

## A proposal to measure absolute environmental sustainability in lifecycle assessment - DTU Orbit (08/11/2017)

### A proposal to measure absolute environmental sustainability in lifecycle assessment

Environmental monitoring indicates that progress towards the goal of environmental sustainability in many cases is slow, non-existing or negative. Indicators that use environmental carrying capacity references to evaluate whether anthropogenic systems are, or will potentially be, environmentally sustainable are therefore increasingly important. Such absolute indicators exist, but suffer from shortcomings such as incomplete coverage of environmental issues, varying data quality and varying or insufficient spatial resolution. The purpose of this article is to demonstrate that life cycle assessment (LCA) can potentially reduce or eliminate these shortcomings. We developed a generic mathematical framework for the use of carrying capacity as environmental sustainability reference in spatially resolved life cycle impact assessment models and applied this framework to the LCA impact category terrestrial acidification. In this application carrying capacity was expressed as acid deposition (eq. mol H<sup>+</sup> ha<sup>-1</sup> year<sup>-1</sup>) and derived from two complementary pH related thresholds. A geochemical steady-state model was used to calculate a carrying capacity corresponding to these thresholds for 99,515 spatial units worldwide. Carrying capacities were coupled with deposition factors from a global deposition model to calculate characterisation factors (CF), which expresses space integrated occupation of carrying capacity (ha year) per kg emission. Principles for calculating the entitlement to carrying capacity of anthropogenic systems were then outlined, and the logic of considering a studied system environmentally sustainable if its indicator score (carrying capacity occupation) does not exceed its carrying capacity entitlement was demonstrated. The developed CFs and entitlement calculation principles were applied to a case study evaluating emission scenarios for personal residential electricity consumption supplied by production from 45 US coal fired electricity plant. Median values of derived CFs are 0.16–0.19 ha year kg<sup>-1</sup> for common acidifying compounds. CFs are generally highest in Northern Europe, Canada and Alaska due to the low carrying capacity of soils in these regions. Differences in indicator scores of the case study emission scenarios are to a larger extent driven by variations in pollution intensities of electricity plants than by spatial variations in CFs. None of the 45 emission scenarios could be considered environmentally sustainable when using the relative contribution to GDP or the grandfathering (proportionality to past emissions) valuation principles to calculating carrying capacity entitlements. It is argued that CFs containing carrying capacity references are complementary to existing CFs in supporting decisions aimed at simultaneously reducing environmental impacts efficiently and maintaining or achieving environmental sustainability. We have demonstrated that LCA indicators can be modified from being relative to being absolute indicators of environmental sustainability. Further research should focus on quantifying uncertainties related to choices in indicator design and on reducing uncertainties effectively. © 2015 Elsevier Ltd. All rights reserved.

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