Hoppet - the first fossil-free preschool

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Abstract. The building sector give rise to one fifth of the Swedish greenhouse gas emissions. This sector needs a climate shift to reach the UN Sustainable Development Goals. Local municipalities play an important role in this shift and the City of Gothenburg has therefore initiated an innovation project, Hoppet - the first fossil-free preschool. The purpose is to highlight the climate issue and inspire the industry to develop new fossil-free products and processes as well as promoting existing ones. Hoppet is an initiative leading the way towards a fossil-free society in Gothenburg City, Sweden and the world.

Hoppet will be built with minimal climate impact and no fossil resources, as far as possible. This includes everything from production and transport of materials to energy used in the building.

The fossil content and climate impact of traditionally built preschools have been calculated as a benchmark for Hoppet. More than 70 % of the 250 building products in a traditionally built preschool has a petroleum-based content, eg plastics. The climate impact of the building products in a traditionally built preschool was calculated to about 390 kg CO_2-eq./m^2 gross area.

The design phase of first Hoppet preschool started in the autumn 2019 and, before materials are chosen, calculations of the actual climate impact are made. Examples of climate calculations and strategies for material selection for Hoppet are presented as well as ongoing and future work for fossil-free construction.

For more than two years, the project has scouted for new innovative materials and old techniques in order to build fossil-free. Finding fossil-free and climate neutral products has been challenging. Product development and innovation are key issues for fossil-free construction, as well as communication and collaboration within the construction industry. Five important strategies for the transition into a fossil-free society have been identified; biobased building products, reused and recycled building products, minimized material usage, fossil-free construction site and a product life cycle perspective.

1. Introduction

The City of Gothenburg, in Sweden has set very ambitious goals to take an active role in mitigating climate change and thus fulfilling the *UN Sustainable Development Goals no 11 – Sustainable Cities and Communities* and *no 13 - Climate Action*. As one of the first municipalities, Gothenburg has set goals, also including emissions occurring outside the city's geographical boundaries, from production of services and goods that are consumed within the city [1]. Construction has been identified as one of the city's activities with the largest climate impact. The City has high standards for energy efficiency in all new construction projects, but so far, no restrictions when it comes to climate impact for building

products. The City is planning to build a large amount of residential and public buildings in the coming years. Investments of 8 billion SEK (about 760 million EUR) are planned for 2020-2023.

During the last 10-20 years, the Swedish building sector has been focusing on energy efficiency measures and accordingly, greenhouse gas emissions from the construction sector have reduced by almost 50% between 1993-2015 [2]. The next challenge is to reduce climate impact from the manufacturing of building products and from fuels used in transportation and on the construction site, considering all parts of a building´s life cycle. To be able to do this, innovations in technology and material and new ways of thinking are needed. Changed building practices will furthermore contribute to the *UN Sustainable Development Goal no 12 - Responsible Consumption and Production*.

In order to reduce the climate impact from construction, a large part of the construction industry has joined the initiative Fossil-Free Sweden and created a roadmap for a Fossil-Free Construction Sector. In the roadmap it is concluded that there need to be an increased focus on the climate impact from the manufacturing of building products, the transports and the construction site [3].

In 2017 the city council of Gothenburg decided to give the Local Premises Administration a big challenge – to build a fossil-free preschool – Hoppet. As much as possible, Hoppet is to be built with fossil-free material and climate neutral construction solutions. The aim of the innovation project Hoppet is to promote fossil-free building products and identify methods and strategies with potential to be scaled up and, in a ten-year perspective, to be applied to all building projects in Gothenburg.

The construction of the first pilot preschool starts in spring 2020 and will be finalised in 2021. For Hoppet, there is a partnering collaboration with the contractors and the design team, to ensure that all measures are made to fulfill the goal of the project.

1.1. Fossil-free content of a traditionally built preschool

To get a better understanding of the challenges ahead, an initial step was taken to increase the knowledge of the fossil content of a traditionally built preschool. The preschool, Byvädersgången is owned by the City and an investigation was made to identify the petroleum-based content of all 250 building products [4, 5]. The result of the inventory is presented in Figure 1. A large part of the products is petroleum based, but to various extents. For example, 16 % of the building products consist of 80-100 % petroleum-based content. The result indicates that about 70 % of the building products for Byvädersgången consist of materials with petroleum-based origin. Products including the highest petroleum-based content are for example piping and plumbing products, insulation, electrical components, plastic films and finishes. The products without petroleum-based content consist mainly of metal, mineral-based insulation and concrete. For these materials there is a large energy demand in the extraction of raw material and in the production processes. Accordingly, the inventory showed that in a traditionally built pre-school there are no products that are fossil-free and without climate impact.

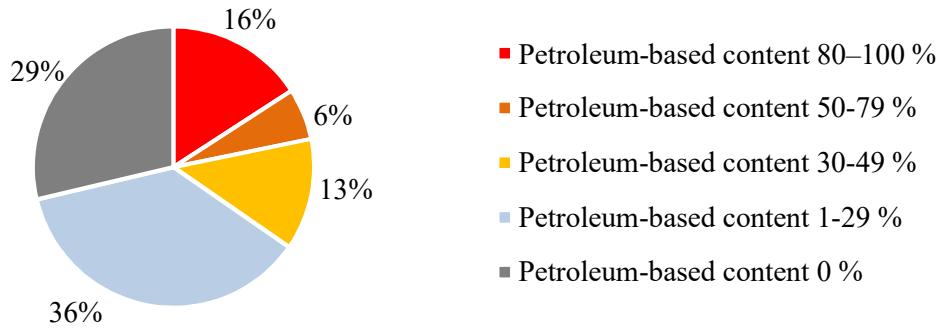

Figure 1. The number of building products with petroleum-based content in relation to the total number of building products (%) in Byvädersgången. The products have been sorted into groups with various shares of petroleum-based content.

1.2. Fossil-free construction and system boundaries

The innovation project, Hoppet considers all parts of a building's life cycle, as presented in Figure 2, from extraction of raw material, manufacturing of material and products, through transport, to the energy usage at the construction site. For example, emissions of greenhouse gases, such as carbon dioxide released when limestone is converted to cement are included. Operation and maintenance of the building is also included, as well as demolition and waste handling. No fossil-based material should be used as raw material and no fossil fuels should be used. Reuse and recycled fossil-based products are accepted as an alternative to products based on virgin fossil raw material. To minimize the overall climate impact, it is important to consider the life cycle of the building, in this case in a one hundred years perspective.

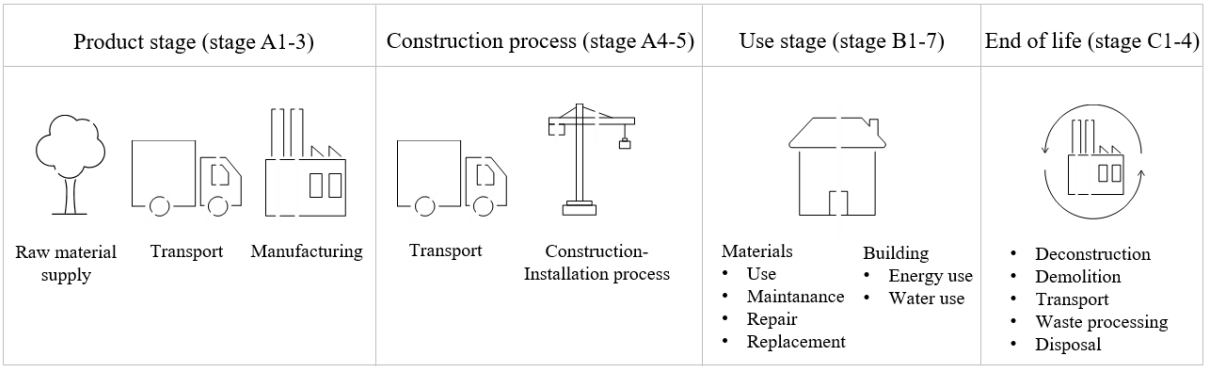

Figure 2. Life cycle stages for a building according to the standard SS-EN 15978 [6].

2. Methodology

To get a better understanding of the challenges ahead, the climate impact of the building materials in a preschool with similar size and design as Hoppet has been calculated. In the early design phase of Hoppet, climate impact for different alternatives of building elements have been calculated as a basis for decisions.

2.1. Methodology - Climate impact assessment of a reference preschool

A thorough material study and climate calculation was performed of Grönskan, a conceptual preschool with a high level of similarity with Hoppet regarding both layout and size. The climate impact calculation was carried out using the "Environmental Impact Calculator for Construction", an LCA calculation tool provided by IVL [7]. Information regarding materials and amounts have been collected from the budget program Sektionsdata. All products and materials provided by Sektionsdata have been included in the study. However, amounts less than 10 kg have been excluded.

The climate impact assessment of the preschool included lifecycle stages A1-A3 and A5.1. The information about materials and amounts for Grönskan was based on estimations of quantities including waste material on the construction site (A5.1). Each product and its climate impact were then registered and compiled in the LCA-tool. When climate data was selected, the following ranking order, verified by IVL [8], was used:

1. Climate data from environmental product declarations (EPDs) with specific or generic data. [9]
2. Climate data from EPDs for similar products.
3. Generic climate data for the product.
4. In case neither EPD nor generic data for the product was found, generic data for the containing materials have been used to calculate the climate impact.

The total climate impact of Grönskan was calculated as the sum of the climate impact of the purchased products, according to equation 1:

$$Climate\ impact_{preschool} = \frac{\sum_{i=1}^{i=n}[Product(kg) \times Climate\ impact\ (kg\ CO_2eq./kg)]_n}{Floor\ area\ (m^2\ gross\ area)} \qquad (1)$$

2.2. Methodology - Climate impact for the early design stage of Hoppet

To minimize the total climate impact of the materials used in the Hoppet building in a life cycle perspective the project team has analyzed climate impacts for alternative construction solutions in an early design phase. For all main building construction parts, i.e. foundation, beam, roof, exterior and interior load bearing walls, three to five alternatives have been evaluated. Input data for the amounts of materials in the alternative solutions has been estimated by the construction team and the calculations of climate impact for each alternative has been completed using the methodology and the IVL tool as described in section 2.1.

3. Results of climate impact

The climate impact results of the traditionally built preschool, Grönskan and examples of results from the early design phase of Hoppet are presented in this section.

3.1. Results – Climate impact assessment of a reference building

The results from the calculation of Grönskan show that the climate impact of the preschool is about 390 kg CO_2-eq per m^2 gross area (A1-A3 and A5.1). This is in line with results from previous studies [10].

Framework, foundation and frame supplements together represent three quarters of the total climate impact, see Figure 3. The major part can be allocated to the framework.

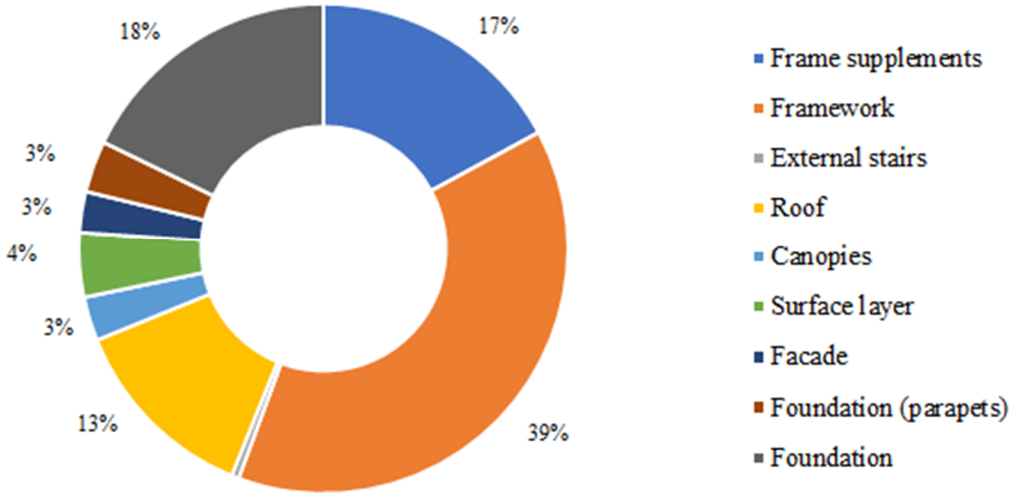

Figure 3. Climate impact of construction components in Grönskan (A1-A3 and A5.1).

When dividing the climate impact into different material groups, one third of the climate impact can be allocated to steel. Insulation and concrete amount to 20 %, respectively and building boards is the fourth largest contributor with about 10 % of the climate impact.

3.2. Results - Climate impact assessment in the early design phase of Hoppet

In the early design phase of Hoppet, climate impacts have been calculated for different alternatives of building elements. Results for foundation and inner walls are found below.

As shown in Figure 3, the foundation is responsible for a large part of the total climate impact of a preschool. An example of calculated climate impact for three different foundation system alternatives for Hoppet are presented in Figure 4. The alternatives are:

A. Concrete slab based on slag/fly ash concrete with reduced climate impact
B. Building elements based on a steel frame and cellular glass insulation
C. Traditional heated foundation with cross-laminated timber beams

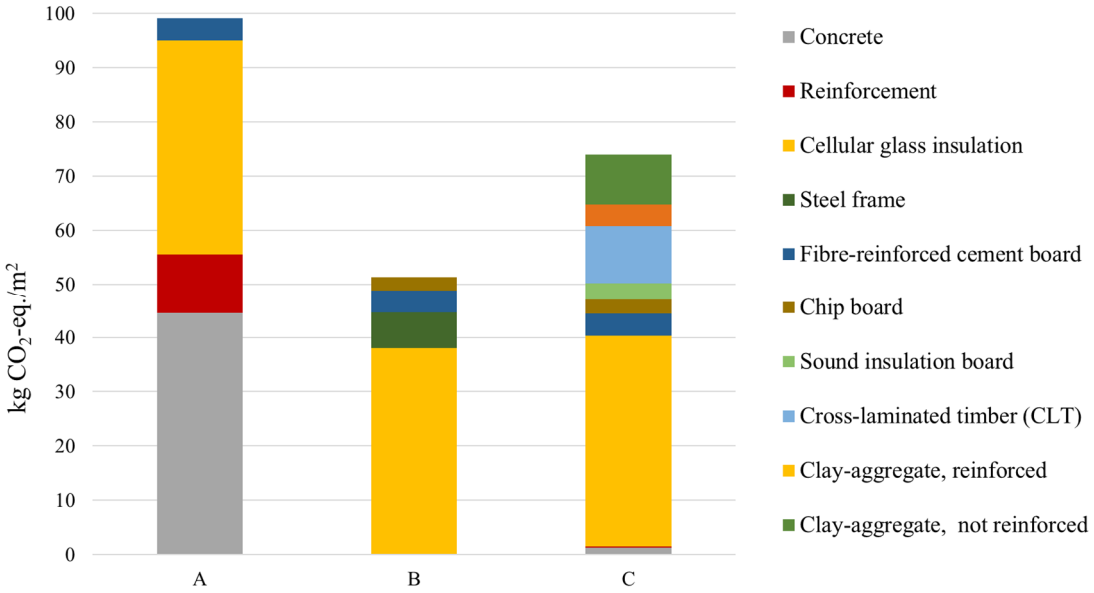

Figure 4. Calculated climate impact (kg CO_2-eq/m^2 gross area) for three foundation alternatives.

As shown in Figure 4, alternative B corresponds to the lowest climate impact for the materials used and has thus been chosen as foundation system for Hoppet. In the future, an increased share of recycled material as well as a shift to fossil-free energy used in the production of cellular glass insulation and steel give the potential for even further reduction of climate impact for alternative B.

For inner walls four alternatives have been designed and analysed. The climate impacts of the different alternatives are presented in Figure 5. The analysed alternatives are:

A. Cross-laminated timber (CLT) in double layers and cellulose insulation
B. Prefabricated walls with wooden beams, cellulose insulation and gypsum
C. CLT in combination with wooden beams, cellulose insulation and gypsum
D. CLT in combination with wooden beams, cellulose insulation and chip board

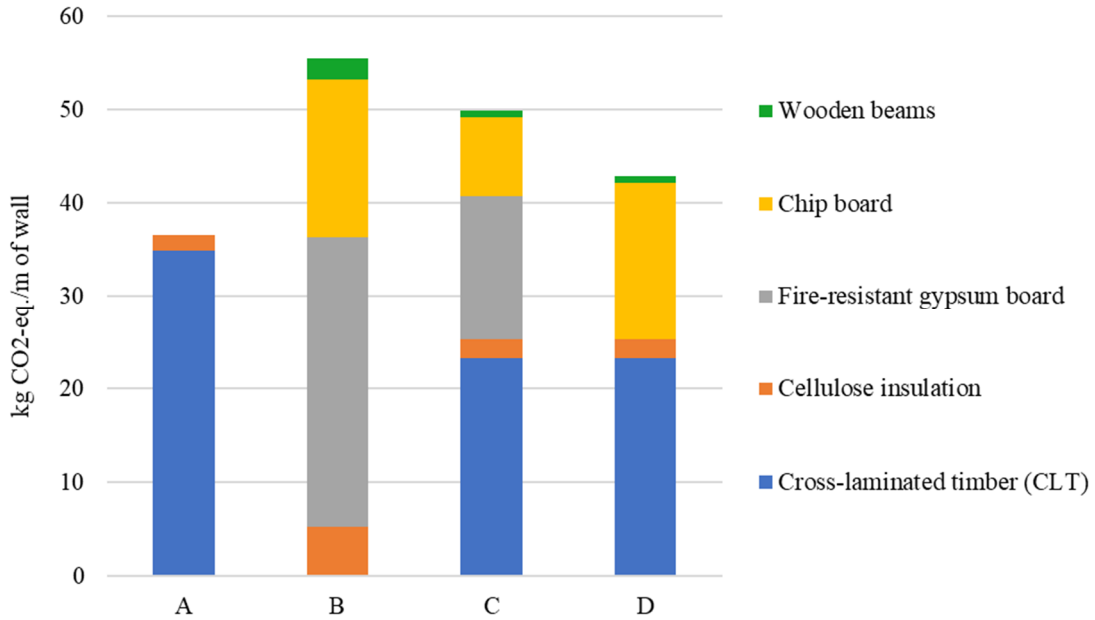

Figure 5. Calculated climate impact (kg CO_2-eq/m of wall) for four inner walls alternatives.

The different rooms in the preschool have different applications and usages and consequently different requirements such as fire-resistance, sound reduction, moisture etc. For Hoppet, different inner wall alternatives (B-D) have been chosen in line with the requirements of the connecting rooms.
Alternative A has not been chosen due to high costs. Unfortunately, the cellulose insulation had to be replaced by mineral insulation due to strict requirements for fire-protection in the neighbourhood. Traditional glass wool has a six times higher climate impact than the cellulose alternative. However, Hoppet is in contact with companies producing glass wool using cleaner energy which will lower the impact of the replacement.

4. Strategies for fossil-free construction, ongoing and future work

When investigating possibilities for replacing construction materials, the project found a sparse selection of fossil-free building product available on the market. Initial calculations showed that further measures are needed to reduce the climate impact. The following strategies for fossil-free construction were identified within the project Hoppet:

- Biobased building products
- Reused and recycled building products
- Exclude and minimize usage of materials
- Fossil-free construction site
- Requirements for building products from a life cycle perspective

These strategies are similar to results from case studies within the field of fossil-free construction [11]. For Hoppet, decisions are made on a case by case basis, evaluating product by product to include the potential for a product to be climate neutral in a long-term perspective. For some product groups, the fossil content can be the most challenging to replace. In that case it is most important to stimulate the development of a biobased alternative. For other products it might be the long transportation distances that have the largest climate impact. For those products it would make sense to promote them by purchasing them, resulting in stimulation of start-up of production sites closer to Gothenburg. The aim in Hoppet is to always choose products where all steps are fossil-free and have the lowest possible climate impact, but when it is not possible to find such products the project aims to promote products with the possibility to be climate neutral in the future.

The benchmark is that the solutions, systems, products and materials we choose should also meet all our standard requirements. The City's Technical Requirements and Instructions for construction exist to ensure poison free environments, energy efficiency, moisture proofing, good indoor environment and the ability to efficiently manage and operate the properties. If a fossil-free solution would contradict any of those requirements, there will be a discussion with the technical specialists on how to proceed.

Further research and development is needed to enable the transition to a fossil-free construction sector. Therefore, Hoppet has initiated and participates in several research and development projects.

Hoppet has been granted funding from EU Interreg for the research project Scandinavian Sustainable Circular Construction (S2C). The aim of the project is, in addition to the strategies above, to introduce fossil-free furnishing and education in the Hoppet building and to share experiences with other Scandinavian projects. [12]

4.1. Biobased building products

Replacing fossil-based building products with new and existing biobased products is crucial to reduce the climate impact in the building sector. Hoppet tries to promote and highlight such initiatives and initiate research when needed.

For the early design stage of Hoppet, wood elements are chosen for load bearing structures in interior walls, beams and roof. Pipes made from biobased plastics and biobased building boards are other alternatives that are under discussion. Hempcrete is planned for one of the complementary buildings for Hoppet.

During spring 2019 the master thesis project "Climate impact from wooden construction techniques" analyzed climate impact and resource issues related to alternative wooden constructions. A comparative

life cycle assessment indicated the lowest climate impact for load-bearing walls of cross-laminated wood and for floor structures of lightweight beam. The result further indicates that it is mainly the insulation and gypsum that contribute to the environmental impact of the structures. [13]

A concrete foundation is usually a large part of a building´s climate impact. In the research project Wood foundation, the possibilities for industrialized production of wood foundations was investigated and the technical performance was evaluated. The result of the project showed that it is possible to compete with traditional methods when optimizing the design. [14]

Today, there are uncertainties regarding under which circumstances biobased plastics are socially and environmentally sustainable alternatives to traditional fossil-based plastics. The research project "Policy for sustainable bio-plastics" aims to create possibilities and guidance for sustainable decisions made by organizations which manufactures, contracts or uses biobased plastics. [15]

4.2. Reused and recycled building products

Reused and recycled products have a great potential to replace products made from virgin raw material. Even though Hoppet aims to be a fossil-free preschool, products with reused or recycled fossil materials will be allowed. It is important to create recycling methods and logistics systems that can enable circularity both for fossil materials and future biobased materials.

For the early design stage of Hoppet, for example reused cable ladders, acoustic boards and furniture are included in the design. Another option being investigated is to reuse hollow core slabs from disassembled buildings as foundation for the complementary buildings. Reused brick stones and roof tiles are an interesting alternative for one of the complementary buildings.

The research project Circularity Index has the aim of increasing the use of circular materials. The goal of the project is to develop a new tool, which will contribute to reducing both climate and environmental impact in construction projects and in the design stage. The project started in January 2019 and will continue for one and a half years. [16]

Hoppet is engaged in the research project Re:Pipe, which aims to recycle plastic material from old pipes or installation waste into new pipes. Funding for two years was granted from the Swedish Energy Agency in February 2019. Currently installation waste is collected with the goal of producing drainpipes and cable protection pipes for Hoppet. [17]

The ReCirculate project was initiated to develop new techniques to build our cities and minimizing the extraction of new material. ReCirculate aims to explore innovative ways of reusing materials and products from demolition and by developing new products with "waste clay" as a raw material. Funding for three years was granted from Viable Cities in November 2019. [18]

4.3. Exclude and minimize usage of materials

There is a large potential in minimizing and excluding materials with fossil content or high climate impact. This is a relatively easy approach, possible to apply for any construction project, which in many cases also saves money and decrease emissions from transports.

For the early design stage of Hoppet, many measures have been discussed. Together with the preschool management, the amount of installed material has been minimized, for example toilet groups, radiators, sinks, electrical sockets and cables. Minimizing the amount of waste during installation is another area in focus.

4.4. Fossil-free construction site

In order to speed up the construction sector's conversion to not only fossil-free, but also emission-free (electric or hydrogen-powered) equipment, Hoppet is involved in the project "Emission-free building and construction sites". It is a collaboration project between partners within Gothenburg City and Business Region Göteborg and aims at mapping the current situation, starting up a dialogue with the industry and developing guidelines for procurement requirements. A study visit to an emission-free construction site in Oslo has been arranged for exchange of experience.

4.5. Requirements for building products from a life cycle perspective

The results from the climate impact of Grönskan show that it is vital to promote products with low climate impact in a life cycle perspective. A public organization, as The City, can set demands in the public procurement process and request data for greenhouse gas emissions verified by an EPD or similar. For transportation of building products, fossil-free alternatives using biofuels or electricity will be required.

5. Concluding discussion

The assignment for Hoppet is to build a fossil-free and climate neutral building. After searching the market for fossil-free and climate neutral building products, the conclusion is that today it would be impossible to exchange all 200-300 building products in a traditional preschool to fossil-free and climate neutral alternatives. Besides scouting for new materials and products, our work has been initiating research projects and trying to inspire other actors and building owners to demand fossil-free and climate neutral building products. Fortunately, we have also found many companies that are starting to decrease their climate impact and to convert their products using fossil-free or recycled materials. All promising, new and old products are evaluated and conscious decisions of what to use in Hoppet are made.

The task is highly challenging, but in close collaboration with experts, researchers, innovators, entrepreneurs, suppliers and decision-makers we think it is possible to build fossil-free and fulfill the *UN Sustainable Development Goal no 13 - Climate Action*. Maybe not for the first preschool, but in a long-time perspective. To inspire change and make a progressive development, an interest and understanding of the importance of fossil-free materials and methods needs to be created in all stakeholders in the construction business. Hoppet, as the first fossil-free demonstration project is an important part of this progress.

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