



## Review

## Changing from petroleum to wood-based materials: critical review of how product sustainability characteristics can be assessed and compared

Gunilla Clancy<sup>a,\*</sup>, Morgan Fröling<sup>b</sup>, Magdalena Svanström<sup>a</sup>

<sup>a</sup>Chemical Environmental Science, Chalmers University of Technology, Göteborg, Sweden

<sup>b</sup>Ecotechnology and Environmental Science, Mid Sweden University, Östersund, Sweden

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## ABSTRACT

This paper reports on a literature survey on available approaches for the assessment of product sustainability, with a specific focus on assessing the replacement of non-renewable petroleum-based materials with renewable wood-based materials in absorbent hygiene products. The results are contrasted to needs in a specific material development project.

A diverse number of methods exist that can help in assessing different product sustainability characteristics for parts of or whole product life cycles. None of the assessment methods found include guidelines for how to make a case-specific interpretation of sustainability and there is a general lack of assessment parameters that can describe considerations in the comparison between the use of wood or petroleum as main raw material. One reason for this is lack of knowledge and/or consensus on how to describe and assess impacts of land and water use, e.g. on ecosystem services, different types of resource depletion and social impacts.

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### 1. Introduction

Due to different concerns, such as diminishing reserves of non-renewable resources and increasing evidence of climate change related to emissions of greenhouse gases (GHGs), many companies are shifting from non-renewable to renewable material resources, expecting that this will result in more sustainable products. However, the sustainability of products is a complex issue that depends on numerous factors; renewability and climate change are only two of these. Changing from a non-renewable to a renewable raw material does not automatically mean that the product will become more sustainable. The material from a renewable resource might, for instance, need more energy in the production stage, or more material might be required for the final product to fulfil its function in a satisfactory way, than if a non-renewable material resource had been used; a situation that has been discussed rather extensively in relation to biofuels, e.g. ethanol (Farrell et al., 2006; Fehrenbach et al., 2008). Therefore, in the short- to mid-term, before we actually run out of a specific fossil resource, it might in

some cases be a better choice to continue to use the fossil resource until suitable materials, improved technologies, or new use patterns have been developed. In fact, it comes down to how 'sustainability' is interpreted in each specific comparison.

With increasing competition for resources following increasing global consumption, resource use needs to a greater extent be valued based on resource limitations and potential competition from other areas of use. In the case of the non-renewable resource petroleum versus the renewable resource wood as a raw material for different products, this could come down to weighing the depletion of limited petroleum resources against increasing land area requirements, including different impacts from the cultivation of wood resources and direct and indirect impacts from land use change. In any such assessment, impacts need to be related to the specific functions that are ultimately fulfilled in society by the product; therefore, a life cycle perspective is necessary, with the product's function as the point of reference. This will ensure that sustainability impacts throughout the product's entire life cycle are considered and that changes that just shift the burden from one stage to another can be avoided.

This study has been performed within the WooDi (the Wood Based Diaper) project, which aims to develop wood-based

\* Corresponding author. Tel.: +46 (0) 31 772 31 02.  
 E-mail address: [clancy@chalmers.se](mailto:clancy@chalmers.se) (G. Clancy).

materials that can replace petroleum-based materials in the absorbent core of a diaper. The research project is a collaboration between industry and university. The goal of the project is that a diaper containing the new materials should be more sustainable than a reference diaper based on present technology. This calls for a methodology that will allow assessing and comparing the sustainability impacts associated with using these different resources in a product.

Munthe, in a report to the Swedish Agricultural Administration in 1997 (Munthe, 1997), defined three questions that should be answered before any assessment effort is started:

- What concerns should be included?
- How should potential trade-offs between the concerns be made?
- How should uncertainties in the required information be handled?

Munthe argued that these questions need to be answered in order to ensure transparency and to avoid being influenced by expected or desired results.

The same type of questions have also been highlighted by others in comparing products, e.g. by Steen (2006), and they are most likely useful as a basis in any product assessment. The three questions can be formulated in the following way for the WooDi project: (1) What sustainability considerations are essential to include in the product assessment, taking into account the specifics of the product systems under study and the challenges that emerge in light of world development and the goal of sustainable development (i.e. which assessment parameters are the most relevant to include)? (2) How should potential trade-offs between these sustainability concerns be handled if the compared sustainability profiles peak in different areas (i.e. what weighting factors should be used)? and (3) How should the yet unknown final product and product system be dealt with in a sustainability assessment?

Since the WooDi project deals with material development, many features of the final product are still unknown, at least early on in the project. Over time, more characteristics of the final product will be possible to estimate and the full product system will eventually be possible to discern. Throughout this material development process, the sustainability assessment approaches that are the most appropriate to employ will likely shift as the needs of the project change. In order to ensure that the new product is developed to become more sustainable than the reference product, the new ideas must, despite the original uncertainties, be benchmarked to a reference product that already exists on the market. The people making important choices in this process need therefore be guided through the important considerations, starting with awareness-raising exercises and working towards a quantitative to semi-quantitative comparison.

This paper reports on available literature on defining, assessing and comparing the sustainability of products made from renewable (wood-based) respectively non-renewable (petroleum-based) materials, specifically for products or activities that are of relevance for the WooDi project, i.e. absorbent materials in diapers and other hygiene products. Knowledge and methodology gaps that need to be filled in order for a sustainability comparison to be performed within the WooDi project are discussed.

## 2. Research method

In order to provide information to the WooDi project, which aims at achieving a shift from petroleum to wood as the material base for the absorbent core of an incontinence diaper, a literature survey was carried out on available sustainability impact

assessment approaches. Besides creating an overview of existing assessment approaches that could prove useful in the project, an emphasis was put on exploring which assessment parameters that have been in actual use in assessing materials of fossil and biological origin and how these parameters have been selected, in order to provide input to the comparative assessment that is to be conducted within the WooDi project. By contrasting the results from the survey with the needs of the WooDi project, existing gaps in knowledge and methodology were evaluated and further steps that need to be taken were identified.

Regarding approaches and techniques for the assessment of environmental sustainability from a systems perspective, an overview has been published earlier by other authors (CHAINET, 2002). In the present paper, the investigation was narrowed down to what is most urgently needed in the WooDi project, i.e. the state-of-the-art in terms of comparing the sustainability characteristics of products made from petroleum-based and wood-based materials.

Fig. 1 provides an overview of the ideas underlying the present study and the type of results that will be reported on in this paper. Different approaches found in literature have been classified according to the CHAINET nomenclature regarding assessment approaches for the environmental dimension of sustainable development (CHAINET, 2002; Wrisberg et al., 2002); 'analytical approaches' are mainly employed to assess the impact of a product system, while 'procedural approaches' primarily focus on determining whether certain requirements are fulfilled.

In Fig. 1, the 'scope' summarises underlying theories and delimitations of this study, as discussed in the previous section. In Section 3, analytical approaches that assess the life cycle performance of products based on one or several environmental parameters are reviewed, including issues related to weighting and also some analytical approaches with a broader, more holistic, scope. In Section 4, procedural approaches such as certification schemes for different resources and biofuels are reviewed. These often include assessment parameters important for resource extraction or cultivation stages which are normally not considered in e.g. life cycle assessments due to the difficulty in measuring things like biodiversity and social progress. In Section 5, case studies, in which products with petroleum and biomass-based materials are compared and reviewed along with case studies assessing diapers. Finally, in Section 6, an overview of sustainability assessment parameters and their use is given and how the different analytical and procedural approaches can be used in the WooDi project is discussed. Only approaches and results relevant to the WooDi project are reported on, i.e. they deal with the sustainability assessment of products and resources and provide input to making a comparison of the use of petroleum and wood-based materials.

## 3. Analytical approaches for assessing the life cycle performance of products

### 3.1. Environmental performance

Life Cycle Assessment (LCA) methodology is widely used to evaluate the environmental performance of product systems. An LCA studies potential environmental impacts of a product or service throughout its life, from resource acquisition through production, use and waste management, by mapping and evaluating flows crossing the system boundary, see for example Pennington et al. and Rebitzer et al. for a more thorough description of LCA methodology (Pennington et al., 2004; Rebitzer et al., 2004). LCA is a standardised method for the environmental assessment of products, included in the ISO 14040 series. An LCA should include the whole life cycle and should look at as many environmental impacts (ecological consequences, resource use and impacts on

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