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Certification of reusability of Peikko products

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RISSANEN ANNE:
Peikon tuotteiden uudelleenkäytettävyyden sertifiointi

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Tämän opinnäytetyön tarkoituksena oli selvittää rakennustuotteiden uudelleenkäytettävyyden sertifiointia Peikko Group Oy:n tuotteille. Rakennusosien uudelleenkäyttö on rakennusteollisuudelle uudehko toimintamalli, mutta kiinnostus sitä kohtaan on kasvussa Euroopan komission asettamien haastavien tavoitteiden vuoksi. Kasvihuonekaasupäästöjä tulisi vähentää tulevina vuosikymmeninä ja rakennusteollisuus nähdään yhtenä pahimmista kasvihuonekaasujen tuottajista.

Kolmannen osapuolen varmennus, sertifiointi tai tuotehyväksyntä, perustuu lainsäädäntöön. Rakennustuotteiden ominaisuuksien todentaminen on määritelty eurooppalaisessa lainsäädännössä sekä rakentamiseen liittyvässä kansallisessa lainsäädännössä. Euroopan komissio on julkaissut vihreän kehityksen ohjelman ja kiertotalouden toimintasuunnitelman, joissa esitetään selkeitä toimia hiilidioksidipäästöjen vähentämiseksi. Nämä toimet johtavat myös rakennustuotteiden uudelleenkäyttöön. Tällä hetkellä ei ole olemassa uudelleenkäytetyn rakennustuotteen tai -komponentin varmennusta, joka ottaisi kantaa rakenteellisiin ominaisuuksiin.

Opinnäytetyö jakaantui kolmeen päävaiheeseen. Ensimmäisenä selvitettiin, miksi rakennustuotteille tarvitaan kolmannen osapuolen varmennus. Toiseksi tutkittiin, mistä uudelleen käytön tarve tulee. Tulosten vahvistamiseksi haastateltiin suomalaisia asiantuntijoita. Haastattelut tehtiin luottamuksellisina ja näin ollen tässä työssä haastatteluyhteenveto on tehty nimettömänä.

Haastattelujen ja taustatutkimuksen perusteella oli ilmeistä, että jonkinlainen uudelleen käytön todentaminen olisi suositeltavaa. Koska valmista sertifiointijärjestelmää ei ole saatavilla, rakennustuotevalmistaja Peikko Group Oy voisi hyödyntää ISO-standardia ja tehdä yhteistyötä sertifiointielimen kanssa. Näin he voisivat tukea asiakkaita, jotka suunnittelevat rakenteita uudelleen käytettäväksi rakennuksen käyttöiän päätyttyä.

Asiasanat: uudelleen käytettävyys, rakennusosat, sertifiointi

ABSTRACT

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This thesis studies the reusability certification possibilities of reused construction products. The reuse of construction components is a relatively new topic for the construction industry. There is rising interest in reuse due to ambitious European level targets to reduce greenhouse gas emissions in the coming decades. The construction industry is seen one of the worst greenhouse gas producers. The study was initiated at the request of the construction product manufacturer, Peikko Group Oy.

The study has three main phases. The first phase was to find out why there is a request to have third party verification for construction products. The second phase examined where the need for reuse comes from. To confirm the results, unstructured interviews were conducted with field professionals in Finland. The interviews are considered confidential and the public report includes an anonymous summary of them.

The third party verification, certification, is based on legislation. The verification of construction product properties is defined in European legislation, and national legislation related to building and construction. The rising demand for more sustainable buildings and products that fulfil circular economy principles is coming from European level. The European Commission has published the Green Deal strategy and the Circular Economy Action Plan, where is stated clear actions how to reduce CO_2 emissions. These actions are encouraging to favour also the reuse of construction products. At the moment there is no certification available that would take in to account the structural properties of reused construction products or components.

Based on the interviews and background study was evident that some verification would be highly recommended. As there is no ready certification scheme available, construction product manufacturer Peikko could utilize the ISO standard and co-operate with the certification body to have confirmation for the reuse documentation. Thus, they could support customers when structures are designed to be reused after building's lifespan ends.

Keywords: reusability, construction components, certification

CONTENTS

ABBREVIATIONS AND TERMS

Abbreviations

CPR	Construction Product Regulation
EPD	Environmental Product Declaration
hEN	European harmonised standard
ETA	European Technical Assessment
EAD	European Assessment Document
GPP	Green Public Procurement
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
EU	European Union
PCR	Product Category Rules

Terms

Circular economy

economy that is restorative and regenerative by design, and which aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles (ISO 20400:2017, 3.1)

Construction component

Part of the building that consists of construction products and materials, for example, a concrete column

Reusability

The ability of a material, product, component, or system to be used in its original form more than once and maintain its value and functional qualities during recovery to accommodate reapplication for the same or any purpose

Reuse

The use of products or components more than once for the same or other purposes without reprocessing

1 INTRODUCTION

Green values are currently receiving close attention across Europe. The European Commission has set targets to be climate neutral by 2050, and they published a European Green Deal strategy that presents the action plans to reach this long-term strategy. These action plans also have guidelines for the construction sector. Some EU countries have set even more ambitious targets, such as Finland, which aims to reach the zero carbon level by 2035 (Ministry of the Environment n.d.).

Because of these targets, it is necessary to also rethink construction business models. One way to reach zero carbon level is to reuse construction components instead of building them from virgin materials. Construction product providers need to consider ways to support the reuse of components and what kind of information is needed to make reuse possible after the building's lifespan has ended.

This thesis was ordered by Peikko Group Oy. Peikko Group Oy, hereafter referred to as Peikko, which is an international company consisting of 34 legal units around the world. They have 11 factories. Peikko was established in 1965 by the Paananen family. In 2019, its turnover was 230 million Euros. Peikko provides slim floor structures, wind energy applications, and connection technology for precast and cast-in-situ. It aims to be a global forerunner and offer a faster, safer, and more efficient way to design and build.

Peikko started investigating possibilities to enable the reuse of building components by using Peikko products. An initial research program was begun on bolted connections to prove that disassembly and reconnection are possible (Yrjölä, 2020). Peikko now faces the question of what kind of proof should be provided to structural designers and other interested parties to make reusability real. This thesis attempts to answer that question.

The thesis consists of a background study about the requirements for reusability and to identify where the need arises for reuse and certification. That will

indicate why something is done and what the requirements by authorities are. A literature review formed the background study. Moreover, interviews were conducted to determine the data needed by interested parties. Based on these, the conclusions and proposal for the next steps were formulated for Peikko. The results were presented to the management team members and CEO of Peikko.

2 RESEARCH METHODS

In this thesis, the question is approached using qualitative research. The topic is analysed as a case study using the background study of available literature and interviews.

The use of a case study aims to create development proposals and ideas for companies, products, or processes. It provides information about the topic in the present environment. The aim is to create a detailed and in-depth analysis of the case. Usually, only one subject is studied. The research methods can vary and may be a combination of qualitative and quantitative methods. Various interview forms are commonly used to collect information. (Ojasalo, Moilanen & Riihilahti 2015, 52-55).

Interviews are among the most used methods to collect information. They are adequate when the research topic is not studied in-depth or the viewpoint of the interviewee is important. Interviews can be combined with other methods, which is also recommended. There are many types of interviews, including structured, unstructured, theme, and team interviews. In the structured interview, questions are prepared before the interview and are asked in a predefined order. The unstructured interview is more like a conversation on the topic and can be informal. The researcher needs to select the most appropriate method for his/her research to gather information. (Ojasalo, Moilanen & Riihilahti 2015, 106-109).

2.1. Research process

The research process started with defining a research question. This was done based on discussions with Peikko and formulated as what kind of proof should be provided to interested parties to make reusability real. Already in the very beginning was evident that both literature review and interviews are needed to gain information about the topic.

The question was approached first by literature review on available documents related to European Commission strategies, legislation, and guidelines. Furthermore, the background for certification need was studied in legislative perspective. Most of the documents have official nature, which leave little room for speculation. The interpretation of these documents can vary, and in this thesis the viewpoint of Peikko was selected. Other interpretations were not studied here.

Partly parallel to literature review the organizing of interviews started. The first interviewees were selected from Peikko contacts and based on their expertise about the topic. Some of the interviewees were able to recommend other experts on the field to be interviewed. All the interviewees were first approached by an email to inquire their willingness to take part to a study and with a proposal of Microsoft TEAMS meeting. The remote meeting was proposed due to COVID-19 situation and recommendations not to meet face-to-face. The interview was scheduled to last an hour and it was recorded with the permission of interviewee.

In this thesis, the interviews were unstructured. The topic of reuse of construction products is relatively new in the construction industry and limited discussion has focused on it. It was decided early that unstructured interviews are the correct approach to the topic. The purpose of the interviews was to confirm the need for certification and gather related information about the environment.

2.2. Literature review and analysis of interviews

The relevant literature search started with investigation of different European Commission web sites and national (Finnish) documents. It continued by reading the found relevant documents and studying other references. The information from literature was collected as notes with correct references to documents. This was then formulated as a written report which is available on chapters 3 – 5. To understand the relations between the subjects a mind map method was used, which was beneficial. The mind map is shown in Figure 3.

Interview recordings were written down as notes and divided to comments based on the subject. The transcription of interviews was not seen beneficial here, because of used unstructured interview method and novelty of the interview topic. The data was sorted carefully by the subject and in case of uncertain expression, the interview recording was listened again. The comments were kept related to experts themselves to create clear view of different point of views to the discussion topic. Due to small number of interviewees making the conclusions was straight forward. Interview summary is presented in the chapter 6. Furthermore, the conclusions of interviews and relation to literature review are in the chapter 7.

3 CERTIFICATION OF CONSTRUCTION PRODUCTS

The construction industry is known to be conservative concerning development and structural design. The conservative approach comes from history: early days when structural principles were poorly understood, the design was based on trial and error and, therefore, based on tried and tested means of developing structures (Smith 2016, 25).

The construction of buildings is highly regulated. For example, Figure 1 presents the regulations related to the certification of construction products in Finland. The regulations are explained in the following chapters.

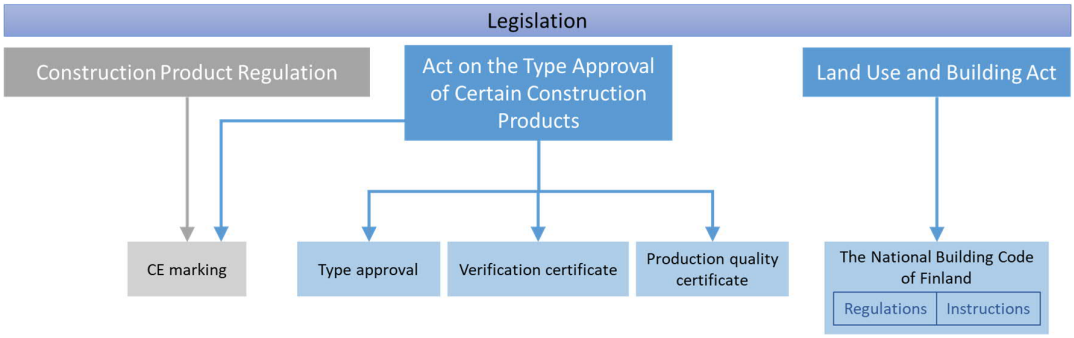


Figure 1. Building regulations related to construction product certification in Finland.

3.1. The Construction Product Regulation and CE marking

The Construction Product Regulation (CPR) (Regulation (EU) No 305/2011) establishes harmonised rules for the construction product markets in the European Union. It has four elements: setting up a system of conformity assessment, describing harmonised technical specifications and CE marking of products, and defining a framework for notified bodies and market surveillance. European Union regulations are implemented to national legislation such that there are no parallel acts.

The harmonised technical specifications describe the performance characteristics that affect the ability of construction products to meet the basic

requirements set in the CPR. The basic requirements are mechanical resistance and stability; safety in case of fire; hygiene, health, and the environment; safety and accessibility in use; protection against noise; energy economy and heat retention; and sustainable use of natural resources. The harmonised technical specification can be either the harmonised standard (hEN) or the European Assessment Document (EAD). Both of these set rules how to show the performance of the construction product, what kind of tests are needed, and what the are the responsibilities of the manufacturer and the notified body. Based on the harmonised technical specification, the manufacturer draws up the Declaration of Performance (DoP) and CE marks the product. The harmonised technical document describes how to show the performance of the product, but it does not set threshold values. The threshold values are set by national regulations or market demand, such as structural design.

When the product belongs to the scope of hEN, it shall have CE marking on it. When the hEN does not exist or the product is only partly in the scope of hEN, the manufacturer can apply voluntary European Technical Assessment (ETA), which is based on EAD. The benefit of CE marking is that it is accepted in all EEA-countries and there should not be any parallel national product approvals with the same scope. Moreover, many customers require CE marking in the tender phase.

3.2. National legislation

European Union member states have their own legislation for buildings and land use, for example, the Building and Land use Act (132/1999) in Finland. That includes provisions on planning and building, plot division, building permits, and supervision by authorities.

The Finnish Building and Land use Act is supplemented by the National Building Code of Finland. It defines substantive technical requirements for buildings and describes, in more detail, the building permit process, and building supervision by authorities. The building code is in line with the Eurocodes, which define how the structural building design can be made.

The Act on the Type Approval of Certain Construction Products in Finland (954/2012) describes how the performance of construction products can be declared when the construction product does not fall within the scope of harmonized technical specifications according to CPR. Three voluntary possibilities show the substantive technical requirements of building products: type approval, verification certification, and production quality certification. Among these three, meeting the requirements can be shown also by a building site specific declaration.

3.3. Legislation and market needs

The declaration of construction product performance, certification, is mandatory by legislation. There are ways to certify the products in a voluntary manner, which is also defined in legislation. Even though there are voluntary certifications according to legislation, the building authorities tend to require those to verify the fit of products for their intended use. Therefore, the customers of construction product producers require certificates and are accustomed to having a certificate that states the properties of the construction products.

National certificates are usually accepted only in that specific country. In some cases, the neighboring countries might accept each other's certificates. For example, a Finnish type approval is often accepted in Estonia and Sweden. Furthermore, some national certificates are held in higher regard in other countries, and good example of these are German type approvals, Allgemeine bauaufsichtliche Zulassung (abZ), which are accepted in all German-speaking nations and also many others.

The certifications usually require third party quality control of products and production. The role of a third party varies and required involvement is based on the product properties, expected behavior in the structure, and how crucial the product is to the total safety of the building.

4 WHERE THE NEED ARISES FOR REUSABILITY

4.1. The European Green Deal Strategy

The European Commission presented a European Green Deal strategy on 11 December 2019. The strategy aims to transform Europe into a resource-efficient and sustainable economy. The European Commission has set a target to decrease greenhouse gas emissions at least 55% compared with 1990 levels by 2030 and to be climate neutral by 2050. (2030 Climate Target Plan n.d.).

The essence of the Green Deal is illustrated in Figure 2. To achieve the strategy targets, the European Commission presented a roadmap for key policies and measurements. These policy areas are biodiversity, from farm to fork, sustainable agriculture, clean energy, sustainable industry, building and renovating, sustainable mobility, eliminating pollution, and climate action. (European Green Deal (COM (2019) 640).

Figure 2. The European Green Deal (COM (2019) 640).

The building and renovating policy describes needed actions related to buildings. Buildings account for 40% of the energy consumed and, therefore,

their energy performance should be increased. The possible methods include better energy-efficiency of buildings, circular design, increased digitalization, and better adaptability of buildings to climate changes. The renovation of older buildings will increase and a special focus will be on social housing, schools, and hospitals. (Building and Renovation fact sheet 2019).

The other policies related to the construction sector are sustainable industry and eliminating pollution. The sustainable industry aims to decarbonise and modernise energy-intensive industries, such as steel and concrete manufacturing (Sustainable Industry fact sheet 2019). The elimination of pollution aims to reduce the harmful pollution from micro-plastics (Eliminating Pollution fact sheet 2019).

The construction sector produces over 35% of the EU's total waste and is estimated to cause 5-12% of total national greenhouse gas emissions (The Circular Economy Action Plan fact sheet 2020). Therefore, it plays a significant role in the Green Deal and has the potential to reduce emissions.

To reach the targets, the European Commission has initiated several legislation renewals, such as the Energy Performance of Buildings Directive 2010/31/EU and Ecodesign Directive 2009/125/EC. Moreover, the Commission has made proposals for Climate Law Regulation. All of these affect the construction sector, whether directly or indirectly. These directives and regulations are in the preparation or proposal phase and, therefore, are not addressed in this thesis.

4.2. The Circular Economy Action Plan

The European Commission published the Circular Economy Action Plan in March 2020. The plan describes in a more practical way, how to reach the targets of the Green Deal in means of a circular economy. The action plan presents initiatives for the entire life cycle of products and is driven by the ambition to make products that last longer and enable citizens to participate in the benefits. (The Circular Economy Action Plan fact sheet 2020).

The Circular Economy Action Plan (2020) presents a sustainable product policy framework that includes designing sustainable products, empowering consumers and public buyers, and circularity in production processes. The framework is presented as actions in several key value chains. (The Circular Economy Action Plan 2020, 6–9).

The key value chain of construction and buildings includes several actions (The Circular Economy Action Plan 2020, 14):

- revising the Construction Product Regulation to address the sustainability of construction products with the introduction of recycled content requirements
- developing digital logbooks for buildings and building design to improve the durability and adaptability of built assets
- integrate lifecycle assessment into public procurement by using Level(s)
- considering a revision of material recovery targets set in EU legislation
- soil usage to be made safer, more sustainable, and circular
- a ‘Renovation Wave’ to lead to significant improvements in energy efficiency.

CPR renewal affects construction products by the requirements set in the harmonised technical specifications. The renewal was announced and the options for the content are presented in the Refined Indicative Options for the Review of the Construction Products Regulation, version 2 (2020). The options are from mild updating to total rewriting, or even to the withdrawal of the regulation. Most of the options include actions to clarify the content related to other EU legislation and addressing environmental aspects of the construction products mentioned in the Green Deal. (Refined Indicative Options …2020, 2–28).

The other key product value chains related to the construction sector are packing and plastics. In the packing, the actions are related to a review of the Packing and Packaging Waste Directive 94/62/EC27 to reduce overpacking and packing waste, design for the re-use and recyclability of packing, and reduce complexity of materials. The plastics have actions for mandatory requirements for recycled content, and waste reduction measures for construction materials.

4.3. Green Public Procurement

The European Commission has defined the Green Public Procurement (GPP) in Communication Public procurement for a better environment (COM (2008) 400). The target of the GPP is to be a tool to achieve environmental goals set in the Green Deal. The EU member states have created their own approach to GPP by formulating National GPP Action Plans which aim to push public procurement towards green choices. These national action plans are in line with the European Commission GPP but offer more detailed guidelines at the national level.

The European Union has developed GPP criteria for several product and service groups, which describe the selection and award criteria, specifications, and contract clauses. GPP criteria are available for, among others, electricity, furniture, indoor lighting, and office buildings. The criteria are based on different data sources and have technical background reports that identify the considerations. The criteria include the following:

- core criteria that enable easy adaptation of key area(s) of environmental performance and aim to keep the costs at a minimum for companies
- comprehensive criteria that define higher levels of environmental performance or more aspects.

The GPP criteria are available on the GPP website together with technical background reports. (Buying Green! 2016).

The Buying Green! A handbook on green public procurement (2016) presentsguidelines for public procurement on how to buy goods and services and ensure they are in line with set goals related to climate change, resource use, and sustainable consumption and production. It describes practical steps to implement GPP in the procurement process, how to define contract requirements, select tenderers, award a contract, and its performance clauses. The handbook presents guidance on how to set requirements beyond EU GPP criteria for products, for example, environmental labels and how to verify the technical properties of products against the specifications. (Buying Green! 2016, 3–4).

According to the handbook (Buying Green! 2016), the technical specifications can be formulated using national, international, or European standards. The product compliance with standards can be shown by a certificate or a test report. The evidence can be shown also via the manufacturer's technical dossier if the third party verification is not possible due to time limits. (Buying Green! 2016, 32 – 33, 38).

The handbook refers also to environmental management systems (EMS), such as ISO 14001, to demonstrate the technical capacity of the tenderer to take into account environmental aspects. It also highlights that the third party certificate is not the key, but the defined actions in EMS are the important measures. (Buying Green! 2016, 46).

The GPP criteria for office buildings describes the important aspects related to green office buildings in design, building, maintenance, usage, and renovation stages. In the design phase, it is recommended to have participants in the project group that have experience, for example, in life cycle assessment (LCA) and life cycle cost (LCC). LCA can be used to analyse the environmental impacts of different designs and it is one of the GPP criteria. The project group should also assess the LCC to evaluate all the costs of the building during its life cycle. The relation of these two is that with LCA the lifespan of a building as a whole can be modelled and optimised, which then influences the costs. (Dodd, Garbarino & Gema 2016a, 8–9).

A commission staff working document about EU GPP Criteria for Office Building Design, Construction and Management (SWD(2016) 180 (2016, 6) provides more detailed criteria descriptions for office buildings and lists their key environmental impacts. The most significant impacts are

- Energy use during building use
- Production of construction materials
- Transportation of aggregates
- Lifespan of the building and its elements

The criteria aim to provide tools to reduce these impacts by choosing and evaluating lower-impact building elements.

The procurers are guided to consider the following aspects by award criteria when rating the bidders and their offers:

- life cycle assessment done to evaluate the impacts of main building elements
- environmental product declarations (EPDs) to determine the total embodied CO_2 equivalent emissions (Global Warming Potential, GWP)
- recycled and reused content (e.g. for concrete)
- reduced emissions from transport of heavy materials

The criteria, therefore, encourage the whole building material industry to focus on reduction of CO_2, recycling and reuse of building components. (SWD (2016) 180 2016, 7).

4.4. Level(s) framework

The Level(s) framework has been developed by the European Union to meet the sustainability targets set in the Green Deal strategy and circular economy policy. The framework helps design and construct buildings in a way that the whole life cycle is considered. Level(s) aims to increase awareness of a building's impact on the environment, identify hotspots and provide tools to reduce the impact. (Level(s) n.d.).

The Level(s) framework User Manual 1 (Dodd, Donatello & Cordella 2020a) describes the set of indicators and metrics to measure the sustainability of buildings by assessing aspects of environmental performance, life cycle cost and value, health and comfort, and potential risks in the future performance. It aims to establish a common language for the sustainability of buildings. The framework has six macro-objectives that describe the strategic priorities:

- macro-objective 1: Greenhouse gas emissions during building's life cycle
- macro-objective 2: Resource-efficient and circular material life cycles
- macro-objective 3: Efficient use of water resources
- macro-objective 4: Healthy and comfortable spaces
- macro-objective 5: Adaptation and resilience to climate change
- macro-objective 6: Optimised life cycle cost and value

Each macro-objective has corresponding indicators for measuring, and there are totally 16 of them. The indicators for macro-objectives 1-3 are shown as means of LCA. (Dodd, Donatello & Cordella 2020a, 7, 11–13).

The framework is divided into three levels by how advanced the reporting on sustainability will be. Level 1 is the simplest, and it focuses on the conceptual design of the building project. Level 2 focuses on detailed design and construction performance, and level 3 on as-built and in-use performance. Any of the levels can be chosen for the building project.

The reusability of construction components is addressed in micro-objective 2: resource-efficient and circular material life cycles indicator 2.4 Design for deconstruction, reuse and recycling. The measurement is a dimensionless scoring of the deconstruction potential of a building. The three aspects are ease of recovery, ease of recycling, and ease of reuse. The reporting for level 1 is based on a checklist and yes/no selection. The checklist of deconstruction design concepts is presented in Table 1. When presenting indicators according to levels 2 and 3, the assessment will follow the German Green Building Council's (DGNB) Ease of recovery and recycling TEC 1.6 criteria. Reporting in levels 2 and 3 will include the overall score and a list of parts with descriptions of the design solutions used to facilitate the aspects. (Dodd, Donatello & Cordella 2020b, 9–14).

Table 1. Checklist of deconstruction design concepts. (Dodd, Donatello, Cordella. 2020b, 9–10).

Deconstruction design concept	**Specific design aspect to address**	**Description**
1. Ease of recovery	1.1 Elements and their parts are independent and easily separable.	The potential to separate elements that are connected to each other and to disassemble elements into their constituent components and parts. The nature of the connections are addressed by design aspects 1.2 and 1.3.
	1.2 Connections are mechanical and reversible.	The use of mechanical, non-destructive connections as opposed to chemical bonding.
	1.3 Connections are easily accessible and sequentially reversible.	Easy and sequential access in order to reverse mechanical connections and remove elements.

Deconstruction design concept	Specific design aspect to address	Description
	1.4 The number and complexity of the disassembly steps are low.	The disassembly should not suppose the need for complex preparatory steps, the intensive use of manpower and machinery and/or off-site processes.
2. Ease of reuse	2.1 Specification of elements and parts using standardized dimensions	Specification of elements and parts that are of a standardized specification in order to provide consistent future stock.
	2.2 Specification of modular building services.	Specification of modular systems that may retain value upon de-installation or which may be more easily swapped out and upgraded.
	2.3 Design supports future adaptation to changes in functional needs.	Design of the building parts to support ongoing use in the same or a different design configuration in the same building.
3. Ease of recycling	3.1 Parts made of compatible or homogenous materials	Specification of components and constituent parts made of homogenous materials, the same materials, or materials mutually compatible with recycling processes. Finishes, coatings, adhesives, or additives should not inhibit recycling.
	3.2 Constituent materials can be easily separated	It should be possible to separate components and parts into their constituent materials.
	3.3 There are established recycling options for constituent parts or materials	The part or material is readily recyclable into products with a similar field of application and function, thereby maximizing their circular value.

The German Green Building Council's (DGNB) Ease of recovery and recycling TEC 1.6 (2020) gives points on the same indicators as Level(s) based on main building components (external walls, floors, etc.) and bonuses. The maximum in these three indicators is 100 points and 30 extra points can be attained with bonuses. As an example, in load-bearing structures, the points can be 0.5 or 1.0 in the ease of recycling indicator, and 20 bonus points can be attained because of reuse or material recovery. (DGNB 2020, 536–539).

4.5 Building Certification schemes

There are several building certification schemes (green building certifications) available across the globe. The most commonly used certifications in Europe are British BREAAM, Dutch GPR Building, German DGNB (German Sustainable Building Certificate), and French HQE (Haute Qualité Environmentale). All of these certifications support the use of LCA during the

design process, which can benefit the building project. Moreover, those emphasise the existence of EPDs for construction products. HQE is a good example of where the EPDs for all construction components needs to exist to earn the highest score. Table 2 compares the main assessment methods. From the table can be seen that the effect of LCA and reusability is small due to fact that it is only one aspect of many factors. (Dodd, Garbarino & Gama, 2016b, 55–59).

Table 2. Comparison of main assessment methods. (Dodd, Garbarino & Gama 2016b, 60).

Scheme	BREEAM	DGNB	GPR	HQE
Method	BRE Environmental Profiles	DGNB Certificate	GPR Building	Démarche HQE
Assessment categories (score)	1. Management (12) 2. Health & Wellbeing (21) 3. Energy (39.9) 4. Transport (4) 5. Water (3.6) 6. Materials (15) 7. Waste (5.25) 8. Land use & Ecology (10) 9. Pollution (12) 10. Innovation (10)	1. ecological quality (22.5%) 2. economic quality (22.5%) 3. socio-cultural and functional quality (22.5%) 4. technical quality (22.5%) 5. process quality (10%)	1. Energy a. Energy performance b. Demand reduction 2. Environment a. Water b. Environmental care c. Materials 3. Health a. Noise b. Air quality c. Thermal comfort d. Lighting and visual comfort 4. User quality a. Accessibility b. Functionality c. Technical quality d. Safety 5. Long term value a. Adaptability and future amenities b. Flexibility c. Perceived value	1. The building's relationship with its immediate environment 2. Integrated choice for construction 3. Low nuisance worksite 4. Energy Management 5. Water Management 6. Management of activity generated waste 7. Servicing & Maintenance 8. Hygrometric comfort 9. Acoustic comfort 10. Visual comfort 11. Olfactory comfort 12. Health quality of space 13. Health quality of air 14. Health quality of water
Impact assessment categories	1. Climate change (GWP) 2. Water extraction (FW) 3. Mineral resource depletion (ADP-Elements)) 4. Stratospheric ozone depletion (ODP) 5. Human toxicity (HTP) 6. Ecotoxicity to water (FAETP) 7. Nuclear waste 8. Ecotoxicity to land (TETP) 9. Waste disposal 10. Fossil fuel depletion (ADP-Fossil) 11. Eutrophication (EP) 12. Photochemical ozone creation (PCOP) 13. Acidification (AP)	1. Global Warming Potential (GWP) 2. Ozone Depletion Potential (ODP) 3. Photochemical Ozone Creation Potential (POCP) 4. Acidification Potential (AP) 5. Eutrophication Potential (EP) 6. Risks For The Local Environment (Qualitative) 7. Sustainable Use of Resources/Wood (Qualitative) 8. Non Renewable Primary Energy Demand (PEnren) 9. Total Primary Energy Demand and Proportion of Renewable Primary Energy (PEges) 10. Drinking Water Demand and Volume of Waste Water (Wkw) (Only use stage) 11. Space Demand (Qualitatively using indicators)	1. Abiotic depletion potential, ADP 2. Global warming potential, GWP 3. Ozone Depletion potential, ODP 4. Photochemical oxidant creation potential, POCP 5. Human Toxicity Potential, HTP 6. Freshwater Aquatic Ecotoxicity, FAETP 7. Ecotoxicity sediments 8. Terrestric Ecotoxicity Potential, TETP 9. Acidification Potential, AP 10. Eutrophication Potential, EP	Determination of the environmental impact indicators of the construction products, in accordance with EN 15804 or standard ISO 21930: 1. Abiotic depletion potential (ADP-elements) for non-fossil resources 2. Abiotic depletion potential (ADP-fossil fuels) for fossil resources 3. Acidification potential of soil and water, AP; 4. Depletion potential of the stratospheric ozone layer, ODP; 5. Global warming potential, GWP; 6. Eutrophication potential, EP;
Normalisation	Division of the impacts by the annual environmental impacts of one UK citizen, giving all categories the units of "per year"	Normalisation stage to be detailed	Shadow price per year of impact assuming 50-year lifespan	-
Weighting	for individual categories is developed by a panel representing the interest of groups	Weighting of the individual categories with the use of significance factors for criteria	Shadow price per year of impact assuming 50-year lifespan	No weighting of categories. Each is equally weighted to give a profile score.

Green building certifications focus on the properties of one building during its life span, and they have very similar assessment categories to Level(s).

4.6. The needs for reusability

The reusability requirements for building components are inherited from European Commission targets to decrease greenhouse gas emissions. Figure 3 shows the relations between European Green Deal, Circular Economy Action Plan, and Green Public Procurement. It also summarises the requirements for the building industry.

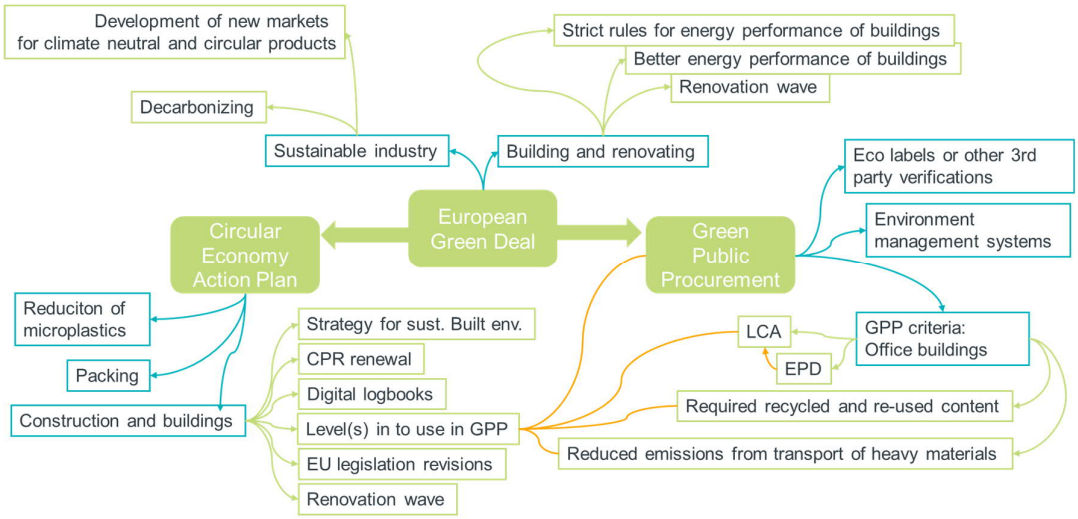


Figure 3. Relations of European Green Deal, Circular Economy Action Plan, and Green Public Procurement, and requirements for building industry.

Reusability is not only in GPP criteria where is required recycled and re-used content, but it is affecting to EPDs and also to Level(s) mentioned in Circular Economy Action Plan.

The green building certifications do not yet demand or require reusability, because the focus is on building functions and properties. However, the reuse of building components will likely be more important in the future.

5 CERTIFICATION SCHEMES REGARDING REUSABILITY

5.1. Environmental labels

Environmental labels, or ecolabels, are designed for both B2C and B2B levels. By having the label, the company can prove that their product or service is ecologically friendlier than other similar products. Usually, this is proven by third party verification. Ecolabels can be used to verify compliance with GPP criteria. (EU Ecolabel for Business n.d.).

There are several public multi-criteria ecolabels on the market that fulfils the requirements of ISO 14024: Environmental labels and declarations. Type I environmental labelling. Principles and procedures., which is the criteria in GPP for ecolabels. These labels are based on criteria set for each product group and meeting the criteria is verified by an impartial third party. These kinds of labels are for example The European Ecolabel, The Nordic Swan, and The Blue Angel. (GPP fact sheet 2008, 3).

The other type of label is the public, single-issue label that present one particular environmental issue. This kind of label is a pass/fail label or a performance-stating label. Examples of these are Energy star as a pass/fail label and the EU energy label that shows the energy efficiency by grades from G to A++. The third type of label is the private label managed by different industries, for example, forestry certification such as the FSC. (GPP fact sheet 2008, 4).

The public labels currently have a limited number of criteria for construction products. Criteria are available for floor coverings, wood, and paints. The criteria for the EU Ecolabel for wood-, cork-, and bamboo floor covering (Commission Decision (EU) 2017/176) include the following: product description, materials, general requirements for hazardous substances and mixtures, specific substance requirements (VOC, etc.), the energy consumption of the production process, emissions of formaldehyde from the floor coverings and the core board, fitness for use, reparability and extended guarantee,

consumer information, and information appearing on the EU Ecolabel. (Commission Decision (EU) 2017/176 2017).

Nordic Swan has criteria to label the whole building. The criteria focus on the total life span of the building, including the energy efficiency of the building (e.g. household appliances), waste management, indoor environment, construction materials, chemical products, quality management of construction process, and maintenance instructions for users. (Nordic Ecolabelling for buildings 2016).

Thus, ecolabels offer information about the ecological properties and safety of products or services, but they do not take into account the reusability. Moreover, the criteria exist primarily for single products in the field of construction products or then for the whole building itself.

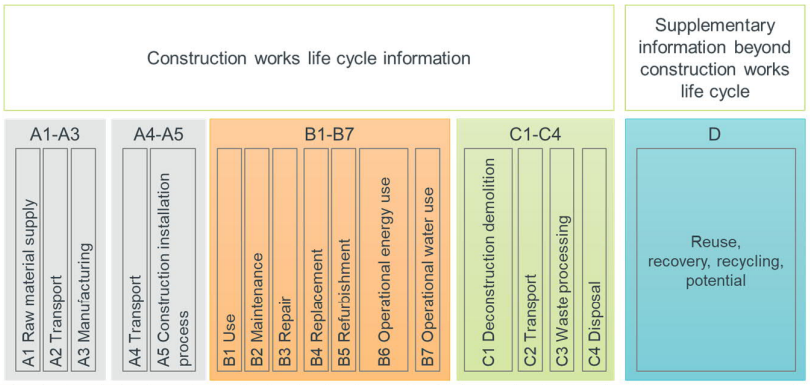
5.2. Environmental Product Declarations

The Environmental Product Declarations (EPDs), are life cycle assessments for products. They offer a standardised description of the environmental impact of the product during its lifespan, which enables communication about the environmental properties and comparison of similar materials, products, components, and even building types in the whole building LCA. To be able to compare different EPDs, they need to follow the same Product Category Rules, PCRs. The PCR defines the scope of the EPD, methodology, data, and indicators used in calculations. For the construction products used in Europe, the PCR is presented in standard EN 15804: Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products. Although there is the standard EN 15804, countries might have their own additional requirements defined in national PCR protocols. These additional requirements are usually in line with the EN 15804, but make the comparison of EPDs more challenging. (Dodd, Garbarino & Gama 2016b, 55–57).

EPDs are usually drawn up by product manufacturers for a single product or group of products, but also industry average EPDs exist. EPDs can also be project-specific when the product is not standard product fitting to a construction

project, such as concrete columns and DELTABEAM® Slim Floor Structure. The EPD creation process starts with defining the type of EPD, collecting the data, and conducting the LCA. The next step is to create the background report where the details and assumptions are explained. Before publishing, the EPD needs to be verified by a third party. EPDs are published in databases that are usually maintained by national program operators and often on manufacturer web sites. National program operators are also setting up national PCRs. Currently, there is no single database that includes all EPDs. The EPD is valid for five years unless major changes occur, for example, in production. (Bionova 2020, 14–16, 19).

The two main types of EPDs are cradle-to-gate and cradle-to-grave. The cradle-to-gate describes what happens before the product leaves from the manufacturer's premises. That is the very minimum scope for EPD and, according to EN 15408, it should include also module D. The cradle-to-grave includes everything from the manufacturing, installation, usage, and demolition of the product. The different EPD types are shown in Figure 4 with modules included.



	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Cradle to gate with C1-C4 and D	M	M	M										M	M	M	M	M
Cradle to gate with options,C1-C4 and D	M	M	M	O	O	O	O	O	O	O	O	O	M	M	M	M	M
Cradle to grave with D	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Cradle to gate	M	M	M														
Cradle to gate with options	M	M	M	O	O												

Figure 4. Types of EPDs and their content. (EN 15804 modified).

The EPD is divided into life cycle stages and modules. The product stage includes modules A1-A3, which includes all raw materials, products, and energy

needed to manufacture the construction product. The construction process stage, modules A4 and A5, includes the transportation to the site and installation. The usage stage with modules B1 to B7 describes the environmental impacts of the product during the building life span. The environmental impacts related to actions when the product life span ends are described in modules C1-C4 in the End-of-life stage. Module D includes reuse, recovery, and recycling potential to show the benefits and loads after the life span of the building ends, but the product life span could be longer. (ISO 15804 2012).

The data collected for different modules is based on historical data. For example, the data for the production stage includes detailed information about the individual raw materials and their compounds, how far those are transported, the resources needed for manufacturing (electricity, water, etc.), emissions, and waste generated during manufacturing. Based on this, data will be generated on the environmental impacts for different categories defined in the PCR. The environmental impacts are expressed as indicators to show the potential to cause such impact (e.g. global warming potential). There are several software available for the calculation of the impacts and creating LCA documentation. (Bionova 2020, 19–20)

Module D is independent of other module calculations and it usually describes scenarios that could occur after the life span of the product ends. As an example, the EPD of painted DELTABEAM® Green (Peikko 2020) considers the recycled scrap that replaces virgin steel in steel profile production (see Table 3).

Table 3. Environmental impacts of painted DELTABEAM® Green (Peikko 2020).

Environmental impact								
Parameter	**Unit**	**A1-A3**	**A4**	**C1**	**C2**	**C3**	**C4**	**D**
Global warming potential	kg CO2 -eqv	1,21E+0	1,70E-2	3,34E-3	8,29E-3	8,07E-2	0E0	-5,79E-3
Depletion of stratospheric ozone layer	kg CFC11-eqv	1,55E-7	2,05E-9	5,99E-10	1,71E-9	1,45E-8	0E0	-2,93E-10
Formation of photochemical ozone	kg C2H4 -eqv	3,70E-4	4,86E-6	6,66E-7	1,27E-6	1,61E-5	0E0	-4,04E-6
Acidification	kg SO2 -eqv	4,96E-3	2,37E-4	2,52E-5	2,11E-5	6,08E-4	0E0	-2,33E-5
Eutrophication	kg PO4 3--eqv	6,70E-4	1,45E-4	5,41E-6	2,91E-6	1,31E-4	0E0	-2,45E-6
Abiotic depletion of non fossil resources	kg Sb-eqv	6,47E-6	3,43E-7	2,24E-9	5,38E-8	5,43E-8	0E0	-7,62E-9
Abiotic depletion of fossil resources	MJ	1,89E+1	2,09E-1	4,78E-2	1,36E-1	1,16E+0	0E0	-7,71E-2

5.3. Carbon handprint

The Finnish Ministry of the Environment has published a method for the whole life carbon assessment of buildings (2019). The method includes both carbon footprint and handprint analyses. It is based on the Level(s) framework, sustainable construction standards, and scientific research. The handprint analysis takes into account the climate benefits when building parts and components are reused or recycled, renewable energy is produced in the building or the site, and biogenic carbon may be bound to construction materials during the building life cycle. The handprint calculation is separate from the footprint and it is not deducted from the carbon footprint. The benefit of the carbon handprint arises when, for example, the component is reused in another building by reducing the carbon footprint of that building. (Webinar held by Finnish Ministry of the Environment 30 November 2020).

5.4. CE marking

The basic principles of CE marking are described in chapter 2.1 Construction Product Regulation and CE marking. As mentioned in that chapter, CE marking is based on either the harmonised standard (hEN) or European Technical Assessment (ETA). Both of these show performance characteristics that affect the ability of construction products to meet the basic requirements set out in the CPR. The current CPR does not have the basic requirement that includes

reusability characteristics of construction products and, therefore, does not support the CE marking for reuse case.

At least one ETA exists for reuse case: recycled clay masonry units, ETA-17/0648. It describes the properties of reused clay masonry units that are used for self-supporting load transferring structures, such as partition walls or linings. The ETA declares the safety in case of fire and some properties in hygiene, health, and environment requirements, such as dimensions, density, and freeze/thaw resistance. There can be a discussion, is the EAD behind this ETA formulated correctly to fulfil the intent of CPR. (ETA-17/0648 2017).

5.5. Voluntary certification

There are two ways to have voluntary certification for the reuse of construction products. At the moment, there are no technical criteria for reuse certification, so criteria need to be formulated. Certification can be attained via two ways: using the existing ISO or EN standard to create a declaration, or statement, verified by a third party; or by creating national criteria with some local construction association (e.g. Finnish Concrete Association) that can also verify the certification.

In both cases, the manufacturer needs to have an intense discussion with the third party. This requires a good relationship, partnership, and understanding from the third party regarding what is looked for from the certificate or statement. The choice of certification depends on the manufacturer’s needs. Generally, can be said that a national certificate applies only in that particular country. The statement based on ISO or EN standard can also be applicable in other countries (e.g. EN standard-based statement could be accepted widely in Europe). The professional recognition of the third party affects how well the certificate or statement could be accepted.

6 INTERVIEWS

Interviews were made as unstructured interviews due to fact that the reusability of construction products on a large scale is a new topic for the construction industry. Interviews started with a short presentation of participants and a Peikko company presentation, when needed, and continued with a short introduction to the topic. The introduction included the findings of the background study and what Peikko-solution enables reuse (Yrjölä, 2020). The interview consisted of open questions related to EPDs, reuse of construction products, certification of reuse, and renewal of the Finnish Building and Land use Act (132/1999) at a general level. Moreover, other topics were addressed at the opinion level during the discussion related to the original topic.

The interviewees were selected based on their expertise about the topic and they were found among Peikko contacts, the thesis writer's own contacts, or on the recommendation of other interviewees. Due to fact that reusability is such a new topic, the number of interviews was limited. After interviewing six persons, it became evident that no new information would be gained from more interviews. Interview results are summarized in the following chapters as anonymous, which ensured that all interviewees could discuss and present information in an open atmosphere.

The recorded interviews were made with the following persons:

- Sustainability Manager, construction product manufacturing
- Senior Sustainability Specialist, sustainability organization
- CEO, precaster
- CEO, industry organization
- Researcher, university
- Technology Manager, design office

Moreover, discussions took place without recording and official interview status with following interviewees to have more information about certification possibilities:

- Global Service Sales and Head of Sustainability Services, certification body
- Certification body
- Sustainability company
- Master thesis worker, precast elements

6.1. Environmental Product Declarations

The EPDs were seen as beneficial for products by many of the interviewees (Sustainability Manager, Senior Sustainability Specialist, CEO precaster, CEO industry organization, Technology Manager). The database of EPDs was discussed with Sustainability Manager and CEO of the industry organization. The Sustainability Manager's company publishes its EPDs in different databases because their customers are all around the world and one database does not serve them all. The CEO of the industry organization mentioned that some construction product manufacturers use a Norwegian operator for their EPDs because they feel that Finnish RTS has strange rules in their national PCRs. It was also mentioned that a comparison of EPDs of the same type of materials is not possible and the only way is to compare those on the building level (Sustainability Manager). The CEO of the industry organization mentioned that the Confederation of Finnish Construction Industries RT (CFCI) will publish generic EPDs for concrete structures.

The role of module D in EPDs raised questions of how it benefits LCA calculations. The conclusion was that it does not, but it offers one scenario of what could happen, and it is basically only written information (Technology Manager). According to the Sustainability Manager, customers are looking for information from module D.

Saint-Gobain Finland has made a comparative study of partition walls' life span between walls made with their products and generic products (Saint-Gobain 2020). According to the Sustainability Manager, this could be a good marketing tool and way to share information about EPDs. The study could also be eye-opening study internally what the EPDs include and how products can be

compared to other similar products. The Sustainability Manager recommended this kind of approach to show the benefits for customers and internally.

The EPD standard and PCR development are ongoing and some new documents will be released in the coming years, the first in 2021. This is a definitely developing area. (Technology Manager, Senior Sustainability Specialist).

There was also criticism of the EPD system in general. The discussion centred on the national PCRs, reliability of EPDs, generic data in LCA tools, and LCA focus on building life span instead of considering the construction products life span (CEO precaster, CEO of the industry organization).

6.2. Certification schemes

The discussion about ecolabels reached the same conclusions found in the background study: construction products are not included (except some single products). According to the Senior Sustainability Specialist, Nordic Swan includes some reusability items and manufacturer can receive an EU Ecolabel.

CE marking was seen as beneficial and reusability should be in it as declared property. It was noted that current CPR does not support this. The renewal of CPR can take 5-10 years, or even longer. (Sustainability Manager, Senior Sustainability Specialist, CEO of the industry organization, Technology Manager).

The third party verification for reuse was seen as vital or highly recommended by all interviewees. They were not able to say what it exactly should contain. Nevertheless, verification would provide trust and the feeling of a safer choice – also ‘street credibility’ (CEO precaster). The Technology Manager stated that structural designers will rebel against products that do not have product approval or certification in general. Reusable products must find a way to include information about where it comes from, what it contains, and other relevant data (CEO of the industry organization). CEO of the industry organization also listed that the product should have information about the

dangerous substances, or all materials and compounds used because we do not know now what may be regarded as dangerous after 20 years.

6.3. Customers and authorities

The renewal of the Finnish Building and Land use Act (132/1999) was discussed with many interviewees. They predicted that it would be in force in the coming years and including CO_2 limits for building types. It is now in the pilot phase. The general opinion was that it will enforce the reuse of construction products in the future. (Sustainability Manager, Senior Sustainability Specialist, Researcher, CEO industry organization).

The CEO precaster mentioned that they already have customers that have projects with reuse of concrete elements. Furthermore, the Technology Manager mentioned that they have customers that would like to reuse components such as frames and not only recycle them. According to the Researcher, there is a drive to do this, especially when the practical issues have been solved. Moreover, reuse is a necessity when the usage of virgin materials is impossible or too expensive.

The practical issues were discussed further with CEO of the industry organization: what kind of buildings are worth designing with reusable components and how about the design itself. The conclusion was that reuse of buildings is most suited to commercial buildings. There is no sense trying to design reusable building if that is not reality, for example, in the case of a block of flats: if it is designed for reuse, it will never be built at all. The design itself has challenges related to design norm competence in long-term life span – is the design still valid after 20 or 50 years? Additionally, what would be required to verify to that the original properties are still valid – tests, extra safety factors during design or reuse, something else?

The data management of the construction component is in a key role to enable the reuse (Researcher, CEO of the industry organization). According to the CEO of the industry organization, CFCI has a project to develop the

digitalization in a way that the product information could flow to digital twin of building without human hands. It could be that the digital twin is the only way to store the data because all extra labels and materials will be removed from the construction product before the installation. The digital twin would require some kind of product or component passport. (Researcher, Technology Manager).

6.4. General comments

Many of the interviewees mentioned the confrontation between wood against steel and concrete when the sustainability and LCA of the buildings are discussed and compared. They felt that the politics affect general discussion without the support of real data and, therefore, wood is favoured. The building material producers are made guilty because the climate effect, reduction of CO_2, needs to be reached now and not after 30 years. Not everything can be built from wood, or even from steel. The construction companies would like to use concrete and steel structures because building with those is faster and safer due to known details and fire safety. (Sustainability Manager, CEO of the industry organization, CEO precaster).

There is a positive aspect: The concrete and cement industry is awake and innovations are coming. Furthermore, the Finnish Concrete Association has a workgroup that is developing carbon sequestration agents. (Sustainability Manager, CEO precaster).

7 DISCUSSION

This thesis aimed to answer the question of what kind of proof should be provided for structural designers and other interested parties to make reusability real. This question was studied by interviews and a background study that addressed where the reusability requirement comes from and what the common procedures are for verifying construction products fit for use.

The certification of construction products has long been mandatory by regulations. The customers of construction product manufacturers require, and demand proof of fit verified by a third party. This was evident in the interviews and there is a similar requirement for reuse. The issue in the certification of reuse is that there is no ready certification scheme available. The currently available certifications focus either on building life span (BREAAM, LCA calculations) or the environmental properties of consumer products (EU Ecolabel, Nordic Swan). These certifications are not able, at the moment, to take into account the reusability and properties of products in that case. If a construction product manufacturer would like to have a certificate for their product(s), the only way to create such a document is together with a third party.

The following chapters present the general challenges of the reuse of construction products and how Peikko could solve the certification need. The last chapter considers the possible future steps in the construction sector and what Peikko could do.

7.1. Challenges of reuse of construction products

The VTT Technical Research Centre of Finland and Tampere University of Technology compiled a publication, the Reuse of structural elements, Environmentally efficient recovery of building components (2014) where they detected several challenges for reuse:

- lack of verification of strength properties of load-bearing components
- deconstruction of existing buildings is difficult and labour intensive

- lack of design for deconstruction

In addition to these, interviewees mentioned (CEO of the industry organization, Sustainability Manager, 2020) the following:

- the hazardous substances in materials
- design norms adaptability for reuse
- historical data about environmental conditions where the component has been
- how to verify the quality of the product or its fitness for use.

Additional practical issues were discussed in the interviews, such as the lack of marketplace for building components and lack of companies in the business. Moreover, the importance of product data attached to the component was highlighted and whether it is in digital or some other form.

The market for reused building components is so new that basic conditions and practices are missing. This can be solved by step-by-step approach and working together, combining expertise from different parties of construction. Forming the practices will take years before reuse is everyday work. The speed will be gained latest when legislation forces the construction sector to actions.

7.2. Voluntary certification for Peikko products and other proposals

While there are several practical issues to be solved on a larger scale, Peikko could take one step forward by offering a verified reuse-package for customers. They could co-operate with the certification body to make third party verified confirmation regarding reuse. The confirmation could be based on documentation of Peikko product and standard ISO 20887 Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance (2020). With this package, Peikko could offer needed information for structural designers about reuse possibilities and give ready documentation to be attached to the digital twin of the building. The referring to ISO standard should also enable the use of confirmation all around Europe and beyond.

The standard ISO 20887 (2020) describes principles of design for disassembly (DfD) and design for adaptability (DfA). It also has potential strategies how to integrate these into the design process. It offers a framework for the project and provides information for different building process parties (owners, architects, engineers, designers, and manufacturers) to understand the potential of DfD/A including different options and considerations.

Standard (ISO 20887, 2020) describes the design for adaptability principles as follows:

- versatility: adapt different functions with minor changes
- convertibility: adapt changes like changing office to residential building
- expandability: the ability of design or system to reform a new space (e.g. vertical or horizontal expansion of floor space).

The design for disassembly principles are described as:

- ease of access to components and services
- independence (systems to be removed or upgraded without affecting the performance of connected or adjacent systems, reversible connections)
- avoidance of unnecessary treatments and finishes
- supporting re-use (circular economy) business models (reusability, refurbishability, remanufacturability, increased recycling, future recycling)
- simplicity
- standardization
- safety of disassembly

To enable the described principles, standard lists actions for designers and product manufacturers. These are related to design details, material constituents, connection details, data digitalisation, information transfer, and management. From the manufacturer's point of view, important documents and information to offer for the project are design principles of product, raw material information, disassembly instructions, contact information, product identification, and possible EPDs. (ISO 20887 2020).

Figure 5 illustrates a simplified way the data flow in the building process when reuse is included in the Peikko point of view.

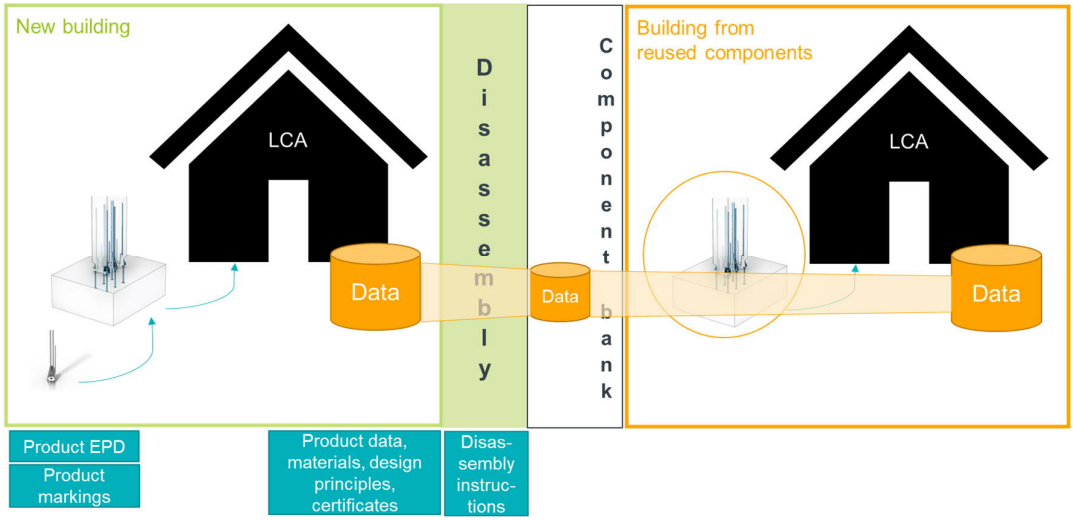


Figure 5. The data flow in the building process when reuse is included in the Peikko point of view.

Peikko has created EPD's for their main product categories and that should be continued to an even more detailed level, meaning product family level. This way they are ready to help customers in current sustainability design problems. The third party verification would support the reuse and make customers understand better the benefits of Peikko products. Peikko as an international company could take part in the development of reuse design practices by participating in the standardization development and common discussion in all markets. That would strengthen the forerunner image.

7.3. Future steps in the reuse of construction products

As mentioned several times already, the reuse of construction components is a new topic on a larger scale for the construction industry. There is a need for development and co-work to solve and find practical solutions for the issues. The sector needs at least to develop and solve the following issues:

Design principles for new products to be reused later. This could include the development of design norms, guidelines, and not, at least, gaining experience from pilots.

Design principles for already used products. The current buildings in use have huge potential to be reused at the building level or the construction component level. Enabling this would require similar actions than for reuse design principles for new products.

Digitalization. To make reuse, and circularity in over all possible, the digitalization of building data needs to be developed. This would include not only the construction phase but also the usage, maintenance, repair, and end-of-life information. The data could be the digital twin of the building to store the structural information and database to store the usage information (e.g. energy consumption), usage changes, and made repairs at a detailed level.

Roles regarding data. At the moment, it is not defined who is responsible for storing and maintain the data of construction components. These should be clarified by agreements.

Component fit for use. In the interviews, arose that there should be a procedure to verify the components fit for use in the reuse case. This would mean, in practice, some kind of check where the construction component has been (environment), fit of products in the component, availability of related structural data, and repair history.

Reuse of construction components offers many new business opportunities. These could be for existing companies in the construction industry or new companies:

- Component refurbishing to make “face-lift” for used products without improving or fixing structural properties.
- Remanufacturing to make the component “as new” condition for resale. This could include the repairs for structural properties.
- Disassembly services. There are already companies doing this, but in the future, the need will increase.
- Component and product marketplaces.
- Verification services to check the component fit for use, for example, non-destructive testing, comparison of digital and real-life components, searching missing data.

In conclusion, can be said that there is much to do until the reuse of construction components is a reality. It will realize, but not in near future due to fact that fundamental practices, guidelines, and business infrastructure are missing.

REFERENCES

2030 Climate Target Plan. n.d. European Commission. Read 2.1.2021. https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en

Ajankohtaiskatsaus rakennusten vähähiilisyyden arviointimenetelmästä – webinar 30th November 2020. The Finnish Ministry of the Environment.

Bionova, 2020. How to make an Environmental Product Declaration And how it helps your business, A Guide for Construction Product Manufacturers. E-book. Read 30.12.2020. https://www.oneclicklca.com/ebook-epd-how-to-make-environmental-product-declaration/

Building and Renovation fact sheet, December 2019. European Commission. Read 7.1.2021. https://ec.europa.eu/commission/presscorner/api/files/attachment/859198/Building_and_Renovating_en.pdf.pdf

Buying green! A handbook on green public procurement, 3rd Edition. European Commission. Read 7.1.2021. https://ec.europa.eu/environment/gpp/buying_handbook_en.htm

Circular Economy Action Plan fact sheet, March 2020. European Commission. Read 7.1.2021 https://ec.europa.eu/commission/presscorner/api/files/attachment/863182/EU_Greendeal_Circular_economy_en.pdf.pdf

Circular Economy Action Plan, For a cleaner and more competitive Europe. Read 7.1.2021. https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf

COMMISSION DECISION (EU) 2017/176 EU Ecolabel criteria for wood-, cork- and bamboo-based floor coverings. Official Journal of the European Union L28/44. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2017.028.01.0044.01.ENG&toc=OJ:L:2017:028:TOC

Communication European Green Deal. COM(2019) 640.11.12.2019. Read 7.1.2021 https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588580774040&uri=CELEX:52019DC0640

Communication Public procurement for a better environment (COM (2008) 400). European Commission. Read 7.1.2021. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52008DC0400

Construction Product Regulation No 305/2011, Official Journal of the European Union, 9.11.2011. Read 7.1.2021 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011R0305

Dodd N.& Garbarino E. & Gama Caldas M. 2016a. Green Public Procurement Criteria for Office Building Design, Construction and Management. Procurement practice guidance document; EUR 28006 EN; doi: 10.2791/858761

Dodd,N.& Garbarino,E.& Gama Caldas,M. 2016b. Green Public Procurement Criteria for Office Building Design, Construction and Management. Technical background report and final criteria; EUR 27916 EN; doi:10.2791/28566. P. 55-56

Dodd,N.& Donatello,S. & Cordella.M. 2020a. Level(s) – A common EU framework of core sustainability indicators for office and residential buildings, User Manual 1: Introduction to the Level(s) common framework (publication version 1.0);

Dodd,N.& Donatello,S. & Cordella.M. 2020b. Level(s) indicator 2.4: Design for deconstruction, User manual: overview, instructions and guidance (Publication version 1.0)

Eliminating Pollution fact sheet, December 2019. European Commission. Read 7.1.2021. https://ec.europa.eu/commission/presscorner/api/files/attachment/860249/Eliminating_Pollution_en.pdf.pdf

ETA-Denmark A/S. 2018. European Technical Assessment ETA-17/0648: Recycled clay masonry units, 6.9.2018. Read 30.12.2020. http://x.etadanmark.dk/danish/eta/pdf/Assessment/ETA170648%20GM%20Reused%20bricks%20r2%202018.pdf

European Commission, Climate strategies & targets n.d. Read 11.01.2021. https://ec.europa.eu/clima/policies/strategies/2050_en

European Commission, EU Ecolabel for Business. n.d. Read 11.01.2021. https://ec.europa.eu/environment/ecolabel/eu-ecolabel-for-businesses.html

European Commission. Level(s) web site. Read 31.12.2020. https://ec.europa.eu/environment/topics/circular-economy/levels_en

German Green Building Council's (DGNB).2020. Ease of recovery and recycling TEC 1.6. Version 2020 International. Read 29.12.2020. https://static.dgnb.de/fileadmin/dgnb-system/en/buildings/new-construction/criteria/05_TEC1.6_Ease-of-recovery-and-recycling.pdf

Green Public Procurement and the European Ecolabel fact sheet. GPP Training Toolkit: Module 1 – Managing GPP Implementation. European Commission. 2008. Read 7.1.2021. https://ec.europa.eu/environment/gpp/pdf/toolkit/module1_factsheet_ecolabels.pdf

Hradil,P.& Talja, A.& Wahlström, M.& Huuhka, S.& Lahdensivu, J.& Pikkuvirta, J. 2014. Re-use of structural elements, Environmentally efficient recovery of building components. VTT Technical Research Centre of Finland and Tampere University of Technology. VTT Technology 200. Read 9.1.2021. https://www.vttresearch.com/sites/default/files/pdf/technology/2014/T200.pdf

Interviews:

CEO, industry organization. 13.11.2020, Teams meeting.

CEO, precaster. 4.10.2020, Teams meeting.

Global Service Sales. Teams meetings on 29.10 2020 and 17.11.2020

Head of Sustainability Services. Teams meetings on 17.11.2020 and 16.12.2020.

Researcher. 25.11.2020, Teams meeting.

Senior Sustainability Specialist, 4.10.2020, Teams meeting.

Sustainability Manager, 4.10.2020, Teams meeting.

Technology Manager. 23.11.2020, Teams meeting

ISO 20400:2017 Sustainable procurement – Guidance. ISO. Read 30.1.2021 Requires access rights. https://online.sfs.fi/fi/index.html.stx

ISO 20887:2020 Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance. ISO. Read on 13.10.2020. Requires access rights. https://online.sfs.fi/fi/index.html.stx

Ministry of the Environment. n.d. Finland's national climate change policy. Read 11.01.2021. https://ym.fi/en/finland-s-national-climate-change-policy

Ministry of the Environment. 2019. Method for the whole life carbon assessment of buildings. 20.9.2019. Read 20.12.2020. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161796/YM_2019_23_Method_for_the_whole_life_carbon_assessment_of_buildings.pdf?sequence=1&isAllowed=y

Nordic Ecolabelling. 2016. Nordic Ecolabelling for Small houses, apartment buildings and buildings for schools and pre-schools, Version 3.11 • 09 March 2016 – 31 December 2022. Read 29.12.2020. https://joutsenmerkki.fi/wp-content/uploads/2017/03/089e_3_11_CD.pdf

Ojasalo, K & Moilanen, T & Riihilahti J. 2015. Kehittämistyön menetelmät : uudenlaista osaamista liiketoimintaan . 3.-4. painos. Helsinki: Sanoma Pro Oy.

Peikko. 2020. RTS EPD, No. RTS_61_20 DELTABEAM® Green, Painted. Read 30.12.2020 https://d76yt12idvq5b.cloudfront.net/file/dl/i/T70Iog/WQUQpeYZR-CYO3ErtDoBqw/RTS-EPD_61-20_PeikkoGroup_Painted_GreenDELTABEAM.pdf

Refined Indicative Options for the Review of the Construction Products Regulation, version 2 – 08.04.2020. European Commission. Read 7.1.2021 https://ec.europa.eu/docsroom/documents/40762/attachments/1/translations/en/renditions/native

Saint-Gobain Finland Oy. 2020. SAINT GOBAIN GYPROC VÄLISEINIEN ELINKAARIVAIKUTUKSET JA VERTAILU VAIHTOEHTOISIIN KIPSIVÄLISEINIIN, Elinkaaren hiilijalanjäljen arviointi (EN 15978). 30.6.2020. Read 6.1.2020. https://www.saint-gobain.fi/sites/saint-gobain.fi/files/media-library/Finland/LCA_Gypsteel_ter%C3%A4srangat_30June2020.pdf

SFS-EN 15804:2012 + A2:2019:en. Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products. Helsinki: Suomen Standardisoimisliitto SFS. Read on 23.12.2020. Requires access rights. https://online.sfs.fi/fi/index.html.stx

Smith, Paul. 2016. Structural Design of Buildings. Hoboken: John Wiley & Sons, Incorporated.

Sustainable Industry fact sheet, December 2019. European Commission. Read 7.1.2021. https://ec.europa.eu/commission/presscorner/api/files/attachment/859442/Sustainable_industry_en.pdf.pdf

SWD(2016) 180 Commission staff working document EU GPP Criteria for Office Building Design, Construction and Management. European Commission. 2016. Read 7.1.2021. https://ec.europa.eu/environment/gpp/pdf/swd_2016_180.pdf

Yrjölä, Jaakko. 2020. Peikko white paper, Bolted Connections for Precast Structures, Enabling Circularity without Compromising Performance. Peikko Group Corporation, 2020. Read 6.1.2021. https://d76yt12idvq5b.cloudfront.net/file/dl/i/YuEX4A/4j9tXYpFDhCL0tqlztJY7w/PeikkoWhitePaper_Boltedconnectionsforprecaststructuresenablingcircularitywithoutcompromisingperformance