IOP Conference Series: Earth and Environmental Science



# The Reporting of End of Life and Module D Data and Scenarios in EPD for Building level Life Cycle Assessment

IOP Conf. Series: Earth and Environmental Science **323** (2019) 012051 doi:10.1088/1755-1315/323/1/012051

# The Reporting of End of Life and Module D Data and Scenarios in EPD for Building level Life Cycle Assessment

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**Abstract.** This paper identifies the need for Environmental Product Declarations (EPD) to provide End of Life (EoL) and Module D data for products for use in building level Life Cycle Assessment (LCA). Although the provision of data for EN 15804 Modules A4-D is not currently mandatory for EPD, many currently report some or all of these. This paper provides an overview of the existing reporting of the end of life (Modules C1-4) and Module D and the types of scenarios used in European EPD. Using examples from existing EPD for two product groups, this paper examines the variation in approaches to scenarios for Module C and D. It explores the difficulties brought by this variation and discusses benefits from using default national scenarios at end of life, but additionally considers the advantages of providing alternative EoL scenarios for products to promote the circular economy.

## 1. Introduction

Life cycle assessment (LCA), as defined in ISO 14044 (1) addresses “the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave).” For construction products, the European Standardisation body, CEN’s Technical Committee TC350 responsible for Sustainable Construction has developed a framework and standards to address the assessment of environmental aspects and impacts for both products and construction works. The life cycle for construction works and for construction products are set out in the framework standard, (2) and used in the building level environmental assessment standard, (3) and the construction product level environmental assessment standard, (4).

This framework clearly separates the end of life stage from the other life cycle stages, and breaks it down into four information modules, C1 (deconstruction), C2 (transport to waste processing), C3 (waste processing for reuse, recovery and recycling), and C4 (Disposal). In addition, another module, Module D is included to show the benefits and loads beyond the system boundary from the net output of recovered material, fuel and energy from the product system.

This framework allows Environmental Product Declarations (EPD) as described in EN 15804 (CEN/TC 350, 2013) to provide information for the various life cycle stages and modules, and for this information to be used, if appropriate, within a building level assessment according to EN 15978 (CEN/TC350/WG1, 2007). EN 15804:2012+A1:2013 only requires the mandatory provision of data for Modules A1-A3 (covering cradle to gate for the product stage), other modules and stages are voluntary. The current amendment of this standard, EN 15804+FprA2:2019 (5) will require Module C and D to be

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provided for all products except a very small number of exceptions, however it does not describe any scenarios which should be assessed for products, other than the requirement already set out in EN 15804:2012+A1:2013, "A scenario shall be realistic and representative of one of the most probable alternatives." (CEN/TC 350, 2013, 6.3.8).

This paper builds on the work of Silvestre, Brito and Pinheiro (2014) (6) which demonstrated that EoL data provided in EPD can be an important source of data for decision-making at the end-of-life of building materials, especially to ascertain whether the minimization of waste flows, the maximization of their reuse or recycling operations, or the increase of the recycled content maximises their C2C environmental performance. At the time of their paper however, few EPD were available and they provided limited data on EoL scenarios. This paper demonstrates that many European product EPD now report some or all of the voluntary modules, including the end of life (C1-4) and beyond end of life (D). Using examples from existing EPD for two product groups, this paper examines the variation in approaches to scenarios for Modules C and D, and highlights some of the difficulties this causes. It discusses the benefits that can be gained from using default national scenarios at end of life, and also considers the advantages of providing alternative EoL scenarios for products to enable specific building LCAs. It also stresses the need for specific product scenarios at EoL to promote the circular economy within the manufacturing industry.

## 2. The purpose of EPD and use of data for Module C and module D data from EPD

### *2.1. Purpose of EPD and scenarios*

EN 15804:2012+A1:2013 states "The purpose of an EPD in the construction sector is to provide the basis for assessing buildings and other construction works, and identifying those, which cause less stress to the environment.". EN 15804, which provides the core Product Category Rules (PCR) for construction product EPD, therefore states it has the objective to ensure:

- *"the provision of verifiable and consistent product related technical data or scenarios for the assessment of the environmental performance of buildings;".*

CEN TR16790:2017, the guidance document for EN 15804 describes the approach for scenarios,

> *"as soon as a construction product leaves the factory gate the assessment is based on scenarios and assumptions: the fate of the product in the building chain will depend on locations, types of transport, installation and constructing methodologies, building type, use of the building, maintenance, repair and waste handling. The manufacturer cannot control these processes completely. An assessment thus requires scenarios to be specified for each module, i.e. for modules A4, A5, all B-modules, all C-modules and for information module D."*

### *2.2. Purpose of EPD for Building Level Assessment*

EN 15978, 8.1 describes how building level LCA assessment needs to evaluate the end of life of the building. "This requires the development and use of appropriate scenarios representing assumptions (or, where known, real information) that can be applied to models for construction, use, and end-of-life stages (modules A4 to C4) of the object of assessment. If information on module D is communicated in a building assessment, scenarios are required to be defined at the building level." As described in the TC 350 Framework, EPD to EN 15804 are the first source of LCA data for construction products to be used at the building level. EN 15978 8.1 states, "Information modules available from EPD shall be reviewed in order to determine if they are representative of the assessed building". This is reiterated in clause 10.2.3, *"Any scenarios incorporated in the EPD and/or other information used for the assessment should be checked for consistency with the scenarios for the building. Where differences occur, it is still possible to take consistent information from an EPD (e.g. cradle to gate information from a cradle to grave EPD) and apply other appropriate scenarios at the building level (e.g. gate to grave)."*

This means that if the building has been "designed for deconstruction" to minimise landfill and to maximise reuse at end of life, that EoL data provided in EPD should only be used if they are representative of this "design for deconstruction" approach; if the EPD provides EoL data based on a scenario for landfill or incineration without energy recovery for example, then it will not be representative of the assessed building and should not be used.

Similarly, if an EPD provides EoL data for Energy Recovery in C3 and its Module D shows the benefit of the exported electricity and heat in the UK with substituted UK grid mix, then this Module D data will not be representative for the end of life of a building located in France, where the French grid mix should be substituted if the product is used for Energy Recovery at end of life.

### *2.3. EPD for Product Comparison*

For comparisons of EPD, EN 15804 states, "comparison of the environmental performance of construction products using the EPD information shall be based on the product's use in and its impacts on the building, and shall consider the complete life cycle (all information modules)."

As described above, products can therefore only be compared in a specific building context over the full life cycle. This means that data for the products end of life will need to be used, and will need to be representative of the chosen building context. It will therefore be necessary to ensure that end of life scenarios in particular reflect the same context – this does not mean that the end of life scenarios have to be the same however – they need to be equivalent; if the context is the typical building in the Netherlands, then it would be appropriate to reflect the typical Dutch end of life for different products – this could be recycling for metals and energy recovery for biomass for example.

## 3. The end of life stage

### *3.1. Benefits of assessing the end of life stage*

The assessment of the end of life of the building (Modules C1-C4), and for Module D allows a number of mitigation strategies to be considered to reduce the impact of the building. This is described in Pomponi & Moncaster (2016) which classified various mitigation strategies (MS) found in the literature, including the following with direct relevance to Modules C1-C4 and Module D of EPD:

- MS1: use of materials with lower embodied energy and carbon;
- MS3: reduction, re-use and recovery of EE/EC intensive construction materials; and
- MS17: demolition and rebuild.

Many materials such as plastics or biogenic materials have high impacts at end of life as their feedstock carbon is emitted through incineration or transferred to future product systems. Other materials (e.g. reinforced concrete) can require recycling processes at the end of life to achieve the "end of waste" state meaning they have crossed the system boundary. The provision of data showing the impacts of end of life, allows the identification of products will lower life cycle impacts (MS1).

Provision of information in the EPD covering the impacts of reuse and/or recovery (Module C1-C4) and its potential benefits in the next product system (Module D) enables the reuse and recovery strategy (MS3) to be evaluated.

MS17 suggests that by demolishing existing buildings and rebuilding them with significantly increased energy efficiency we can make reductions in the whole life impacts of our built environment compared with refurbishment. The data provided in Modules C and D of EPD for products used in the building and EPD for new products can be used to assess refurbishment and redevelopment options and provide the information to assess the validity of this controversial proposal.

### *3.2. Assessment of end of life in Building Level studies*

Despite the potential use of data from Modules C and D to mitigate the impacts of the built environment, these are seldom assessed in whole building LCAs. Wallhagen, Glaumann, & Malmqvist (2011) (7) point out that these stages are not addressed by Adalberth et al. (8), Chen et al. (9), Peuportier (10), Blengini (11) and Ortiz et al. (12). Silvestre, De Brito, & Pinheiro (13) also find that "*…the LCA results from more than 10 years of international research studies on the environmental impact of a building's external walls has shown that … just a third (21 out of 63) include the end-of-life of the building assembly.*"

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This may be partly because end of life impacts are often considered small as for example found by Nemry et al. (2010) (14) though aggregating Module C and D together may have reduced the impact shown at end of life. Other studies show the impact of the EoL stage is greater. Pomponi, Moncaster, & De Wolf (2018) reviewed the assessment of five buildings undertaken by different consultants using different tools and found the impacts of the End of life module C averaged around 6 to 8% of the whole life carbon, but in some cases were as high as 15%.

It is also the case that the end of life stage varies in importance for different product types. For metals for example, the end of life stage is often assumed to have no impact, as the metal is assumed to reach the end of waste state on collection in C1. For masonry, many EPD only include collection as demolition rubble in C1 to be the end of waste state. However, for products such as those based on biomass or fossil feedstocks, the end of life stage can have significant impacts due to emission or transfer of feedstock carbon. The authors suggest that for buildings with higher proportions of bio-based products, the end of life stage impacts may be significantly greater than those provided in the literature above.

## 4. Reporting End of life in EPD

### *4.1. Approach to the Review of End of life Data in EPD*

While reporting of Module C is not mandatory, many EPD from European EPD Programs do report Module C and D scenarios, as shown below. In some EPD Programs such as the French National EPD Program (15), it is a requirement to evaluate and report Module C as French EPD must cover cradle to grave.

The authors have reviewed over half (2464) of the EPD compliant with EN 15804 and registered by ECO Platform members (ECO Platform, 2018) over the period December 2018-January 2019. The study excludes all EPD from the IBU and EPD Norge Programs which are still being evaluated. 784 PEP EcoPassport EPD for electrical products used in buildings have also been excluded as although they are cradle to grave EPD, they do not report modules C1-C4 separately. The EPD were assessed and classified as to whether each module was "Reported" or "Not Reported". If it was marked "not relevant" this was classified as "Not Reported".

### *4.2. Results of the Analysis*

The analysis showed that 72% of these EPDs report Module C1 (Demolition/deconstruction), 77% report Module C2 (Transport to waste processing), 76% report Module C3 (Recovery), 82% report module C4 (disposal) and 51% report Module D.

There was wide variation between EPD Programs in relation to reporting of end of life (EoL) modules (C3 and C4). For example, within the ITB Program in Poland, the DapHabitat Program in Portugal, EPD Global in Spain, EPD Danmark (Denmark) EPD Norge in Norway and EPD Ireland, less than 50% of all EPD provide EoL modules. However in RT EPD (Finland), MRPI (the Netherlands) and Bau EPD (Austria), over 75% provide EoL modules. The FDES and PEP Ecopassport programs (France) require all EPD to cover cradle to grave.

## 5. Analysis of declaration of Module C and Module D and scenarios for two product groups

### *5.1. Overview*

A more detailed analysis was undertaken of the reporting and description of scenarios for two particular product/material groups, namely polystyrene insulation, including expanded and extruded polystyrene (EPS and XPS) insulation, and wood panel products, including medium density fibreboard (MDF), orientated strand board (OSB), particleboard and plywood. The end of life impacts of these product groups are likely to be significant due to the emission or transfer of feedstock carbon.

### *5.2. Classification of reporting of Modules:*

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For these EPD, the authors propose the classification of Module C1-C4 and Module D reporting as to whether modules were "**declared**" with an impact, declared with "**zero"** impact, "**not declared**" (MND), or declared "**not relevant**" (MNR).

## *5.3. Types of Scenario used in EPD*

Additionally, the types of scenario declaration for module C1-C4 and Module D were analysed. The authors propose four separate types of scenarios used for gate to grave and Module D in EN 15804 EPD:

- **"100%"** scenario: where only one approach is reported for the module or modules in the EPD, eg 100% of the product is sent to landfill. These scenarios can also include consecutive processes, for example, where 100% of the product is used for energy recovery in C3 and then the incinerator ash is landfilled in C4, or where the waste is transported by road and then by sea to waste treatment.
- **"Mixed"** scenario: where a combination of two or more approaches is considered in a single scenario reported for the module in the EPD, with a proportion using each approach – e,g. 50% of the EoL product is sent to landfill (C4) and 50% used for energy recovery (C3), or 25% is sent to landfill (C4) and 75% sent to incineration without energy recovery (C4). These scenarios are often typical of a national situation;
- **"Multiple"** 100% scenarios: where two or more 100% scenarios are reported for the module in the EPD.
- **"Mixed+100%"** scenario: where a mixed scenario is reported for the module in the EPD together with 100% scenarios for the contributing approaches, as described in CEN/TR 15970 clause 6.3.8.

*5.3.1. 100% scenarios:* It should be noted that EN 15804, and more specifically the guidance document to the standard, CEN/TR 16970:2016 6.3.8(16), states that 100% scenarios should also be declared if a mixed scenario is provided:

> *"When different scenarios are developed for information modules C1-C4 the most relevant scenarios are provided as 100 % versions. For example when 20 % of a product is recycled, 50 % is incinerated and 30 % is deposited, scenarios for 100 % of incineration, 100 % of recycling and 100 % of deposition are declared. This allows the building assessor to choose and calculate the correct scenario on building level as actual waste management practices vary in different member states".*

## *5.4. Analysis of Description of Scenarios*

The description of the scenarios provided in the EPD were also analysed considering the level of detail provided and the type of processes included in each module.

## *5.5. EPS and XPS Polystyrene Insulation*

20 EPD from nine EPD programmes were identified and analysed under the product category "polystyrene insulation" and the results described in Table 1. Where several EPD for different but very similar specific products were produced using the same scenarios, only one was assessed.

10 EPD provided 100% scenarios, four provided two separate 100% scenarios and five EPD provided a "mixed" scenario. There were also some differences in the way in which EPD reporting a 100% scenario for C3 declared module C4 and vice versa. As Module C and Module D are intended to become mandatory requirements in EN15804+FprA2 then consistency in considering this situation would be useful.

Only four EPD declared C1, with 3 declaring the impact to be zero. 16 declared C2 with quite varied scenarios. Distances range from 10 km, 50 km, 200 km, and one Norwegian EPD used 1000 km by road to a recycling plant. For such a lightweight product as polystyrene insulation, it would be expected that the volume capacity might be considered in the transport scenarios, but few EPD mention it: two used

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**Table 1**. Scenario data for Polystyrene Insulation EPD.

| Product | Scenario type | Stated scenario for Module C1 | Stated scenario for Module C2 | Stated scenario for Module C3 | Stated scenario for Module C4 | Stated scenario for Module D | Programme/ Location of Manufacture |
|---|---|---|---|---|---|---|---|
| EPS | 100% | Collection, no impact | 10 km, 5% capacity | Energy recovery | MNR | Substitution exported energy | DK / DK |
| EPS | 100% | Collection, no impact | 10 km, 5% capacity | Energy recovery | MNR | Substitution exported energy | DK/ DK |
| EPS | 100% | Deconstruction | Zero impact | Energy recovery | Zero impact | Substitution exported heat (district heat) | RT / FI |
| EPS | mixed | Collection, no impact | 10 km | 44% recycling, 53% energy recovery | 2% landfill | Substitution exported heat + electricity and virgin product | EPD-Norge/ NO, SE |
| EPS | multiple 100% | MND | No info | Recycling | related disposal | Substitution of virgin product | EPD Italy/ IT |
| | | | | Energy recovery | related disposal | Substitution of exported energy | |
| EPS | 100% | Collection, no impact | 25 km | Zero impact | Landfill | MND | Inies/ FR |
| EPS | multiple 100% | MNR | 50 km | Recycling | | Substitution of virgin EPS | IBU/ EU |
| | | | | Zero impact | Incineration eff.<60% | Substitution exported energy | |
| EPS | 100% | MND | MND | MND | Incineration eff.<60% | Substitution exported heat +electricity | IBU/ DE |
| EPS | MND | MND | MND | MND | MND | MND | EPD Ireland/ IE |
| XPS | mixed | INA | INA | 50% reaches EoW on collection | 50% landfill | 50% processed to substitute of virgin product | BRE/ PO, CZ |
| XPS | mixed | MND | 50 km, 21% capacity | MND | 10% incineration, 90% landfill | MND | BRE/ UK |
| XPS | 100% | Collection, no impact | 50 km | no recycling | Landfill | MND | International EPD/ ES, PT |
| XPS | 100% | MND | MND | MND | Landfill | MND | International EPD/ TU |
| XPS | multiple 100% | MND | no info | MND | Landfill | MND | IBU/ EU |
| | | | | MND | Incineration eff.<60% | Substitution exported heat (nat. gas) + electricity (EU) | |
| XPS | 100% | Collection, no impact | not info | Energy recovery | Zero impact | Substitution exported heat (district heat) | RT/ FI, LI, ES |
| XPS | multiple 100% | MNR | no info | MND | Landfill | | IBU/ DE |
| | | | | | Incineration eff<60% | Substitution exported electricity (EU) + heat (natural gas) | |
| XPS | multiple 100% | MNR | no info | MND | Landfill | | IBU/ DE |
| | | | | | Incineration eff.<60% | Substitution exported electricity (EU) + heat (natural gas) | |
| XPS | mixed | MND | 18% capacity, 10 km to ER, 1000 km to recycling | 28% recycling, 63% energy recovery | 9% landfill | Substitution of virgin polystyrene, exported electricity + heat (oil) | EPD Norge/ NO, SE |
| XPS | mixed | MND | 10 km | 44% recycling, 53% Energy recovery | 3% landfill | Substitution of virgin polystyrene, exported electricity + heat (oil) | EPD Norge/ NO |
| XPS | 100% | Mixed waste collection | 200 km | Zero impact | Landfill | MND | Inies/ FR |

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**Table 2**. Scenario data for wood panel product EPD.

| Product description | Scenario type | Stated scenario for C1 | Stated scenario for C2 | Stated scenario for C3 | Stated scenario for C4 | Stated scenario for Module D | Programme/ Location of Manufacture |
|---|---|---|---|---|---|---|---|
| MDF | MND | MND | MND | MND | MND | MND | BRE / Ireland |
| MDF | multiple 100% | MND | MND | Shredding + energy recovery | MND | Substitution exported heat (natural gas) | EPD Australasia / Australia |
| | | | | Recycling to wood chip | MND | Substitution (virgin wood chip) | |
| | | | | MND | Landfill DOCF 0.7% | Substitution electricity ER of landfill gas | |
| | | | | MND | Landfill DOCF 10% | Substitution electricity ER of landfill gas | |
| MDF | mixed | Mixed wood waste | 85km in NO. % to SE | 90% Energy Recovery | 2% landfill, 7% incineration | Substitution exported electricity + heat (NO + SE) | EPD Norge /Norway |
| MDF | 100% | not given | 85km | Energy recovery | MND | Substitution exported electricity + heat | EPD Norge /Norway |
| MDF* | 100% | MND | MND | Chipping to secondary fuel | MND | Substitution exported electricity + heat | IBU / Germany |
| MDF | 100% | MND | MND | processing to secondary fuel | MND | Secondary fuel use, EU average substitution | IBU/ Germany |
| MDF | 100% | Removal | MND | Zero impact | MND | Secondary fuel use | IBU / Germany |
| MDF | 100% | Removal | 20km | Crushing | Incineration eff. 35% | Substitution of exported heat + electricity | IBU / Germany |
| MDF | 100% | MND | MND | Chipping to secondary fuel | MND | Substitution of exported heat + electricity | IBU / Germany, Portugal, South Africa, Spain |
| MDF | 100% | MND | MND | Energy recovery | MND | substitution of exported heat + electricity | IBU / Poland |
| MDF | 100% | MND | MND | Chipping to secondary fuel | MND | Secondary fuel use, Substitution heat (natural gas), electricity (ES) | International EPD /Spain and Portugal |
| OSB | MND | MND | MND | MND | MND | MND | EPD Ireland / Ireland |
| OSB | 100% | MND | MND | Chipping to secondary fuel | MND | Secondary fuel use, EU average substitution | IBU /Germany, Romania |
| OSB | 100% | MND | MND | Chipping to secondary fuel | MND | Substitution exported heat & electricity | IBU /Germany |
| OSB | 100% | MND | MND | Energy recovery | MND | Substitution exported heat & electricity | IBU /German, Poland |
| Particleboard | mixed | Mixed construction waste | 33% 85km (NO), 67% by road and sea (SE) | 91% Energy Recovery | 2% Landfill 7% incineration | Substitution exported electricity & heat (NO + SE) | EPD Norge /Norway |
| Particleboard | 100% | MND | MND | Only bioCO2 transfer | MND | Substitution exported heat | IBU / Austria |
| Particleboard | 100% | MND | MND | | MND | Substitution exported heat | IBU / Austria |
| Particleboard | 100% | MND | MND | Only bioCO2 transfer | Zero impact | Secondary fuel use | IBU / Belgium |
| Plywood | 100% | Mixed construction waste | 85km | Only bioCO2 transfer | Energy recovery eff. <60% | Substitution exported electricity + heat | EPD Norge / Norway |
| Plywood | mixed | not given | 85km | Energy recovery | Landfill of ER ash | Substitution exported electricity + heat (NO) | EPD Norge / Sweden |
| Plywood | multiple 100% | MND | MND | Chipping to secondary fuel | Zero impact | Secondary fuel use, substitution heat (natural gas) | International EPD /Australia |
| | | MND | MND | Recycling to wood chip | Zero impact | Substitution of virgin woodchip | |
| | | MND | MND | Reuse | Zero impact | Substitution of virgin product | |
| | | MND | MND | Zero impact | Landfill DOCF 0.7% | Substitution exported heat & electricity from landfill gas | |
| | | MND | MND | Zero impact | Landfill DOCF 10% | Substitution exported heat & electricity from landfill gas | |
| Plywood | MND | MND | MND | MND | MND | MND | International EPD /Italy |
| Plywood | MND | MND | MND | MND | MND | MND | International EPD /Spain |
| Wood panel | 100% | not given | 100km | Energy Recovery | MND | MND | FDES /France |

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a 5% capacity including empty returns, one 18% capacity and one 21%. Fuel consumption for the trucks was reported variously as 0.2 l/km, 0.38 l/km, 25 l/km, 0.173 l/tkm, 0.4 l/tkm, and 0.026 l/tkm for the large capacity trucks travelling 1000km.

There was a wide range of end of life options, including recycling, energy recovery in C3 and incineration with energy recovery in C4. 14 EPD declared Module D showing the benefit of energy and material recovery, though few stated what electricity or energy was substituted.

*5.6. Wood panel products: OSB, MDF, particleboard/chipboard and plywood*

Twenty five EPD from five EPD programs were considered within this product group and details of the modules reported and scenarios used are provided in Table 2. Again, there are a range of mixed, 100% and multiple 100% types of scenarios declared. As for polystyrene, very few declared C1. Reporting for C2 (transport to waste processing) was also varied with distances varying from 20 to 100 km. Although almost all EPD declaring end of life modelled use of the waste timber for energy, there was a big variation with some processing and using the waste for energy recovery in C3, some incinerating in C4, and some considering the use of secondary fuels in Module D with some also reporting processing in C3.

## 6. The Role of Product TCs and c-PCR

CEN/TR 16970:2016 (16) provides guidance to CEN Product Technical Committees on developing complementary PCR (c-PCR) to EN 15804. It says in the development of c-PCR, the following are considered, in 5.1.2, "inclusion of default scenarios related to a specific application of the product including guidance on:

i) The specific content of all information modules of the life cycle and information module D, for default scenarios;
ii) The definition of the end-of-waste status;
iii) The technical scenario information for all information modules of the product system and information module D".

It also states in 6.3.8, that "when different scenarios are developed for information modules C1-C4 the most relevant scenarios are provided as 100% versions. For example, when 20% of a product is recycled, 50% is incinerated and 30% is deposited, scenarios for 100% of 100% of incineration, 100% of recycling and 100% of deposition are declared. This allows the building assessor to choose and calculate the correct scenario on building level as actual waste management practices vary in different member states."

*6.1. EoL scenarios in c-PCR in practice*

Unfortunately, few of the c-PCR developed to align with EN 15804 provide detailed technical scenario information for the end of life and only one provides an assumption for the end-of-waste status if product specific information is not available. One states that geography will affect the EoL routes used.

*6.1.1. EN 16783:2017* is the c-PCR for insulation. This does not provide any default scenarios or specific guidance on the End-of-Waste state for insulation products, but states in clause 6.3.4.5 that the products can be sorted and separated for recycling or for energy recovery and scenarios can vary with the application and with geographical location (17).

*6.1.2. EN 16485:2013*, the PCR for round and sawn timber (the raw material for use in board products), provides an assumption on the end of waste state for timber where product specific information is not available, which is after sorting and chipping for untreated timber, and gives some guidance on the types of process to include in modules C1-C4 for different end of life options depending on when the end of waste state is reached (18).

*6.1.3. Other c-PCR:* The c-PCR for Glass (EN 17074:2018, clause 9.8.4) states that "End-of-life scenarios and routes can vary according to national and regional legislation, de-construction schemes and requirements, collection and sorting schemes in place and end-of-life treatments available"(19). The c-PCR for concrete (EN 16757:2017) gives detailed technical scenarios for possible EoL options for concrete. It does state, as a note, that "The legal interpretation of End-of-Waste can differ significantly at national level. At some regions, crushed concrete stored indefinitely at demolition sites over long periods will revert to being waste. In such case, certainty over the legal End-of-Waste status is only confirmed when demand exists and a certain market is allocated and the crushed concrete is removed from site"(20). Again, this emphasises the differences that geography plays in determining EoL scenarios for EPD and highlights the difficulty in European c-PCR providing relevant default EoL scenarios when practice varies so widely geographically, due to differences in national and regional legislation, the recycling schemes in place and the EoL treatments available.

## 7. Discussion

### *7.1. Variation in reporting*

The detailed analysis of end of life scenarios and reporting undertaken for this paper highlights the wide variation in end of life routes assumed within EPD. The authors are also concerned by possible errors in modelling or reporting of fuel consumption and vehicle capacity, differences in assumptions for transport distances, and the differences in the "end of waste state" used. The "end of waste state" can vary regionally as markets and demand may vary, the secondary material may not be commonly used in some regions and the legal definition of end of waste may also vary. But even for MDF EPD for the German Market, there is not consistency regarding the end of waste state – with one assuming the end of waste before chipping. Analysis shows these differences in scenarios also lead to differences in impact reported in Module C and Module D. The wide variation in scenarios also means that there is a general level of distrust with gate to grave data with many Building LCA tool providers telling the authors they do not use gate to grave data from EPD in their tools.

Provision of a national default scenario, such as that for the Netherlands (21) reduces the effort to produce gate to grave EPD data for that market as manufacturers and LCA practitioners do not need to individually research and develop representative end of life scenarios, and this is likely to be associated with reduced costs.

### *7.2. Insufficient description of scenarios*

The authors note that many EPD provide insufficient information on scenarios for those using EPD for Building LCA to ensure "*Any scenarios incorporated in the EPD and/or other information used for the assessment should be checked for consistency with the scenarios for the building"* as suggested by EN 15978 10.2.3. If the type of heat or electricity substituted in Module D is not provided for example, then the module cannot be checked for consistency with building level scenarios for substitution.

### *7.3. Provision of multiple 100% scenarios*

Very few of the EPD provided more than one 100% scenario for different end of life options, although there were several different end of life routes given across the product groups. EPD providing mixed scenarios did not provide any 100% scenarios for the individual processes despite the text in CEN/TR 16970:2016 6.3.8 recommending this. C-PCR also fail to recommend this option, although it would help to deal with the different EoL options available in different locations due to variations in legislation, recycling schemes and treatments available. Providing 100% scenarios for recycling, energy recovery, landfill and incineration (potentially with different end-of-waste states if relevant) gives an understanding of the different impacts of these end of life options and can be used for buildings currently being demolished, wherever they are, to assess the most advantageous options. Where 100% scenarios are reported for re-use and/or recycling in addition to energy recovery, they also enable use of the data

IOP Conf. Series: Earth and Environmental Science **323** (2019) 012051 doi:10.1088/1755-1315/323/1/012051

for different building level scenarios, such as design for deconstruction, providing encouragement for the circular economy.

## 8. Conclusion

The authors have provided several new approaches to classifying the scenarios reported in EPD, and identified that a significant proportion of EN 15804 EPD already report Modules C1-C4 and Module D. However, the authors are concerned that their analysis of existing EPD has highlighted such wide variation in the modelling, description and reporting of these modules. With reporting of Module C and Module D likely to become mandatory for all EPD based on FprEN15804+A2:2019, the authors recommend that EPD programmes provide more guidance on modelling, description and reporting to ensure that EPD data can be checked for consistency with building level scenarios and used with confidence. It is also clear that Product TCs find it difficult to develop c-PCR with default EoL scenarios due to the geographical differences in real EoL routes. To address the differences in different locations, and encourage the circular economy, the authors also highlight the benefit for c-PCR and EPD of providing multiple 100% scenarios so the impact of different end of life options can be considered and circular economy approaches to building design can be evaluated in many locations. The authors also recommend that building level assessment schemes together with EPD program consider developing and publishing default national scenarios to enable consistent assessment for benchmarking.

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