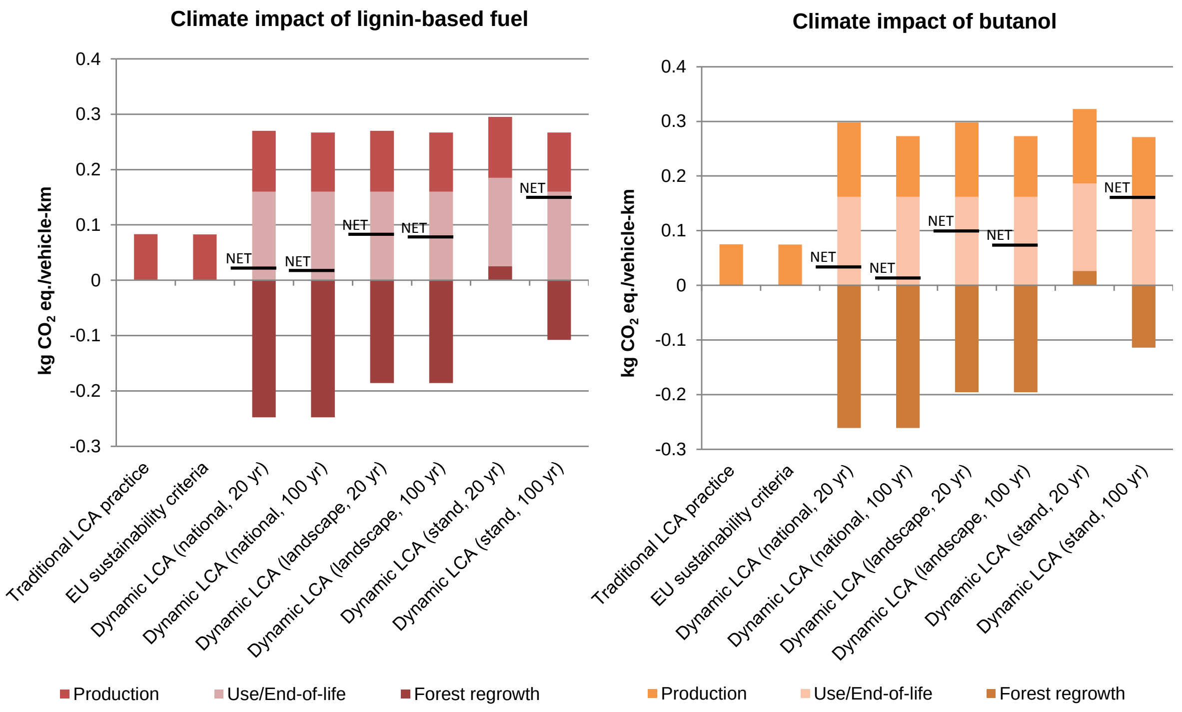

Figure 1. Climate impact of the biofuels for different carbon footprint methods.

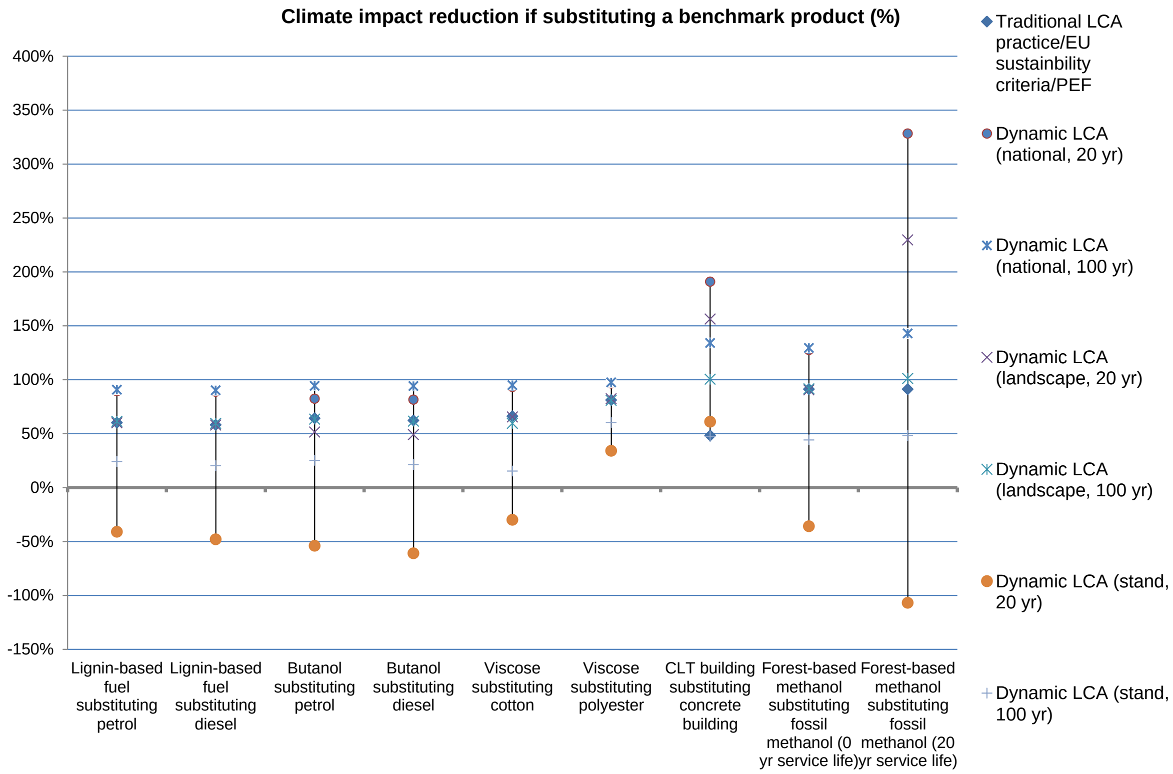

Figure 2. Climate impact reductions, if each forest product is assumed to substitute its benchmark product (values >0% mean that substituting the benchmark reduces impact; values >100% mean that more than all the impact of the benchmark is offset).

Our findings

Because there is (still) limited knowledge about how forest products influence the climate, and as carbon footprints will always depend on value-based assumptions (e.g. regarding geographical system boundaries), it is not possible to recommend one specific method which is suitable regardless of context. As different carbon footprint methods can give very different results, our key message is that we need to increase **consciousness** on these matters. It is important to be aware of the assumptions made in the study, the effects of those assumptions on results, and how results can and cannot be used for decision support in a certain context. More specific recommendations for decision makers are listed below. Further details and results can be found in the main report, along with recommendations for LCA practitioners and researchers.

- Decision makers must be aware that the main methodological choices influencing carbon footprints of Swedish forest products are the choice of geographical system boundaries (e.g. national-, landscape- or stand-level system boundaries) and whether the timing of CO_2 capture and GHG emissions is accounted for. This is because Swedish forests are, in general, slow growing.
- If the aim of the decision is to obtain short-term climate impact reduction – for example, the urgent reduction that is possibly needed for preventing the world average temperature to rise with more than 2°C – the timing of CO_2 capture and GHG emissions should be taken into account. Decision makers must be aware that a particular method for capturing timing (such as dynamic LCA) can be combined with different system boundaries, which can yield different results.

- When conclusions from existing LCA studies are synthesized for decision support, the decision maker must be aware that most existing studies do not account for the timing of CO_2 capture and GHG emissions. This is particularly important when the decision concerns the prioritization of forest products with different service lives (e.g., fuels versus buildings).

- When timing is considered, decision makers must be aware that there are different views on when the CO_2 capture occurs, which will influence the carbon footprint. One could either consider the CO_2 captured before the harvest (i.e., the capture of the carbon that goes into the product system), or the CO_2 captured after the harvest (i.e., the consequence of the harvest operation). In this study, we tested the second alternative when we applied dynamic LCA with a stand perspective – this does not mean we advocate the use of the second alternative over the first alternative.

- Decision makers must be aware that the location and management practices of the forestry influence the climate impact of a forest product. For example, growth rates, changes in soil carbon storages and fertilisers (a source of GHGs) differ between locations.

- Based on our results, we cannot say that the carbon footprints of some product categories are more robust than for others, i.e. less influenced by choice of methodology. However, the more forest biomass use in the product system, the higher the influence of the choice of method.

- As many interactions between the forest and the climate are still not fully understood, it is important to be open to new knowledge gained in methodology development work.

- Regarding how to use Swedish forests for the most efficient climate impact reduction, it is impossible to draw a general conclusion on the basis of our results. Factors that influence the “optimal” use are:

    - Which fraction of forest biomass that is used. Various products use different fractions (as was the case in our case studies) and do not necessarily compete for the same biomass. However, a production system may be more or less optimised for a specific output. So there may be situations of competition also when feedstocks are not directly interchangeable.

    - Which non-forest product that is assumed to be replaced by the forest product (if any). The carbon footprint of the non-forest product matters, but also how large the substitution effect is (i.e., does the forest product actually replace the non-forest alternative, or merely add products to the market, and what are the rebound effects from increased production?).

    - If all other factors are identical: the longer the service life of the forest product the better, due to the climate benefit of storing carbon and thereby delaying CO_2 emissions. This effect is particularly strong if the aim is to obtain short-term climate impact reduction. Moreover, the effect supports so-called cascade use of forest biomass, e.g. first using wood in a building structure, then reusing the wood in a commodity, and at end-of-life, as late as possible, recovering the energy content of the wood for heat or fuel production.

- Traditional LCA practice and methods required by the EU sustainability criteria and PEF have limitations in the support they can provide for the transition to a bio-economy, as they cannot capture the variations of different forest products in terms of rotation periods and service lives.

Thus, decision makers need to consider studies using more advanced methods to be able to distinguish better or worse uses of forest biomass. We have tested one such advanced method (dynamic LCA), that proved applicable in combination with several different geographical perspectives, but also other methods exist (e.g. GWP_{bio}).

- Climate change is not the only environmental impact category which is relevant in decision making concerned with how to use forests. Other environmental issues, such as loss of biodiversity and ecosystem services, are also important. There are also non-environmental sustainability issues of potential importance, e.g. related to indigenous rights and job creation.