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BUILDING LIFE-CYCLE STAGES' GLOBAL WARMING POTENTIAL BENCHMARKING FOR CONSTRUCTION PROJECTS IN FINLAND

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ABSTRACT

High demand for construction projects' environmental impact limiting resulted in the need for setting up benchmarks for buildings in Finland. Today the global aim of reducing the emissions and hindering global warming is the top priority for most of the countries in the world. Constructions make up a significant part of emissions and are included in plans on impact reduction as one of the key issues. The aim of the present study was to create reference and limit values for constructions of different types in Finland.

Data containing information on building projects was analysed using quantitative methods. Literature review was applied for background information search. The existing data on the study issue was found first, followed by analysis of the data provided by commissioner.

The analysis of the theoretical and numerical data was performed. The environmental impact benchmarking and limit values for building projects were set for use of the commissioner as part of life-cycle assessment online platform as well as for benefits of other interested parties allowed by the commissioner. The set limit for all new buildings is 7.7 to 9 CO_2 e/m^2/y or 540 CO_2 e/m^2 for the whole building's life-cycle of 50 years. The benchmarks and limit values are available for both new and renovated buildings and are also set for construction stages. A significant difference in values and data assessment methodologies between the Nordic countries was found.

Keywords: LCA, benchmark, sustainability, construction project, emission limit

CONTENTS

1 INTRODUCTION

The thesis is based on topic provided by the client company that commissioned the thesis, One Click LCA Ltd. The thesis studies are research-based work and are aimed to develop benchmarks with reference values for global warming potential of buildings in Finland due to high demand for legislative limitations on new construction projects in order to comply with targets stated in Paris Agreement that came into force in 2016 (UN 2015). In other words, the thesis will answer the question: what are the most suitable environmental limitations and classification for building projects in Finland? In addition, a comparison to legislations of other Nordic countries (Denmark, Iceland, Estonia, Sweden and Norway) is performed.

2 ENVIRONMENTAL LEGISLATION

The modern history of environment protection started in 1997, when the Kyoto Protocol to the United Nations Framework Convention on Climate Change was signed. The document came into force on 16 February 2005. (UNFCCC, n.d.) The Kyoto Protocol has set the first environmental goals in order to prevent climate change. The key benefit of it was that it was signed and ratified by most of the countries in the world. The parties list includes 192 countries. Among them are Denmark, Estonia, Finland, Iceland, Norway and Sweden. (UN 2005.) The requirements for the countries that signed the protocol included improving the energy efficiency and sustainability, as well as reducing greenhouse gas (GHG) emissions to particular levels specific for each country (UNFCCC 1998, 2). The GHGs for reduction were Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6) (UNFCCC 1998,19). As a general and overall requirement for greenhouse gas emissions the protocol set a value of 5% lowering from 2008 till 2012 compared to the level of 1990 (UNFCCC 1998, 3). While most of the Nordic countries had to decrease the emissions by 8%, Norway and Iceland were allowed to stay at the same level as they had in 2005 or even increase their values but not significantly (UNFCCC 1998, 20).

The Paris Agreement was meant as a successor of the Kyoto protocol. The document was signed in 2015 and came into force in 2016. (UN 2015.) The convention agreed on the new limitations aimed to minimize climate change. The reference value was set at 2°C of maximum temperature increase compared with pre-industrial level and 1.5°C increase as a voluntary but also most desired aim. In addition to that the peak of GHG emissions should have been reached as soon as possible together with possible carbon neutrality for the agreement parties. (UNFCCC 2015, 3-4.) The agreement was signed by European Union (EU) representatives and later ratified by its participants. All Nordic countries have ratified the Paris Agreement and base their aims and legislations on it. (UN 2015.)

The European Union has set several intermediate stages for impact reduction as part of the Climate Target Plan and Green Deal. The first target was to reach a 20% reduction of GHG by 2020 (EC 2012), then a minimum of 55% greenhouse gas emissions reduction from the levels of 1990 by 2030 (EC 2014) and the latest aim is to be carbon neutral by 2050. According to The European Green Deal, signed in 2020, such indexes can be possible only with the help of total renovation of 35 million buildings and higher energy efficiency. For that at least 3 % of the countries' total GIFA (gross internal floor area) has to be renovated annually, as well as special benchmarks for constructions and building renewing have to be set. (EC 2021.)

In addition to the documents mentioned above, the European Union has adopted Directive 2016/2284 on 14 December 2016 in order to set the targets for reduction of emissions of certain atmospheric pollutants in member countries. Among the countries that use the directive are the Nordic countries, except for Norway and Iceland that are not part of the EU. The emissions should be reduced by certain percentages (see Table 1) compared to the levels of 2005 and are reported and assessed from 2020. The values are set for sulphur dioxide (SO_2), ammonia (NH_3), nitrogen oxides (NO_x), particulate matter that are 2.5 microns or smaller ($PM_{2.5}$) and non-methane volatile organic compounds (NMVOC). (Directive 2016/2284, 21.) These matters are produced during several processes, including transportation, burning, energy production and other. Their limitation directly affects the construction sphere as not only the material production has to be improved, but also the transportation and energy use needs to be reduced. In life-cycle analysis (LCA) the values for these pollutants are always presented as CO_2 equivalent.

Table 1. Air pollutants reduction targets for Nordic countries in EU

Country/ Pollutant/ Period	SO_2		NO_x		NMVOC		NH_3		$PM_{2.5}$	
	Before 2029	From 2030	Before 2029	From 2030	Before 2029	From 2030	Before 2029	From 2030	Before 2029	From 2030
Denmark	35%	59%	56%	68%	35%	37%	24%	24%	33%	55%
Estonia	32%	68%	18%	30%	10%	28%	1%	1%	15%	41%
Finland	30%	34%	35%	47%	35%	38%	20%	20%	30%	34%
Sweden	22%	22%	36%	66%	25%	36%	15%	17%	19%	19%

As we see in Table 1 all of the listed countries have to reduce their emissions significantly for some substances and slightly less for others. It is also seen that ammonia has to be limited from 2020, but no new limits are set from 2030, except for possible increase in Sweden, while limits for sulphur dioxide and small particulate matters stay the same there. The key reductions are usually made in transportation, industrial and construction spheres.

3 LIFE-CYCLE ASSESSMENT

The benchmarks for constructions and the general assessment of the impact that the building has on environment is possible with the help of life-cycle assessment, also known as LCA. LCA is the evaluation of the impacts caused by all the incoming and outcoming matters as well as ongoing processes related to the whole life-cycle of a product or building (SFS-EN 15804:2012 + A2:2019:en, 8). The assessment of the building is performed by calculating how much different greenhouse gases were emitted during the production of the materials for construction, the processes of installation and use, and finally during demolition. For convenience, all the gases are equated to carbon dioxide or CO_2 with different indexes that correspond to impact significance. The units that are used for calculations are kg CO_2 eq/m^2 for the total impact and kg CO_2 eq/m^2/y for annual emissions. Some other forms of writing the unit of GWP are g CO_2 eq/m^2/y, kg CO_2 e/m^2, kg CO_2 eq/m^2/a, and kg CO_2 e/m^2/a. The life-cycle is divided into 17 stages, that can be found in Figure 1 below.

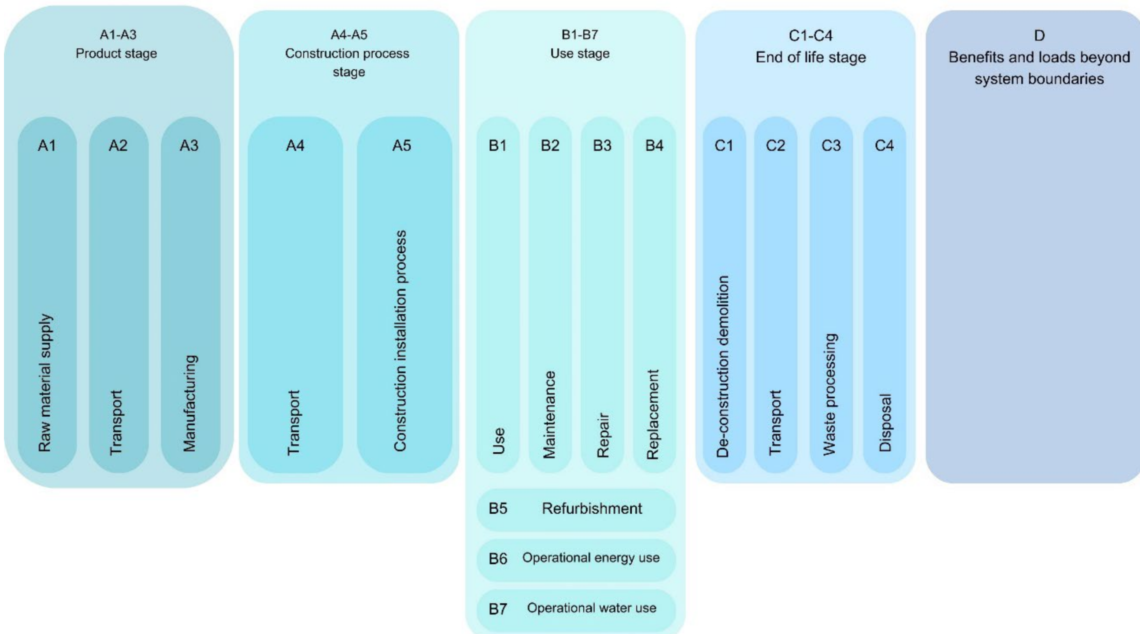

Figure 1. Life-cycle stages

The calculations are done per stages that mean different processes in the life-cycle. All 17 stages are collected into 5 bigger groups. A1-A3 is the product stage, A4-A5 includes the construction process, B1-B7 is use, C1-C4 is End-of-Life stage (EoL), and D contains all the benefits and loads outside of the system boundaries like reuse, recycling and others. The LCA may include either all or just some stages. Dependent on that, the scope of analysis may be cradle-to-gate (A1-A3), cradle to practical completion (A1-A5), cradle-to-grave (A1-C4) and cradle-to-cradle covering all parts of the life-cycle. (Masson 2023a.) According to ISO 14040:2006, the LCA is also divided into four stages that include defining the aims and the scope of assessment, analysis of the life-cycle itself, assessing the impacts, and the final clarification of the received data.

The very important and always highly assessed part of the buildings' lives is the product stage. Much attention is paid to the sources of information that are used for calculations of impacts from materials. For that the environmental product declarations (EPDs) or local generic data can be used. Today, there are two key standards for declarations, EN 15804:2012+A1:2013 and EN 15804:2012+A2:2019. The EPD is done based on LCA for a product that is, in general, similar to the assessment of a building. The compulsory part of analysis has to include only A1-A3 stages, or production stage. However, the best option is the cradle-to-grave assessment. (SFS-EN 15804 + A1:en, 16.) The difference between the two standards is the creation of subsets for climate change categories as a new step in assessing the global warming potential of the product. This includes counting not only the total GWP of the matter, but also the biogenic, fossil, and land use and land use change (LULUC) one. (SFS-EN 15804 + A1:en, 33; SFS-EN 15804:2012 + A2:2019:en, 34-35.) By more in-depth analysis of the impact the total GWP is usually higher in the EPDs that are made according to the latest standard. Different countries have set their requirements on EPDs used for LCA and this may affect the difference in total GWP of buildings significantly. As Finland requires to use mainly the A1 and generic declarations, the big disparity in data is not expected. As for the end-of-life scenarios, they always have to be set specifically for each product, whilst for waste management options like landfilling should be calculated for 100 years (SFS-EN 15978:en, 29). In addition, all the data used for LCA calculations cannot be older than 10 years in order to prevent using outdated information and technologies (SFS-EN 15978:en, 41).

3.1 European Union perspective

European Union includes 27 countries in Europe. The construction sector of them varies a lot due to different climate, traditions, culture and funding. Nevertheless, all these countries signed the Paris Agreement and are now establishing rules and limits for buildings in their territory.

According to the studies of Ramboll, global engineering and sustainability consulting company from Copenhagen, Denmark (Ramboll, n.d.), average residential or non-residential building in EU makes up about 600 kg CO_2 e/m^2, even though the range of values for the whole life-cycle varies a lot from one project to another (Ramboll 2022, 38). They analysed 769 projects from Belgium, Denmark, Finland, France, Netherlands and other countries. Most of the countries in Europe did not have enough projects for precise analysis as their number was significantly lower than 50 in the particular databases. (Ramboll 2022 ,51.) They state that the mean value for multi-family houses and for row houses showed the highest mean value at 700 kg CO_2 e/m^2 and the lowest medium at 400 kg CO_2 e/m^2 of emissions respectively. As for non-residential buildings, hospitals and recreational buildings, they reached 800 kg CO_2 e/m^2, while the offices had the lowest mean at 600 kg CO_2 e/m^2. (Ramboll 2022, 51.) Mean values for emissions during the whole construction's service period in Belgium, Denmark, Finland, France and Netherlands were 591 kg CO_2 e/m^2, 352 kg CO_2 e/m^2, 497 kg CO_2 e/m^2, 661 kg CO_2 e/m^2 and 387 kg CO_2 e/m^2, each. In other words, Denmark showed the lowest results during analysis. (Ramboll 2022, 54.) This data is interesting as it can be compared with my results.

This company also collected key information on the standardisation and legislations for building LCA around EU. As for March 2022, only Denmark, Finland, France and Sweden (Norway and other countries were not mentioned as they are not members of the union) had special legislation for buildings' life-cycle assessment methodology. Other countries, including Estonia, have not established special ways of calculations yet. (Ramboll 2022, 27-32.)

In addition to legislations and methodology, countries adopt certification systems for construction LCA of local projects. Thus, Level(s) is Europe wide programme, while LEED v4 (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), DGNB (German Sustainable Building Council) and some other are recognised internationally. More country specific certifications are RT(S)-Ympäristötyökalu (Environmental tool) for Finland, DK-DGNB for Denmark, BREEAM NOR for Norway, NollCO2, BREEAM SE, as well as Miljöbyggnad for Sweden and Svanurinn in Iceland. (One Click LCA Ltd 2018 31-33.) All these systems are initially based on Level(s) but have some exceptions that affect the results of local building projects impact evaluation.

3.1.1 Level(s)

Today in Europe, most of the life-cycle assessments and certification are based on the European standards and the Level(s) system. Level(s) is a unified and non-localized European system for analysis of impacts made by construction projects. It is the common framework for all the countries around EU. Level(s) is using 6 macro-objectives and 16 indicators within them to fully evaluate the impacts. This helps to represent how a building can be allied with European sustainable development strategies. (EC, n.d.) The scope of calculations may vary dependent on the required level of assessment (1, 2 or 3). The first level usually includes only the product stage. The second will also have A4-A5, B6 and B7, while the third requires the full assessment. The calculation period is always 50 years; that is a common period in most of the countries. The Level(s) allows both A1, A2 and generic data as a source. (Masson 2023b.)

The Level(s) is used not only for new construction, but also for renovation. According to their strategy, one of the best ways to reduce GHG emissions is to renovate the existing buildings and to improve the effectiveness of all building services, reduce embodied carbon, and use more green materials. This tendency increases the interest of the countries in the certification and impact assessment of renovations in order to reach the sustainability goals faster. (EC 2023.)

3.2 Finland

Constructions and real estate business covers about 15% of the GDP (gross domestic product) of Finland today and is extremely important for economy (Climate roadmaps, n.d.). The sector covers one third of all greenhouse gases emissions in the country (Ministry of Economic Affairs and Employment of Finland 2022, 22) and in total it makes up about 17 Mt CO_2e annually according to the statistics from 2017 (Climate Act 423/2022). This makes buildings a huge and influential part of GHG production. The total emissions in 2017 were 55.4 Mt CO_2e, excluding the land use sector (LULUCF) (Statistics Finland 2019), while in 2022 they were already 45.8 Mt CO_2e (State Treasury Republic of Finland, n.d.); that shows at least 21% change in five years.

Finland came up with the Climate Change Act in 2022. This document has set the reduction values for total emissions of the country with several intermediate stages. First of all, it plans to get 60% reduction by 2030, then 80% by 2040 and 90% or preferably 95% by 2050. Carbon neutrality is set as an aim for 2035. The reduction is calculated from the emissions level of 1990, the same as in most of the European legislation. (Ministry of the Environment 2023, 14.) The mentioned key sectors to work on are the agriculture, forestry, land use and other effort sharing sectors that include constructions and energy production. Meanwhile the target for 2030 has not changed since the previous version of the Climate Change Act, that was signed in 2015 The plan for 2050 got stricter and more confident, as the last time Finland aimed to reach only 80% reduction. (Climate Change Act 609/2015, 3.) The change was possible due to several factors including technological progress and better baseline assessment. The baselines for the target making show extremely ambitious points, as they state that Finland can reach 3.7 Mt CO_2e by 2035 and 0.9 Mt CO_2e in 2050. (Climate Act 423/2022.) According to the Low carbon roadmap of construction industry prepared by Finnish Ministry of Economic Affairs and Employment, from 2017 the construction industry may lower its emissions by 66% with current technologies and by 78% with use of innovations. By 2050 they can go from 80% to 95% decrease. As they state the carbon neutrality level at 3.3 Mt CO_2e, they also see the possibility to reach it between 2035 and 2040, but not later than early 2050s. (Confederation of Finnish Construction Industry RT 2020, 3.)

The average building in Finland has a set service life of 50 years. During this period 76% of all emissions are formed by operational energy use, 15% are materials (including their production and energy used for manufacturing), 7% are caused by transportation and side activities and 2% are the rest emissions. (Gaia Consulting Oy 2020, 16.) Energy being the key emissions source has the biggest potential for total GWP reduction. Energy consumption is normally divided into two parts: heating and electricity. In Finland district heating is used in a bit fewer than half of all the buildings (Ministry of Economic Affairs and Employment of Finland 2022, 176). Meanwhile, building specific heating is part of the effort sharing sectors and is making about 7% of all emissions from it (Ministry of the Environment 2023, 19). 48% of all heating emissions are coming from residential buildings heat and 36% are from service buildings. Oil heating is popular in older building and produces the most of the GHG within all the heating fuels. Because of that, it is forbidden to use oil heating in new buildings and the old constructions' systems must be replaced with biofuel-based ones by the beginning of 2030s. (Ministry of the Environment 2023, 48-49.) The emissions from fossil oil heating tend to decrease year by year but they are still far from 0. The progress of emission minimization can be seen in Figure 2.

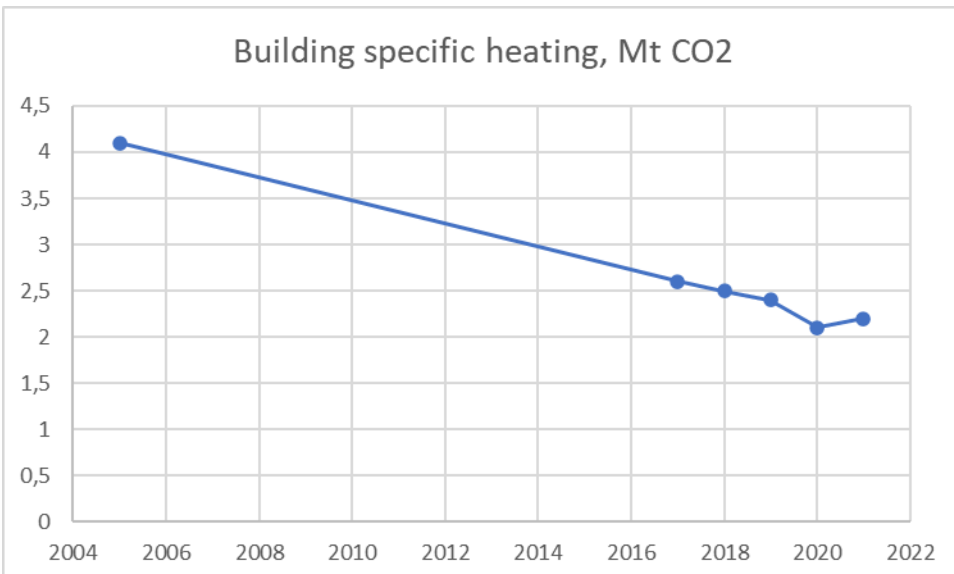

Figure 2. Building specific heating, annual values (Ministry of the Environment 2019a, 25; Ministry of the Environment 2020, 37; Ministry of the Environment 2021, 50; Ympäristöministeriö 2023, 51)

The heating emissions are highly dependent not only on heat source, but also on the annual change in temperature. Winter in 2020 was not as cold as in 2018, but still warmer than in 2021 (Ministry of the Environment 2020, 37). This causes abrupt changes in the values and also means that the strict limits for heating emission cannot be set. The only way to decrease the effect is to change the energy source as well as energy efficiency of the buildings. For that Energy efficiency agreement on distribution of Liquid Heating Fuels HYÖLÄ IV, of 2016 was approved. It includes the plan to start replacing oil heating systems from 2017 and to provide grants on development (Energy efficiency agreements 2016, 4). In addition to oil removal the gas-powered systems should be replaced starting from April 2022. Coal heating will be prohibited from 2029. The heat pump systems are used more widely currently and are highly recommended for installation. By 2017 the number of heat pumps increased by 40% compared with 2010. Even though, the pump is decreasing emissions from heating, it still has one big disadvantage that is currently not considered. The key element of such system is F-gases (Fluorinated gases), that are included in the GHG list. (Ministry of the Environment 2017, 64.) Thus, the government is trying to achieve lower emissions from heating and cooling systems and to introduce the use of either biofuel or renewable energy (Ministry of the Environment 2023, 50). The interesting finding was that in Governmental Report on Medium-term Climate Change arranged in 2017 the use of clean combustion with pellets and firewood as fuel was promoted as a way of solving the issue of high heating emissions, as this kind of heat decreases the emission of black carbon and fine particulate matters, that are especially active air pollutants (Ministry of the Environment 2017, 90). The same idea or suggestion was not mentioned in any other documents.

According to studies, the most polluting heating systems were installed in detached or semi-detached houses. In 40% of all such buildings oil was used. Also 4800 houses use natural gas. In 2019, 0.8 Mt CO_2e were emitted that makes up about 85% of all heating emissions from residential buildings. (Ministry of the Environment 2023, 49.) This fact leads to a reflection that the heating systems of detached or semi-detached houses must have stricter limits and requirements, as well as high number of renovations have to be done.

Electricity use is another big part of the GWP content. Due to digitalization and shift from fossil and biofuels to electricity use, the demand for it is going to rise. The baseline shows that the consumption in Finland in 2000s was between 80 and 90 TWh in a year, while they might rise to 92 TWh by 2030 and to 96 TWh by 2040. (Ministry of Economic Affairs and Employment of Finland 2022, 169.) The use of renewable energy sources reduces the emissions, but the volumes of production are still too low to have significant effect. In order to reduce emissions from electricity use, it is important to improve both new and existing buildings. For that, the energy efficiency should be improved as well as most of the energy should come from renewable sources like wind, solar or waterpower. (Ministry of Economic Affairs and Employment of Finland 2022, 23.) As for renovations, the buildings that have energy class A, B or C, that make up about 1/5 of all existing construction, do not need improvements. The ones that are classified as E or D, that are about 2/3, have low need for renovation, while the rest, marked as energy class F or G have to be renovated as soon as possible. (Gaia Consulting Oy 2020, 14.) This will also allow Finland to reach the rate of 90% of zero (neutral) energy buildings; 40% are planned to be achieved by removal of fossil fuel heating systems, 20% by improvement of energy efficiency and 30% by improvement of space efficiency in the edifices or by their removal for replacement with green zones or with modern houses (Gaia Consulting Oy 2020, 19).

3.2.1 Life-cycle assessment method

In 2019, Finland released a book with the methodology of the national assessment of buildings' life carbon. This document is part of RakL or Rakennuslaki, also known as Construction law of Finland. This method is preferred for all the projects in the country and is base for the local assessment systems and certifications. In general, the method is the based on the Level(s) way of analysis, but still has some peculiarities. The assessment scope for the new constructions and renovations is A1-A3, A4-A5, B3, B4, B6, C1-C4, D, where A1-A3 is compulsory for all designs and B3 is voluntary. (Ministry of the Environment 2019b, 34.) The set service life of the whole building is always 50 years (Ministry of the Environment 2019b, 33), while the service life of the materials and parts is either applied in the same way as in the EPD (environmental product declaration) of the matter or from the reference book KH90-00403. It includes the data for all generic material types without connection to a particular manufacturer or to special product (RTS 2008). According to the decision of Finish Ministry of Economic Affairs and Employment, reused, recycled or recovered materials can be included into product stage of assessment, but their impact will be equal to zero. In other words, neither positive nor negative CO_2 emissions are considered from that. (Nordic Sustainable Construction 2023.)

As for 2019, the end-of-life (EoL) scenarios were always fixed, but in 2021 the update of the document allowed to choose between fixed and other options (Ministry of the Environment 2019b, 21).

For the needs of the Finnish LCA, One Click LCA Platform has launched several versions of YM (Ympäristöministeriö) tool. The first dates back to 30 August 2019 and strictly follows the official method of assessment. The background documentation is Level(s), EN 15643, EN 15978 and EN15804. Stages A1-A3 and B6 are considered as data based on the project properties, while the rest of the parts are fixed. No benefits beyond the boundary of system are analysed. MEP or the building technologies have some fixed values that can be used on a voluntary basis. In addition, the energy use impact is not calculated based on current values of emissions multiplied by the total volume of use, but based on the national plan of energy emissions reduction, that can be chosen for several periods of service (50 years is the most used plan as service life of the construction is set to half of the century). (Masson 2022b.) After the documentation update in 2021, the improved version of YM was launched (One Click LCA Help Center 2023). Transport got the fixed values of 90% highway and 10% city roads driving for all materials (Masson 2023c). EoL got a database with several options of scenarios. Moreover, the possibility of exporting energy from the building was added, so the energy can now have not only positive GWP, but also the negative one. (One Click LCA Help Center 2023.)

3.2.2 LCA tools

The One Click LCA Platform uses different data dependent on the tool and location of the construction site. For Finland, the EPDs following the standard and EN 15804:2012+A2:2019 are preferred, but the ones made according to EN 15804+A1 or generic are also accepted. (Ministry of the Environment 2019b.) The service lives are set according to KH90-00403 and may last the same period as the building (that is usually applied for the base structures) or as long as their life-time did not pass. The building technologies also rely on the use conditions and frequency. (Masson 2021.) Energy consumption (B6) emissions and costs are coming from IEA (International Energy Agency) and the Statistics Finland website. Values for heating are provided by Kaukolämpötilasto (Statistics of district heating) annual reports. (Masson 2022a.)

One Click LCA is not the only popular assessment tool for construction projects in Finland. RTS-ympäristöluokitus (Construction Information Foundation Environmental Rating) is a certification system made specially for Finland in 2020. It is based on the national methodology of analysis but also provides rating of the existing projects. Thus, the projects are sorted in the order of ascending emissions level and the top 15% (showing the best results) are getting five points and title Excellent. The next 15% are High level of performance with 4 points, the ones that are between 75% and 50% of the best are Good, next 15% are better than usual, followed by 15% of Normal and the rest 25% are not acceptable. (Rakennustietosäätiö RTS sr 2020, 5.) The assessment can be done for offices, day care for children, educational buildings, apartment and commercial constructions, hotels, hospitals, sport facilities and industrial buildings (Rakennustietosäätiö RTS sr 2020, 9).

3.2.3 Low-carbon constructions

The key aim for the Finnish construction sector is to reach as many low-carbon buildings as possible. It is required that all of the new buildings are following this status. However, there are some exceptions from the list of buildings, that are not critically assessed for lowering the emissions. These buildings are the ones smaller than $50m^2$, summer cottages or other residential houses that are not planned for winter residence, temporary houses that are built for 2 years or less, some service buildings as well as religious, cultural or historical places. For all of the buildings it is asked to have at least 38% of renewable energy used in cases when such level can be reached. (Maankäyttö- ja rakennuslaki 16 luku 21.4.2023/752.) As for the compulsory requirements for low-carbon status awarding, these constructions have to be at least 10% more energy efficient than the regulatory level. They have to be classified as A or B energy class and at least 10% of all materials that were used are to be recycled. (Ministry of the Environment 2018, 30-31.)

Finland has not yet come up with concrete limits for the global warming potential of the construction. Nevertheless, it already has several rules, legislations and requirements for the building sector and is suggesting opportunities for current and future emissions reduction.

3.2.4 Existing stage limits

Studies on Carbon Footprint limits for different building types were already done before twice. The first report, that dates back to 2021, was published, while the new one, that was done in 2022 or 2023 is still covered with confidentiality responsibility and cannot be found in open access. The report was prepared by One Click LCA Ltd. and the Ministry of the Environment, Finland.

During the study the projects of residential buildings, row houses office buildings, healthcare buildings, service buildings, educational buildings, day care centres, primary schools and commercial buildings were analysed. The information is originally from the One Click LCA database, and all of the projects have service life of 50 years. All structures of the buildings were analysed. (One Click LCA Ltd 2021, 12-15.) The results of the study are presented in Table 2.

Table 2. Limits suggestion by One Click LCA Ltd. (One Click LCA Ltd 2021, 35)

Building type	Residential	Office	Service	Education	Commercial
A1-A3, kg CO_2 e/m^2/y	11.5	10	14	11	10
A4-A5, B3, C1-C4, kg CO_2 e/m^2/y	1.5	1.5	1.5	1.5	1.5
Total, kg CO_2 e/m^2/y	13	11.5	15.5	13	11.5
Total, for 50 years, kg CO_2 e/m^2	650	575	775	650	575

As it is clear from the table, the highest emissions come from the service buildings, followed by residential and educational ones, and then are all the rest. We can also see that value for A4-A5, B3 and C1-C4 is fixed for all buildings, while the product stage varies. These limits can be used as reference for my analysis results.

The latest updates of the local legislations of Helsinki have set the limit for all new limits. The rule came into force on 20.06.2023 and requires all the building to have impacts below 16 CO_2 e/m^2/y for a 50-year calculation period. However, this norm is not strict and can have some exceptions, like the possibility of exceeding limits by 10% in case of complicated wall geometry or parking lots inclusion, as well as other significant reasons that are considered by local authorities. All the future emissions will be controlled by supervisors. (Helsingin kaupunki 2023.)

3.3 Denmark

Denmark, as part of EU is following the European rules on LCA assessment of constructions. However, its methodology and certification variety are different from the Finnish ones.

3.3.1 Environmental legislation

The Climate Act of Denmark was signed on 26 June 2020 by the Danish Ministry of Climate, Energy and Utilities. It takes into account the requirement of the Paris Agreement on not exceeding the 1.5°C increase of temperature compared with the pre-industrial levels and sets the target of reducing the total GHG emissions by 70% from 1990 till 2030 as well as reaching carbon neutrality by 2050. (Climate Act 965/2020, 1.)

The environmental legislation of Denmark also includes the National Strategy of Sustainable Construction of April 2021 together with the building regulation BR18 (Masson 2023d). This is one of the most specific plans of limitations for greenhouse gas emissions in the construction sector in the Nordic countries. For the period from 2023 till 2025 the limits are set only for big constructions with area above 1000 m^2, and such buildings cannot exceed 12 kg CO_2 e/m^2/y, while the voluntary value is 8 kg CO_2 e/m^2/y. The voluntary value is applied to all building types and is lowered by 1 kg CO_2 e/m^2/y during every period. Next, starting from 2025 all buildings have not to exceed the same limits, that are 10.5 CO_2 e/m^2/y in 2025-2027, 9 e/m^2/y in 2027-2029 and 7.5 e/m^2/y starting from 2029. In 2027 the norms may be revised. (Ministry of interior and housing 2021, 12-13.) The same strategy suggests the methods for reduction of emissions. There are 21 options. Some of them are the following:

- Cooperation between Nordic countries in terms of sustainability
- Green materials
- Post use materials recycling
- Waste reduction during construction stage
- Development of more accurate material data
- Development of better LCA and LCC (life-cycle cost) methods
- Parking area reduction
- Energy efficiency
- Subsidies for energy savings

Some of these points are common, while others are new and unexpected. (Ministry of interior and housing 2021, 19.) When green materials use and energy efficiency was mentioned even before, cooperation between the Nordic countries and development of materials and buildings life-cycle impacts assessment is new. This may lead to increase of impacts on one side, if new emissions will be discovered, but can also reduce them by better logistics ways, manufacturing places locating and discovery of new possibilities for reduction. Parking area requirements are advised to be reduced in order to promote cars refusal and minimize emissions from exhausts. Energy saving subsidies may give people a will to reduce their use of energy and further emissions for some monetary award.

In addition to legislative limitations, some values are suggested by the institutions. Thus, Sweco and Teknologisk Institut, came up with fixed values for several building structures based on the analysis of the existing buildings and providing the average values. This is made in order to reduce the documentational loading on companies when doing project analysis. They demonstrated the values for drain, water and heating/cooling systems (HVAC).

The result of their studies can be found in Table 3 (Teknologisk Institut & Sweco 2022a, 9; Teknologisk Institut & Sweco 2022b, 12-13).

Table 3. Fixed values for drain, water and HVAC in Denmark

Building type	Drain, kg CO_2 e/m^2/y	Water, kg CO_2 e/m^2/y	HVAC, kg CO_2 e/m^2/y
Single-family houses	0.02	0.06	0.6
Row houses	0.1	0.04	0.51
Apartment buildings	0.12	0.06	0.51
Schools, offices, day care	0.04	0.06	0.84
Other buildings	0.05	0.08	1.09

This data is suitable for most of the building types that are usually assessed. It can be used for LCA reports development but can also be replaced with more accurate and project-oriented numbers if needed.

3.3.2 Certification

Denmark has altogether three local certification platforms for LCA. Some of them are done only for Denmark, and others are adjusted to its requirements, but are originally made by other countries.

Denmark National Building Class or Den frivillige bæredygtighedsklasse is a voluntary certification system, that evaluates the buildings' emissions during 50 years; it includes all stages except for B1-B3, B7 and C1-C4. Currently the program is being tested till the beginning of November 2023, while it was launched in May 2020. (Den frivillige bæredygtighedsklasse, n.d. a; Den frivillige bæredygtighedsklasse, n.d. b.)

DGNB Denmark is originally based on the German system, called Deutsche Gesellschaft für Nachhaltiges Bauen in German, German Sustainable Building

Council in English. It is suitable not only for new constructions but also for renovation projects. The platform analyses the A1-A3, B4, B6, C3-C4 and D stages (DGNB GmbH 2020, 67). The reference period is also 50 years (DGNB GmbH 2020, 79). The Danish version uses the fixed values prepared by the government and the materials data from local databases. The benefit of this system is that it includes the benchmark that awards the projects with different mark dependent on the sustainability level. The grades are bronze, silver, gold and platinum and are based on the number of points gained during assessment for several environmental factors. (RFB, n.d.)

The third LCA certification is Svanurinn. The key requirement for Svanurinn or Nordic Ecolabeling in Denmark is impacting below 8 kg CO_2 e/m^2/y (Ecolabeling 2022, 20) before 2023 and below 10.5 kg CO_2 e/m^2/y after 2023(Ecolabeling 2023, 36). It is a whole Nordics platform and is also evaluating the projects with points. However, it is mostly used and developed in Iceland.

3.4 Iceland

Iceland is not part of EU but is still part of Nordics and it also follows the targets set in the Paris Agreement. In 2019, the total annual emissions came to approximately 360 Mt CO_2 e/m^2/y. The annual emissions are caused by both new and existing constructions. A1-A3 accounts for 45% of all impact, followed by B6 with 30%, B4-B5 with 12%, A5 making up 11% and the rest from A4. (Byggjum grænni framtíð 2022b, 14.) Iceland uses its own methodology on buildings' life-cycle assessment represented in "The act on Environmental Assessment of Projects and Plans" of 2022. According to this document, analysis never includes end-of-life stage, and only covers A1-A3, A4-A5, B4, B5, meanwhile B6 is supplementary. (Byggjum grænni framtíð 2022b, 9.) The average demolition waste is recycled for 83% and 17% are disposed (Byggjum grænni framtíð 2022b, 12).

The same act suggests the targets and limits for construction sector to reach by 2030. First, the emissions from materials have to be reduced by 55% (Byggjum grænni framtíð 2022a, 19). The same reduction is expected for the B4-B6 stage

(Byggjum grænni framtíð 2022a, 38). Transportation and machinery have to be lowered by 70% (Byggjum grænni framtíð 2022a, 29). 95% of the waste will be reused (Byggjum grænni framtíð 2022a, 53) and the total waste production has to fall from 54 kg/m^2 in 2020 to 38 kg/m^2 in 2030 or by 30% (Byggjum grænni framtíð 2022a, 14).

Iceland accepts both BREEAM and Svanurinn. The Svanurinn, that is also known as Nordic Ecolabeling, specifies the calculation period of 50 years but does not require it (Ecolabeling 2023, 14). No limits are set either. The minimum report should include at least A1-A5, B4, B6, C3, C4 and D (Ecolabeling 2022, 20). The analysis is possible for residential, educational and office buildings only. In addition, the certification is done in a similar way as other systems do by giving points for several requirements and setting some minimum level for confirmation. More or less the same general requirements are applied to other Nordic countries using Svanurinn.

3.5 Estonia

Estonian legislative limitations for construction sector are still in progress, but Estonia's 2030 National Energy and Climate Plan or NECP 2030 is already in force since 2019 and being updated during 2023. The aims are to reach the 70% reduction of GHG emissions around the country before 2030 compared with 1990 and 80% (as planned in 2019) (Government of the Republic of Estonia 2019, 8) or even 95% (as for 2023) by 2050 (Government of the Republic of Estonia 2023, 4) and to be fully carbon-neutral by this year. In 1990 the emissions were 40.4 Mt CO_2 e/m^2 so the aim for 2030 is not to exceed the 12.12 Mt CO_2 e/m^2, while the predicted value is 10.7 to 12.5 Mt CO_2 e/m^2. Another plan is to stabilize the energy consumption at today's level of approximately 32.5 TWh and to reach 42% of renewable energy share in 2030 (Government of the Republic of Estonia 2019, 8). The aim of switching to renewable energy was updated in 2023 and states the need to use 100% renewable electricity in 2030. No special limits or reference values are set for constructions. (Government of the Republic of Estonia 2023, 4.)

The certification of the building using LCA is currently voluntary. The most popular and recognized platforms are the international BREEAM, LEED and DGNB (NJORD 2022). However, Estonia's own methodology was created in 2016. It follows the standard EN 15804 and requires the assessment of stages A1-A3, B2-B4, C2-C4 and D (Oviir 2016, 355). The service life can be chosen between 10, 50 and 70 years (Oviir 2016, 353), but 50 is the preferred period for Rohemärgis system, also called the Green Label that was founded in 2015 but is in process of redevelopment since 2022 (NJORD 2022). The system is evaluating the projects according to several aspects, where the building can be graded with A (Best), B (Very good), C (Good) or failed that means inability to certify the project (Oviir 2016, 359).

The Estonian system's development towards sustainability is in progress. In addition, it is very much dependent on foreign studies and systems even for local projects.

3.6 Norway

Norway has created several methodologies and standards for environmental assessment. However, as it is not in European Union and does not follow its declarations, Norwegian policies are mostly based on Paris Agreement and local targets. The target of 40% emissions reduction by 2030 is part of the Agenda 2030, that is in turn a road map of reaching the Sustainable Development Goals (Ministries 2016, 3). Other certain aims for further reductions are not set yet.

3.6.1 Standards

Today Norwegian construction companies may follow two key standards for LCA: TEK17 and NS3720. In addition to them, most of the regions are having some local norms and regulations that are not adopted on the whole country level.

TEK17 is the standard that can be followed when assessing the building's life-cycle in Norway. It was signed on 1st July 2022 and accounts for only the materials used for apartment and commercial buildings. The assessment is limited to stages A1-A3, A4, A5 and B4. The study period is 50 years. The excepted maximum of generic data used for calculations is 25%, that is quite a lot compared to other assessment systems. In addition, both standards with values for biogenic carbon and without it can be used without strict preferences. (Steven 2023.)

In 2018 Standard Norge adopted the Standard NS 3720:2018. In this document the Norwegian methodology of GHG calculation and emission assessment for buildings is presented. It includes more specific building categories compared with TEK 17 and covers 60 years of construction lifetime. This standard also pays special attention to the location of the building and specifically calculates the impacts caused by the transportation to the site. (Masson 2022c.) This resulted in setting a new stage of assessment, B8, that includes the transportation of people and goods during use of construction (Vandervaeren et al. 2022, 2). Thus, the standard requires to fully cover the whole life-cycle of the building and specify the stages A1-A3, A4-A5, B1, B2-B7, B8, C1-C4 and D. In general, NS 3720 follows the rules of the Level(s) system, but also has some differences that cause significant difference in the resulting values. (Vandervaeren et al. 2022, 9.)

Norway is not part of European Union that causes and allows big differences in LCA processed in different places. However, the Norwegian system may be named as improved and widened version of the European one.

3.7 Sweden

Sweden is the country that is planning to become fully carbon neutral by 2045. In order to reach this goal, limits for construction are being developed. However, the first reference values are expected by 2027, which will be also later made stricter in 2035 and 2043. (Boverket 2020, 12.) For the same aim the Regulation on climate declaration for buildings is set. This standard set the 50 years of analysis of the building (Boverket 2020, 14) and by 2027 the assessment must be compulsory for all new projects covering A1-A5, B2, B4, B6 and C1-C4 (Boverket 2020, 44). The today’s aim requires the reduction of emissions from multi-dwelling and single-family houses as well as non-residential constructions by

40% and by 80% from 2027 till 2035 and 2043, respectively. Based on this target the limit values are being made. (Boverket 2020, 16.)

The certification in Sweden is usually done with Svanurinn, BREEAM SE or the local program Noll CO_2. While the other systems set only the minimum scope and period for assessment, Noll CO_2 has a maximum value that cannot be exceeded for certification. The scope includes the whole life-cycle during 50 years and the EPDs have to follow the 15804:2012+A2:2019 standard (SGBC, n. d.). Important is that stages A1-A5 (or the whole production and construction stage) must be below 300 kg CO_2 e/m^2 (Stoll et al. 2019, 5). In addition, transportation and installation cannot be over 55 kg CO_2 e/m^2 (Stoll 2022).

BREEAM SE, that was previously known as CEEQUAL. This system is mostly equal in all countries but can have various background database with localized data. In Sweden, same as in Norway, the assessment includes most of the stages of the building life-cycle (One Click LCA Ltd 2022) and can be done for residential, industrial, retail, educational buildings, as well as offices, hotels and shelters. The key idea of this certification is the grading system for the projects. Its requirements are similar to Finnish RTS-ympäristöluokitus, and it grades the buildings from unclassified to outstanding dependent on the final emissions figures. (SGBC and BRE Global 2023.)

Sweden uses a wide range of assessment tools for LCA. However, only Noll CO_2 is having some real limit values, that are not stated in any other systems.

4 METHODS

The theory part data search is based on already existing reports on similar topics and their references. This way, it is possible to find some results of finished studies as well as legislative base for that. In addition to that, most of the legislations and standards have a list of previous and following documents on the same topic. The main study begins with reports and research search in public access via internet. Then, all the official reports and legislations are found at the authorized websites of the organizations that posted them. Finally, the standards are either found in the Xamk library Kaakkuri databases or bought in the online shop of International Organization of Standardization.

The statistical studies are performed based on the reference data provided by the commissioner. The information is presented in form of an Excel file with projects' and designs' values downloaded from the database of the One Click LCA platform. One Click LCA Ltd. was founded in Finland in 2001 and its platform is widely used there. The most widely used calculation tools for building LCA are Level(s) EU, YM (Ympäristöministeriö), RTS and sometimes BREEAM or LEED. All these systems do not have the same methodology, which may cause significant difference in results made for the same building. One important issue is the building life-cycle period that usually varies from 50 to 60 years in Finland but may also be completely different from the set ones, even though the official methodology YM (Ministry of the Environment) imply 50 years calculation period. In order to prevent the errors, the extracted database has the values calculated always for 60 years. Thus, the buildings can follow a similar scenario and be comparable. Due to security and confidentiality reasons the database itself is not published or directly mentioned in the thesis work. Nevertheless, some general facts about it, as well as change log, are provided. The Excel file has the general information about the designs, as well as GWP for different life-cycle stages and building parts. Global warming potential is calculated based on impacts of materials, works and other resources. This impact is a collection of several impacts from different substances (NOx, SO and other greenhouse gases) represented in CO_2 equivalent and having unit kg CO_2 eq/m2 (kilogram of carbon dioxide equivalent per square meter of the buildings gross internal floor area). For the benchmarks the total GWP of the projects will be used in addition to the manually calculated annual values that are more commonly used in studies and limits of other countries.

4.1 Data filtering

To begin with, the Excel file with the data provided by the company is analysed keeping the initial data properties in mind. As not all of the projects can be considered in the calculation and only one design per construction can be used to avoid emissions calculation for same building several times, the projects and designs are filtered. The first option is the construction type. The renovation projects and new construction, together with unspecified buildings, are moved to separate tables for further analysis, while the rest of the files are deleted. To make sure that all of the projects are managed in the same way, the two files with different construction types (new and renovated ones) are analysed simultaneously and all the changes and reasons for them are logged. According to the specification from One Click LCA Ltd. the application licences named after it should not be considered in the studies except for the ones used commercially. It is also asked not to use the educational licences. This leads to deletion of several designs.

Some of the certifications used in Finland divide the analysis into parts like Mat1, Mat2, and so forth, many projects include the designs analysing only one part of the life-cycle corresponding with the certification part. This is usually mentioned in the design naming. The project name having some signs of building parts is ignored from the deletion process. Next, not all of the projects are used for real analysis process, but are tutorials, testing or study projects. In addition to them, most of the projects include the baseline that is either required by the certification organisation or by the organisation granting the construction permissions. These designs are very different from the real projects and need to show worse emissions compared with the final versions of the project. The names may vary a lot, but the most common ones that are highlighted and later removed from analysis are “baseline”, “base case”, “base building”, “perustaso” and others. Due to issues in the platform, some designs may duplicate within one project representing different version of the same design or the deleted and freshly made option with the same name. In such case, only the ones that were edited recently stay, as they are considered as improved and widened versions of other designs. At this point the naming and non-numerical filtering is finished.

The best and most realistic designs include most of the possible information and construction parts. The projects with too small area may be done wrongly or incorrectly show the results. Thus, all the buildings that have an area below 50 m^2

are deleted. 50 m^2 is the reference value mentioned in the Finnish legislation as the minimum are of considerable construction and not a temporary place. As not all of the national area measuring systems use square meters, another option is square feet that is about 10 times bigger than square meter. For filtering I choose the projects that surely have the GIFA (gross internal floor area) or building area above or equal to 50 m^2 and then manually choose the ones that have GFA (gross floor area) 500 sq. ft or other Finnish area types exceeding these values.

Next, it is considered that all constructions have to include at least 10 materials; if not, they are deleted. However, in some cases the platform may also mark some of the materials number as too low, based on the statistical data used in the helping tool of One Click LCA, even if the value is above 10. Such issues are marked as failed for the point “too few materials”. To avoid other technical errors, constructions with zero or negative total emissions or GWP from production stage are put aside. Some other parts of the constructions, like windows, basement, walls and so on, are crucial for any project. Therefore, the following requirements have to be marked as passed or acceptable and not be equal to 0: vertical structures, horizontal structures, foundation mass and ready-mix concrete, structure mass, too dominate one material, replacements share and concrete, steel or timber frame mass corresponding with the frame type mentioned in the project data. As for windows, they may be mentioned in several positions like windows, glass, PVC windows, wooden framed windows etc, the rows with zeros in all of the options are deleted. The commissioner also asks to avoid projects, in which the embodied carbon credible mass is below 50 or above 2000. After all these filtering options are applied and unnecessary designs are deleted, manual design selection begins.

The final aim of all the selection process is to choose the best projects and to choose only one design per project. For that in every project the designs with higher RIBA stage are chosen. They correspond with the project performance. They begin with RIBA 0 as pre-design, and end with RIBA 7 as use. The higher the stage is, the wider an analysis is performed. However, this question is optional for construction designing and does not surely mean the evaluation fullness. Thus, the highest stages are chosen for each project. After the sample size was minimised, the deletion of extreme values for total global working potential and total mass is considered. For that, all of the values for the terms were moved to another Excel sheet and placed in the ascending order into two columns. With help of formula percentile.incl for percentages 1,5,10, 20, 50, 70, 80, 88, 90, 95 and 100, the reference values were found and presented as a horizontal bar chart. They can be seen in Figure 3 for GWP and Figure 4 for mass. As a result of analysis of significant gaps within values range consistence, the limit value of 200-750 kg CO_2 e/m^2 for emissions and of 350-4500 kg for masses were established and applied to the dataset.

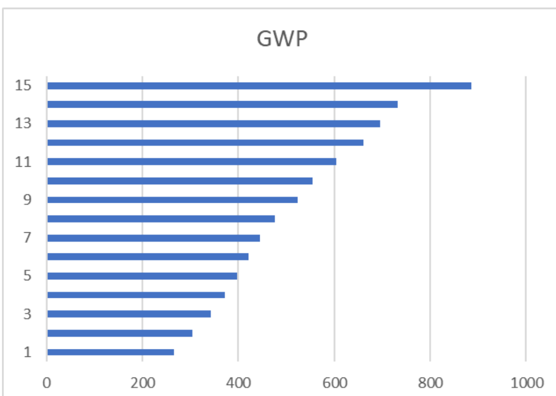

Figure 3. GWP percentile

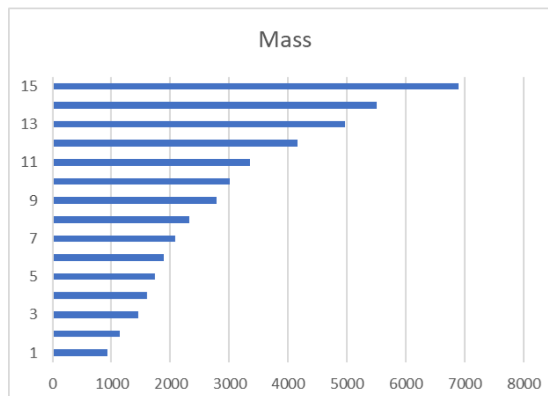

Figure 4. Mass percentile

The closing step of filtering is manual selection of designs. There are several points that are analysed during this process, and they are presented below in the order of importance, from the key ones, to the least significant.

- Naming: some designs are named as the final versions or the design used for the final construction, while others can be named as “not to use” or “failed design”.
- Due to legislative reasons 50 years analysis is preferred in Finland.
- For designs with small difference in total global warming potential (below 20%), the one with the bigger value is chosen.
- In case of big variation within numbers, the mean option is used.
- Last edited is preferred.
- The bigger materials value is considered as better option.

As a result, only the most indicative constructions are left for benchmark creation. The changes in designs number are presented in the Changes log in Appendix 1.

4.2 Benchmarking

When all the designs are sorted the benchmarking starts. For that, in a separate sheet or file, the columns with special naming (detecting the building type, location, included stages and sample size) are made. The data is also exported in two forms, one including the total values for the whole life-cycle of the building (60 years) that is used for all benchmarks, and as an annual GWP for the total emissions values only, as only the total GWP can be considered equal for every year, while other LCA stages are time specific. The division by 60 is performed automatically using Excel formula. The classification is also made for different options that are building type, all stages of LCA or just one significant stage, and new construction or renovation project. The overall idea is to create limit values for each class A to F and mark everything that is beyond those limits as G class. The planned distribution of analysed projects should be approximately equal to the one presented in Table 3. However, it is not possible to reach such exactness with manual analysis and considering the requirements that are set for the reference values.

Table 3. Benchmark stages and distribution

Stage	Value
A	≤15%
B	≤20%
C	≤20%
D	≤20%
E	≥0%
F	≥0%
G	≥0%

All the stages should have the stated volume of projects from the whole sample size. The values are not recommended to be exceeded, but maybe be lower. Another rule for setting the benchmark is that the step between each class's maximum has to be equal. In addition, due to convenience and aesthetic reasons there is also a requirement to have all the limits divisible by 5 or, preferably, by

10, to the values that are easy to read and understand. Nevertheless, this rule is not applied to the benchmarks that have smaller values in general, like GWP for A4 or C1-C4. For these cases it is advisable to have the values and steps between them in form of integer, but one figure after period is also possible. To comply with all those requirements the stages' contents percentages may be different from the set in Table 1, but not significantly. This is particularly often possible for small samples. Another aim that is reached is to make such limit values for classes that the samples included into stages B-F made up not less than 75% and not more than 90% of all projects. To make such values, the Excel file is filled in with special formulas and the data for analysis is added into set cells in ascending order. The final values are then analysed. Some other results of the analysis also include the sample sizes, mean values for each impact type, limits for the best 10% and the worst 75% and 90% projects emissions as other possible limitation type without classification that is often used in other regions. The other properties of the designs, like year, certification or distribution of frame type use within the market are assessed using Pivot tables in Excel.

The final results and side information is presented in the next section together with prior results analysis and suggestions on the use of the data. These ideas may be used not only by the commissioner, but also by other parties for further studies or application in real life.

5 RESULTS

The data filtering significantly decreased the sample size. However, the analysis resulted in a wide range of various information and conclusions.

5.1 Database properties

Initial database included 15,121 rows of data with 3,813 projects including 4 designs on average. At the end there are 1,797 designs and projects, where 1,736 are new constructions and only 61 renovations. The overall decrease in data makes up more than 88%, while the projects deletion is about 53%. In other words, the majority of all presented designs are either construction option that are often made for options variety during certification or the unreliable designs not suitable for use.

The database does not include most of the private information about the designs. However, data about the project's year, frame type and certification is available. Everything from this list, except for year, are the voluntary questions in the project description form, so not all of the options that were chosen by the architects can be considered as fully reliable.

5.2 Projects properties

New construction projects cover a wide range of building types as seen in Figure 5. Most of them are made for apartment buildings, followed by one-dwelling houses that include winter cottages, which are extremely popular in Finland. Other often assessed buildings are primary schools, offices, day care facilities, attached houses and other educational buildings. Due to the lack of data, not all of the building types are analysed for benchmark, but the key ones are.

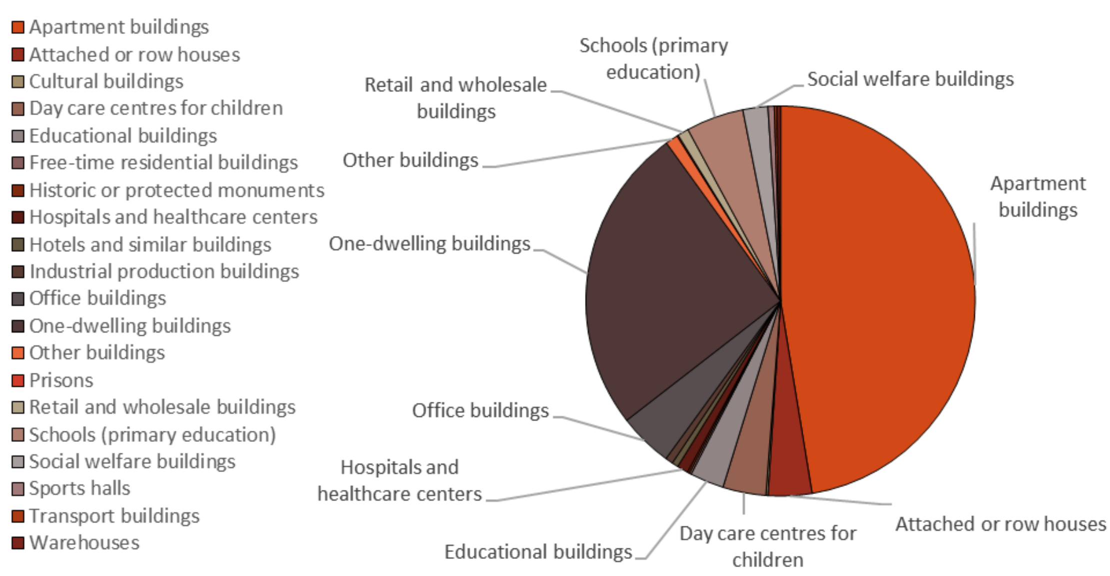

Figure 5. Building types. New construction

Renovation projects are not as spread as the new constructions or are not assessed in many cases. There are just 61 projects and among them apartment and office buildings are the most often analysed. Some other renovated buildings are primary schools, other educational buildings and buildings without specific type.

Figures 6 and 7 represent the projects distribution within year from 2019 till 2023 for new constructions and renovations respectively. As the database was downloaded in May 2023, it is possible that some new projects are not included in it. Nevertheless, the designs for Finnish constructions were first added to the platform that is currently used just in 2019 and there were only a few projects then. Most of the constructions were analysed in 2022 for both types, followed by 2021.

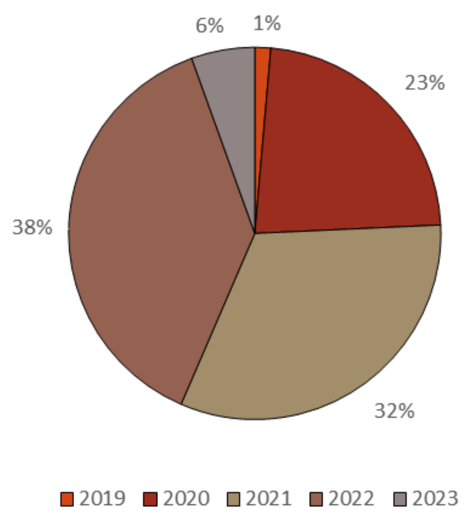

Figure 6. Year. New construction

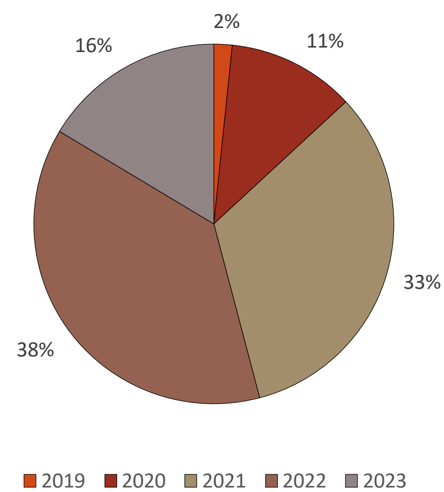

Figure 7. Year. Renovation

The frame type options are not similarly distributed within different construction types as years (see Figure 8 and 9). For new constructions, frame type is not specified for most of the projects. Despite that the rest of the buildings are usually made from concrete, followed by steel, other materials and timber. The renovations usually have an existing frame that is logical for such process. Other materials are rated in such order: not determined, concrete, other and timber in the same proportion and the least used one is steel. This can be dependent on the building technologies that used the easily produced material more often before, while steel production was less cost efficient.

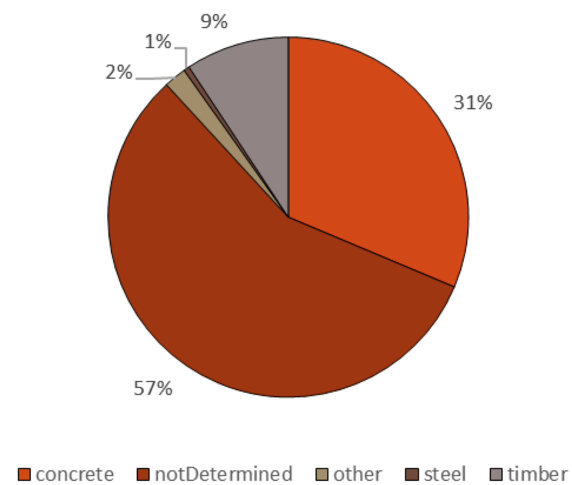

Figure 8. Frame type. New construction

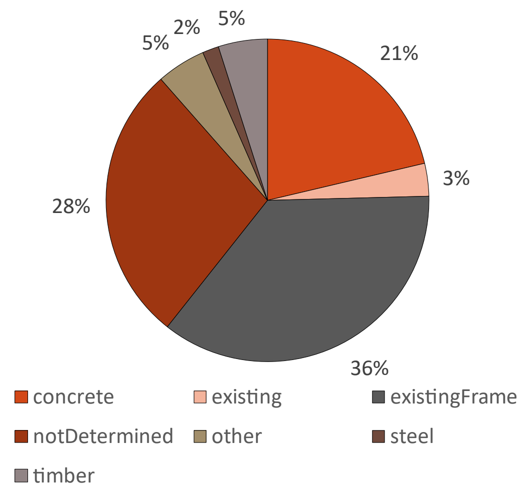

Figure 9. Frame type. Renovation

The certification systems that are planned to be used for the projects are presented in Figure 10 and 11. If not to consider the datapoints that lack certification type for a building, the projects are usually planned for evaluation under the Finnish systems Ympäristöministeriö and Green Building Council Finland that was used only a few times for new constructions. Various versions of BREEAM were the next preference, followed by European Level(s) and LEED. Some new constructions are also prepared for Norwegian NS 3720 assessment.

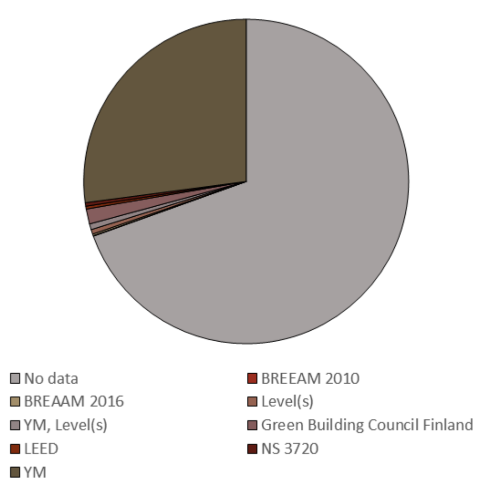

Figure 10. Certification. New construction

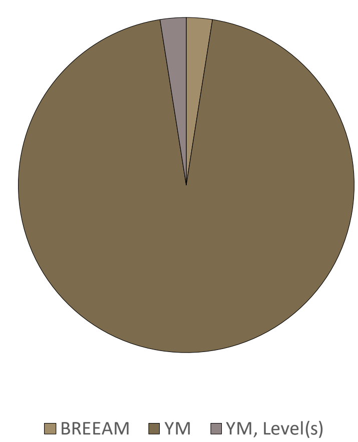

Figure 11. Certification. Renovation

5.3 Benchmarks and limits

The benchmarks are made for total GWP and for GWP of some stages. The whole service life GWP benchmark is also prepared for the annual emissions. The whole tables with calculations, formulas and all benchmark values can be found in Appendix 2.

The annual values are quite small as they are the result of dividing the total value by 60. That is why these values are not integers and are not expected to form perfectly looking benchmarks with readable boundaries. Thus, many limit and reference values are so small and usually rounded only to the one figure after period.

5.3.1 Whole life-cycle

In Table 4 the benchmark for annual global warming potential of new constructions is presented. Due to the small size of sample only some building types were analysed: apartment buildings, attached or row houses, day care and educational buildings, hospitals, primary schools, industrial, office, one-dwelling, retail, social welfare and other buildings. According to the table schools and day care facilities are expected to have better properties compared with others, when assigned to the A class. In general, the best project of any or unspecified type should have the GWP at 5 kg CO_2 e/m^2/y or less, while the results above 9.8 e/m^2/y may be considered as bad performance and invalid design.

Table 4. Reference values for annual total GWP (kg CO2 e/m^2/y). New construction

Stage	All construction types	Apartment buildings	Attached or row	Day care	Educational buildings	Hospitals	Industrial	Office buildings	One-dwelling buildings	Other	Retail	School	Social welfare

A	5	5.5	5	4.2	5.3	6	5	4.5	5.3	5.5	6	4.3	5.1
B	5.8	6.2	5.7	5.4	6.4	6.8	5.8	5.8	5.9	6.6	6.8	5.5	6.3
C	6.6	6.9	6.4	6.6	7.5	7.6	6.6	7.1	6.5	7.7	7.6	6.7	7.5
D	7.4	7.6	7.1	7.8	8.6	8.4	7.4	8.4	7.1	8.8	8.4	7.9	8.7
E	8.2	8.3	7.8	9	9.7	9.2	8.2	9.7	7.7	9.9	9.2	9.1	9.9
F	9	9	8.5	10.2	10.8	10	9	11	8.3	11	10	10.3	11.1
G	9.8	9.7	9.2	11.4	11.9	10.8	9.8	12.3	8.9	12.1	10.8	11.5	12.3

The reference values for renovation are presented in Table 5. Due to lack of data and small values in general, the analysis is done only for all building types. The emissions from renovation processes are expected to be lower than for a new building. However, the impact decrease is not linear and can vary from very low to the level that is similar to new construction GWP. In such cases the conclusion may be that it is more efficient to build a new house than to renovate the existing one.

Table 5. Reference values for annual GWP (kg CO2 e/m^2/y). Renovation

Stage	All
A	1.4
B	2.5
C	3.6
D	4.7
E	5.8
F	6.9
G	8

In addition to benchmarks, the limits can be set based on some intermediate values. To calculate the limits two borders are used: one is the minimum limitation when 90% of all projects are accepted and another is a stricter limit declining about 25% of the projects that are not efficient enough. Such limits suggestion can be found in Table 6 that states that the maximum GWP for not failed buildings have to be below 540 kg CO_2 e/m^2 or even 463 kg CO_2 e/m^2 as the best option. Annual limits for all buildings may vary from 9 to 7.7 kg CO_2 e/m^2/y.

Table 6. Limit values 75% and 90%. New construction

Limit level	All	Apartment buildings	Attached or row	Day care	Educational buildings	Hospitals	Industrial	Office buildings	One-dwelling buildings	Other	Retail	School	Social welfare
Limits for total building GWP (kg CO2 e/m^2) (whole life-cycle)													
75%	463	468	434	460	485	532	475	501	413	615	483	488	543
90%	540	534	521	562	602	588	495	662	472	659	588	580	607
Limits for annual GWP (kg CO2 e/m^2/y)													
75%	7.7	7.8	7.2	7.7	8.1	8.9	7.9	8.4	6.9	10.2	8.1	8.1	9.1
90%	9.0	8.9	8.7	9.4	10	9.8	8.2	11	7.9	11	9.8	9.7	10.1

Renovations limits are not as specific and as type oriented as the ones for new buildings. However, the total emissions boundary is available for all building types, as well as offices and apartments, while the annual limit is unified for all buildings only. All the limits can be found in Table 7 below. The limits are significantly lower for reconstruction compared with new structures. In addition, the comparison of benchmark values with limit values shows that to comply with the stated maximum levels a project has to be classified at least as E group. F and G class designs may be failed under application of the stated limits. This is also relevant for other benchmarks and limits for all building and construction types.

Table 7. Limit values 75% and 90% (kg CO2 e/m^2). Renovation

Type	All	Office building	Apartment building	All
Period	Total	Total	Total	Annual
75%	291	223	240	4.9
90%	319	320	266	5.3

5.3.2 Per life-cycle stage

The first life-cycle stage that is available for analysis is the product stage or A1-A3. As seen from both the initial database together with the benchmarks from Table 8, product stage makes up the majority of whole building's emissions. Moreover, it was noticed that there's no clear dependence of the total GWP volume on the emissions produced at the first stages. In other words, the building with higher total impact does not always have the highest GWP at the product stage and vice versa. The reference values for G stage maximum are just the reference values that were applicable for the analysed sample as in real use the G group can contain all of the projects whose global warming potential level is above the maximum limit for F class. For A1-A3 stages of a new construction the total GWP cannot exceed 409 kg CO_2 e/m^2 with weaker limitations and 349 kg CO_2 e/m^2 for more critical issues. However, for one-dwelling buildings stronger limits can be taken into account.

Table 8. Stage A1-A3 benchmark and limits (kg CO2 e/m^2). New construction

Stage/limit	All	Apartment buildings	Attached or row	Day care	Educational buildings	Hospitals	Industrial	Office buildings	One-dwelling buildings	Other	Retail	School	Social welfare
A	200	240	200	170	205	250	250	190	200	230	240	180	210
B	245	280	235	220	255	290	275	260	230	285	280	240	260
C	290	320	270	270	305	330	300	330	260	340	320	300	310
D	335	360	305	320	355	370	325	400	290	395	360	360	360
E	380	400	340	370	405	410	350	470	320	450	400	420	410
F	425	440	375	420	455	450	375	540	350	505	440	480	460
G	470	480	410	470	505	490	400	610	380	560	480	540	510

75%	349	368	310	329	356	361	347	398	267	435	340	365	381
90%	409	414	354	403	416	410	359	471	336	503	417	416	413

Product stage of the renovation projects in general acts in the same way as the one of new constructions: it emits the majority of gases for the whole lifetime of the construction and is not in direct response with total GWP. The values for the renovations are typically smaller than the ones for the new projects, and that is why the reference values and steps between them do not have to be divisible by 5 or 10 (see Table 9). However, the numbers still have to be integers. The best projects need to have the GWP for A1-A3 below 40 kg CO_2 e/m^2. Nevertheless, the limit values are very strict, only the designs from classes C or higher may be accepted. This is mainly because the renovation projects' emissions are very uneven and the reconstruction volume may vary a lot from little interior and HVAC (heating, ventilation and air conditioning) systems replacement to the total renovation including vertical and horizontal load-carrying structures. Thus, the majority of the impacts from the projects are low, but in some cases, they may exceed all existing limits and still be more sustainable than a new construction.

Table 9. Stage A1-A3 benchmark and limits (kg CO2 e/m^2). Renovation

Stage/ limit	All	Office building	Apartment building	All	All	Office building	Apartment building
Period	A1-A3	A1-A3	A1-A3	A4	C1-C4	C1-C4	C1-C4
A	40	19	55	0.05	1.4	2.5	0.5
B	88	63	90	0.85	4.7	18	2
C	136	107	125	1.65	8	33.5	3.5
D	184	151	160	2.45	11.3	49	5
E	232	195	195	3.25	14.6	64.5	6.5
F	280	239	230	4.05	17.9	80	8
G	328	283	265	4.85	21.2	95.5	9.5
75%	156	137	151	1	9	9	6
90%	179	169	175	4	18	24	8

Stage A4 or transportation processes are the hardest part of the life-cycle to be benchmarked or evaluated. First, it is not compulsory for assessment in most of the certification systems in the Nordics and also in Finland some fixed values are set and can be used. Thus, the number of designs that include this data is minimum. Most of the buildings have 0 kg CO_2 e/m^2 for transportation. The proportion of designs with and without A4 is very different, for example only 34% of reconstructions include information about this process, while for new constructions this value goes from 63% for industrial buildings to only 1.5% for attached houses. The one-dwelling, attached, and social welfare houses are the least analysed building types for this issue. Lack of data results in majority of zeroes in the analysed range and prevents proper assessment. As a solution, only the projects with positive values were included into analysis that significantly decreased the accuracy and the sample size resulting in less benchmark and limit variety. The results of the calculations can be found in Table 9 and 10 for reconstructions and new buildings respectively. The limit for new construction is set at 14.1 kg CO_2 e/m^2 and 11.5 kg CO_2 e/m^2 as a voluntary option. For renovations this range is 4 kg CO_2 e/m^2 to1 kg CO_2 e/m^2. As a possible option of setting a fixed values for transportation, the mean values for all building types may be used. For existing buildings, it amounts to 1 kg CO_2 e/m^2, while for new houses it can be 8.1 kg CO_2 e/m^2.

Table 10. Stage A4 limits (kg CO2 e/m^2). New construction

Limit level	**All**	**Apartment buildings**	**Educational buildings**	**Office buildings**	**One-dwelling buildings**	**School**
75%	11.5	12.1	9.9	9.0	6.6	10.3
90%	14.1	15.0	13.4	13.3	7.8	13.2

The last benchmarked stage is C1-C4. This stage is also not always included into LCA, but it is available in 87% of cases. To avoid issues caused by large amount of data insufficiency, end-of-life stage was analysed in the similar way as A4. However, due to better data presence, the sample size was bigger and only a few benchmarks were considered as invalid and deleted from resulting tables that can be found in Table 9 for renovation and Table 11 for new constructions. This part of the analysis is also not always compulsory or may be done not fully and exclude, for example, stage C4. Thus, the values are very poorly distributed within the range and caused unreliability of benchmarks for old apartments and offices. This means that for renovation projects the unified limits are preferred, while the building specific ones should be used with awareness of possible errors. For renovation, the distribution is so uneven that the higher limit of 18 kg CO_2 e/m^2 corresponds with class F and even G in some better cases, while the stricter limit allows only the projects that have end-of-life global warming potential below 9 kg CO_2 e/m^2 and are classified as A, B or C stage. For new constructions the limits are expectedly higher at 31.4 kg CO_2 e/m^2 or 24.8 kg CO_2 e/m^2 and the hospitals are expected to be the most eco-efficient buildings.

Table 11. Stage C1-C4 benchmark and limits (kg CO2 e/m^2). New construction

Stage/limit	All	Apartment buildings	Attached or row	Day care	Educational buildings	Hospitals	Office buildings	One-dwelling buildings	Other	Retail	School	Social welfare
A	13	10.5	16.5	14	14	11.6	11	16.5	12.7	14	16.5	16
B	17	14.6	20.2	18.8	17.2	13.6	15	20.5	18.4	19.2	19.9	19.4
C	21	18.7	23.9	23.6	20.4	15.6	19	24.5	24.1	24.4	23.3	22.8
D	25	22.8	27.6	28.4	23.6	17.6	23	28.5	29.8	29.6	26.7	26.2
E	29	26.9	31.3	33.2	26.8	19.6	27	32.5	35.5	34.8	30.1	29.6
F	33	31	35	38	30	21.6	31	36.5	41.2	40	33.5	33
G	37	35.1	38.7	42.8	33.2	23.6	35	40.5	46.9	45.2	36.9	36.4
75%	24.8	23.2	27.3	27.3	24.5	16.6	23.1	27.9	25.5	30.3	26.2	25.3
90%	31.4	26.0	35.1	38.6	31.6	18.0	28.1	34.5	33.6	39.8	33.7	38.5

The life-cycle stages include also other periods of the buildings’ service life. The A5 stage is assessed extremely rarely, while the use stage is not properly standardised and is not exported from the database of OneClick LCA. Buildings’ benefits beyond system boundaries cannot be analysed yet, due to complete absence of data.

6 ANALYSIS OF RESULTS

The results of the study consist of large amount of background information and numerical data. Nevertheless, this does not allow to fully avoid errors in calculations and requires taking them into account during future use in any further studies or implementations. This is also important during the comparison of the current study results comparison with previous studies or information provided by other countries.

6.1 Data comparison

The comparison of the results with the current situation in construction sphere in other Nordic countries has shown a significant difference in the overall assessment status. First, many projects are not specifically aimed for third party certification and often use only the local method of sustainability evaluation, not the international one. This leads to some possible variation in the assessment scope and rules. The existing benchmarks for total GWP prepared by One Click LCA earlier are confidential and not available for comparison. Meanwhile, the limit values suggested by previous studies at One Click LCA Ltd. differ from my results in all points. The table with comparison of existing limits previously prepared by the commissioner (blue font) and my suggestions (black font) can be found below in Table 12. From this table it is seen that in general the new limits are much stricter both for annual and for the total values. However, the total limits values for offices and commercial buildings turn out to be less narrow in my suggestion, compared with the previous study of One Click LCA Ltd. The assessment of difference is very limited due to difference in the calculation methodology. Thus, in my case all of the emissions from particular stages included the total value and not the annual, while the other study used the annual emissions. In addition, the building type or categories are not exactly similar, and the content of these categories may vary. Finally, the previous study is based on very limited database that was collected earlier.

Table 12. Limits comparison (Finland) (Blue: previous study suggestion, black: my suggestion)

Type	Apartments	Residential	Hospital	Service	Educational	Educational	Office	Office	Retail	Commercial
Total annual, kg CO_2 e/m^2/y	8.9	13	9.8	15.5	10	13	11	11.5	9.8	11.5
Total, kg CO_2 e/m^2	534	650	588	775	602	650	662	575	588	575

The other countries included in the list of Northern countries are usually making the limits without specification for different building type, so they are always very general.

Global warming potential limitations stated in the legislation are available only in Denmark and in Sweden as part of national certification system. Danish limits are not as severe as suggested for Finland, but the maximum values for emissions are prepared for several period and get lower over time there. The limits suggested by me are more alike with the ones that are planned for the period 2027-2029 (marked with green in Table 13) in Denmark, at least for compulsory limits type. Nevertheless, the voluntary limits in Denmark are mostly stricter than the possible ones in Finland. The comparison can be found in Table 13.

Table 13. GWP limits in Finland and Denmark (kg CO_2 e/m^2/y)

Limit type	**Finland (now)**	Denmark			
		2023-2025	2025-2027	2027-2029	2029-2031
Compulsory (90%)	**9**	12	10.5	9	7.5
Voluntary (75%)	**7.7**	8	7	6	5

As for Swedish certification, the limitations there always include the A5 stage that is the installation process, while the database used in my work does not have data on this stage. However, their limits seem to be significantly milder which may mean the total gentleness of certification in Sweden. Other possible reason for that may be the difference in assessment or building technologies that result in higher total emissions. All of this data is compared for the new constructions, while the limits or benchmarks for renovations are not available in any of the assessed countries.

6.2 Discussion

Initially, the results of the studies are prepared for the use of One Click LCA. However, some side conclusions or limit values can be useful for other parties too. The values are also important for understanding the whole situation on the construction market and identification of points for improvement. The information is also important for comparison with the data from other Nordic countries.

The first aim of this work was to create the benchmarks for constructions that are located in Finland and this idea is supported by the current work on the environmental limits for buildings that are currently being created by Finnish Ministry of the Environment. Either the benchmarks or the two limiting options can be used during the legislation elaboration. In addition, the mean values for stage A4 can be seen as possible fixed values for methodology update. Finally, the overall database analysis including the number of the projects, their certifications, year of edition or other information can be used as an overview of the current situation with LCA making for construction sphere.

One Click LCA Ltd. has created this thesis application for possible development of stage specific benchmarks for their main market: Finland. This may allow to improve the appreciation of their platform and gain new users due to help in identifying the parts of the design that can be improved. As part of the thesis the visual representation of data use is prepared. This is not the main part of the study but may be important for the future implementation of the results. All of the presentation options are prepared on my own are not sourced from any third-party resource. The data helps to classify the project in general and its stages according to the classes that correspond with the efficiency of the building. The example of the representation model that is currently widely used can be found in Figure 12. For comparison, the pyramid-like chart is presented in Figure 13.

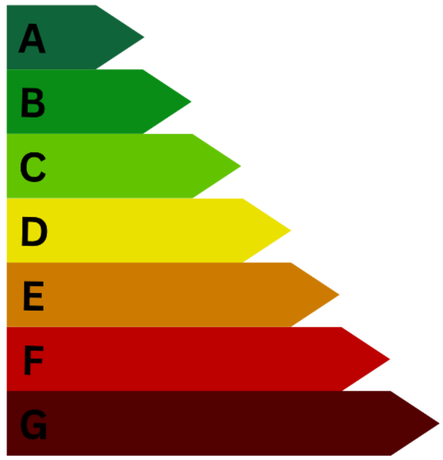

Figure 12. A chart of eco efficiency (common)

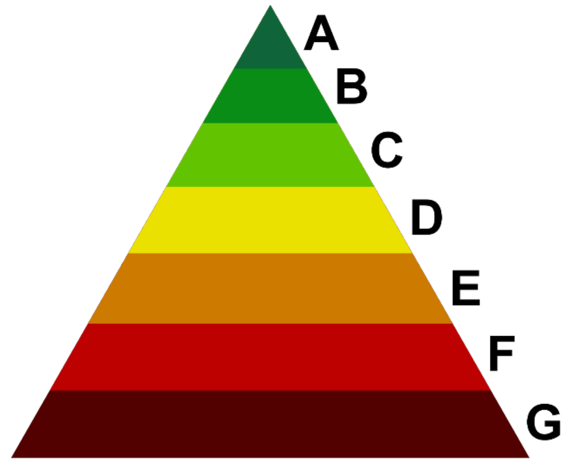

Figure 13. A chart of eco efficiency (pyramid)

As more comprehensive version of the pyramid chart the class detector can be made as seen in Figure 14 and 15. In this case the building by the pyramid represents the general view of the construction of the chosen building type, while its height and colour corresponds with the class that is awarded to the project. For example, Figure 14 is suitable for an office building of A class, while Figure 15 shows the one-dwelling house that gained G class.

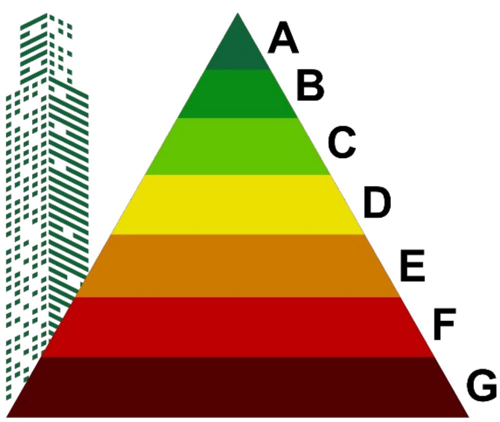

Figure 14. Pyramid chart for A class

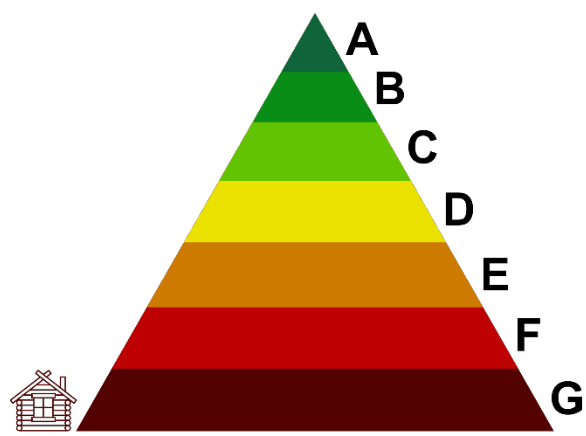

Figure 15. Pyramid chart for G class

Another option is linear chart as shown in Figure 16. It has a triangle indicator that is coloured in the same colour as the awarded class. This version is not as visually beautiful as the previous ones but is clearer and more understandable for the user. All of these designs can be the visual representation of the projects classification that is based on the reference values prepared in this study.

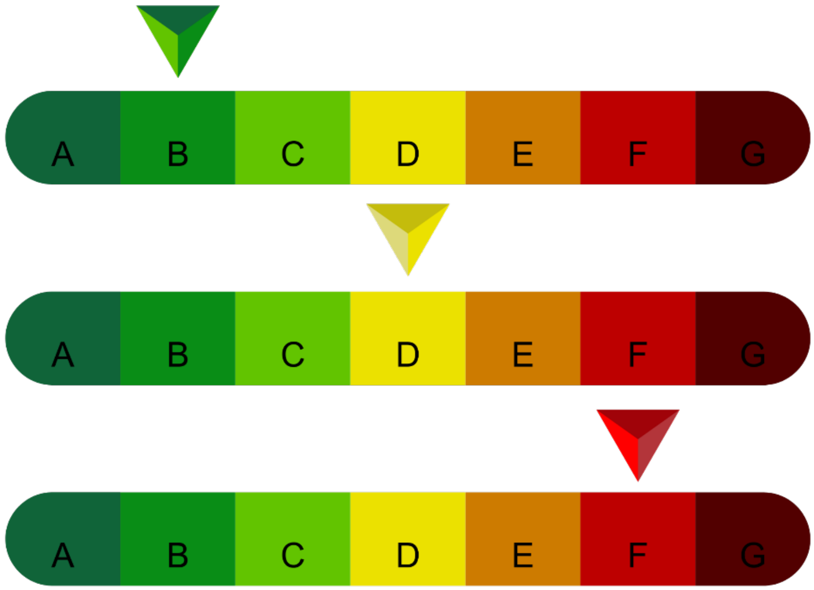

Figure 16. Linear chart

In addition to limiting the emissions of the building projects some tips on how to decrease the total GWP suggested by different agencies of the Nordic countries were collected and can be found below.

- Timber frame use and possibility of heating with wood pellets,
- Heating using biofuel (no oil, coal or natural gas use),
- Renewable electricity,
- Maximisation of waste recycling after demolition,
- Minimisation of transportation distances for both materials during construction phase and waste during end-of-life,
- Energy and heat efficiency increase,
- Maximization of use of recycled materials,
- Use of heat pump (still has some pros and cons),
- Not centralized heating (building specific heat),
- Energy production in the building (e.g., solar panels).

All these points may help to comply with legal requirements for new and existing constructions. However, the LCA quality should be also improved and should cover more stages with better standard methodology of evaluation. This may require more labour and increase the total values, but it can also help to identify the critical points for emissions reduction.

6.3 Errors

Errors is the issue that can ruin any study or work if they are not taken into account during calculations or as a separate notice. This research is done primary manually, so mistakes may exist.

To begin with, the initial data cannot be taken as perfect as it is based on the input data from the users who can be people who are not trained to use the platform. It is expected that the calculations performed by platform are right. However, the fullness and correctness of initial information as well as proper use of software cannot be guaranteed. In addition, the difference in the methodology may cause errors. The various certification systems, as well as legislative or companies' own requirements vary. The projects include different assumed data, cover not the same stages, and have differences in buildings' service life. The mistakes can be also intensified by possible errors in data download or conversion.

The errors occur not only in the data collection step, but also during data analysis. Choosing the right designs for reliable analysis is partly subjective task. This is caused by inability to fully and clearly identify the right options for filtering and reasons for that, while some projects can be good with existing filters, but have other significant gaps in data in other issues and vice versa for the projects deleted during the sorting process. The same problem is the issue during manual selection one design per project. It is hard to identify which option is more real or better done, and this is caused by lack of side information about the projects and use of several languages from projects naming, so initially wrong designs with corresponding named just cannot be found.

Benchmarks cannot be evaluated as fully reliable either. First of all, benchmark setting is done by hand and is approximate; no exact formulas are applied to the final reference values. However, this does not apply to limit values that are created by calculation. Nevertheless, all of the sample values were rounded either to get an integer or to have only one decimal. This limits the variety of total

GWP and future benchmarks. It is also important to mention that excluding zeroes from analysis for some stages could cause inaccuracy. Finally, the specific benchmarks and limits are not available for some building types, which required the use of general values and accepting some possible assumption of not fully complying with the requirements.

All these errors cannot be assessed mathematically, but still can be taken into account during data use. This may also cause an extra need for further studies for the commissioner.

7 CONCLUSION

The development of the benchmarks for environmental assessment of the construction projects is a particularly important part of world development towards circular economy and emissions reduction. The benchmarks allow to classify the projects based on their sustainability, while the stage specific classification highlights the possible building life-cycle stages for improvement.

Limitations are extremely important for compliance with the Paris Agreement for all the countries that signed the document. Thus, the developed limits can be used for setting the legislation aimed for promoting the sustainability in construction sphere.

So, what are the most suitable environmental limitations and classification for building projects in Finland? The limits are such that the buildings' schemas with the best qualities have to emit not more than 5 kg CO_2 e/m^2/y, in such cases the constructions can be classified as class A. The projects whose impacts exceed 9 kg CO_2 e/m^2/y cannot be accepted for further processing as they are classified as class G, the most not eco-friendly buildings' group and as they are included in the 10% of all projects that exceed the upper boundary of sustainability in construction sector.

The study is based on the data obtained from the real projects performed in Finland using One Click LCA platform and stored in its database. The reliability and fullness of data is considered during analysis as well as the possible errors in the process of data assessment. The results and suggestions for development of the currently existing terms is explained and presented together with the options for visual data representation.

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Table 14. Change log

Initial sample size: 15121 Initial number of projects: 3813		
Deletion reason	Deleted	Left
Non new constructions	1262	13859
Licence type	2879	10980
MAT01 designs	29	10951
Test, reference, trial etc. projects	469	10482
Test, reference, trial etc. design	130	10352
Baseline	87	10265
Total or A1-A3 GWP equal or below 0	26	10239
Dataset or “too few materials below 10 or failed	1641	8598
Area below 50 m^2	20	8578
Duplicates within project	3	8575
Other naming issues	393	8182
Too dominate material failed	306	7876
Vertical structures failed	339	7537
Horizontal structures failed	127	7410
Ready mix mass	446	6964

Foundation mass	1173	5791
Replacement share	279	5512
Embodied carbon limit 50-2000 kg CO_2 e/m^2	11	5501
No windows	26	5475
Existing frame	6	5469
Failed concrete/steel/timber frame	171	5298
Higher RIBA stage	521	4777
Total GWP limits	80	4697
Mass limit	152	4545
One design per project	2809	1736
Non renovations	14464	657
Licence type	29	628
MAT01 designs	6	622
Test, reference, trial etc. projects	5	617
Test, reference, trial etc. design	7	610
Baseline	4	606
Total or A1-A3 GWP equal or below 0	10	596
Dataset or “too few materials below 10 or failed	179	417
Area below 50 m^2	4	413

Duplicates within project	-	413
Other naming issues	84	329
Too dominate material failed	20	309
Vertical structures failed	8	301
Horizontal structures failed	5	296
Ready mix mass	-	296
Foundation mass	-	296
Replacement share	-	296
Embodied carbon limit 50-2000 kg CO_2 e/m^2	-	296
No windows	11	285
Existing frame	Not applicable	285
Higher RIBA stage	11	274
Total GWP limits	3	271
Mass limit	94	177
One design per project	116	61
Total sample size: 1797 New constructions: 1736 Renovations: 61 Total deleted: 13324		

Appendix 2

Table 15. New construction benchmarks. Total GWP. Part 1

	MIN	minimum value	116	155	189	210	187
	MAX	maximum value	743	739	664	701	698
	Best 10%	**"=PERCENTILE.INC(C37:C2001;0,1)"**	**301**	**314**	**296**	**245**	**295**
	Mean	**"=AVERAGE(C37:C777)"**	**410**	**398**	**389**	**395**	**433**
	Limit 75%	**"=PERCENTILE.INC(C37:C2001;0,75)"**	**463**	**468**	**434**	**460**	**485**
	Limit 90%	**"=PERCENTILE.INC(C37:C2001;0,9)"**	**540**	**534**	**521**	**562**	**602**
	Country	**Country**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**
	Type	**Type**	**All**	**Apartment buildings**	**Attached or row**	**Day care**	**Educational buildings**
	Stage	**Stage**	**Total**	**Total**	**Total**	**Total**	**Total**
	COUNT	**Sample size**	**1734**	**823**	**63**	**62**	**49**
	Start	**A max limit**	**300**	**325**	**305**	**250**	**300**
	End	**F max value**	**550**	**550**	**505**	**550**	**625**
	Step	"=ROUND((C16-C15)/5;0)"	50	45	40	60	65
15%	**A %**	"=COUNTIFS(C$37:C$2005;"<"&C29)/C$13"	10%	12%	14%	11%	12%
20%	**B %**	"=COUNTIFS(C$37:C$2005;">"&C29;C$37:C$2005;"<"&C30)/C$13"	18%	19%	22%	16%	18%
20%	**C %**	"=COUNTIFS(C$37:C$2005;">"&C30;C$37:C$2005;"<"&C31)/C$13"	24%	21%	16%	19%	20%
20%	**D %**	"=COUNTIFS(C$37:C$2005;">"&C31;C$37:C$2005;"<"&C32)/C$13"	19%	19%	21%	16%	27%
20%	**E %**	"=COUNTIFS(C$37:C$2005;">"&C32;C$37:C$2005;"<"&C33)/C$13"	13%	14%	8%	13%	10%
20%	**F %**	"=COUNTIFS(C$37:C$2005;">"&C33;C$37:C$2005;"<"&C34)/C$13"	7%	6%	8%	11%	6%
15%	**G %**	"=COUNTIFS(C$37:C$2005;">"&C34)/C$13"	9%	8%	11%	13%	6%
		"=SUM(C19:C25)"	*100%*	*100%*	*100%*	*100%*	*100%*
	In B-F	**"=SUM(C20:C24)"**	**81%**	**79%**	**75%**	**76%**	**82%**
	A max	"=C15"	300	325	305	250	300
	B max	"=C29+C$17"	350	370	345	310	365
	C max	"=C30+C$17"	400	415	385	370	430
	D max	"=C31+C$17"	450	460	425	430	495
	E max	"=C32+C$17"	500	505	465	490	560
	F max	"=C33+C$17"	550	550	505	550	625
	G max	"=C34+C17"	600	595	545	610	690

Table 16. New construction benchmarks. Total GWP. Part 2

MIN	291	275	159	116	201	209	169	264
MAX	621	566	732	729	676	632	743	722
Best 10%	**344**	**311**	**260**	**306**	**327**	**358**	**249**	**304**
Mean	**455**	**405**	**427**	**383**	**483**	**443**	**404**	**442**
Limit 75%	**532**	**475**	**501**	**413**	**615**	**483**	**488**	**543**
Limit 90%	**588**	**495**	**662**	**472**	**659**	**588**	**580**	**607**
Country	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**
Type	**Hospitals**	**Industrial**	**Office buildings**	**One-dwelling buildings**	**Other**	**Retail**	**School**	**Social welfare**
Stage	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**
COUNT	**16**	**11**	**78**	**443**	**18**	**16**	**83**	**36**
Start	**355**	**300**	**275**	**315**	**350**	**350**	**260**	**310**
End	**630**	**550**	**675**	**465**	**675**	**600**	**620**	**660**
Step	55	50	80	30	65	50	72	70
A %	13%	9%	13%	13%	11%	13%	14%	14%
B %	25%	27%	23%	16%	28%	25%	16%	25%
C %	19%	9%	19%	24%	11%	19%	25%	11%
D %	13%	18%	22%	17%	11%	19%	17%	22%
E %	19%	27%	8%	11%	11%	6%	14%	14%
F %	13%	0%	6%	7%	22%	6%	8%	8%
G %	0%	9%	9%	12%	6%	13%	5%	6%
	100%	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
In B-F	**88%**	**82%**	**78%**	**75%**	**83%**	**75%**	**81%**	**81%**
A max	355	300	275	315	350	350	260	310
B max	410	350	355	345	415	400	332	380
C max	465	400	435	375	480	450	404	450
D max	520	450	515	405	545	500	476	520
E max	575	500	595	435	610	550	548	590
F max	630	550	675	465	675	600	620	660
G max	685	600	755	495	740	650	692	730

Table 17. New construction benchmarks. Total annual GWP. Part 1

MIN	minimum value	2	3	3	4	3
MAX	maximum value	12	12	11	12	12
Best 10%	**"=PERCENTILE.INC(C37:C2001;0,1)"**	5,0	5,2	4,9	4,1	4,9
Mean	**"=AVERAGE(C37:C777)"**	**6,8**	**6,6**	**6,5**	**6,6**	**7,2**
Limit 75%	**"=PERCENTILE.INC(C37:C2001;0,75)"**	**7,7**	**7,8**	**7,2**	**7,7**	**8,1**
Limit 90%	**"=PERCENTILE.INC(C37:C2001;0,9)"**	**9,0**	**8,9**	**8,7**	**9,4**	**10,0**
Country	**Country**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**
Type	**Type**	**All**	**Apartment buildings**	**Attached or row**	**Day care**	**Educational buildings**
Stage	**Stage**	**Total, annual**	**Total, annual**	**Total, annual**	**Total, annual**	**Total, annual**
COUNT	**Sample size**	**1736**	**823**	**63**	**62**	**49**
Start	**A max limit**	**5**	**5,5**	**5**	**4,2**	**5,3**
End	**F max value**	**9**	**9**	**8,5**	**10**	**11**
Step	"=ROUND((C16-C15)/5;1)"	0,8	0,7	0,7	1,2	1,1
A %	"=COUNTIFS(C$37:C$2005;"<"&C29)/C$13"	10%	13%	13%	13%	14%
B %	"=COUNTIFS(C$37:C$2005;">"&C29;C$37:C$2005;"<"&	17%	18%	22%	21%	20%
C %	"=COUNTIFS(C$37:C$2005;">"&C30;C$37:C$2005;"<"&	23%	20%	17%	21%	20%
D %	"=COUNTIFS(C$37:C$2005;">"&C31;C$37:C$2005;"<"&	19%	18%	21%	21%	27%
E %	"=COUNTIFS(C$37:C$2005;">"&C32;C$37:C$2005;"<"&	13%	13%	10%	11%	6%
F %	"=COUNTIFS(C$37:C$2005;">"&C33;C$37:C$2005;"<"&	7%	7%	6%	6%	8%
G %	"=COUNTIFS(C$37:C$2005;">"&C34)/C$13"	10%	9%	11%	6%	4%
	"=SUM(C19:C25)"	*99%*	*99%*	*100%*	*100%*	*100%*
In B-F	**"=SUM(C20:C24)"**	**79%**	**76%**	**76%**	**81%**	**82%**
A max	"=C15"	5	5,5	5	4,2	5,3
B max	"=C29+C$17"	5,8	6,2	5,7	5,4	6,4
C max	"=C30+C$17"	6,6	6,9	6,4	6,6	7,5
D max	"=C31+C$17"	7,4	7,6	7,1	7,8	8,6
E max	"=C32+C$17"	8,2	8,3	7,8	9	9,7
F max	"=C33+C$17"	9	9	8,5	10,2	10,8
G max	"=C34+C17"	9,8	9,7	9,2	11,4	11,9

Table 18. New construction benchmarks. Total annual GWP. Part 2

MIN	5	5	3	2	3	3	3	4
MAX	10	9	12	12	11	11	12	12
Best 10%	5,7	5,2	4,3	5,1	5,5	6,0	4,1	5,1
Mean	**7,6**	**6,8**	**7,1**	**6,4**	**8,0**	**7,4**	**6,7**	**7,4**
Limit 75%	**8,9**	**7,9**	**8,4**	**6,9**	**10,2**	**8,1**	**8,1**	**9,1**
Limit 90%	**9,8**	**8,2**	**11,0**	**7,9**	**11,0**	**9,8**	**9,7**	**10,1**
Country	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**
Type	**Hospitals**	**Industrial**	**Office buildings**	**One-dwelling buildings**	**Other**	**Retail**	**School**	**Social welfare**
Stage	**Total, annual**	**Total, annual**	**Total, annual**	**Total, annual**	**Total, annual**	**Total, annual**	**Total, annual**	**Total, annual**
COUNT	**16**	**11**	**78**	**443**	**18**	**16**	**83**	**36**
Start	**6**	**5**	**4,5**	**5,3**	**5,5**	**6**	**4,3**	**5,1**
End	**10**	**9**	**11**	**8,3**	**11**	**10**	**10,3**	**11**
Step	0,8	0,8	1,3	0,6	1,1	0,8	1,2	1,2
A %	13%	9%	13%	14%	11%	13%	14%	11%
B %	19%	27%	23%	20%	28%	25%	14%	25%
C %	25%	9%	18%	26%	11%	31%	25%	11%
D %	13%	18%	21%	18%	6%	6%	18%	22%
E %	13%	18%	9%	6%	11%	6%	14%	14%
F %	6%	9%	5%	6%	22%	6%	8%	8%
G %	13%	9%	12%	7%	11%	13%	5%	6%
	100%	*100%*	*100%*	*98%*	*100%*	*100%*	*100%*	*97%*
In B-F	**75%**	**82%**	**76%**	**77%**	**78%**	**75%**	**81%**	**81%**
A max	6	5	4,5	5,3	5,5	6	4,3	5,1
B max	6,8	5,8	5,8	5,9	6,6	6,8	5,5	6,3
C max	7,6	6,6	7,1	6,5	7,7	7,6	6,7	7,5
D max	8,4	7,4	8,4	7,1	8,8	8,4	7,9	8,7
E max	9,2	8,2	9,7	7,7	9,9	9,2	9,1	9,9
F max	10	9	11	8,3	11	10	10,3	11,1
G max	10,8	9,8	12,3	8,9	12,1	10,8	11,5	12,3

Table 19. New construction benchmarks. Stage A1-A3

MIN	96	105	135	136	113	218	198	96	97	135	170	127	177
MAX	638	638	450	534	558	472	360	570	598	565	455	556	510
Best 10%	200	228	196	163	192	251	252	185	194	219	233	169	212
Mean	**298**	**304**	**279**	**276**	**312**	**327**	**297**	**314**	**251**	**351**	**317**	**294**	**311**
Limit 75%	**349**	**368**	**310**	**329**	**356**	**361**	**347**	**398**	**267**	**435**	**340**	**365**	**381**
Limit 90%	**409**	**414**	**354**	**403**	**416**	**410**	**359**	**471**	**336**	**503**	**417**	**416**	**413**
Country	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**
Type	**All**	**Apartment buildings**	**Attached or row**	**Day care**	**Educational buildings**	**Hospitals**	**Industrial**	**Office buildings**	**One-dwelling buildings**	**Other**	**Retail**	**School**	**Social welfare**
Stage	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**	**A1-A3**
COUNT	**1734**	**823**	**63**	**62**	**49**	**16**	**11**	**78**	**443**	**18**	**16**	**83**	**36**
Start	**200**	**240**	**200**	**170**	**205**	**250**	**250**	**190**	**200**	**230**	**240**	**180**	**210**
End	**425**	**440**	**375**	**420**	**455**	**450**	**375**	**540**	**350**	**505**	**440**	**480**	**460**
Step	45	40	35	50	50	40	25	70	30	55	40	60	50
A %	10%	13%	14%	15%	12%	13%	9%	14%	14%	11%	13%	14%	11%
B %	20%	17%	13%	13%	10%	19%	18%	21%	29%	28%	6%	16%	22%
C %	21%	21%	16%	21%	27%	19%	36%	29%	29%	17%	38%	27%	17%
D %	18%	22%	29%	23%	24%	25%	0%	10%	9%	0%	25%	17%	17%
E %	14%	14%	13%	13%	14%	13%	18%	15%	5%	22%	0%	17%	22%
F %	9%	7%	6%	6%	6%	6%	18%	5%	6%	11%	13%	6%	6%
G %	7%	7%	10%	10%	6%	6%	0%	5%	8%	11%	6%	4%	6%
	100%	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
In B-F	**82%**	**81%**	**76%**	**76%**	**82%**	**81%**	**91%**	**81%**	**77%**	**78%**	**81%**	**82%**	**83%**
A max	200	240	200	170	205	250	250	190	200	230	240	180	210
B max	245	280	235	220	255	290	275	260	230	285	280	240	260
C max	290	320	270	270	305	330	300	330	260	340	320	300	310
D max	335	360	305	320	355	370	325	400	290	395	360	360	360
E max	380	400	340	370	405	410	350	470	320	450	400	420	410
F max	425	440	375	420	455	450	375	540	350	505	440	480	460
G max	470	480	410	470	505	490	400	610	380	560	480	540	510

Table 20. New construction benchmarks. Stage A4

MIN	0	0	0	0	0	0	0	0	0	0	0	0	0
MAX	24	24	4	9	21	12	15	22	8	12	13	19	13
Best 10%	0,3	2,1	3,8	0,0	0,0	2,8	7,2	2,6	0,8	2,5	0,9	0,0	9,6
Mean	**8,1**	**9,3**	**3,8**	**4,0**	**6,9**	**7,1**	**10,0**	**7,7**	**4,8**	**6,8**	**5,8**	**6,8**	**11,2**
Limit 75%	**11,5**	**12,1**	**3,8**	**7,5**	**9,9**	**8,4**	**11,5**	**9,0**	**6,6**	**11,6**	**7,4**	**10,3**	**12,2**
Limit 90%	**14,1**	**15,0**	**3,8**	**8,3**	**13,4**	**10,7**	**13,1**	**13,3**	**7,8**	**11,7**	**9,1**	**13,2**	**12,7**
Country	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**
Type	**All**	**Apartment buildings**	**Attached or row**	**Day care**	**Educational buildings**	**Hospitals**	**Industrial**	**Office buildings**	**One-dwelling buildings**	**Other**	**Retail**	**School**	**Social welfare**
Stage	**A4**	**A4**	**A4**	**A4**	**A4**	**A4**	**A4**	**A4**	**A4**	**A4**	**A4**	**A4**	**A4**
COUNT	**257**	**106**	**1**	**7**	**23**	**5**	**7**	**39**	**10**	**5**	**8**	**27**	**3**
Start	**2**	**4**	**1**	**1**	**0,1**	**0,01**	**0,01**	**4**	**0,8**	**0,01**	**0,01**	**0,1**	**210**
End	**17**	**19**	**16**	**16**	**22**	**12**	**25**	**16**	**11**	**13**	**11**	**18,5**	**545**
Step	3	3	3	3	4,4	2,4	5	2,4	2	2,6	2,2	3,7	67
A %	14%	15%	0%	43%	22%	0%	0%	15%	10%	0%	0%	15%	33%
B %	11%	10%	100%	0%	17%	20%	0%	23%	10%	20%	25%	11%	0%
C %	25%	29%	0%	29%	26%	0%	43%	33%	30%	20%	13%	30%	0%
D %	22%	26%	0%	29%	22%	20%	57%	5%	30%	20%	13%	26%	33%
E %	18%	11%	0%	0%	9%	40%	0%	15%	20%	0%	38%	15%	0%
F %	6%	6%	0%	0%	4%	0%	0%	3%	0%	40%	0%	0%	0%
G %	4%	2%	0%	0%	0%	20%	0%	5%	0%	0%	13%	4%	33%
	100%	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
In B-F	**82%**	**83%**	**100%**	**57%**	**78%**	**80%**	**100%**	**79%**	**90%**	**100%**	**88%**	**81%**	**33%**
A max	2	4	1	1	0,1	0,01	0,01	4	0,8	0,01	0,01	0,1	10
B max	5	7	4	4	4,5	2,41	5,01	6,4	2,8	2,61	2,21	3,8	10,6
C max	8	10	7	7	8,9	4,81	10,01	8,8	4,8	5,21	4,41	7,5	11,2
D max	11	13	10	10	13,3	7,21	15,01	11,2	6,8	7,81	6,61	11,2	11,8
E max	14	16	13	13	17,7	9,61	20,01	13,6	8,8	10,41	8,81	14,9	12,4
F max	17	19	16	16	22,1	12,01	25,01	16	10,8	13,01	11,01	18,6	13
G max	20	22	19	19	26,5	14,41	30,01	18,4	12,8	15,61	13,21	22,3	13,6

Table 21. New construction benchmarks. Stage C1-C4

MIN	2	2	11	5	13	8	10	4	2	7	10	4	4
MAX	97	97	45	71	47	29	57	60	67	39	46	74	44
Best 10%	11,1	9,4	15,7	13,9	14,3	11,5	13,3	10,9	15,2	10,7	12,2	15,8	15,4
Mean	**21,1**	**18,6**	**23,6**	**24,6**	**21,4**	**15,5**	**25,1**	**19,9**	**24,1**	**22,7**	**24,0**	**24,0**	**22,7**
Limit 75%	**24,8**	**23,2**	**27,3**	**27,3**	**24,5**	**16,6**	**28,1**	**23,1**	**27,9**	**25,5**	**30,3**	**26,2**	**25,3**
Limit 90%	**31,4**	**26,0**	**35,1**	**38,6**	**31,6**	**18,0**	**36,8**	**28,1**	**34,5**	**33,6**	**39,8**	**33,7**	**38,5**
Country	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**	**Finland**
Type	**All**	**Apartment buildings**	**Attached or row**	**Day care**	**Educational buildings**	**Hospitals**	**Industrial**	**Office buildings**	**One-dwelling buildings**	**Other**	**Retail**	**School**	**Social welfare**
Stage	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**	**C1-C4**
COUNT	**1438**	**667**	**56**	**55**	**44**	**15**	**9**	**71**	**342**	**16**	**15**	**80**	**30**
Start	**13**	**10,5**	**16,5**	**14**	**14**	**11,6**	**14**	**11**	**16,5**	**12,7**	**14**	**16,5**	**16**
End	**33**	**31**	**35**	**38**	**30**	**21,5**	**40**	**31**	**36,5**	**41**	**40**	**33,5**	**33**
Step	4	4,1	3,7	4,8	3,2	2	5,2	4	4	5,7	5,2	3,4	3,4
A %	15%	14%	13%	13%	7%	13%	11%	11%	15%	13%	13%	13%	13%
B %	16%	17%	23%	29%	27%	20%	22%	20%	19%	13%	33%	25%	20%
C %	21%	15%	27%	15%	23%	13%	22%	23%	25%	25%	13%	19%	33%
D %	24%	26%	14%	22%	16%	40%	22%	20%	18%	31%	13%	20%	13%
E %	12%	21%	7%	5%	9%	7%	11%	14%	8%	13%	7%	8%	0%
F %	4%	4%	5%	5%	2%	0%	0%	3%	9%	6%	7%	5%	0%
G %	8%	2%	11%	11%	16%	7%	11%	10%	6%	0%	13%	11%	20%
	100%	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
In B-F	**77%**	**84%**	**77%**	**76%**	**77%**	**80%**	**78%**	**79%**	**80%**	**88%**	**73%**	**76%**	**67%**
A max	13	10,5	16,5	14	14	11,6	14	11	16,5	12,7	14	16,5	16
B max	17	14,6	20,2	18,8	17,2	13,6	19,2	15	20,5	18,4	19,2	19,9	19,4
C max	21	18,7	23,9	23,6	20,4	15,6	24,4	19	24,5	24,1	24,4	23,3	22,8
D max	25	22,8	27,6	28,4	23,6	17,6	29,6	23	28,5	29,8	29,6	26,7	26,2
E max	29	26,9	31,3	33,2	26,8	19,6	34,8	27	32,5	35,5	34,8	30,1	29,6
F max	33	31	35	38	30	21,6	40	31	36,5	41,2	40	33,5	33
G max	37	35,1	38,7	42,8	33,2	23,6	45,2	35	40,5	46,9	45,2	36,9	36,4

Table 22. Building renovation benchmarks

MIN	23	23	64	0,4	14	14	37	0,00	0	0	0
MAX	514	514	319	8,6	385	385	179	5,00	85	85	8
Best 10%	**64**	**47**	**92**	**1,1**	**37**	**18**	**49**	**0**	**1**	**2**	**1**
Mean	**209**	**180**	**191**	**3,5**	**123**	**107**	**115**	**1**	**9**	**14**	**3**
Limit 75%	**291**	**223**	**240**	**4,9**	**156**	**137**	**151**	**1**	**9**	**9**	**6**
Limit 90%	**319**	**320**	**266**	**5,3**	**179**	**169**	**175**	**4**	**18**	**24**	**8**
Country	**Finland**	**Finland Office**	**Finland Apartment**	**Finland**	**Finland**	**Finland Office**	**Finland Apartment**	**Finland**	**Finland**	**Finland Office**	**Finland Apartment**
Type	**All**	**buildings**	**buildings**	**All**	**All**	**buildings**	**buildings**	**All**	**All**	**buildings**	**buildings**
Stage	**Total**	**Total**	**Total**	**Total, annual**	**A1-A3**	**A1-A3**	**A1-A3**	**A4**	**C1-C4**	**C1-C4**	**C1-C4**
COUNT	**61**	**13**	**13**	**61**	**61**	**13**	**13**	**21**	**56**	**11**	**11**
Start	**85**	**50**	**100**	**1,4**	**40**	**19**	**55**	**0,05**	**1,4**	**2,5**	**0,5**
End	**410**	**450**	**350**	**7**	**280**	**240**	**230**	**3,9**	**18**	**80**	**8,2**
Step	65	80	50	1,1	48	44	35	0,8	3,3	15,5	1,5
A %	15%	15%	15%	15%	15%	15%	15%	14%	14%	18%	9%
B %	16%	23%	23%	15%	15%	23%	23%	48%	27%	64%	36%
C %	23%	31%	15%	23%	25%	23%	15%	19%	27%	9%	18%
D %	20%	8%	23%	20%	36%	15%	23%	0%	13%	0%	0%
E %	21%	15%	15%	21%	7%	15%	23%	0%	5%	0%	9%
F %	0%	0%	8%	0%	0%	0%	0%	10%	4%	0%	9%
G %	5%	8%	0%	5%	3%	8%	0%	10%	11%	9%	18%
	100%	*100%*	*100%*	*98%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
In B-F	**80%**	**77%**	**85%**	**79%**	**82%**	**77%**	**85%**	**76%**	**75%**	**73%**	**73%**
A max	85	50	100	1,4	40	19	55	0,05	1,4	2,5	0,5
B max	150	130	150	2,5	88	63	90	0,85	4,7	18	2
C max	215	210	200	3,6	136	107	125	1,65	8	33,5	3,5
D max	280	290	250	4,7	184	151	160	2,45	11,3	49	5
E max	345	370	300	5,8	232	195	195	3,25	14,6	64,5	6,5
F max	410	450	350	6,9	280	239	230	4,05	17,9	80	8
G max	475	530	400	8	328	283	265	4,85	21,2	95,5	9,5