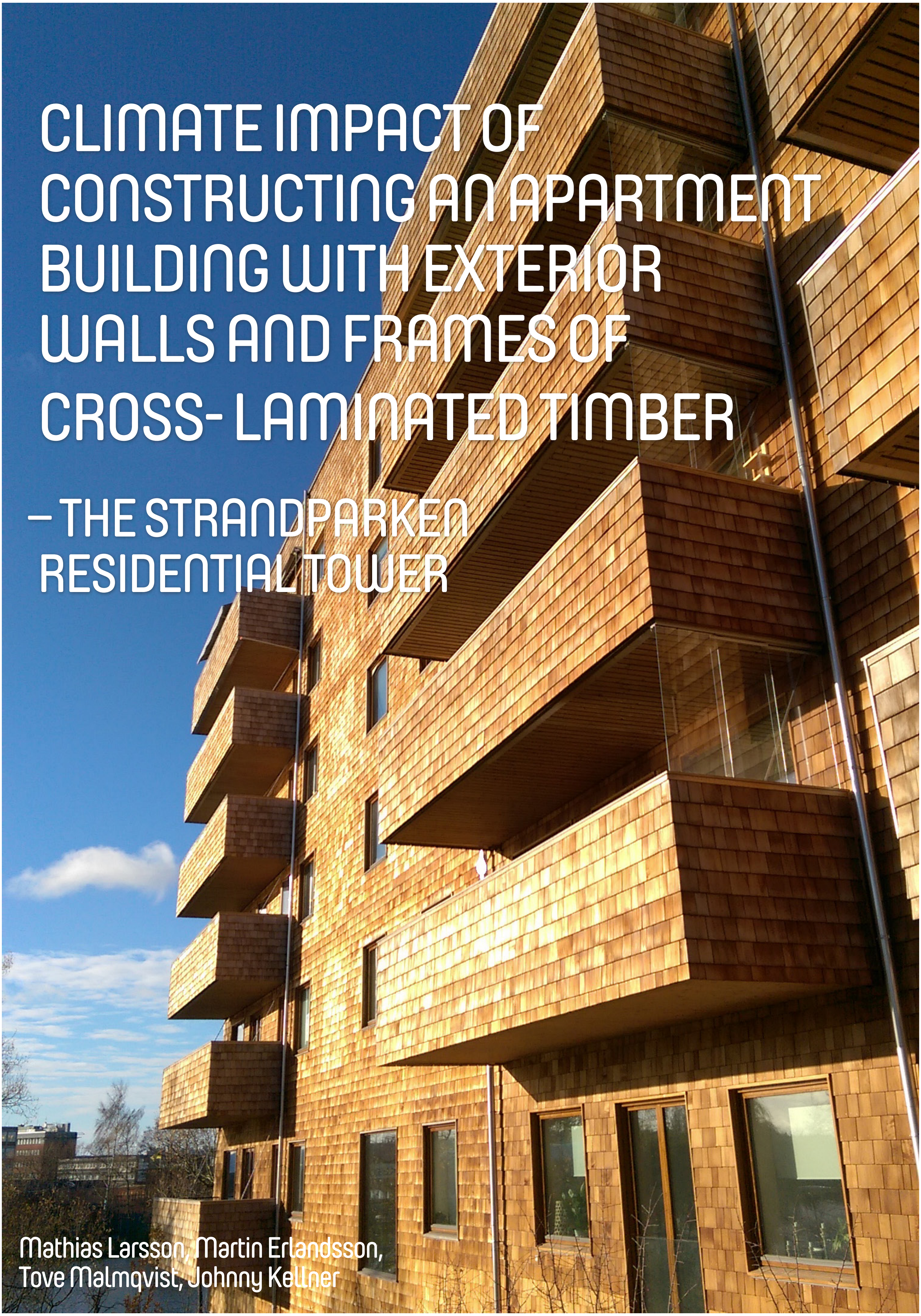

CLIMATE IMPACT OF CONSTRUCTING AN APARTMENT BUILDING WITH EXTERIOR WALLS AND FRAMES OF CROSS- LAMINATED TIMBER

– THE STRANDPARKEN RESIDENTIAL TOWER

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Climate impact of constructing an apartment building with exterior walls and frame of cross-laminated timber

— the Strandparken residential towers

Summary report based on a lifecycle assessment (LCA), carried out by IVL Swedish Environmental Research Institute and KTH Royal Institute of Technology and targeting an apartment building constructed almost entirely of wood. The project's main report (IVL report No B2260) is entitled "The construction phase's climate impact. Life cycle calculation of the climate impact and energy use of a newly produced energy-efficient residential building in concrete with wooden frames" (in Swedish).

The LCA focuses on an eight-storey apartment building with exterior walls and frames of cross-laminated timber and an additional souterrain floor. The souterrain floor is made of concrete and includes a basement and parking spaces. Folkhem acted as entrepreneur and property developer of the Strandparken wooden houses complex in Sundbyberg, a suburb of Stockholm. Completed in 2013, these are the tallest apartment buildings with wooden frames in Sweden.

When assessing the climate impact of the Strandparken building the earthworks and foundation installation were included, which is unusual for this type of LCA. Foundation work accounts for 8 per cent of the building's carbon footprint. To facilitate comparisons of the environmental performance of individual buildings it is customary to restrict the analysis to the building proper, i.e. the ground level concrete slab and everything on top of that. Garages are normally also excluded in such comparative studies. However, anyone interested in the total climate impact of a particular sector or in promoting environmental improvements should make sure that all aspects of the construction process are evaluated.

The Strandparken building has a climate impact of 265 kg CO_2e/m^2 (heated area). The measured energy performance is 65 kWh/m2. Over and above that, earthworks and foundation installation have contributed 24 kg CO_2e/m^2. The building related environmental impact, throughout the whole life cycle, is roughly equivalent to that incurred using district heating over a period of 50 years. A similar building with an alternative configuration utilizing a floating raft slab and with an energy performance elevated to meet FEBY12 requirements (55 kWh/m²) has a climate impact of 163 kg CO_2e/m^2 (excluding earthworks and foundation installation). The energy use of this latter building stands for approximately 40 percent of the total climate impact over 50 years.

Previously, a comparable study focused on the Blå Jungfrun residential building in Hökarängen, which was constructed with concrete frames (Liljeström et al 2015). The Blå Jungfrun and Strandparken case studies show that the climate impact of a building with exterior walls and a frame of cross-laminated timber is lower than that of a building with concrete in exterior walls and the frame. We can also note that the Strandparken building, with its floating slab construction and superior energy performance in line with FEBY12 passive house recommendations, has the lowest climate impact of any LCA targeting a residential building hitherto published in Sweden.

However, it is also important to emphasize that the purpose of this study is not to ventilate technical and functional differences that may exist between the Strandparken and Blå Jungfrun buildings. Our objective has been to examine the climate impact of the construction phase, and thereby add knowledge to the construction industry, authorities and politicians. This study does not address the question of which materials are most suitable for any particular building project from a holistic point of view. A wide variety of different framing techniques for apartment buildings will continue to be in use for many years to come and each building has to be assessed as a unique object.

It is to be hoped that the facts now emerging about the climate impact of construction will lead both to continued advances in knowledge and methodology designed to highlight appropriate measures for the amelioration of climate impact at all stages of the construction process.

Background and purpose

Climate change impact is one of the greatest ecological challenges facing our generation, and it is vital that we all bring to the table any contribution we are able to make. It has previously been assumed that the climate impact of a building's energy consumption during operation is significantly greater than the carbon footprint of the construction phase. Until now, a rule of thumb in the construction industry in Sweden has been that approximately 15 percent of climate impact and energy consumption takes place during the construction phase, and 85 percent over operational lifetime. New building construction has proved this to be inaccurate, and a new rule of thumb ought to be that both these impacts should be judged to be of equal magnitude.

In recent years, energy consumption per square meter of living space has dropped, and an increasing proportion of this energy now comes from renewable sources. The combination of both these factors means that a building's energy consumption has less impact on the climate than was the case previously. At the same time, we can note that the Swedish national building code stipulates mandatory provisions for energy consumption during operation, but does not regulate climate impact in the construction phase.

In 2015 a study of Blå Jungfrun, a low-energy concrete building, showed that climate impact during the construction phase was roughly equivalent to the energy use impact over 50 years of operation (Liljeström et al 2015). This project should be seen as a continuation of that study, but in this instance a newly built apartment building with frames and exterior walls of cross-laminated timber is under the microscope.

The project aims to deliver a transparent life cycle assessment of the climate impact of a newly produced apartment building with frames of cross-laminated timber (CLT). Addressing the building's whole life cycle means including all aspects of the construction phase, including the production of materials, building transports and processes on the construction site, as well as energy use during the building's operating life, maintenance and ultimate demolition.

Our goal is to:

- Expand knowledge of the construction process and the climate impact of building materials.
- Evaluate the relative magnitudes of environmental impacts incurred during construction and operation.
- Provide an up-to-date scientific foundation for assessing the environmental impact of the construction phase and determine whether this impact is similarly significant when building with wooden frames.

Life cycle assessment

Life cycle assessment methodology is used to assess the climate impact of a product in a holistic perspective. A lifecycle assessment (LCA) describes environmental impact quantitatively divided into a range of different categories, such as, climate change, eutrophication, ground level ozone impacts and resource use.

To ensure that a LCA is unequivocal, i.e. arrives at more or less the same result no matter who carries it out, it is important to establish methodological guidelines and provide definitions and clarifications. The choice of methods and definitions made in this study adheres to EN 15804 and EN 15978 standards. This means, among other things, that calculations have been carried out following attributional LCA principles (also known as "book keeping" LCA). An attributional LCA is characterized by the belief that, in theory, it is possible to sum up the carbon emissions associated with materials and processes, and that the figure thus arrived at is a true reflection of the climate impact of global the emissions actually taking place.

The methods applied in this study are the same as those used to analyse the Blå Jungfrun residential building, with its frames and exterior walls of concrete. If we were to recalculate the environmental impact of Blå Jungfrun, we would include the lifts and modify the end-of-life demolition data. These dissimilarities in approach, the research methodology employed and the assumptions made for the Strandparken LCA are set forth in the main report.

The various life stages of a building structure

In order to increase transparency when carrying out a life cycle assessment of a building, it is important to elucidate the stages of the building's life cycle that are to be included. In this respect, dividing the phases of the life cycle into stages and modules as shown in Figure 1 is a useful approach. The thrust of the project is to expose the climate impact of the construction phase (modules A1-A5 in the figure), and to relate this to module B6 – operating energy. In the Strandparken study all stages of the building's lifecycle data have been calculated, excluding maintenance (B3) and renovation (B5), as data relating to these is lacking they have not been included in the building's reference period of 50 years. At the present time, water usage during operation (B7) and climate impact associated with wastewater treatment are not normally incorporated within building LCAs in Sweden.

When carrying out life cycle assessments it is necessary to specify a study period. In this case was 50 years selected, but results have also been calculated for a study period spanning 100 years. Because as a rule buildings are expected to be long lived, it is possible to choose a long period of analysis and therefore the analysis period need not be equivalent to life expectancy.

A problem associated with choosing an analysis period of 100 years is that buildings will normally be refurbished before the end of that period. At this point there will be the choice of either keeping all or part of an existing building or demolishing and building new. Setting a study period that is significantly longer than a rebuilding cycle therefore means that working out this scenario becomes somewhat academic. Furthermore, distant scenarios become more uncertain the longer the analysis period chosen. It has become common to use a study period of 50-60 years for this type of assessment. Assumptions and descriptions of the calculations used are presented in the main report (Larsson et al 2016).

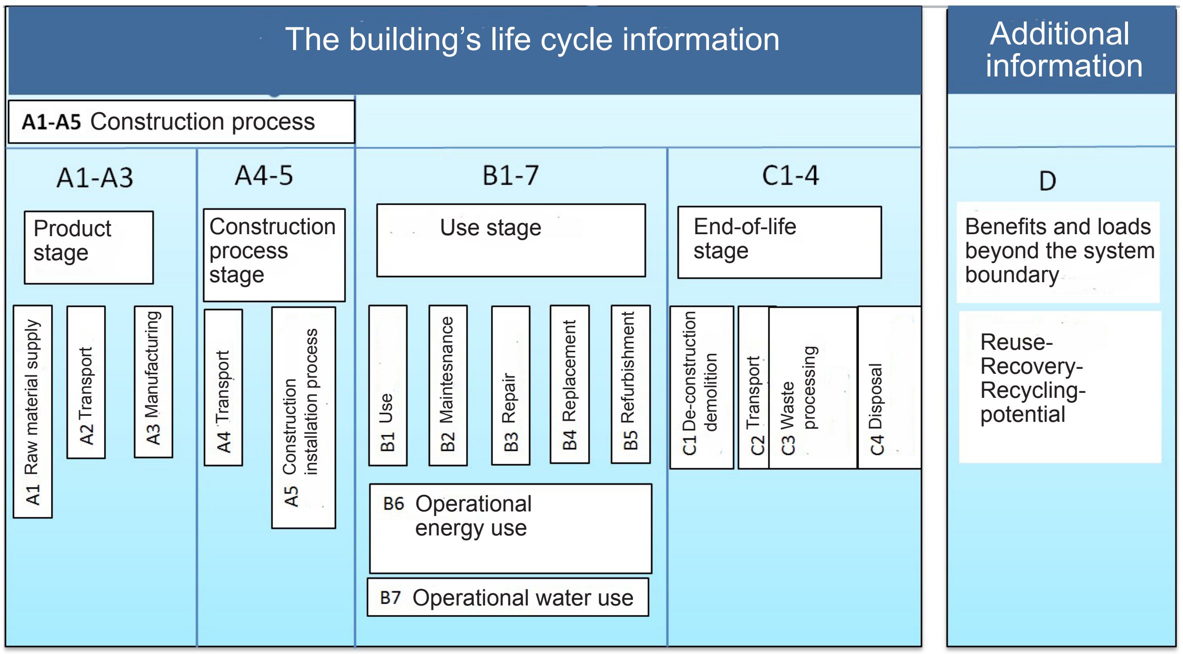

Figure 1. A building's life cycle stages and information modules in accordance with EN 15804 and EN 15978 standards (the designation Construction Phase A1-5 is not present the standards but used here)

The Strandparken Residential Towers

The Strandparken Residential Towers are located in Sundbyberg, a suburb of Stockholm. Here, the property developer Folkhem has erected two apartment blocks with frames and exterior walls of cross-laminated timber — Stockholm's first eight-storey residential complex constructed entirely of wood. The building selected from this block as case study object is the building with cedar shingles both on the facade and for roofing, see figure 2. Development work began in 2011, and in August 2014 both blocks were ready for occupancy. The complex lies on sloping ground on the shore of the Bällstaviken inlet and stands on a piled foundation.

The ground floor and garage were built with precast concrete elements. The exterior walls are insulated with stone wool. The adjusted energy consumption used in the calculations is 65 kWh/m^2 and year. The building is heated with district heating and utilizes waterborne underfloor heating. Electric underfloor heating is available in all sanitary areas and warm water underfloor heating has also been installed in sanitary rooms with windows.

Figure 2. The Strandparken building with cross section. (Photo: Petra Bindel)

Result

The climate impact of the Strandparken building stands for 265 kg CO_2e/m^2. This is excluding the earthworks, which accounts for 24 CO_2e/m^2 A_{temp}. Materials production is primarily responsible for the climate impact incurred during the construction stage. Materials transports and on-site construction are responsible for a smaller proportion, see figure 3. Materials and processes stand for 8 percent of the climate impact incurred during the construction stage (A1-5). Although this is a small percentage compared to materials production associated with the building itself (including the garage).

Upstream environmental impact (A1-A5) including garage

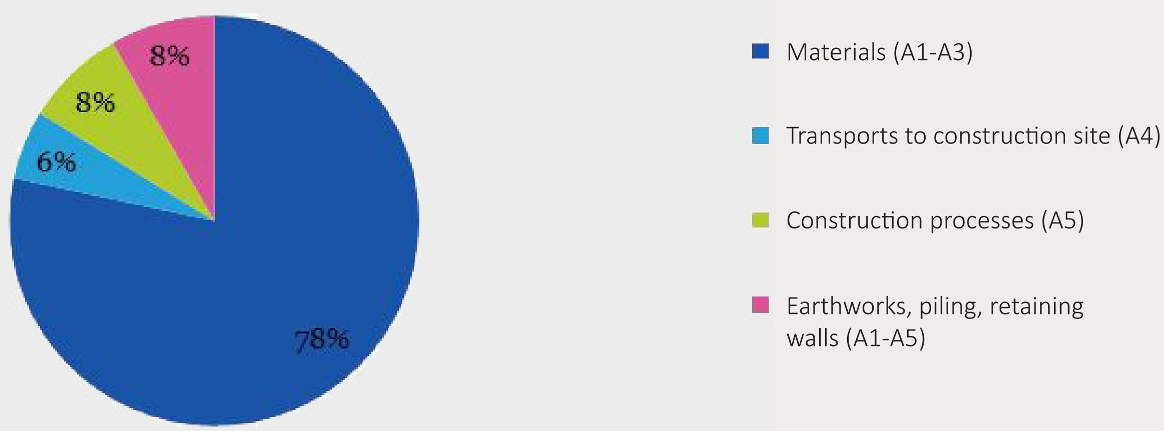

Figure 3. Upstream climate impact of building construction phase (modules A1-A5) including garage.

The building construction elements and materials that contribute most to the upstream climate impact (modules A1-A5) are shown in figure 4. Concrete in the foundation, garages and basements, and in hollow core slabs accounts for the greater part of the materials contribution to the carbon footprint. Cross-laminated timber (CLT) and stone wool insulation in exterior walls are responsible for a roughly equal share. The catch-all category 'Other' subsumes a variety of diverse materials and components, see figure 4.

Climate impact of various materials (A1-A5) including garage, but excluding ground installation materials

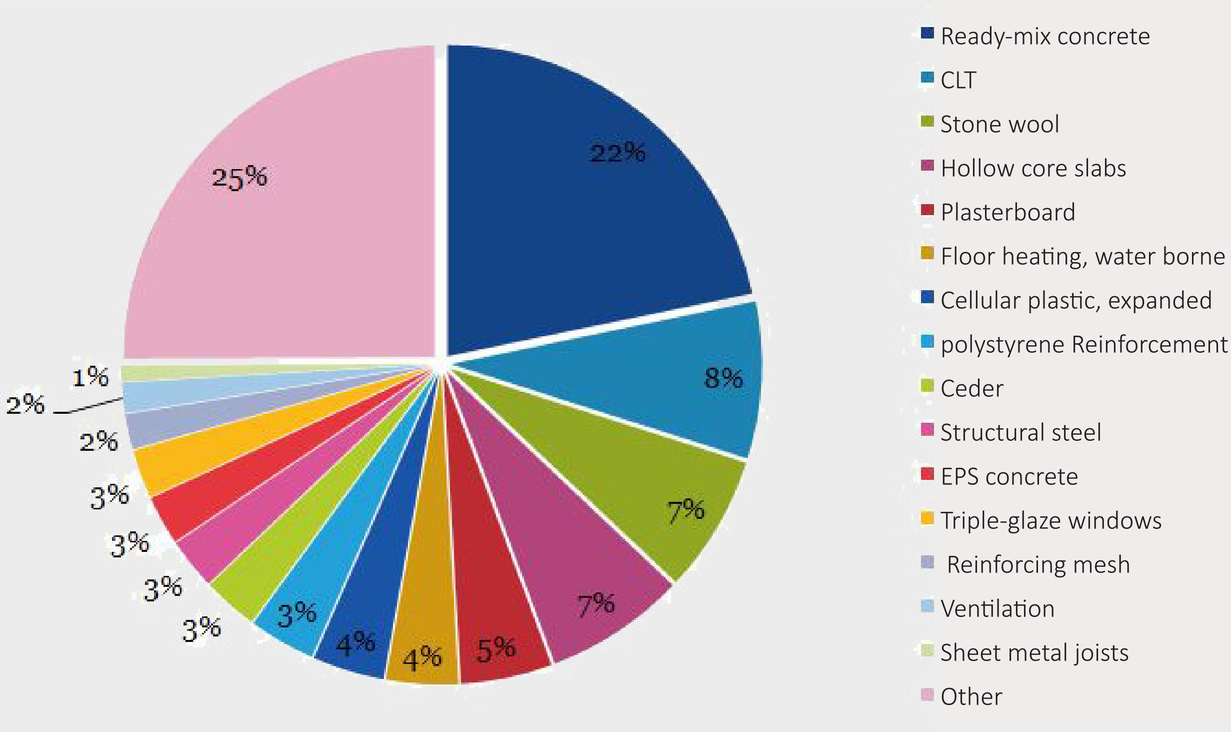

Figure 4. Climate impact of various materials including raw material production (modules A1-3), transports to construction site (module A4) and disposal of resulting waste (module A5). Including garage, but excluding ground installation materials.

Carbon footprint over the building's life cycle amounts to just above 700 kg CO_2e/m^2 for an analysis period of 50 years with mean scenarios for operational energy use and replacement cycles. The construction phase is responsible for 265 kg CO_2e/m^2 or 38 percent of total climate impact over an analysis period of 50 years, see figure 5.

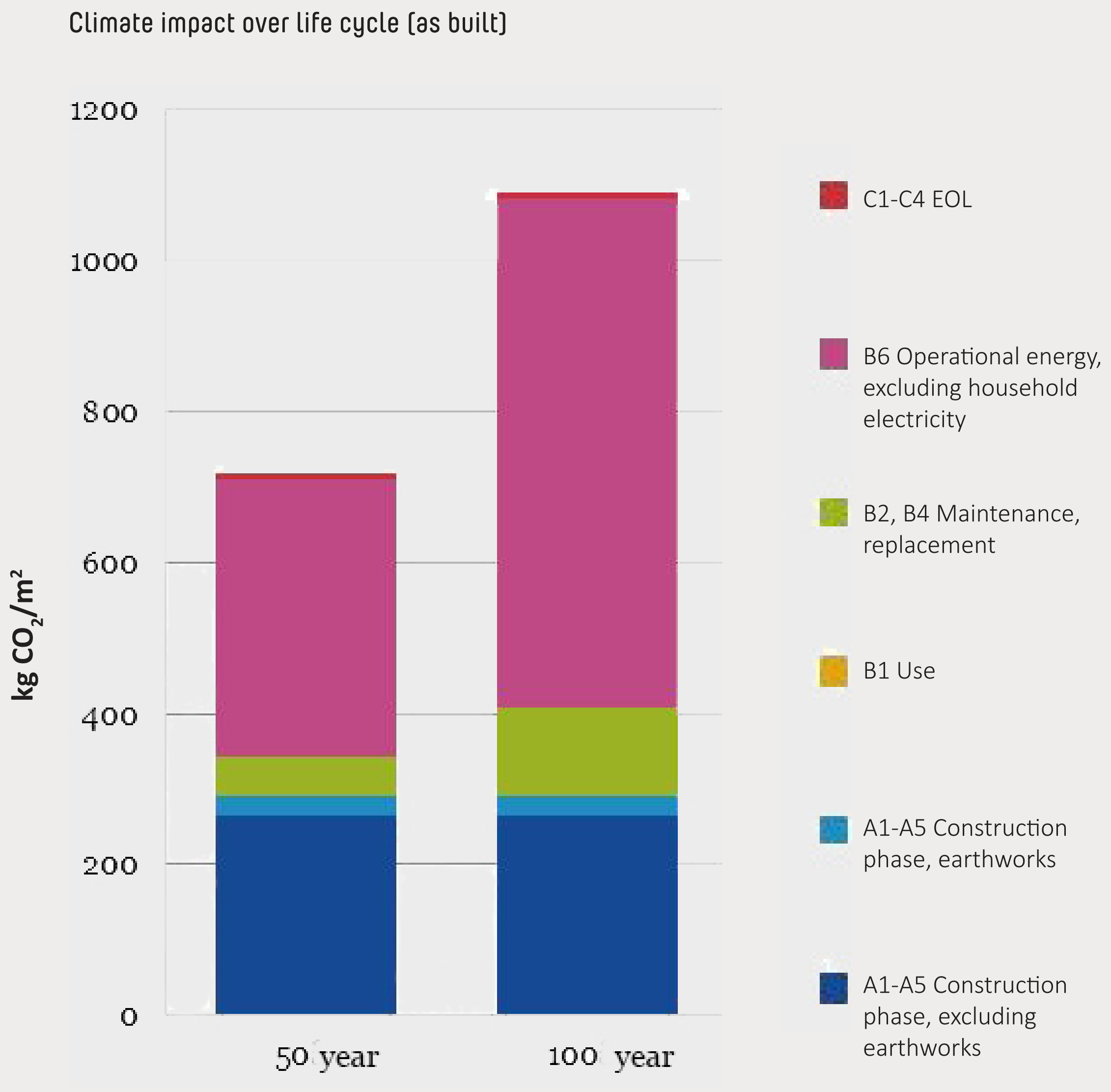

Figure 5. Climate impact (kg CO_2e/m^2) of the Strandparken complex divided into life cycle stages. Study periods 50 and 100 years, respectively. Mean energy scenario, module B6: 65kWh/m², and year, excluding household electricity. Mean maintenance and replacement scenarios, modules B2, B4.

In figure 5, the 'B1 Use' module that includes carbonation of concrete is so small in this context that it is not visible. The climate impact of the construction phase has been totalized and not broken down per year, and will thus be the same whether the analysis period is 50 or 100 years. Emissions of greenhouse gases in the construction phase have already taken place when the building is completed, which is why it is misleading to report them annually — for example, over a 50-year period this would suggest that these emissions occur in the future. The Strandparken building's energy use during operation will have a significant impact on the climate, but this will vary greatly depending on the choice of electricity and district heating mix. With an energy scenario using a low proportion of fossil fuels the construction phase will be responsible for 62 percent of the carbon footprint over the building's lifecycle. In the longer term this can be seen as a likely scenario, but the forecast is that Swedish district heating will utilize fossil elements up until 2030, not least due the incineration of waste plastic.

The study also shows that it is possible to reduce energy requirement to 55 kWh/m² and year, which matches the Blå Jungfrun energy use, without significantly raising carbon dioxide emissions during the construction phase. This means that both this and the Blå Jungfrun study indicate that the construction phase's contribution to climate change over the life cycle is higher than previously assumed. But this fact is no reason not to build and renovate to high energy efficiency standards. However, the present study does not take into account the cost aspects of energy efficiency measures.

The Strandparken building boasts a garage and basement in precast cement that contributes to its climate impact. The building can be constructed theoretically, without either garage or basement, and with a floating slab, instead of the actual piled foundation. With this alternative configuration the climate impact of the building phase is reduced to 161 kg CO_2e/m^2 compared to 265 kg when basement and garage are included. This theoretical configuration of the Strandparken building, despite its simplification, can then be compared with the previously studied Blå Jungfrun residential building that lacks both garage and basement.

The comparison of the Blå Jungfrun och Strandparken buildings shows that the alternative configuration applied to the Strandparken building reduces climate impact during the construction phase to half that of the Blå Jungfrun building. See figure 6 below.

Climate impact comparison between Strandparken and Blå Jungfrun (modified configuration)

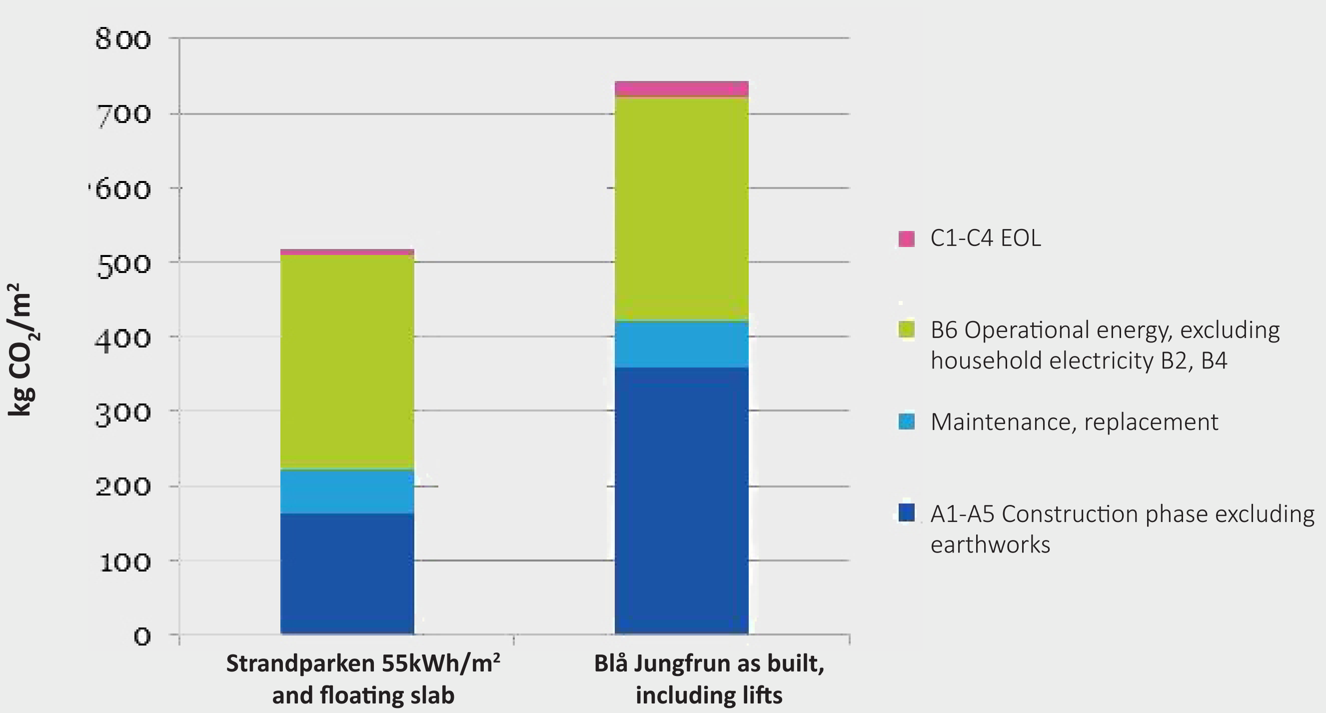

Figure 6. Climate impact comparison with modified configuration of Strandparken building and actual Blå Jungfrun building. Energy scenario module B6: 55 kWh/m² and year, mean scenario, excluding household electricity. Mean maintenance and replacement scenario module B2, B4: for Strandparken building.

These differences are primarily due to the choice of materials. But disparities between Strandparken and Blå Jungfrun in the final life cycle stage, discernable in Figure 6, are functions of the fact that the Strandparken study exploited new methods for calculating the environmental impact of demolition with data based on Erlandsson et al (2015).

The difference in the amount of concrete used is a critical reason for discrepancies in the environmental impact of Blå Jungfrun and Strandparken, Blå Jungfrun has a frame and exterior walls made of concrete, while seven of Strandparken's eight floors are built with cross-laminated wood in both frames and exterior walls. Thus, the greatest potential for improving the two building types lies in more active involvement in the choice of environmental friendly concrete. In certain applications the use of various cement substitutes can halve the climate impact of the concrete used.

Conclusions

This study shows that the construction, maintenance and eventual end-of-life demolition of the wooden building under investigation accounts for roughly 40 to 50 per cent of total climate impact over an analysis period of 50 years, in comparison with the environmental costs of district heating (see Figures 5 and 6). The study demonstrates that it is equally important to evaluate the carbon footprint of the construction phase when building with wood as when traditional materials are used.

The Blå Jungfrun and Strandparken case studies indicate that the climate impact of using frames of cross-laminated timber is less than when concrete frames are used. It is important to stress that no other technical or functional dissimilarities between Strandparken and Blå Jungfrun have been studied. The aim has been to highlight the carbon footprint left by the construction phase and in so doing increase knowledge at the disposal of the construction industry, authorities and politicians.

To minimize the risk that the juxtaposition of the two projects may confuse the issue at hand, the report also presents a theoretically simplified comparison of Blå Jungfrun and Strandparken. It is important to point out that this comparison has only been made from a climate impact perspective. Other important factors such as fire risk, humidity, power reduction, economy, etc. have not been taken into consideration. The study is not intended to be the basis for the choice of any particular building materials, such as wood, concrete, or steel. Other graphs and results cannot be compared with those of the Blå Jungfrun building, because the scope of the inventory is dissimilar.

We conclude that from a climate and resource point of view it is of great importance to optimize the choice of materials, to choose the right materials for the right application, to use durable and long-lasting materials and to husband energy consumption when new buildings are being planned.

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