Lifecycle assessment of steel-framed building

HAMK Sheet Metal Centre

HÄMEEN AMMATTIKORKEAKOULU
HÄME UNIVERSITY OF APPLIED SCIENCES

Bachelor’s thesis

Construction Engineering degree

Spring Semester 2023

Georgi Georgiev

HÄMEEN AMMATTIKORKEAKOULU
HÄME UNIVERSITY OF APPLIED SCIENCES

Degree Programme in Construction Engineering | Abstract
Author | Georgi Georgiev | Year 2023
Subject | Lifecycle assessment of steel-framed building HAMK Sheet Metal Centre
Supervisor | Zhongcheng Ma

This thesis highlights a practical software implementation utilizing Tekla and OneClick LCA to produce a Lifecycle Assessment report of HAMK Sheet Metal Centre. The assessment adheres to European policies and regulations concerning LCA, specifically ISO 14040 and ISO 14044. The building has already been constructed during the assessment, so the report concentrates on comparing the building's circularity between two end-of-life scenarios.

The findings include building assessment information, classification, and life-cycle stages for various parameters. Additionally, the report emphasizes the legal framework assessors need to comply with to generate reliable results and the importance of their interpretation. The thesis presents evidence that deconstructing and reusing materials enhances building circularity, ultimately reducing the energy input required for new materials.

The results show that designing for deconstruction and reuse of the steel profiles and sandwich panels improves the building circularity index by 8 percent.

Keywords Lifecycle Assessment, software implementation, building circularity
Pages 38 pages and appendices 12 pages

Content

List of figures and tables

Appendices

1 Introduction

The challenges of climate change, resource depletion and sustainable development have become main topic of discussion in the past decade. Economic stimulus and the cost of materials motivate the market to seek alternatives by developing new efficiency and construction methods. The construction industry plays a major role in global resource consumption, and it requires advancements to meet growing needs. To evaluate the environmental impact of buildings from raw material extraction to recycling, a comprehensive methodology called life-cycle assessment is increasingly being used.

Over time, the design and construction of buildings have become increasingly complex, and with advancements in materials, they are now able to withstand greater loads and more severe environmental conditions. At certain stage, the organic progress in materials development hits a sustainability roadblock. For example, Portland cement, stainless steel, or insulation materials are products of chemical and mechanical processing of raw materials. The manufacturing of steel is another example of a very high energy-demanding process. From an environmental standpoint, such a rapid jump in raw material processing emits a high volume of carbon dioxide into the atmosphere. One of the main benefits of Life Cycle Assessment (LCA) is its capability to measure the environmental impact of a building in a quantitative manner. It does not necessarily promote the use of less materials but to use them in a more innovative, and efficient way. Aspiring civil engineers must understand the environmental implications of their decisions. To this end, this thesis presents a quantitative approach to implementing Life Cycle Assessment (LCA) for a building and exploring several alternative options.

1.1 Research question and objectives

The thesis aims to conduct a Lifecycle assessment of an already existing steel-framed building by utilizing available LCA and Building Information Software (BIM). The assessment will comply with current standards and local regulations, and the results will be analysed based on the proposed framework of the ISO standard. The data used will be exclusively quantifiable. Another crucial objective is to provide a legal framework for performing LCA and conduct relevant literature review. Furthermore, it will present two scenarios. Scenario one will determine what will the building circularity be in the case of reusing the steel columns, beams, and trusses. Scenario two will determine what will be the building circularity in the case of reusing the sandwich panes as well as the steel frame in another project. There is an endless count of comparison scenarios, but this building circularity percentage is representative of most.

1.2 Scope and limitations

The evaluation focuses on a building that has been existing for seven years since its construction. Ideally, LCA should be conducted during the early stages of a project, particularly during the design phase, for optimal results. According to ISO 14040 (International Standards Organization, 2006), LCA should start as early as the design phase. At this stage, deciding on the right materials and concepts is crucial. LCA can be helpful in making that decision. However, since it is currently not an option, the existing building is analysed using available tools and data. But this approach comes with challenges, such as the need for more material information and transportation methods specific to the time of manufacture and construction site.

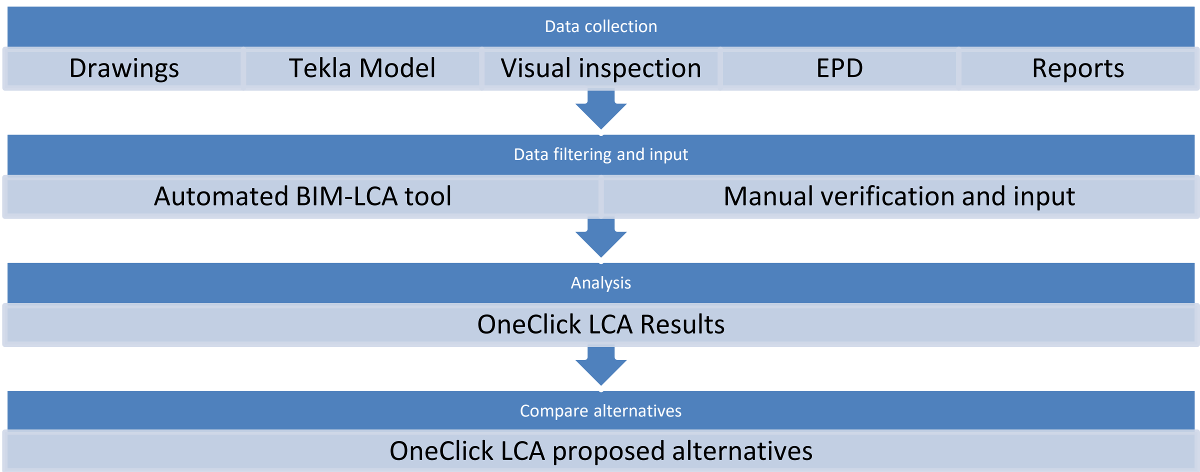
1.3 Methodology and research approach

1.3.1 Data collection and sources

Data for all the materials used in the analysis is obtained through OneClick LCA database. It contains almost all the required Environmental Product Declarations (EPD), which are declared by the manufacturers themselves. Electricity usage is obtained through direct measurements performed in 2019 as well as the designed energy usage of the building. Water data is obtained from Finnish Statistical Institute as a statistical average per occupant. The input from the solar panels that are in the front of the building is approximated, as the performance data is not available or is of limited validity. For the literature review, data is obtained through reputable sources such as Science Direct, Research Gate, and manufacturers' websites. Other sources, such as Wikipedia or non-scientific articles, may also be used, but the information obtained there will be used for searching reputable articles or books.Lifecycle assessment methodology and assumptions

The thesis focuses on performing LCA by utilizing BIM software in conjunction with an LCA tool. All calculations and methodology are executed on the back end of the LCA platform. The calculations are automated, and results are presented as is from the platform. Materials and quantities are manually verified and corrected if necessary. At the outset, the Tekla model of the building was imported into OneClick LCA, leading to the automatic generation of the bill of materials. However, after a visual inspection, certain inconsistencies came to light. The data collection and analysis process are outlined in Figure 1. It was observed that the total volume of all 19 columns in the building amounted to only 0.19 cubic metres, which is equivalent tothe volume of a single column. This finding highlights the need for further investigation into the accuracy of the measurements taken.

Figure 1. Thesis methodology



1.3.2 Software and tools used for analysis

The quality of the final assessment in Life Cycle Assessment (LCA) greatly relies on the software used. The outcome of the assessment can significantly impact project costs, either positively or negatively. Hence, it is crucial for project designers to carefully choose the appropriate LCA software based on their requirements. While some software, such as GaBi or SimaPro, offer greater flexibility, their complexity may not be justifiable for small-scale projects. For accurate results, standard materials from reputable manufacturers with regularly maintained Environmental Product Declaration (EPD) data are sufficient for software platforms like OneClick LCA. OneClick LCA offers specific tools like Carbon Designer or alternative solutions to materials, which cater to the needs of the construction industry and simplify data input and analysis.

Figure 2. OneClick LCA Carbon Designer. Source: (One Click LCA 2015. Helsinki: One Click LCA Ltd.)

To ascertain the ideal level of specificity necessary, the designer's foremost task is to meticulously evaluate the LCA software. This extensive evaluation should encompass various factors such as the software's efficiency, user-friendliness, precision of data, lucidity, and ability to replicate results, compatibility with other software, availability of technical support, and the overall cost involved. By considering each of these elements, the designer can ensure that the final product meets all necessary requirements and delivers accurate and reliable results.

2 Literature review

The literature review includes all relevant information and recent development in the context of European development in LCA. Additionally international standards and common practice are included, so that the foundation for EN standards is established. Specific procedure and requirements for conducting LCA are outlined in this chapter, as well as some additional information, such as sensitivity analysis. Output parameters, such as carbon dioxide equivalent and other relevant data are described briefly, such that the reader would have understanding of what each number means and its implications to the overall assessment score.

2.1 Building codes and standards

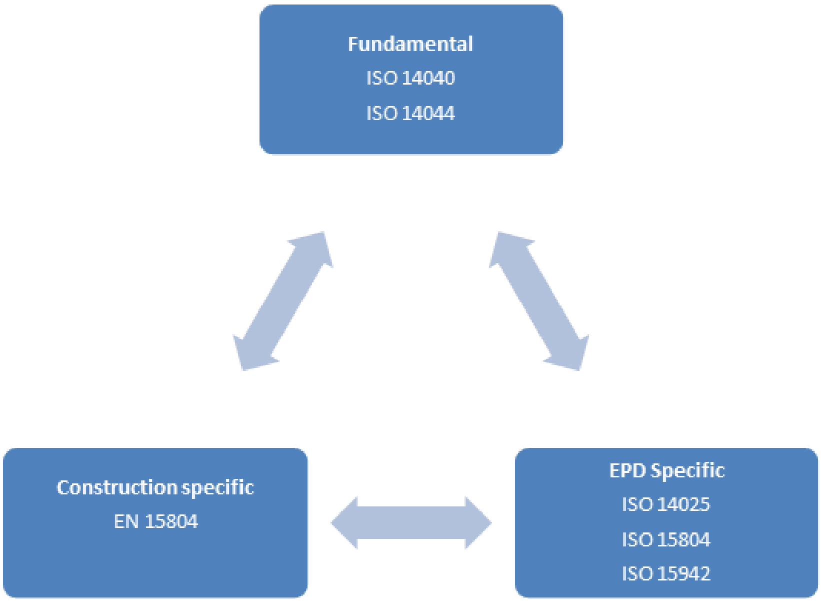
The International Organization for Standardization (ISO) is tasked with developing globally applicable standards for a variety of purposes, including lifecycle assessment. These standards serve as a benchmark for industries throughout the value chain, irrespective of the LCA tool being used. It is worth noting that these standards are universally applicable. European Committee for Standardization (CEN), on the other hand, develops European Norm (EN) standard, which is applicable in the European Union.

The main reason ISO and CEN coexist is due to the reason that CEN standards are explicitly developed for Europe. European Union has one of the strictest rules on environmental assessment and therefore requires specific to the member countries. However, EN standards are primarily based on ISO. Consequently, one would not find significant differences but specific parts that would be adjusted or added to the needs of CEN.

For example, EN 15804 (European standard for conducting LCA of construction products) is based upon ISO 14040 (Environmental management — Life cycle assessment — Principles and framework) and ISO 14044 (Environmental management — Life cycle assessment —

Requirements and guidelines). As a result, what guides LCA can be summarized into the following subcategories as shown in Figure 3. (Bruce-Hyrkäs & LCA, p. 12)

Figure 3. Standards and regulations



2.1.1 Fundamental standards

ISO 14040 is a standard that provides a comprehensive framework for conducting a Life Cycle Assessment (LCA). This standard highlights the importance of adopting a lifecycle thinking approach, which involves analysing the complete cycle of a product or system of products. The key pillar of this standard is to clearly define the goal and scope of the study. The standard encompasses all essential elements of a valid LCA, including defining the study goals and scope, inventory of inputs and outputs, impact assessment, and interpretation of results.

The standard also stresses the significance of maintaining a transparent study approach, which involves following clear guidelines and utilizing reliable and verifiable data sources. Furthermore, the standard mandates the use of the best available LCA tools to ensure the accuracy and completeness of the assessment. Overall, ISO 14040 serves as a valuable resource for conducting a thorough and robust LCA. (International Standards Organization, 2006)

The ISO 14044 standard serves as a beneficial framework for a wide range of entities, including governmental bodies, non-profit organizations, and private businesses. Its purpose is to provide guidance for these entities to assess and manage the environmental impacts associated with their products or services. This standard builds upon ISO 14040 and outlines a set of key steps that should be followed, including scope and definition, life cycle impact assessment, impact assessment, and interpretation. By incorporating this standard into their operations, entities can make informed decisions and effectively communicate results to all stakeholders involved. The comprehensive approach of this standard ensures that environmental considerations are addressed throughout the product or service's life cycle, thus minimizing negative environmental impacts. (International Standards Organization, 2006)

2.1.2 Construction-specific standards

European Norm (EN) 15804 is a standardized adaptation of the International Organization for Standardization (ISO) standards that pertain to life cycle assessment (LCA). This standard provides construction project stakeholders with the necessary tools and calculation methods to quantify the LCA impact of their project. The primary focus of analysis is the environmental performance of the project, which serves as a determining factor for the societal and economic impact and overall sustainability, as outlined in EN 15643-1, -2, -3, -4.

EN 15804 also provides guidance for the creation of Environmental Product Declarations (EPD) for any construction products. An EPD is a verified declaration of a construction product that describes its environmental performance and data throughout its lifecycle. In the case of a complete construction project, EN 15804 adopts a similar approach as the EPD, requiring that the assessment includes all stages of the lifecycle, from the extraction of raw materials to end-of-life treatment.

EN 15804 is a crucial tool for construction project stakeholders looking to measure their projects' environmental impact and foster sustainability in the industry. It is designed to be utilized by a broad range of stakeholders, including engineers, architects, and public services. (Finnish Standardization Association, 2012)

In July 2022, some noteworthy modifications were made to EN15804. These changes have led to the implementation of additional requirements for biogenic carbon emissions and storage handling. Additionally, 19 environmental and 17 reporting categories have been included. It is now mandatory for all products to disclose their end-of-life scenario and Module D, as well as to comply with the new EN15804+A2 compliant PCR. Finally, data must be presented in International Life Cycle Data System (ILCD) format to promote accessibility. (OneClick LCA, 2021).

The ILCD format is a standardized approach for organizing and documenting LCA data and results. Its purpose is to facilitate the exchange and analysis of information among researchers, policymakers, and industry professionals. The format is comprised of a series of handbooks that provide recommendations on a variety of topics, from the qualifications of reviewers to the criteria for models and indicators. Many of these recommendations are also included in ISO 14040/44. Overall, the ILCD format is an effective tool for ensuring consistency and accuracy in LCA studies. (European Commission, 2014)

2.1.3 EPD-specific standards

This standard sets forth a comprehensive set of requirements for Environmental Product Declarations (EPDs), which includes the necessary information, methodology, and verification that are essential to the process. The consistent and validated data harmonization would facilitate all stakeholders in gaining a complete understanding of the product's overall environmental performance. Furthermore, ISO 15804 and ISO 15942 offer more detailed specifications on data and methodology that can aid in the process.

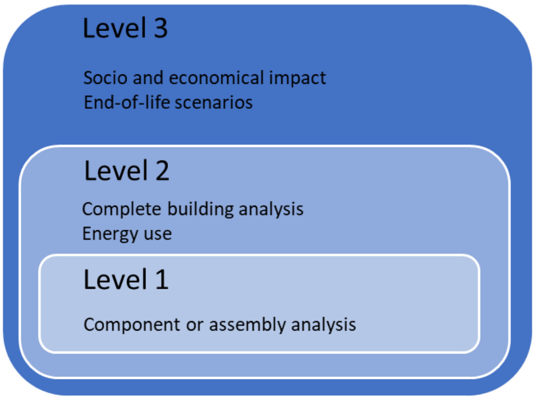
2.2 Lifecycle assessment tools and BIM

Incorporating Building Information Modelling (BIM) into a project can significantly improve its efficiency. This is supported by a study conducted by Stanford University's Centre for Integrated Facility Engineering, (Mitchell & Parken, 2009) which found that based on more than 30 projects, BIM integration reduces unbudgeted costs by 40 per cent, as well as 80 per cent reduction in time to prepare cost estimates. These savings can vastly improve Return-on-

Investment (ROI) on a project. Therefore, integrating LCA within the BIM framework would streamline the design choices in the pre-design phase and end-of-life scenarios.

LCA tools can be divided into three levels. Level 1 are building material and components combination (BMCC), which focuses on individual assemblies or components. Such analysis would only compare one assembly against another based on specific criteria, for instance, economic or environmental (Trusty & Horst, 2005). Good examples of Level 1 tools include GaBi, SimaPro, or Umberto. Level 2 tools consider all data obtained from Level 1 but cover the whole building, including its energy use, sustainability aspects, etc. Level 3 tools include all data from Level 2, but along with objective, collectable data, it also includes subjective criteria and ratings. It covers the social and economic impact of a project. A good example of a Level 3 tool is BREEAM or LEED. OneClick LCA would fall into Level 2 tools.

Figure 4. LCA Software levels



The combination of LCA and BIM is a strategic move that presents numerous benefits to the construction industry. One of the primary advantages is the enhancement of the decision-making process. With this integration, decision-makers can identify the root causes of problems and minimize potential future damages caused by material selection and construction. The reasoning mechanism of decision-making is thus improved to ensure sustainable and efficient project outcomes.

It is worth mentioning that some LCA tools face challenges in obtaining accurate bill of materials. However, with deeper integration, the labour-intensive data input process can be significantly reduced. Moreover, the integration allows for the selection of various manufacturers based on their submitted Environmental Product Declarations (EPD). This provides a wider range of choices for decision-makers, which is critical for optimizing project sustainability and efficiency.

Overall, the integration of LCA and BIM presents an asset for businesses and academic settings seeking to achieve sustainable development goals. By making informed decisions based on accurate data, decision-makers can minimize the environmental impact of their projects and promote more sustainable practices in the construction industry. (Azizoglu & Seyis, 2019)

2.3 Lifecycle assessment methodology

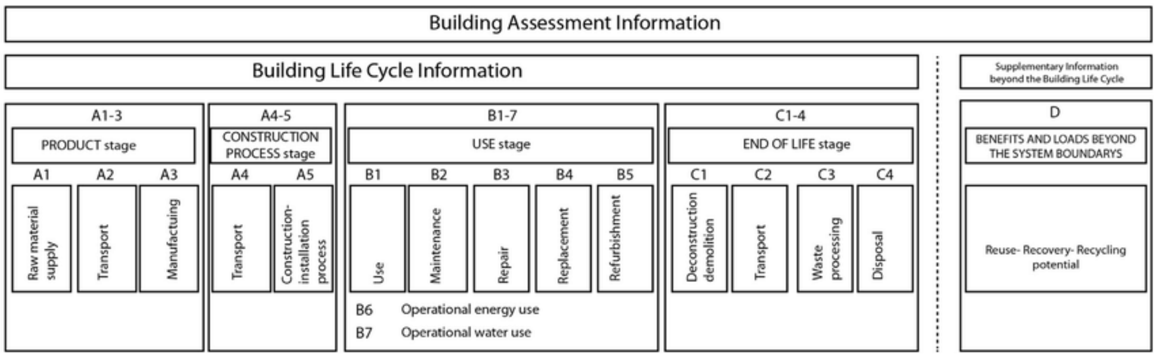
According to European guidelines (European Platform on LCA | EPLCA, 2013), LCA can be categorised into four main phases: 1) goal and scope, 2) inventory analysis, 3) impact assessment, and 4) interpretation.

During the goal and scope phase of an assessment, it is imperative to define the assessment's objectives and scope. The abundance of available information can lead to an overly extensive scope, so it is crucial to consolidate numerous parameters into a few key figures and conclusions. All objectives must be clearly defined in a format that is easily understandable to the intended audience. Stakeholders with no prior knowledge may not be able to make informed decisions if presented with overly technical information, such as photochemical ozone formation.

Life cycle inventory (LCI) is the second phase, where data collection and calculation procedures are laid out. It involves collecting EPDs, quantifiable data and other information related to the project and, more importantly, related to the goals and objectives. All information should be validated and checked.

Life cycle impact assessment (LCIA) is the third phase, where LCI results are categorized into environmental impact categories. According to EN 15804:2012, LCIA are split into five phases, A1-3, A4-5, B1-7, C1-4, D. Each category summarises the environmental impact from raw extraction of material (A1-3), Construction process stage (A4-5), Use phase (B1-7), End of life stage (C1-4) and Benefits beyond system boundaries (D). Each category is explained in the next chapter. (Europen Comission, 2012)

Figure 5. Building Assessment information table (A-D)



There are two main design concepts regarding the lifecycle of a project or material: Cradle to Cradle (CtC) or Cradle to Grave (CtG). Recent changes to EN 15804 have been implemented to ensure that manufacturers and designers consider the consequences that may arise after a product's useful life.

The Cradle to Grave methodology follows a straight product lifecycle approach, starting with material extraction, product creation, utilization, and disposal. On the other hand, the Cradle-to-Cradle approach is a closed-loop lifecycle, beginning with raw material extraction, followed by product creation, utilization, and finally, either upcycling or recycling. Some experts argue that recycling can cause long-term issues, while upcycling is a more effective solution. (William & Braungart, 2002). Nonetheless, it should be noted that this subject is quite extensive and delving into it further would require more time and resources than what is currently available for this thesis.

The last step of the LCA is the interpretation phase. In this phase, results from LCI and LCIA are interpreted according to the goals and scope defined in Phase 1. This phase includes (1) Completeness, (2) Sensitivity, and (3) Consistency, which exist to ensure robustness and reliability of results.

It is imperative to consider all relevant data to achieve a comprehensive evaluation in life cycle assessment (LCA). This involves accurately allocating all environmental impacts to their respective categories and calculating them precisely. Sensitivity analysis is crucial in identifying the factors that significantly impact the assessment by assessing the influence of assumptions and parameters on the LCA results. Lastly, consistency is essential in ensuring a logical path for the assessment, and appropriately analysing the data while identifying any discrepancies resulting from using different data sources. To achieve a thorough and accurate LCA, maintaining these three elements is crucial. (International Standards Organization, 2006)

2.4 Sensitivity analysis

As mentioned earlier, ISO 14044 prescribes that LCA studies include sensitivity analysis of significant inputs and outputs. A study on the *Methods for global sensitivity analysis in life cycle assessment* (Groen, Bokkers, Heijungs, & de Boer, 2015) shows that various statistical methods may be applied in determining the data uncertainty in LCA. The goal is to determine the true value of environmental impact. One such method is Monte Carlo simulation, a mathematical technique used to evaluate the possible outcomes of an uncertain event or process (IBM, n.d.). It involves running multiple iterations of the LCA model. Each iteration randomly samples the input parameters with their respective probability distribution. The result is a range of possible outcomes and their respective probability. This method allows stakeholders and decision-makers to make informed choices and understand the range of LCA results under different conditions. One such study demonstrates the benefits of this method, using a case study of crystalline silicon photovoltaics (Blanco, Cucurachi, Steubing, & Heijungs, 2022). The application of a case study to a construction project can be a valuable endeavour, albeit one that may involve a higher level of data complexity. Furthermore, the utilization of sensitivity analysis via Monte Carlo simulation can offer a range of potential benefits, including the ability to estimate the probability of both the lowest and highest possible environmental impact. Additionally, this information can be utilized to determine the most ecologically viable combination of materials. While not a focus of the present thesis, exploring Monte Carlo simulation further could prove to be a compelling area of study.

2.5 LCA output parameters

2.5.1 Global warming potential

Global warming, in the context of LCA output data, refers to the potential contribution of a product, process or system of processes to the increase in average global temperature. LCA output data typically includes the quantification of greenhouse gas emissions, particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These emissions are expressed in terms of carbon dioxide equivalents (CO_2e), which allows for a standard comparison of the warming potential of gases. It measures how much energy the emission of these gases will absorb over a given period, relative to the emissions of 1 ton of carbon dioxide. (United States Environmental Protection Agency, n.d.). By analysing global warming potential (GWP), one can easily compare data.

2.5.2 Acidification

Acidification refers to the deposition of acidifying contaminants in the surrounding areas. Main contaminants include sulphur dioxide (SO_2), nitrogen oxides (NOx), and NHx (Dincer & Bicer, 2018).

2.5.3 Eutrophication

Eutrophication refers to the gradual increase in the concentration of phosphorus and nitrogen in water bodies. These nutrients, when in abundance, can accelerate the growth of algae and aquatic plants, leading to harmful effects and oxygen depletion in the water. (Encyclopedia Britannica, n.d.)

2.5.4 Ozone Depletion

Ozone depletion potential (ODP), in the context of LCA output data, refers to the contribution of a product or process to the reduction of ozone (O3). LCA output data includes the quantification of emissions of ozone-depleting substances (ODS), hydrochlorofluorocarbons

(HCFCs), and halons. These substances can undergo chemical reactions that break down ozone molecules, leading to depletion of ozone layer.

2.5.5 Total use of primary energy

Primary energy is the energy that is obtained from natural resources, such as fossil fuels, coal, or wind energy. Electricity in that regard is not primary energy, but energy currency and a by-product. (Energy Education, 2015) It is measured in megajoules (MJ).

2.5.6 Biogenic carbon storage

Biogenic carbon is the carbon that biologically based materials, such as timber store. Carbon accumulates through photosynthesis and therefore can contribute to reducing the levels of carbon dioxide on the atmosphere. (OneClick LCA, 2023). It is noteworthy that the OneClick LCA methodology considers biogenic carbon to be a negative factor, whereas other research studies may treat it as having a positive environmental impact. This discrepancy in approach is attributable to the differing time horizons adopted by the respective studies. A long-term perspective would indicate that the carbon is stored and would eventually be released, either through burning or decomposition. On the other hand, a short-term outlook may suggest that the organic material's lifespan exceeds the project's duration, or that the material will be reused in a non-incineration or non-decomposition related activity.

2.6 Environmental impacts of steel framed buildings

Until 2008, approximately 8% of total emissions of CO2 were attributed to steel production (International Energy Agency, 2008). According to industrial data, the most significant share of energy spent on steel manufacturing is the liquification of metal (Worrell, Price, & Neelis, 2007).

Recent advancement in Scandinavia to reduce the energy demand of metal liquification is done by SSAB in cooperation with LKAB. The new pelletizing process decreased CO2 emissions from 192 kg/ton to 31 kg/ton in 2013 (Pei, Petäjäniemi, Regnell, & Wijk, 2020) In past decade, the production of steel has experienced a significant shift towards automation.

This transformation has resulted in factory conditions that provide a highly regulated quality assurance process, leading to the creation of steel products with longer lifespans. In some instances, the products made from steel end up outliving the buildings they were initially meant for, which then calls for one of three probable outcomes, namely recycling, waste, or reuse. The primary factor responsible for emissions during the production phase of steel is the energy input. Figure 6 summarises the energy demands at different lifecycle stages, which is particularly important for steel products.

Figure 6. LCA phases and Relevant Energy consumption (Najjar, Figueiredob, Palumboc, & Haddad, 2017)

LCA phases and relevant energy consumption.

Life cycle phase	Activities	Relevant contained energy
Pre-Building Phase	extraction of raw materials, manufacturing, packaging, and transporting to the site	Embodied Energy: is the energy consumed in the extraction and manufacture of construction materials. Grey Energy: is the energy consumed in transporting building materials from the factory to the construction site.
Building Phase	Construction, installation, operation, and maintenance	Induced Energy: Is the energy consumed in the construction and building steps. Operation Energy: Is the energy consumed in the operation of the building.
Post-Building Phase	Demolition and recycling	Disposal Energy: Is the energy consumed in the demolition and disposal of the building.

The Pre-Building Phase is the most energy-intensive stage in the lifecycle of steel, whereas the Building and Post-Building Phases are heavily reliant on factors such as usage, distance, and machinery. Conducting a comprehensive Life Cycle Assessment (LCA) that includes the calculation of Module D could help minimize the overall impact of steel by upcycling or reusing it in another project. (International Energy Agency, 2008) However, this approach raises the question of what parameters should be considered when assessing the reusability of steel elements after construction. Presently, there is no widely accepted method for estimating the degree of usability of steel elements after construction, which would be validated by engineering authorities.

2.7 Building circularity

2.7.1 BREEAM and LEED

BREEAM and LEED are sustainable assessment systems for buildings that advocate for the utilization of environmentally friendly and resource-efficient materials, encourage waste reduction and efficient waste management practices, and recognize innovative practices related to materials and resources, including those aligned with circular economy principles. LEED takes it a step further by promoting an integrative approach to building design and construction, which considers circularity principles to identify opportunities for material reuse, waste reduction, and design strategies that enhance the circularity of the project. In both systems, building circularity is integrated into their sustainability frameworks, but it should be noted that neither BREEAM nor LEED has established specific approved standards or comprehensive calculation methods for measuring building circularity. Instead, circularity principles are incorporated within broader sustainability categories. BREEAM and LEED offer guidance and criteria for building circularity, but they do not provide explicit definitions or standardized methods for calculating circularity indicators (BREGROUP, n.d.); (U.S Green Building Council, 2019).

2.7.2 Circular Building Assessment

The Circular Building Assessment (CBA) methodology is a comprehensive framework for assessing circularity in buildings. It includes indicators and criteria that cover various aspects of circularity in buildings, such as material reuse, recycling potential, waste management, adaptability, and disassembly potential. The methodology typically considers multiple life cycle stages of a building, including design, construction, use, and end-of-life phases. The assessment process involves collecting relevant data on the building's materials, construction methods, waste management practices, and design features. The CBA methodology assigns scores or ratings to each indicator based on the building's performance against predefined criteria, which are then aggregated to provide an overall Circular Building Score. The CBA methodology may evolve over time, and the specific calculation details may vary depending on the version or iteration being used.

2.7.3 EU Level(s)

The EU Level(s) framework provides a standardized approach for measuring and reporting the sustainability performance of buildings. Rather than offering specific calculation methods and formulas, the framework defines key indicators and offers guidance on data collection, assessment, and reporting. Calculation methods and data requirements may vary depending on the context and specific regulations, but the framework is designed to be flexible and adaptable to different building types, locations, and regulatory contexts within the European Union. To ensure accuracy and consistency, it is recommended to refer to national or regional guidelines, technical specifications, or relevant standards for specific calculation procedures related to the performance indicators covered by the framework. These guidelines may be developed by national authorities or organizations responsible for implementing the EU Level(s) framework locally. (European Commission , 2021)

The lack of specific formulas for calculating building circularity in recognized platforms can be attributed to complexity and variability, the evolving field, context-specific considerations, lack of consensus, and the need for flexibility and adaptability. While this absence may present challenges, it also allows for innovation and the development of context-specific methodologies.

3 LCA Assessment of Sheet Metal Centre

3.1 Goal and scope

The goal of this LCA is to evaluate the environmental performance of existing steel framed building – “HAMK Sheet Metal Center”, using OneClickLCA and Tekla Structures. The assessment can be used to inform stakeholders about the impact the building has over its lifetime of 50 years as well as to identify opportunities and recommendations for optimizing the building’s environmental impact throughout its remaining life cycle. The calculation period is 50 years from the time of completion of this assessment.

3.1.1 System boundaries

The evaluation will comprehensively encompass every stage of the building's lifespan, encompassing all building components, the construction process, the operational phase, and possible end-of-life scenarios. The assessment will carefully consider both direct and indirect environmental impacts, including energy consumption, water usage, material supply chains, material production, and transportation. In some cases, the input data will be based on the average values from Finnish statistics and OneClickLCA averages, for instance, related to the building's construction phase and concrete manufacturing and casting. Energy performance data will play a crucial role in determining energy usage. This will be based on simulations carried out prior to the construction phase. The building will be assessed as a whole, and office spaces and other related rooms are taken as one space.

There are no noteworthy geographical boundaries specific to this assessment that would change the result. The transportation of materials is taken as average of 100km per distance (leg) from the manufacturer to the construction site. Having more accurate data on distance and transportation means would vastly improve the accuracy of the transportation distances. For future reference, this distance is referred as “leg” in the software.

The output data that is is presented is derived from the Building Information Specification (BIS) table, as well as most contributing to carbon dioxide emission materials as well as present an alternative. Other related data may also be included, but only if it supports data from the BIS table.

The calculation relies on a set of fundamental building parameters, as shown in Table 1. External doors, including gates, are considered. The HVAC system is programmed to respond to the design heating and cooling set point, which triggers the circulation of warm or cold air. Consequently, the recommended standard indoor temperature range is between 18 and 25 degrees Celsius. The air handling unit (AHU) has efficiency of 75 to 78 percent. For building drawings, refer to Appendix 3

Table 1. Building parameters

HAMK Sheet Metal Center Building parameters

Parameter	Unit	Value
Location		Finland
Net floor area - Building area	m^2	1496,5
External walls	m^2	1201
Roof area	m^2	1467
Windows area	m^2	158
External doors	m^2	67
Design heating set point	C°	18
Design cooling set point	C°	25
AHU heat recovery	%	75/78

3.2 Lifecycle inventory

3.2.1 Foundation

According to the available drawings, the floor slab of the building has a specified thickness of approximately 550 millimetres. The concrete layer is specified as having the thickness of 200 mm. Unfortunately, there is no information provided regarding the strength or reinforcement details. To ensure accuracy in calculations, it is recommended to assume a standard strength of C30/37 and a reinforcement of 0.5 percent of the total volume of concrete.

There are additional steel piles with varying lengths that contribute to the heating and cooling of the building through the floor slab and air circulation after that. The function and contribution of the piles are to be calculated in the Energy performance of the building. For the foundation calculation, the only parameter needed is volume and material. Transportation is assumed to be 100 km per leg.

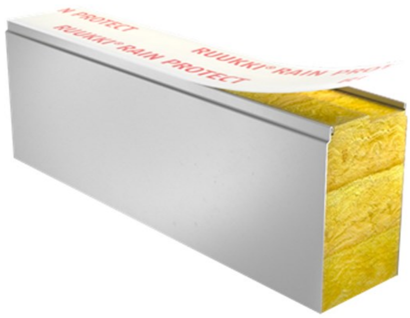
The third and last main structure is the foundation footings. Their total volume is 96,4 cubic meters.

Due to the materials being used, the foundation structures contribute negatively to the final score of the building. As they are an integral part of the building, they cannot be excluded from assessing the life cycle. The end-of-life scenario is for the piles to be left in the soil and the concrete slab and pads to be crushed into aggregate and steel recycled. This process is expensive and due to the greater thickness, might contribute negatively to the emissions and waste.

3.2.2 Vertical structures and facade

Vertical structures are divided into three main categories, external walls (façade), internal walls, and vertical load-bearing columns. The exterior walls are Ruukki 230mm SPA E-Life mineral wool panels as shown in Figure 7. The panels rank relatively lower than other competitive products but with stone wool as the core material. The total area of external walls is 1201 square meters.

Figure 7. Sandwich wall panel. Source: (Ruukki, 2016)



Ruukki also manufactured the internal walls with a thickness of 160 millimeters of the same category product. The total area of the interior walls is 242.3 square meters. The insulation material of the product has some amount of recycled material. However, it is not specified explicitly whether the steel sheeting or the core material is produced from recycled material (Ruukki, 2016).

As an end-of-life scenario, the panels will be recycled as material, meaning the core material may be separated from the steel sheeting.

The column's length spans from approximately 9 to 11 meters. There are four profiles used across the building: (1) 18 x 300/200/10 S420 MH, (2) 8 x 180/180/6 S420MH, (3) 12 x 150/150/4 S420MH, (4) 6 x CFCHS101.6X5 S355J2H. The total volume of steel used is 2.14 cubic meters. The end-of-life scenario is steel recycling, assuming no plan for reusing the columns.

3.2.3 Horizontal structures: beams, floors and roofs

Horizontal structures are divided into three categories: (1) Trusses, (2) Roof, and (3) Bracing. Roof trusses are made of the following profiles: (1) 12 x CFRHS180X180X6 S420MH, (2) CFRHS120X120X6 S420MH, (3) 148 x CFRHS80X80X4 S420MH. One roof truss has a total volume of 0.18 cubic meters of S420MH grade steel. The software calculates all truss components and other connected elements as separate quantities. Connections are also included. Roof panels are made by Ruukki with an area of 1467 square meters. The EPD and model are the same as the exterior wall.

3.2.4 Other structures and materials

In the assessment of steel structures, it is crucial to consider the connections between the beams and columns, despite their relatively small volume compared to other components. These connections amount to 0.038 cubic meters. Additionally, the support for the exterior sandwich panels is made up of precast concrete wall elements, which include approximately 20 cubic meters of concrete and 1% steel content. The three other materials involved in this analysis are: (1) Glass, (2) Doors, and (3) EPS Insulation.

3.2.5 Energy, water, and construction

The model of the building showcases data concerning the use of 60x11m energy piles and 2x200m heat wells. Additionally, the solar collectors boast a total surface area of 24 square meters, and they are linked to the inlet side of the energy piles through a heat exchanger. Table 2 provides an overview of the building's total energy consumption. (Fadejev & Kurnitski, 2016)
Regarding energy consumption, it is important to differentiate between "energy need" and "delivered energy". The former refers simply to the amount of energy required for a specific task or system, without considering any losses that may occur during the distribution process or inefficiencies in heat generation. On the other hand, "delivered energy" is a more comprehensive measurement that considers a variety of factors, including efficiency, conveyance, and control, as well as coefficients of performance for heating and cooling. Delivered energy is multiplied by the weighting factors in energy performance value (EPV).

Ultimately, delivered energy represents the true amount of energy required once all energy generated by internal HVAC systems has been considered. Table 2 lists all the energy parameters, which sum up to 61578 kWh total need of electricity, or 41.1 kWh/m²/a.

Table 2. Energy simulation results.

	Energy Requirement		**Renewable produced**		**Delivered**	
	kWh	**kWh/m²**	**kWh**	**kWh/m²**	**kWh**	**kWh/m²**
Top-up heating	3906	2,6	434	0,3	4340	2,9
Heat pump	61713	41,2	48223	32,3	13490	9
Cooling	3353	2,2	3353	2,2	0	0
Fans electricity (SFP=2.0)	14302	9,6	0	0,0	14302	9,6
Pumps electricity	6254	4,2	0	0,0	6254	4,2
Lighting	19498	13	0	0,0	19498	13
Hot water	5918	4	2224	1,5	3694	2,5
Total	**114944**		**54234**		**61578**	**41,1**

Water consumption has not been recorded. However, statistical data from OECD provides the number of 75 cubic meters per capita. With a people capacity of, the building would theoretically use 2250 cubic meters per annum. (The Organisation for Economic Co-operation and Development , 2018)

The energy input for construction site operations in relation to a certain building is not publicly accessible. OneClickLCA grants users access to data on the average energy consumption for a specified area in Finland. The deconstruction and demolition scenarios rely on the information entered in the previous section, and the software additionally provides suggestions for energy input in these categories.

4 Results

4.1 Building assessment information

Due to the size of the table, the data is split into two tables. Table 3 presents GWP, Acidification and Eutrophication, while Table 4 presents Ozone Depletion potential, Formation of ozone of lower atmosphere and Primary energy use. The outcomes have been divided and assessed based on established criteria, and the display format is split due to spatial limitations. Certain values may be negative, as they signify an enhancement in the environmental impact of the associated category.

Concrete is the primary driver of the most negatively impacting categories. There is hardly any replacement for it, when it comes to foundation structures, but improvements may come with decreasing thickness or eliminating areas that are not under heavy loading. Biogenic carbon storage is zero, because there are no biological substances in any of the materials. As already mentioned earlier, this factor can be seen as positive or negative, depending on the interpretation of the assessor and the time frame of analysis. In the case of a timber structure with demountable and reusable design, this factor may influence the overall environmental score in a positive manner. It is also evident that using steel frame, in combination with timber may have very positive impact. All data for inputs and outputs of the software can be seen in Appendix 1 and 2 accordingly.

Table 3. Building Assessment Information 1/2

Section	Result category	Global warming kg CO_2e	Acidification kg SO_2e	Eutrophication kg PO_4e
A1-A3	Construction Materials	**380592**	**947,34**	**117,91**
A4	Transportation to site	**13492,35**	**24,69**	**5,15**
A4	Transport to the building site	**13492,35**	**24,69**	**5,15**
A4-leg2	Transportation to site - leg 2			
A5	Construction/installation process	**35549,32**	**66,84**	**14,84**
B1-B5	Maintenance and material replacement	**4885,13**	**38,09**	**3,25**
B6	Energy consumption	**532118,36**	**2894,41**	**622,08**
B7	Water use	**30446,84**	**208,29**	**48,46**
C1-C4	End of life	**35527,48**	**76,26**	**18,12**
C1	Deconstruction/demolition	**12607,59**	**25,87**	**7,9**
C2	Waste transport	**8276,23**	**37,84**	**8,24**
C3	Waste processing	**14474,02**	**11,3**	**1,72**
C4	Waste disposal	**169,64**	**1,25**	**0,27**
D	External impacts (not included in totals)	**-126713,4**	**-405,66**	**-59,66**
A5m-benefit	Construction site - material use - benefit			
A5-benefit	Construction site - material wastage - benefit	**-5698,86**	**-19,05**	**-2,81**
D2	Exported energy (not included in totals)			
D	Installed Materials - benefit	**-121014,55**	**-386,61**	**-56,85**

Table 4. Building Assessment Information 2/2

Section	Result category	Ozone Depletion kg CFC11e	Formation of ozone of lower atmosphere kg	Total use of primary energy ex. raw materials MJ	Biogenic carbon storage kg CO_2e
A1-A3	Construction Materials	**0,012**	**126,41**	**3372563,38**	**0**
A4	Transportation to site	**0,0023**	**1,89**	**226236,46**	
A4	Transport to the building site	**0,0023**	**1,89**	**226236,46**	
A4-leg2	Transportation to site - leg 2				
A5	Construction/installation process	**0,006**	**5,67**	**930982,71**	
B1-B5	Maintenance and material replacement	**0,00033**	**1,85**	**80874,58**	
B6	Energy consumption	**0,066**	**120,21**	**33637779,54**	
B7	Water use	**0,0022**	**7,32**	**499966,91**	
C1-C4	End of life	**0,004**	**3,86**	**549188,31**	
C1	Deconstruction/demolition	**0,0018**	**2,65**	**193421**	**0**
C2	Waste transport	**0,0016**	**0,5**	**260779,78**	
C3	Waste processing	**0,0005**	**0,69**	**66057,93**	
C4	Waste disposal	**0,00003**	**0,034**	**28929,6**	
D	External impacts (not included in totals)	**-0,0051**	**-59,83**	**-1408471,57**	
A5m-benefit	Construction site - material use - benefit				
A5-benefit	Construction site - material wastage - benefit	**-0,00024**	**-2,79**	**-64098,39**	**0**
D2	Exported energy (not included in totals)				
D	Installed Materials - benefit	**-0,0048**	**-57,04**	**-1344373,18**	**0**

4.2 Global warming potential

Figure 8 and Figure 9 show GWP, sorted by class, while Figure 9 sorts them by their respective lifecycle stage. Electricity use is the primary driver of GWP with 532118 kg CO_2e for the building, followed by the concrete used in the foundation with 320330 kg CO_2e.

Figure 8. Global Warming listed according to classification. Source: OneClick LCA (2015)

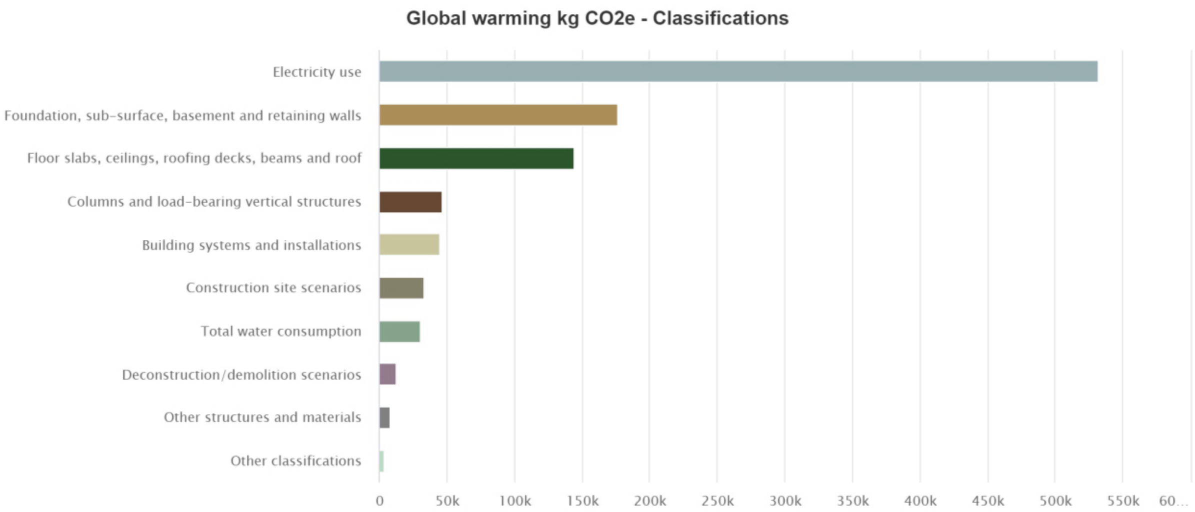
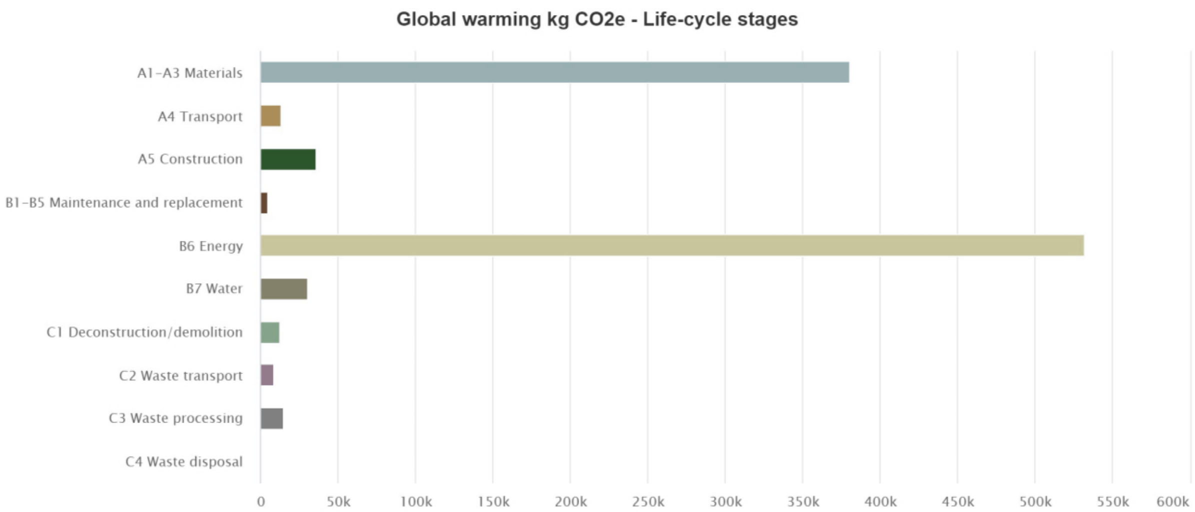


Figure 9. Global Warming listed according to life-cycle stages. OneClick LCA (2015)



Columns and other steel elements contribute with 46347 kg CO_2e. Full data available in Appendix 2.

4.3 Acidification

The phenomenon of acidification shares a similar pattern to that of GWP, except when it comes to water. The reason for this deviation lies in the use of treatment chemicals, such as sulfuric acid or hydrochloric acid, during water purification. These chemicals, when discharged into the environment during water treatment, may contribute to the acidification process. It is however unlikely that all 30 occupants would be present at all times, but to determine what would be the maximum acidification, the maximum capacity may be used.

Figure 10. Acidification listed according to classification. Source: OneClick LCA (2015)

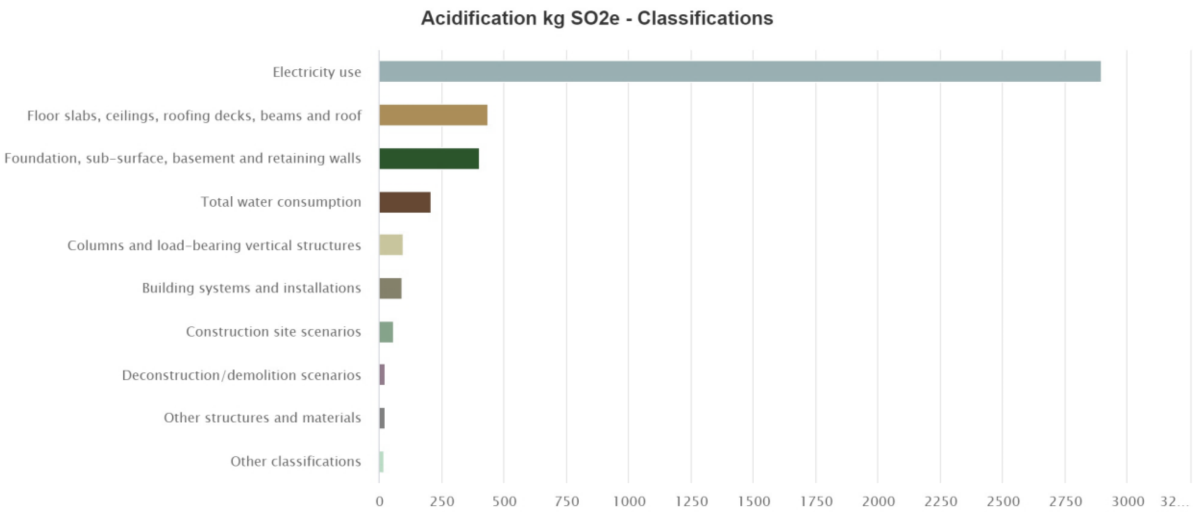
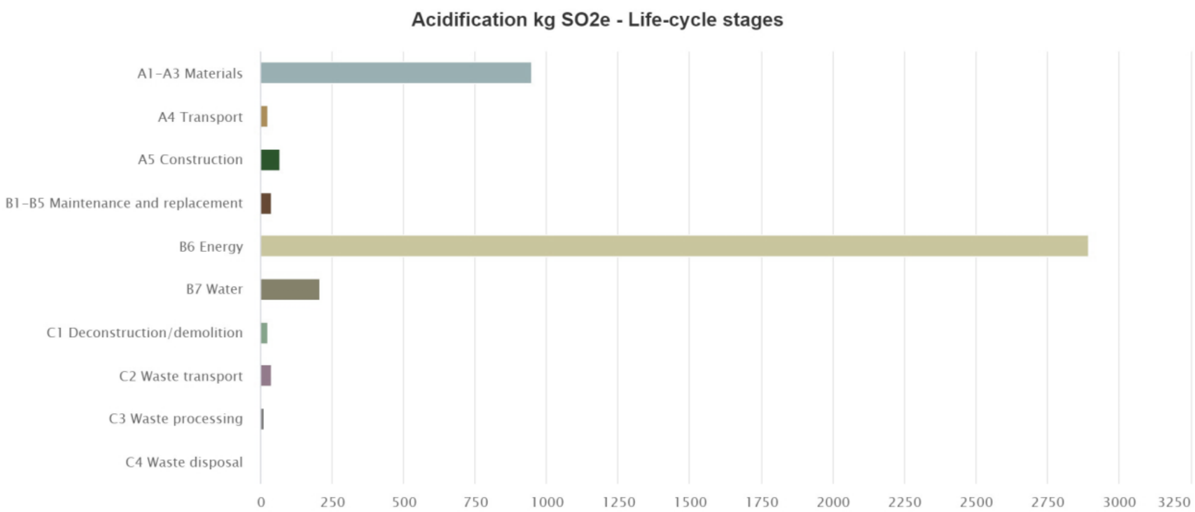


Figure 11. Acidification listed according to life-cycle stages. Source: OneClick LCA (2015)



4.4 Eutrophication

The graphs for Acidification and Eutrophication, presented in Figure 12 and Figure 13 display similar patterns since excessive nutrient loading can enhance the growth of aquatic plants, particularly algae, which results in algal blooms. The decomposition of these plants leads to oxygen depletion in the water, known as hypoxia, as they consume oxygen during the process. In such hypoxic conditions, anaerobic bacteria can flourish and produce hydrogen sulfide, which is a compound that can induce acidification when released into the water. (Water Resources Mission Area, 2019)

Figure 12. Eutrophication listed according to classification. Source: OneClick LCA (2015)

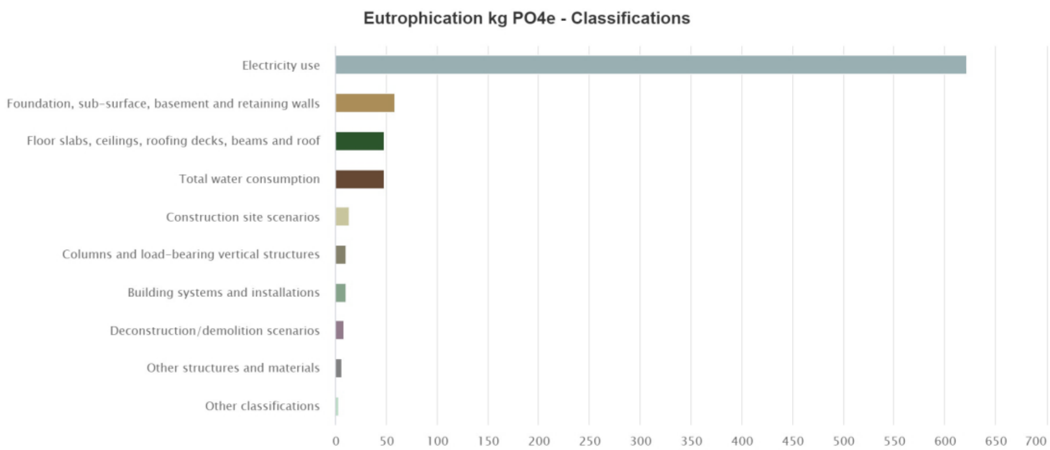
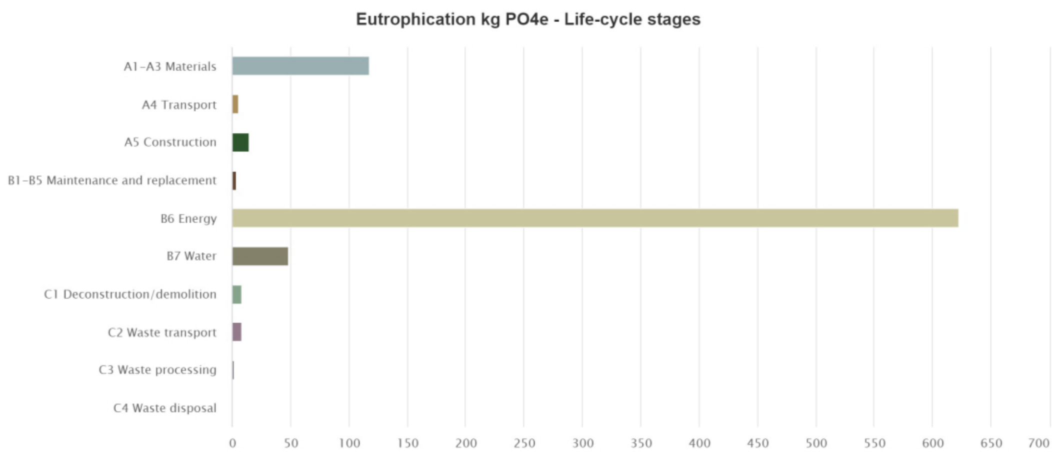


Figure 13. Eutrophication listed according to life-cycle stages. Source: OneClick LCA (2015)



4.5 Ozone Depletion

Figure 14. Ozone depletion listed according to classification. Source: OneClick LCA (2015)

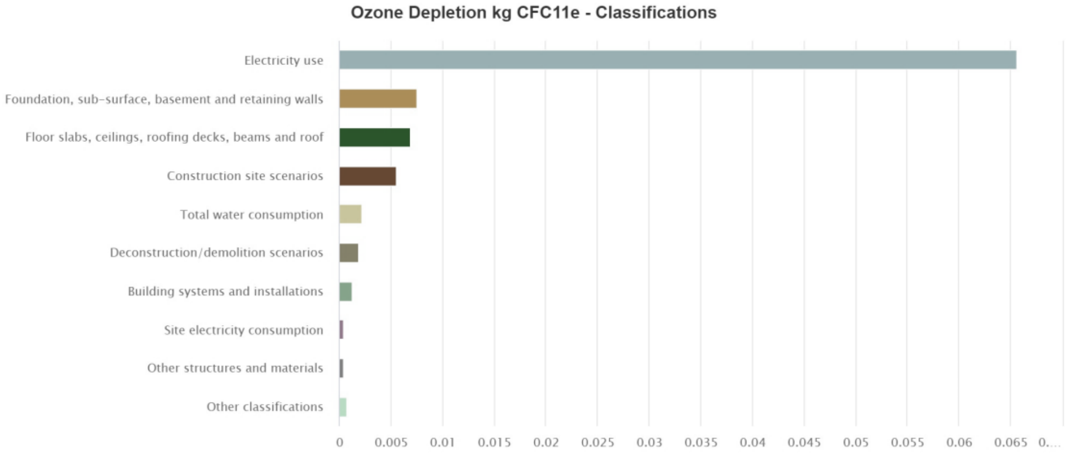
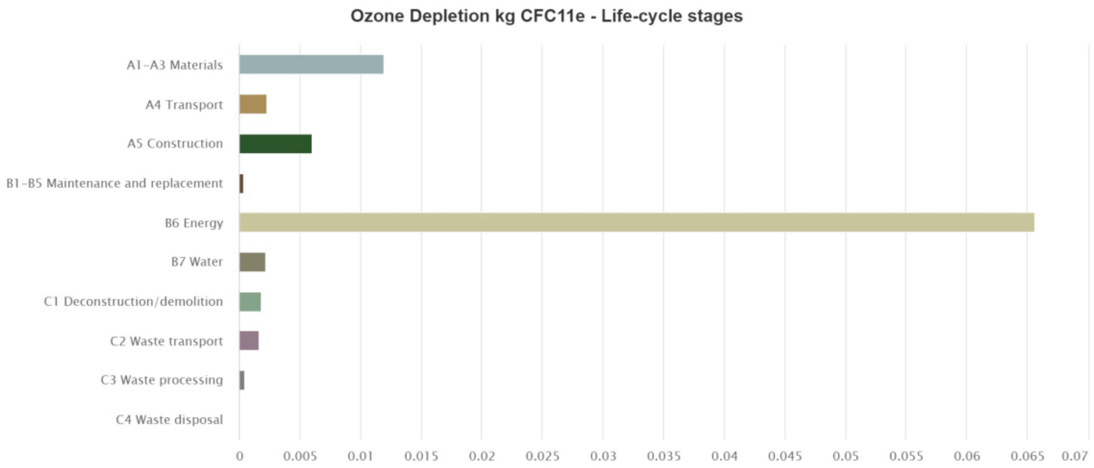


Figure 15. Ozone depletion listed according to life-cycle stages. Source: OneClick LCA (2015)



Ozone depletion has similar distribution among the main contributors. One reason why these three parameters share a similar pattern is that Ozone depletion influences UV radiation levels. The depletion of ozone layer allows for increased UV radiation that affects phytoplakton, which also inhibits their growth and productivity, potentially altering nutrient cycling and eutrophication processes. (Tennessee Department of Health, 2019)

4.6 Biogenic carbon storage

There is no biogenic carbon storage present in any material. Therefore, the data is not available for this parameter.

4.7 Total use of primary energy

Figure 16. Total use of primary listed according to classification. Source: OneClick LCA(2015)

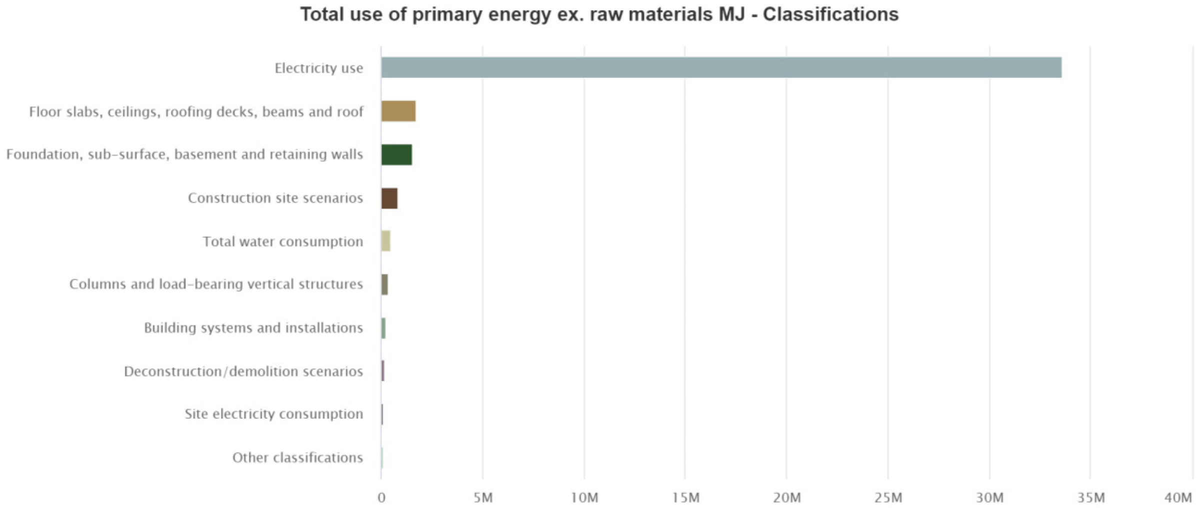
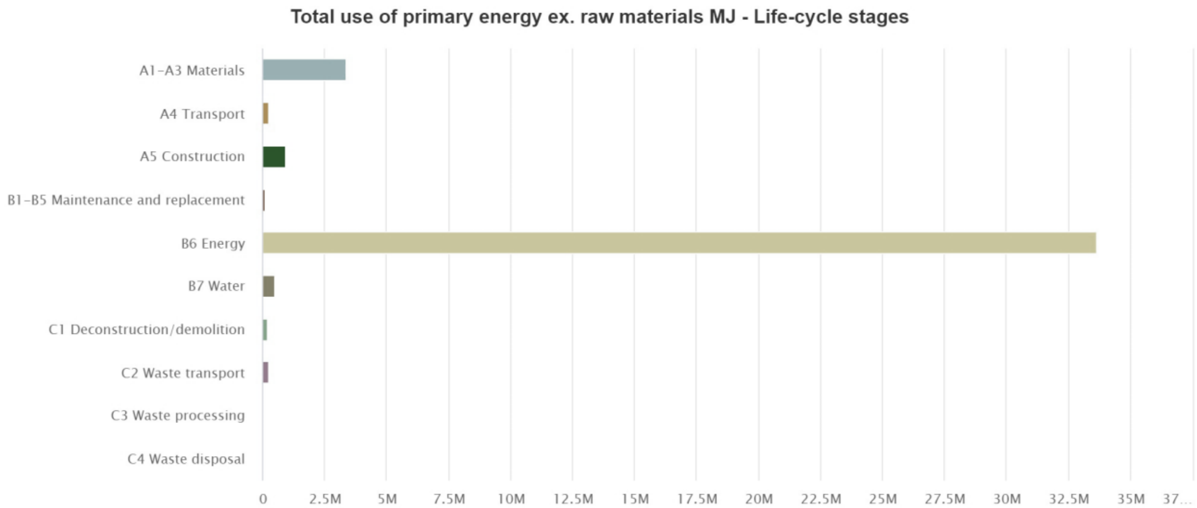


Figure 17.Total use of primary energy listed according to life-cycle stages. Source: OneClick LCA (2015)



Electricity use is again the primarly contributor to primarly energy, excluding raw materials with 33637779 MJ, while materials make up 3372563 MJ or approximately 10 times less.

4.8 Other results

Figures 18 and 19 depict the proportion of embodied carbon by structure and lifecycle. Although concrete stands as the most detrimental material in terms of carbon footprint, steel accounts for 37 percent of the embodied carbon due to its processing. Should the calculation exclude the concrete floor, steel would emerge as the primary contributor to the negative impact. However, this assertion presupposes that the elements in question will not be reused in the future. If the designer incorporates reusability, the embodied carbon will be considered only once during the manufacturing phase and not subsequently. The adoption of a design for deconstruction approach would have a positive impact on the embodied carbon associated with construction works while reducing any manufacturing costs, both environmental and economic, linked to the physical connections between steel elements.

Figure 18. Embodied carbon by structure type. Source: OneClick LCA (2015)

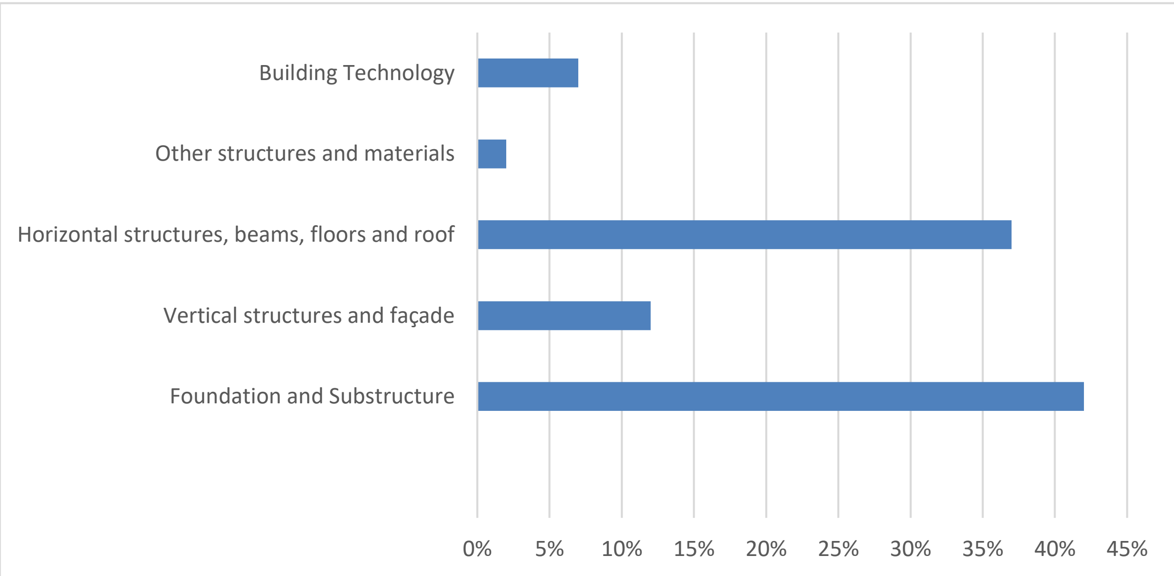
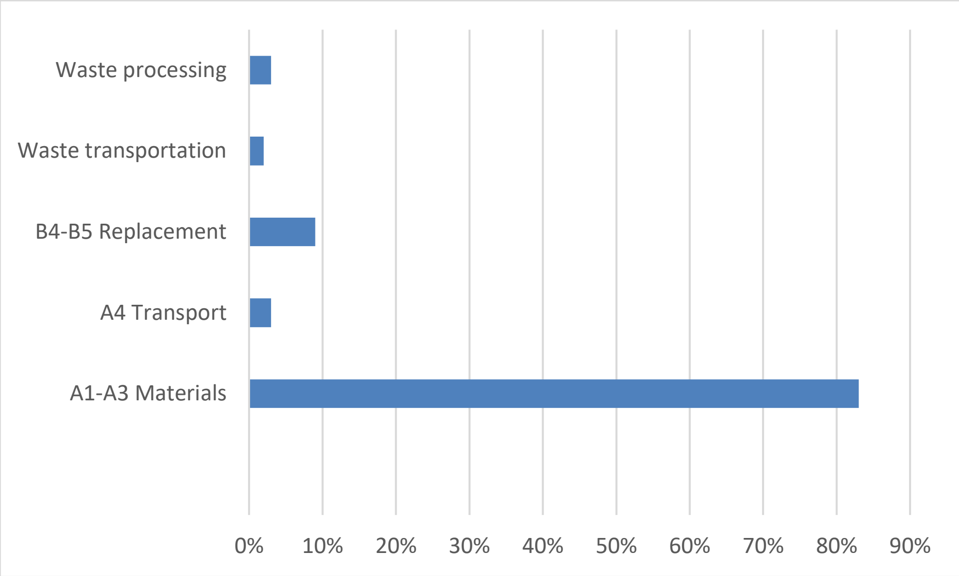


Figure 19. Embodied carbon by lifecycle stage. Source: OneClick LCA (2015)



4.9 Most contributing materials

The three most contributing materials are Sandwich panels with 24,7 percent in A1-A3 category, followed by Hot rolled steel sections used for columns and beams with 23.4 percent and concrete with 21,6 percent.

Table 5. Most contributing materials. Source: OneClick LCA (2015)

Most contributing materials (Global warming)	Percentage
Sandwich panel, steel and mineral wool, U = 0.17 W/(m2K), 230 mm, 28.9 kg/m2	24,7 %
Steel hot rolled, I, H, U, L, T and wide flats, FI average	23,4 %
Ready-mix concrete, normal-strength, generic, C30/37 (4400/5400 PSI), 0% recycled binders in cement (300 kg/m3)	21,6 %
Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 0% recycled binders in cement (400 kg/m3)	9,4 %
Precast concrete piles, 144 kg/m	7,2 %

5 Result analysis

The above results provide an overview of key performance indicators related to the environmental impact of HAMK Sheet Metal Center. The building has relatively good performance, compared to similar averaged buildings in North Europe. The data is suggesting that the building has 305 $CO_2e/m^2/a$, which gives it rating “B”. The volume of the building makes it difficult to find a suitable alternative to the current HVAC system, which is performing below the ZEB proposed 120 $kW/m^2/a$. The system itself has its deficiencies, as discovered by a previous study, but they are related to automation and not installing additional physical components.

The solar collector installations on the wall and roof of the building are considered a net decrease in energy use and are factored into the energy information input as Energy delivered. If conventional electricity or district heating is used to replace the energy they supply, there will be a slight increase in Embodied carbon. When considering the complete energy recovery system, including solar panels, energy piles, energy storage and AHU unit, there is a total decrease in net electricity need of 53800 kWh per annum.

On average, the building’s environmental impact is 1 033 tons CO_2e and 13.8 kg $CO_2e/m^2/a$. Comparing the embodied carbon of similar buildings, HAMK Sheet Metal Center’s performance is shown in Table 6 (Gervasio & Dimova, 2018; Simonen, De Wolf, & Rodriguez, 2017).

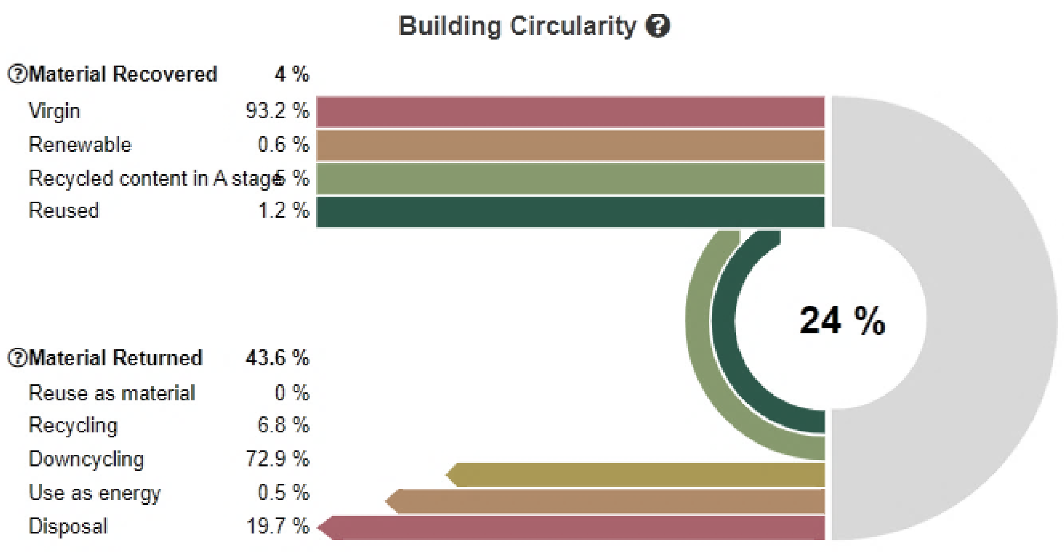
Table 6. Embodied carbon benchmark.

Embodied carbon buildings HAMK OHLK = 100%		
	Embodied GWP(kg $CO_2e/m^2/a$)	**Benchmarked**
HAMK Sheet Metal Center	305	100 %
EU Average	385	126 %
US Average	462	151 %

In Figure 20, building circularity score can be seen, which considers the total materials used in the project and how they are handled at the end of their life. The calculation is based on the mass of the materials. Once all the materials used in the building are inputted, the system checks how much of them are recycled, renewable, or reused, as well as their potential for disassembly or adaptation. The final factor that is considered is the end-of-life scenario. After considering the weights and their respective design and manufacturing properties, weighting factors are applied, typically set at 1, but can be adjusted according to the designer's needs.

The term "Materials Recovered" pertains to the utilization of circular materials throughout the project, whereas "Materials Returned" refers to the circular handling of materials at the end of their life. This metric denotes the proportion of materials that are either recycled or reused, plus 50 percent of the materials that are either downcycled or repurposed as energy.

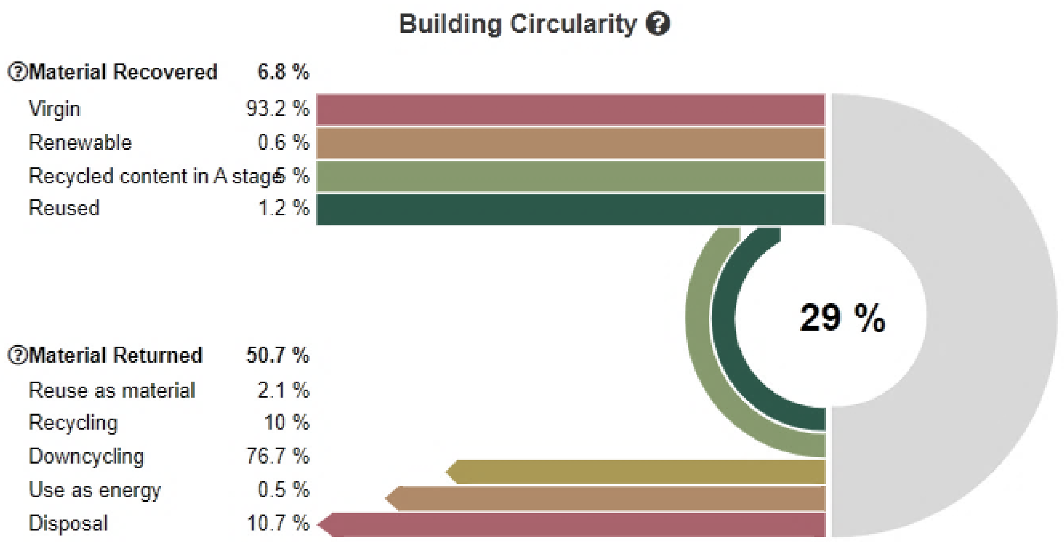
Figure 20. Building circularity index "As Build". Source: OneClick LCA (2015)



Scenario 1: Reuse steel columns and beams

Figure 21 shows improvement of five percent over “build as is”. The number of disposed materials has decreased by 9 percent, while recyclable materials also increased by 3.2 percent. Other data is shown in the graph.

Figure 21. Building circularity index Scenario 1. Source: OneClick LCA (2015)



Scenario 1 involves reusing all steel and columns "as is" in another project. The scenario does impact mostly the circularity percentage of the building. What the result show, is that less waste will be generated, while materials can continue further their useful life. This percentage (29 percent) is the average from the materials recovered added up to the materials returned.

Scenario 2: Reuse Steel columns and beams, and panels.

Figure 22. Building circularity index Scenario 2. Source: OneClick LCA (2015)

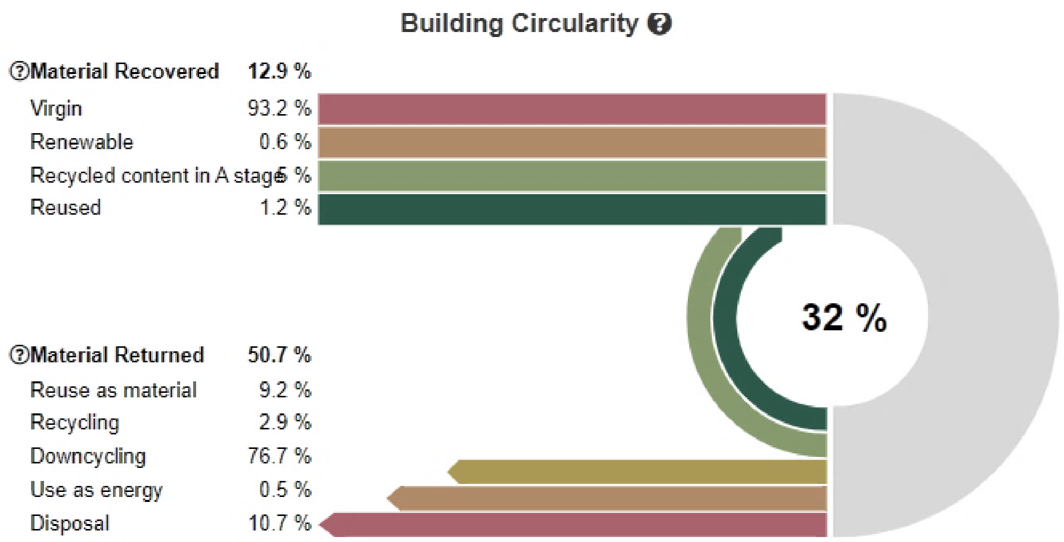


Figure 22 shows the result, if the building has its steel elements, as well as the sandwich panels reused. It is an incremental increase over Scenario 1, but a substantial one over “as build”. This result demonstrates that design for deconstruction and reusability positively impacts the environmental score of the building. The same principle may be applied to similar buildings.

6 Conclusion

It has been demonstrated that reusing elements can have a positive impact on building circularity. This can result in a decrease in future energy input required for new materials and potentially reduce transportation costs if the reused elements are located nearby. To ensure a comprehensive and objective Life Cycle Assessment (LCA), it is crucial to accurately evaluate its challenges and limitations. Although LCA is a widely recognized and utilized methodology, it does have inherent issues that must be addressed. Researchers and practitioners must question each step of the process to overcome these challenges.

One primary challenge is the limited availability and quality of data, which poses a threat to a reliable Life Cycle Inventory (LCI). While there are few widely accepted databases, there are inconsistencies in how the material's impact is calculated from one database to another. Therefore, it is essential to address these inconsistencies to maintain the accuracy and reliability of the LCA results.

In the construction industry, manufacturers of construction materials are not widely recognized for their pioneering innovations. The market appears to be primarily demand-driven, whereby manufacturers invest in satisfying the market's demands for sustainable materials only when consumers demand them. However, the generation of Environmental Product Declarations (EPDs) does not guarantee accuracy when making Life Cycle Inventories (LCIs) for specific projects. It is important for manufacturers to exercise due diligence when generating EPDs and ensure that they are based on comprehensive and reliable data to avoid any potential inaccuracies in LCI calculations.

Another potential challenge is an incorrect or biased setting of system boundaries. Determining where to draw the boundary of the environmental impact of a manufacturing process or operational phase is very subjective. The inclusion or exclusion of specific processes might generate entirely different results in the final stages of LCA. For example, neglecting end-of-life impact or disregarding the full extent of material extraction may invalidate the idea of LCA. A timber manufacturer who produces many types of products may shift some of the energy input to the low-profit product category to create a false image of the low environmental impact of high-profit products.

7 References

Azizoglu, B., & Seyis, S. (2019). Analyzing the Benefits and Challenges of Building Information Modelling and Life Cycle Assessment Integration. Advances in Building Information Modeling (pp. 161-169). Istanbul: EBF.

Blanco, C., Cucurachi, S., Steubing, B., & Heijungs, R. (2022). Implementation of uncertainty analysis and moment-independent global sensitivity analysis for full-scale life cycle assessment models. Journal of Industrial Ecology, 374-391.

BREGROUP. (n.d.). Circularity and resilience. Retrieved from Circularity and resilience: https://bregroup.com/products/breeam/breeam-solutions/breeam-circularity-and-resilience/

Bruce-Hyrkäs, T., & LCA, O. L. (n.d.). 7 Steps guide to building life cycle assessment. OneClick LCA.

Civil Engineering history. (2015, 01 01). Civil Engineering history. Retrieved from Civil Engineering history: http://www.thecivilengg.com/History.php#

Dincer, I., & Bicer, Y. (2018). Comprehensive Energy Systems (Vol. 1). Elsevier.

Encyclopedia Britannica. (n.d.). Eutrophication. Retrieved from Encyclopedia Britannica: https://www.britannica.com/science/eutrophication

Energy Education. (2015). Primary energy. Retrieved from Primary energy: https://energyeducation.ca/encyclopedia/Primary_energy

European Commission . (2021). Environment. Retrieved from Let's meet Level(s): https://environment.ec.europa.eu/topics/circular-economy/levels/publications_en

European Commission. (2014). European Platform on LCA | EPLCA. Retrieved from ILCD International Life Cycle Data system: ILCD International Life Cycle Data system

European Parlament. (2010). DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Official Journal of the European Union, 1-3.

European Platform on LCA | EPLCA. (2013). Life Cycle Assessment (LCA). Retrieved from European Commission: https://eplca.jrc.ec.europa.eu/lifecycleassessment.html#:~:text=LCA%20is%20based%20on%204,impact%20assessment%2C%204)%20interpretation.

Europen Comission. (2012). Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products. 72.

Fadejev, J., & Kurnitski, J. (2016). HAMK OHUTLEVYKESKUS Energy performance. Tallinn.

Finnish Standardization Association. (2012). Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method. Helsinki: Finnish Standardization Association.

Gervasio, H., & Dimova, S. (2018). Environmental benchmarks for buildings. Bruxelles: European Commission.

Groen, E. A., Bokkers, E. A., Heijungs, R., & de Boer, I. J. (2015). Methods for global sensitivity analysis in life cycle assessment. Int J Life Cycle Assess (2017) 22:1125–1137, 1.

IBM. (n.d.). What is Monte Carlo simulation? Retrieved from IBM: https://www.ibm.com/topics/monte-carlo-simulation

International Energy Agency. (2008). Energy technology perspectives 2008: scenarios and strategies to 2050. Paris: IEA.

International Standards Organization. (2006, 07 01). ISO 14040:2006. Retrieved from International Standards Organization: https://www.iso.org/obp/ui/#iso:std:iso:14040:ed-2:v1:en

International Standards Organization. (2006, 07 01). ISO 14044:2006. Retrieved from ISO: https://www.iso.org/standard/38498.html

Mitchell , J., & Parken, D. (2009). National Guidelines for Digital Modelling. Brisbane: Cooperative Research Centre for Construction Innovation.

Najjar, M., Figueiredob, K., Palumboc, M., & Haddad, A. (2017). Integration of BIM and LCA: Evaluating the environmental impacts of. Journal of Building Engineering, 116.

OneClick LCA. (2021). Getting ready for EN 15804+A2. Retrieved from OneClick LCA: https://www.oneclicklca.com/getting-ready-for-en-15804-a2-whats-changed-and-how-to-prepare-for-it/

OneClick LCA. (2023, 1). Biogenic Carbon. Retrieved from https://oneclicklca.zendesk.com/hc/en-us/articles/360015036640-Biogenic-Carbon#:~:text=Biogenic%20carbon%20is%20the%20carbon,the%20challenge%20of%20climate%20change.

Pei, M., Petäjäniemi, M., Regnell, A., & Wijk, O. (2020). Toward a Fossil Free Future with HYBRIT: Development of Iron and Steelmaking Technology in. ResearchGate, 4-5.

Ruukki. (ei pvm). HAMK Ohutlevykeskus. Noudettu osoitteesta Ruukki Construction: https://www.ruukki.com/fin/building-envelopes/products/wall-structures/sandwich-panels-for-external-walls/sandwich-panel-detail/sandwich-panel-spa-e-life-energy

Simonen, K., De Wolf, C., & Rodriguez, B. X. (2017). Benchmarking the Embodied Carbon of Buildings. Technology|Architecture + Design(1:2), 208-218.

Tennessee Department of Health. (2019). Environmental Health Topics. Retrieved from Ozone: https://www.tn.gov/health/cedep/environmental/environmental-health-topics/eht/ozone.html#:~:text=Ozone%20depletion%20can%20cause%20increased,fatal%20of%20all%20skin%20cancers.

Tennessee State Government. (n.d.). Envrionmental Heath Topics. Retrieved from Ozone: https://www.tn.gov/health/cedep/environmental/environmental-health-topics/eht/ozone.html#:~:text=Ozone%20depletion%20can%20cause%20increased,fatal%20of%20all%20skin%20cancers.

The Organisation for Economic Co-operation and Development . (2018). Financing Water Supply Sanitation and Flood Protection Country Fact Sheet Finland. The Organisation for Economic Co-operation and Development.

Trusty, W., & Horst, S. (2005). LCA Tools Around the World. Building Design & Construction.

U.S Green Building Council. (2019, 9 18). How LEED v4.1 addresses the circular economy. Retrieved from LEED: https://www.usgbc.org/articles/how-leed-v41-addresses-circular-economy

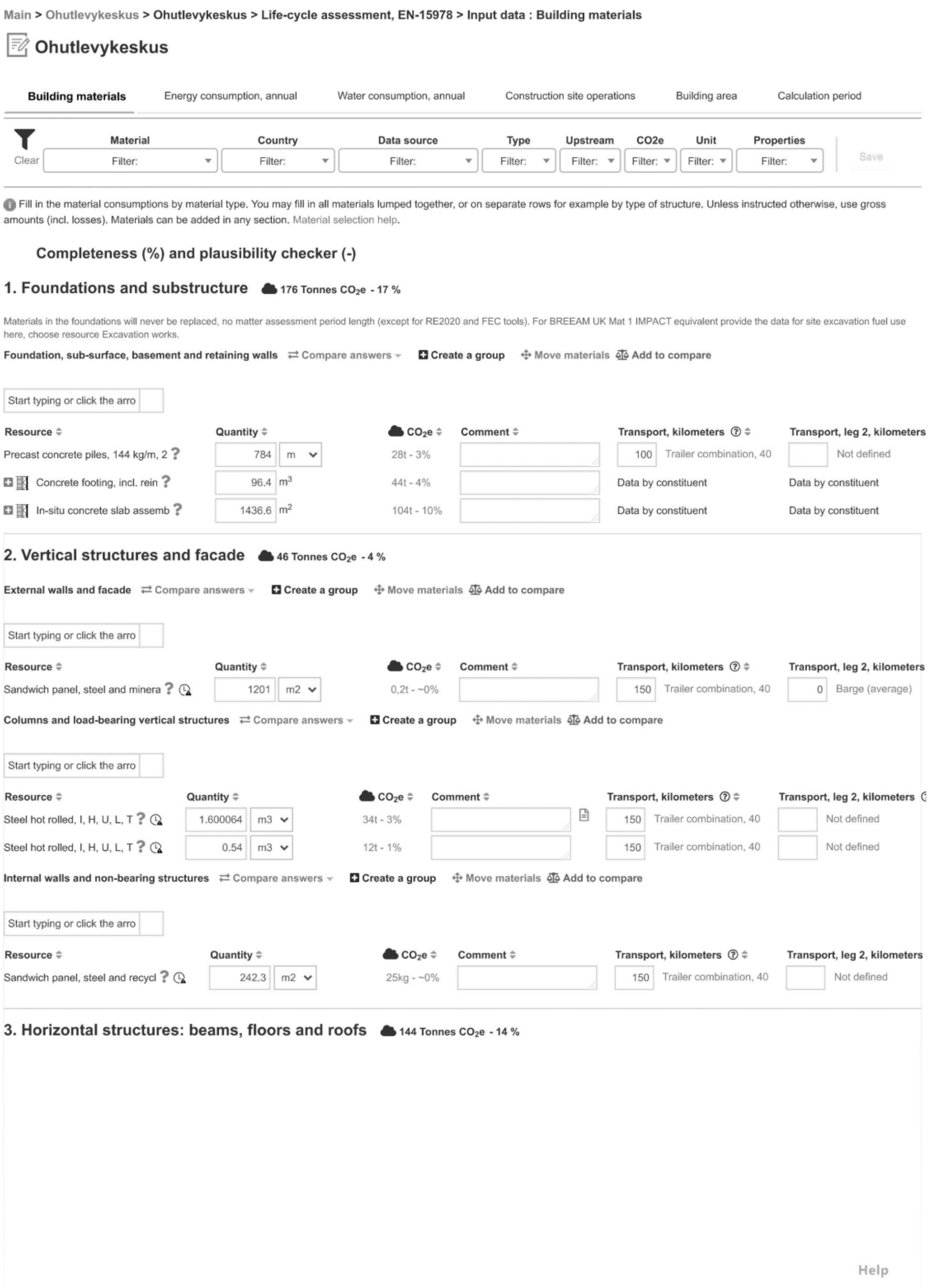
United States Environmental Protection Agency. (n.d.). Understanding Global Warming Potentials. Retrieved from United States Environmental Protection Agency: https://www.epa.gov/ghgemissions/understanding-global-warming-potentials#:~:text=The%20Global%20Warming%20Potential%20(GWP,carbon%20dioxide%20(CO2).

Water Resources Mission Area. (2019, 3 3). Nutrients and Eutrophication. Retrieved from United States Geological Survey: https://www.usgs.gov/mission-areas/water-resources/science/nutrients-and-eutrophication

William, M., & Braungart, M. (2002). Cradle to Cradle: Remaking the Way We Make Things. North Point Press.

Worrell, E., Price, L., & Neelis, M. (2007). World Best Practice Energy Intensity Values for Selected Industrial Sectors. Lawrence Berkeley National Laboratory.

Appendix 1. OneClick LCA LCI Data input



Floor slabs, ceilings, roofing decks, beams and roof ⇄ Compare answers ▾ Create a group ✥ Move materials Add to compare

Start typing or click the arro

Resource	Quantity		CO_2e	Comment	Transport, kilometers		Transport, leg 2, kilom
Structural hollow steel sections (H	0.052	m3	1,5t - 0,1%		110	Trailer combination, 40	Not defined
Structural hollow steel sections (H	0.031	m3	0,88t - 0,1%		110	Trailer combination, 40	Not defined
Structural hollow steel sections (H	0.03	m3	0,85t - 0,1%		110	Trailer combination, 40	Not defined
Structural hollow steel sections (H	0.007	m3	0,2t - ~0%		110	Trailer combination, 40	Not defined
Structural hollow steel sections (H	0.007	m3	0,2t - ~0%		110	Trailer combination, 40	Not defined
Structural hollow steel sections (H	0.005	m3	0,14t - ~0%		110	Trailer combination, 40	Not defined
Structural hollow steel sections (H	0.003	m3	85kg - ~0%		110	Trailer combination, 40	Not defined
Structural hollow steel sections (H	0.003	m3	85kg - ~0%		110	Trailer combination, 40	Not defined
Structural hollow steel sections (H	0.002	m3	57kg - ~0%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T	0.849	m3	18t - 2%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T	0.387	m3	8,4t - 0,8%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T	0.315	m3	6,8t - 0,7%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T	0.232	m3	5t - 0,5%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T	0.163	m3	3,5t - 0,3%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T	0.054	m3	1,2t - 0,1%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T	0.04	m3	0,86t - 0,1%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T	0.013	m3	0,28t - ~0%		110	Trailer combination, 40	Not defined
Steel hot rolled, I, H, U, L, T		kg			0	Trailer combination, 40	Not defined
Sandwich panel, steel and minera	1467	m2	96t - 9%	Roof structure	200.0	Trailer combination, 40	Not defined

4. Other structures and materials

9 Tonnes CO_2e - 1 %

Other structures and materials ⇄ Compare answers ▾ Create a group ✥ Move materials Add to compare

Start typing or click the arro

Resource	Quantity		CO_2e	Comment	Transport, kilometers		Transport, leg 2, kilom
Steel connections for concrete elem	0.013	m3	0,26t - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0.012	m3	0,24t - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0.004	m3	81kg - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0.002	m3	40kg - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0.002	m3	40kg - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0.001	m3	20kg - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0.001	m3	20kg - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0.001	m3	20kg - ~0%		110	Trailer combination, 40	Not defined
Steel for reinforcement profiles	0.001	m3	3,6kg - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0.001	m3	20kg - ~0%		110	Trailer combination, 40	Not defined
Steel connections for concrete elem	0	m3			110	Trailer combination, 40	Not defined
Precast concrete internal wall elem	20	m3	8,1t - 0,8%		70	Trailer combination, 40	Not defined

Windows and doors ⇄ Compare answers ▾ Create a group ✥ Move materials Add to compare

Start typing or click the arro

Finishes and coverings ⇄ Compare answers ▾ Create a group ✥ Move materials Add to compare

+ Click to input data

5. External areas and site elements

Materials and constructions for external areas ⇄ Compare answers ▾ Create a group ✥ Move materials Add to compare

+ Click to input data

6. Building technology

45 Tonnes CO_2e - 4 %

Building systems and installations ⇄ Compare answers ▾ Create a group ✥ Move materials Add to compare

Building systems and installations can be added through this section only.

Start typing or click the arro

Resource	Quantity					CO_2e	Comment	Transport, kilometers		Transport, leg 2, kilome	
Float glass, single pane, generic, ?	158	m2	x	8	mm	7,7t - 0,8%		110	Trailer combination, 40		Not defined
Gliding door, per unit, 1140 x 2 ?	8	unit				2,2t - 0,2%		130	Trailer combination, 40		Not defined
EPS insulation panels, graphite, L= ?	1496	m2	x	150	mm	35t - 3%		180	Trailer combination, 40		Not defined

One Click LCA © copyright One Click LCA LTD | Version: 0.14.0, Database version: 7.6
Backend param handling took: 0.6s, GSP param handling took: 1.3s, Dom ready: 1.8s, Window loaded: 0.3s, Overall: 4.0s.

Main > Ohutlevykeskus > Ohutlevykeskus > Life-cycle assessment, EN-15978 > Input data : Energy consumption

Ohutlevykeskus

Building materials | **Energy consumption, annual** | Water consumption, annual | Construction site operations | Building area | Calculation period

For building life-cycle calculation and most other purposes the figures are provided on an annual basis. For product EPD calculations the data may also be given per unit of product, if desirable.

1. Electricity consumption

532 Tonnes CO_2e - 52 %

Electricity use (mandatory) ⇄ Compare answers

Select type of electricity and fill in the consumption and the use of electricity. The bought electricity is reported here. Electricity can be reported separate by purpose of use, or as overall electricity consumption. Average electricity is always used in building design stage calculations. For NS 3720 always use Norwegian degressive energy profiles here

Start typing or click the arro

Resource	Quantity		CO_2e	Comment	Profile	Usage	
Electricity, Finland (Statistics Fi ?	4340	kWh	32t - 3%		2020 - Oi	Heating	change
Electricity, Finland (Statistics Fi ?	0	kWh			2020 - Oi	Cooling	change
Electricity, Finland (Statistics Fi ?	13490	kWh	99t - 10%	heat pump	2020 - Oi	Heating	change
Average electricity, Finland (2011- ?	14302	kWh	154t - 15%	Fans	default	User equipment	change
Average electricity, Finland (2011- ?	6254	kWh	67t - 7%	Pump	default	Facility	change
Electricity, Finland (Statistics Fi ?	19498	kWh	143t - 14%	Lights	2020 - Oi	Facility	change
Electricity, Finland (Statistics Fi ?	3694	kWh	37t - 4%		2021 - Oi	User equipment	change

2. Fuels demand, stationary units

Fuel use ⇄ Compare answers

Select the fuels and fill in their consumption. Fuel for backup power generators is also typed in here. Select the fuels according to the unit you wish to use. Use fuel demand figures which account for efficiency. Do not provide transport fuels here.

Start typing or click the arro

3. The consumption of district heating

District heat use ⇄ Compare answers

+ Click to input data

Fuels used in nearby or on-site heat suppliers ⇄ Compare answers

+ Click to input data

4. District cooling

District cooling use ⇄ Compare answers

+ Click to input data

5. Exported energy

Exported energy ⇄ Compare answers

+ Click to input data

One Click LCA © copyright One Click LCA LTD | Version: 0.14.0, Database version: 7.6
Backend param handling took: 0.3s, GSP param handling took: 0.4s, Dom ready: 0.7s, Window loaded: 0.0s, Overall: 1.4s.

Help

Main > Ohutlevykeskus > Ohutlevykeskus > Life-cycle assessment, EN-15978 > Input data : Water consumption

Ohutlevykeskus

Building materials | Energy consumption, annual | **Water consumption, annual** | Construction site operations | Building area | Calculation period

This query collects data of water consumption.

1. The water consumption

30 Tonnes CO_2e - 3 %

Total water consumption ⇄ Compare answers

Water embedded into structures or products is not reported here. They are reported separately.

Start typing or click the arro

Resource	Quantity		Comment	
Tap water, conventionally treated (?	2250	m3		change

One Click LCA © copyright One Click LCA LTD | Version: 0.14.0, Database version: 7.6
Backend param handling took: 0.3s, GSP param handling took: 0.1s, Dom ready: 0.3s, Window loaded: 0.0s, Overall: 0.7s.

Help

Main > Ohutlevykeskus > **Ohutlevykeskus > Life-cycle assessment, EN-15978 > Input data : Building area**

Ohutlevykeskus

Building materials | Energy consumption, annual | Water consumption, annual | Construction site operations | **Building area** | Calculation period

Provide building area data for benchmarking and calculation purposes. See GUIDE here

1. Area definitions

Building area (mandatory) ⇄ Compare answers

Please always provide gross internal floor area to get benchmark feedback. These figures are always given excluding parkings and motor vehicle circulation areas, but including basements. You may mark further detail on the basis of the area definition in the comments and provide additional national area definitions. Using additional national definitions allows for national level benchmarking.

Start typing or click the arro

Resource	Quantity		Comment	
Gross Internal Floor Area (IPMS/RIC ?	1496,5	m^2		change
Number of users ?	30			change
Heated net area ?	1436,6	m^2		change
Conditioned Building Volume ?	13000	m^3		change

One Click LCA © copyright One Click LCA LTD | Version: 0.14.0, Database version: 7.6
Backend param handling took: 0.3s, GSP param handling took: 0.1s, Dom ready: 0.5s, Window loaded: 0.0s, Overall: 0.9s.

Help

Appendix 2. OneClick LCA Output

Main > Ohutlevykeskus > Ohutlevykeskus > Life-cycle assessment, EN-15978

Ohutlevykeskus - Life-cycle assessment, EN-15978 Project basic information

Result report: Ohutlevykeskus

Project	Ohutlevykeskus - Ohutlevykeskus
User	Georgi - 15.05.2023
Tool	Life-cycle assessment, EN-15978
Details	Building life-cycle assessment according to the European Standard EN 15978. This LCA software covers life cycle stages from cradle to grave with separate reporting to product stage, construction process, use stage, operational energy, and end of life. This LCA software and related datasets are compliant with ISO 14040/14044 or EN 15804. It is compliant with the Active House Specification requirements.
General information	
Type	Industrial production buildings
Country	Finland
Address	Visakaarre 9, 13100 Hämeenlinna
Gross Floor Area (m²)	1436.6
Number of above ground floors	1
Frame type	steel

Commercial usage is forbidden. One Click LCA Student (International) Business + Carbon Designer, EDUCATION, Georgi 15.05.2023 13:13

1 030 Tonnes CO_2e **13.77 kg CO_2e / m^2 / year** **51 525 € Social cost of carbon**

Carbon Heroes Benchmark

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)		kg CO_2e/m^2
(< 250)	A	
(250-310)	B	304
(310-370)	C	
(370-430)	D	
(430-490)	E	
(490-550)	F	
(> 550)	G	

CH Q3 2021 Finland

Download as image

Results

Life cycle assessment results Download Results Summary

Help

	Result category	Global warming kg CO_2e	Acidification kg SO_2e	Eutrophication kg PO_4e	Ozone Depletion kg CFC11e	Formation of ozone of lower atmosphere kg Ethenee	Total use of primary energy ex. raw materials MJ	Biogenic carbon storage kg CO_2e bio	
A1-A3	Construction Materials	3,81E5	9,47E2	1,18E2	1,19E−2	1,26E2	3,37E6	0E0	Details
⊞ A4	Transportation to site	1,35E4	2,47E1	5,15E0	2,32E−3	1,89E0	2,26E5		Details
A5	Construction/installation process	3,55E4	6,68E1	1,48E1	5,99E−3	5,67E0	9,31E5		Details
B1-B5	Maintenance and material replacement	4,89E3	3,81E1	3,25E0	3,26E−4	1,85E0	8,09E4		Details
B6	Energy consumption	5,32E5	2,89E3	6,22E2	6,57E−2	1,2E2	3,36E7		Details
B7	Water use	3,04E4	2,08E2	4,85E1	2,18E−3	7,32E0	5E5		Details
⊞ C1-C4	End of life	3,34E4	6,46E1	1,56E1	3,59E−3	3,77E0	6,44E5		Details
⊞ D	External impacts (not included in totals)	−6,99E4	−1,68E2	−2,42E1	−1,98E−3	−2,62E1	−5,1E5		Details
	Total	**1,03E6**	**4,24E3**	**8,27E2**	**9,2E−2**	**2,67E2**	**3,94E7**	**0E0**	
	Results per denominator								
	Gross Internal Floor Area (IPMS/RICS) 1496.5 m^2	6,89E2	2,84E0	5,53E−1	6,15E−5	1,78E−1	2,63E4	0E0	
	Number of users 30.0	3,43E4	1,41E2	2,76E1	3,07E−3	8,9E0	1,31E6	0E0	
	Heated net area 1436.6 m^2	7,17E2	2,95E0	5,76E−1	6,41E−5	1,86E−1	2,74E4	0E0	
	Conditioned Building Volume 13000.0 m^3	7,93E1	3,26E−1	6,36E−2	7,08E−6	2,05E−2	3,03E3	0E0	

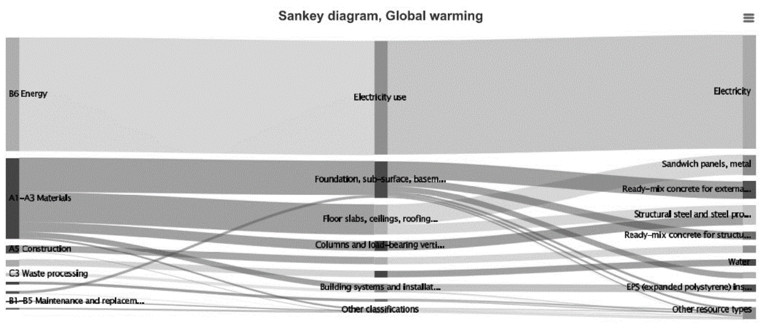
Completeness (%) and plausibility checker (-)

Most contributing materials

Graphs

Overview | Bubble | **Sankey** | Treemap | Life-cycle stages | Annual | Spidergram | Stages - stacked | Materials - stacked | Classifications | All graphs

Configure your chart



Data sources

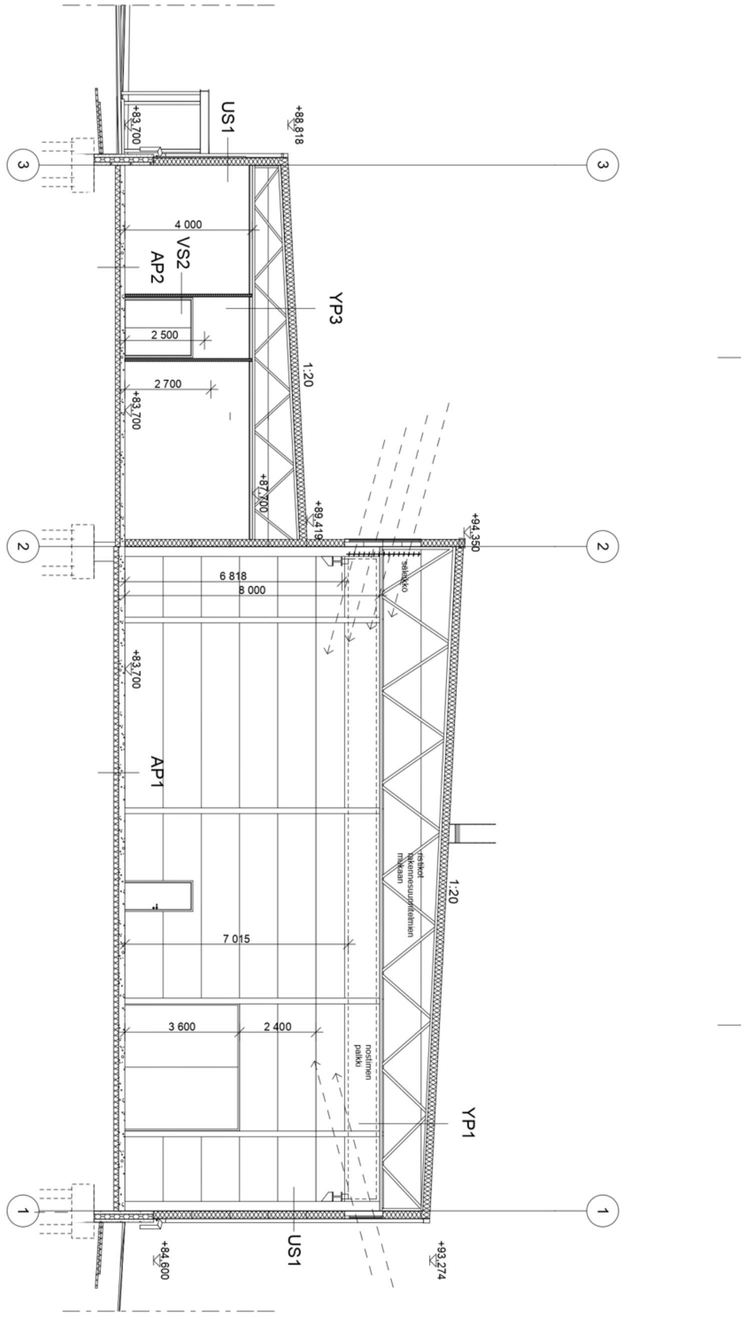
Sources

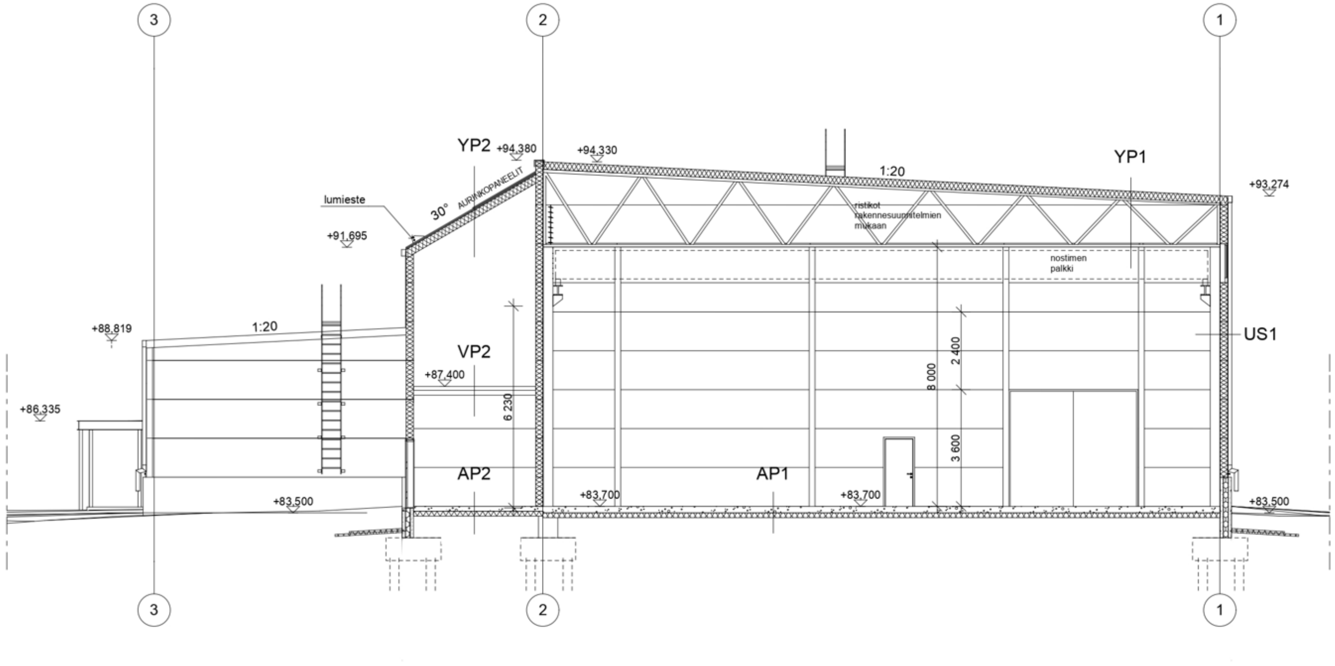
Resource name	Technical specification	Product	Manufacturer	EPD program	EPD number	Environment Data Source	Standard	Verification	Year	Country	Upstream database	Densi
Average electricity, Finland (2011-2015 average)				One Click LCA		LCA study for country specific electricity mix based on Statistics Finland, OneClickLCA 2017		Internally verified	2015	finland	ecoinvent	
Concrete footing, incl. reinforcing, per m3 of element	C35/45			One Click LCA		One Click LCA generic construction definitions				europe	Ecoinvent	
EPS insulation panels, graphite	L= 0.033 W/mK, R= 3.03 m2K/W, 100 mm, 3 kg/m2, 30 kg/m3, compressive strength 220 kPa, 100% recycled polystyrene, Lambda=0.033 W/(m.K)		One Click LCA	One Click LCA	-	One Click LCA	EN15804+A1, EN15804+A2	Internally verified	2023	LOCAL	ecoinvent	
Electricity, Finland			Statistics Finland	One Click LCA		LCA study for country specific electricity mix based on Statistics Finland, OneClickLCA 2022		Internally verified	2020	finland	ecoinvent	
Electricity, Finland			Statistics Finland	One Click LCA		LCA study for country specific electricity mix based on Statistics Finland, OneClickLCA 2023		Internally verified	2021	finland	ecoinvent	
Float glass, single pane, generic	3-12 mm (0.12-0.47 in), 10 kg/m2 (2.05 lbs/ft2) (for 4 mm/0.16 in), 2500 kg/m3 (156 lbs/ft3)			One Click LCA	-	One Click LCA	EN15804+A1	Internally verified	2018	LOCAL	ecoinvent	2500.
Gliding door, per unit	1140 x 2300 mm, 2.622 m2, 135.12 kg/unit	Gliding Door 10l	KONE	IBU	EPD-KON-20160136-IBA1-EN	EPD	EN15804+A1	Third-party verified (as per ISO 14025)	2016	finland	GaBi	
In-situ concrete slab assembly, incl. One Click LCA generic data				One Click LCA		One Click LCA generic construction definitions				finland	Other	
Precast concrete internal wall element	250 mm, 611 kg/m2		Betoniteollisuus ry	-	-	EPD VÄLISEINÄELEMENTTI 150 MM, 200 MM JA 250 MM	EN15804+A1	Third-party verified (as per ISO 14025)	2021	finland	ecoinvent	
Precast concrete piles	144 kg/m, 235x235 mm	SP-1	Peab Grundläggning AB (2020)	International EPD System	S-P-01729, v.2020	EPD PRECAST CONCRETE FOUNDATION PILES	EN15804+A1	Third-party verified (as per ISO 14025)	2020	sweden	GaBi	
Ready-mix concrete, normal-	C40/50 (5800/7300 PSI), 0%			One Click LCA	-	One Click LCA	EN15804+A1, EN15804+A2	Internally verified	2018	LOCAL	ecoinvent	2400.

Resource name	Technical specification	Product	Manufacturer	EPD program	EPD number	Environment Data Source	Standard	Verification	Year	Country	Upstream database	Densi
strength, generic	recycled binders in cement (400 kg/m3 / 24.97 lbs/ft3)											
Ready-mix concrete, normal-strength, generic	C30/37 (4400/5400 PSI), 0% recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3)			One Click LCA	-	One Click LCA	EN15804+A1, EN15804+A2	Internally verified	2018	LOCAL	ecoinvent	2400.
Reinforcement steel (rebar), generic	90% recycled content, A615			One Click LCA	-	One Click LCA	EN15804+A1	Internally verified	2018	LOCAL	ecoinvent	7850.
Sandwich panel, steel and mineral wool	U = 0.17 W/(m2K), 230 mm, 28.9 kg/m2	SPA230E, SPA230E Energy	Ruukki	RTS	-	Sandwich panels, Ruukki 2014	EN15804+A1	Third-party verified (as per ISO 14025)	2014	finland	GaBi	125.6
Sandwich panel, steel and recycled glass wool	U = 0.25 W/(m2K), 150 mm, 17.8 kg/m2	SPA150E Life	Ruukki	RTS	-	Sandwich panels, Ruukki 2014	EN15804+A1	Third-party verified (as per ISO 14025)	2014	finland	GaBi	118.6
Steel connections for concrete elements	7850 kg/m3		Peikko Group Corporation, Finland plant	EPD Hub	EPD HUB-0027	EPD Connecting Parts Peikko Finland Oy	EN15804+A1, EN15804+A2	Third-party verified (as per ISO 14025)	2022	OCLEPD, finland	ecoinvent	7850.
Steel for reinforcement profiles			Celsa Steel	International EPD System	S-P-00307	Steel Reinforcement Products for Concrete	EN15804+A1	Third-party verified (as per ISO 14025)	2015	finland	ecoinvent	7700.
Steel hot rolled, I, H, U, L, T and wide flats, FI average			Ruukki	-	-	EPD Ympäristöseloste teräsrakenteet, Kuumavalssatusta levystä ja kelasta valmistetut, hitsatut ja pintakäsitellyt profiilit, ristikkorakenteet ja palkit , Ruukki 2014	EN15804+A1	Third-party verified (as per ISO 14025)	2014	finland	GaBi	7850.
Structural hollow steel sections (HSS), cold rolled, generic	10 % recycled content, circular, square and rectangular profiles, S235, S275 and S355			One Click LCA	-	One Click LCA	EN15804+A1, EN15804+A2	Internally verified	2018	LOCAL	ecoinvent	7850.
Weber floor smoothing screed	5-50mm layer thickness, 34 kg/m2	vetonit 130 Core	weber.	RTS	Nro 12 VAHEPD-2017-108	EPD weber.vetonit	EN15804+A1	Third-party verified (as per ISO 14025)	2017	finland	ecoinvent	1700.

Appendix 3

LEIKKAUS A-A





LEIKKAUS B-B

RAKENNETYYPIT:

AP 1 (U=0.14 W/m^{2}K)
Hallin lattia
Pintamateriaali
200 Teräsbetonilaatta
150 Solupolystyreeni
>300 Salaojitussora
Perusmaa

AP2 (U=0.14 W/m^{2}K)
Toimisto-osan lattia
Pintamateriaali
120 Teräsbetonilaatta
150 Solupolystyreeni
>300 Salaojitussora
Perusmaa
Huom. kosteat tilat: vesieristys

AP3 (U=0.14 W/m^{2}K)
IV-konehuoneen lattia
Pintamateriaali
Vedeneriste
120 Steelcomp-liittolaatta
300 Mineraalivilla
9 Tuulensuoja
22 lauta
alakatto

VP1
Parvi
Pintamateriaali
180 Steelcomp-liittolaatta
Pintamateriaali

VP2
IV-konehuone
Pintamateriaali
120 Steelcomp-liittolaatta
Pintamateriaali

YP 1 (U=0.12 W/m^{2}K)
Hallin katto
PVC -kate
230 Kattoelementti

YP 2 (U=0.12 W/m^{2}K)
IV-konehuoneen katto
Ruukki Classic solar -lämpökatto
32 Ruukki rei`itetyt orret
PVC-kate
230 Kattoelementti

YP 3 (U=0.12 W/m^{2}K)
Sivusiipi
PVC -kate
230 Kattoelementti
Välitila
Poimupelti

US 1 (U=0.16 W/m^{2}K)
Hallin ja toimisto-osan ulkoseinä
230 Ruukki-seinäelementti

VS 1
Hallin väliseinä
100 Ruukki-seinäelementti

VS 2
Hallin ja tsto-osan väliseinä
230 Ruukki-seinäelementti

VS3
Testihuoneiden väliseinät
Pintakäsittely
13 Kipsilevy EK
92 Teräsranka + min.villa 50
13 Kipsilevy EK
Pintakäsittely
Laatoitetulla alueella kosteussulku-
käsittely ja VTT:n sertifioima veden-