Modelling options for module C and D: Experiences from 50 EPD for wood-based products in Norway

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Abstract. Introducing the EN 15804 standard as a core PCR for building products included several specifications for LCA end-of-life and benefits beyond the life cycle. There are however several issues that the LCA practitioner need to interpret during the modelling and generic data needs to be adjusted for being representative and in accordance to EN 15804. The modelling of module C and D has been developed in three different stages during making 50 EPDs over several years. First the model was mainly based on generic data from ELCD database. The second was a statistics-based mix of different treatment options, where the substation of other energy sources in module D was a representative mix of district heating mix, electricity, coal in cement production, wood chips in wood industry and ELCD for exported waste. The third represented a 100 % scenario for energy recovery in municipal waste incineration and substituting statistical mix of electricity and district heating. The objective of the study is to present the experiences from developing and implementing the module C and D in the 50 EPD that where verified at EPD-Norway and discuss in relation to requirements in standards and usability in a building context.

1. Introduction
The environmental product declarations (EPD) for wood products was first introduced in 1996 for some generic products from the Nordic countries. The second generation wood EPDs came in 2009 and was based on the ISO 21930 (1). Several of these were representative for the most common products from the members of the Norwegian Wood Industry Federation. These EPDs was also third party verified and published through the Norwegian EPD Foundation. The use of EPD was however limited, but in 2012 the Norwegian Green Building council (NGBC) released a Norwegian adaption of building environmental certification scheme BREEAM. Known as BREEAM-NOR [2], it included credits for provided EPDs for the most used products and made a sudden increase in demand for EPDs. In 2013 the revision of product category rules (PCR) for wood products was released, NPCR015 [3], and was based on the EN 15804. The launch of BREEAM-NOR made EPDs requested for many more specific products, such as claddings, windows and engineered wood products.

Prior to EN 15804, end-of-life was assumed as energy recovery and that the emissions were allocated to the energy user. However, with EN 15804 it was required that emissions until end-of-waste state was included, but also optioned for including the benefits of energy recovery. The procedure was however not very specific, and the approach was improved in mainly three steps in making about 50 EPD over four years. The aim of this paper is to present this development in procedures with discussion to the relation to standards and practice.
2. Materials and methods
The review has focused on two main issues in modelling of end-of-life modelling:

- Development of scenarios
- Development of life cycle inventories for incineration of materials

2.1. Materials
Three EPDs are selected to represent the three stages of development in scenario modelling module C and D according to EN 15804 and NPCR015 [3]. The EPDs are listed in table 1.

| Product                          | Year | EPD number | Description                                                      |
|---------------------------------|------|------------|------------------------------------------------------------------|
| First model                     |      |            | Statistical mix of end-of-life treatment and generic data for benefits |
| Pine moulding                   | 2013 | NEPD00232  |                                                                  |
| Second model                    |      |            | Statistical mix for end-of-life treatments and market mix of benefits |
| Pine panelling                  | 2015 | NEPD-309-179|                                                                  |
| Third model                     |      |            | Most common end-of-life treatment and average benefit             |
| Cross laminated timber          | 2017 | NEPD-1269-410|                                                                |

One crucial aspect discovered over the years for EPD development was the LCI of incineration of resin in the wood products. This model was also developed in three different stages and EPDs representative for these are listed in table 2.

| Product                          | Year | EPD number | Description                                                      |
|---------------------------------|------|------------|------------------------------------------------------------------|
| First model                     |      |            | ELCD dataset for whole product                                   |
| Glulam beam                     | 2014 | NEPD00263  |                                                                  |
| Second model                    |      |            | Ecoinvent dataset for each material component                    |
| Standard glulam                 | 2015 | NEPD-336-222|                                                                  |
| Third model                     |      |            | Ecoinvent dataset adjusted to carbon content                     |
| Glulam for custom projects      | 2018 | NEPD-1577-605|                                                                |

2.1.1. Methods
The EPDs are reviewed based on the scenario information and the life cycle inventory is remodelled according to the writer’s experiences. The exact LCI is however not publicly available.

3. Results and discussion
3.1. Scenario modelling
3.1.1. First model: Statistical mix of end-of-life treatment and generic data for benefits
The first model for end-of-life of pine moulding coated with paint. In the PCR applied, a reference was give to CEN/TR 15941 (2010) for the use of generic data. This states that generic data for scenarios in
end-of-life stage should among others reflect: “today’s average practice an dmix of different end-of-life treatment of the product group in the location where the process takes place”. Hence, this was interpreted as that the Norwegian mix of treatment of wood waste should be used for the end-of-life modelling. The most recent statistics at the time of publishing the EPD was from the year 2011 and where about 91 % of wood waste was sent to incineration with energy recovery, 7 % to incineration without energy recovery and 2 % to landfilling.

The module D was based on generic data for energy substitution in ELCD datasets for wood incineration. The ELCD dataset had two versions, one with only emission from incineration and one with also the benefits of energy recovery. Hence, one dataset corresponded to C3 and the other to C3+D. In order to model module D, the first was subtracted to the second.

3.1.2. Second model: Statistical mix for end-of-life treatments and market mix of benefits

The mix of waste treatment was the same in the first and second model for C3, but the substitutions in module D was quite different and because of this also some differences in transport scenario, module C2. The new substitution model aimed at reflecting the current average substitution, hence taking into account that the wood was treated in both municipal incineration and industrial, in addition to a quite large export to Sweden. Based on several sources, a bottom-up approach was applied to estimate the amount to different treatments and what they substituted. The mix of treatment are listed in table 3.

### Table 3. List mix of treatments in C3 and substitutions in module D

| Treatment in C3                      | Share [\%] | Substitution                              |
|-------------------------------------|------------|-------------------------------------------|
| Municipal incineration              | 25         | District heating mix and electricity consumption mix |
| Cement plant                        | 5          | Heat from coal                             |
| Chipping to industrial fuel for sawmill and particleboard industry | 10         | Wood chip fuel                             |
| Pulp and paper industry             | 14         | Heat from fuel oil                         |
| Export to Sweden                    | 46         | ELCD dataset substitution mix             |

3.1.3. Third model: Most common end-of-life treatment and average benefit

The third model was a result of more understanding of the EN 15804, but also more recent data understanding. The Norwegian EPD Foundation gathered LCA-practitioners from different research institutes in Norway to work together on a study to harmonize the scenarios in EPDs. This work revealed that EN 15804 requires to use one or more of the most common scenarios. Hence, the requirement for scenarios implies that it should not be a mix. The work also shows how disposal of ashes from incineration could be included in module C4 [4]. The situation in Norway had also changed and in statistics no wood waste was disposed in landfill or incinerated without energy recovery. The third model assumed then that municipal incineration with energy recovery was the one of the most common end-of-life treatments in Norway for waste wood. The amount of energy recovered was based on national statistics of district heating and which also included the amount of electricity generated. The substitution was the mix of heating sources in the district heating in Norway.

There are currently work on PCR in Norway, but also EN 15804 in Europe. The Norwegian PCR for wood products has included several reference scenarios that shall be include, but more can be included if relevant. For update of the EN 15804, it is included an informative appendix with formulas for calculating the module C and D. There is also a requirement to include module C, with some exceptions.
3.2. Inventory modelling for incineration of glulam

3.2.1. First model: ELCD dataset for whole product
European reference life cycle database (ELCD) was established by the European Commission’s Joint Research Centre (JRC). It consists of LCI data on a system process type, which means that each dataset only includes elementary flows. This makes the dataset easier for exchange between different users, but not possible to adjust the data and quality control is difficult. The data for wood products incineration is representative for a European technology mix of incineration. For the waste composition, the products OSB and particleboard are mentioned. An example of LCI are performed as shown in table 4.

| Waste specification | Name | Amount | Unit | Comment |
|---------------------|------|--------|------|---------|
| C3, incineration glulam | 1 | m³ | | Outputs to technosphere. Waste and emissions to treatment |
| Waste incineration of wood products (OSB, particle board), EU-27 | 470 | kg | Weight of product according to product standard |

3.2.2. Second model: Ecoinvent dataset for each material component
In the second inventory model used for glulam, ecoinvent database was used instead of ELCD. Ecoinvent is available both as system and unit processes. The unit processes include technosphere flows, like energy use, transport, etc. In addition, the elementary flows are specific to the relevant activity and not aggregated as in system processes. The inventory for incineration of glulam was based on a dataset for untreated wood and one for incineration of polyurethane. Polyurethane was then chosen as a proxy for the resin, as it was also used for treatment of waste resin in manufacturing of glulam in an ecoinvent unit processes for glulam manufacturing. The total weight of the product was the same as in the first model, but divided between wood part and resin part. The LCI modelling is shown in table 5.

| Waste specification | Name | Amount | Unit | Comment |
|---------------------|------|--------|------|---------|
| C3, incineration glulam | 1 | p per functional unit | | Outputs to technosphere. Waste and emissions to treatment |
| Waste wood, untreated {CH} | 461.22 | kg | Wood weight |
| treatment of, municipal incineration | | | |
| | Alloc Rec, S | | |
| Waste polyurethane {CH} | 8.78 | kg | Resin weight |
| treatment of, municipal incineration | | | |
| | Alloc Rec, S | | |

3.2.3. Third model: Ecoinvent dataset adjusted to carbon content
The third model is based on an update of the EPD in the second model. The company owning the EPD was interested in how they could reduce their carbon footprint and a contribution analysis was performed. The incineration of resin was found to be an important part of the life cycle greenhouse gas emissions and was therefore reviewed. The inventory for incineration was then adjusted to correct for the actual dry content of resin in the final product and the carbon content of the resin. The polyurethane
LCI has a carbon content of about 63%, while melamine urea formaldehyde (MUF) resin has a carbon content of about 30%. Hence, the carbon dioxide emissions from combustion of the resin is about half per kg. An simplified example of this inventory is shown in table 6.

Table 6. Life cycle inventory from example of third model for module C3

| Waste specification | Name | Amount | Unit | Comment |
|---------------------|------|--------|------|---------|
| C3, incineration of glulam | 1 | p | per functional unit |
| Outputs to technosphere. Waste and emissions to treatment | Waste wood, untreated [CH] | 375/(1-0.17408) | kg | Dry weight of wood, adjustment, LCI |
| | treatment of, municipal incineration | | | adjustment to dry |
| | Cut-off, S | | | |
| | Waste polyurethane [Europe without Switzerland] | 4.85*0.5 | kg | Dry weight of resin, adjustment to actual carbon content |
| | treatment of waste polyurethane, municipal incineration | | | |
| | Cut-off, S | | | |

The implication of the three models on the results on carbon is that the first model is actually not including the emissions from incineration of the resin in wood products. The second model overestimates these emissions of more than double when MUF resin is applied. The third model aims at modelling the emission as correctly as possible, but is more complicated to perform. The importance of the modelling to the total results are on a medium level for glulam, but for wood-based panels, like particleboard, these models would have a dominating effect on the total carbon footprint results. The modelling of the production of resin is usually based on specific data from the manufacturers of resin. In the future, it would be beneficial that all upstream LCI data for EPD also is supported with downstream specific LCI for waste treatment. At least for combustible materials.

The modelling of biogenic carbon has been another important issue with wood EPDs and in the future modelling of end-of-life scenarios and inventory of incineration it could have a crucial part. So far, biogenic carbon has been assumed by many of being climate neutral over the life cycle, as the end-of-life scenario of wood will lead to emission of the same amount of carbon dioxide as has been sequestrated during forest growth. Hence, as long as the climate impacts are not time-adjusted, the different approaches for biogenic carbon has the same climate impacts over the life cycle [5]. However, plans for establishing carbon capture and storage (CCS) in Norway at waste incinerator that treat a notable share of the wood waste will lead to new methodological challenges. A case study has been performed on this for treated wood and which leads to climate negative results over the life cycle [6]. This would probably lead to discussions as many believe that biogenic carbon is always neutral over the life cycle.

4. Conclusions
This study has presented modelling principles for modelling end-of-life practiced in a selection of EPDs published between 2014 and 2018. The modelling has been improved on a mainly three step development, both for scenario and for life cycle inventory. These experiences should be utilized in future development of EPD requirements in PCR, but is also in important message for the importance of transparency in LCI datasets in databases and during verification.

For PCR development, these experiences have been included in the revision of the PCR for wood products applied in Norway. The proposal for PCR now includes conservative reference scenarios for the end-of-waste scenario. For wood products, the end-of-life scenarios can be quite different dependent on the country. Hence, the references scenarios are separated between different markets.

For the LCI datasets applied, it is important that they are specific for each material composition of the product. The LCI data should also be available on a unit process type in both databases and during
verification. Future methodological challenges will be climate negative situations when biogenic carbon will have final storage when CCS is practiced at end-of-life of wood products.

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