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Eetu Toroskainen

Building Life Cycle Assessment Process in Design

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The goal of this bachelor’s thesis was to analyse the current building LCA processes and the process development potential of a multi-disciplinary design company. The possibility in adopting a proposed national assessment method for building life cycle carbon footprint and combining the national energy standardized energy calculation process with the current LCA processes was reviewed.

The LCA process was described based on the current company practices. The description of the building LCA process was compared with the proposed national assessment method and the European standard EN 15978. Reviewing the development needs in the LCA processes was implemented by communicating with architectural and structural design teams in-house.

The outcome of the thesis showed that the current building LCA processes in the company are carried out according to the common building LCA frameworks and standards. The proposed national assessment method for building LCAs could be adopted in the company with minor adjustments in the company process. Combining the national standard energy calculation process with the LCA process cost effectively was found to be partly feasible. Process development potential was found from adopting screening LCAs. Current LCAs are made at late design stages and the screening LCAs could support early design stage decision making.

Keywords	life cycle assessment, LCA, carbon footprint, environmental impact

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Tämän insinöörityön tavoitteena oli tuottaa prosessikuvaus rakennusalan suunnittelutoimiston tämänhetkisestä rakennusten LCA prosessista ja arvioida prosessin kehitystarpeita. Työssä arvioitiin yrityksen valmiutta ottaa käyttöön ympäristöministeriön ehdottamaa kansallista hiilijalanjäljen arviointimenetelmää ja mahdollisuutta yhdistää pakollista energiatodistusta varten vaadittu E-luvun laskentaprosessi rakennusten LCA prosessien kanssa kustannustehokkaasti.

Prosessikuvaus tehtiin yrityksen nykyisiin toimintatapoihin perustuen. Tiedot prosessikuvausta varten kerättiin tekemällä toimistokohteeseen LCA sekä hyödyntämällä yrityksessä aiemmin toteutettuja arviointeja. Tuotettua prosessikuvausta verrattiin ehdotettuun kansalliseen rakennuksen elinkaaren hiilijalanjäljen laskentamenetelmään ja eurooppalaiseen EN 15978 standardiin. Mahdollisuutta kustannustehokkaasti yhdistää E-luvun laskentaprosessi nykyisen LCA prosessin kanssa arvioitiin lähtötietovaatimuksiin ja molempien prosessien mallinnusvaatimuksiin perustuen. Kehitystarpeita LCA prosesseihin liittyen kartoitettiin keskustelemalla yrityksen arkkitehti- ja rakennesuunnittelijoiden kanssa.

Työn tulos osoitti, että yrityksen tämänhetkinen LCA prosessi perustuu yleisesti tunnustettuihin arviointimenetelmiin ja standardeihin. Ympäristöministeriön ehdotus kansallisesta rakennuksen elinkaaren hiilijalanjäljen arviointimenetelmistä perustuisi myös yleisiin laskentamenetelmiin ja täten menetelmän käyttöönotto yrityksessä olisi toteutettavissa pienin muutoksin. Energiatodistusta varten vaadittavan E-luvun laskentaprosessin ja LCA prosessin yhdistäminen kustannustehokkaasti osoittautui kannattavaksi vain lähtötietojen yhdistämisen osalta. Yhteisen lähtötietokokoelman kerääminen kohteesta voi säästää resursseja. Molempien prosessien mallinnusvaiheet ovat hyvin erilaiset ja erityisesti energiamallinnuksen vaatimukset estävät yhteisten mallien ja työkalujen käytön mallinnusvaiheissa. Kehitystarpeita nykyiseen LCA prosessiin löydettiin aikaisen vaiheen arvioinneista. Tällä hetkellä elinkaarianalyysejä tehdään lähinnä myöhäisissä suunnitteluvaiheissa. Aikaisen vaiheen analyysit voisivat tukea arkkitehtisuunnittelun päätöksentekoa.

Avainsanat	elinkaarianalyysi, LCA, hiilijalanjälki, ympäristövaikutus

Contents

1 Introduction

As a member of European Union, Finland is under an obligation to reach the common goals for the reduction of greenhouse gas (GHG) emissions set for the member states. The Finnish environmental building regulation systems have mainly been based on controlling the energy consumption of the buildings. To reach the GHG emission reduction goals, the Finnish Ministry of Environment is developing a regulative framework to control the life cycle carbon footprint of new buildings. The proposed building regulation would be gradually adopted by the end of the year 2025. [1.] It can be expected that the demand for life cycle assessments (LCA) will increase due to the changing legislative environment. Building design and building production are, like other fields, influenced by the proposed regulation and must, therefore, prepare for the change.

Optiplan Ltd (referred as the case company), a multi-disciplinary design company, provides life cycle assessments as a part of their lifecycle services in Finland. The main objective of this thesis is to describe the current LCA processes in the company and review the potential in the process development. Important topics covered in the thesis are how prepared the case company is to adopt the proposed national carbon footprint calculation method, and whether it is possible to combine the process of standardized energy calculation for the national energy certification with the current LCA process. This thesis provides the case company with information about its current LCA processes and how to develop the processes further.

The thesis is divided in three parts. The first part, chapters 2 and 3, describe the principles of LCA both in general and from the point of view of building assessments. The second part comprising, chapters 4 and 5, considers the environmental impact of buildings and the legislative environment in EU and Finland. The third, and final, part describes the LCA processes in building design. The conclusions of the final year project are given in chapter 10.

2 Life Cycle Assessment

2.1 LCA Process

The purpose of an LCA is to study the environmental aspects and impacts during the life cycle of a product. The whole life cycle of a product includes raw material extraction, production, use and disposal. [2.]

The life cycle assessment process is defined in the international standards ISO 14040 and ISO 14044. The principles and framework of LCA are described in the ISO 14040. The requirements and guidelines are defined in more detail in the ISO 14044. The life cycle assessment process consists of four necessary parts: definition of goal and scope, inventory analysis, impact assessment and interpretation. The LCA framework according to the standard ISO 14040 is illustrated in figure 1 and the parts are discussed below the figure. [2.]

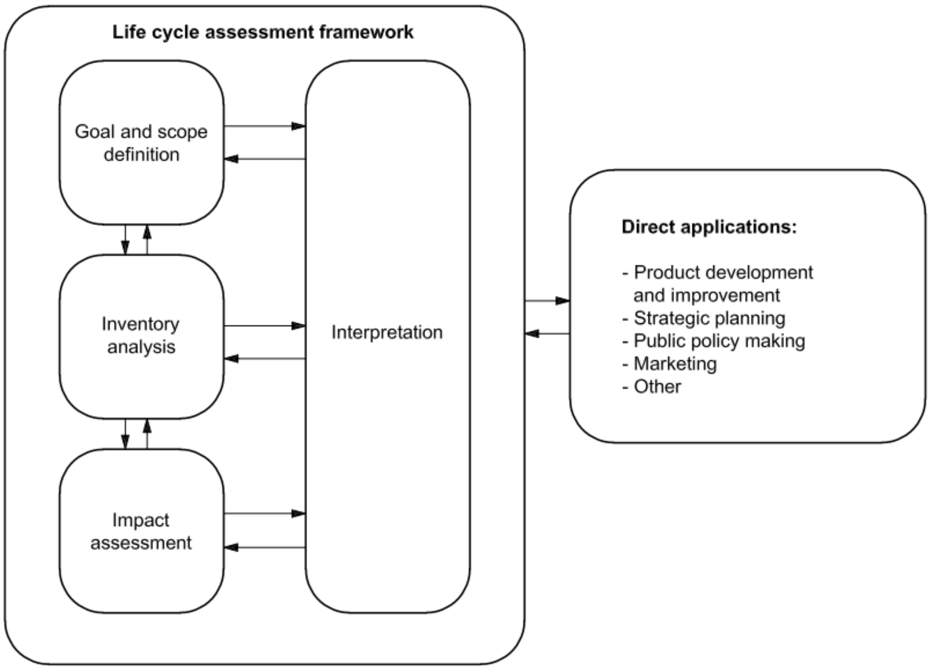

Figure 1. Life cycle assessment framework according to the standard ISO 14040 [2].

Goal and Scope Definition

The goal and scope of LCA must be carefully defined for each case according to the intended use of the assessment. According to the standard ISO 14044, the goal of the LCA should indicate:

- the intended use of the analysis
- the reasons for carrying out the analysis
- the intended audience
- public accessibility.

The goal definition is set by the commissioner of the study [3].

The scope of the LCA should describe the details of the analysis and prove that the goal of the study can be achieved. The following aspects should be included:

- product system
- functions of the product system
- functional unit
- system boundary
- allocation procedures
- life cycle impact assessment (LCIA) methodology and types of impacts
- interpretation to be used
- data requirements
- assumptions
- value choices and optional elements
- limitations
- data quality requirements
- type of critical review
- type and format of the report required for the study.

The standard ISO 14044 underlines that LCA is an iterative technique and the scope may have to be redefined during the assessment process [4; 5].

Inventory Analysis and Functional Unit

The inventory analysis (LCI) of the LCA of a product comprises the data collection and simulation of the product. The LCI phase should be done according to the goals and scope requirements set for the LCA. The results of the LCI are used as in input for the next phase of LCA, life cycle impact assessment. [6.]

In the LCI phase, all input and output flows to and from the analysed system are collected. The flows include the energy and raw materials used and emissions to the atmosphere, water and soil. The data collection phase is often a resource-intensive process where software tools and databases are utilized. [7.]

Analysed environmental impacts are reviewed by using functional units that provide normalised values for the environmental impacts the LCA studies. A functional unit should be measurable and defined clearly. [4.] Commonly used functional units for product LCAs are a mass unit or a unit of volume for the product.

Life Cycle Impact Assessment

The next phase of the LCA, the life cycle impact assessment (LCIA) is based on the data collected in the LCI stage. The data are associated with environmental impact categories and category indicators that are chosen in the LCI phase and, the selection of impact categories may have to be readjusted in the LCIA stage. The overall goal of the LCIA stage is to improve the overall understanding of the environmental effects of the assessed process. [2; 4.]

Interpretation

In the interpretation stage of the LCA, conclusions are made based on the results of the previous stages LCI and LCIA, and recommendations are given according to the initial goals of the study. Furthermore, the results of the LCA are reported in an informative way in the interpretation stage. The standardized elements in ISO 14044 are the identification of significant issues, evaluation considering completeness, sensitivity and consistency checks, conclusions, limitations and recommendations. [3.]

2.2 LCA System Boundary

Product systems are divided into sets of unit processes which are the smallest elements for which inputs and outputs are assessed in the LCI. Dividing the product system into unit processes facilitates the process of assessing the specific input and output flows of the product system. [2.]

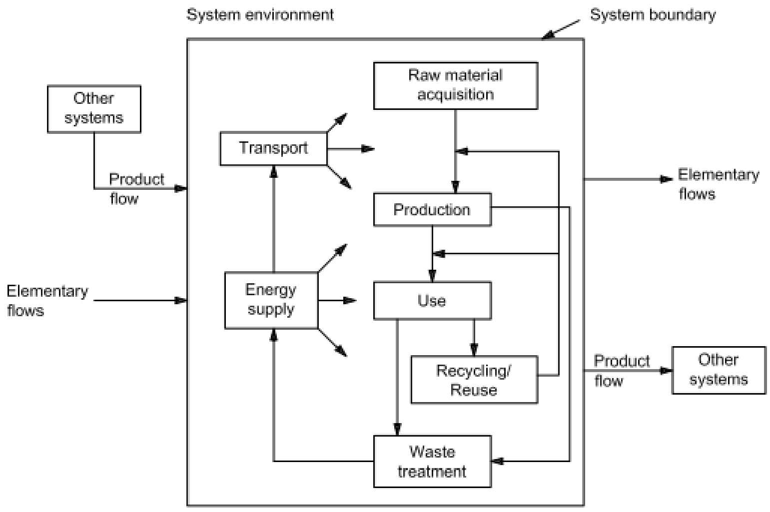

Figure 2. LCA system boundary according to ISO 14040 [2].

The system boundary defines which processes and activities are included in or left out of the LCA. Furthermore, the system boundary establishes which unit processes are part of the product system. Input and output flows to and from the product system are specified by the system boundary. [2.] A basic system boundary of an LCA according to ISO 14040 is shown in figure 2 above.

2.3 Environmental Impact Categories

The different environmental issues that may result from an assessed product or process are classified in environmental impact categories. The impact categories are not listed or recommended in the standard ISO 14044. The selection of the impact categories should be based on the goal and scope of the study. Furthermore, the impact category selection should be prior to the determination phase of the goal and scope of the study. [3.] Common environmental impact categories used in the building life cycle assessment are global warming which is discussed below, acidification, eutrophication, ozone depletion potential, formation of ozone in the lower atmosphere, and primary energy [8].

Global warming potential (GWP) is an impact indicator for global warming. The total GWP is often called a carbon footprint especially in assessments that study the global warming potential as the only environmental impact factor. The name carbon footprint can be misleading as the total GWP includes also other greenhouse gasses (GHG) and not just carbon dioxide. [3.] The total GWP is an important topic for this thesis, elaborated in more detail in this chapter.

In a global warming impact assessment, a weighted sum of the assessed GHG emissions is given in mass unit of CO_2. Several GHGs are assessed in the process and each one of them has its characteristic impacts on the climate change. The impacts are indicated in global warming potentials, GWPs. The impacts of each assessed GHG are scaled to the equivalent of 1 kg of CO_2 (kg CO_2 e). Each GHG has its individual specific tropospheric lifetime which affects the environmental impact of each gas to a high extent. The GWPs are scaled to a common lifetime horizon to have comparable impact results. In the LCA processes, GWPs, with a lifetime horizon of 100 years (GWP_{100}), are often used. [3.]

From the variety of assessed GHGs in an LCA process, CO_2 has been shown to be the most important contributor to the total GWP. For the calculation of GWP, fossil and biological CO_2 sources should be separated. The biological CO_2 sources are extracted from the atmosphere by photosynthesis and then released back by incineration or aerobic degradation. CO_2 emissions from the biological sources are sometimes called CO_2 neutral even though it is only true on a significantly long time scale. [3.]

3 Environmental Impact Assessment of Buildings

Life cycle approach in the context of building processes means assessing the impacts of a building product or a building during its whole life cycle from the construction material production to the decommissioning. The impacts of a building life cycle are often assessed within the framework of environmental, social and economic aspects of sustainable development. The emphasis of this thesis is on the environmental impacts. The purpose of using the life cycle approach is to get an overview of the impacts of a building to its environment, identify problems that can appear at various life cycle stages, and avoid increased negative environmental impacts caused by a too limited scope of the study. [9.]

Complete detailed building LCAs in Europe are based on the standard EN 15978. Standardized LCAs should cover the entire building life cycle as well as all material and energy flows in constructing, operating and decommission the building. Many building LCA frameworks follow the standard EN 15978 but the scope and completeness may vary. [10.]

Depending on the goal and scope of the study and the stage of the building process, the environmental impact assessment can be carried out either on a very general level or on a detailed level, following the compliant standards. An early design stage LCA, or a screening LCA, is carried out with very limited input information, and the calculation process includes major uncertainties. In an early building design phase, the screening LCA can be beneficial as the environmental impacts of different design solutions are reviewed. The screening LCAs provide useful information of the studied impacts, but often the calculation method does not follow any standards and cannot be scientifically proven or compared. [11.]

Indicating the environmental impact on global warming is a part of a building LCA process in line with the standard EN 15978 where the environmental impacts of a building are assessed throughout its life cycle [12]. A time horizon of 100 years is used for the GWPs when using environmental product declarations in line with the standard EN 15804. [13].

3.1 Building Life Cycle Stages

For the assessment of environmental impacts of buildings, the building life cycle stages are standardized and defined in the standard EN 15978. The building life cycle is divided in four main stages: A1-3 Product stage, A4-5 Construction process stage, B1-7 Use stage and C1-4 End of life stage. [13.] The life building life cycle stages are shown in more detail in figure 3 below.

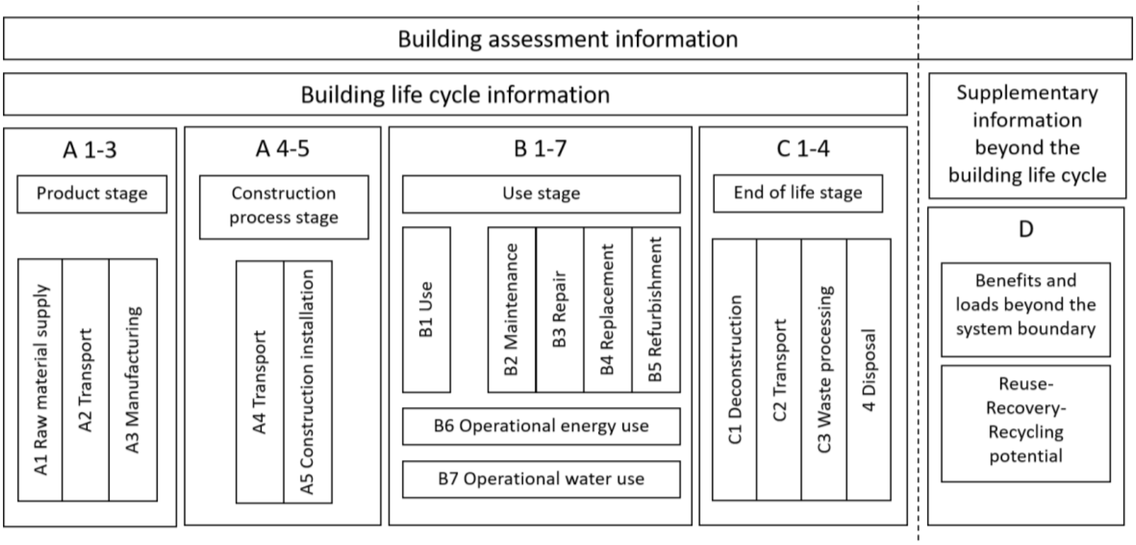

Figure 3. Building life cycle stages according to the standard EN 15978 [12].

Additional information beyond building life cycle can be reported in stage D Benefits and loads beyond the system boundary. Results of module D are not subtracted from the total environmental impacts [12].

3.2 Building System Boundary and Building Model

The system boundary for the LCA of a new construction building should include all life cycle stages when the standard EN 15978 is followed [12]. It should be noted here that not all the assessments discussed in this thesis follow the EN 15978 standard. Therefore, the system boundary presented here is not suitable for every building LCA. A simplified representation of a building LCA system boundary is illustrated in figure 4 below.

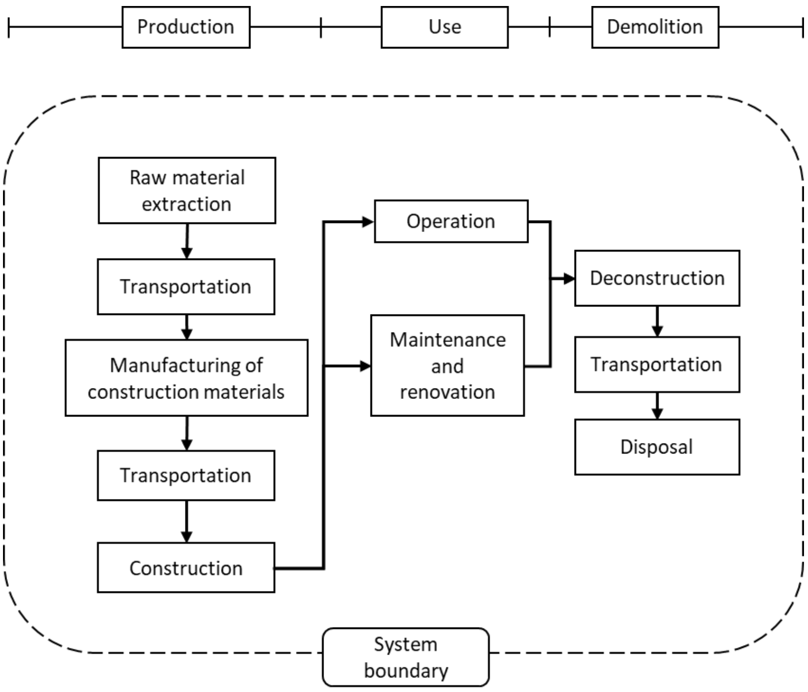

Figure 4. A simplified building LCA system boundary [14].

The building model for the full building life cycle assessment should be formed to enable the evaluation and quantification of the mass and energy flows. The model should include, where applicable, the physical characteristics of the building, the building components, and the building services. The use stage energy flows can be based on the national standardized calculation methods. [12.]

The calculation period or a reference study period, for a building life cycle is generally based on the required service life of the assessed building. The calculation period can differ from the required service life depending on the intended use of the assessment, used regulations, or national guidance. [13.]

3.3 Environmental Data

Environmental product declarations (EPD) are verified and standardized descriptions of the environmental impact of a given product or service. The EPDs give transparent information about the product during its life cycle. The standard EN 15804 gives requirements for construction product EPDs in the European environment. [13.]

The environmental data for LCAs for following the standard EN 15978 should be based on EPDs that fulfil the requirements of the EN 15804. If there are no standardized EPDs available, the environmental data should include the required minimum information stated in the EN 15804. [13.] The minimum requirements are listed in appendix 2.

4 Impact of Buildings on Global Warming

Buildings play a major role in the climate change. In the EU, new construction and renovations are responsible for a half of the overall material consumption [10]. In Finland, the construction sector is responsible for one third of the total GHG emissions [15].

4.1 Building Life Cycle Emissions Distribution

The highest environmental impacts of the life cycle of a building are typically caused in the product stage A1-A3 and the energy use stage B6. The operational energy use is the dominant source of environmental emissions of a typical new building in Finland. Therefore, any improvement of energy efficiency is the most important means in reducing the environmental impacts. The source life cycle stages of total GWP of a typical new concrete structure building in the life cycle categories are illustrated in figure 5. [16.]

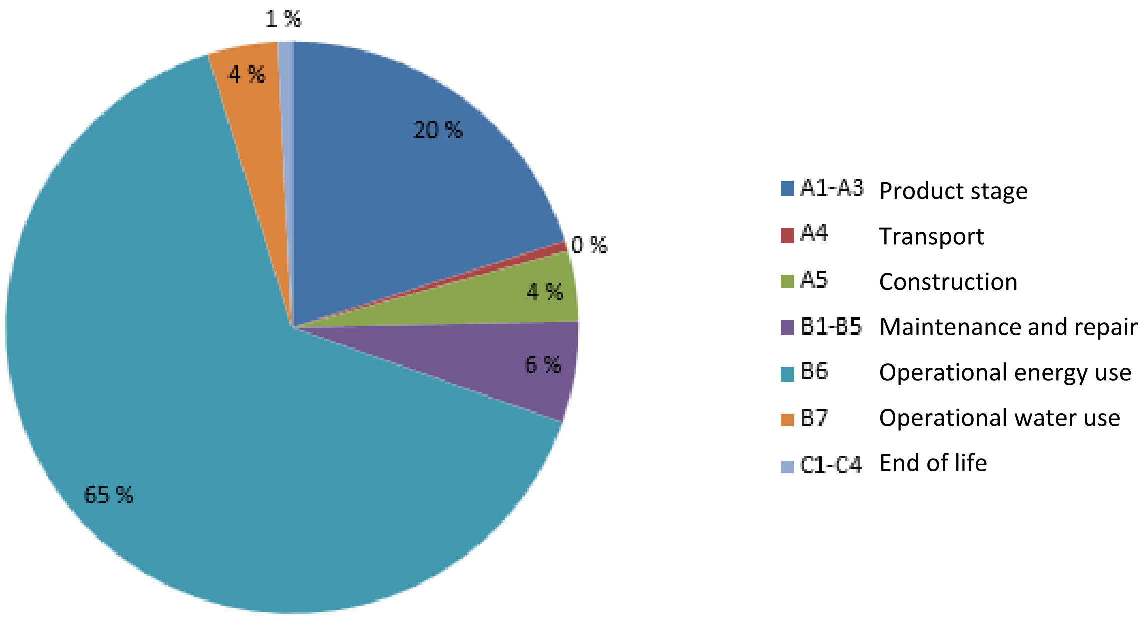

Figure 5. Typical distribution of building life cycle GWP divided in life cycle stages [16].

In a typical multi-storey residential building with concrete structures the building components causing most environmental impacts are the foundation, exterior walls, horizontal structures and building services systems. A typical distribution of life cycle GHG emissions between building components categories generated in the final year project LCA case study is illustrated in figure 6 below.

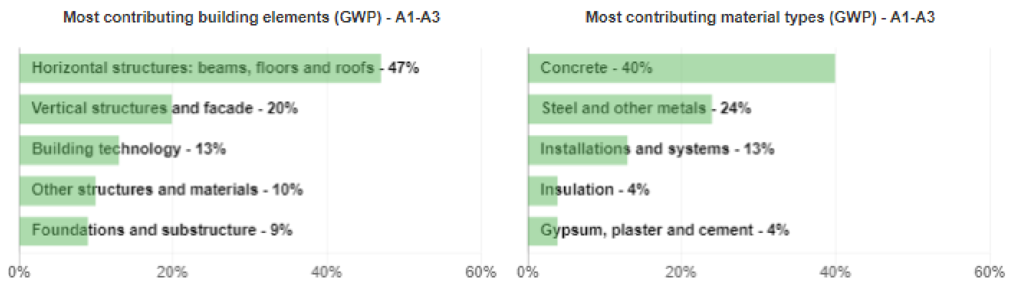

Figure 6. A typical distribution profiles of a building life cycle GWP in One Click LCA.

The foundation type is dependent on the ground type on the site. Having to use piling increases the emissions significantly. The piles are typically driven deep into the ground and, depending on the soil type the piles may have to be placed densely. Deep pile foundations require a high volume of concrete and steel which result in increased emissions. Concrete and steel components generally affect the total impact the most as the cement and steel production are both energy intensive processes. The larger the mass of concrete and steel in the structures, the higher are the impacts. As an example, a thin solid concrete slab has lower impact than a thick hollow core slab. New buildings contain many different building services systems. When assessing the GHG emissions, the share of the building services systems can be up to one third of the total emissions in a residential building. [16.]

4.2 Embodied and Operational Emissions

The whole building life cycle emissions include both the embodied emissions and operational emissions. The embodied emissions include the GHG emissions in the life cycle stages that are not included in the use stage. The embodied emissions include raw material extraction, manufacturing, transportation, assembling, maintaining, replacing, deconstructing and disposing of building materials and equipment installed in a building. The operational emissions indicate all GHG emissions within the use stage of the building, including heating, cooling, electricity and water. The embodied impacts include life cycle stages A1-A3, A4, B1-B3, B4-B5, C1, C2 and C3-C4. The operational impacts are placed under stages B6-B7. [17].

Energy is used for many purposes throughout a whole building life cycle. In the use stage, energy is mainly consumed by building services systems and electrical equipment. This use stage energy consumption is called operational energy. During the whole life cycle of a building, energy is also required outside the use stage in material and component production, transportation, construction processes, maintenance and decommissioning processes. All energy that is not operational energy is called embodied energy. [18.]

Emissions or energy do alone not describe the environmental performance of the life cycle of a building. The emissions of the energy production affect both the embodied emissions and the operational emissions. When embodied impacts and operational impacts are compared a distinction between emissions and energy should be made as well. [18.]

4.3 Whole Life Cycle Emissions vs. Use Stage Emissions

The greatest factor affecting the building life cycle GWP is the use of fossil fuels in the energy production process. The energy consumed in the use stage of a building and the energy used in the material production are generally the main sources of GHG emissions during a building life cycle because of the emissions of the energy production. [10.]

Due to the international environmental agreements, the share of renewable energy systems in the energy production and energy efficiency of buildings is expected to increase. According to the European Environment Agency EEA, the use of renewable energy and a reduction in household energy consumption are increasing trends in the EU. [19.] The EEA has also reported that the emissions from the energy industry are on a declining trend in EU [20].

Due to the declining trend in energy production emissions and an improvement in building energy efficiency the operational emissions of a building become decreasingly important during the whole life cycle of a building. Respectively, the share of embodied emissions become higher when the emissions resulting from energy production decrease. [10.]

It was found during the final year project that the ratio between the use stage emissions and the whole life cycle emissions is highly dependent on the length of the assessment reference period. The longer the study period the larger are the use stage emissions. For this reason, the ratio does not give an absolute representation of the environmental performance of a building. The chosen assessment reference period defines whether the weight of the assessment is on the operational emissions or embodied emissions.

5 Reduction of Building Emissions in EU

5.1 Building Energy Efficiency in EU and Finland

The European Union has set goals to make its member states gradually reduce their GHG emissions. The EU has pledged to cut its GHG emissions by 20 % from the level of 1990, and to produce 20 % of its energy by renewables and to improve its energy efficiency by 20 % by the year 2020. [21.] By the year 2030, the GHG emissions should be cut by 40 % from the level of 1990, 27 % of the energy should be produced by renewables and the energy efficiency should be increased by 27% [22]. In November 2018, the European Commission presented its vision for a long-term strategy where Europe would operate at a climate neutral level by 2050 [23].

The directive 2010/31/EU for the energy performance of buildings required the member states to set national building requirements for nearly zero energy buildings (nZEB). In simple terms a nZEB is a building that has high energy efficiency and its operational energy is provided from renewables to a high extend. The regulative framework states that all new buildings in EU have to be nZEBs by the end of the year 2020. [24.]

In Finland, the energy performance of buildings is regulated by legislation. The Ministry of Environment of Finland have set requirements and benchmarks for all new buildings and major renovations regarding the energy efficiency of the buildings. A national energy certification is required in for all new buildings and major renovations. [25.]

5.2 Level(s)

Level(s) is a voluntary reporting framework for increasing sustainability of buildings developed by the European Commission based on the CEN/TC 350 standards. The aim of the framework is to create a simple method for the assessment and communication of building sustainability for professionals working in the construction industry and to unify the methods used in sustainability reporting in European Union. [26.]

There are six macro-objectives included in the framework, illustrated in figure 7. The macro objectives are divided in 14 indicators for sustainability. The first macro-objective Greenhouse gas emissions along building's life cycle includes two indicators The indicator one Use stage energy performance and two Life cycle Global Warming Potential The latter should be assessed in accordance with the standard EN 15978. The reference period for all buildings assessed with the Level(s) framework is 60 years. All life cycle stages defined in the standard EN 15978 are taken into account in the Level(s) assessments. [27.] The Level(s) reporting framework is under development and tested at the time of writing this thesis [26].

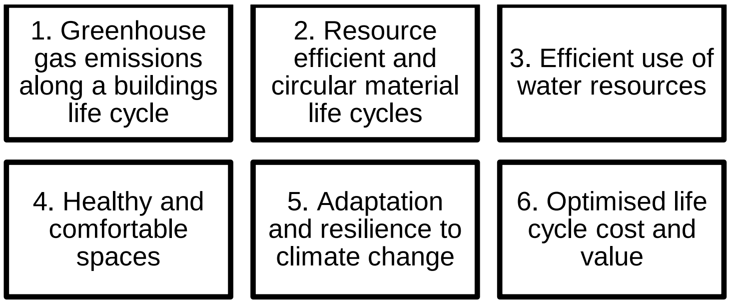

Figure 7. Macro objectives of Level(s) framework [26].

In Finland, the Level(s) framework is tested by the officials and by commercial actors in the construction sector. The framework is taken into account in the development of the national building regulation for low carbon construction. [28.]

5.3 National Carbon Footprint Regulation Process in Finland

As a member of UNFCCC and European Union, Finland is under obligation to set national goals for emission reduction. A significant measure of Finnish GHG is emitted through the built environment. The emission reductions of the built environment in Finland are directed to the fields of land use, energy efficiency, maintenance, material use and renewable energy. [29.]

The Finnish regulations for the environmental construction have mainly been based on improving the energy efficiency of the use stage of buildings. Further cost effective improvements in energy efficiency of the use stage can be challenging according to the Ministry of Environment. Therefore, the beginning and end of a building life cycle have become increasingly important in the whole life cycle emission reduction process. The goal is to regulate the GHG emissions of new constructions by the year 2025. [15.]

It has been proposed that an assessment of the GWP of a building should be an obligatory part of the building permit application process, similarly as national energy certification is required for new constructions and renovations. The proposed calculation method would be based on the standards EN 15634, EN 15978, EN 15804 and the Level(s) framework. [30.]

The national calculation method would allow the calculation of the impact of the buildings on global warming on two levels of detail. A calculation with a lower level of detail would be based on a national standard emission database. The more detailed calculations could be carried out using detailed emission data given in EPDs in accordance with the standard 15804. [30.]

6 LCA in Building Design Processes

Building LCA is used in building design processes in the case company. This chapter describes how LCA is used in design processes of the case company. The availability of inventory data and the quality of the data are highly dependent on the stage of the ongoing design process. Each field of design involved in the design process design stages that may not be interchangeable over the design fields. To simplify the discussion of the design process, it is in this thesis divided in three parts: *sketch, design development* and *construction*. These stages have special characteristics that separate them from one another. An LCA can be carried out at each stage.

6.1 Design Process Stages

The level of detail of the LCA depends completely on the available data quality. To simplify the description of the processes, the LCAs with different levels of detail are linked with the design stages above as shown in table 1.

Table 1. Available data quality and applicable LCA types in different stages of design.

	Sketch	Design development	Construction
Available data quality	very limited available data • gross floor areas • number of floors • location	general data available in addition to sketch stage: • floor plans • main structures • location and orientation	very detailed data available in addition to design development stage • construction details • component specifications
LCA detail level	Screening LCA	LCA with generic impact data	Full LCA based on product specific EPDs and generic data
Fields of design providing documents	Architectural	Architectural Structural	Architectural Structural Building services systems

The early design stage LCAs, or screening LCAs, are best applied in the sketch stage of design where the available data are very general. The screening can be used for example to compare the environmental impacts of very early stage architectural designs. At the design development stage, the provided design documents are rather detailed although product specific data may not be available. When the materials and products are not specified in the design, generic environmental impact data can be used for the assessment. The most informative data are available at the construction stage. Here all major decisions have been made and the LCA can be carried out using product specific EPDs where applicable.

The motivation for the designers to implement an LCA is mainly based on the requirements of a client. The architectural design has a significant role in the accumulation of environmental impacts of a building. Architects are typically the main responsible designers of building projects and they are involved in all stages of design. Other designers, as building services systems designers and structural designers, are involved in the design process at later stages, when many major decisions have already been taken. Therefore, the possibilities to affect the environmental impacts are lower.

In the project acquisition stage, a screening LCA can be used as a tool for supporting proposed solutions and communicating the environmental impact of different solutions. Showing the environmental impacts of a building with the design proposal can add value in the early stage designs especially if the assessment can be implemented cost effectively. [31.]

From the point of view of the embodied emissions, the structural components of the building contribute the most. The major decisions considering the material of the main structures have often already been made when the structural designers start working on the project. LCAs typically consider the whole building, not only the structural elements, and there was only small interest in the field of structural design towards LCA studies at the time of the final year project. [32.]

Building services systems typically affect the total environmental impacts of a building significantly due to the amount of required installations and the energy consumption of the systems. Typically, the life time of building services systems is shorter than that of the assessed building and the systems must be renewed several times throughout the life cycle of the building. The building services design also affects the energy consumption of the building. Therefore, it indirectly affects the overall environmental impact of the assessed building. [33.] Assessing the impacts of building services systems can be challenging as there is a lack of EPDs related to the building services equipment in the market and the building services material assessments must often be made on the basis of estimations. [34.]

6.2 Client Motivation Towards LCA Studies

There can be several reasons for carrying out a building LCA depending on the executing body of the study. The focus of this thesis is on the current LCA processes of the case company. Therefore, the view of this chapter is limited to topics that are interesting from that point of view.

Environmental building certification processes are major environmental impact assessment and design management systems for office and commercial buildings used in the case company. The LCAs that are conducted in the case company can be used for gaining points for the certification processes of many major certification systems, such as BREEAM and LEED. For certification purposes, the considered environmental impact assessment categories and calculation framework are selected according to the definition of the certification body.

Independent LCAs that are not related to any certification processes are done for all building types, including residential, commercial and office buildings. The independent LCAs made in the case company in many cases only consider the impact assessment category *climate change,* often referred to as *carbon footprint.* These independent studies are used for research purposes or to give project owners and stakeholders information about the environmental performance of their buildings.

In general, a majority of the implemented LCAs in the case company are related to the environmental building certification processes. However, the legislative environment and public opinion in the European Union and Finland is changing, and it can be expected that the general interest for LCAs will increase.

7 Software and Databases

Based on the research done during the final year project the inventory analysis stage is a very resource consuming stage in the LCA process. Therefore, for practical reasons software and EPD databases are utilized for the purpose. The LCA software discussed in this thesis is One Click LCA.

One Click LCA (referred to as OCL) is a tool specifically designed for building LCAs, and based on the standards ISO 14040, ISO 14044 and EN 15978 for the European markets. The tool is connected to several verified EPD databases which can be used also for the inventory required for an LCA in line with the standard EN 15978. [8.]

The EPD databases include both specific product data and generic data based on average values for a given material or process. The inventory assessment with OCL can be implemented at many levels of detail depending on the available building data and data quality.

The OCL cannot directly handle building information models, but data can be imported into the tool from the models using provided software integrations. The supported BIM formats for the data import are IFC2x3, IFC4, Revit, ArchiCAD and Tekla Structures. Some of the available integrations allow data exchange directly through the used software, but data can also be exchanged through Excel spreadsheets. Data in IFC format can be directly imported into the tool using Simplebim software, which was used during the final year project. [8.]

When data is exchanged using BIM the quality of the LCA study depends on the quality of the used building information model. In order to effectively utilize the OCL in the process, the building information model should contain specific information about construction materials. [35.]

The geometry of the building should be modelled in detail because the geometrical data are often directly imported into the software. The most important data retrieved from a building information model are quantitative data such as material mass and areas. [35.]

The elements that the building model contains should be labelled in as high detail as possible. The calculation software does recognize the material labels and assigns the

BIM elements to material EPDs accordingly. Very general labels or implicit labels should be avoided. [35.]

Building information models often contain multi-layered elements, such as exterior wall structures. Each layer of the element should be labelled and identified. Another common case within BIM is a multi-material component that is modelled as a solid element. These elements should include labels that indicate all the included materials and material volumes. In the case of hollow objects, the objects should be modelled as hollow or, if modelled solid, the label should contain the material thickness. [35.]

8 Building LCA Process Description

The LCA process described here is based on the current LCA processes of the case company. Information about the LCA processes of the case company was retrieved by conducting an LCA for an office building according to the procedures of the case company. The assessments are most often made at a design stage where major design decisions regarding the building have already been made and the available design data are relatively detailed or very detailed.

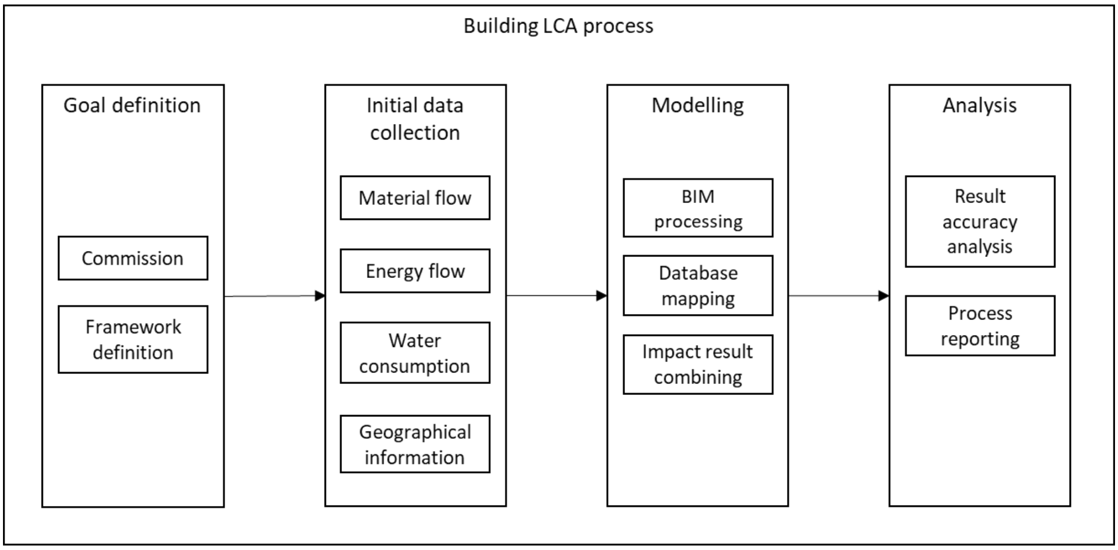

Figure 8. A simplified process flow chart of a building LCA.

In this thesis, the description of the LCA process is based both on previous LCAs made in the case company and on an LCA of an office building carried out during the final year project. The results of the LCA are shown in appendix 3. The LCA process of the case company is divided in four steps that are illustrated in figure 8 above.

8.1 Goal Definition

The goal and scope definition is the basis for starting an LCA process as described in chapter 2.1. The goal is defined by the purpose of use of the LCA or by the client. The LCA may be used as evidence in the process of getting a sustainability certificate for the building, or in some cases a client wants the carbon footprint of the project calculated. The framework to be implemented, the standards used and the calculation period are defined in the goal definition stage. The basic idea of a building LCA is always the same regardless of the framework of the study. Building LCAs can be implemented with varying levels of completeness from simple building material screenings to full LCAs in accordance with EN 15978.

8.2 Initial Data Collection and Calculation Setup

The purpose of the initial data collection phase of an LCA is to collect all the required information for the study. The initial data needs for an LCA process was discovered during the final year project. Data about material flow, energy flow and other building related information is gathered from different sources at the initial data collection and calculation setup stage in the case company as illustrated in figure 9.

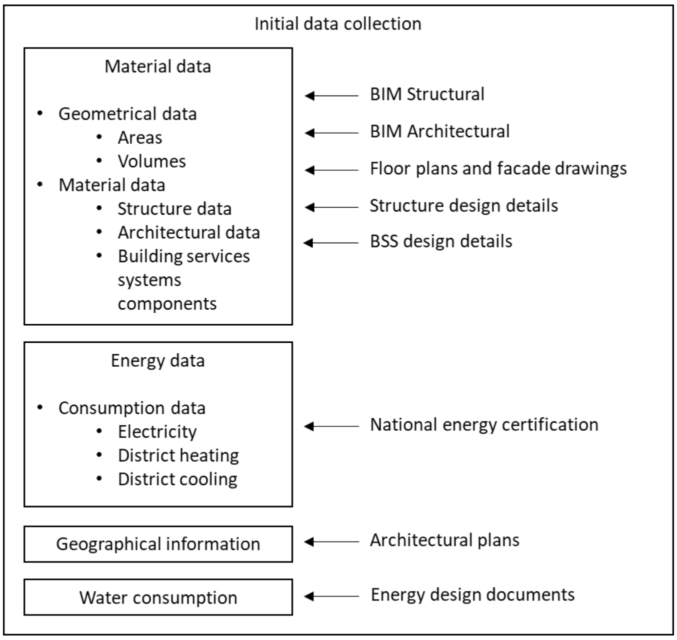

Figure 9. Initial data collection phase.

Depending on the stage of the design process the quality of available data can vary significantly. A starting point of an LCA is to use the best data available at the time of the assessment. In the case company, the LCAs are usually done at design stages where all the major decisions have already been made and the quality of the available data is relatively high. For a successful implementation of a building LCA at least the following data is collected in the process of the case company:

- national energy certification

- structural building information model
- architectural building information model
- structural building component details
- floor plans
- façade drawings.

It was discovered during the final year project that the most important information to retrieve is the geometrical data about the building. The LCA calculations are mostly based on areas and volumes of building components. Therefore, the geometrical data should be correct. Other useful, but not necessary, documents that are often collected in the company are construction specifications, installation specifications and detailed structural design documents. The initial data for the LCA process are retrieved from the responsible design party.

The LCA process could be carried out manually without utilizing building information models but was discovered during the final year project that it would require extensively more resources. The building information models are processed in the IFC format in the LCA process of the case company. The models in IFC format can be easily modified and the models can be utilized in the used LCA software.

8.3 Modelling

After the initial data collection phase, the collected input flows are assigned to representative EPDs. At this modelling stage, extensive amounts of data and databases are dealt with and it is the most resource consuming stage of an LCA process. In the case company, the stage is managed by utilizing purpose made software that contains the required environmental data for material and energy flows. The software used at the case company is OCL. The modelling process flow is illustrated in figure 10.

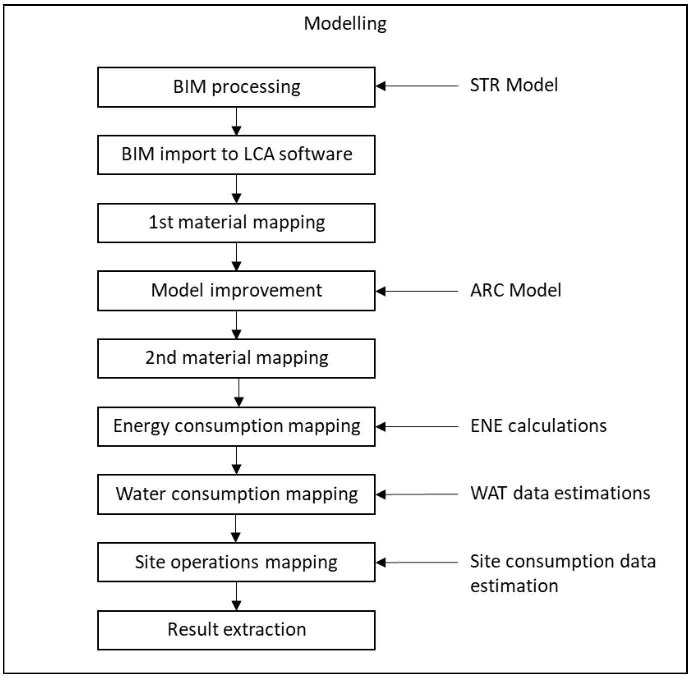

Figure 10. LCA modelling stage.

Building information can be imported into the OCL either manually or by utilizing an automated BIM based input process. It was discovered during the final year project that in the case company the automated process is preferable and practically the most regularly used method. The building information models used in the company are processed in IFC format whose material data can be imported into OCL utilizing an integration in Simplebim software. The utilized building information model is modified in Simplebim if needed and then imported directly into OCL.

It was discovered during the final year project that structural models contain detailed information about the components, that in general have the highest environmental impact. Therefore, in the LCA processes of the case company the structural models are usually preferred over the architectural models when data are initially imported into OCL. The architectural models contain information about non-bearing structures and other components, such as fenestration, that is not included in the structural models. The material data collected from the structural model must be improved manually with the information extracted from the architectural model and other design documents. The structural building information models do not usually contain the reinforcement steel for concrete, which has to be manually calculated on the basis of the concrete component types, volumes and structural design documents. Structural and architectural models are not imported into the OCL simultaneously due to the overlapping geometric information. The building services systems models cannot be imported into OCL directly because the models do not contain applicable data about the materials and geometry of the modelled systems. The assessment of the building services systems is done using generic average data according to the size and type of the building.

Even though the inventory collection stage of the LCA process of the case company is highly automated, not all material data are automatically mapped in correct material databases or EPDs. The building information models always contain materials that cannot be recognized by the OCL. These materials must be manually mapped to correct EPDs. Sometimes materials may be mapped in wrong or inappropriate databases in the import process. Therefore, validation of the material selection must be done before progressing to the following stage of the assessment.

The impacts of the transportation of materials are typically estimated using the OCL software in the LCA processes of the case company. The transportation distances are calculated on the basis of generic average datasets chosen by the user in the calculation setup phase. If detailed data about the material manufacturer are available, the transportation distances and mode of transportation are manually modified for each material individually.

Energy consumption data used in the LCAs of the case company are based on the standardized national energy calculations which provide values for the annual energy consumption and production of a building. For the LCA purposes, the energy consumption is divided by the energy carrier as the energy production impacts vary depending on the energy carrier and the energy source. Depending on the location of the building and the energy carrier, the environmental impact of the energy use of the building can vary significantly. The energy carrier categories in OCL are grid electricity, on site consumed fuels, district heating and district cooling. Furthermore, exported energy can be used in the calculation. The energy flow data is mapped to the best profile for energy emission that is both representative and available.

It was discovered in the final year project that construction site operations depend on many variables and it can be difficult to estimate the environmental impacts of the construction site operations in detail. In practice, the site operations of the LCAs done in the case company are estimated using generic average data based on the location and size of the construction. Actions taken into account in the site operations assessment that cause environmental impacts are for example energy consumption and waste production. The input data can be defined if there are measured consumption data available about the site operations.

Environmental impacts of an assessment are got as a result of the modelling phase. The results are combined and categorized according to the used assessment framework. The results of the LCAs of the case company are typically given for each assessed environmental impact category.

8.4 Analysis and Result Communication

The results of an LCA are analysed according to the goal and scope of the study. The LCA processes require estimations and management of uncertainties that must be critically reviewed. Typical subjects that are analysed are discussed in this chapter.

The validity of the results of an LCA are not reviewed as absolute values in the processes of the case company. Instead, the study should be reviewed on the basis of the quality of the inventory. In general, it can be stated that higher detail of the input inventory results in higher quality LCA results. It was found during the final year project that typical mistakes made during the process are related to input flow quantities. An example of input flow mistakes could be confusing areas with volumes or counting in the same material quantity several times. The results of an LCA done in the case company are compared to benchmarking cases that give a broad image about the range where the results of the assessment should be. At the case company, the comparison can be made with other assessments made in-house by or utilizing the embodied emission benchmark database provided by the OCL. An example of the visualization of the benchmark results of the case study retrieved from the OCL is illustrated in the figure 11.

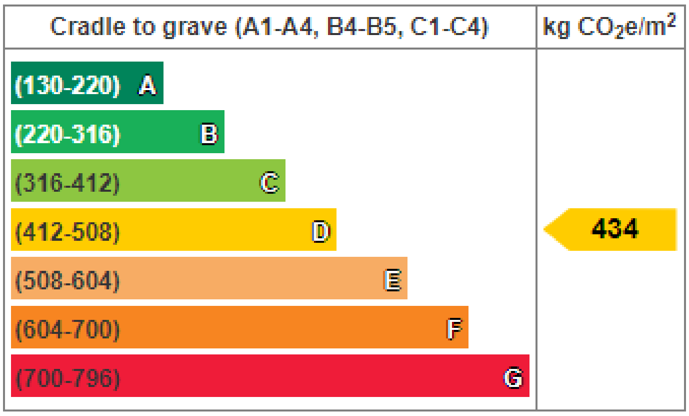

Figure 11. Visualization of One Click LCA embodied carbon benchmark.

The results of a typical LCA made in the case company are allocated to the life cycle stages. The results of the case study, and other LCAs made in house, indicate that the most important contributors to the total environmental impacts are the product stage (A1-A3) and the operational energy stage (B6). The impacts of these stages are often the most interesting piece of information when reporting the results of the assessment. In many cases, more defined information about the environmental impacts is found. The impacts of the LCAs done in the case company are typically also divided by building material type or by building component type.

The results of the LCAs done in the case company are typically benchmarked and the results are reported to the client. For example, the results of an LCA for certification purposes, e.g. for BREEAM category Mat 01, are compared with those of another pre-defined case building. The case building can be, for example, a standard building that fulfils the energy consumption and other regulations in its country. The results of comparisons are also used to support the presentation of the results of the assessment, and to make the results more understandable. Comparisons can be made between entire buildings or between some specific building components or materials.

The results of an LCA are to be reported in a way that supports the communication with the commissioner and other stakeholders associated with the study. The reporting phase depends completely on the previous stages and the intended use of the study. Information about the process should be reported at each assessment stage, but the emphasis of the reporting can be the analysing stage. Information retrieved from the analysing stage is usually the most valuable piece of information to be reported for the commissioner.

9 Process Analysis

The process analysis described in this chapter is based on the current process practices at the case company. Further research should be done for more in-depth analysis and development proposals, but this thesis describes how prepared the case company is to adopt the national carbon footprint assessment process and if national energy certification process can be combined with the LCA process in a cost effective way.

9.1 Combining Energy Calculation Processes with LCA Processes

Data about energy consumption are required for all LCAs that include the use-stage impacts. It has been proposed by the Finnish Ministry of Environment that the upcoming obligation to declare the carbon footprint of new constructions could be combined with the current energy certification. [1.] One of the goals of this thesis is to review whether it is possible to combine the energy certification processes and the LCA processes of the case company in a cost-effective way. Possible cost savings in the processes could be achieved through faster process time and by utilizing common software in the processes. The similarities between the energy calculations and LCA processes are looked into by studying the initial data collection requirements and the modelling phases of both processes. The energy calculation process is assessed by studying in-house projects and by concluding an energy calculation process for an office building. The review outcome is described in this chapter.

The national standard energy calculations are often made in three design stages of a building process. The results are needed for the sketch design phase, for the building permit and in in the handout-stage. The LCAs can be carried out in the same design stages. In practice detailed data availability for a full LCA is high enough only in the handout stage. The energy simulation models are updated twice in the process as the national energy certification for the building permit is developed on the basis of the sketch stage calculations and then later updated in the handout stage.

The required initial data for both processes are very similar. The required initial documents for both processes are listed in table 2 and the importance of the documents for both calculation processes is assessed. Most collected initial documents can be utilized in both processes. Using the same initial documents collection can save time as the sourcing of the documents does not have to be done twice.

Table 2. Initial data comparison for energy calculation and LCA processes.

Initial data	Imprortance	
	ENE	LCA
Geometry and architecture		
BIM (Structural)	N	H
BIM (Architectural)	N	H
Floor plans	H	H
Sections	H	L
Facades	H	H
Floor areas list	N	L
Material data		
Structure type details	H	H
U-values	H	N
Window g-values	H	N
Window listing	N	N
Door listing	N	N
Strucural implementation specification	L	N
Component material specification	L	H
Systems		
Heating systems details	H	N
Water systems details	N	N
Ventilation systems description	H	N
Ventilation air flows	H	L
Water consumption	H	H
Energy consumption	n/a	H
BSS design documents	L	N
BSS implementation specification	N	N

H	high
N	neutral
L	low

The energy calculations for national standard calculation purposes are done utilizing the space modelling software Magicad Room and the dynamic energy simulation program IDA ICE. The Magicad Room is used for creating a space model of the studied building. The space model is imported into IDA ICE, which is used for energy simulations. There are specific requirements for the building information models used for energy calculations in the case company. The energy models used are based on spaces limited by the interior dimensions of the building envelope. It is critical to define the geometrical data of the modelled spaces correctly. There also are other specific pieces of information, such as space labelling, that should be optimized for the energy simulation purposes. The standardized national energy calculations are based on the heated net area of a building limited by internal dimensions of the thermal envelope. All cold spaces are excluded from the energy models. Therefore, even large parts of the building may not be modelled in the energy models. An example of the composition of the energy model is illustrated in figure 12.

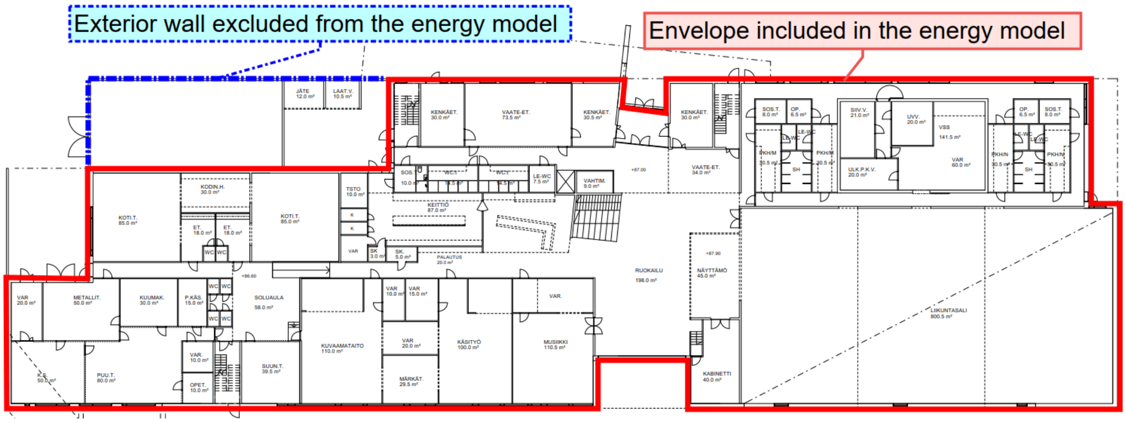

Figure 12. An example of an energy model outline [36; 37].

Currently, architectural models are not used for energy simulation purposes as there often are compatibility issues between the architectural models and the simulation software. The architectural models also contain information that is not relevant for the purpose. To eliminate the compatibility issues and to assure desired space details, geometrical models for energy simulation purposes are modelled separately with Magicad Room. The geometrical building information model from Magicad Room is imported into the energy simulation program IDA ICE in the IFC format. The energy model is then created in IDA ICE.

The quality of geometric data is equally important for the energy calculation purposes and LCA processes. There is a plugin available for the energy simulation software IDA ICE which enables exporting the geometrical model created for the energy simulation purposes to be used for an LCA in the OCL. However, as the energy model is only optimized for the energy calculation purposes it does not include detailed information about data that are relevant for LCAs. In addition, energy models are manually re-modelled from original architectural documents, so the geometric data may not be as accurate as in architectural building information models. Due to the specific requirements of the energy model, it is not viable to use a common building information model for both standardized national energy calculation purposes and in LCA processes.

A Collection of common initial documents could speed up both standardized national energy calculation processes and LCA processes. It was discovered during the final year project that is not feasible to utilize common building information models or software for both processes. It should be noted that the produced energy consumption data are compulsory input flow data for most LCA processes of the case company. The combination of standard national energy calculation and LCA processes could be beneficial for the case company when the same team or personnel conduct both studies.

9.2 Adopting National Carbon Footprint Assessment Method

At the time of writing this thesis the, preparation of a national calculation method for building life cycle footprint was still in process in Finland. The framework around the method is in place, but not completed, so the review of the preparedness of the case company in implementing the upcoming national calculations can only be done on a general level. The proposed national calculation method is based on the standard EN 15978. The major differences to the standard would be related to the building components included and the calculation period. [29.]

It has been proposed that the building life cycle carbon footprint could be calculated on two different levels of detail. The simpler calculation method would be similar to a typical screening LCA and it would be calculated with national standard emission values. The more detailed calculation should be implemented with project specific material and energy flow information. [30.] These more detailed calculations could be done with the software the case company already uses.

As discussed in chapter 8 above the LCA processes can be implemented in accordance with several different standards or frameworks. As the proposed national calculation method is based on commonly known standards, the only difference to LCAs done at the case company is the goal and scope setup. Based on the first proposed calculation method description the LCA process of the case company is easily adaptable to the national method for calculating the carbon footprint of buildings.

9.3 Common Practices and Quality Assurance

The LCA results are estimations and usually highly dependent on the author and the utilized calculation software. The typical result variation of LCAs is not only a company specific but also a universal challenge. [38.] On a company level there are several methods to control the work of the case company to improve the accuracy of the results and the comparability of the implemented studies.

On a company level it is possible to control the own work with various methods. The first method is software use related practices. In the case company only one software is used for the purpose. The OCL has functions that support the common assessment practices. The software saves EPD selections from the material labelling, and the selections are saved on the company account. Selection of certain materials from previous projects are automatically selected for the following projects which include similar material labelling. Furthermore, there is a model checker tool included in the OCL which can be used for the filtering of any major inconsistencies in the LCA model. Another effective method for controlling the process and enhancing the common practices is to utilize a common checklist that is used in all LCA projects of the case company.

9.4 Utilization of Native Building Information Models

The most important building information models for carrying out an LCA process are architectural and structural models. BIM cooperation was discovered between teams in the case company. The teams involved were the architectural design, structural design, HVAC design and life cycle team. The main tool for modelling in the architecture department is Graphisoft Archicad and in the structural design the main tool for modelling is Tekla Structures. There are plugins available for both modelling programs that allow data export to the LCA software OCL.

The building information models are processed in the IFC format which enables an efficient use of the models throughout the design fields. When a building information model is converted into the IFC format, some data modifications always take place in the process. As an example, composite structures that consist of many layers may be combined as one layer in the process. These combined structures contain data for several layers that cannot be directly processed in OCL and must be manually split in the process.

From the point of view of maximizing data quality of a design field model, the use of native models instead of the IFC format could be beneficial. [32.] However, utilizing the native models for LCA processes requires either very close co-operation with the responsible design party or a possibility to use the same software as the designer. If the design is not produced in-house a close co-operation may be challenging. Furthermore, it is not feasible to provide all the necessary tools for both the design team and the team conducting LCA studies due to software expenses.

The best practice currently available for LCA processes is to use IFC files for the data exchange together with model inspection. The simplicity and versatility of the data exchange was found in the final year project to be more important than the possible data quality improvements achieved from using native models.

9.5 Assessment of Building Services Systems

Building services systems (BSS) data cannot usually be exported from a BIM as the data are not suitable for inventory analysis. The data do not always contain material data need to be imported into OCL. Illustration of a typical ventilation ductwork in a BSS model studied in the final year project LCA case study is illustrated in figure 13.

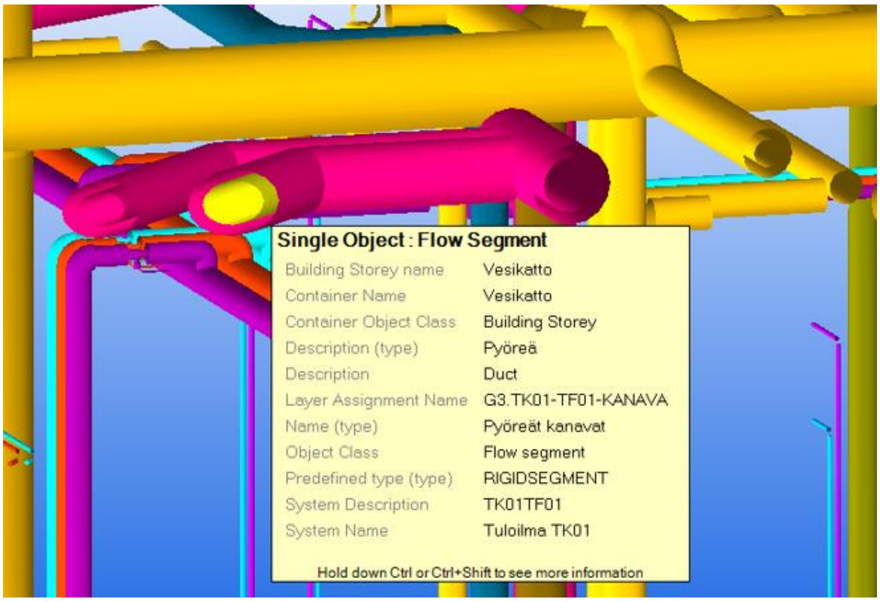

Figure 13. Typical details from a BSS model.

The practices of component labelling the BSS design are very different from the needs of LCA. Furthermore, the geometrical data for hollow components with very low material surface thickness can be difficult to handle. The BSS models also contain technical equipment that cannot be assessed on the basis of the volume and mass of the components. The assessment of the building services systems must be done by the floor area of the building based on the general average values for each installed system category. The problem of BSS equipment is not company specific but an issue that concerns the whole industry.

9.6 Potential in Adopting Screening LCA

At the time of this study, the LCA projects in the case company were carried out mainly in the late design stages. A natural next step in developing the LCA services would be to introduce screening LCAs.

Screening LCAs can be best utilized for communication between the designers in the company. For a multi-disciplinary design company as the case company where multiple different design fields co-operate with each other using the screening could be highly beneficial. Especially for architectural design teams, the early design stage impact assessment information can be very valuable. The architectural decisions define and limit the possibilities of other fields of design to affect the environmental impacts of a building. It should be noted here that a screening LCA does not provide comparable or standardized results. Therefore, reporting the result outside the company should be carefully considered.

Tools that can be used for the screening LCAs are available in the case company. It was discovered during the final year project that implementation of the screening would not be very resource consuming as the teams are already familiar with the tools. The OCL tool provider supports an early stage tool for GWP estimations, similar estimations can be done with the case company's own estimation tool.

10 Conclusion

The purpose of this thesis was to describe the current LCA processes of the multi-disciplinary design company and review the potential for process development. The thesis looked into, first, how prepared the company was to adopt a proposed national carbon footprint calculation method and, second, whether it was possible to combine the process of standardized energy calculation for the national energy certification with the current LCA process of the case company.

The LCA process of the case company is currently done at late design stages where all major building design decisions have already been made. The available building data at the late stages are detailed and the full standardized LCAs can be carried out.

Building information models are utilized in LCA processes of the case company to a high extend. Major parts of the inventory analysis stage are automated using BIM when importing data into building LCA software. Carrying out an LCA is an iterative process and after importing selected building information models, the LCA model is refined on the basis of other building design documents. The building information models are processed in the IFC format because of the versatility of the data exchange over the fields of design and organizations the IFC format provides.

The proposed national method for assessing the life cycle carbon footprint of buildings is based on the same frameworks that are already used in most LCA studies. LCA processes of the case company are already based on these common standards and frameworks and adopting the proposed national method in the company would require only minor changes in the setup phase. The proposed national assessment method was under development at the time of writing this thesis, and the final assessment method may differ from the first version reviewed in this thesis.

The standardized energy calculations needed for national energy certification for buildings are carried out regularly as part of the energy services at the company. The possibility to cost effectively combine the standardized energy calculations with the LCA processes was reviewed in the thesis. Cost savings could be achieved through saving time in the processes and utilizing common tools and models for both processes. It was discovered that the initial data collection for both energy calculation and LCA processes could be combined as the necessary initial data for both processes are similar. However, energy calculations require specific data from the building information models, and separate building information models are created for the energy calculation purposes. Due to the specific needs for modelling in energy calculations, it was established that the best practice is to keep the modelling phase for both energy calculations and LCA processes separate.

The development of the company LCA processes could be done by adopting early design stage screening LCAs. The screening LCAs could support the decision making in very early stages of architectural design. In a multi-disciplinary design company where architectural design and the LCAs are done in house, the co-operation could be particularly beneficial. The screening LCAs could be used in communicating the environmental performance of the building between the designers in-house.

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EN 15804 minimum environmental data quality requirements [12].

If there are no standardized EPDs available, the environmental data should have a certain level of detail to be used for LCAs in line with EN 15978. The minimum requirements are listed in the EN 15978 as follows:

- data should be as current as possible. Validation of the data shall not be older than 10 years;
- dataset for calculations should be based on one-year averaged data if relevant; reasons for a different
- assessment period shall be listed;
- emissions from disposal processes shall be accounted for at least 100 years;
- emissions that occur beyond 100 years should be inventoried in a dataset as separate 'long-term'
- elementary flows and included in the impact assessment if relevant;
- data shall have been checked for plausibility and compliance with the rules of EN 15804;
- the technological coverage shall reflect the physical reality for the declared product or product group;
- the geographical coverage shall be representative of the region where the production is located.

Study case LCA results

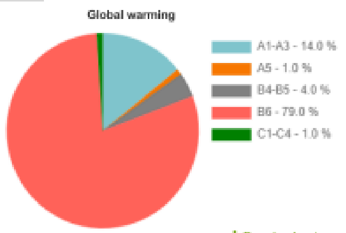
One Click LCA report of a typical office building LCA

Case X - **LCA for BREEAM Int'l/ES/NOR/SE**

Result report: LCA BREEAM DS (Rev B)

Workflow Guidance

Project	Case X
User	Eetu Toroskainen - 11.04.2019
Tool	LCA for BREEAM Int'l/ES/NOR/SE
Details	This is officially approved LCA in compliance with BREEAM International NC 2013 and 2016 as well as BREEAM-NOR More...



Download as image

Change impact category

Completeness and plausibility checker

Life-cycle assessment results for BREEAM International versions as per EN 15978

	Sector	Global warming kg CO2e	Acidification kg SO2e	Eutrophication kg PO4e	Ozone depletion potential kg CFC11e	Formation of ozone of lower atmosphere kg Ethenee	Non hazardous waste disposed kg	
A1-A3	Construction Materials	1,79E6	5,58E3	9,7E2	3,42E-1	6,96E2	1,46E5	Details
A4	Transportation to site	3,95E4	1,27E2	2,73E1	7,31E-3	3,93E0	1,66E2	Details
A5	Construction/installation process	1,39E5	2,35E2	5,46E1	2,3E-2	2,15E1	7,23E3	Details
B4-B5	Material replacement and refurbishment	5,04E5	2,38E3	4,5E2	2,87E-1	1,58E2	6,5E4	Details
B6	Energy use	1E7	4,85E4	7,3E3	1,26E0	2,35E3	3,14E5	Details
B7	Water use	5,33E4	3,73E2	1,07E3	5,38E-3	1,56E1	2,63E4	Details
C1-C4	Deconstruction	7,51E4	2,07E2	4,74E1	5,2E-3	1,48E1	5,44E5	Details
D	External impacts (not included in totals)	-4,13E5	-8,27E2	-1,87E2	-3,18E-2	-8,45E1	-9,03E3	Details
	Total	**1,26E7**	**5,74E4**	**9,91E3**	**1,93E0**	**3,26E3**	**1,1E6**	
		Show graph	Show graph	Show graph	Show graph	Show graph	Show graph	
	Results per denominator							
	Gross Internal Floor Area (IPMS/RICS) 7145.0 m2	1,77E3	8,03E0	1,39E0	2,71E-4	4,56E-1	1,54E2	

Methodologically consistent and regionally representative LCA data

Metropolia University of Applied Sciences

	Answer
Local compensation method	v1.0 Recommended
Local compensation method	v1.0 Recommended
Service life values for materials	Technical service life (same for same material)
Local compensation target region	Finland
Transportation distance values for materials	Nordic

Compensation to local conditions, if applied by the user, is made according to CEN/TR 15941 and One Click LCA's BRE-approved methodology.

Mat 06 Materials efficiency and biogenic carbon

	Sector	Biogenic carbon storage kg CO2e bio	Mass of raw materials kg	
1-A3	Construction Materials	4,01E4	1,99E7	Details
4-B5	Material replacement and refurbishment		2,73E5	Details
		Show graph	Show graph	

Workflow
Guidance

Mat 01 EPDs for the additional and exemplary credits

ost contributing building elements and material types for Global warming (GWP)

Change impact category

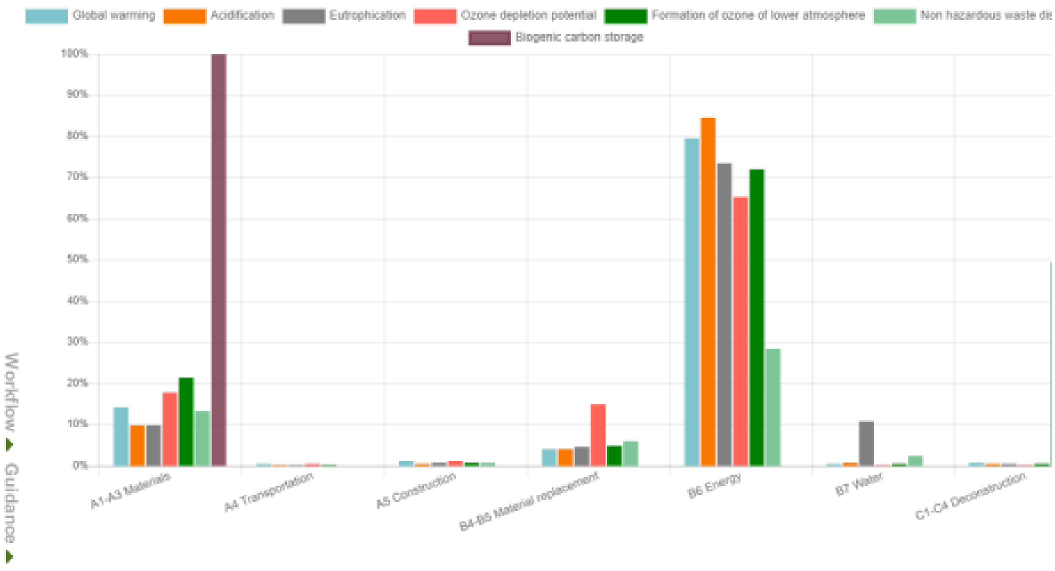
12 631 Tons CO_2e | 29 kg CO_2e / m2 / year | € 631 564 Social cost of carbon

Most contributing materials (GWP) - A1-A3

1. Steel, structural steel construction products, cold formed - **21.1 %** - show sustainable alternatives
2. Hollow core concrete slab + reinforcement - **8.2 %** - show sustainable alternatives
3. Precast concrete wall elements (solid, uninsulated), generic - **7.3 %** - show sustainable alternatives
4. Reinforced concrete piling 300x300 mm - **6.5 %** - show sustainable alternatives
5. Drainage system, PP, room area m2 - **4.8 %** - show sustainable alternatives
6. Concrete C28/35 - **3.9 %** - show sustainable alternatives
7. Vinyl flooring - **3.4 %** - show sustainable alternatives
8. Glass wall system, façade glazing, per m2 - **2.9 %** - show sustainable alternatives
9. Ready-mix concrete, normal-strength, generic - **2.9 %** - show sustainable alternatives
10. Multipurpose floor leveling screed - **2.7 %** - show sustainable alternatives

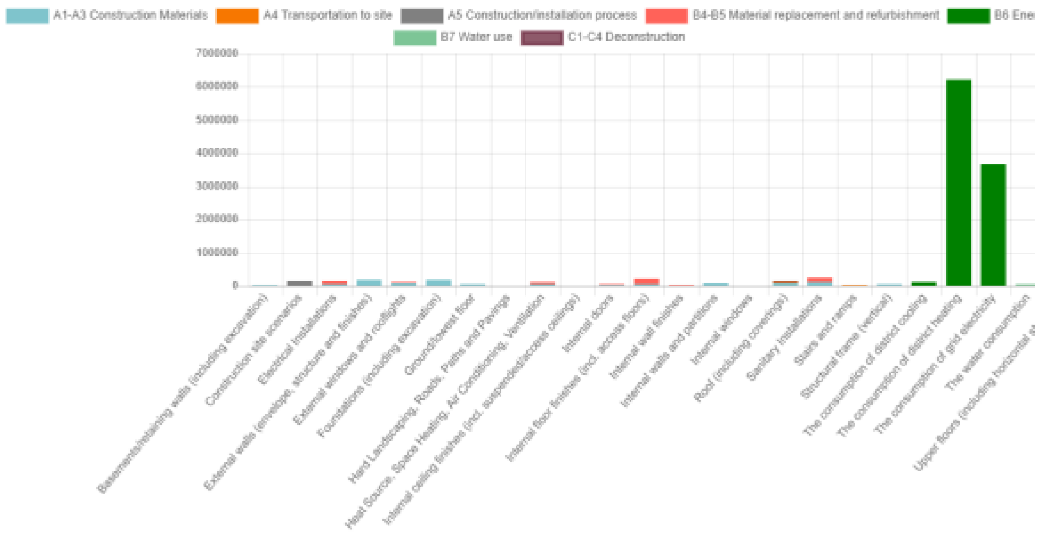
Results distribution by life-cycle stage

Click on a category legend to hide/unhide   Download as image



Global warming (GWP), grouped by Mat 01 element breakdown

Click on a category legend to hide/unhide Download as image



Study case energy simulation results

Report 1: Office energy simulation result

Office zones

EQUA SIMULATION TECHNOLOGY GROUP

Input data Report

Project		Building	
CASE XXX Office jäähdytyksen lämpötilat: IV: 10/18 (häviökerroin 0,2) Puhallinkonvektori: 10/18 (häviökerroin 0,15) Säteilypaneeli: 15/18 (häviökerroin 0,1) Käytetty varmuudeksi jäähdytyksen häviökertoimena 0,2. (Taulukko 9.1. Energiatehokkuusohje 2018 (http://www.ym.fi/download/noname/%7BDFC56F1D-7C3A-404A-8E4F-4A77DE4C04F7%7D/133701)) Jäähdytyslaitteen keskimääräinen lämpötila 17 degC. Oletuksena neuvotteluhuoneessa puhallinkonvektori, toimistotiloissa säteilypaneeli. FIN YMa1010/2017Toimistorakennus Mallinnus perustuu vesiradiaattorijärjestelmään 70/40 lämpötiloilla, joka liitetty kaukolämmön alakeskukseen. Mallinnus YMa1010/2017 mukainen. -Vuotoilma YMa1010/2017 kohta 4.3.3 ja 2.3.2(tasauslaskennan mukainen vuoto, 5-kerroksinen rakennus) Mallinnusta täydennetty "YMohje ("D5") 2018" arvoilla seuraavasti: -"YMohje ("D5") 2018" taulukko 3.1-3.3, rakenteiden väliset kylmäsillat (betoniset rakenteet) -KL-alakeskuksen vuosihyötysuhde ja sähkönkäyttö, "YMohje ("D5") 2018" taulukko 7.1 (ja 7.2) -Lämmitysjärjestelmien lämmönjaon ja -luovutuksen vuosihyötysuhde, "YMohje ("D5") 2018" taulukko 6.1 -Lämmitysjärjestelmän apulaitteiden sähkönkulutus, "YMohje ("D5") 2018" taulukko 6.1 -Lämpimän käyttöveden häviöt "YMohje ("D5") 2018" kohta 6.3 (ei varaajaa). Kiertojohdon ominaispituus 0,06 m/m2. Kierron ja varastoinnin häviöistä 50 % lasketaan hyödyksi tilojen lämmityksessä. LKV kokonaishäviöistä 41 % lasketaan hyödyksi tilojen lämmityksessä.(Jakojohdon häviöistä ei lämpöä hyödyksi) -Lämpimän käyttöveden pumpun sähkönkulutus "YMohje ("D5") 2018" kohdan 6.3.4 mukaisesti (kiertojohdon eristystaso 1,5*D) -Tasauslaskimeen(IDA-tuloste) kaikki lähtötiedot syötetään lämpimien tilojen mukaisilla arvoilla. Käyttäjän tulee itse täydentää ja tarvittaessa myös muuttaa tietoja tasauslaskentatulostukseen. -Halutessaan energiatodistustulosteen(IDA-tuloste) luokan 9 rakennukseen käyttäjä voi valita rakennuksen mallipohjaksi jonkun luokan 1-8 rakennuksista ja muuttaa sitä suunnittelutapausta vastaavaksi. Simuloinnin jälkeen käyttäjä voi sitten muuttaa rakennuksen käyttötarkoitusluokan IDA-energiatodistustulosteen sivulle 1.		Model floor area	4171.9 m²
Customer		Model volume	14104.9 m³
Created by	Eetu Toroskainen	Model ground area	252.3 m²
Location	Helsinki (Ref 2012)	Model envelope area	3395.6 m²
Climate file	HKi-Vantaa_Ref_2012	Window/Envelope	17.7 %
Case	7091_Eluku_toimistorakennus	Average U-value	0.314 W/(m² K)
Simulated	30.8.2018 10:55:39	Envelope area per Volume	0.2407 m²/m³

Fixed infiltration airflow rate			130.472 l/s	
Building envelope	**Area [m²]**	**U [W/(m² K)]**	**U*A [W/K]**	**% of total**
Walls above ground	**1067.97**	**0.18**	**194.01**	**18.20**
US6	244.65	0.22	54.21	5.08
D3 2012 ulkoseina(betoni),lammin tila	823.32	0.17	139.80	13.11
Walls below ground	**22.58**	**0.13**	**3.00**	**0.28**
KS2	22.58	0.13	3.00	0.28
Roof	**1100.47**	**0.09**	**100.72**	**9.45**
YP2 U=0,12	51.85	0.12	6.25	0.59
D3 2012 ylapohja(betoni),lammin tila	1048.62	0.09	94.47	8.86
Floor towards ground	**252.29**	**0.09**	**23.76**	**2.23**
D3 2012 alapohja maata vasten, lammin tila	252.29	0.09	23.76	2.23
Floor towards amb. air	**340.75**	**0.15**	**50.87**	**4.77**
AP3	340.75	0.15	50.87	4.77
Windows	**602.29**	**1.00**	**602.29**	**56.49**
g=0,37 U=1,0	602.29	1.00	602.29	56.49
Doors	**9.24**	**1.01**	**9.29**	**0.87**
D3 2012 ovi, lammin tila	9.24	1.01	9.29	0.87
Thermal bridges			**82.29**	**7.72**
Total	**3395.58**	**0.31**	**1066.23**	**100.00**

Thermal bridges	Area or Length	Avg. Heat conductivity	Total [W/K]
External wall / internal slab	698.12 m	0.000 W/(m K)	0.000
External wall / internal wall	26.78 m	0.000 W/(m K)	0.000
External wall / external wall	65.67 m	0.060 W/(m K)	3.940
External windows perimeter	1269.81 m	0.040 W/(m K)	50.792
External doors perimeter	21.60 m	0.040 W/(m K)	0.864
Roof / external walls	142.80 m	0.080 W/(m K)	11.424
External slab / external walls	67.25 m	0.240 W/(m K)	16.140
Balcony floor / external walls	0.00 m	0.000 W/(K m)	0.000
External slab / Internal walls	0.00 m	0.000 W/(K m)	0.000
Roof / Internal walls	29.91 m	0.000 W/(m K)	0.000
External walls, inner corner	14.50 m	-0.060 W/(m K)	-0.870
Roof / external walls, inner corner	21.70 m	0.000 W/(m K)	0.000
External slab / external walls, inner corner	30.02 m	0.000 W/(m K)	0.000
Total envelope (incl. roof and ground)	3112.50 m²	0.000 W/(m² K)	0.000
Extra losses	-	-	-0.000
Sum	-	-	82.291

Windows	Area [m²]	U Glass [W/(m² K)]	U Frame [W/(m² K)]	U Total [W/(m² K)]	U*A [W/K]	Shading factor g
NE	166.65	1.00	1.00	1.00	166.65	0.37
SE	174.65	1.00	1.00	1.00	174.65	0.37
SW	101.30	1.00	1.00	1.00	101.30	0.37
NW	159.69	1.00	1.00	1.00	159.69	0.37
Total	602.29	1.00	1.00	1.00	602.29	0.37

Air handling unit	Pressure head supply/exhaust [Pa/Pa]	Fan efficiency supply/exhaust [-/-]	System SFP [kW/(m³/s)]	Heat exchanger temp. ratio/min exhaust temp. [-/C]
AHU	660.00/420.00	0.60/0.60	1.10/0.70	0.72/-20.00

DHW use	kWh/m2 floor area and year	Total, [l/s]
	6.000	0.014

Metropolia University of Applied Sciences

Delivered Energy Overview

	Purchased energy		Peak demand	Primary energy	
	kWh	kWh/m²	kW	kWh	kWh/m²
Valaistus, kiinteistö	77706	18.6	27.12	93248	22.4
LVI sähkö	66526	16.0	17.4	79831	19.1
Total, Facility electric	144232	34.6		173079	41.5
Lämmitys, kaukolämpö	186852	44.8	186.4	93426	22.4
LKV, kaukolämpö	51428	12.3	5.87	25714	6.2
Kaukojäähdytys	19384	4.6	181.1	5427	1.3
Total, Facility district	257664	61.8		124567	29.9
Total	401896	96.3		297646	71.4
Laitteet, asukas	93258	22.4	32.54	111909	26.8
Total, Tenant electric	93258	22.4		111909	26.8
Grand total	495154	118.7		409555	98.2

Used energy

kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
1	21798.0	0.0	9988.0	0.0	4237.0
2	19378.0	0.0	8711.0	0.0	3827.0
3	17504.0	0.0	8165.0	0.0	4236.6
4	9392.0	0.0	2271.0	93.2	4100.0
5	4315.7	-0.0	118.2	1188.0	4236.8
6	3282.0	-0.0	5.1	2206.0	4100.0
7	2793.3	0.0	0.0	8227.5	4237.0
8	3157.0	8.4	0.0	7432.0	4237.0
9	5659.3	0.0	191.6	229.2	4100.6
10	11660.0	0.0	1462.0	0.0	4237.0
11	16906.6	0.0	5692.8	0.0	4099.8
12	20876.0	0.0	7906.0	0.0	4237.0
Total	136722.0	8.4	44510.7	19375.9	49885.7

Utilized free energy

kWh (sensible and latent)

Month	AHU heat recovery	AHU cold recovery	Plant heat recovery	Plant cold recovery	Solar heat	Ground heat	Ground cold	Ambient heat	Ambient cold
1	59733.0	0.0							
2	52307.0	0.0							
3	54462.0	0.0							
4	34223.0	-0.0							
5	18551.0	-26.6							
6	8829.0	-13.7							
7	2475.1	-352.1							
8	5912.0	-485.3							
9	16371.4	-0.0							
10	34070.0	0.0							
11	47316.3	0.0							
12	51726.0	0.0							
Total	385975.9	-877.7							

Generated electric energy

kWh

Month	Solar (PV)	Wind turbine	CHP
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
Total			

Auxiliary energy

kWh

Month	Humidification	Fans	Pumps
1		4373.0	7.2
2		3803.0	6.2
3		4188.6	5.9
4		4030.0	1.9
5		4446.6	3.5
6		4075.0	6.3
7		4280.8	23.6
8		4470.0	21.3
9		3867.1	0.8
10		4419.0	1.1
11		4200.0	4.1
12		4000.0	5.7
Total		50153.1	87.4

Distribution Losses

kWh

Month	Domestic hot water circuit	Heating	Cooling*	Air ducts*
1	2111.0	2180.0	0.0	0.0
2	1906.0	1938.0	0.0	0.0
3	2110.8	1750.3	0.0	0.0
4	2043.0	939.3	0.0	0.0
5	2110.5	431.6	-0.0	0.0
6	2043.0	328.3	-0.0	0.0
7	2111.1	279.3	0.0	0.0
8	2111.0	315.7	1.7	0.0
9	2042.7	566.0	0.0	0.0
10	2111.0	1166.0	0.0	0.0
11	2042.3	1690.8	0.0	0.0
12	2111.0	2088.0	0.0	0.0
Total	**24853.4**	**13673.3**	**1.7**	**0.0**

*positive loss when conduit is cooler than building

IDA Indoor Climate and Energy
Version: 4.8

Report 2: Commercial spaces energy simulation result

Commercial zones

EQUA SIMULATION TECHNOLOGY GROUP

Input data Report

Project

CASE XXX commercial

jäähdytyksen lämpötilat:

IV: 10/18 (häviökerroin 0,2)
Puhallinkonvektori: 10/18 (häviökerroin 0,15)
Säteilypaneeli: 15/18 (häviökerroin 0,1)

Käytetty varmuudeksi jäähdytyksen häviökertoimena 0,2. (Taulukko 9.1. Energiatehokkuusohje 2018 (http://www.ym.fi/download/noname/%7BDFC56F1D-7C3A-404A-8E4F-4A77DE4C04F7%7D/133701))

Missään ikkunassa ei sälekaihtimia.

FIN YMa1010/2017Toimistorakennus
Mallinnus perustuu vesiradiaattorijärjestelmään 70/40 lämpötiloilla, joka liitetty kaukolämmön alakeskukseen. Mallinnus YMa1010/2017 mukainen.
-Vuotoilma YMa1010/2017 kohta 4.3.3 ja 2.3.2(tasauslaskennan mukainen vuoto, 5-kerroksinen rakennus)
Mallinnusta täydennetty "YMohje ("D5") 2018" arvoilla seuraavasti:
-"YMohje ("D5") 2018" taulukko 3.1-3.3, rakenteiden väliset kylmäsillat (betoniset rakenteet)
-KL-alakeskuksen vuosihyötysuhde ja sähkönkäyttö, "YMohje ("D5") 2018" taulukko 7.1 (ja 7.2)
-Lämmitysjärjestelmien lämmönjaon ja -luovutuksen vuosihyötysuhde, "YMohje ("D5") 2018" taulukko 6.1
-Lämmitysjärjestelmän apulaitteiden sähkönkulutus, "YMohje ("D5") 2018" taulukko 6.1
-Lämpimän käyttöveden häviöt "YMohje ("D5") 2018" kohta 6.3 (ei varaajaa). Kiertojohdon ominaispituus 0,06 m/m2. Kierron ja varastoinnin häviöistä 50 % lasketaan hyödyksi tilojen lämmityksessä. LKV kokonaishäviöistä 41 % lasketaan hyödyksi tilojen lämmityksessä.(Jakojohdon häviöistä ei lämpöä hyödyksi)
-Lämpimän käyttöveden pumpun sähkönkulutus "YMohje ("D5") 2018" kohdan 6.3.4 mukaisesti (kiertojohdon eristystaso 1,5*D)
-Tasauslaskimeen(IDA-tuloste) kaikki lähtötiedot syötetään lämpimien tilojen mukaisilla arvoilla. Käyttäjän tulee itse täydentää ja tarvittaessa myös muuttaa tietoja tasauslaskentatulostukseen.
-Halutessaan energiatodistustulosteen(IDA-tuloste) luokan 9 rakennukseen käyttäjä voi valita rakennuksen mallipohjaksi jonkun luokan 1-8 rakennuksista ja muuttaa sitä suunnittelutapausta vastaavaksi. Simuloinnin jälkeen käyttäjä voi sitten muuttaa rakennuksen käyttötarkoitusluokan IDA-energiatodistustulosteen sivulle 1.

Project		Building	
Customer		Model floor area	1210.2 m²
		Model volume	3960.7 m³
Created by	Eetu Toroskainen	Model ground area	0.0 m²
Location	Helsinki (Ref 2012)	Model envelope area	574.9 m²
Climate file	HKi-Vantaa_Ref_2012	Window/Envelope	46.9 %
Case	7091_Eluku_liiketila_SFP-1,4-opt-valaistusteho	Average U-value	0.6124 W/(m² K)
Simulated	28.8.2018 14:19:14	Envelope area per Volume	0.1451 m²/m³

Fixed infiltration airflow rate 36.637 l/s

Building envelope	Area [m²]	U [W/(m² K)]	U*A [W/K]	% of total
Walls above ground	**291.75**	**0.18**	**51.20**	**14.54**
US6	32.09	0.22	7.11	2.02
D3 2012 ulkoseina(betoni),lammin tila	259.65	0.17	44.09	12.52
Walls below ground	**0.00**	**0.00**	**0.00**	**0.00**
Roof	**0.00**	**0.00**	**0.00**	**0.00**
Floor towards ground	**0.00**	**0.00**	**0.00**	**0.00**
Floor towards amb. air	**0.00**	**0.00**	**0.00**	**0.00**
Windows	**269.37**	**1.00**	**269.37**	**76.52**
g=0,37 U=1,0	269.37	1.00	269.37	76.52
Doors	**13.74**	**1.01**	**13.82**	**3.93**
D3 2012 ovi, lammin tila	13.74	1.01	13.82	3.93
Thermal bridges			**17.65**	**5.01**
Total	**574.85**	**0.61**	**352.03**	**100.00**

Thermal bridges	Area or Length	Avg. Heat conductivity	Total [W/K]
External wall / internal slab	330.95 m	0.000 W/(m K)	0.000
External wall / internal wall	32.98 m	0.000 W/(m K)	0.000
External wall / external wall	22.99 m	0.060 W/(m K)	1.379
External windows perimeter	377.48 m	0.040 W/(m K)	15.099
External doors perimeter	34.00 m	0.040 W/(m K)	1.360
Roof / external walls	0.00 m	0.000 W/(K m)	0.000
External slab / external walls	0.00 m	0.000 W/(K m)	0.000
Balcony floor / external walls	0.00 m	0.000 W/(K m)	0.000
External slab / Internal walls	0.00 m	0.000 W/(K m)	0.000
Roof / Internal walls	0.00 m	0.000 W/(K m)	0.000
External walls, inner corner	3.22 m	-0.060 W/(m K)	-0.193
Roof / external walls, inner corner	26.54 m	0.000 W/(m K)	0.000
External slab / external walls, inner corner	0.00 m	0.000 W/(K m)	0.000
Total envelope (incl. roof and ground)	609.22 m²	0.000 W/(m² K)	0.000
Extra losses	-	-	-0.000
Sum	-	-	17.645

Windows	Area [m²]	U Glass [W/(m² K)]	U Frame [W/(m² K)]	U Total [W/(m² K)]	U*A [W/K]	Shading factor g
NE	94.72	1.00	1.00	1.00	94.72	0.37
SE	37.19	1.00	1.00	1.00	37.19	0.37
SW	59.43	1.00	1.00	1.00	59.43	0.37
NW	78.02	1.00	1.00	1.00	78.02	0.37
Total	269.37	1.00	1.00	1.00	269.37	0.37

Air handling unit	Pressure head supply/exhaust [Pa/Pa]	Fan efficiency supply/exhaust [-/-]	System SFP [kW/(m³/s)]	Heat exchanger temp. ratio/min exhaust temp. [-/C]
AHU	540.00/360.00	0.60/0.60	0.90/0.60	0.70/-20.00

DHW use	kWh/m2 floor area and year	Total, [l/s]
	4.000	0.003

Delivered Energy Overview

	Purchased energy		Peak demand	Primary energy	
	kWh	kWh/m²	kW	kWh	kWh/m²
Valaistus, kiinteistö	88373	73.0	21.78	106048	87.6
LVI sähkö	21552	17.8	4.33	25862	21.4
Total, Facility electric	109925	90.8		131910	109.0
Lämmitys, kaukolämpö	28916	23.9	39.94	14458	12.0
LKV, kaukolämpö	12207	10.1	1.39	6104	5.0
Kaukojäähdytys	13925	11.5	65.6	3899	3.2
Total, Facility district	55048	45.5		24461	20.2
Total	164973	136.3		156371	129.2
Laitteet, asukas	4910	4.1	1.21	5892	4.9
Total, Tenant electric	4910	4.1		5892	4.9
Grand total	169883	140.4		162263	134.1

Used energy

kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
1	997.3	0.0	5587.0	0.0	1006.0
2	678.1	0.0	4962.0	0.0	908.2
3	204.9	0.0	4090.0	0.0	1006.0
4	0.0	187.2	854.4	37.5	973.1
5	-0.0	921.4	3.4	463.2	1006.0
6	-0.0	1542.0	0.1	986.9	973.1
7	-0.0	2315.0	0.0	3226.0	1006.0
8	-0.0	1188.0	0.0	2916.0	1006.0
9	-0.0	40.2	50.0	101.3	973.1
10	41.8	-0.0	1080.0	0.0	1006.0
11	400.1	0.0	3482.0	0.0	973.1
12	786.1	0.0	4831.0	0.0	1006.0
Total	3108.3	6193.8	24939.8	7730.9	11842.6

Utilized free energy

kWh (sensible and latent)

Month	AHU heat recovery	AHU cold recovery	Plant heat recovery	Plant cold recovery	Solar heat	Ground heat	Ground cold	Ambient heat	Ambient cold
1	20583.0	0.0							
2	18900.0	0.0							
3	19828.0	0.0							
4	12527.0	-0.0							
5	6420.0	-0.0							
6	2969.0	-0.0							
7	685.0	-22.7							
8	1941.0	-87.4							
9	6270.0	-0.0							
10	12108.0	0.0							
11	16697.0	0.0							
12	18647.0	0.0							
Total	137575.0	-110.1							

Generated electric energy

kWh

Month	Solar (PV)	Wind turbine	CHP
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
Total			

Auxiliary energy

kWh

Month	Humidification	Fans	Pumps
1		1434.0	4.0
2		1274.0	3.6
3		1435.0	2.9
4		1339.0	0.7
5		1457.0	1.3
6		1408.0	2.8
7		1412.0	9.2
8		1464.0	8.4
9		1349.0	0.3
10		1448.0	0.8
11		1386.0	2.5
12		1383.0	3.5
Total		16789.0	40.0

Distribution Losses

kWh

Month	Domestic hot water circuit	Heating	Cooling*	Air ducts*
1	594.3	99.7	0.0	0.0
2	536.8	67.8	0.0	0.0
3	594.3	20.5	0.0	0.0
4	575.1	0.0	37.5	0.0
5	594.3	-0.0	184.3	0.0
6	575.1	-0.0	308.4	0.0
7	594.3	-0.0	462.9	0.0
8	594.3	-0.0	237.6	0.0
9	575.1	-0.0	8.0	0.0
10	594.3	4.2	-0.0	0.0
11	575.1	40.0	0.0	0.0
12	594.3	78.6	0.0	0.0
Total	**6997.3**	**310.9**	**1238.7**	**0.0**

*positive loss when conduit is cooler than building

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Report 3: Parking garage spaces energy simulation result

Parking garage

EQUA SIMULATION TECHNOLOGY GROUP

Input data Report

Project		Building	
CASE XXX Parking garage FIN YMa1010/2017Toimistorakennus Mallinnus perustuu vesiradiaattorijärjestelmään 70/40 lämpötiloilla, joka liitetty kaukolämmön alakeskukseen. Mallinnus YMa1010/2017 mukainen. -Vuotoilma YMa1010/2017 kohta 4.3.3 ja 2.3.2(tasauslaskennan mukainen vuoto, 5-kerroksinen rakennus) Mallinnusta täydennetty "YMohje ("D5") 2018" arvoilla seuraavasti: -"YMohje ("D5") 2018" taulukko 3.1-3.3, rakenteiden väliset kylmäsillat (betoniset rakenteet) -KL-alakeskuksen vuosihyötysuhde ja sähkönkäyttö, "YMohje ("D5") 2018" taulukko 7.1 (ja 7.2) -Lämmitysjärjestelmien lämmönjaon ja -luovutuksen vuosihyötysuhde, "YMohje ("D5") 2018" taulukko 6.1 -Lämmitysjärjestelmän apulaitteiden sähkönkulutus, "YMohje ("D5") 2018" taulukko 6.1 -Lämpimän käyttöveden häviöt "YMohje ("D5") 2018" kohta 6.3 (ei varaajaa). Kiertojohdon ominaispituus 0,06 m/m2. Kierron ja varastoinnin häviöistä 50 % lasketaan hyödyksi tilojen lämmityksessä. LKV kokonaishäviöistä 41 % lasketaan hyödyksi tilojen lämmityksessä.(Jakojohdon häviöistä ei lämpöä hyödyksi) -Lämpimän käyttöveden pumpun sähkönkulutus "YMohje ("D5") 2018" kohdan 6.3.4 mukaisesti (kiertojohdon eristystaso 1,5*D) -Tasauslaskimeen(IDA-tuloste) kaikki lähtötiedot syötetään lämpimien tilojen mukaisilla arvoilla. Käyttäjän tulee itse täydentää ja tarvittaessa myös muuttaa tietoja tasauslaskentatulostukseen. -Halutessaan energiatodistustulosteen(IDA-tuloste) luokan 9 rakennukseen käyttäjä voi valita rakennuksen mallipohjaksi jonkun luokan 1-8 rakennuksista ja muuttaa sitä suunnittelutapausta vastaavaksi. Simuloinnin jälkeen käyttäjä voi sitten muuttaa rakennuksen käyttötarkoitusluokan IDA-energiatodistustulosteen sivulle 1.		Model floor area	1676.0 m²
Customer		Model volume	4608.3 m³
Created by	Eetu Toroskainen	Model ground area	1129.0 m²
Location	Helsinki (Ref 2012)	Model envelope area	1816.8 m²
Climate file	HKi-Vantaa_Ref_2012	Window/Envelope	0.0 %
Case	7091_Eluku_parkkihalli	Average U-value	0.131 W/(m² K)
Simulated	31.8.2018 10:28:52	Envelope area per Volume	0.3943 m²/m³

Fixed infiltration airflow rate			42.627 l/s	
Building envelope	Area [m²]	U [W/(m² K)]	U*A [W/K]	% of total
Walls above ground	**101.11**	**0.21**	**21.39**	**8.98**
US6	50.23	0.22	11.13	4.67
KS2 U=0,2	50.89	0.20	10.26	4.31
Walls below ground	**320.82**	**0.15**	**47.08**	**19.78**
KS2 U=0,20	275.79	0.15	40.47	17.00
KS2 U=0,2	45.04	0.15	6.61	2.78
Roof	**265.92**	**0.12**	**32.04**	**13.46**
YP2	265.92	0.12	32.04	13.46
Floor towards ground	**1128.99**	**0.09**	**106.46**	**44.72**
D3 2012 alapohja maata vasten, lammin tila	1128.99	0.09	106.46	44.72
Floor towards amb. air	**0.00**	**0.00**	**0.00**	**0.00**
Windows	**0.00**	**0.00**	**0.00**	**0.00**
Doors	**0.00**	**0.00**	**0.00**	**0.00**

Thermal bridges			31.09	13.06
Total	1816.84	0.13	238.06	100.00

Thermal bridges	Area or Length	Avg. Heat conductivity	Total [W/K]
External wall / internal slab	33.40 m	0.000 W/(m K)	0.000
External wall / internal wall	7.44 m	0.000 W/(m K)	0.000
External wall / external wall	10.19 m	0.060 W/(m K)	0.611
External windows perimeter	0.00 m	0.000 W/(K m)	0.000
External doors perimeter	0.00 m	0.000 W/(K m)	0.000
Roof / external walls	40.73 m	0.080 W/(m K)	3.258
External slab / external walls	113.41 m	0.240 W/(m K)	27.219
Balcony floor / external walls	0.00 m	0.000 W/(K m)	0.000
External slab / Internal walls	0.00 m	0.000 W/(K m)	0.000
Roof / Internal walls	32.55 m	0.000 W/(m K)	0.000
External walls, inner corner	0.00 m	0.000 W/(K m)	0.000
Roof / external walls, inner corner	0.00 m	0.000 W/(K m)	0.000
External slab / external walls, inner corner	0.00 m	0.000 W/(K m)	0.000
Total envelope (incl. roof and ground)	1788.66 m²	0.000 W/(m² K)	0.000
Extra losses	-	-	0.000
Sum	-	-	31.088

Windows	Area [m²]	U Glass [W/(m² K)]	U Frame [W/(m² K)]	U Total [W/(m² K)]	U*A [W/K]	Shading factor g
Total	0.00	0.00	0.00	0.00	0.00	0.00

Air handling unit	Pressure head supply/exhaust [Pa/Pa]	Fan efficiency supply/exhaust [-/-]	System SFP [kW/(m³/s)]	Heat exchanger temp. ratio/min exhaust temp. [-/C]
TKPK1 - Pysäköinti	550.00/350.00	0.50/0.50	1.10/0.70	0.75/-20.00

DHW use	kWh/m2 floor area and year	Total, [l/s]
	0.000	0.000

Delivered Energy Overview

	Purchased energy		Peak demand	Primary energy	
	kWh	kWh/m²	kW	kWh	kWh/m²
Valaistus, kiinteistö	21645	12.9	7.63	25974	15.5
LVI sähkö	31405	18.7	8.6	37686	22.5
Total, Facility electric	53050	31.7		63660	38.0
Lämmitys, kaukolämpö	138263	82.5	71.13	69132	41.3
LKV, kaukolämpö	0	0.0	0.0	0	0.0
Kaukojäähdytys	0	0.0	0.0	0	0.0
Total, Facility district	138263	82.5		69132	41.3
Total	191313	114.1		132792	79.2
Laitteet, asukas	0	0.0	0.0	0	0.0
Total, Tenant electric	0	0.0		0	0.0
Grand total	191313	114.1		132792	79.2

Used energy

kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
1	0.0	0.0	19239.0	0.0	0.0
2	0.0	0.0	17367.0	0.0	0.0
3	0.0	0.0	18183.0	0.0	0.0
4	0.0	0.0	13226.0	0.0	0.0
5	0.0	0.0	9719.7	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	15.9	0.0	0.0
9	0.0	0.0	10207.9	0.0	0.0
10	0.0	0.0	12913.0	0.0	0.0
11	0.0	0.0	15779.4	0.0	0.0
12	0.0	0.0	17465.0	0.0	0.0
Total	0.0	0.0	134115.9	0.0	0.0

Utilized free energy

kWh (sensible and latent)

Month	AHU heat recovery	AHU cold recovery	Plant heat recovery	Plant cold recovery	Solar heat	Ground heat	Ground cold	Ambient heat	Ambient cold
1	44125.0	0.0							
2	39067.0	0.0							
3	40691.0	0.0							
4	27870.0	0.0							
5	19300.0	-0.0							
6	0.0	0.0							
7	0.0	0.0							
8	8.8	0.0							
9	17141.7	-0.0							
10	28117.0	0.0							
11	35967.6	0.0							
12	39399.0	0.0							
Total	291687.1	-0.0							

Generated electric energy

kWh

Month	Solar (PV)	Wind turbine	CHP
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
Total			

Auxiliary energy

kWh

Month	Humidification	Fans	Pumps
1		2420.0	13.8
2		2108.0	12.6
3		2322.4	13.1
4		2234.0	12.9
5		2457.6	17.6
6		2274.0	0.0
7		2380.4	0.0
8		2485.0	0.0
9		2146.0	17.8
10		2443.0	12.8
11		2324.5	12.2
12		2221.0	12.5
Total		27816.0	125.3

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