YRKESHÖGSKOLAN NOVIA

Implementation of Environmental Product Declarations into the Design Process

A Case Study of Steel and Concrete Structures using Tekla Structures

Michelle Österblad

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BACHELOR'S THESIS

Author:	Michelle Österblad
Degree Programme and place:	Construction and Civil Engineering, Vaasa
Specialization:	Structural Engineering
Supervisors:	Anders Borg, Novia Dan Pada, Nordec Oy

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Abstract

This thesis has been conducted on behalf of Nordec Oy to investigate the possibilities of implementing Environmental Product Declarations (EPDs) into their design process for steel and concrete. With new legislations coming into effect, companies will be required to declare the environmental impact of their products, which can be facilitated through EPDs. Consequently, the need to seamlessly integrate relevant information into the design process has increased to streamline the declaration process and enhance accessibility of the information. The aim was to develop a user-friendly system for integrating EPDs within the design process for all parties involved in the project process.

The thesis includes a theoretical exploration of EPDs, presenting the concept, benefits, life cycle phases, and creation of declarations. Furthermore, the thesis provides an overview of general legislation and standards regarding EPDs, along with a comparative analysis of Nordic countries' regulatory frameworks on the subject.

Through discussion and feedback from experts in the field, an alternative integration system has been developed. This system has subsequently been implemented in the Tekla Structures program, accompanied by a step-by-step description. The results include sample drawings for steel and concrete, which have been created using the system, to demonstrate the application of the system. The system's effectiveness and usability are finally analyzed in the results and discussion chapters of the thesis.

Language: English
Key words: Environmental Product Declaration, Tekla Structures, BIM

EXAMENSARBETE

Författare:	Michelle Österblad
Utbildning och ort:	Byggnads- och samhällsteknik, Vasa
Inriktning:	Konstruktionsteknik
Handledare:	Anders Borg, Novia
	Dan Pada, Nordec Oy

Titel: Implementering av miljövarudeklarationer i designprocessen

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Abstrakt

Detta examensarbete har genomförts på beställning av Nordec Oy för att undersöka möjligheterna att implementera miljövarudeklarationer (EPD:er) i deras designprocess för stål och betong. Med nya lagar som träder i kraft blir företag skyldiga att deklarera miljöpåverkan av deras produkter, vilket kan underlättas genom EPD:er. Följaktligen har behovet av att integrera relevant information i designprocessen ökat för att effektivisera deklarationsprocessen och förbättra tillgängligheten av informationen. Målet med arbetet var att utveckla ett användarvänligt system för att integrera EPD:er i designprocessen för alla parter som är involverade i projektprocessen.

Arbetet inkluderar en teoretisk utforskning av EPD:er, varpå konceptet, fördelarna, livscykelstadierna och skapandet av deklarationerna presenteras. Dessutom ger avhandlingen en översikt över allmän lagstiftning och standarder gällande EPD:er, samt en jämförande analys av de nordiska ländernas regelverk gällande ämnet.

Genom diskussion och återkoppling från experter inom området har ett alternativt integreringssystem utvecklats. Detta system har därefter implementerats i Tekla Structures, tillsammans med en steg för steg beskrivning. Resultaten inkluderar exempelritningar för stål och betong, skapade med systemet för att visa tillämpningen. Systemets effektivitet och användarvänlighet analyseras slutligen i resultat- och diskussionskapitlen av examensarbetet.

Språk: engelska
Nyckelord: miljövarudeklarationer, Tekla Structures, BIM

OPINNÄYTETYÖ

Tekijä:	Michelle Österblad
Koulutus ja paikkakunta:	Rakennus- ja yhdyskuntatekniikka, Vaasa
Suuntautumisvaihtoehto:	Rakennussuunnittelu
Ohjaajat:	Anders Borg, Novia
	Dan Pada, Nordec Oy

Nimike: Ympäristötuotteen julistusten käyttöönotto suunnitteluprosessiin

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Tiivistelmä

Tämä opinnäytetyö on suoritettu Nordec Oy:n toimeksiannosta ja on tutkittu mahdollisuuksia ottaa käyttöön ympäristötuotetiedot (EPD) yrityksen teräksen ja betonin suunnitteluprosessiin. Uusien lakien astuessa voimaan yrityksillä on velvollisuus ilmoittaa tuotteidensa ympäristövaikutuksista, mikä voi helpottua EPD:ien avulla. Näin ollen tarve integroida relevanttia tietoa suunnitteluprosessiin on lisääntynyt deklarointiprosessin tehostamiseksi ja saatavuuden parantamiseksi. Työn tavoitteena oli kehittää käyttäjäystävällinen järjestelmä EPD:ien integroimiseksi suunnitteluprosessiin kaikille projektin osapuolille.

Työhön sisältyy teoreettinen tutkimus EPD:istä, jossa käsitellään käsitettä, etuja, elinkaaren vaiheita ja deklaraatioiden luomista. Lisäksi työssä esitellään yleistä lainsäädäntöä ja standardeja EPD:ien osalta sekä vertaileva analyysi Pohjoismaiden sääntelykehyksistä aiheeseen liittyen.

Keskustelujen ja alan asiantuntijoiden palautteen perusteella on kehitetty vaihtoehtoinen integraatiosysteemi. Järjestelemästä on tehty yksityiskohtainen käyttöohje ja järjestelmä on otettu käyttöön Tekla Structures-ohjelmistossa. Tuloksiin sisältyvät teräksen ja betonin esimerkkipiirustukset, jotka on luotu järjestelmää käyttäen sen soveltuvuuden osoittamiseksi. Järjestelmän tehokkuutta ja käytettävyyttä analysoidaan lopulta opinnäytetyön tulosten ja keskustelun luvuissa.

Kieli: englanti
Avainsanat: ympäristötuotetiedot, Tekla Structures, BIM

Table of content

Terminology

EPD	Environmental Product Declaration, which is a standardized way of quantifying the environmental impact of a product or service over its lifetime. (One Click LCA, n.db).
LCA	Life Cycle Assessment, a method used to analyze the environmental impact of a product or a service throughout its entire life cycle. (Quist, n.d.).
PCR	Product Category Rules, which provide guidelines and requirements for how to develop an EPD for a specific product category, as defined by the relevant program operator. (One Click LCA, 2020).
BREEAM	Building Research Establishment’s Environmental Assessment Method, an environmental certification system developed in the UK in 1990. (Brem, Cusack, Adrita, O'Sullivan, & Bruton, 2020).
LEED	Leadership in Energy & Environmental Design, an environmental certification system developed by the Green Building Council in the U.S. in 1998. (Brem, Cusack, Adrita, O'Sullivan, & Bruton, 2020).
GWP	Global Warming Potential, a measure of the ability of a greenhouse gas to contribute to global warming over a specific period. (Boverket, n.dd).
GHG	Greenhouse gas, which are gases that permit shortwave solar radiation to enter the Earth’s atmosphere while absorbing segments of the planet’s thermal radiation. (Boverket, n.dd).
Tekla	Tekla Structures, a software 3D application mostly used in the structural design and engineering industry to create, manage, and analyze detailed 3D models of buildings and structures. (Trimble, n.d.).
BIM	Building Information Modelling, which involves the creation and management of information for a built asset. (Autodesk, n.d.).

1 INTRODUCTION

The environmental requirements for the building industry are becoming stricter all the time and are expected to become mandatory in several countries, including the Nordic countries (One Click LCA, 2022, p.12; Lavikka, et al., 2023, p. 9). Not only must companies meet the requirements of different standards and regulations, but customers also want their buildings to be more environmentally friendly.

The client for this thesis is looking for a system for implementation of Environmental Product Declarations (EPDs), into their design process. Furthermore, they aim to develop a guide that can be used by external designers, explaining the system and how it should be utilized while working for the company. The goal of the thesis is to develop a seamless system that meets the needs and desires of all stakeholders involved in projects.

1.1 Nordec Oy

The client for the thesis is Nordec Oy. Nordec was created in 2020 when Ruukki Building Systems Oy and Normek Oy merged. The name of the company refers, among other things, to the company’s high expertise in design, engineering, and construction. Today Nordec is one of the leading providers of frame structures for buildings, facades, and steel bridges in the Nordic countries with over 600 employees in six different countries.

The company is divided into three main organizations, each specializing in different areas. The organizations are: Single-Storey, which specializes on the structural design of single-story buildings; Multi-Storey, which focuses on the structural design of multi-story buildings; and Heavy Industry and Bridges, which focuses on bridges and industrial buildings. Additionally, there is an organization called Central Eastern Europe (CEE), which deals with operations in Central and Eastern Europe.

Nordec has four different production units each specializing in certain types of steel structures, enabling the company to maintain product quality and efficient production processes. Two of these units are situated in Finland, one in Poland and one in Lithuania. (Nordec, n.d.)

1.2 Background

Buildings are currently responsible for 39 % of the world's annual CO_2 emissions, and the building environment sector has a vital role to play in responding to the climate emergency (World Green Building Council, n.d.). With new regulations soon to take effect, companies must declare the environmental impacts of their products and the materials used in their buildings.

In order to declare the environmental impacts of products, EPDs can be used. The intention of this thesis is to document the necessary information related to materials and EPDs on the respective drawings and other project documentation. Documentation is essential for tracking and managing the environmental impact of the building, particularly for calculating CO_2 emissions. As the implementation of EPDs into the design process is a new and experimental topic for the client, the system developed in the thesis is regarded as an experiment that will likely evolve and improve over time.

1.3 Delimitations and methods

This thesis will primarily focus on the design process for the projects the company has won, excluding those in the tender phase. However, the intention for the future is to also implement EPDs for projects in the tender phase.

To achieve the objectives of this thesis, the following research questions were asked:

- What is an Environmental Product Declaration?
- What are the differences in legislation concerning CO_2 emissions reduction in the construction industry between Finland, Sweden, and Norway?
- Where must Environmental Product Declarations be implemented?

To be able to answer the first and the second research question, a theoretical framework was established. After gathering information about the topic, interviews could be held with experts in the field to gain deeper insights. Then the need of EPDs in the design process was clarified and the implementation process could be done.

During this investigation, only specific EPDs are considered. These are Nordec's own EPDs, EPDs for concrete from subcontractors and some EPDs for steel constructions from subcontractors. Meaning the thesis will cover steel and concrete products. The company has already developed a few own EPDs, but more are added over time. Since Nordec doesn't manufacture concrete products in their own factories they don't have own EPDs for them. Instead, EPDs from subcontractors are being used. Similarly, some steel constructions are purchased from subcontractors with their own EPDs.

The thesis investigation will take a comprehensive approach, combining literature review and interviews with professionals working in the field. For the theoretical framework standards, regulations and reports will serve as references. Additionally, tools such as One click LCA and Echochain will be frequently utilized throughout the thesis. One Click LCA is an automated life cycle assessment software used for calculating and reducing the environmental impacts of buildings, infrastructure projects, products, and portfolios (One Click LCA, n.da). While the primary focus lies on the design process, the thesis will also provide insights into project management and the sourcing practices. The implementation of EPD information will be integrated into the Tekla Structures software.

2 ENVIRONMENTAL PRODUCT DECLARATION

According to One Click LCA's eBook and Emily Lalonde's article on Echochain (One Click LCA, 2020, p. 6; Lalonde, 2023), an Environmental Product Declaration, or EPD, can be defined as a standardized and verified document that provides transparent information about the environmental impact of any product or service over its lifetime. An EPD is calculated via a life cycle assessment, also known as LCA, which considers the product from raw material extraction to waste management and recycling. While there are three different types of EPDs, the most common type covers one single product manufactured by one company. EPDs typically have a validity period of five years unless there are major changes to the production practice. An example of how an EPD is structured is presented in "*Appendix 1*", which applies to a steel truss manufactured by Nordec in their factory in Peräseinäjoki, Finland.

Reading an EPD involves understanding and analyzing the presented information. Typically, an EPD includes three main components: general information, methodology and results from the assessment. The document begins with general information about the manufacturer, the standards and program operators considered, and the product the EPD considers. This is followed by the methodology section where the method used to assess the environmental impacts of the product throughout its life cycle is outlined. This often involves a life cycle assessment associated with all stages of a product's life. The final section of an EPD presents the results of the environmental assessment conducted in the methodology stage in table format. These tables include data broken down by impact category and life cycle stage. Life cycle stages are defined in Chapter 2.3 of this thesis. (One Click LCA, 2020, p. 7; Vertotech Saint Gobain, 2019).

The overall goal of an EPD is to contribute to a more sustainable and environmentally conscious marketplace by providing accurate and comparable information about the environmental impact of products, while also meeting various communication needs (EPD International, n.d.). Additionally, there is no central EPD repository, meaning construction product EPDs are published on several different platforms (One Click LCA, 2020, p. 8).

2.1 Regulations and Standards

For industries with significant environmental impacts, such as the construction industry, it is important to comply with local laws and regulations. In a report from the Buildings Performance Institute Europe (Broer, Simjanovic, & Toht, 2022, p. 11-13) policies targeting upfront emissions for buildings are listed for The Netherlands, France, Denmark, Sweden, and Finland. The report highlights that all the mentioned countries in one way or another have established regulations or initiatives for environmental assessment of buildings with a focus on reporting and data collection. It is also noted that most of these regulations are in countries that already have fairly energy-efficient buildings. The status for regulations, methods and limit values for the Nordic countries and Estonia are presented in Table 1. From the table, it can be stated that every county is establishing its own methods for conducting mandatory building LCAs. But also, that all countries have progressed differently in the process.

Table 1. *The status regarding regulatory building LCAs and associated limit values in the Nordic countries and* Estonia.

Country	Mandatory building LCA	Source of the method	Limit values
Denmark	Since January 2023	BR18	Since January 2023
Estonia	Will be in force in 2025	Proposed method for climate declaration (2022)	Under discussion
Finland	Will be in force January 2025	Proposed method for climate declaration (2021)	Will be in force January 2025
Iceland	Coming soon	Method under development (2023)	Maybe in 2026
Norway	Since July 2023	TEK17	Maybe in +5 years
Sweden	Since January 2022	Act (2021: 787) on climate declaration for buildings. Ordinance (2021: 789) on climate declaration for buildings. Provision (BFS 2021:7) on climate declarations for buildings.	Proposed July 2025

(Lavikka, et al., 2023, p. 9)

The following Chapters will give a brief insight into the Nordic countries' regulations regarding building life cycle assessments, presented in Table 1. Given that Nordec's largest custom base is in the Nordic countries, this thesis will only address to national laws, policies, and industry-specific guidelines for the Nordic countries, but with a focus on Finland, Sweden, and Norway.

2.1.1 Finland

In Finland, the new Reforming Land Use & Building Act was confirmed in 2023 and enters into force in the beginning of 2025 (Ministry of the Environment, n.da). The primary goal of the reform is to create a healthy, safe, and pleasant living environment that meets the needs of different population groups. As a part of this reform, whole-life carbon assessments will be required for all projects when applying for a construction permit. These assessments will include strict limits on embodied carbon emissions based on the type of building. However, certain projects are exempt from this requirement, such as buildings under $50m^2$, free-time residentials, industrial facilities, religious buildings, agricultural production sites and military buildings and temporary buildings in use for less than two years. Furthermore, the reform involves promoting the use of energy-efficient technologies, materials, and renewable energy sources in construction projects. (One Click LCA, 2022, ch. 3.4; Lavikka, et al., 2023, p. 35-43).

To facilitate these assessments, the Finnish government is developing a carbon assessment method based on European standards and the Level(s) method (Ministry of the Environment, n.db). Level(s) is a framework developed by the European Commission for measuring resource efficiency in constructions and promoting sustainable building practices across Europe (Ministry of the Environment, n.dc). This method requires the inclusion of the life cycle stages A1-A3, B4, B6, C1-C4 and D1-D6 in the calculation, with a 50-year period considered (Lavikka, et al., 2023, p. 37). The extent of the building components included in the assessment is described in Figure 1. Matti Kuittinen has in a report, describing the method, defined even more precisely which parts must be considered in the assessment. (Kuittinen, 2019, p. 11-12, 17-21).

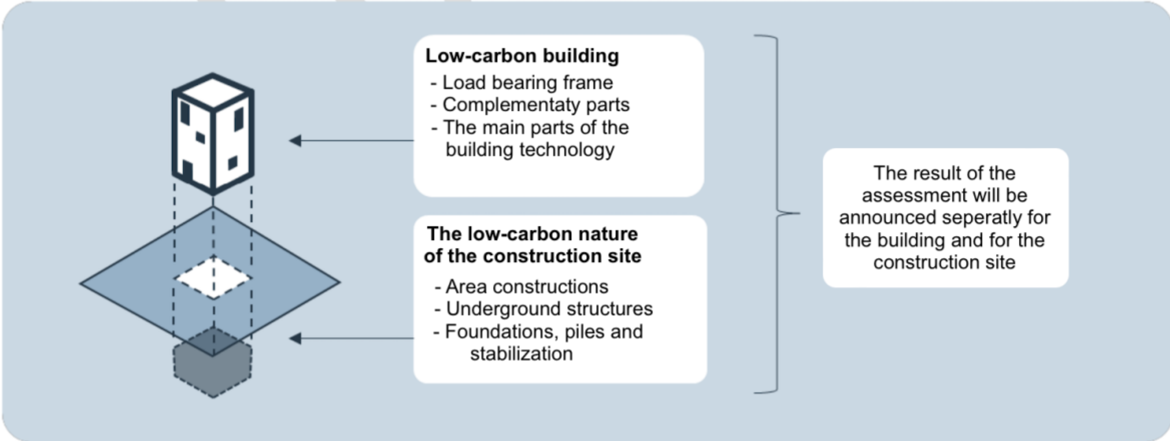

Figure 1. *Load-bearing structures, supplementary structures, foundations, earthworks, and key parts of the building's technical systems should be considered in the assessment. (Ministry of the Environment, 2021).*

Additionally, the Finnish Environment Institute, in collaboration with experts in the industry, has developed a national emission database called CO2data on behalf of the Ministry of the Environment. The database includes emission data for approximately 250 products and services. It has open access meaning calculations of buildings' carbon dioxide footprint and carbon handprint are possible early in the design phase or especially for products without EPDs. (Finnish Environment Institute, 2021).

Moreover, the Ministry of Environment recommends the use of green building certifications such as Leadership in Energy and Environmental Design (LEED) or the Building Establishment Environmental Assessment Method (BREEAM). These certifications aim to promote sustainable building practices and materials. (Ministry of the Environment, n.db).

2.1.2 Sweden

In Sweden, climate declarations for buildings became mandatory in 2022 through the Law 2021:787 (Landsbygds- och infrastukturdepartementet BB) . This law requires climate declarations for all new buildings requiring a building permit over 100m^2. Like Finland, certain buildings are exempt from the requirements, including temporary buildings used for less than two years, industrial buildings and buildings used for defense or agriculture. The primary aim of the law is to reduce the climate impact from the construction of buildings, aligning with global efforts to alleviate climate change (Boverket, n.da). (One Click LCA, 2022, ch. 3.10).

In the initial phase, there are no limit values for environmental impact which allows some flexibility. However, starting no later than 2027 the Swedish National Board of Housing, Building and Planning proposes to implement maximum values for environmental impact. These limit values apply to modules A1-A5 in the life cycle calculation. For product impact data it is preferred to use EPDs, and any generic data used must be sourced via the national climate declarations database provided by the National Board of Housing, Building and Planning (Broer, Simjanovic, & Toht, 2022, p. 13). This database includes generic data for over 200 products and is openly accessible (Boverket, n.db). The climate declaration must include specific parts of the building, as listed in Figure 2, with further definitions found in the Law 2021:787 about climate declarations for buildings. (One Click LCA, 2022, ch. 3.10; Lavikka, et al., 2023, p. 65-73).

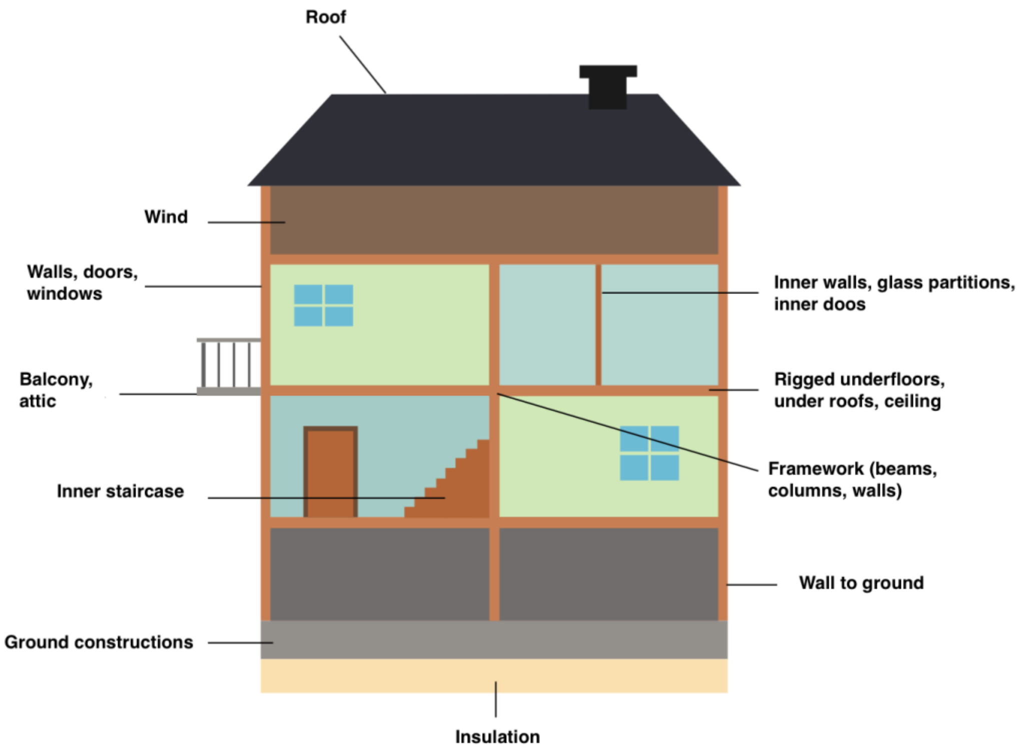

Figure 2. *The building's climate shield, all load-bearing structural parts and interior walls are parts of the building that must be included in the climate declaration.* (Boverket, n.dc).

2.1.3 Norway

In Norway, requirements for climate declarations are governed by the Norwegian Building Regulation. The chapters about climate declarations, referred to as "klimagassregnskap fra materialer", were implemented in July 2022 under TEK17 § 17-1, with a one-year transition period before becoming mandatory. These requirements apply to both new constructions and major remodeling projects. TEK 17 establishes a framework for accounting greenhouse gas emissions specifically related to materials used in construction projects for apartment blocks and commercial buildings. (One Click LCA, 2022, ch. 3.9; Direktoratet for byggkvalitet, 2023; Lavikka, et al., 2023 p. 48-62).

The LCA must adhere to the standards NS 3720:2018 and NS 3720, both of which are commonly used and based on the EN 15978 standard. These standards cover the whole life cycle of the building, including operational emissions. However, the regulation specifically requires an assessment of material production stages A1-A3, transport impacts A4 and material replacement B4. Table 2 outlines the building components that must be included in the life cycle assessment.

Table 2. *Building elements that must be included in the life cycle assessment for materials.*

When building and major renovations of residental buildings and commercial buildings, a greenhouse gas account must be prepared based on the method in the Norwegian standard NS3720:2018 Method for greenhouse gas calculations for buildings. The greenhouse gas account must at least include modules A1-A4, B2 and B4 for the building elementsspecified in the building parts table. In addition, the waste from the construction site must be included in the greenhouse gas accounts.

Table Building parts

Building parts*)	Building element
215 216	Pile foundation Direct foundation
22	Structural system
23	Outer walls
24	Interior walls
25	Covers
26	Extra ceiling

*) The numbers refer to the Norwegian standard NS3451:2022 Building parts table and system code table for buildings and associated outdoor areas.

(Direktoratet for byggkvalitet, 2023, ch. 1.1).

The assessment should cover a 60-year period, measuring only Global Warming Potential, GWP. The regulation takes a proactive approach by preparing the industry for potential future regulations that might impose stricter requirements regarding greenhouse gas emissions. To declare the climate impact, it is recommended to use EPDs. In the absence of specific EPDs, neither generic databases nor national databases are recommended for use. (Lavikka, et al., 2023, p. 48-62; One Click LCA, 2022, ch. 3.9).

2.1.4 Denmark

In Denmark, the Danish Parliament has adopted a climate act aimed at reducing greenhouse gas emissions by 70% by 2030, compared to 1990 levels (Broer, Simjanovic, & Toht, 2022, p.13). The Danish Building Act serves as the national regulatory framework for construction activities. Starting in 2023, performing an LCA analysis has become mandatory for obtaining a building permit for most types of buildings. This means that for new buildings with a floor area exceeding 1000 m^2, an LCA must be conducted according to specified limit values. The limit values will be further tightened every second year and are expected to be mandatory for all new buildings, regardless of the size, in 2025. However, for the moment structures with a floor area smaller than 1000 m^2 are only required to perform an LCA study. The assessment should encompass modules A1-A3, A4, A5, B4, B6 and C1-C4. As for the other countries, specific types of buildings are exempt from the LCA requirements. These are cottages, retrofitting, transformation projects, and unheated buildings in terrain. (One Click LCA, 2022, ch. 3.3; Lavikka, et al., 2023, p. 23-28)

The Danish government has developed a tool named LCAbyg for LCA calculations. For the calculation, generic data from BR18's Table 7, values from Ökobautat or any EPD can be used (Lavikka, et al., 2023, p. 12). BR18, or "Bygningsreglementet 2018", is a set of building regulations and rules that govern the planning, construction, and operations of buildings in Denmark (Social- og Boligstyrelsen, n.d.). The calculation too LCAbyg uses generic emission values sourced from Ökobautat, which is a German database. Ökobaudat is also recommended for use when no specific EPD is found. (One Click LCA, 2022, ch. 3.3).

2.1.5 Iceland

In Iceland, the work towards circular construction takes place through both policies and regulations, particularly with the national construction regulation, as well as through collaboration with society. The national building regulations are scheduled to be enforced in 2024, as outlined in the plans (Lavikka, et al., 2023, p. 44-47). These regulations encompass provisions for nature conservation and pollution prevention. (One Click LCA, 2022, ch. 3.7).

To initiate this process, the government, in partnership with the industry, has released a roadmap titled "Building a green future" or "Byggjum grænni framtíð". The roadmap is aimed at promoting a more environmentally sustainable construction approach. This roadmap includes goals and sets of actions to reduce the carbon footprint associated with construction processes. These actions are categorized into six primary areas: building materials, construction stage, building use stage, end-of-life stage, planning and design, and incentives and other means to encourage change (Green Building Council Iceland, n.d.). (One Click LCA, 2022, ch. 3.7).

Together with the national building regulation, there are plans to mandate LCA calculations for all types of new buildings, including family houses, apartments, and all types of common buildings. The implementation of limit values is scheduled for 2026. For the LCA calculation, modules A1-A3, A4-A5, B6, C and D are expected to be included. (Lavikka, et al., 2023, p. 44-47).

2.1.6 EPD standards

Besides following national regulations, an EPD must also comply with international standards. EPDs are also recognized based on their standard compliance. The process of creating an EPD involves adhering to international LCA and EPD standards, as well as the use of Product Category Rules (PCR). Additionally, EPDs must undergo verification in line with international verification standards.

Table 3. *The market for EPD-related standards.*

MARKET	EPD STANDARD AND CORE PRODUCT CATEGORY RULES	LCA STANDARD	INDEPENDENT VERIFICATION STANDARD
International	ISO 21930 (compatible with EN 15804+A1)	ISOs 14040 and 14044	ISO 14025
EU and EEA	EN 15804+A1 (to be phased out in July 2022) and EN 15804+A2		
North America	ISO 21930 with TRACI 2.1		

(One Click LCA, 2020, p.8)

The concept of EPDs is based on the standard ISO 14025, which is recognized globally and developed by the International Organization for Standardization. The standards that are being used are divided geographically, with the European standard EN 15804+A2/A1 being the most widely used EPD standard. However, other standards apply beyond the European Union and are listed in Table 3. (One Click LCA, 2020, p.8).

By referring to standards in the EPD, credibility and transparency are enhanced. Standards provide a common framework for assessing and reporting environmental information, ensuring consistency and comparability among different products. They also facilitate clarity regarding the conditions and assumptions underlying the results. Analysis, approval, and publication of EPDs are conducted by program operators such as EPD International, EPD Norge, MRPI or EPD Hub.

2.2 Benefits of Having an Environmental Product Declaration

Since EPDs come with a price, some question whether the investment is worth it. However, with carbon targets playing an increasingly important role in the construction sector, the demand for EPDs is growing. Companies can align with environmental goals by providing EPDs, demonstrating their commitment to measuring and reducing the carbon footprint of their products. One Click LCA has listed several benefits of having EPDs in their eBook and Echochain on their web pages (One Click LCA, 2020, p. 10, 14, 30-34; EPD International, n.d.).

Companies can benefit competitively from having EPDs on their products. Some markets and clients may require EPDs as a prerequisite for contract fulfillment. Companies that can present EPDs for their products can offer environmentally friendly options, potentially motivating customers to choose low-carbon products. With new requirements upcoming, customers will have to calculate the lifetime impact of every element of the project. Consequently, they are likely to prioritize product suppliers who can disclose the environmental impact of their products.

Moreover, companies can achieve EPD and LCA credits in various certification schemes, such as BREEAM and LEED. About 70% of the international and European green building standards offer credits for the use of materials labeled with an EPD. LCA credits are very cost-efficient compared to the other credit's requirements for the building's certifications. Therefore, having EPDs can help customers gain accreditation for green building certifications and schemes.

Furthermore, EPDs can spark innovation within the company, encouraging the development of even more sustainable materials, processes, and products. This innovation can lead to cost savings and potentially create revenue streams. Overall, the investment in EPDs can yield both short-term benefits, such as market access and certification credits, and long-term advantages, including innovation and improved environmental performance across the supply chain.

2.3 Life Cycle Stages

When making an EPD different life cycle stages for a product's lifetime can be considered. They can be defined as different periods of a building's lifetime. Shaun Masson has in an article published on One Click LCAs web page (Masson, 2023) defined the different life cycle stages and the meaning of them.

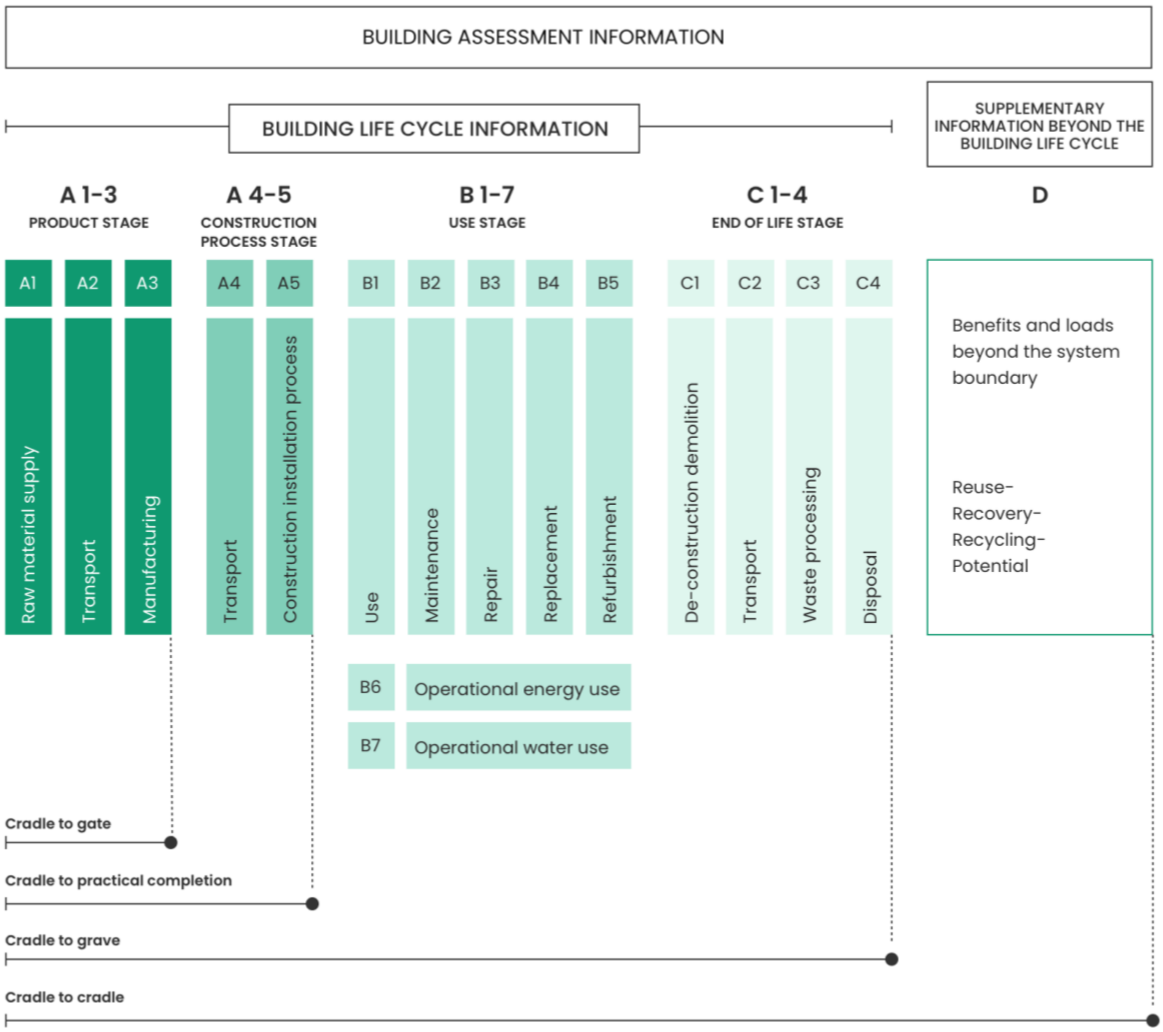

***Figure 3**. Life cycle stages according to EN standards. (Masson, 2023).*

In Figure 3, all modules and different models of the life cycle stages are defined according to EN standards. In European markets, these stages are defined by different EN standards; EN 15978 for buildings, EN 15804 for products and EN 17472 for infrastructure. These standards play a crucial role in defining the requirements for assessments conducted at either the product level or building level.

According to the European standard EN 15804:2012 + A2:2019 (SFS-EN 15804:2012 + A2:2019, 2019, ch. 6.2) module A1-A3 covers the product stage but also serves as an information module. It encompasses environmental impacts from raw material extraction to the point where the product leaves the manufacturing site. Meaning this stage includes raw material extraction and processing, transport to the manufacturer, manufacturing, and provision of all materials, products, energy, as well as waste processing up to the end-of-waste state.

Stages A4 and A5 represent the construction process stage, also serving as information modules, including transport to the building site, installation into the building, and related losses during this process. Module B1-B5 covers the use stage related to the building’s life cycle, including maintenance, repair, replacement, and refurbishment, but is also an information module. Stages B6 and B7 deal with operational energy use and operational water use and are a part of the use stage, but act as information modules related to the operation of the building.

When a building enters the C1-C4 modules, it has reached the end of its lifetime. This stage includes deconstruction, transport to waste processing, waste processing and disposal but also like the other stages any related losses during this process. The final module, the D stage, is an information module representing benefits and loads beyond the system boundary, including reuse, recovery, and/or recycling potentials expressed as net impacts and benefits.

The inclusion of different life cycle stages can be either mandatory or optional, depending on the scope of the life cycle assessment or on the available data. Typically, there are four different product life cycle models to choose from, which are visualized in the lower section of Figure 3. The model that encompasses the fewest stages in the lifecycle is cradle-to-gate, which in practice is the same as the product stage, where module A1-A3 must be included to comply with EN 15804+A1. But for the EPD to comply with EN 15804+A2, it also needs to report on modules C1-C4 and D, indicating a broader scope that encompasses the entire life cycle from raw material extraction through construction to end-of-life stages (One Click LCA, 2020, p. 24). (Quist, n.d.)

Cradle-to-practical completion refers to the entire life cycle of a construction project, from its design process to the point where the project is complete and ready for its intended use. Cradle-to-grave covers all stages of a product's life cycle, including raw material extraction, manufacturing, distribution, use, and end-of-life treatment. Lastly, the cradle-to-cradle model can be linked to circular economy, as it replaces the waste disposal stage with recycling and reuse. (Quist, n.d.).

2.4 How an EPD is created

This thesis will only briefly describe how an EPD is created for a better understanding of what must be included and how the process runs. The client for the thesis already has a few own EPDs and is developing them in-house.

EPDs can be created in different ways depending on which software is being used. Since One Click LCA is used when making EPDs at Nordec, this step-by-step description will be according to them. Except from One Click LCA alternatives such as Gabi or SimaPro can be used for EPD creation. Figure 4 presents the six main steps involved in the EPD making using One Click LCA. This process follows a structured approach to assess and communicate a product's environmental performance based on a life cycle perspective.

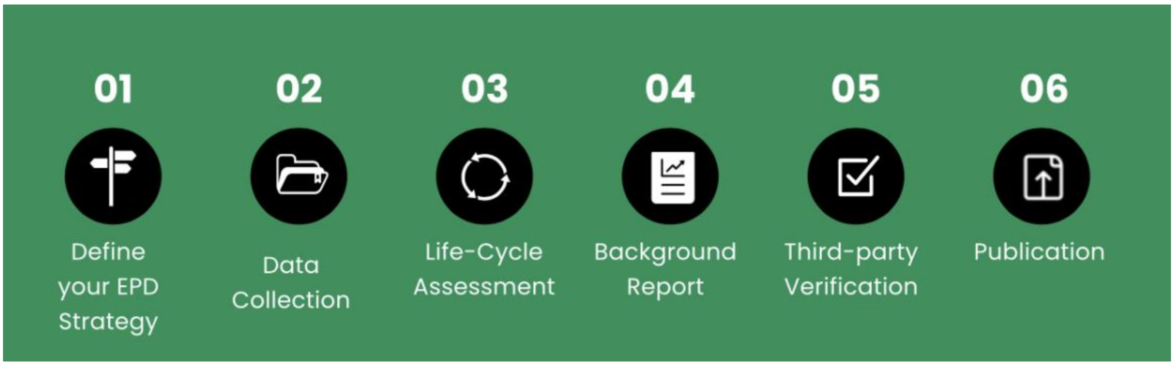

Figure 4. *Six main steps to creating an Environmental Product Declaration according to One Click LCA. (One Click LCA, 2020, p.16).*

One Click LCA's eBook (One Click LCA, 2020, p.16-29) defines six steps to creating an EPD according to them. The first step involves defining goals and developing an EPD strategy to ensure alignment with the company's and the client's needs. Defining the EPD strategy is based on several factors. Firstly, the type of the EPD must be decided, which often is a single product and manufacturer EPD or a group EPD. Beyond the mentioned, the type can be plant specified EPD or industry average EPD which can be included in a group EPD. Additionally, manufacturers can choose to hire external consultants to manage the process or invest in an EPD capacity in-house.

Furthermore, specifying the product category and adhering to established Product Category Rules (PCRs) are crucial steps in the process. PCRs are a set of specific and standardized guidelines that define the requirements for conducting an LCA and creating EPDs within a specific category (The International EPD System, n.d.). For example, some of the product categories supported by One Click LCA’s EPD Generator include metal products, insulation products, and plumbing products. Also, selecting the program operator is essential. Program operators are responsible for various tasks, ranging from creating and maintaining PCRs to approving and publishing the EPD.

Once the strategy is established, the data-collecting phase begins, marking the second step of the process. Three types of data need to be collected: manufacturing data, transport data and end-of-life data. Manufacturing data must be recent, representative, and reliable, while transport data is collected based on typical routes and vehicles used. End-of-life data is based on scenarios defined by program operators and PCRs. The assumptions must be well documented and justified.

The third step, known as life-cycle assessment or LCA, forms the foundation of EPDs. LCAs utilize standardized methods to calculate a product’s environmental impact across its life cycle. When conducting an LCA several factors must be considered, including the raw material involved in the production process and their sources, as well as the production operation, such as heating, water, and ventilation. But also, transportation methods, whether by truck, ship or airplane play a significant role in the assessment.

Impact categories, defined in Figure 5, are used to evaluate and quantify the environmental impacts associated with the entire life cycle. Within these impact categories, various emissions that cause the same impact are converted into one single unit, which is then translated into a corresponding impact category. EN 15804 + A2 defines the environmental impact categories. The specific PCR and EPD standard chosen for a specific product will dictate which impact categories must be included in the LCA.

IMPACT CATEGORY	DESCRIPTION
CLIMATE CHANGE OR GLOBAL WARMING POTENTIAL	Climate change or global warming potential due to emissions of greenhouse gases (GHG). EN 15804+A2 includes climate change subcategories of fossil, biogenic, and land use and land use change (LULUC).
OZONE DEPLETION POTENTIAL	Emissions to air that cause the destruction of the stratospheric ozone layer.
ACIDIFICATION POTENTIAL	Acidification of soils and water due to the release of gases such as nitrogen oxides and sulphur oxides.
EUTROPHICATION POTENTIAL	Emissions of Nitrogen and Phosphorus increasing the flow of nutrients to ecosystems, which can lead to damage such as excessive algae growth. EN 15804+A2, includes sub categories of aquatic freshwater, aquatic marine and terrestrial.
PHOTOCHEMICAL OZONE FORMATION POTENTIAL	Indicator of emissions of gases that affect the creation of photochemical ozone in the lower atmospheric ozone (commonly known as smog).
DEPLETION OF FOSSIL RESOURCES	The use of non-renewable fossil resources in an unsustainable way (e.g. from materials to waste).
ABIOTIC DEPLETION	The use of non-renewable resources in an unsustainable way. In EN 15804+A2, the category is divided into fossil resources and minerals and metals.

Figure 5. *LCA environmental product categories. (One Click LCA, 2020, p.26).*

The impacts are expressed as midpoint impacts, representing equivalent quantities of matter, such as CO_2, which has the potential to cause such impacts. However, these equivalents do not directly indicate the actual harm. For instance, while global warming potential represents the amount of greenhouse gases released, the final impact may manifest as the acceleration of polar ice melt.

The fourth step consists of an LCA background report which is a vital accompaniment to the public EPD. Unlike the EPD, the background report is not published, instead, it supports verification by providing further details about relevant standards, methodology and assumptions made. Third-party verification is the fifth step in the EPD process. As already mentioned, all EPDs must be third-party verified for them to be published. By having the EPD third-party verified it ensures the accuracy and reliability of the assessment's data and methodology. Typically, the program operator in which the EPD is created offers third-party verifiers they are working with. In the case of Nordec's EPD, "Nordec Low CO_2 Truss" which is presented in "*Appendix 1"*, EPD Hub serves as the third-party verifier which can be found on page 11 in the EPD.

The final stage involves publication, which occurs after the EPD has undergone verification by an independent third party. Submission of the EPD document to the program operator is essential to facilitate processing, registration, and eventual publication. One EPD can be published on several different platforms.

3 INSIGHTS FROM PROJECT MANAGEMENT

As mentioned, this thesis will mainly focus on the design process, but at the end of the day every phase of the project is linked. This chapter gives a brief overview of the significance of implementation in design within the project context. The writer of the thesis has discussed the topic with two people working in the field to hear their opinions and wishes.

3.1 Project management

Peter Marins, Project Team Leader at Nordec (Personal communication 1.11.2023), raises several valid challenges regarding the implementation of EPDs into the company's design process. Notably, since EPDs are manufacturer-specific, it is impractical for designers to incorporate all specific EPDs into the design model. This would be very time-consuming and difficult since the designer then should know the final manufacturing location of the products and elements as getting the design ready. Moreover, who should decide which EPD to use for each product and element? This complexity extends to the process of naming construction components, where two identical-looking products may need to adhere to different EPDs.

Marins also highlights the complications that arise when external factories are utilized, which might happen if Nordec's own factories are fully booked. Then the external factory must achieve the environmental requirements that are set for each product. This leads to a smaller selection of external factories, which in turn can lead to delays and other unexpected problems on the way. After some discussion back and forth, it was determined that the easiest way is to develop generic levels for each material. Then the external factories that meet the requirements on the generic levels can be an alternative when external factories are needed. This provides flexibility and alternatives when internal factories are fully booked.

Finally, Marins points out the risks associated with data handling, potential loss, or modification of data throughout the project stages. To minimize the risks of data handling, regular audits and checks can help identify and rectify any discrepancies.

As a conclusion many different factors must be considered in order for the implementation of EPDs throughout the projects to run as smoothly as possible. Apart from the requirements from the customer, regulation, and national requirements, the project itself sets requirements. The project's requirements include life cycle assessments and carbon footprints. Beyond that the availability of raw material and building products on the market is crucial. To be able to follow the requirements, there must be materials and building products that be used that fulfill the requirements.

When the project enters the design phase, all requirements are included into the design models by designers. As the design gradually becomes ready the information from the model, converted into material lists and drawings, passes on to a production management system and sourcing management can start to acquire raw materials and site materials as per the requirements.

At last, the product documentation, where all information about every element and raw material needs to be available and an LCA must be done when the project is done. For this to work, collaboration among customers, designers and manufacturers must be encouraged to determine the most suitable solution for projects. Which ensures that decisions are well-informed and consider a range of perspectives.

3.2 Sourcing

After deciding that the implementation of EPDs will be through both EPDs and generic levels, the idea was presented to sourcing manager Magnus Sjöholm (Personal communication 15.11.2023), who is working at Nordec. Sjöholm points out that generic levels would work best for sourcing instead of using manufacturer-specific EPDs for each product since it might become very time-consuming. If it is set which generic level to follow early in the project, it is easier for sourcing to book manufacturers that meet the requirements within the levels. Due to the availability on the market, the price could differ a lot within the levels, which might be a problem for the customers.

There is no compilation of product specific EPDs yet, since there are no requirements that must be followed. However, it is good to include the environmental data in an early stage since it will become mandatory over time according to Sjöholm. Although, adding environmental information data to every project will become very project-specific, since every project and its requirements look different. Meaning the information used for one project cannot be used for the next project to the same extent.

Sjöholm also emphasizes that clients are primarily concerned with the overall environmental impact or performance of a building rather than the specific details of each product used in the construction. So, by categorizing buildings or projects into different levels that indicate the overall environmental performance, it could simplify the decision-making for clients. Then Nordec could also choose manufacturers to work with, as long as they stay within the limits of the chosen level. This would allow flexibility while maintaining a commitment to sustainability. Same as Marins, Sjöholm raises the question of who should have the authority to decide which EPDs and EPD levels to work with.

4 EPD LEVELS

Based on interviews and discussions with people from the field and on the goal of the thesis, it was decided that generic levels for each material would work best in practice. These generic levels are called EPD levels in this thesis. As already mentioned, the EPDs this thesis considers are Nordec's own EPDs and EPDs from subcontractors considering steel and precast concrete products. With that as a basis, EPD levels were developed for steel and concrete.

At the beginning of a project, the customers get to choose project-specific environmental levels for their whole project. These levels are ranked according to how good or bad the buildings turn out environmentally. Every project is unique, and customer´s preferences regarding environmental performance may vary, so by offering a range of levels allows for tailored solutions that meet the specific needs and priorities of each customer. Based on the selected environmental level for the project, EPD levels are then selected for different materials. These EPD levels are chosen in collaboration with project managers and designers. By letting the customers choose the environmental level for the whole project it is also easier for sourcing to find manufacturers that meet the levels. Also, giving customers the ability to choose environmental levels encourages ongoing dialogue and collaboration around sustainability. The environmental levels are based on a percentage reduction in environmental impact, based on the fact that customers often ask for a percentage reduction for their projects, according to Peter Marins. The levels are not defined in this thesis but as a reference example, level 2 could have a 20% lower environmental impact compared to the average impact.

4.1 Global Warming Potential

The results of a life cycle assessment are often communicated using Global Warming Potential, GWP, in an EPD, which is an impact category defined in Figure 5. Therefore, GWP values servers as the metric guiding the EPD levels for each material in this thesis. GWP is a measure of how much different types of gases contribute to climate change. It tells how much heat a greenhouse gas traps in the atmosphere over a specific time, usually 100 years. It is calculated by comparing each gas to carbon dioxide (CO_2), which serves as the reference gas and has a GWP of 1. GWP is a vital tool in environmental science and climate policy, providing a standardized way to express the warming potential of different greenhouse gases. Also, according to the European standard EN 15978, GWP is calculated using carbon dioxide equivalents which is a standard unit for measuring the carbon footprint. (SFS-EN 15978, 2021, table 2). The unit $kgCO_2e$ is often used to express the GWP of e.g. 1 kg of a certain product. (Vallero, 2019, ch. 8.3.2.).

As described in Figure 5, GWP can be expressed differently based on which emissions that are included in the assessment. For example, GWP-fossil refers to the greenhouse gas emissions resulting from the combustion or degradation of fossil fuels, while GWP-biogenic relates to the greenhouse gas emissions originating from biological materials or processes. GWP-luluc, which stands for land use and land-use change, refers to the greenhouse gas emissions and removals associated with changes in land use, such as deforestation. GWP-total represents the sum of greenhouse gas emissions from all three aforementioned sources (SFS-EN 15804:2012 + A2:2019, 2019, ch. C.2).

Different countries have different requirements regarding GWP scopes. Finland's legislation requires the use of GWP-total values, whereas Sweden and Norway utilize the use of GWP-GHG. GHG is a term for greenhouse gases, meaning GWP-GHG stands for "Global Warming Potential-Greenhouse gas", which indicates the climate impact excluding absorption and emissions of biogenic carbon (Boverket, n.dd). Denmark employs GWP-total, while Iceland has yet to declare their preference as they are in the planning process. (Lavikka, et al., 2023, p. 12-13)

4.2 Steel

When designing a construction at Nordec, the steel quality S355J2 is used as a starting point. Starting with the steel quality S355J2 as a baseline is a common practice due to its widespread availability, good mechanical properties, and suitability for various applications. S355J2 is a structural steel grade specified in the European Standard EN 10025-2:4.2.2, with "S" for structural steel and the number indicating its minimum yield strength in MPa, meaning 355 MPa for S355. The factor "J2" indicates that the steel has been impact-tested at -20 degrees Celsius. (SFS-EN 10025-2:2019, 2019, ch. 4.2.2).

Changing to another steel quality may be necessary under certain circumstances. For example, availability, project-specific requirements, performance enhancement or regulatory compliance. Unless the factories have access to the specified steel quality, they may need to use an alternative that is available to them. Also, if the project involves extreme environmental conditions, for example corrosive environments, high or low temperatures, specialized steels with enhanced properties may be required to ensure durability and performance. Since the initial state of steel quality used in construction projects is consistently S355J2 the EPD levels for steel are based on that specific steel quality.

Table 4. *EPD levels for steel products.*

Steel Products (S355J2)	
Levels	GWP-total kg CO2e/ton, max
LS_0	typical value, undefined
LS_1	1800
LS_2	1600
LS_3	1400
LS_4	1200
LS_5	1000
LS_6	< 800

The steel EPD levels for steel, defined in Table 4, go from LS_0 to LS_6, where “L” stands for level and “S” for steel. This system categorizes steel products based on their environmental impact, focusing on GWP-total, during life cycle stages A1-A3. Since the values are developed according to Finnish legislation, they are specified with GWP-total units. LS_0 represents an undefined status with a typical value, which is being used at Nordec unless nothing else is mentioned. It indicates that no effort has been made to reduce the environmental impact of the steel product. This means the GWP value is unspecified, but it serves as a baseline for comparison against more environmentally conscious options. Levels LS_1 to LS_6 represent increasing efforts to reduce GWP. Each level sets a maximum GWP value that the steel product must not exceed. For example, if a column is marked with LS_4, it means that the maximum allowable GWP for that object is 1200 GWP-total kg CO2e/ton.

To improve the steel to achieve the EPD levels, several factors can be considered. The World Steel Association published a report in 2021 outlining various changes that can be implemented to make iron and steel production more environmentally friendly (World Steel Association, 2021). The report highlights the fact that there is no single solution yet to significantly reduce CO_2 emissions from steel production. However, by following certain key steps, a transformation towards more environmentally friendly production methods can be achieved.

A more environmentally friendly steel production can be achieved by increasing efficiency through optimization of current processes, and the development of new technologies. This may involve embracing circular economy principles, such as increased reuse, remanufacturing, and recycling of materials. Reusing steel can occur in different ways, including melting down steel products in order to make new ones or utilizing steel products as they are. SSAB has developed a new technique, called HYBIT-technology, which replaces carbon with hydrogen as an input material in the steelmaking process (SSAB, n.d.). This results in water rather than CO_2 as a byproduct. Furthermore, beyond these improvements, optimizing by using less steel in design can make the entire building more environmentally friendly. (World Steel Association, 2021, p. 2-5)

4.3 Concrete

As already mentioned, Nordec does not manufacture their own concrete products but buys them from subcontractors. Therefore, they do not produce their own EPDs for concrete either. Instead, values from Svensk Betong's guide to climate-improved concrete are being used as reference values (Svensk Betong, 2022). Svensk Betong is a trade association for manufacturers who produce precast concrete, install concrete products, and perform concrete pumping (Svensk Betong, n.da). By using established values from Svensk Betong, Nordec can still provide valuable information to stakeholders about the climate impact of concrete products. This also ensures reliability in assessing the environmental footprint of their operations and products, even if they are sourced from subcontractors.

The values represented in Table 5 describes the climate impact for precast concrete products in dry indoor environments, mainly in offices, residences, schools, and hotels but also values for products in humid environments outdoor. Values for humid, indoor environments are listed in Table 6, which applies to parking garages and industrial buildings. The values for both indoor and outdoor environments show the carbon dioxide emissions, GWP-GHG, from life cycle stages A1-A3, expressed as kg CO_2e/ton of product. GHG is a term for greenhouse gases, and GWP-GHG is therefore "Global Warming Potential-Greenhouse gas", which indicates the climate impact excluding absorption and emissions of biogenic carbon (Boverket, n.dd). Same as for steel there are typical values in the table where no effort has been made to reduce the environmental impact from the products.

Table 5. *Climate impact from precast concrete products which is applied to dry, indoor environments, and humid outdoor environments.*

precast concrete products							
Offices, residences, schools and hotels			Climateimpact GWP-GHG, kg CO2e/ton				
	Exposure class	w/c ratio eq*	typical values	Climate improved, max			
Products				Level 1	Level 2	Level 3	Level 4
Indoor, dry environment	XC1						
Hollow-core slab		0,40	135	120	110	95	< 80
Hollow-core slab		0,50	115	105	95	80	< 70
Massive pre-stressed concrete slabs		0,50	185	165	145	130	< 110
TT slabs		0,50	185	165	145	130	< 110
Massive slack-reinforced slabs		0,50	185	165	145	130	< 110
Flat bearing		0,55	185	165	145	130	< 110
Sandwich wall		0,55	235	210	185	165	< 140
Half sandwich		0,55	205	185	165	145	< 125
Shell wall		0,55	185	165	145	130	< 110
Slack-reinforced beam		0,45	200	180	160	140	< 120
Pre-stressed beam		0,40	190	175	155	135	< 115
Columns		0,50	240	215	190	179	< 145
Walls		0,50	155	140	125	110	< 95
Stairs		0,45	210	190	170	145	< 125
Outdoor, humid enviroment	XC3						
Balconies		0,45	210	190	170	145	< 125
Attic passages		0,40	220	190	175	155	< 130

(Svensk Betong, 2022, p.18).

Table 6. *Climate impact from precast concrete products which is applied in humid indoor environments.*

precast concrete products							
Parking garages and industrial buildings			Climateimpact GWP-GHG, kg CO2e/ton				
	Exposure class	w/c ratio eq*	typical values	Climate improved, max			
Products				Level 1	Level 2	Level 3	Level 4
Humid environment	XC3						
Hollow-core slab		0,40	140	125	115	105	< 85
Massive pre-stressed concrete slabs		0,50	185	165	150	130	< 100
TT slabs		0,45	220	200	175	155	< 130
Sandwich wall		0,55	235	210	190	165	< 140
Slack-reinforced beam		0,45	200	180	160	140	< 120
Pre-stressed beam		0,40	190	170	150	135	< 115
Columns		0,50	240	215	190	170	< 145
Walls		0,50	155	140	125	110	< 95

(Svensk Betong, 2022, p. 19).

The values are derived from estimated average data for concrete products manufactured in 2019. Variations can occur both ways depending on factors such as the individual product's composition, function, manufacturer, and manufacturing site. The given values in the tables correspond to the typical values stated in the Swedish National Board of Housing, Building and Planning's database, discussed in Chapter 2.1.2. The values also include reinforcement, casting details and any insulation. (Svensk Betong, 2022, p. 18-19).

The tables from Svensk Betong also include the concrete's exposure class and w/c ratio equivalent. The term exposure class refers to a classification system that categorizes the environmental conditions to which a concrete structure will be exposed to over its lifetime (Svensk Betong, n.db). Water-cement ratio, shortened w/c ratio, is a crucial parameter in concrete mix design and plays a significant role in determining the strength, durability, workability, and other properties of concrete (Ultra tech cement, n.d.). The typical w/c ratio equivalent varies between 0,40-0,60 for different grades of concrete mix. For hollow core slabs, in Table 5, there are different values depending on the water-cement ratio equivalent.

To make the levels climate improved Svensk Betong has defined what changes they have made to the concrete in order to make it more environmentally friendly. In level 1 they have replaced cement clinker with optional binders such as fly ash or slag. This substitution helps lower the CO_2 emissions associated with concrete production. These alternatives typically have lower carbon footprints compared to traditional cement, and by using them the environmental impact of the concrete is reduced. Building upon the improvements made in level 1, Svensk Betong has for level 2 experimented further with the concrete recipe to achieve additional reductions in CO_2 emissions. By following the standard SS 137003:2021 the options of binders grow even more which allows for optimizing the recipe to enhance the environmental performance.

At the higher levels, levels 3 and 4, Svensk Betong focuses not only on replacing binders but also evaluates and modifies the production process itself. This includes examining factors such as curing time and demolding time to identify opportunities for reducing cement consumption. By slowing down certain stages of the production process, the amount of cement required can be minimized, leading to further reductions in CO2 emissions. Furthermore, Svensk Betong emphasizes the importance of considering transportation in addition to concrete production when evaluating the environmental impact of construction projects. The distance and mode of transportation can significantly affect the overall carbon footprint of concrete. It is also noted that the achievable level of climate improvement in a project may also be influenced by regulations and technical conditions specific to the construction industry. (Svensk Betong, 2022, p. 18-19).

When converting the values from Svensk Betong into EPD levels, the values for exposure class and w/c ratio are excluded. The EPD levels for precast concrete products in dry indoor environments, defined in Table 7, go from LCD_0 to LCD_4. In the table “L” stands for level, “C” for concrete and “D” for dry environmental conditions. Notable the values for hollow core slabs are different depending on the water-cement ratio.

Table 7. *EPD levels for precast concrete products for dry, indoor environments.*

precast concrete products (dry environment)					
Offices, residences, schools and hotels	**Climateimpact GWP-GHG, kg CO2e/ton Climate improved, max**				
Products	**LCD_0**	**LCD_1**	**LCD_2**	**LCD_3**	**LCD_4**
Indoor, dry environment					
Hollow-core slab (w/c ratio eq* 0,40)	135	120	110	95	< 80
Hollow-core slab (w/c ratio eq* 0,50)	115	105	95	80	< 70
Massive pre-stressed concrete slabs	185	165	145	130	< 110
TT slabs	185	165	145	130	< 110
Massive slack-reinforced slabs	185	165	145	130	< 110
Flat bearing	185	165	145	130	< 110
Sandwich wall	235	210	185	165	< 140
Half sandwich	205	185	165	145	< 125
Shell wall	185	165	145	130	< 110
Slack-reinforced beam	200	180	160	140	< 120
Pre-stressed beam	190	175	155	135	< 115
Columns	240	215	190	179	< 145
Walls	155	140	125	110	< 95
Stairs	210	190	170	145	< 125

Corresponding EPD levels for precast concrete products in humid environments, indoor and outdoor, are represented in Table 8, in which the levels go from LCH_0 to LCH_4 where “H” stands for humid environment. The values indicated with 0 refer to typical values where no climate improvement has been considered. These levels represent different degrees of environmental impact or sustainability performance, with higher levels indicating greater environmental improvement.

Table 8. *EPD levels for precast concrete products for humid environments indoor and outdoor.*

precast concrete products (humid environments)					
Parking garages and industrial buildings	**Climateimpact GWP-GHG, kg CO2e/ton**				
	Climate improved, max				
Products	**LCH_0**	**LCH_1**	**LCH_2**	**LCH_3**	**LCH_4**
Indoor, humid environment					
Hollow-cole slab	120	125	115	105	< 85
Massive pre-stressed concrete slabs	185	165	150	130	< 100
TT slabs	220	200	175	155	< 130
Sandwich wall	235	210	190	165	< 140
Slack-reinforced beam	200	180	160	140	< 120
Pre-stressed beam	190	170	150	135	< 115
Columns	240	215	190	170	< 145
Walls	155	140	125	110	< 95
Outdoor, humid enviroment					
Balconies	210	190	170	145	< 125
Attic passages	220	190	175	155	< 130

By categorizing EPD levels separately for dry and humid environments, Nordec can more effectively address the unique environmental challenges and considerations associated with each environment. Different values for dry and humid environments are also necessary since there are similar objects in the tables with different values, which is because the objects perform differently in dry and humid environments. For example, TT slabs in dry indoor environments (Table 7) have a maximum allowable climate impact of 130 GWP-GHG, kg CO2e/ton to achieve EPD level LCD_3. Compared to TT slabs in humid environments (Table 8) which have a maximum value of 155 GWP-GHG, kg CO2e/ton to achieve EPD level LCH_3. This also reflects the need for stricter environmental performance criteria in dry environments.

5 IMPLEMENTATION INTO TEKLA STRUCTURES

After consulting with people from different stages of the projects and gathering their feedback, the implementation of the EPD levels into Tekla Structures was developed. Implementation of EPD levels into Tekla Structures involves linking the environmental data to the corresponding materials and products used in a building model. The EPD levels play a crucial role in the design process by providing valuable information about the environmental impact of a product through material lists and drawings. In practice, the implementation of EPD levels into Tekla will involve collaboration between designers and project managers, since the EPD levels probably are not set when the design phase begins and are likely to change during the process. In order for the implementation to work out successfully the design team must be familiar with the concept of EPDs and the importance of considering environmental impacts in the design process. It is important to ensure that the integration of the EPD data within Tekla Structures is user-friendly and intuitive, allowing users to easily access and interpret the EPD data within their workflow, even for external designers. A step-by-step description for designers is also presented in *"Appendix 4"*.

5.1 Tekla Structures

Tekla Structures, developed by Trimble is the software application used at Nordec for Building Information Modeling (BIM), structural engineering and construction. Tekla Structures being a BIM software involves data handling to manage the information associated with the projects. Meaning that the software contains data related to the material properties, construction details, connections, and other project-specific data. This facilitates collaboration and coordination among different stakeholders. (Trimble, n.d.).

Tekla Structures is suitable for the implementation of EPD levels as the data inserted into parts of the model can easily be included in project documentation, provided that the data affects the numbering. Nordec has their own Tekla Structures environments in which the EPD levels will be implemented. Tekla Structures version 2021 has been used for modeling and example drawings for this thesis.

To be able to create drawings in Tekla or accurate reports, all parts of the model must be numbered. Numbering refers to the process of assigning unique identifiers or numbers to different objects within the structural model. The numbering system helps to organize the model and facilitates various tasks such as fabrication, assembly, and documentation. Numbers are also needed for the exportation of a model. Each part gets its own number which helps identify and track individual parts throughout the manufacturing and assembly process, ensuring that the right components are fabricated, shipped, and installed at the construction site. Along with the number comes a part mark for each part and assembly in the model. The mark includes part or assembly prefix and position number, but also profile or material grade. Every project has its own instructions on how to use the prefixes and how parts shall be marked. Identical parts within a numbering series share the same number, which simplifies the production and planning process.

Since the EPD levels will be different for many parts of the model, the numbering should be affected when adding EPD levels. If two beams look the same in appearance but have different EPD levels, they also need different numbers. The levels can be treated as a parameter within the model, similar to other properties such as material type, profile size, or assembly sequence.

5.2 Implementation of EPD Levels for Steel Objects

The EPD levels for steel can be defined in Tekla Structures by clicking on an optional part in the model, with the “component objects" selection switch activated, and changing its properties. The properties window can be accessed by selecting an object in the model and right-clicking on it. From the context menu that appears, properties can be chosen, alternatively the right toolbar can be used. The properties window, visualized in Figure 6, displays a list of properties associated with the selected object. In this thesis, a brace has been selected for visualization of the process. The properties may include different data depending on the Tekla Structures environment and version. But often they include geometric dimensions, material properties, numbering series, and other relevant data. Adding an EPD level to the selected object from the model can be done by changing the material grade.

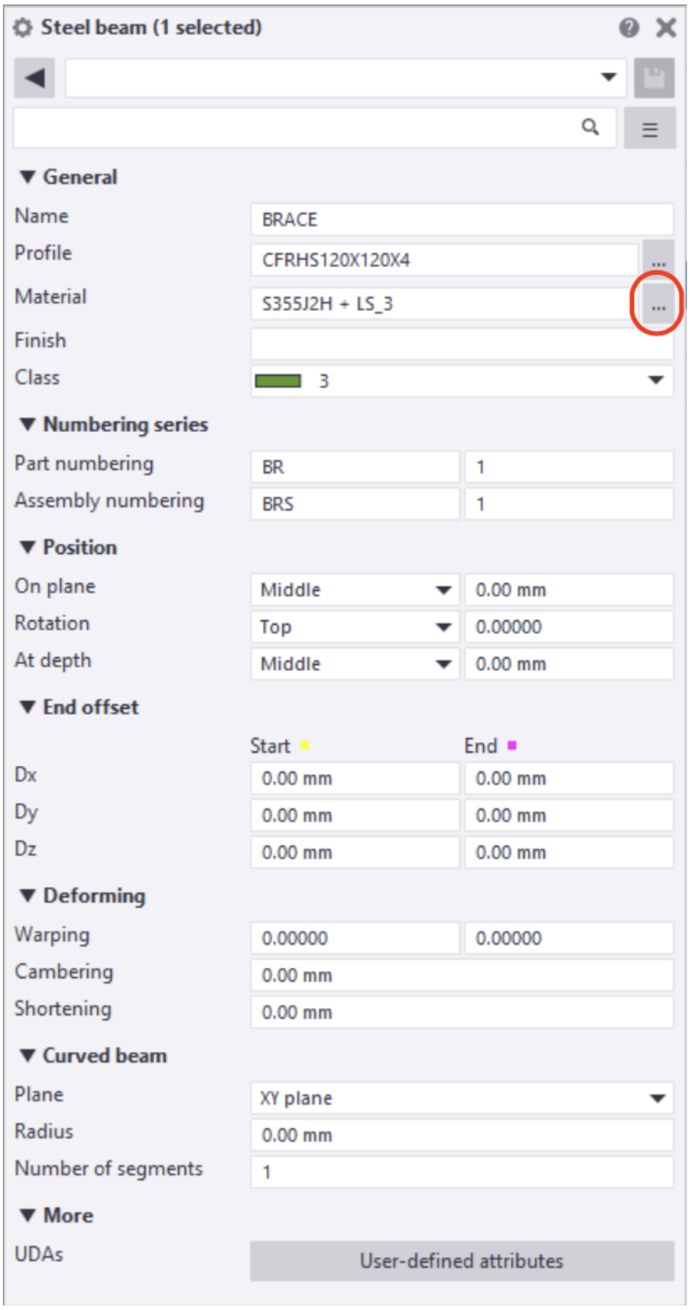

Figure 6. *Object properties.*

By clicking on the button with three dots, indicated in red in Figure 6, a window appears from where the material can be selected, visualized in Figure 7. Depending on what type of object the selected object has been defined to be, different types of material options will appear in the material selection list. For example, if an object has been defined to be a steel beam, the material list will only present different types of steel qualities.

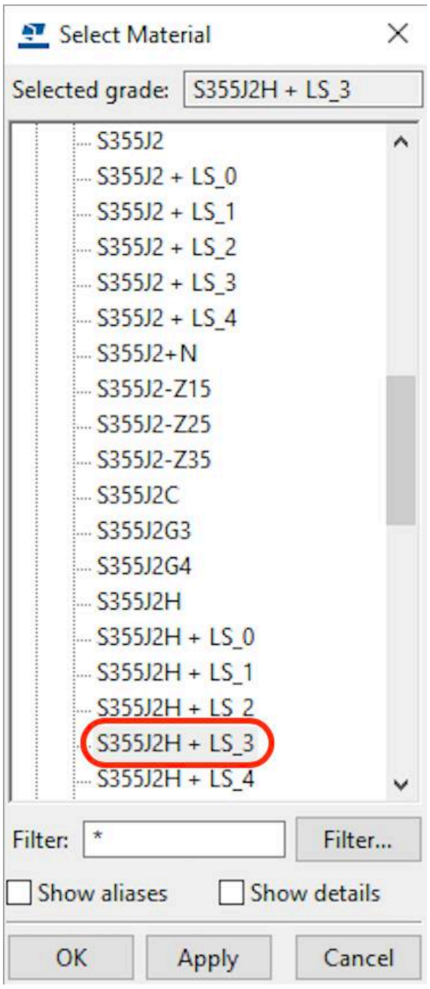

Figure 7. *Different material options for steel, from where EPD levels can be chosen.*

The beam chosen in this example has a steel quality of S355J2H, where "H" stands for hollow profile (SFS-EN 10025-2:2019, 2019, ch. 4.2.2). From the window that shows various material options available to the user (Figure 7), the EDP levels for the steel quality S355J2 and S355J2H can be chosen. As indicated in red in Figure 7, S355J2H + LS_3 has been chosen for the beam.

Once the user selects the desired EPD levels and the model has been numbered, Tekla Structures marks the part drawings and associated documents with the chosen steel qualities, along with the EPD levels. The long-term goal is to incorporate EPD levels for each steel quality available within Nordec's Tekla Structures environment. That allows users to make environmentally conscious decisions regardless of the specific steel grade they choose for their project.

5.3 Implementation of EPD Levels for Concrete Objects

The implementation of EPD levels for concrete follows a similar process as for steel, apart from the different EPD levels. However, the use of EPD levels for concrete may not be as central as for steel, as concrete design is often outsourced to other companies or handled by concrete suppliers themselves. Additionally, Nordec can adopt a collaborative approach in which preliminary design of concrete products are developed in-house, with final structural design and specifications determined by suppliers. Meaning the structural design aligns with Nordec's preliminary design and associated EPD level requirements. In this thesis, an example is provided based on the assumption that Nordec conducts the preliminary design, while another company is responsible for the final structural design.

Due to this, often an undefined concrete material grade is being used in the preliminary design for concrete products. Then, whoever does the structural design can choose the concrete quality later in the process. With the implementation of EPD levels, this approach is being updated. Instead of using an undefined material grade, the EPD level for each specific concrete product is utilized in the preliminary design.

By changing the material grade for a concrete product, an EPD level can be chosen. For this thesis, a hollow-core slab is used as an example to visualize the process. The hollow-core slab is created through a component from the Tekla Structures catalog for applications and components named "Floor layout", meaning the material grade must be changed from the component's dialog box. The material can also be changed for a single concrete product, as visualized for steel objects in Chapter 5.2.

By double-clicking on the concrete product with the component selection activated the properties can be accessed. The structure of all components looks different, but they all have a dialog box where properties for the component can be defined and changed. The dialog box for the component that makes hollow core slabs is visualized in Figure 8. Under the tab "Layer" properties and the material quality can be changed for the hollow-core slab.

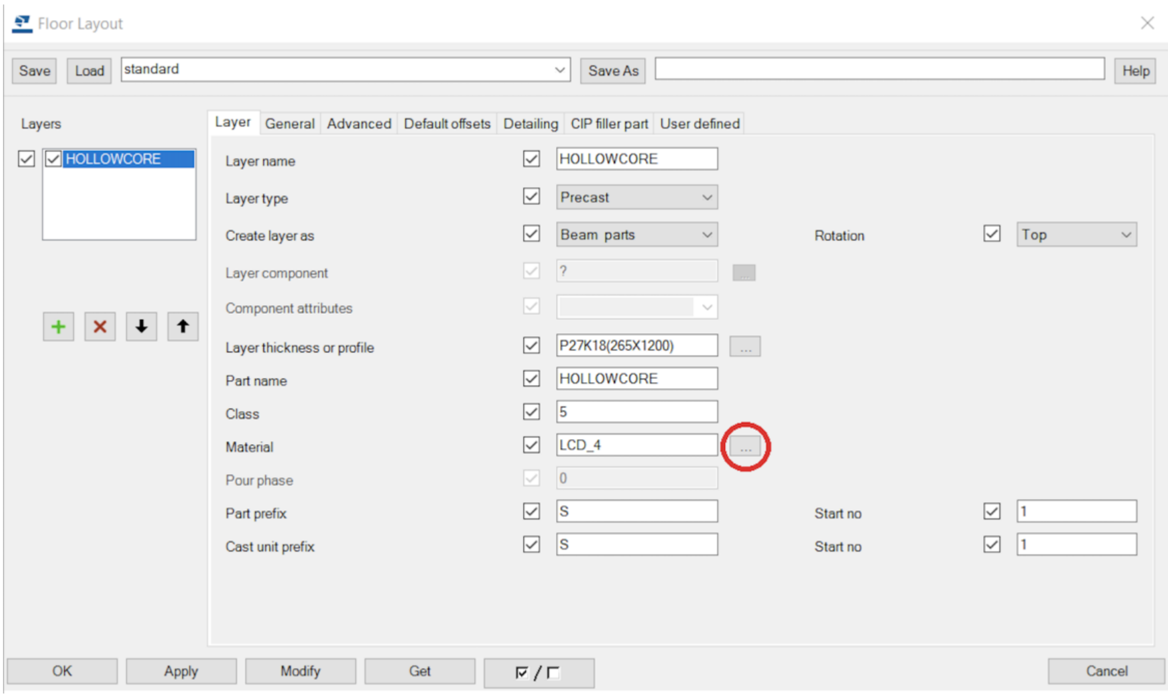

Figure 8. *The dialog box for floor layout component.*

By clicking on the button with three dots, indicated in red in Figure 8, a list appears from where EPD levels can be selected. This window is visualized in Figure 9, showing all EPD levels for both dry and humid environments from table 7 and Table 8.

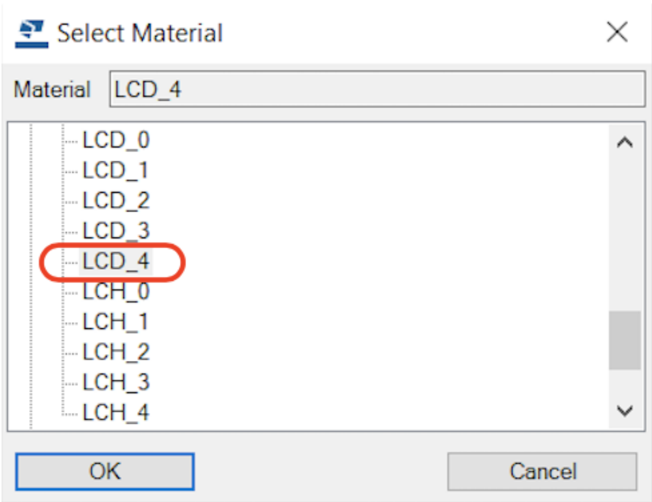

Figure 9. *Different material options for concrete, from where EPD levels can be chosen.*

As with steel, by choosing an EPD level for the objects, the level becomes visible on drawings and associated documentation after the parts have been numbered. For this thesis, EPD level LCD_4 is chosen for the hollow-core slab, which refers to a dry environment and a maximum value of 80 GWP-GHG, kg CO2e/ton for concrete with a water-cement ratio of 0,80. *"Appendix 3"* contains a drawing of a hollow-core slab, where the EPD level is visible as the material grade.

5.4 Implementation of EPDs for Assemblies

For assemblies, specific EPDs can be added by opening the window for user-defined attributes. This window can be accessed by right-clicking on the entire assembly, with the assembly selection activated, and choosing properties. But properties can also be selected from the right toolbar. Once the properties window is opened, user-defined attributes can easily be accessed, visualized with red in Figure 10.

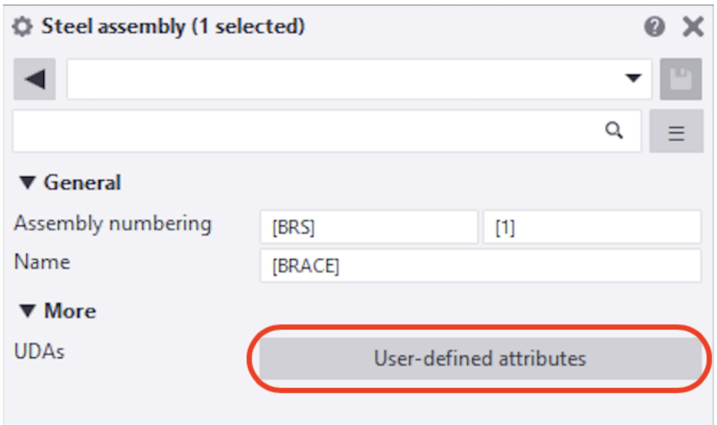

Figure 10. *Properties window for assemblies.*

Under the tab "Nordec Attributes" in the user-defined attributes window, visualized in Figure 11, the specific name of the EPD for the entire assembly can be added in the EPD field, marked with red. Notable is that the user-defined attributes window may appear differently depending on the Tekla Structures environment, and this is a specific Nordec attribute. The EPD set at this stage is also the EPD which will be represented for the entire element in the assembly drawing. For example, if the assembly is a steel truss and is to be manufactured according to Nordec's EPD, "Nordec Low CO_2 Truss, Peräseinäjoki factory", which is visualized in *"Appendix 1"*, the name can be added in the field marked in Figure 11.

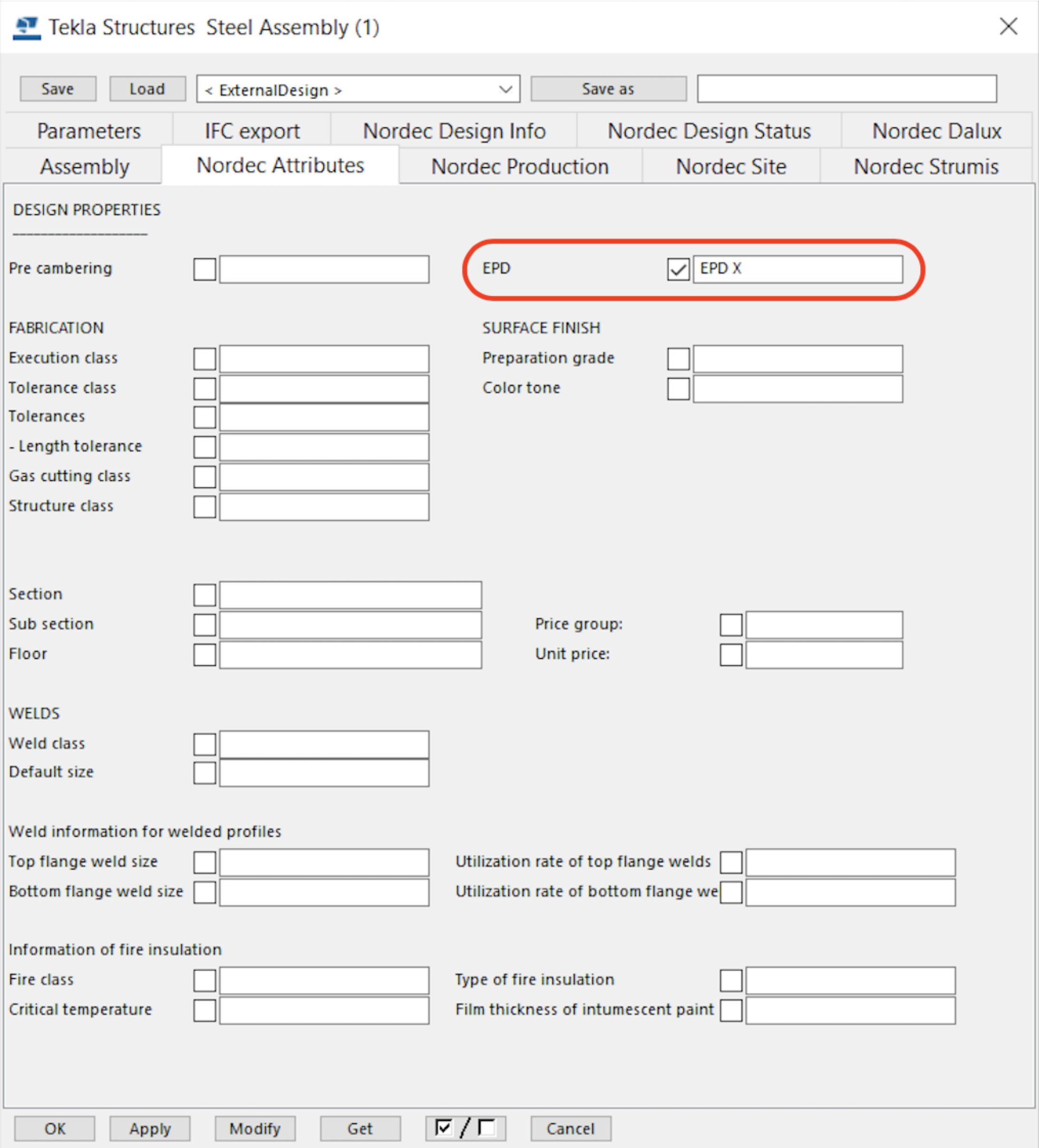

Figure 11. *User-defined attributes for assemblies.*

After completing the model and the EPD levels and EPDs have been added to all parts and elements, the drawings are produced. Drawings including EPD levels and EPDs are presented in "*Appendix 2"* visualizing an assembly drawing and its part drawings. The part drawings are marked with EPD level LS_3, indicating that they must be produced according to LS_3 for them to comply with the specific EPD, which is specified in the assembly drawing. No specific EPD has been chosen for the assembly drawing in this example, only indicated with "EPD X" for visualization.

6 RESULTS

The goal of this thesis was from the beginning to develop a system for the implementation of EPDs into Nordec's design process. After discussion and testing it was decided that the implementation would work better in practice if both EPD levels and EPDs were used. Based on that, levels with maximum values for environmental impact regarding steel and concrete were developed. The levels were then implemented together with EPDs in Tekla Structures. The goal was also that the implementation system would be easy to use and time efficient for all users, whether they are designers, project managers or manufacturers.

Based on which EPDs that are set for elements, EPD levels for all including parts are chosen. In manufacturing, the parts are then manufactured according to the chosen levels, so that the final assembly fulfills the selected EPD. Beyond the levels and system, guidelines for external designers were created for internal use. These guidelines include step-by-step instructions to follow the system and guidance on interpreting and applying EPD levels and EPDs in practice.

The system requires that designers get training about both the system itself but also about EPDs in order for them to know how to work with it. They need to understand how to navigate the system, generate EPD levels for different materials, and interpret the results. Once the building is finished a life cycle assessment is done. With EPDs available, much of the data needed for the assessment is already compiled and standardized, which simplifies the data collection process. Without EPDs, conducting an LCA requires gathering data from various sources which can be time-consuming and challenging.

By having environmental data for the building, it is also easier to maintain and manage the building throughout its life cycle. If the building is made of environmentally friendly materials, the energy performance has been optimized, and the owners have proactive maintenance strategies, the building owners can enhance the resilience, longevity, and sustainability of their properties.

What is an Environmental Product Declaration?

When the project began, familiarity with the term EPD was limited. However, extensive research on the topic has led to a deeper knowledge and understanding. In short, an EPD is a verified document that provides valuable information about a product's or service's environmental impact over its lifetime, as described in more detail in Chapter 2. It is anticipated that EPDs will assume a central role in many industries as environmental requirements are getting stricter year by year.

What are the differences in legislation concerning CO_2 emissions reduction in the construction industry between Finland, Sweden, and Norway?

It is difficult to compare the three countries as legislation regarding CO_2 emissions varies between the countries due to differences in national policies, regulations, and priorities. Finland is advancing with its upcoming Reforming Land Use & Building Act, while Sweden has enacted the Law (2021:787), and Norway follows TEK17.

It can be stated that all three countries have either implemented or are planning regulations mandating the building LCAs to calculate carbon footprints, alongside established or anticipated limit values. However, differences in LCA calculation methods persist, including variations in system boundaries, life cycle scenarios, and reporting requirements. Overall, these countries are dedicated to promoting energy efficiency, sustainability, and the use of renewable energy sources to foster more environmentally friendly built environments.

Where must Environmental Product Declarations be implemented?

To achieve the objective of including EPD information on every drawing, it was necessary to integrate the EPD data into Tekla Structures in a way that seamlessly affected the numbering system, while minimizing time consumption for users. To ensure that it would not become time-consuming it was essential to streamline the process as much as possible. By incorporating EPD levels directly into Tekla Structures' material libraries, users can easily access the information during the modeling and design phase. Material selection is already an inherent part of the modeling process, eliminating the need for an additional step. While selecting EPD for assemblies may be a time-consuming step in the initial phase, it is most likely to gradually become as efficient as other steps in the design phase. However, it is crucial to regularly update and maintain the system to keep values and integration tools current with evolving environmental data and standards.

7 DISCUSSION

This thesis has given me a greater understanding of the significant role environmental impact plays in the construction and operation of buildings. By delving into topics such as life cycle assessment, embodied carbon, Environmental Product Declarations, and resilience to climate change I have gained insight into the multifaceted nature of sustainable building practices.

The system that has been developed in this thesis has many development possibilities. Once the testing phase is complete and any necessary adjustments have been made, methods for implementing EPDs for a wider range of materials, qualities, and products, such as panels, roofing sheets, and other commonly used construction materials can be explored. By extending the system to include a broader range of materials, designers gain access to a more comprehensive database of environmental performance data. This in turn allows for greater flexibility in material selection, resulting in potentially more sustainable designs. The system can also be further developed to allow for customization and tailoring to specific project requirements. This means designers could input project-specific criteria and preferences to generate EPD levels for materials that align closely with the project's sustainability goals.

This thesis can be further developed by delving even deeper into the topic of Environmental Product Declarations, exploring not only their significance but also their practical implementation across various sectors of the construction industry. Specifically, conducting in-depth research on upcoming regulations in different countries.

Personally, I think the system requires a lot of testing and experimenting until it works well. As Marins and Sjöholm mentioned in Chapter 3, one of the main challenges might become the coordination between designers and project managers. But also to keep the inserted data up to date since a lot of information often changes several times during projects. The system also requires a lot of updating, for example maximum values or new EPDs, which might become time-consuming. Overall, I think that it is good for Nordec to have a developed system and to incorporate it in an early stage so that when it becomes mandatory, they already have a well-working system.

Looking ahead, in the future, I believe the circular economy will play an increasingly significant role in the construction industry, particularly focusing emphasis on the reuse of existing buildings and their components. For instance, materials like steel offer numerous opportunities for reuse. Moreover, by mandating the use of construction EPDs, authorities and stakeholders can ensure transparency and accountability throughout the building's lifecycle. As the demand for sustainable construction practices continues to rise, the refurbishment and renovation of existing buildings are likely to take center stage. This shift may also prompt companies like Nordec, primarily focused on new constructions, to recognize the relevance of incorporating EPDs into existing buildings to align with evolving sustainability standards.

7.1 Comments from Designer

Aleksi Slotte, Structural Engineer at Nordec (personal communication 6.5.2024), who has also been assisting with the Tekla Structures aspect, was asked for his thoughts on the system, potential challenges it may present and how it might come to use. Here are his comments:

"I expect the system to work well once the challenges have been worked out in the piloting phase. The main challenge as I see it will be the process leading to smooth coordination between designers and project managers. Especially since the EPDs might change mid-project, which in turn might cause extra work for the designers. Also inputting new attributes to elements in Tekla might prove difficult to remember for some.

The data can be used to make lists and visualizations easily, provided that all data has been correctly inputted into the correct elements in Tekla.

We need to update some list templates and probably make some new list templates in order to use these EPD attributes outside of Tekla."

7.2 Comments from Project Team Leader

To gain insight from the project management perspective, the system was presented to Peter Marins, Project Team Leader at Nordec (Personal communication 7.5.2024), to gather his thoughts on the developed system.

Marins points out that the system appears user-friendly and the guide for designers could also serve as a helpful guide for project managers and fabric workers, aiding their understanding of this functionality. During the presentation, he emphasized the effectiveness of incorporating both visual aids and textual explanations within the system.

He thinks that for the system to work out best in practice, Nordec must strive to have the same EPD levels for as many products as possible, or at least use the same levels in different factories or projects. Having varying levels across different factories could lead to inefficiencies as it would be time-consuming and economically disadvantageous to produce products according to different levels. This means it would require a wider range of raw materials, and element production would be much more complicated when the elements must be put together with parts made according to the right levels.

As Slotte, Marins highlights the potential challenges in raw materials availability and coordination between designers and project managers, since information might change over time depending on several factors. Overall, Marins emphasizes the system's clarity and user-friendliness, seeing it as a promising first step towards integrating EPDs into the design process.

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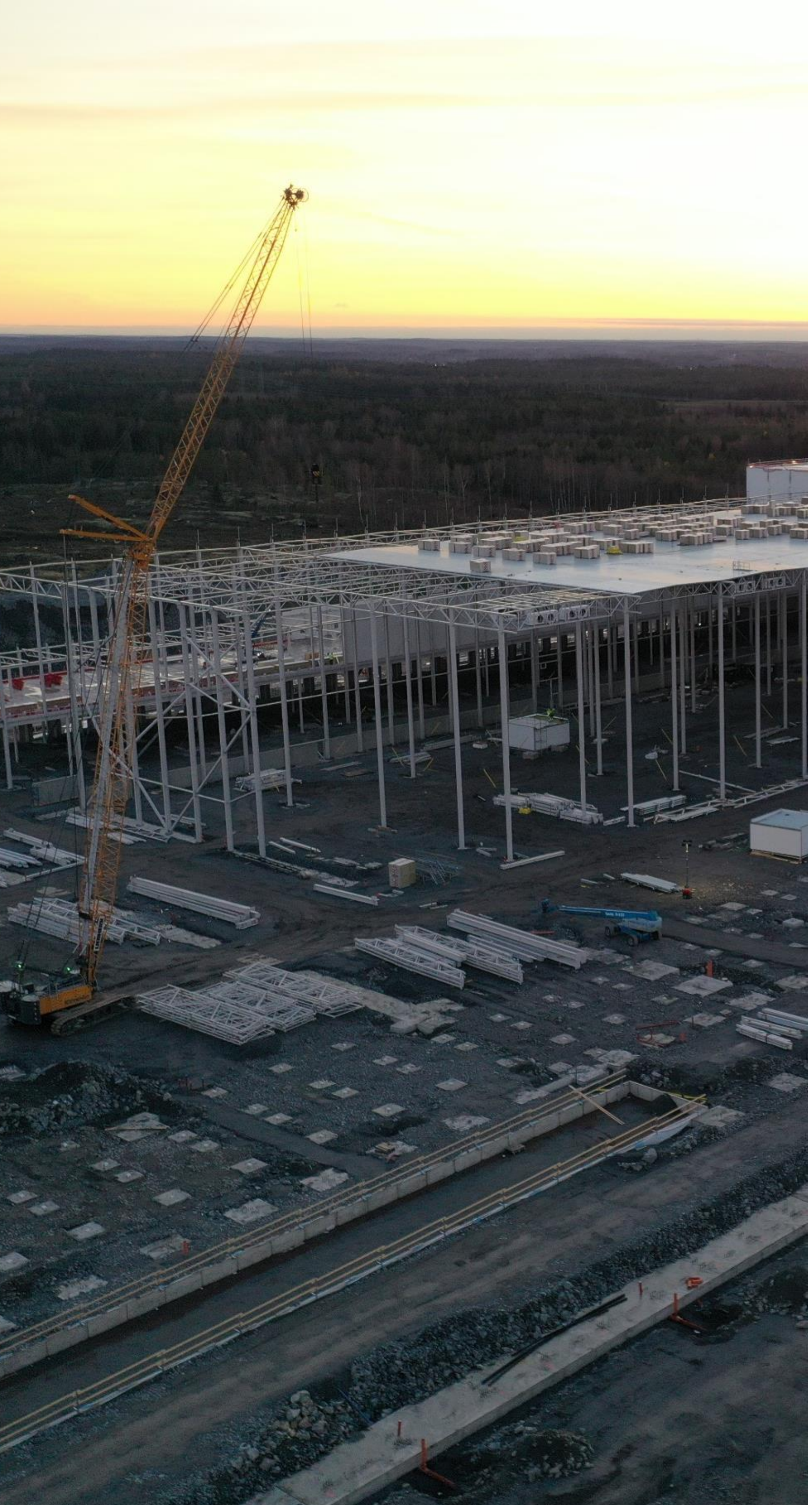

ENVIRONMENTAL PRODUCT DECLARATION

IN ACCORDANCE WITH EN 15804+A2 & ISO 14025 / ISO 21930

Nordec Low CO_2 Truss, Peräseinäjoki factory.

Nordec Group Oyj

EPD HUB, HUB-0918

Publishing date 5 December 2023, last updated on 5 December 2023, valid until 5 Jun 2025.

Created with One Click LCA

GENERAL INFORMATION

MANUFACTURER

Manufacturer	Nordec Group Oyj
Address	Itämerenkatu 5, 00180 Helsinki, Finland
Contact details	info@nordec.com
Website	nordec.com

EPD STANDARDS, SCOPE AND VERIFICATION

Program operator	EPD Hub, hub@epdhub.com
Reference standard	EN 15804+A2:2019 and ISO 14025
PCR	EPD Hub Core PCR version 1.0, 1 Feb 2022
Sector	Construction product
Category of EPD	Design phase EPD
Scope of the EPD	Cradle to gate with options, A4-A5, and modules C1-C4, D
EPD author	Dan Pada, Nordec Group Oyj
EPD verification	Independent verification of this EPD and data, according to ISO 14025: ☐ Internal certification ☑ External verification
EPD verifier	Magaly González Vázquez, as an authorized verifier acting for EPD Hub Limited

The manufacturer has the sole ownership, liability, and responsibility for the EPD. EPDs within the same product category but from different programs may not be comparable. EPDs of construction products may not be comparable if they do not comply with EN 15804 and if they are not compared in a building context.

PRODUCT

Product name	Nordec Low CO_2 Truss
Additional labels	-
Product reference	-
Place of production	Peräseinäjoki, Finland
Period for data	01.01.2022-31.12.2022
Averaging in EPD	No averaging
Variation in GWP-fossil for A1-A3	-

ENVIRONMENTAL DATA SUMMARY

Declared unit	1 kg of painted steel truss
Declared unit mass	1 kg
GWP-fossil, A1-A3 (kgCO2e)	0,906
GWP-total, A1-A3 (kgCO2e)	0,890
Secondary material, inputs (%)	96.3
Secondary material, outputs (%)	92.1
Total energy use, A1-A3 (kWh)	4.1
Total water use, A1-A3 (m3e)	1,27E-02

PRODUCT AND MANUFACTURER

ABOUT THE MANUFACTURER

Nordec is the leading provider of frame structure solutions in the Nordic countries, operating also in Central Eastern Europe. Nordec has decades of experience in designing, producing and delivering frame structures and envelopes for buildings and bridges and industry, optimizing the whole value chain from design to installation. Nordec has 4 factories for the steel structure production in Finland, Poland and Lithuania.
Sustainability is an integral part of Nordec's strategy and the development of low-carbon products and solutions is of high priority. We want to minimize the environmental impact of our products by optimizing material usage and waste. We work together with our material suppliers and customers to find the most sustainable solutions for each project.

PRODUCT DESCRIPTION

This EPD represent steel trusses made of mainly hot-rolled open profiles and cold-formed hollow sections. The steel trusses are used in buildings and industrial projects, most often as roof trusses.
Both the hot-rolled open profiles and the cold-formed hollow sections are made of recycled steel, with a recycling content of 100 %. Steel used for outfitting parts, mainly plates, is made of virgin steel. The steel trusses are produced in Nordec's factory in Peräseinäjoki, Finland.
By using a steel truss, the design can be optimized by adjusting the height of the truss and by combining profiles of different sizes and thicknesses to enable an efficient use of the material. Steel trusses can span great lengths and carry big loads, providing a large open space in the building, enabling flexibility and adaptibility of the building. Furthermore, as the steel trusses are connected to supporting structures using bolted connections, the truss can easily be dismounted and used in another building in the future, enabling a circular economy.

Further information can be found at nordec.com.

PRODUCT RAW MATERIAL MAIN COMPOSITION

Raw material category	Amount, mass- %	Material origin
Metals	99	EU
Minerals	-	-
Fossil materials	1	EU, UK
Bio-based materials	-	-

BIOGENIC CARBON CONTENT

Product's biogenic carbon content at the factory gate

Biogenic carbon content in product, kg C	0
Biogenic carbon content in packaging, kg C	0.008241818

FUNCTIONAL UNIT AND SERVICE LIFE

Declared unit	1 kg of painted steel truss
Mass per declared unit	1 kg
Functional unit	-
Reference service life	-

SUBSTANCES, REACH - VERY HIGH CONCERN

The product does not contain any REACH SVHC substances in amounts greater than 0,1 % (1000 ppm).

PRODUCT LIFE-CYCLE

SYSTEM BOUNDARY

This EPD covers the life-cycle modules listed in the following table.

Product stage			Assembly stage		Use stage							End of life stage				Beyond the system boundaries		
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D		
x	x	x	x	x	MND	MND	MND	MND	MND	MND	MND	x	x	x	x	x		
Raw materials	Transport	Manufacturing	Transport	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstr./demol.	Transport	Waste	Disposal	Reuse	Recovery	Recycling

Modules not declared = MND. Modules not relevant = MNR.

MANUFACTURING AND PACKAGING (A1-A3)

The environmental impacts considered for the product stage cover the manufacturing of raw materials used in the production as well as packaging materials and other ancillary materials. Ancillary materials used are steel shots for shot blasting, welding gases, lubricating oils and cutting liquids. Packaging materials used are wood, cardboard and plastic film. Also, fuels used by machines, and handling of waste formed in the production processes at the manufacturing facilities are included in this stage. Waste treatment include landfilling of inert materials and treatment and incineration of hazardous oils and liquids. Also VOC-emissions to air are considered. The study also considers the material losses occurring during the manufacturing processes as well as losses during electricity transmission.

The main raw material is hot-rolled open steel profiles used in the chords, whereof close to 100 % is made from recycled steel in electric arc furnaces, as well as cold-formed hollow sections, used in the diagonals and verticals, whereof close to 100 % is made from recycled steel in electric arc furnaces.

Outfitting parts are made of mostly hot-rolled plates, whereof close to 100 % is made from virgin steel produced in blast furnaces. The steel is transported by train, lorry and ship to the production site in Peräseinäjoki, Finland. The steel profiles are shot blasted and cut to length and shape. The structure is assembled and outfitted with plates for connections and all parts are welded together. The welded structures are painted and packed for transportation.

TRANSPORT AND INSTALLATION (A4-A5)

Transportation impacts occurred from final products delivery to construction site (A4) cover fuel direct exhaust emissions, environmental impacts of fuel production, as well as related infrastructure emissions.

Distance and method of transportation from the factory to the building sites is calculated as a weighted average of the actual transports in the year studied (2022). Method of transportation is lorry and ship. Transportation does not cause any losses as the structures are packaged properly and secured to the trailer.

Energy consumption for installation on site is assumed to be the same as for demolition (C1), i.e. 0,01 kWh/kg, as diesel used in the building machinery.

Packaging materials (wood, cardboard and plastics) are recycled or incinerated for energy recovery, which is considered in this model, as well as direct emissions to the air of carbon dioxide to balance emissions of biogenic CO_2.

PRODUCT USE AND MAINTENANCE (B1-B7)

This EPD does not cover the use phase.

Air, soil, and water impacts during the use phase have not been studied.

PRODUCT END OF LIFE (C1-C4, D)

The energy consumption of the demolition process is on average 10 kWh/m2 (Bozdag, Ö. & Secer, M. 2007). Considering an average mass of 1000 kg/m2 of a concrete building, the energy consumption for demoltion (C1) can be assumed to be 0,01 kWh/kg. The source of energy is diesel used in the building machinery.
100 % of the steel structures are assumed to be collected during demolition and transported 50 km by lorry (C2) for further treatment.
Based on data from the European Steel Association, the recycling rate of steel from construction is assumed to be 93 % (C3). The remaining 7 % is taken to landfill for final disposal (C4). Due to the recycling process the end-of-life product is converted back into recycled steel (D), however, benefit is considered only for the virgin steel, not for the recycled steel. The benefit from the packaging material recovery is considered.

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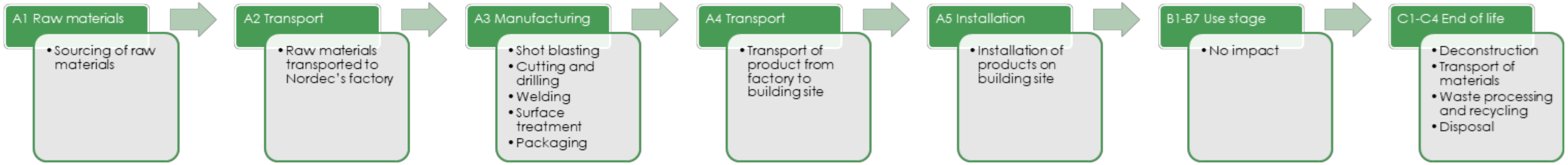
MANUFACTURING PROCESS



LIFE-CYCLE ASSESSMENT

CUT-OFF CRITERIA

The study does not exclude any modules or processes which are stated mandatory in the reference standard and the applied PCR. The study does not exclude any hazardous materials or substances. The study includes all major raw material and energy consumption. All inputs and outputs of the unit processes, for which data is available for, are included in the calculation. There is no neglected unit process more than 1% of total mass or energy flows. The module specific total neglected input and output flows also do not exceed 5% of energy usage or mass.
Fastening materials are excluded from A5 as they form a very small part of the installed product and are not always part of the scope of delivery. The paint coating has not been separated from the steel for waste processing as it is assumed the paint is not removed before recycling and any impacts are deemed to be negligible.

ALLOCATION, ESTIMATES AND ASSUMPTIONS

Allocation is required if some material, energy, and waste data cannot be measured separately for the product under investigation. All allocations are done as per the reference standards and the applied PCR. In this study, allocation has been done in the following ways.
Raw materials are based on product recipe whereas packaging materials, ancillary materials and manufacturing energy and waste are known on factory level and allocated to 1 kg of product.

Data type	Allocation
Raw materials	No allocation
Packaging materials	Allocated by mass or volume
Ancillary materials	Allocated by mass or volume
Manufacturing energy and waste	Allocated by mass or volume

AVERAGES AND VARIABILITY

Type of average	No averaging
Averaging method	Not applicable
Variation in GWP-fossil for A1-A3	-

This EPD is product and factory specific and does not contain average calculations.

LCA SOFTWARE AND BIBLIOGRAPHY

This EPD has been created using One Click LCA EPD Generator. The LCA and EPD have been prepared according to the reference standards and ISO 14040/14044. Ecoinvent v3.8 and One Click LCA databases were used as sources of environmental data.

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ENVIRONMENTAL IMPACT DATA

CORE ENVIRONMENTAL IMPACT INDICATORS – EN 15804+A2, PEF

Impact category	Unit	A1	A2	A3	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
GWP – total[1)]	kg CO_2e	6,55E-01	1,61E-01	7,44E-02	8,90E-01	4,35E-02	3,40E-02	MND	MND	MND	MND	MND	MND	MND	3,31E-03	8,15E-03	3,09E-02	8,89E-04	-1,24E-02
GWP – fossil	kg CO_2e	6,41E-01	1,61E-01	1,04E-01	9,06E-01	4,35E-02	3,78E-03	MND	MND	MND	MND	MND	MND	MND	3,31E-03	8,14E-03	2,40E-02	3,69E-04	-1,24E-02
GWP – biogenic	kg CO_2e	-7,93E-03	4,22E-05	-2,97E-02	-3,76E-02	1,58E-05	3,02E-02	MND	MND	MND	MND	MND	MND	MND	6,06E-07	0,00E+00	6,91E-03	5,20E-04	-1,40E-05
GWP – LULUC	kg CO_2e	2,18E-02	1,12E-04	5,16E-05	2,20E-02	1,99E-05	5,08E-07	MND	MND	MND	MND	MND	MND	MND	3,30E-07	3,26E-06	3,12E-05	3,48E-07	-1,10E-05
Ozone depletion pot.	kg CFC-11e	2,37E-08	3,21E-08	1,25E-08	6,83E-08	1,02E-08	7,64E-10	MND	MND	MND	MND	MND	MND	MND	7,07E-10	1,89E-09	2,58E-09	1,49E-10	-6,44E-10
Acidification potential	mol H^+e	3,34E-03	3,65E-03	2,07E-04	7,19E-03	5,19E-04	3,80E-05	MND	MND	MND	MND	MND	MND	MND	3,44E-05	2,31E-05	2,75E-04	3,47E-06	-9,29E-05
EP-freshwater[2)]	kg Pe	6,72E-05	1,41E-06	1,12E-06	6,97E-05	2,61E-07	1,66E-08	MND	MND	MND	MND	MND	MND	MND	1,10E-08	5,81E-08	1,04E-06	3,86E-09	-4,63E-07
EP-marine	kg Ne	6,35E-04	9,32E-04	6,22E-05	1,63E-03	1,27E-04	1,68E-05	MND	MND	MND	MND	MND	MND	MND	1,52E-05	4,62E-06	5,83E-05	1,20E-06	-1,11E-05
EP-terrestrial	mol Ne	6,48E-03	1,03E-02	6,86E-04	1,75E-02	1,41E-03	1,84E-04	MND	MND	MND	MND	MND	MND	MND	1,67E-04	5,13E-05	6,72E-04	1,32E-05	-1,38E-04
POCP (“smog”)[3)]	kg NMVOCe	2,20E-03	2,71E-03	3,90E-03	8,82E-03	3,96E-04	5,01E-05	MND	MND	MND	MND	MND	MND	MND	4,59E-05	1,97E-05	1,84E-04	3,84E-06	-4,07E-05
ADP-minerals & metals[4)]	kg Sbe	3,06E-06	3,28E-07	1,57E-07	3,55E-06	9,10E-08	3,34E-09	MND	MND	MND	MND	MND	MND	MND	1,68E-09	2,95E-08	2,74E-06	8,47E-10	-3,51E-08
ADP-fossil resources	MJ	7,32E+00	2,16E+00	1,46E+00	1,09E+01	6,50E-01	4,95E-02	MND	MND	MND	MND	MND	MND	MND	4,45E-02	1,21E-01	2,87E-01	1,01E-02	-1,55E-01
Water use[5)]	m^3e depr.	2,79E-01	1,12E-02	9,03E-03	2,99E-01	2,70E-03	1,38E-03	MND	MND	MND	MND	MND	MND	MND	1,20E-04	5,67E-04	4,88E-03	3,21E-05	-1,00E-03

1) GWP = Global Warming Potential; 2) EP = Eutrophication potential. Required characterisation method and data are in kg P-eq. Multiply by 3,07 to get PO4e; 3) POCP = Photochemical ozone formation; 4) ADP = Abiotic depletion potential; 5) EN 15804+A2 disclaimer for Abiotic depletion and Water use and optional indicators except Particulate matter and Ionizing radiation, human health. The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator.

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USE OF NATURAL RESOURCES

Impact category	Unit	A1	A2	A3	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Renew. PER as energy[8)]	MJ	2,49E+00	4,13E-02	1,27E+00	3,80E+00	7,36E-03	3,64E-04	MND	MND	MND	MND	MND	MND	MND	2,54E-04	1,76E-03	4,42E-02	8,78E-05	-3,71E-02
Renew. PER as material	MJ	7,77E-02	0,00E+00	2,38E-01	3,15E-01	0,00E+00	-2,43E-01	MND	MND	MND	MND	MND	MND	MND	0,00E+00	0,00E+00	-6,75E-02	-5,08E-03	-1,61E-04
Total use of renew. PER	MJ	2,56E+00	4,13E-02	1,51E+00	4,12E+00	7,36E-03	-2,42E-01	MND	MND	MND	MND	MND	MND	MND	2,54E-04	1,76E-03	-2,33E-02	-4,99E-03	-3,72E-02
Non-re. PER as energy	MJ	7,35E+00	2,16E+00	1,45E+00	1,10E+01	6,50E-01	4,95E-02	MND	MND	MND	MND	MND	MND	MND	4,45E-02	1,21E-01	2,87E-01	1,01E-02	-1,51E-01
Non-re. PER as material	MJ	5,46E-02	0,00E+00	7,14E-04	5,53E-02	0,00E+00	-4,29E-03	MND	MND	MND	MND	MND	MND	MND	0,00E+00	0,00E+00	-4,75E-02	-3,57E-03	1,61E-04
Total use of non-re. PER	MJ	7,41E+00	2,16E+00	1,45E+00	1,10E+01	6,50E-01	4,52E-02	MND	MND	MND	MND	MND	MND	MND	4,45E-02	1,21E-01	2,39E-01	6,53E-03	-1,51E-01
Secondary materials	kg	9,63E-01	1,09E-03	1,04E-03	9,65E-01	2,05E-04	2,47E-05	MND	MND	MND	MND	MND	MND	MND	1,74E-05	4,13E-05	3,08E-04	2,12E-06	1,10E-03
Renew. secondary fuels	MJ	4,06E-05	4,15E-06	9,00E-06	5,37E-05	1,40E-06	8,34E-08	MND	MND	MND	MND	MND	MND	MND	5,70E-08	4,54E-07	1,57E-05	5,55E-08	-4,75E-06
Non-ren. secondary fuels	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	MND	MND	MND	MND	MND	MND	MND	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of net fresh water	m^3	1,22E-02	2,93E-04	2,19E-04	1,27E-02	7,45E-05	-8,09E-07	MND	MND	MND	MND	MND	MND	MND	2,70E-06	1,55E-05	1,39E-04	1,11E-05	-1,28E-04

8) PER = Primary energy resources.

END OF LIFE – WASTE

Impact category	Unit	A1	A2	A3	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Hazardous waste	kg	9,42E-02	3,74E-03	4,96E-03	1,03E-01	7,28E-04	6,48E-05	MND	MND	MND	MND	MND	MND	MND	5,96E-05	1,38E-04	2,21E-03	0,00E+00	-1,37E-03
Non-hazardous waste	kg	7,58E-01	6,02E-02	3,78E-02	8,56E-01	1,08E-02	1,91E-02	MND	MND	MND	MND	MND	MND	MND	4,19E-04	2,45E-03	5,59E-02	7,00E-02	-3,75E-02
Radioactive waste	kg	4,09E-05	1,50E-05	1,73E-06	5,76E-05	4,52E-06	3,30E-07	MND	MND	MND	MND	MND	MND	MND	3,13E-07	8,34E-07	1,26E-06	0,00E+00	-7,89E-07

END OF LIFE – OUTPUT FLOWS

Impact category	Unit	A1	A2	A3	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Components for re-use	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	MND	MND	MND	MND	MND	MND	MND	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for recycling	kg	1,90E-02	0,00E+00	0,00E+00	1,90E-02	0,00E+00	7,00E-04	MND	MND	MND	MND	MND	MND	MND	0,00E+00	0,00E+00	9,30E-01	0,00E+00	0,00E+00
Materials for energy rec	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	MND	MND	MND	MND	MND	MND	MND	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,69E-01	MND	MND	MND	MND	MND	MND	MND	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

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ENVIRONMENTAL IMPACTS – EN 15804+A1, CML / ISO 21930

Impact category	Unit	A1	A2	A3	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Global Warming Pot.	kg CO_2e	6,44E-01	1,60E-01	1,02E-01	9,05E-01	4,31E-02	3,74E-03	MND	MND	MND	MND	MND	MND	MND	3,27E-03	8,07E-03	2,36E-02	3,61E-04	-1,21E-02
Ozone depletion Pot.	kg CFC_{-11}e	3,77E-08	2,55E-08	1,09E-08	7,40E-08	8,07E-09	6,07E-10	MND	MND	MND	MND	MND	MND	MND	5,60E-10	1,50E-09	2,08E-09	1,18E-10	-5,37E-10
Acidification	kg SO_2e	3,06E-03	2,90E-03	1,60E-04	6,13E-03	4,16E-04	2,71E-05	MND	MND	MND	MND	MND	MND	MND	2,45E-05	1,90E-05	2,22E-04	2,62E-06	-7,88E-05
Eutrophication	kg PO_4^{3}e	1,64E-03	3,72E-04	5,48E-05	2,06E-03	5,47E-05	8,43E-06	MND	MND	MND	MND	MND	MND	MND	5,69E-06	4,10E-06	6,90E-05	5,65E-07	-1,91E-05
POCP ("smog")	kg C_2H_4e	2,19E-04	7,69E-05	1,64E-05	3,13E-04	1,22E-05	6,38E-07	MND	MND	MND	MND	MND	MND	MND	5,36E-07	9,59E-07	8,44E-06	1,10E-07	-4,02E-06
ADP-elements	kg Sbe	3,50E-06	3,22E-07	1,54E-07	3,98E-06	8,86E-08	3,20E-09	MND	MND	MND	MND	MND	MND	MND	1,65E-09	2,88E-08	2,74E-06	8,35E-10	-3,52E-08
ADP-fossil	MJ	7,99E+00	2,17E+00	1,46E+00	1,16E+01	6,50E-01	4,95E-02	MND	MND	MND	MND	MND	MND	MND	4,45E-02	1,21E-01	2,87E-01	1,01E-02	-1,52E-01

VERIFICATION STATEMENT

VERIFICATION PROCESS FOR THIS EPD

This EPD has been verified in accordance with ISO 14025 by an independent, third-party verifier by reviewing results, documents and compliancy with reference standard, ISO 14025 and ISO 14040/14044, following the process and checklists of the program operator for:

- This Environmental Product Declaration
- The Life-Cycle Assessment used in this EPD
- The digital background data for this EPD

Why does verification transparency matter? Read more online
This EPD has been generated by One Click LCA EPD generator, which has been verified and approved by the EPD Hub.

THIRD-PARTY VERIFICATION STATEMENT

I hereby confirm that, following detailed examination, I have not established any relevant deviations by the studied Environmental Product Declaration (EPD), its LCA and project report, in terms of the data collected and used in the LCA calculations, the way the LCA-based calculations have been carried out, the presentation of environmental data in the EPD, and other additional environmental information, as present with respect to the procedural and methodological requirements in ISO 14025:2010 and reference standard.

I confirm that the company-specific data has been examined as regards plausibility and consistency; the declaration owner is responsible for its factual integrity and legal compliance.

I confirm that I have sufficient knowledge and experience of construction products, this specific product category, the construction industry, relevant standards, and the geographical area of the EPD to carry out this verification.

I confirm my independence in my role as verifier; I have not been involved in the execution of the LCA or in the development of the declaration and have no conflicts of interest regarding this verification.

Magaly González Vázquez, as an authorized verifier acting for EPD Hub Limited
05.12.2023

VERIFIED ISO 14025

ANNEX 1 – ADDITIONAL INFORMATION FOR NORWAY

The following self-declared data are given to meet the requirements for Norway.

MODULE A4, TRANSPORT FROM PRODUCTION SITE TO OSLO

GWP total: 9,83E-02 kgCO_2e
GWP fossil: 9,82E-02 kgCO_2e

DANGEROUS SUBSTANCES

The ready product does not contain any dangerous substances according to REACH or the Norwegian priority list in amounts greater than 0,1 % (1000 ppm).

ELECTRICITY IN MANUFACTURING PROCESS, MODULE A3

Peräseinäjoki: Electricity production, hydro, run-of-river (Reference product: electricity, high voltage). Ecoinvent 3.8. 0,0042 kgCO_2e/kWh

INDOOR AIR EMISSIONS

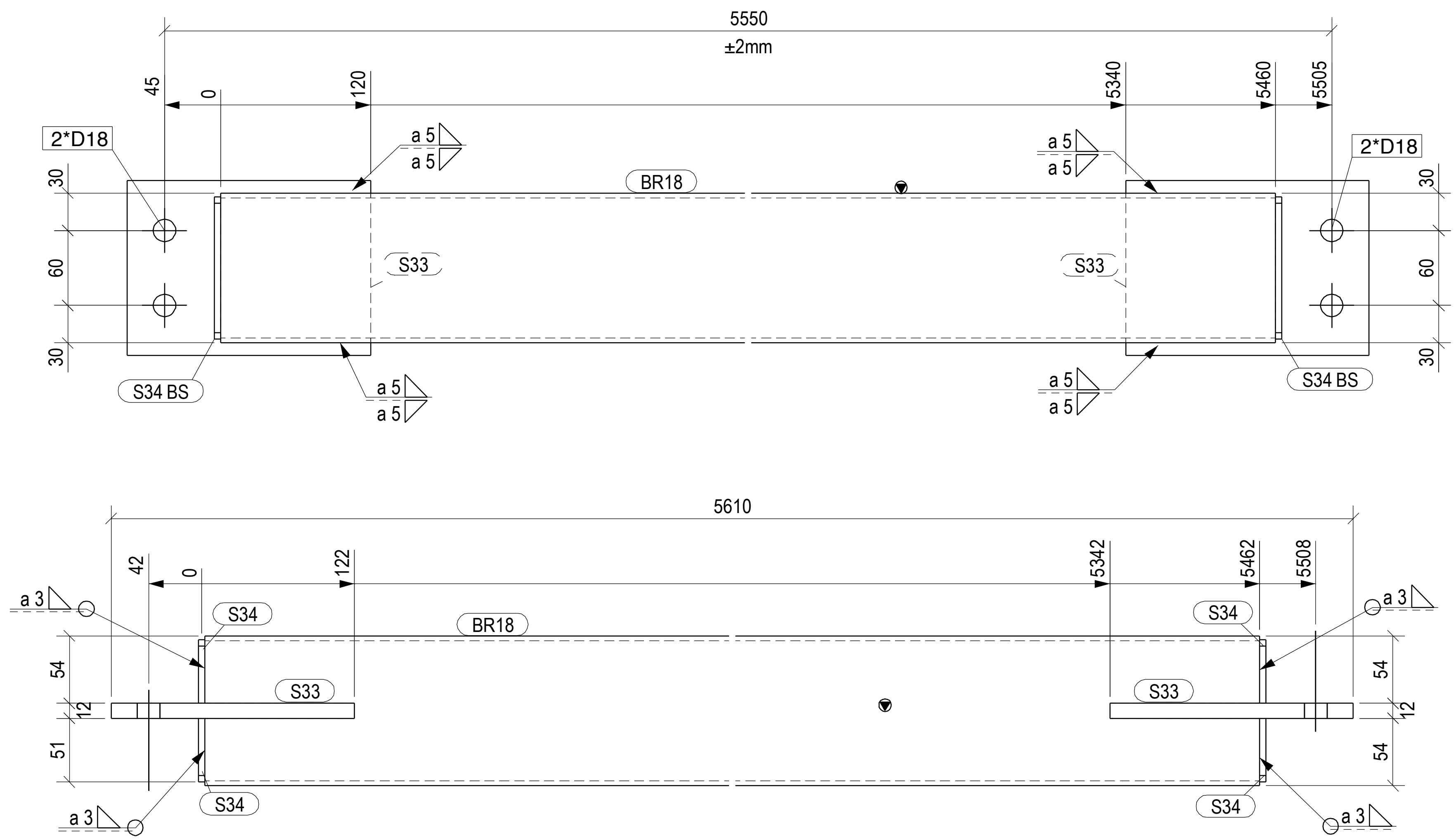
The ready product does not cause any indoor air emissions.

Identification label at this end

Quality control according to quality plan		Execution class:	EXC2 (SS-EN 1090-2)
Structural class:	Sk3/CC2a	Tolerance class:	Class 1 (SS-EN 1090-2)
Preparation grade:	P2 (SS-EN ISO 8501-3) According to manufacturing plan	Fabrication tolerances:	542 (SS-EN ISO 9013)
		- length tolerance	
Welding class:	C (SS-EN ISO 5817)	Pre-camber:	
Thermal cutting class:		Welds, if not otherwise noted:	
Surface treatment:	TE65 B (EP100/1-FeSa2½)		
Colour:	RAL7047	EPD:	EPD X

Part	Profile	Length (mm)	Material	Pcs	kg/Pcs
BR18	CFRHS120X120X4	5460	S355J2H + LS_3	1	77.8
S33	PL12X140	195	S355J2 + LS_3	2	2.6
S34	PL5X51	114	S355J2 + LS_3	4	0.2

BRS22		
	TOTAL WEIGHT OF ASSEMBLY [kg]	84
	ASSEMBLIES TO BE MANUFACTURED [pcs]	1



Mark	Revision	Created by	Date

Construction site and address	Content of drawing	Scale
Nordec Oy	BRACE	1:5

Nordec Oy
Hovrättsesplanaden 19 A
FIN-65100 Vasa
tel. +358 20 420 7000

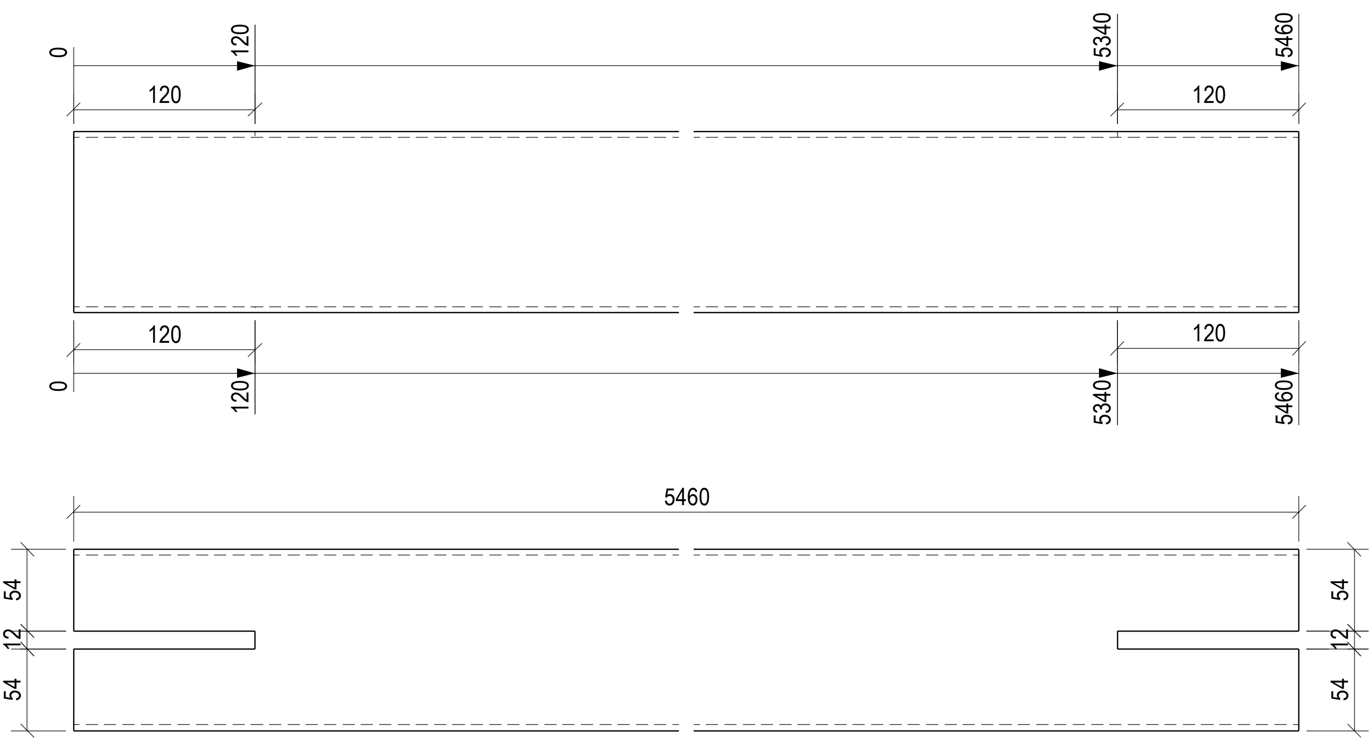
Drawn by	Designed by	Drawing type	Project number
M Österblad	M Österblad		1
Date	**Approved by**	**Drawing number**	**Revision**
26.02.2024		BRS22	

Tekla Structures

Execution class:	Part	Profile	Length (mm)	Material	Pcs	kg/Pcs
EXC2 (SS-EN 1090-2)	BR18	CFRHS120X120X4	5460	S355J2H + LS_3	1	77.8

Thermal cutting class:

Preparation grade:
P2 (SS-EN ISO 8501-3)



Mark	Revision	Created by	Date

Construction site and address: Nordec Oy

Content of drawing: BRACE

Scale: 1:5

Nordec Oy
Hovrättsesplanaden 19 A
FIN-65100 Vasa
tel. +358 20 420 7000

Drawn by	Designed by	Drawing type	Project number
M Österblad	M Österblad		1

Date	Approved by	Drawing number	Revision
26.02.2024		BR18	

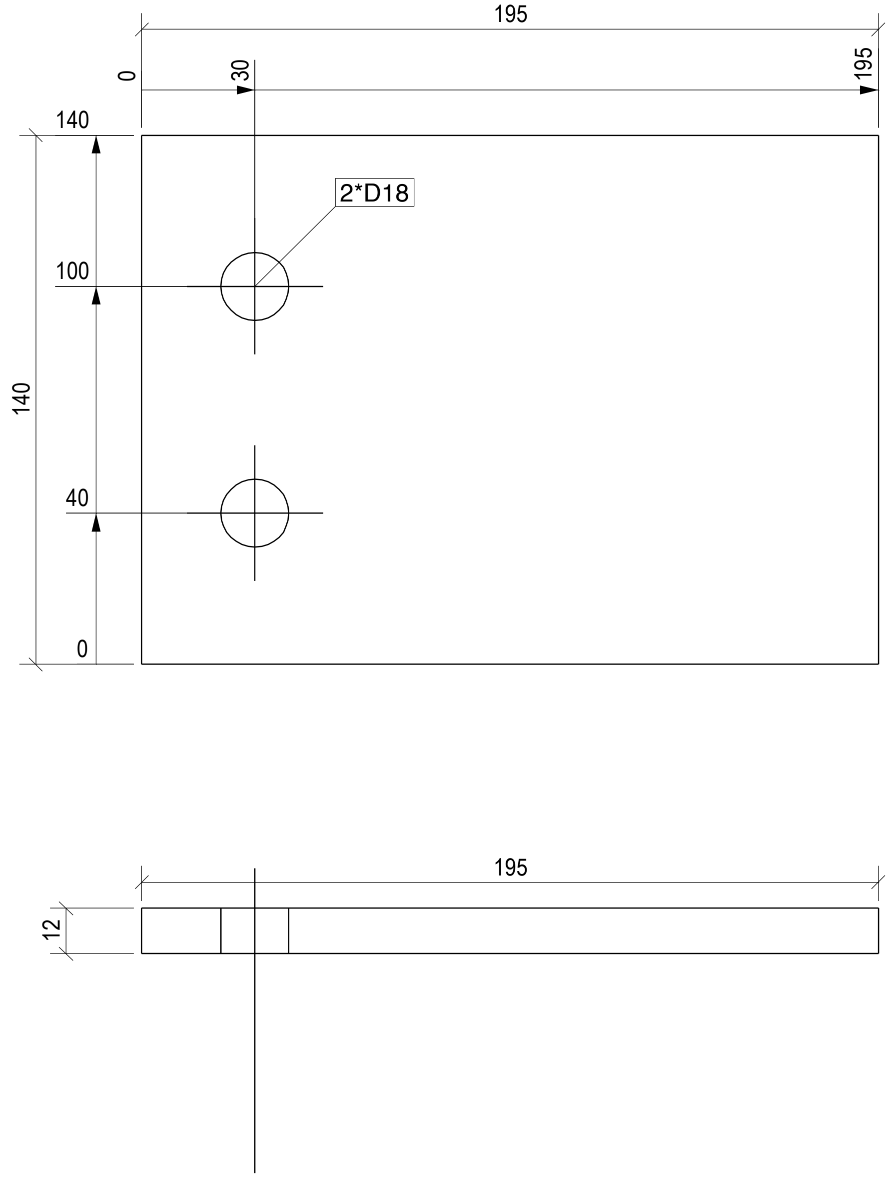
Tekla Structures

Execution class:	Part	Profile	Length (mm)	Material	Pcs	kg/Pcs
EXC2 (SS-EN 1090-2)	S33	PL12X140	195	S355J2 + LS_3	2	2.6

Thermal cutting class:

Preparation grade:

P2 (SS-EN ISO 8501-3)



Mark	Revision	Created by	Date

Construction site and address

Nordec Oy

Nordec Oy
Hovrättsesplanaden 19 A
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tel. +358 20 420 7000

Content of drawing: PLATE

Scale: 1:2

Drawn by	Designed by	Drawing type	Project number
M Österblad	M Österblad		1

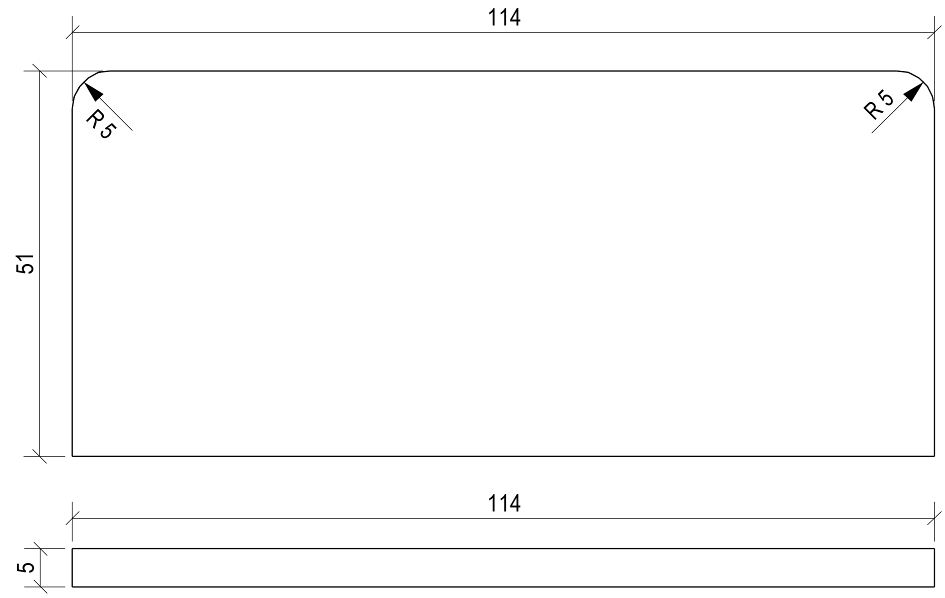
Date	Approved by	Drawing number	Revision
26.02.2024		S33	

Tekla Structures

Execution class:	Part	Profile	Length (mm)	Material	Pcs	kg/Pcs
EXC2 (SS-EN 1090-2)	S34	PL5X51	114	S355J2 + LS_3	4	0.2

Thermal cutting class:

Preparation grade:
P2 (SS-EN ISO 8501-3)



Mark	Revision	Created by	Date

Construction site and address Nordec Oy	Content of drawing PLATE		Scale 1:1
Nordec Oy Hovrättsesplanaden 19 A FIN-65100 Vasa tel. +358 20 420 7000			
Drawn by M Österblad	Designed by M Österblad	Drawing type	Project number 1
Date 26.02.2024	Approved by	Drawing number S34	Revision

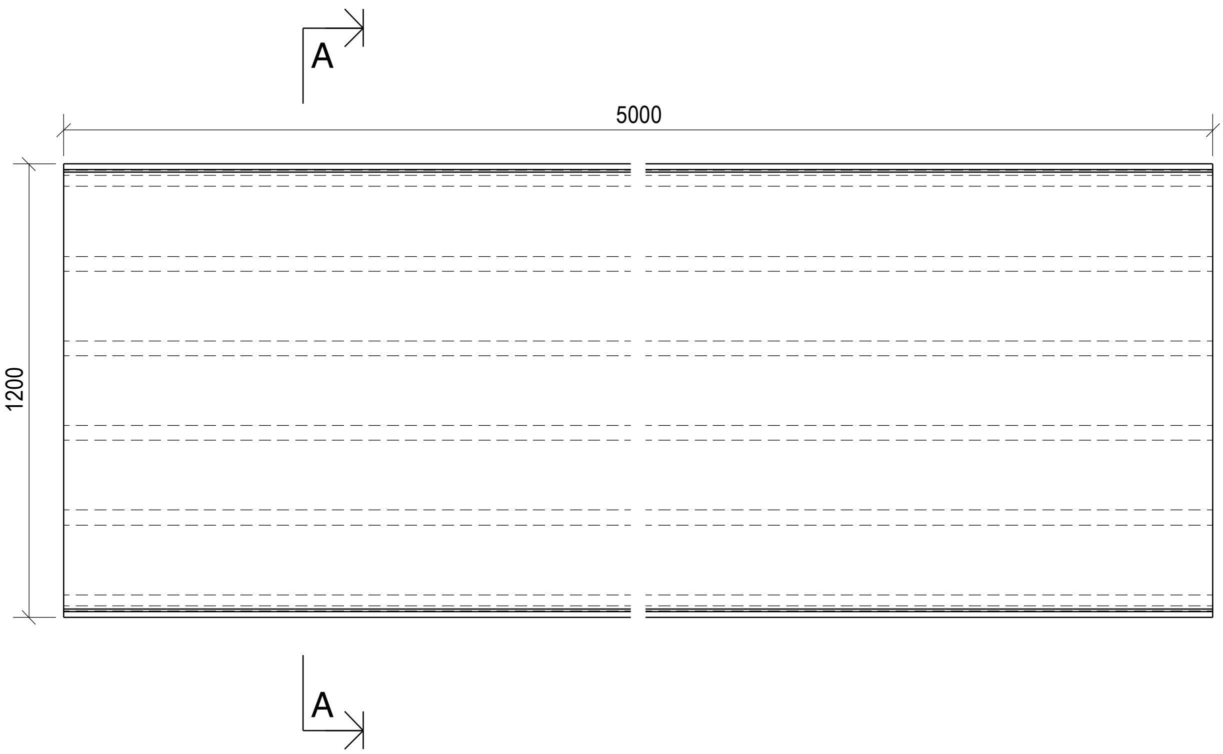
Tekla Structures

Execution class:	Part	Profile	Length (mm)	Material	Pcs	kg/Pcs
EXC2 (SS-EN 1090-2)	1HCS1000	P27(265X1200)	5000	LCD_4	1	2094.2

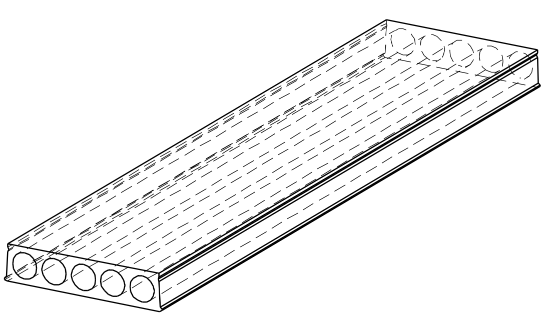
Thermal cutting class:

Preparation grade:

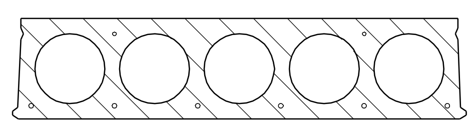
P2 (SS-EN ISO 8501-3)



Top view
1:20



3D view
1:50



A - A
1:20

Mark	Revision	Created by	Date

Construction site and address Nordec Oy Nordec Oy Hovrättsesplanaden 19 A FIN-65100 Vasa tel. +358 20 420 7000		Content of drawing HOLLOW-CORE-SLAB	Scale
Drawn by M Österblad	Designed by M Österblad	Drawing type	Project number 1
Date	Approved by	Drawing number 1HCS1000	Revision

Tekla Structures