Assessing Climate Impact of Industrial Symbioses: A Dynamic Approach

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1. Introduction

In economies where natural resources are rarefying, Industrial Symbioses (IS) are becoming promising solutions to manage natural resources. IS however do not have as corollary the absence of environmental impacts, that thus remain to be assessed [1]. Global warming impact (GWI) is an environmental phenomenon the reduction of which is at present of major importance. The most widely used method to link GWI to GHG emissions of industrial systems (as used in product life-cycles) is the Global warming potential (GWP) and its indicator CO_2 equivalent (CO_2-eq), also commonly used to express the GWI of IS [2;3] However, although its use is relevant for assessing GWI of products or comparing efficiencies between several emission years, it does not express the GWI at different time horizons. Both dynamics GHG emissions and their GWI assessment, that are essential to aptly assessing structural changes engendered by IS projects, are not considered while using the GWP, which biases the analysis.

Here, we briefly recall the semantic and mathematical reason of the limits of assessing an activity's impact through GWP and propose a derived model and tool that we subsequently illustrate.

Global warming potential

GWP is defined [4] as the quotient of time-integrated global mean radiative-forcing (RF) of a pulse emission of 1kg of a gas (g), relative to that of CO_2, as follows:

$$GWP_g = \frac{AGWP_g}{AGWP_{CO_2}} = \frac{\int_0^t RF_g(t)\,dt}{\int_0^t RF_{CO_2}(t)\,dt} \qquad (1)$$

where time-integrated RF is equally called absolute global warming potential (AGWP) and t temporal horizon that in reference to Kyoto protocol in currently set to 100 years [4]. Since CO_2 is a persistent GHG, as such the GWP minimizes the impact of short-lived GHG.

In addition, a fixed time horizon, e.g. from 0 to 100 years, limits the use of invariant potentials and thus does not allow to assess GWI over time, either residual RF or cumulative RF (i.e. AGWP).

Assessing AGWP over time

The GWP is inconsistent with the GWI assessment of structural system changes. Acknowledging the relevance of RF concept and its cumulative effect, as suggested by IPCC, we propose to assess their GWI by using AGWP. This, however, implies to consider the emission year as variable (**temporal inventory**), as well as RF. Indeed, RF is defined as follows:

$$RF_g(t) = a_g . C_g(t) \qquad (2)$$

where a_g is the radiative efficiency of a given GHG and C_g its time dependent abundance function, which has an exponential form.

The ultimate formula stating the AGWP of multi-annual system σ then becomes:

$$AGWP^{\sigma}(t) = \sum_{y=0}^{l} \sum_{g} E_{gy}^{\sigma} \cdot \int_0^{t-y} RF_g(t)\,dt \qquad (3)$$

where y is the (variable) emission year, l the last emission year, E_{gy} temporal inventory of gas emissions (in kg).

Projections comparison and discussion

Once a temporal inventory is established, its AGWP has to be assessed by using equation (3); we built a R-script for this purpose that enables to compare it to the current GWP method.

Figure 1 presents the results for two dummy processes simulated over 30 years (2015-2045). Process 1 is a transport-type process (mainly CO_2 and CO emissions) and Process 2 is composting-type process (mainly CH_4, CO_2, N_2O emissions).

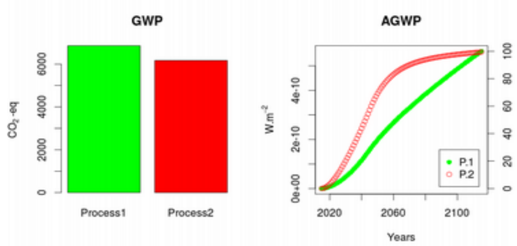

Figure 1. GWP vs. AGWP from a temporal inventory

On the left, current GWP aggregates all the emission impact over time and concludes that process 1 is more harmful, while the dynamic AGWP (right) mitigates such a conclusion: P1 barely exceeds P2 after 100 years.

This clearly calls 1) to reconsider the current use of GWP and 2) to explicitly address the temporal horizon with stakeholders when eco-designing structural system changes such as IS.

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