World Conference on Timber Engineering Oslo 2023

GHGs EMISSIONS FROM SAWNWOOD PRODUCTS IN NORWAY– THE IMPORTANCE OF HARMONISED LCA METHODOLOGY IN ENVIRONMENTAL PRODUCT DECLARATIONS (EPDs)

Johann Kristian Næss[1], Ana Maria Santos Bouzada[1], Roja Modaresi [1*]

ABSTRACT: Wood is often considered a low-emission and sustainable material. However, there is always potential for the industry to further reduce environmental impacts if hotspots in the production phases are identified. When a contribution analysis is performed in LCA for building materials, the different processes, raw materials or life cycle stages contribution to a functional unit's overall impact can be compared. However, methodological choices in the LCA can be decisive for how a contribution analysis should be interpreted. This study has two main purposes; 1) to perform a contribution analysis for planed timber products in terms of Global Warming Potential, representative for sawmill industry in Norway, 2) to highlight the importance of harmonised LCA methodology in Environmental Product Declarations (EPDs) by performing a sensitivity analysis for the choice of allocation assumptions, as Product Category Rules (PCRs) can be interpreted differently by EPD practitioners. Calculations are based on data from five timber manufacturers in Norway, whereas three of these also had facilities for surface treatment on site. The uptake of carbon dioxide in the timber products was not considered in the GWP calculations. Results show that forestry and sawlog transport contribute the most to the GWP of planed timber. Furthermore, results for A1 and A2 modules (A1: raw material, A2: transport of raw material) are sensitive to allocation assumptions defined in A3 of the LCA model (A3: manufacturing). Using physical properties instead of economic values for allocation of these upstream emissions in forestry and transport, reduces the GWP emissions by approximately 30%, from 59.1 to 41.6 kg CO_2-eq/m^3. This demonstrates how allocation choices across life cycle stages matters. Inconsistency in allocation practices impairs the comparability of EPDs developed for wood building materials and deteriorates rationale environmental decisioning for the building sector.

KEYWORDS: Sawmills, Emissions, Forestry, EPD, EN15804, Allocation, LCA

INTRODUCTION

Wood increases its legitimacy in comparison to other materials, often associated with relatively low greenhouse gas emissions (GHGs) in processing, in addition to the carbon sequestration possibilities in the use phase [1-4]. Norway has an annual production of about 13 Mm^3 of roundwood [5, 6]. 2.7 Mm^3 of sawn timber are produced in Norway annually by relatively small sawmills, where 75% of the total production is coming from 18 sawmills with a capacity of above 50 000 m^3 [7]. Several LCA studies on forestry have been conducted since the early 1990s, however, there are differences in assumptions, background data, and their subsequent results [8]. GHGs from Norwegian forestry and transport to industry has previously been well documented for roundwood [9]. However, there has been a lack of similar studies that includes downstream production activities from the forest, such as sawmilling and planing of timber. This makes it difficult to compare the GHGs from different stages in the Norwegian value chain for timber building materials. Such an assessment exists for individual sawmills in other countries. For example, Lauri et. al compared different allocation methods for timber products and included results for different life cycle stages, using manufacturers data from three sawmills in Europe [10]. Beside all the existing studies, interpretation of LCA results for the production phases of sawn timber must be made with caution in EPDs and LCA studies. This difference in practice, becomes important when joint co-production processes are present in one or more of these life cycle stages. Such processes can be defined as undividable processes that has more than one output product with positive economic value. In these cases, environmental impacts associated with the joint-co production process including upstream impacts from materials and energy needed, must be partitioned to the products in a rational way. Partitioning of the flows to different products are often referred to as allocation in LCA. Allocation is usually based on physical properties such as mass or energy content. However, flows shall be allocated by economic value for the distinct co-products when the differences in the respective revenues are high, >25% according to a 'Note' in EN 15 804 [11]. A typical joint-co production process in the value chain of wood building materials is the sawing process, with outputs of sawn timber, chips and sawdust. For these co-products, the differences in revenues are relatively high. Different interpretations for the interlink between life cycle stages are made in LCA of wood materials in Nordic countries, where mainly two different methodical frameworks have been established for the development of EPDs. Two

[1] NTI Norwegian Institute of Wood Technology, Norway
* Corresponding author: Roja Modaresi Norwegian Institute of Wood Technology, rmo@treteknisk.no +47 402 95 791

https://doi.org/10.52202/069179-0133

different program operators are publishing EPDs, in Norway (EPD-Norge) and Sweden (International EPD system (IES)). Program operators provides guidelines for the development of EPDs by providing PCRs for specific product groups, but the rules must follow PCRs' higher in the hierarchy, such as EN 15804 [11] and EN 16485 [12], the latter is currently being revised. Rules for accounting of greenhouse gas emissions are also increasingly being governed by law, which can affect the new revisions of EPD standards. LCA is still a field under development, and despite the great number of PCRs that exist to harmonise methods for calculations, rules in standards and Product Category Rules (PCRs) are still open for interpretation [10]. There is a lack of knowledge among the EPD users [13]; and problems especially occurs when EPDs from different program operators are compared, with the aim of selecting a product with a better environmental profile. It is clearly shown in a study of 436 EPDs which were published under two different programme operator and therefore two different PCRs; that almost 90% of EPDs were incomparable [14].
The aim of this study is to perform; 1) GWP assessment for surface treated claddings, and planed timber products produced in Norway, using a contribution analysis format and LCA principles from development of EPDs 2) sensitivity analysis of using two different methodical frameworks that is present in EPD development in Nordic countries.

METHODOLOGY

A cradle-to-gate GHG assessment was made for planed timber and surface treated cladding in a contribution analysis format, meaning that the contribution of different products or processes impacts to the final result can be examined. Furthermore, a sensitivity analysis was performed for different methodical frameworks practiced for EPDs in Norway and Sweden; "NO method", following NPCR 015 and the older version of EN 16485. Also referred to as the traditional value chain calculation, "SE method", which differentiates from the value chain calculation by allocating upstream activities (roundwood) in forestry (A1) and transport of roundwood to sawmills (A2) after mass in joint co-production processes at sawmills.

Contribution analysis

Included activities inventoried in this assessment are highlighted in Figure 1. The system boundary is defined by the outer grid in the figure, which includes processes from rejuvenation activities in forestry until the finished product (planed timber or surface treated cladding) is packaged and stored within the factory gate. The functional units are 1 m³ of planed timber and 1 m² of surface treated timber cladding. Planed timber includes a varieties of untreated timber products that has undergone sawing, drying and planing and are used as building materials for both structural and non-structural purposes, indoor or outdoor. Cladding is used for exterior façade of houses and buildings, and one layer of primer and paint is applied in the manufacturing (industrially coated) for this functional unit. In the contribution analysis for planed timber, the same production activities within the dotted border in Figure 1 represents the grouping of sawmill activities, and in addition, Forestry and roundwood transport are also a separate group. For surface treated cladding, only the timber cladding and the surface treatment constitutes the two contribution groups in this analysis. Other important activities that are not depicted by Figure 1 is the production of paint and diesel, emissions from the manufacturing of these raw materials are included in the analysis groups for surface treatment and internal transport, respectively.
Five sawmills, located in the South-eastern parts of Norway, constitutes the providers of specific manufacturers data in this study. The results are represented by the mid-point category for greenhouse gas emissions, GWP-IOBC (Global Warming Potential assuming instantaneous oxidation of biogenic carbon). This means that the uptake of carbon dioxide into biogenic carbon in the wood material is not included in the GWP result. This indicator is described in more detail in PCR part A from EPD-Norway [15]. The correct characterisation for methane in the PCR is not clear enough. Therefore, this study follows IPCC 2019 guidelines [16], in addition to EN 15 804.

1. Life Cycle Inventory (LCI)

The background LCI is built on a selection of Ecoinvent v3.7.1 data [17], combined with datasets tailormade for the Norwegian wood industry, e.g. roundwood production [18]. The specific data was gathered in EPD projects, involving five manufacturers of sawn timber, whereas three of these manufacturers had facilities for industrial surface treatment. A flow chart highlighting the included wood value chain activities in this study are presented in Figure 1.

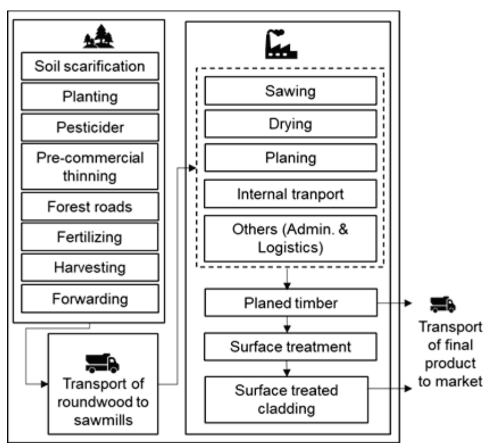


Figure 1: *Flow chart that summarizes included processes for processing of wood throughout the wood value chain.*

The reference year for annual activity data varies for the different subprocesses in forestry, but all are within the years 2016-2020, and based on national statistics data [19-21]. Otherwise, the LCI for forestry processes is taken from previous studies [9, 22]. LCI for fuel used is taken

https://doi.org/10.52202/069179-0133

from Vennesland et al. [23]. Regarding the silvicultural activity of fertilizing, it is assumed that 150 kg of nitrogen are used per ha of forest and that the secondary release of dinitrogen monoxide into the atmosphere due to the added fertilizer are 2,75 kg per ha [24]. The total area fertilized are based on national statistics data from the reference year of 2020 [25]. The allocation between sawlog and pulpwood has been adjusted to be in line with the requirements in EN 15804 [11] and NPCR 015 [26]. This means an economic allocation of silviculture operations and harvesting, except for the activity of forwarding (terrain transport of roundwood from the felling to the forest gravel road). It is assumed that the forwarding is not affected by the demand for roundwood, or pulpwood and these assortments can be transported separately from each other.

The dataset used for the road transport of roundwood is originally Ecoinvent data that has been modified at NTI to be more suitable for roundwood transport in Norway. The adjusted parameter values on fuel consumption, lorry weight, fuel blend, average load weight, and vehicle load capacity are based on information from actors within forestry operating in Eastern Norway (Norsk Virkesmåling, Viken Skog and Trekk Tømmer). A mix of 7% biofuel in the diesel is assumed, following NS-EN 590 [27]. For logs transported by sea, the background data are based on generic Ecoinvent data [17].

The process for industrial heat production, which is generated by the combustion of wood biomass by-products at the sawmill plants, is based on Ecoinvent data [17] for a 5000 megawatt wood furnace. But the process input inventory has been adjusted, by changing the inputs of wood by-products to specific data modelled in the EPD projects. In this way LCI flows are allocated back to the timber production, e.g. in the drying process of timber where heat energy is important. Bark is the most important fuel in the furnaces, in addition to sawdust. The data is validated by using a bioenergy calculator developed at NTI [28].

The upstream data for infrastructure and electricity are taken from Ecoinvent [17]. Data for alkyd coating applied in the surface treatment process are also based on generic Ecoinvent data for both the primer and paint. Similarly, the acryl coatings added for this alternative are based on generic Ecoinvent data for losses of chemicals, energy use and waste treatment, but the components in the acryl coatings is based on literature study [29]. The amount of paint applied on the claddings is based on the dried weight amount of coating on the claddings as stated in the original EPD projects. Furthermore, this amount is assumed for both acryl and alkyd coating application in this assessment, although correct application amounts for such paints can vary between coating manufacturer and type of binder used.

Weighting averages

Weighted average of the five sawmills are calculated based on the production capacity of the factories (total output of finished timber products). The process of industrial surface treatment is averaged by the production capacity of the different factories in terms of finished timber products with coating. The wood timber input in surface treatment (untreated cladding) are however weighted in the same way as for planed timber and in fact are the same cradle to gate (A1-A3) average result for planed timber for the five different factories, only adjusted for conversion to m² assuming a 19 mm thick cladding with a simple profile, giving 0,019 m³/m² of cladding.

Sensitivity analysis for different allocation practices in Nordic countries

Considerable differences in the EPDs' results of similar products from Norway and Sweden were recognized. Therefore, NTI initiated the communication with two national associations, Treindustrien in Norway and SvenskTrä in Sweden, which took over the administrative lead to figure out the differences present between EPD actors and harmonise the methodical differences present. Two different approaches were recognised in the communication, which are applied in this sensitivity analysis carried out for planed timber. All other assumptions in the LCA are kept constant to show how the methodical frameworks may affect the results.

Allocation of upstream emissions from forestry activities and the transport of roundwood (A1 and A2) was different for the two modelling approaches. Minor differences were also present for allocation of emissions occurring in the manufacturing (A3), but this consequence was considered less important for affecting final results and was modelled in the same way for both approaches in the sensitivity analysis.

The model framework applied for the 'NO model' are similar to Ecoinvent models [17], similar approaches are also present in other published LCAs for wood products [30-33]. The main difference of the SE and NO models is that special treatment is made for allocation of upstream emissions in the SE model, i.e., emissions not a part of energy use or direct emissions at the manufacturing. These can be emissions occurring in forestry or transport of roundwood, which are allocated by mass in joint co-allocation processes at sawmill, in contrast to economic value which are used in the NO model.

In the SE model, the roundwood input including transport to the sawmill is held constant at 1.15 m³, where 1 m³ represents the forestry emissions and transport of logs allocated to the climate impact for planed timber, and 0,15 m³ likewise are allocated to bioheat purposes at the sawmill factories, which are then allocated back to the planed timber. This means that also 1,15 m³ of roundwood is assumed transported from the forest to the sawmill, as shown in Table 1. Sometimes additional allocation procedures are made for the forestry part in the SE model, leading to a higher input of roundwood than shown in the table. A perfect mass balance approach was however assumed for SE in this analysis, to recognise the biggest possible differences present for sawn timber products in EPDs today. In the NO model, the wood raw material needed in the timber manufacturing will accumulate throughout the value chain, for every joint-co production process dividing the flow of emissions to main and by - products. This leads to accumulated use of roundwood along the value chain, and as shown in Table 1, 1,65 m³ illustrate the use of roundwood for the 1 m^3 of sawn timber production. While 2,14 m³ are the use of roundwood produced in forestry, accumulated during the allocation to pulpwood and roundwood from forestry sub processes. NO amounts in Table 1 are approximate amounts used for the harmonisation meetings and planed timber is assessed for this sensitivity analysis and not rough sawn timber (the wood input in the planing process), as in the table. The planing process also leads to accumulation of roundwood needed, following the NO model.

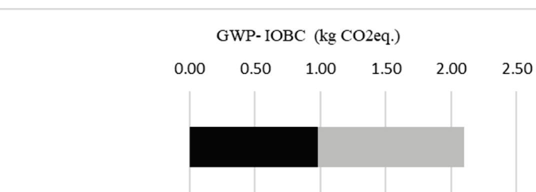
Table 1: *Assumptions for roundwood consumption in the production of rough sawn timber in Nordic countries. The outcome from the EPD harmonisation work by Treindustrien and Svensk Trä.*

Scenario no.	Roundwood (Forestry) (A1) [m^3]	Transport of roundwood (A2) [m^3*km]
NO Method	2.14	1.65
SE method	1.15	1.15

Note: The NO method is not developed in Norway nor limited to EPD development in Norway and the same applies for the SE method, but the abbreviations were used in the harmonisation work, which has been started between the two countries.

RESULTS

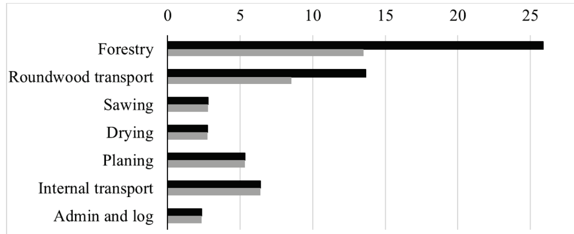
The average result of GWP-IOBC for 1 m^2 of planed wood and surface treatment activity for a façade product with a 19 mm thickness is shown in Figure 2. Production of 1 m^2 planed wood correspond to 1.1 kg CO_2-eq. While almost 1 kg CO_2-eq is emitted for the industrial surface treatment process including the production of paint, which are the average result for the three sawmills with surface treatment combination plants.



■ Avg. surface treatment	0.98
■ Avg. planed wood	1.1

Figure 2: *GWP-IOBC for 1 m^2 of surface treated cladding products for an average of Norwegian sawmills.*

Figure 3 presents the results as a contribution analysis for planed timber production per activity, average for the five sawmills using the two defined methodical frameworks: 'NO method' and 'SE method'. All upstream forestry processes mentioned in Figure 1 are grouped together to represent a single forestry activity. While other sawmill processes are presented separately. Forestry shows the highest contribution, followed by roundwood transport. There is a distinct difference in the result for forestry and roundwood transport for the different methods.



	Admin and log	Internal transport	Planing	Drying	Sawing	Roundwood transport	Forestry
■ NO method	2.3	6.4	5.3	2.8	2.8	13.6	25.9
■ SE method	2.3	6.4	5.3	2.8	2.8	8.5	13.5

Figure 3: *Weighted average for GWP- IOBC contribution [kg CO_2 eq] per activity to produce 1 m^3 of planed timber in the five selected Norwegian sawmills.*

The two methods can be compared in Figure 1, by the ratio for contribution for GWP in A1-A3. In the SE method, sawmill activities show the highest share, due to the different approach for calculating upstream emissions. While in NO method, the forestry has the highest share in the overall contribution.

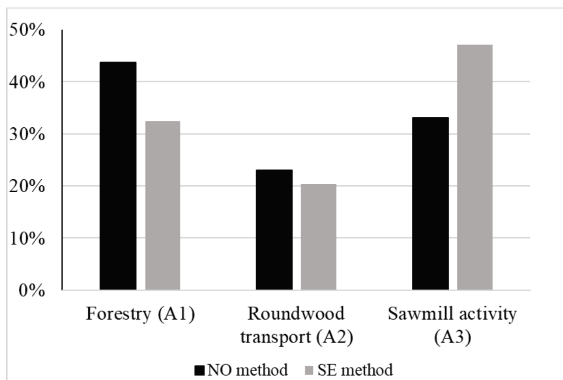


Figure 4: *Contribution by different production stages to GWP-IOBC for planed timber.*

DISCUSSION

The planed wood and surface treatment are having almost equal contribution for production of surface treated cladding. In addition, one layer of surface treatment is advised after the installation, and during each maintenance interval of the façade in the use phase of buildings. Considering the application of paint during the lifetime of a building, a previous study showed that the contribution of paint is dominating throughout the lifecycle [34].

Forestry is the highest contributor for planed timber, because of several energy intensive silvicultural activities. Roundwood transport from forest to sawmills has a considerable effect. However, this can vary depending on the sawmill location and the forest resources.

Results in EPDs are sensitive to the choice of allocation assumptions across the production phases. The author's interpretation is that the EPD standard (EN 15804) is not

https://doi.org/10.52202/069179-0133

explicit enough for the allocation treatment of upstream raw material acquisition and processing, including the transport thereof, and requires a better common understanding between EPD practitioners.

The different production stages (modules) are treated more separately in the SE model compared to the NO model, resulting in a lower amount for the assumption of roundwood consumption in the production of sawn timber. In the harmonisation discussions, argumentation for using the SE method is that forestry products and residues can be input for a wide range of products, and that this is not known at the time of harvest. The owner structure from forest management to the production of wood building materials are often merged in Sweden, which can make it difficult to estimate the economic value of intermediate wood products and therefore apply the allocation principles demanded in EN 15 804. The NO model is the rationale choice for partitioning of emissions throughout the value chain of wood in many trade regions around the world, but this is put on the test by ownership structures in some regions and the market situation for raw wood and intermediate products. However, differences in results that are not due to actual conditions in production are unwanted by anyone producing or using LCA data. Nor is this wanted by regulatory law either, which set new rules for environmental documentation and performance at an increasing rate. Finally, inconsistency in methodology will deteriorate manufacturers possibility of comparing themselves with other manufacturers.

The result demonstrates how methodology choices across life cycle stages matters. Inconsistency in allocation practices impairs the comparability of EPDs developed for wood building materials and deteriorates rationale environmental decisioning for the building sector when performing building LCA. With increasing use of EPDs, it is important to have comparable methods for timber material between different countries. In addition to that, it is important to be able to compare timber material with similar functionality with other types of building materials, such as steel and concrete. EN 16485 is currently under revision, and it may bring the solution for harmonising methodical choices in LCA for EPDs on wood building materials.

ACKNOWLEDGEMENT

This work has been funded by Norwegian Institute of Wood Technology. Special thanks to Vegard Ruttenborg for technical support and initiation of the work. Silje Unander for commenting the abstract.

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