INTEGRATED LCA OF WOOD BUILDING PRODUCTS ON A REGIONAL SCALE: CONCEPTUAL AND METHODOLOGICAL CONSIDERATIONS

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Abstract
Performing a LCA study to evaluate the environmental profile of the wood building products sector in an integrated way requires a well-designed conceptual framework. This framework should consider the specific features characterising this particular part of the primary economy. Large quantities of co-products as well as multi-functional products are generated within the closely intertwined companies. These products, combined in several building components, have typically long use-phases and multiple reuse or recycling loops. The end-of-life scenario is particular as well, focusing on energy provision. Methodological considerations arise from these specific features concerning allocation procedures, temporal considerations of the different life spans or inherent qualities of wood building products linked to environmental performances.

For the case study of the Walloon Region, only wood building products that undergo at least a product transformation stage within the region are considered. Aggregated production chains have been described for sawn timber, fiber boards, floorings, laminated components, window frames and insulation materials. Through participation of a significant number of industrial partners, primary data will be collected to support the outcome of the LCA study. The available opinions and hypotheses found in literature to approach this multi-output configuration are then discussed in light of the specific situation of the several industrial segments.

The objective of this study is to address an adapted concept for the Walloon Region incorporating new insights and hypotheses to the available literature as well as stating methodological bottlenecks. The development of the LCA concept will be presented and the first implementation steps will be discussed with regard to practical experience from primary data collection.

Keywords: Integrated LCA, wood construction products, building, multi-output, allocation

1. INTRODUCTION

The use of biomaterials in building components can offer sustainable solutions for the construction sector. A life cycle assessment (LCA) objectively evaluates the environmental performance of (wood) building products, through the consideration of potential impacts occurring from resource extraction, product manufacturing, use and waste treatment. Several LCA studies have been carried out for wood products (e.g. [1–3]) or on the building level (e.g., [4–6]).

Product manufacturing is an important step of the life cycle (LC) because a significant part of environmental impacts usually occurs throughout this LC phase (e.g. energy consumption, application of chemicals) and the characteristics of the final product are defined in the manufacturing process. The achieved product quality is an important criterion for the environmental performance of the subsequent LC stages like the use phase as well as for the end of life situation.

The product system is multifunctional; different applications are closely interlinked. In order to evaluate the produced materials from an environmental point of view, the specific regional situation has to be taken into account. A research project is ongoing aiming to develop LCA profiles for different wood construction products, following the suggested integrated approach. This article presents the conceptual and methodological framework of this LCA study and discusses the first implementation steps with regard to practical experience from primary data collection.
2. GOAL, SCOPE AND APPROACH

The objectives of the study are: (i) provision of quantitative LC data on wood construction products, as to the current state of technology (ii) identification of hot spots of environmental impacts and optimization of the energy performance and (iii) information of industry and policy makers. The attributional LCA study will be applied on the product level (cradle- to- gate) as well as for the whole building LC.

The case study concerns the Walloon region of Belgium and focuses on wood construction materials: only wood building products that undergo at least a product transformation stage (before application in a building component) within the region are considered. Aggregated production chains have been described for sawn timber, (medium) fiber boards, floorings, laminated components, window frames and insulation material.

In order to develop the methodological framework for the LCA study, at first, the case study region has been characterised through an analysis of material flows based on literature and industry data. A literature review has been carried out for wood products and wood buildings. The available approaches dealing with the sector characteristics have been discussed in light of the specific regional situation and finally, an adapted concept was developed. Through participation of significant number of industrial partners, primary data will be collected to support the outcome of the LCA study.

3. WOOD BUILDING PRODUCTS SECTOR AND LCA

3.1. Characteristics of the wood building products sector

Figure 1 presents the material flows of the Walloon wood building sector and their linkages with other industry segments (located inside or outside the region). A significant amount of mainly locally exploited softwood is dedicated to the regional sawmill and medium density fibreboard (MDF) industry. Currently, the manufacturing industry produces approx. 1.7 Mm³/yr sawn wood products and 0.3 Mm³/yr MDF [7,8]. Sawn wood products are used for direct applications (e.g. beams, planks), dedicated to the 2nd transformation construction industry (laminated wood industry, windows, doors and floorings) or transformed into packaging material or furniture. Beside this diversity of products, 0.45 million tons (dry matter) of co-products like bark, sawdust or woodchips are produced in the Walloon region [9]. They are partly used internally for energy provision (e.g. for MDF production) or further traded to other industries for material or energy applications (e.g. packaging, particle boards, cogeneration). In Belgium, a significant part (> 80 %) of the recovered wood is recycled and used for a material application, mainly particle board [10]. The material flow analysis deals with the problem of establishing a border between the construction sector and other industries (parts of the sawn products are dedicated to packaging industry) and to set regional boundaries (import and export flows).
3.2. Characteristics of the life cycle of wood building products

The LC of wood building products is multi-levelled and has four main characteristics: (i) The production stage has closely interlinked product flows, as is shown in Fig. 1 (ii) The use phase as a building component is very long and complex with a typical building life time of 50 years. For conventional buildings, the use phase is very important because the operating energy represents the dominant part of the total LC energy consumption. The development towards low energy buildings has reduced the importance of the use phase and shifted it towards the impacts of the production stage [11] (iii) After the use of wood as a building component, demolition wood can be recycled in the particle board industry and follow several recycling loops until (iv) the end of life phase where (bio)energy is generated.

These characteristics are similar for other building products. A unique feature for wood is the temporal storage of biogenic carbon during the material application as a building component or in the recycled product.

3.3. Methodological aspects

Allocation. The three possible situations where allocation should be considered are (i) multi-output, (ii) multi-input and (iii) open-loop recycling, all of which could be relevant for wood products. The wood products sector shows multiple products as well as bark, sawdust, side cuts, wood chips, which currently achieve a considerable economic value and can be classified as co-products (and not as waste). Therefore, the study has to deal primarily with (i) multi-output allocation.

Choosing an allocation method has a significant impact on the result, especially for the wood products industry [12–14]. Following the stepwise procedure stated in the ISO standards, the possibility to avoid allocation through system expansion (SE) has to be evaluated firstly [15, 16]. SE is applied in attributional LCA when several LC with several functions are in the scope of the study [17]. If the additional function is energy provision, the avoided burden approach, as a special case of SE is often used (e.g. in [2, 18]. Although this LCA study aims to analyse several industry segments, not all related industries (e.g., pulp and paper industry, packaging) can be included. Furthermore, the avoided burden approach fails to define appropriate substitutes for biomaterials. As the second step, ISO standards propose a partitioning of in- and outputs reflecting underlying physical relationships.

The wood manufacturing sector is a typical example for physical allocation. The physical causality is established through the fact that round wood that is entering a sawmill is equally found in product and co-products [19]. However, as for highly manufactured wood products, the material yield may be relatively low (<50 %) and a significant part of potential environmental impacts would be allocated to other segments. The European standard EN 15804 recommends economic allocation for construction
products when the difference in revenue between product and co-product is high (difference of more than 25%) [20].

The allocation situations (ii) and (iii) are referring to the end of life of the products. In this case study, the recovered construction wood undergoes a change to its inherent properties when either particle board is produced or energy is provided therefore the definition of open-loop recycling. It is also a multi-input situation because different raw materials enter the production of a particle board or the incineration plant. The general way to choose the allocation method consists of the same stepwise procedure as explained in the previous paragraph. In [2] and [21], recovered wood is used as a thermal resource and system expansion is applied. However, in case of recycling or reuse, the allocation problem is more complex. In his paper [22], Borg et al. focus on recycling of building products and propose an economic approach which allocates environmental loads on the upstream product and on the downstream recycled raw material. The method considers the economic value of the primary and secondary raw materials, based on the market prices, in order to assign the loads.

Considering the current market situation in the wood processing sector, De Boever and Van Acker (2008) demonstrated an on-going narrowing of prices within the entire wood-processing industry chain. It was found that this phenomenon is similar throughout different regions within Europe [23]. At the low-end product side, prices are increasing due to a largely subsidised energy market (e.g., green certificates). On the other hand, disappeared and/or missing technology regionally lowers the prices for high-quality/large-dimension stems [24]. This market development may result in the fact that there is no significant difference between an allocation method based on price or on a physical relation (mass). An allocation method which leaves out the influence of subsidies and the lack of certain technology could reflect the market situation more appropriately.

**Quality considerations.** For the interpretation of results, it has to be considered that the current material flows in the sector do not reflect the cascade principle that suggests a sequential use of resources for different purposes according to quality aspects. The impacts of optimizing production chains according to quality aspects can be analysed with scenario approaches that compare the current situation in the region with alternative resource flows.

**Handling of temporal effects.** The third methodological aspect is the handling of temporal effects and biogenic carbon balances. Wood is used for material applications and for energy provision at different LC points in time. If harvesting residues or co-products are used as an energy carrier, they emit directly (biogenic) CO$_2$ at point x. With an application as a building material the emission is delayed for a certain time (x + product life span). Whether or not to give a credit for delayed emissions (temporal carbon storage) is still under debate in the scientific community [25]. Standards for the calculation of the carbon footprint are under development and approaches that use dynamic characterisation factors have been published [26]. Within this study, the sequential use of a resource for different purposes at different points in time will be investigated and the effect of choosing different time horizons will be demonstrated.

### 3.4. Integrated approach and practical experience

The LCA case study presents an integrated approach for the investigation of multiple products coming from one sector and one region. This approach combines an analysis of regional material flows and a product LCA. Identifying the linkages between the enterprises for the trade of products, co-products and energy and creating a temporal inventory of production allows the inclusion of temporal effects.

Practical experience from primary data collection has shown that (i) linkages are more complex than expected (ii) there exists a high flexibility regarding the raw material supply and (iii) trading activities (e.g. for wood chips) occur primarily within the wood products sector.

### 3. CONCLUSION

The specific features of the wood products sector and of the characteristics of the life cycle have been identified. Based on this specific configuration, methodological considerations for multi-output allocation, the handling of quality issues, and temporal aspects have been discussed. An integrated LCA approach based on regional material flows, will make it possible to address these multiple issues at the same time.

### 4. REFERENCES


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