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This letter is written in response to the article 'Quantifying the climate effects of bioenergy – Choice of reference system' (Koponen *et al.*, 2018), which presents guidance for selecting reference systems for understanding 'the climate effects of a bioenergy system'. Although there are many useful and well-supported points in the proposed guidance, there are also a number of serious problems:

1. **'Natural regeneration' is not the appropriate land reference system for inventories of anthropogenic impacts**, whereas Koponen et al. state that if 'the goal is to study the climate effects of bioenergy as a part of total anthropogenic activity, the appropriate land reference is regeneration toward natural potential vegetation' (2018, p. 2278). The article selectively cites from the literature in order to support the proposed approach, but does not acknowledge the on-going debate on this subject, with more recent articles providing a detailed critique of 'natural regeneration' baselines (Brander, 2015, 2016). Essentially, a 'natural regeneration' baseline is not appropriate for separating anthropogenic and non-anthropogenic environmental flows as the potential for regeneration is caused by human activity (i.e. land use and land use change), and so is not a truly 'natural' (i.e. non-anthropogenic) baseline.

2. **The descriptions and proposed uses for two of the reference approaches are misleading as they imply the study of a cause-effect relationship**. Koponen et al. (2018) identify three different reference approaches, with the first two answering the respective questions: 1a 'What are the absolute climate effects from the studied bioenergy system within a specified temporal window?' (2018, p. 2272); and 2a 'How much does the studied bioenergy system *contribute to total anthropogenic climate forcing* within a given temporal window?' (2018, p. 2273) [Emphasis added]. In both these cases the wording implies the representation of a cause-effect relationship, whereas neither approach represents the effects caused by

bioenergy systems. In the case of 1a, the approach includes non-anthropogenic flows, which by definition are not caused by human activity, and therefore the approach cannot claim to represent the effects from bioenergy, which is a human activity. In the case of both 1a and 2a, climate forcing is assigned to bioenergy systems based on the physical processes used within the bioenergy system, and effects associated with multi-functional processes are allocated by normative rules (e.g. mass, energy content, or economic value – as recognised in Koponen et al. (2018)). This allocative approach is normative, and does not represent the climate effects caused by bioenergy systems.

A more accurate articulation of the questions answered by the two approaches is: 1a 'What is the anthropogenic and non-anthropogenic climate forcing normatively allocated to bioenergy?'; and 2a 'What is the anthropogenic climate forcing normatively allocated to bioenergy?'. Once transparently articulated in this way it is more obvious that there is no useful purpose for approach 1a (this point is largely acknowledged by Koponen et al. (2018)), i.e. in what context would it be useful to normatively allocate non-anthropogenic climate forcing to an anthropogenic activity?

3. **Koponen et al. (2018) do not provide explicit guidance on the choice of reference system for attributional and consequential LCA**, stating that 'it is more important to clearly define the goal of the study and to choose the reference system that is suitable and appropriate for the goal than to categorise the LCA modelling technique [i.e. attributional or consequential LCA]' (2018, p. 2272). This appears to be an attempt at dodging the issue, and will inevitably leave practitioners with the question 'Which type of reference system is appropriate for attributional and consequential LCA?'. Dodging the issue is also doomed to failure as the goal of the study will determine whether attributional or consequential LCA is the appropriate method, and that choice will in turn will determine the appropriate reference system.

To resolve the problems with the proposed guidance it would be considerably clearer and simpler to state that:

a. Attributional LCA is an inventory of anthropogenic impacts, conceptually akin to other forms of environmental inventory, and is appropriate if the goal of the study is assigning responsibility for a set of anthropogenic impacts, setting reduction targets, or allocating impact budgets (see Brander (2016)). The appropriate form of reference system for attributional LCA is a 'natural' baseline, i.e. what would have happened in the absence of all human activity, as this separates anthropogenic from non-anthropogenic impacts.

b. Consequential LCA is an assessment of the system-wide change caused by a specified decision, and is appropriate if the goal of the study is to inform decisions intended to reduce impacts. The appropriate form of reference system is what would have happened in the absence of the decision in question.

I hope that this letter helps to advance the discussion on the choice of reference system, and I would like to thank Kati Koponen and her co-authors for this stimulating debate.

References:

Brander, M. (2015) 'Response to "Attributional life cycle assessment: is a land-use baseline necessary?"—appreciation, renouncement, and further discussion', *International Journal of Life Cycle Assessment*, 20(12). doi: 10.1007/s11367-015-0974-8.

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