Master's thesis

Environmental science

Material choices for the building frame

Effects on the accomplishment of the Sustainable Development Goals' targets

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Abstract

Potential synergy effects and conflicts, so-called interactions, between a climate action that aims to mitigate the climate impact and five targets of the Sustainable Development Goals are identified in this study. The climate action is *Conscious material choices for the frame,* and the materials assessed are climate improved concrete and domestic wood. Standard concrete is used as the business as usual scenario. A pre-school building is used as an example building to demonstrate the difference in the climate impact of a frame made from the two materials assessed in the study. Life cycle assessments (LCA) of the frames shows that the domestic wood frame has a lower climate impact than the climate improved concrete frame.

Two methods are used in this study. The first method is making an LCA for transportation of the materials assessed to see the environmental impact, and there is one scenario for each material where the transportation method is by a truck and one that is by train. The second method used for the study is a goal interaction scoring-method from "A draft framework for understanding SDG interactions" by Nilsson et al. (2016) that gives the interactions a score based on specific criteria. The scores are visualised in a colour coordinated matrix. The interactions generate synergies if the sums of the scores in the matrix are positive and will likely help accomplish the target. If the sums of the scores in the matrix are negative, it indicates that there are conflicts that could endanger the possibilities to reach the target.

LCA of the transport scenarios shows that when the transportation distance is long, the climate impact is lowest when transporting as much as possible of the materials by train. Transporting the domestic wood for the frame by train (for longer distances) has a lower climate impact than transporting the climate improved concrete. For shorter distances, there is not a significant difference between transportation by truck or by train. The climate improved concrete gets score 0, meaning that there are neither positive nor negative interactions for the chosen material for the frame. The domestic wood gets the score +8, which indicates that there are synergies. Both the climate improved concrete and the domestic wood should not interfere with the accomplishment of the Sustainable Development Goal's targets. However, the domestic wood for the frame generates more synergies and by choosing the domestic wooden frame for a building using a train as a transportation of the material when possible has the lowest environmental impact of the assessed materials for the frame.

Keywords

Concrete frame, wooden frame, building frame, Sustainable Development Goals, synergy effects, mitigation, adaptation, life cycle analysis, LCA

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1 Introduction

In October 2018, The Intergovernmental Panel on Climate Change (IPCC) issued a special report on the impacts of global warming of 1,5° C, the SR15. Previous to 2018, the IPCC has focused on estimations on possible impacts due to global warming if the average temperature rises by 2° C. However, the SR15 shows that a large number of the impacts due to climate change will show already at global warming of 1,5° C (United Nations, 2020a). Limiting global warming to 1,5° C instead of 2° C benefits both people and ecosystems as well as ensuring a more sustainable society. Providing a more sustainable society does, on the other hand, require rapid, abiding and unprecedented changes in all aspects and levels of society (United Nations, 2020a). The United Nations have worked out a universal plan, the 2030 Agenda for Sustainable Development, for achieving sustainability with the three dimensions of sustainable development including the environmental, social and economic dimension. The Sustainable Development Goals (SDGs) are 17 goals within the agenda that interlink the three dimensions to achieve sustainable development for all by the year 2030 (United Nations, 2020b).

According to Boverket's (Sweden's National Board of Housing, Building and Planning) environmental indicators, the environmental impact caused by the building sector in Sweden is increasing. In the year 2017, it represented 19% of Sweden's greenhouse gas emissions for both construction and operation (Boverket, 2020a). In 2016, greenhouse gas emissions from the Swedish building sector represented 20% of the national emissions, an increase in import explains the decrease compared to the number from 2017. Therefore, in addition to the domestic environmental impact from the Swedish building sector, the sector also contributes to emissions in other countries by import (Boverket, 2020b).

The environmental impact of energy use of buildings is a field that is well discussed and relatively well explored. However, the environmental impact from the building process, the so-called cradle-to-gate phase (including material extraction, manufacturing of building material, transports and building site production), is not as well explored (Liljenström et al., 2015). A report from Sveriges Byggindustrier in 2018 regarding decreasing the environmental impact from new buildings, where five different building constructions are assessed, concludes that the production and construction phase has a significant environmental impact seen from a life cycle perspective of buildings (Erlandsson et al., 2018).

Boverket recognises the importance of increased awareness for the environmental impact related to choices made at different stages of building and construction (Boverket, 2020a), in other words, there is a need for awareness within the Swedish building sector when talking about the environmental impact of used products. Therefore, significant efforts are required to fulfil the Swedish climate goal and comply with the Paris Agreement (Boverket, 2020a). Since the building sector plays a substantial role in Sweden’s environmental work, climate change mitigation and adaptation within the sector is important for Sweden’s contribution to tackle climate change on a global level (Boverket, 2020a).

Fastighet, Umeå kommun (local premises department, Umeå municipality) and Göteborgs lokalförvaltning, Göteborgs stad (local premises department, Göteborg municipality) in Sweden, from here on referred to as Umeå and Göteborg unless anything else is specified, cooperate on various areas within the field of building and construction. Umeå and Göteborg have proposed a climate action* for mitigation and adaptation within the building sector that aims to reduce the contribution to atmospheric CO_2. The climate action is making a *Conscious material choice for the frame* of a building. A pre-school building in Umeå is used as an example building, where using standard concrete for the frame is the business as usual (BAU) scenario. There are two climate actions, using climate improved concrete for the frame and using wood for the frame. The climate action effects on five targets of five of the United Nations’ Sustainable Development Goals, the SDGs, (United Nations, 2020c) is to be analysed in this study by using a comparative analysis method by Nilsson et al. (2016).

**The climate action* Conscious material choice for the frame *is not to be confused with Sustainable Development Goal number 13 called* Climate action.

1.1 Purpose and research question

1.1.1 Purpose

The purpose of the study is to identify potential synergy effects and conflicts, so-called interactions, between the climate action and five targets of the SDGs. Identification is made by analysing the environmental impact and potential for mitigation and adaption of the climate action *Conscious material choice for the building* *frame*. In the long-term, the purpose of the study will help to avoid negative interactions with the goal accomplishments of the SDGs and the climate action.

This study should answer the research question:

- How is a building with a climate improved concrete frame or domestic wood frame, respectively, contributing to the accomplishment of the Sustainable Development Goal targets?

1.1.2 Scope

The study has a national perspective and is limited to the environmental impact of material use in the Swedish building sector. The study is limited to the production- and transportation phase of LCA (A1-A4). Climate action effects on Sustainable Development Goals' targets number 9.4, 12.7, 13.2, 15.2 and 17.14 are assessed. There are no economic calculations or construction time included in this study.

2 Background

2.1 Mitigation and adaptation

Carbon dioxide (CO_2) emission is the centre of attention when talking about greenhouse gas emissions (GHGs) and is often viewed as the most crucial GHG (Middleton, 2013, p 245). The most significant source of anthropogenically caused additions to the increasing level of atmospheric CO_2 is the burning of fossil fuels (Middleton, 2013, p 245). It is important to note that factors like cement manufacturing, land use and deforestation also are anthropogenic factors that contribute to the addition of atmospheric CO_2. When looking at the global carbon dioxide emission rates from fossil fuel combustion and cement manufacturing, it shows that these two alone make up more than 75 % of the increased atmospheric CO_2 level since the pre-industrial times. Europe, together with North America, is the largest source of industrial fossil fuel combustion and cement manufacturing (Middleton, 2013, p 245).

The policy responses to climate change due to global warming, in broad terms, consists of two categories of responses, mitigation or adaptation (Middleton, 2013, p 263). In general, mitigation aims to prevent change and adaptation is more focused on adapting to the new conditions that come with change (Middleton, 2013, p 263). When speaking of climate change, mitigation and adaptation are given more specific definitions and are described as:

- *Mitigation* - the rate of climate change is reduced by managing the drivers of climate change (Middleton, 2013, p 263).
- *Adaptation* - adjusting to new or expected climate and its effects to moderate harm, or take advantage of beneficial opportunities (Middleton, Nick, 2013).

When mitigation and adaptation are put together, they complement each other leading to a possible reduced risk of climate change impact on societal, environmental as well as the economic level. However, mitigation and adaptation effects can vary over time and space (Global casino, p 236). Mitigation tends to have more global benefits, but time lags when it comes to the effects of the mitigation action. Adaptation, on the other hand, have local to regional benefits, and the effect of climate action is more immediate compared to benefits connected to mitigation (Middleton, Nick, 2013).

The climate action *Conscious material choice for the frame* is related to the material used for the frame of the building. The frame is a part of the building that can be built by using different materials and is chosen as a climate action to compare the interactions of the material choice and the SDG targets. Umeå and Göteborg are both responsible for buildings constructed and owned by the municipality. In the work of climate change mitigation, both municipalities have developed so-called climate actions on their own based on their local environmental goals. The climate action *Conscious material choice for the frame* that the municipalities have in common is the climate action that is analysed in this study.

2.2 The Paris Agreement

At the climate conference in Paris in December 2015, COP21, a *"first-ever universal, legally binding global climate change agreement"* was adopted (European Commission, 2020).
On the 4th of November 2016, the so-called Paris Agreement (PA) was put into force (United Nations Climate Change, 2020). The PA is under the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations Climate Change, 2020). The PA aims to make a global response to the threat of climate

change stronger. The strengthen global response will be made possible by keeping the global temperature rise well below 2°C during this century compared to pre-industrial levels. This is made possible through countries in the PA reporting and improving their efforts for climate change mitigation and adaptation by so-called national determined contributions (NDCs) (Johannesdottír, Adalheidur, 2016). Efforts should also be made to keep the temperature increase limit to 1,5°C. As a consequence, the PA will then lead to countries strengthening their ability to deal with climate change impacts (United Nations Climate Change, 2020).

2.3 The 2030 Agenda for Sustainable Development

The 2030 Agenda for Sustainable Development (Agenda 2030) is the UN agenda for achieving sustainable development worldwide by the year 2030. Agenda 2030 was adopted in September 2015 by Heads of State and Government at a UN summit (European Commission Environment, 2019) and has 17 underlying SDGs that includes in total 169 targets. The SDGs is under United Nations General Assembly (UNGA) (Nordic Council of Ministers, 2017). Together the SDGs form a commitment to reach the goal set for 2030 without leaving anyone behind. At the same time, the SDGs set a shared global vision for sustainable development (European Commission Environment, 2019) as well as highlight the need for climate action in terms of climate change mitigation, adaptation and resilience with a synergistic** approach (Nordic Council of Ministers, 2017). The SDGs, see Appendix A, are interconnected and address the global challenges that humanity must face to achieve a more sustainable future for everyone living on this planet (United Nations, 2020c).

***A synergy effect is when the cooperation of two or more effects generates an effect where the sum is greater compared to the effects working on their own. A synergy effect can be positive or negative* (Nationalencyklopedin, 2020).

2.4 Response to climate change in Sweden

Sweden has an integrated response to the threat of climate change in different areas and levels of society. The following are relevant to this study.

2.4.1 The Swedish climate policy framework

In 2017, Sweden adopted a climate policy framework which aims to, in the long term, make Sweden achieve zero net emissions of greenhouse gases by the year 2045 (Naturvårdsverket, 2019). The climate policy framework consists of three parts: the climate act, the climate goals and, the climate policy council. The climate policy was put into force on the 1st of January 2018 (Naturvårdsverket, 2019). With the new climate policy framework, each government of Sweden must pursue a climate policy and report its progress. The climate policy aims to result in long-term climate goals, and it is also a key component in helping Sweden comply with the Paris Agreement (Regeringskansliet, 2017).

2.4.2 The 16 environmental quality objectives

The 16 environmental quality objectives is Sweden's national implementation of the ecological dimension of the SDGs and in the sustainable development discourse on a national level (Naturvårdsverket, 2020). However, The 16 environmental quality objectives are set for the year 2020 (Naturvårdsverket, 2020) but since Sweden have a climate policy framework, Sweden must pursue working towards sustainable development and Agenda 2030 to comply with the Paris Agreement. The climate action is based on the national environmental goals but the climate action effects on the SDGs, and not the effect on the 16 environmental quality objectives, are analysed in this study.

2.4.3 Local environmental goals

Sweden has environmental goals on a local level that work towards fulfilling the 16 environmental quality objectives, and this applies to both Umeå and Göteborg.

The newest version of Umeå municipality's local environmental goals was decided 24th of February 2020. For the objective "A Good Built Environment" under the section "Environmentally friendly buildings", the big environmental challenge when it comes to building and construction for Umeå is greenhouse gas (GHG) emissions and hazardous chemicals in building products. Environmental impact for buildings is to be measured through Life Cycle Assessments for refurbishment, new, additional as well as re-building for Umeå (Umeå kommun, 2020).

Just like Umeå, Göteborg has local environmental goals where building and construction are categorised under the objective "A Good Built Environment" (Göteborgs stad, 2020). Göteborg's goal is to expand and densify the city's built environment sustainably by the year 2020 (Göteborgs stad, 2020). To reach the sustainability goal by 2035, Göteborg has implemented a climate programme starting in 2014 for the municipality (Göteborgs stad, 2020). Emissions from the construction phase of buildings are highlighted in the climate programme, and it also includes emissions from imported material.

2.4.4 Public procurement

Sweden has a national public procurement strategy that emphasises the need for an environmentally responsible public procurement. According to the National Agency for Public Procurement, the national public procurement strategy can be used as a strategic tool for supporting Sweden's work with the SDGs and Agenda 2030 by using environmental criteria (Ministry of Finance, 2017). The authority also recognises that public procurement can be a driving force for sustainable development and that environmentally aware public procurement should have a life cycle perspective (Ministry of Finance, 2017).

2.5 Response within the Swedish building sector

Boverket (Sweden's National Board of Housing, Building and Planning) is a government authority under the Ministry of Finance. Boverket operates in the fields of housing, building and planning and compiles facts and statistics in Sweden, as well as internationally, to make new policy suggestions. Evaluations and impact assessments of policy initiatives are included in Boverket's work on both a national and regional level. Boverket's main field of activities is analysing the housing market, issuing building regulations and supervising the municipal and county planning (Boverket, 2020c).

2.5.1 Boverket's climate declaration

The government of Sweden aims to impose requirements for climate declarations of new buildings, starting 1st of January 2022 (Boverket, 2020d). The new requirement will apply to developers and require them to submit a climate declaration for the frame of the new building as a step towards reducing the environmental impact (Boverket, 2020d) during the construction phase (Boverket, 2020e). The suggested climate declaration law creates a need to start using the life cycle assessment methodology for identifying and quantifying climate impact related to buildings (Boverket, 2020c). In the life cycle assessment, generic data for the climate declaration is accepted, and the climate declaration will be limited to the cradle-to-gate (A1-A5) phase of the life cycle assessment (Boverket, 2020e). The unit of measure suggested by Boverket for the climate declarations are CO_2e per m^2 (gross area), but at the moment, there are no emission limitations, although Boverket has been assigned by the government of Sweden to develop a future model of the climate declarations for such requirements (Boverket, 2020f).

2.5.2 Life Cycle Assessment

A Life Cycle Assessment (LCA) is an analysis technique and tool with a cradle-to-grave perspective that assesses the environmental impact of a product at different stages of the product's life span (Science Direct, 2020). The cradle-to-grave perspective means that the environmental impacts from the whole lifespan are included in the assessment (Science Direct, 2020). Because of the LCA phase limitation of Boverket's climate declaration, the scope of the study is limited to the same phase when using environmental impact data based on LCAs. The climate declaration is limited to the climate impact during the production and construction phase (Boverket, 2020e), the A1-A4 phase of the LCA, see table 1.

Table 1. The phases of LCA, the figure is translated and revised from Boverket (2020).

Phase	Module	Scope
Production	A1	Raw material extraction
	A2	Transport
	A3	Manufacturing
Construction	A4	Transport
	A5	Construction- and installation process
Use	B1	Use
	B2	Maintenance
	B3	Reparation
	B4	Substitution
	B5	Reconstruction
	B6	Operation, energy
	B7	Operation, water use
End	C1	Demolition
	C2	Transport
	C3	Waste treatment
	C4	Disposal
Benefits and loads outside the system boundary	D	

Boverket suggests several tools of different levels of advancement for LCAs specifically for the building and construction sector, and this allows various requirements of previous knowledge and competence for creating LCAs (Boverket, 2020g). Byggsektorns miljöberäkningsverktyg version 1.0 (BM) is the LCA tool that is used for modelling the transportation scenarios (A4) in this study.

The results of an LCA study allows products to be compared with each other. However, it is important that the methodology of each LCA is the same to make the products comparable (Science Direct, 2020). LCAs of building material are helpful for the building sector because it can help construct buildings with low environmental impact (Boverket, 2020e).

2.6 Building materials for the frame

2.6.1 Concrete frame

Concrete is a material that is commonly used for the frame of buildings in Sweden; 85 % of buildings built in 2018 had concrete frames (SCB, 2018). Sweden produces five to six million m^3 concrete for buildings and infrastructure every year, about 75 % end up being used for the construction of buildings. Climate improved concrete could then lower the CO_2 emissions from concrete with 15 % per year (Svensk Betong, 2017). Concrete consists of cement, water and ballast. The ballast content can vary but is usually sand, gravel and similar products (Kungliga tekniska högskolan, 2012). The cement that is made from clinker is used as a binder for concrete (Svensk Betong, 2017). Concrete is in a liquid state when it is freshly made and is solid when it is hardened, the concrete can, therefore, be shaped using moulds (Kungliga tekniska högskolan, 2012). When the concrete is cast in place, it is delivered to the construction site in its liquid form usually by truck. The concrete can also be delivered as precast blocks which allow longer transportation distances (Betongindustri AB, 2020). Transportation represents between 5-8 % of the CO_2 emissions related to concrete production in Sweden (Svensk Betong, 2017). According to Svensk Betong (2017), the cement clinker production represents 90 % of the CO_2 emissions for concrete from an LCA perspective. The cement clinker is made from powdered limestone and clay that is heated to about 1450 °C, and this process is called calcination. CO_2 emissions from calcination represent 60 % of the total CO_2 emissions from the cement clinker production; the rest (40 %) is traced to the heating process (Svensk Betong, 2017).

2.6.2 Wooden frame

Wooden frames usually consist of glue-laminated timber (GLT) and are most commonly used for supporting constructions, like the building frame (Svenskt Trä, 2018). 13 % of new buildings in Sweden in 2017 was built with a wooden frame, and this is the highest number of new buildings in Sweden with a wooden frame since 2004 (SCB, 2018).

GLT is made from lamina (wood) glued together in industrial processes. Spruce is commonly used as a material for GLT, and therefore also used for wooden frames. The material is renewable in the meaning that it can be reused or recycled (Svenskt Trä, 2018). To dry the wood byproducts are used, this means that biomass is used to dry the GLT to the right moisture content. Using biomass allows less use of electricity for the drying process. The moisture content in GLT at delivery to the construction site is 16 % (Svenskt Trä, 2018).

3 Method

Applied methods in this report are literature studies, data collection from an LCA of an example building (A1-A4), LCA analysis for transportation scenarios (A4) of materials and a comparative method for analysing**.** The literature helped to fulfil the aim of analysing the climate action effects on the SDGs, the so-called interactions. The LCAs for the transportation scenarios are made to see the environmental impact of different transportation distances, and the LCA results were then put together with the research from the literature studies to be able to perform the comparative analysis. The comparative analysing will investigate the connection between the climate action and the targets of the SDGs; this will help to identify synergy effects and conflicts to reach the SDGs.

3.1 Chosen climate action

The climate action analysed in this study is a *Conscious material choice for the frame*. In this study, the example building with a concrete frame using standard concrete is set to be the business as usual scenario. The building materials for the frame that are assessed in this study, concrete and wood, make up two climate actions:

Material choices for the climate action *Conscious material choice for the frame*:

1. Climate improved concrete
2. Domestic wood

3.2 The example building

The example building is a two-story pre-school located in Umeå. An LCA of two types of frames (concrete and wood) for the building has been made by Tyréns AB using the LCA tool *Byggsektorns Miljöberäkningsverktyg version 1.0 (BM)*. The LCA has an A1-A3 perspective. The functional unit for the example building is m^2. The example building has an area of 1080 m^2 (gross area) where both stories are included. The frame includes beams and pillars and the belonging joists and interior walls. For the wooden frame, the beam consists of glue-laminated timber (GLT), and the joists are massive wood of cross-laminated timber (CLT) (Tyréns AB, 2020).

The LCA of the two frames for the example building show that the building with a concrete frame has a higher climate impact compared to the example building with the wooden frame. The environmental impact is counted in global warming potential (GWP), the concrete frame has a GWP of 152 tonne CO_2e, and the wooden frame has a GWP of 43 tonne CO_2e (Tyréns AB, 2020), the total environmental impact for the two frames is found in figure 1.

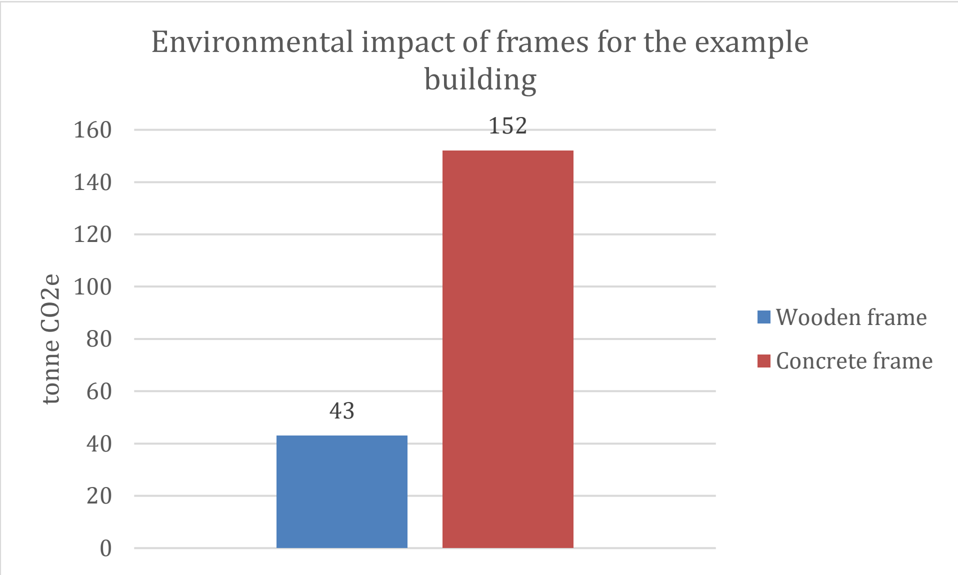


Figure 1. Total environmental impact, (in tonne CO_2e) for the example building, A1-A3, with a wooden frame and a standard concrete frame (Tyréns AB, 2020).

3.2.1 The example building with a concrete frame

The example building with a concrete frame includes concrete for the frame, the interior walls and joists (Tyréns AB, 2020). See table 2 for the amount of material used for the concrete frame when modelled in BM.

Table 2. Building materials and amounts for the example building with a concrete frame.

Building part	**Material**	**Amount [kg]**	**Name of the process in BM**
Frame, steel	Steel pillar	2117	Konstruktionsstål, obelagd (IVL LCR)
Interior wall, concrete	Reinforcement	5165	Högvärdigt armeringsstål, spännarmering (primärstål)
Interior wall, concrete	Concrete	216200	Husbyggnadsbetong (vct 0,68, C25/30)
Concrete joists	Reinforcement	19600	Högvärdigt armeringsstål, spännarmering (primärstål)
Concrete joists	Concrete	575750	Husbyggnadsbetong (vct 0,68, C25/30)

3.2.2 The example building with the wooden frame

The example building with a wooden frame includes GLT for the frame, the interior walls and joists. See table 3 for the amount of material used for the wooden frame when modelled in BM (Tyréns AB, 2020).

Table 3. Building materials and amounts for the example building with a wooden frame.

Building part	**Material**	**Amount [kg]**	**Name of the process in BM**
Frame, GLT	GLT beam and pillar	18900	Limträbalk (IVL LCR)
Frame, GLT	Screws	250	Konstruktionsstål, galvad (IVL LCR)
Frame, GLT	Concrete cast	71	Husbyggnadsbetong (vct 0,68, C25/30)
Interior wall, wood	Gypsum board	10305	Gipsskivor, kartonggipsskivor ospecificerat (IVL LCR)
Interior wall, wood	Wooden stud	3411	Furu/gran, hyvlad & sågad, 473 kg/m^3 u=16% (IVL LCR)
Interior wall, wood	Glass wool	374	Glasull (IVL LCR)
Interior wall, wood	Interior wall, CLT	11571	Korslimmat trä (KL-trä av gran) (IVL LCR)
Joists	CLT	60316	Korslimmat trä (KL-trä av gran) (IVL LCR)
Joists	Rock wool	11707	Stenull (IVL RR)
Joists	Steel stud	5395	Stålreglar (IVL LCR)

3.3 Transportation modelling in BM

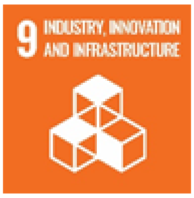
The building material amounts for the example building are taken from a projected two stories pre-school in Umeå (LCA rapport), the pre-school is at the stage of planning at the moment. The functional unit for the example building is m^2. The area of the example building is 1080 m^2 (gross area) for both stories of the pre-school. The frame includes beams and pillars and the belonging joists and interior walls. Transport scenarios have been calculated with data from the example building using the LCA tool Byggsektorns miljöberäkningsvertyg version 1.0 (BM) provided by IVL, Svenska miljöinstitutet (The Swedish Environmental Research Institute) (IVL Swedish Environmental Research Institute, 2020). The climate improved concrete frame is modelled in BM by using the process “Ospecificerad klimatförbättrad husbyggnadsbetong (410 kg bindemedel/m^3)” with the same amount as for the standard concrete. The particular climate improved concrete-process was chosen due to that was the only process available for climate improved concrete in BM. For each process in BM, a mapping quality of how well the data corresponds to the environmental product declaration (EPD) is chosen for the process. The choices for mapping quality are good, neutral or bad. The mapping quality for generic data processes in BM for this study is set to neutral.

The transportation distances are 10 km, 100 km and 1000 km. The particular distances used when modelling in BM are chosen to demonstrate the impact of distances for the transportation phase of LCA. A waste scenario of 5% is included in the LCAs. For each transportation scenario, there is one LCA for the transport of the frame material (concrete or wood) with a truck and one LCA for transport with truck + train.

3.4 Relevant SDGs and associated targets

According to Umeå and Göteborg, all SDGs and associated targets are not relevant for their work in the field right now. Therefore, not all targets are relevant to the climate action in this study. The climate action effects are compared to the, at the moment, most relevant SDG targets for Umeå and Göteborg. The most relevant targets are selected with the support of the SDGs indicators (United Nations, 2020d), see table 4 for the relevant SDGs and the associated targets.

Table 4. The Sustainable Development Goals (United Nations, 2020c).

Symbol	Goal	Relevant target	Target indicator
	**Industry, innovation and infrastructure**	**9.4** By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	**9.4.1** CO_2 emission per unit of value added
	**Responsible consumption and production**	**12.7** Promote public procurement practices that are sustainable, in accordance with national policies and priorities	**12.7.1** Number of countries implementing sustainable public procurement policies and action plans
	**Climate action**	**13.2** Integrate climate change measures into national policies, strategies and planning	**13.2.1** Number of countries that have communicated the establishment or operationalisation of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of

			climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production (including a national adaptation plan, nationally determined contribution, national communication, biennial update report or other)
15 LIFE ON LAND	**Life on land**	**15.2** By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	**15.2.1** Progress towards sustainable forest management
17 PARTNERSHIPS FOR THE GOALS	**Partnership for the goals**	**17.14** Enhance policy coherence for sustainable development	**17.14.1** Number of countries with mechanisms in place to enhance policy coherence of sustainable development

3.4.1 Comparative analysis

To identify and analyse potential synergies and conflicts between the climate actions and the targets of the SDGs a comparative analysis method is used to allow comparison between climate actions and the SDGs, so-called interactions.

The method used for comparative analysing (between the climate actions and the targets of the SDGs) is based on a framework called "A draft framework for understanding SDG interactions" by the International Council for Science (Nilsson et al., 2016). The framework measures the intensity of the interactions on a scale ranging from -3 points (cancelling) to +3 points (indivisible), the scale is called "Goal Interaction Scoring" (Nilsson et al., 2016). The Goal Interaction Scoring scale classification is used in this study, see figure 2. A higher score increases the chance of accomplishing the SDG goal. A lower score increases the risk of not reaching the SDG goal.

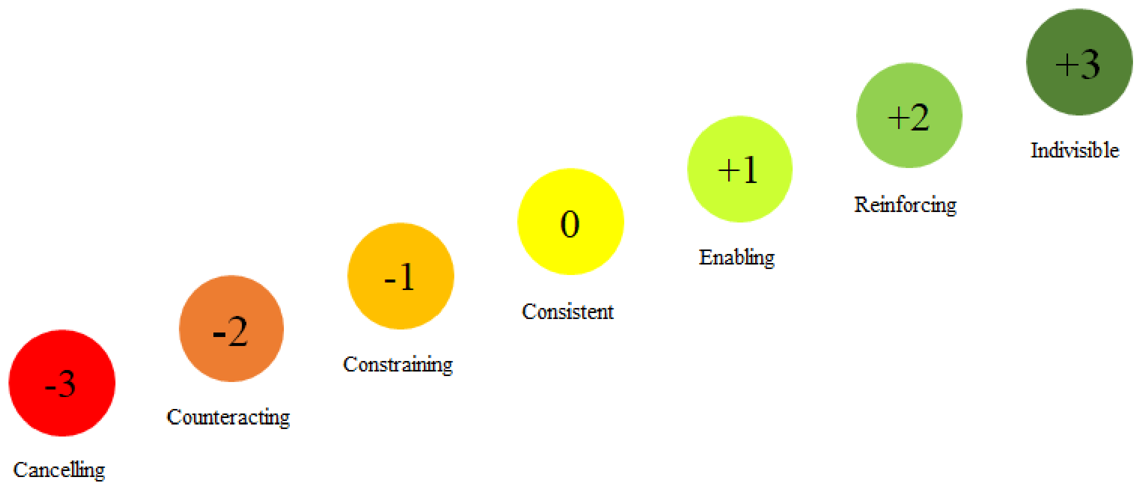


Figure 2. Classification of seven steps, based on the "Goal Interaction Scoring" by Nilsson et al. (2016) used for the interactions between climate actions and the SDGs.

Based on the classification of seven steps, the connections between the climate actions and the SDG target can be analysed and given a certain score. The score is by this based on possible synergies and possible conflicts of the interactions.

The interaction assessment is based on the question "How is the *Sustainable Development Goal target* affected by the *climate action*?", the reversible assessment of the interaction is not investigated.

Assessment criteria

The assessment of the interactions between climate actions and the SDG targets are given a score based on the following criteria:

> **+3** The climate action has the strongest form of positive interaction with the SDG and will fulfil the goal accomplishment of the SDG.
>
> **+2** The climate action creates multiple synergy effects for the SDG.
>
> **+1** The climate action creates a positive synergy effect for the SDG.
>
> **0** The climate action is in a neutral state, neither positive or negative interaction, or there is no significant interaction between the climate action and the SDG.
>
> **-1** The climate action leads to a mild conflict with the SDG due to constraint in the achievement of another.
>
> **-2** The climate action leads to a conflict with the SDG due to constraint in the achievement of another.
>
> **-3** The climate action has the strongest form of negative interaction with the SDG and will not fulfil the goal accomplishment of the SDG.

The result of the different interactions is then visualised in a matrix, see section 3.3, for an example of the matrix.

3.4.2 Matrix

The result of the interactions is put in a matrix. The results are colour coordinated, using the same colours as in figure 3, to make them easier to spot. The SDG targets are listed on the horizontal axis, and the business as usual (BAU) scenario and the climate actions are listed on the vertical axis.

Explanation of the business as usual scenario and the climate actions on the vertical axis:

- BAU = standards concrete for the frame
- C1 = climate improved concrete for the frame
- C2 = domestic wood for the frame

The matrix, see figure 3, is used to visualise the results of the interactions. The total scores for the interactions are summed up, the interactions between the climate action and the SDG target are found in the sum to the right. If the total sum of a climate action is positive, it indicates that the effects on the SDG targets are generating synergies which can be beneficial for reaching the SDGs in the long term. If the total sum of a climate action is negative, it indicates that there are conflicts of the interactions which can make it more challenging to reach the SDGs in the long term.

	Target 9.4	**Target 12.7**	**Target 13.2**	**Target 15.2**	**Target 17.14**	**Σ**
BAU						
C 1						
C 2						

Figure 3. Template of the matrix.

4 Results

4.1 Transportation modelling in BM

The LCAs of the A1-A4 phases modelling in BM have given the total environmental impact for A1-A4 for different transportation methods, these are found in tables 5-8.

Table 5. Climate improved concrete, environmental impact per transport method A1-A4, transported by truck.

Transportation method	**Transport distance [km]**	**Environmental impact [tonne CO_2e]**
Truck	10	142
Truck	100	149
Truck	1000	215

Table 6. Climate improved concrete, environmental impact per transport method A1-A4, transported by train.

Transportation method	**Transport distance [km]**	**Environmental impact [tonne CO_2e]**
Train	10	141
Train	100	142
Train	1000	150

Table 7. Domestic wood, environmental impact per transport scenario A1-A4, transported by truck.

Transportation method	**Transport distance [km]**	**Environmental impact [tonne CO_2e]**
Truck	10	40
Truck	100	41
Truck	1000	51

Table 8. Domestic wood, environmental impact per transport scenario A1-A4, transported by train.

Transportation method	**Transport distance [km]**	**Environmental impact [tonne CO_2e]**
Train	10	40
Train	100	40
Train	1000	41

The modelling in BM also gave the results for the phases A1-A3, A1-A4 and A4 separately, see figures 4-7.

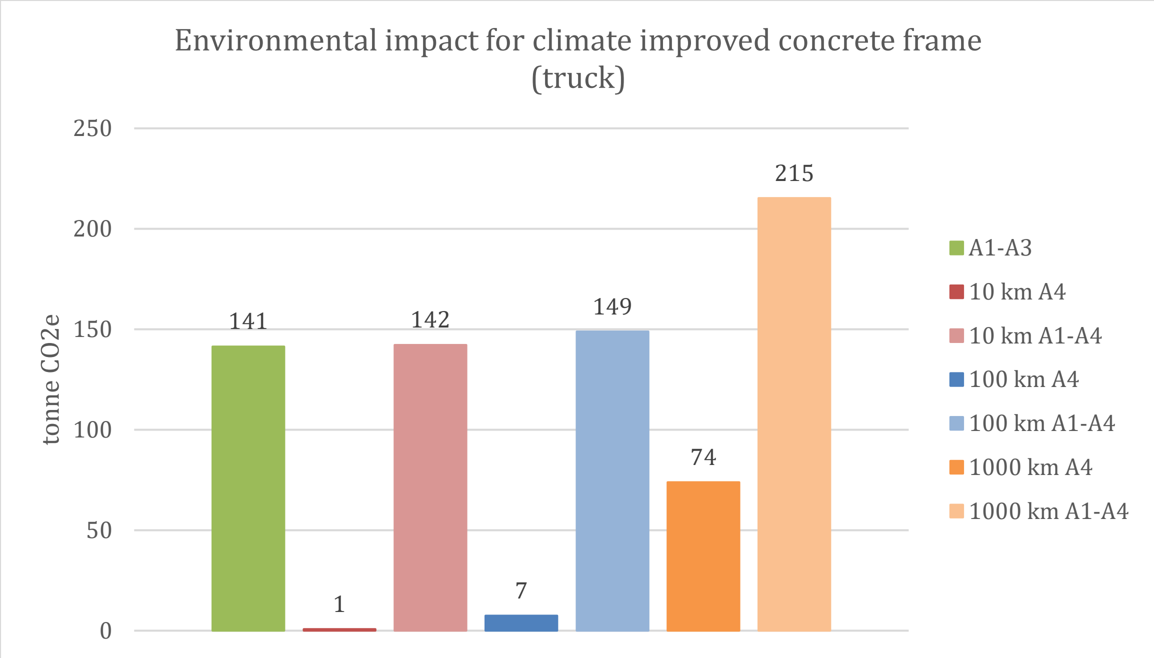


Figure 4. The environmental impact from the different A1-A4 phases for the climate improved concrete frames, and the transportation method is by truck.

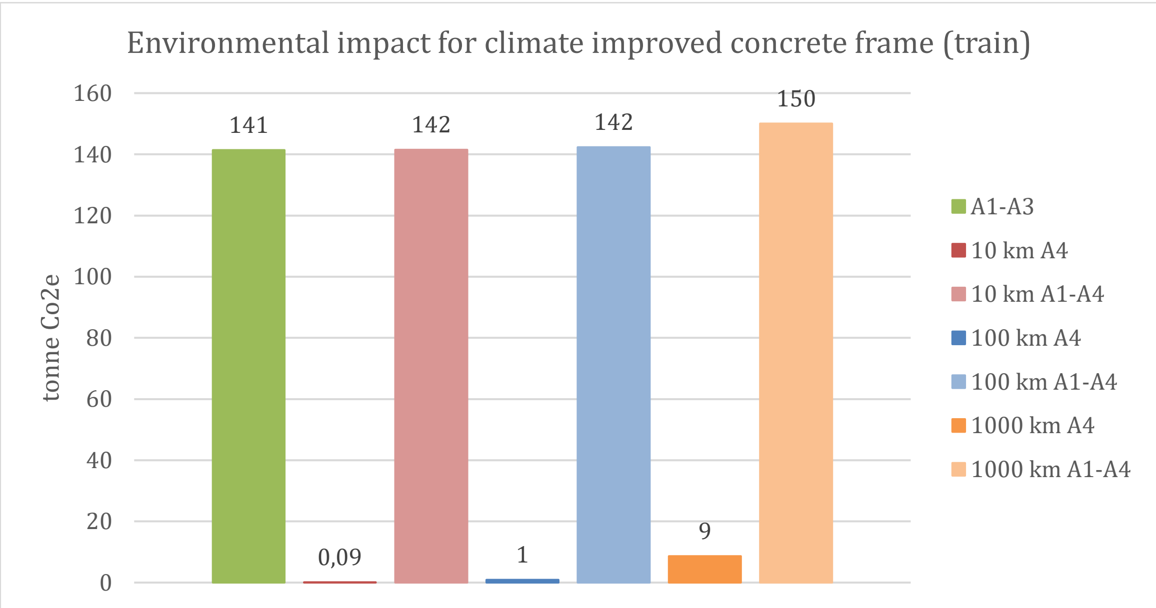


Figure 5. The environmental impact from the different A1-A4 phases for the climate improved concrete frames, and the transportation method is by train.

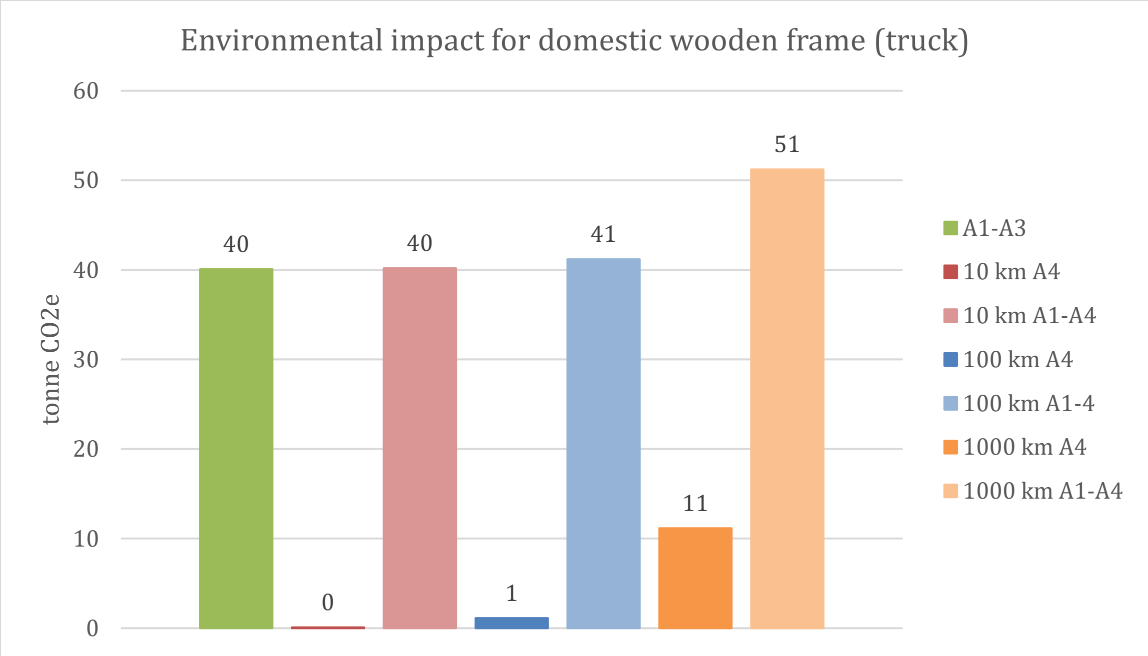


Figure 6. The environmental impact from the different A1-A4 for the domestic wooden frames and the transportation method is by truck.

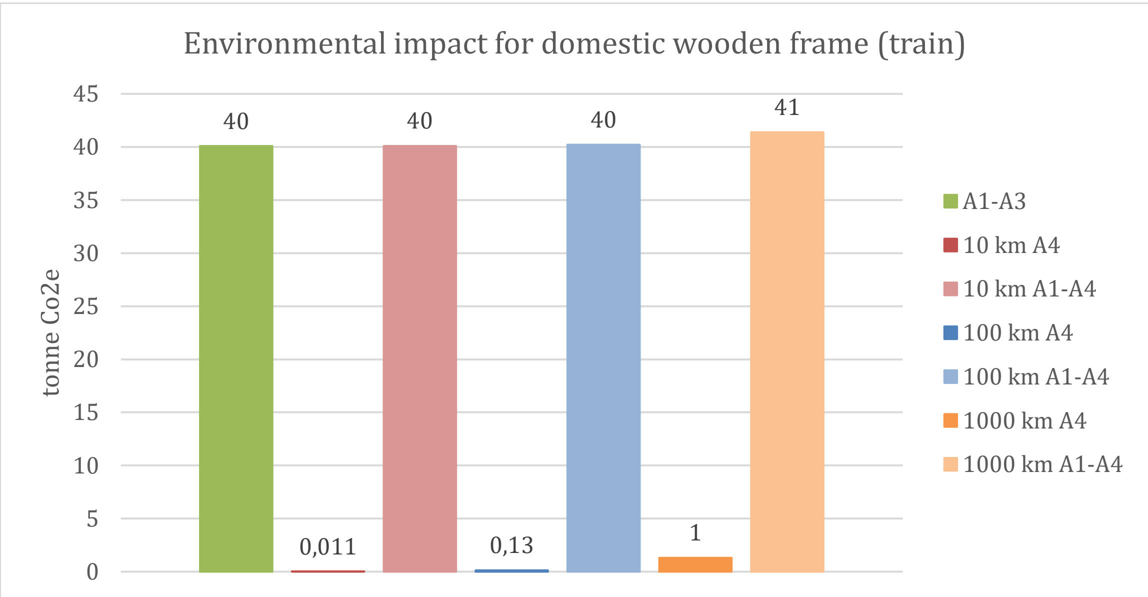


Figure 7. The environmental impact from the different A1-A4 for the domestic wooden frames and the transportation method is by train.

The results for the modelling in BM of the A1-A4 show that transportation of concrete with a truck has a higher environmental impact than transportation with train, the same situation applies to transportation of wood. The highest percentual increase in environmental impact for the A1-A4 phase is at the longest transportation distance, and this applies to both transportation of concrete and wood. The difference [%] for the A1-A4 are found in tables 9-10.

Table 9. Comparison of the environmental impact, A1-A4 phase for concrete.

Distance [km]	**A1-A4 truck [tonne CO_2e]**	**A1-A4 train [tonne CO_2e]**	**Difference [tonne CO_2e]**	**Difference truck and train [%]**
10	142	141	1	0,7
100	149	142	7	4,7
1000	215	150	65	30,2

Table 10. Comparison of the environmental impact, A1-A4 phase for domestic wood.

Distance [km]	**A1-A4 truck [tonne CO_2e]**	**A1-A4 train [tonne CO_2e]**	**Difference [tonne CO_2e]**	**Difference truck and train [%]**
10	40	40	0	0
100	42	40	2	4,8
1000	51	41	10	19,7

Looking at the percentual difference for the transportation methods for the A1-A4 phases, the greatest difference in climate impact from the assessed materials occur at longer transportation distances for both climate improved concrete and domestic wood.

4.2 Goal interaction scoring

4.2.1 Goal 9, Industry innovation and infrastructure

SDG target 9.4: By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.

How is the SDG target 9.4 affected by climate improved concrete for the frame?
Lower CO_2e emissions when using climate improved concrete for the frame compared to standard concrete. CO_2e emissions are highly dependent on the concrete recipe, improving concrete recipes and using green technology in the product enables the use of the product in greater extent. Adapting to climate improved concrete in the building sector can help decrease emissions during the A1-A3 phase but is dependent on byproducts from other industries, like fly ash, which

is counteracting. Incorporation CCS/CCR technology in the concrete industry enables greater use and development of new technology in the field.
BAU score: -2, C1 score: -1

How is the SDG target 9.4 affected by domestic wood for the frame?
A wooden frame has a lower environmental impact compared to a concrete frame. Lowering emissions from the construction of the building frame by using domestic wood makes a wooden frame a more sustainable choice than a concrete frame for the A1-A3 phase. A wooden frame should then benefit sustainability in the building sector. Building a wooden frame with domestic wood from nearby areas the transportation is more efficient, that together with using a transportation method that has a lower environmental impact, train instead of truck for longer distances, to the extent that is possible, generates synergies for the industry and makes the climate action reinforcing.
C2 score: +2

4.2.2 Goal 12, Responsible consumption and production

SDG target 12.7: Promote public procurement practices that are sustainable, in accordance with national policies and priorities.

How is the SDG target 12.7 affected by climate improved concrete or domestic wood for the frame?
Sweden promotes public procurement that the National Public Procurement Authority recognises as a possible driving force for sustainable development. Public procurement with a lifecycle perspective enables environmentally aware public procurement. Criteria and requirements on public procurement, like asking for LCAs of the concrete and wooden frame for buildings to be built, conscious choices can be made that are in line with Sweden taking a step towards accomplishing the SDG 12.7 target. Since the domestic wood frame has a lower climate impact than the climate improved concrete frame, using LCAs to promote the public procurement of wooden frames lowers the climate impact more than the climate improved concrete frame.
BAU score: -1, C1 score: +1, C2 score: +2

4.2.3 Goal 13, Climate action

SDG 13.2 Integrate climate change measures into national policies, strategies and planning.

How is the SDG target 13.2 affected by climate improved concrete for the frame?
Climate improved concrete for the frame is an adaption that lowers CO_2-emissions and mitigates climate change in line with national policies like the climate policy framework. Climate improved concrete for the frame help reaching the SDG 13.2 target, not as much as a wooden frame would lower the environmental impact though. Using alternative binders based on fossil material during the production of the clinker, like fly ash, is cancelling and does not necessarily adverse impact of climate change or foster climate resilience.
BAU score: -2, C1 score: -1

How is the SDG target 13.2 affected by domestic wood for the frame?
Choosing domestic wood for the frame based on LCA results can integrate both planning tools like Boverket's climate declaration and motivate requirements in public procurement to lower the environmental impact of the building frame. Using strategies and planning tools like public procurement and climate declarations of buildings integrates climate change measures and communicates policies like Sweden's climate policy framework and 16 environmental quality objectives.
C2 score: + 2

4.2.4 Goal 15, Life on land

SDG 15.2: By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

How is the SDG target 15.2 affected by climate improved concrete for the frame?
There is no clear interaction between the target and the BAU and the climate improved concrete for the frame. Emissions from the production of the climate improved concrete could contribute to the acidification of forests which could have an impact on ecosystems.
BAU score: -1, C1 score: -1

How is the SDG 15.2 affected by domestic wood for the frame?
Forests in Sweden has a good status, and the harvest rate does not exceed the growth rate, this enables using wood for frames of buildings. A wooden frame has a lower environmental impact than a concrete frame and increasing the rate of buildings with a wooden frame in Sweden is reinforcing for as long as the harvest rate higher than the growth rate. This can then help to adapt to an environmentally friendlier way of constructing buildings and help mitigate climate change. Extended use of domestic wood for building frames could have a greater impact on ecosystems if more significant amounts of trees are harvested.
C2 score: 0

4.2.5 Goal 17, Partnership for the goals

SDG 17.14: Enhance policy coherence for sustainable development.

How is the SDG 17.14 affected by climate improved concrete or domestic wood for the frame?
Sweden has mechanisms in place for the coherence of sustainable development through the 16 environmental quality objectives which support the Agenda 2030. On a local level, requirements in public procurement enable lowering the environmental impact from material for the frame, like requirements for the transportation method. Boverket's climate declaration is another step towards an overview of the environmental impact of different frames for the building sector and can be applied to frames made of climate improved concrete and domestic wood. These mechanisms could enable accomplishment of the SDG target 17.14.
BAU score: 0, C1 score: +2, C2 score: +2

4.2.6 Matrix

The result of the scoring from the comparative analysis put in a matrix, see figure 8, to make the synergies and conflict of the interactions visible. The BAU scenario is used as a reference.

	Target 9.4	Target 12.7	Target 13.2	Target 15.2	Target 17.14	Σ
BAU	-2	-1	-2	-1	0	**-6**
C 1	-1	+1	-1	-1	+2	**0**
C 2	+2	+2	+2	0	+2	**+8**

Figure 8. The matrix with the scoring from the comparative analysis. The sum of the scores for each climate action is shown to the far right on the horizontal axis.

None of the frames made of climate improved concrete and the frame made of domestic wood gets a negative sum, the C1 and C2 get the scores 0 and +8, respectively when summed up in the matrix, see figure 9. Since the wooden frame gets a higher score using the Goal Interaction Scoring method, it implies that there are more synergy effects for the wooden frame compared to the climate improved concrete frame assessed in this study. Using domestic wood for the frame gives similar scores on the whole horizontal axis, the difference between the lowest and the highest score is 2 point. However, the climate improved concrete frame score is a bit more uneven distributed, and the difference between the lowest and the highest score is 3 points. The BAU, used as the reference scenario, gets a negative score of -6.

5 Discussion

5.1 Modelling in Byggsektorns miljöberäkningsverktyg (BM)

The data used for the products in the LCAs when modelling in BM are generic data, meaning that there are no specific environmental product declaration data used for the materials of the example building. When choosing a product to include in the LCA in BM, there is an opportunity to choose the quality of the data, so-called mapping quality. The mapping quality intends to reflect how well the environmental data in BM matches the data from the actual products that are used. The choices for the matching of the mapping quality are good, neutral or bad. For the modelling of the transportation scenarios in BM, the mapping quality of the data is set to neutral. The reason the data mapping quality is set to neutral (neither good nor bad) is that the example building, the pre-school building in Umeå, is not yet built. At the moment of this study, the pre-school is still in the design stage and therefore, it is not certain what exact materials that will be used. Because of the uncertainty of which exact materials that will be used for the pre-school, the generic data for used product are set to neutral.

A weakness when using BM that does not have an impact on the results is that it is a time-consuming tool to use, especially if multiple scenarios are created. It is not possible to create parallel scenarios based on the same input data, for example, material amounts and transport distances; each scenario had to be modelled manually, and that was time-consuming. A strength for BM though is that it is user-friendly, especially for beginners. It takes some time to understand how to use the tool, but with some guidance from the manual, it is quite simple to create an LCA even though it was time-consuming. Hopefully, since the BM version used to create scenarios for this study is version 1.0, the tool will be developed and improved. Improving the BM tool would be good, mainly if the tool is used as the LCA tool for creating the climate declarations in the upcoming law from Boverket (Boverket, 2020d). Using BM for this study worked well, even though it was time-consuming since the tool provided useful environmental data for the method used in this study.

5.2 Goal interaction scoring

The Goal interaction scoring-method from "A draft framework for understanding SDG interactions" by Nilsson et al. (2016) is a method for an overview of possible interactions with the SDGs. What is good about the method is that it provides a broad overview of interactions and visualise the interactions on a scale; this makes the challenges and possibilities of the Agenda 2030 easier to identify. The method could have been easier to use if the scale had more points, but this would have required addition assessment criteria. The assessment criteria in the goal interaction scoring-method needed careful analysis to be able to give the interactions their scores, adding more criteria could make the scoring a bit confusing. In the method used in this study, there were seven points on the scale, and it would have been favourable to have nine or eleven points on the scale due to that it sometimes was difficult to place the interactions on the seven-point scale. Although, this is only favourable if it does not make the assessment criteria more difficult or confusing.

The sensitivity of giving the interactions a score never differed much. If there was any uncertainty, the uncertainty was never whether the score should be -2 or +2 for the interactions. The question was rather whether the interactions should be given one of two scores being next to each other on the steps, like +1 or +2. Overall, the Goal interaction scoring-method worked well for assessing the interactions between the material choices, and the targets chose for this study.

The strength of this study is that the basis for the scoring, when using the Goal interaction scoring-method, is based on the results from the literature studies and results from modelling LCAs in BM of an actual building. The scoring of interactions between the climate action *Conscious material choice for the frame* and the SDGs are based on the author's conclusions from the background information and the results from LCAs of the transportation scenarios. The background information and the results from the LCAs were put together. For each of the chosen SDG targets, the put together-information was compared to which of the assessment criteria for the scores that it matched. By doing this, the interactions were given the scores. The scores of the interactions in this study should not be viewed as facts, and the scores should neither be viewed as qualified assessments since the scores are results of literature studies and LCAs. The scores should be viewed as a guideline that can point out what area of the interactions that might generate synergies or conflicts for the assessed climate action.

The Goal interaction scoring-method made it easier to identify synergy effects, conflicts and areas where mitigation and adaptation are needed for the climate actions assessed. By providing results, the method also helped answer the research question.

5.3 Materials for the frame

5.3.1 Concrete

The so-called climate improved concrete is not one single concrete product. The climate improved concrete has lower CO_2 emissions due to changes in the recipe, but the climate improved concrete still has to follow the same rules and standards as standard concrete to ensure the requirements of functionality and performance (Svensk Betong, 2017). The recipe for climate improved concrete vary depending on what the final product is, and this means that the environmental impact for climate improved concrete also varies depending on the recipe (Svensk Betong, 2017). As an example, looking at two third-party validated environmental product declarations (EPD), one for standard concrete with an environmental impact of 359 kg CO_2e

(Betongindustri AB, 2020) and one for climate improved concrete with the environmental impact of 199 CO_2e (AB Sydsten, 2020), the environmental impact was lowered with 45% when using the climate improved concrete. To lower the environmental impact from the transportation of the concrete, the fuels could be changed into fossil-free fuels (Svensk Betong, 2017). The remaining 10 % of the CO_2 emissions from producing concrete is transportation (of raw material to and within the factory and delivery to the construction site), the concrete production itself (electricity included) and other material such as ballast, water and additives (Svensk Betong, 2017).

According to Svensk Betong, improving the concrete recipe is a short-term solution to lower the environmental impact from concrete, technology and process development as well as new types of binders have a long-term effect. For example, the concrete recipe could lower the environmental impact by decreasing the amount of cement clinker. Alternative binders could then be fly ash or slag. The function of the concrete is the guiding principle that sets the requirements for how much it is possible to optimise the concrete recipe to lower its environmental impact (Svensk Betong, 2017). Development in technology related to producing the concrete requires broad cooperation where the industry, researchers, the society and politicians are included. One technology that could be used to lower the environmental impact in the process of making the concrete is CCS/CCR (Svensk Betong, 2017). CCS/CCR is a technology where CO_2 is separated from the fumes and then either stored (CCS) for example, under the seabed or reused (CCR) in other industrial processes (Kameyama, et al., 2011).

5.3.2 Wood

The Swedish Forest Agency (SFA) is the national authority supervising and managing forest-related issues (Skogsstyrelsen, 2020). According to the SFA, the production of trees for timber and biomass is an ecosystem service that has a good status in Sweden due to the country's long history and experience of managing forests. The national rate of harvesting trees is lower than the growth (Skogsstyrelsen, 2017). However, the production of timber and biomass have a significant influence and impact on other ecosystem services and, therefore, the managing of forests are of high importance both now and in the future (Skogsstyrelsen, 2017). The reason why the production of timber and biomass has such a large influence and impact on other ecosystem services is that the forests in

Sweden cover a large area (Skogsstyrelsen, 2017). 69 % of the area of Sweden consists of forests, and this equals 28,1 million acres. 57 % of the area of Sweden (23,3 million acres) is forest used for production. This makes the production of timber and biomass from forests, the dominating ecosystem service in Sweden (Skogsstyrelsen, 2017). The statistical status overview for Sweden's work with Agenda 2030 for 2019 implies that forestry in Sweden harms national ecosystem services. There is a need for consideration for ecosystem services at harvesting and reforestation to reduce negative environmental impact (SCB, 2019).

5.4 Transportation and comparative analysis discussion

5.4.1 Goal interaction scoring and transportation

SDG 9.4 Industry innovation and infrastructure

Boverket's climate declaration, including planning tools like LCAs, with requirements of CO_2e emissions for buildings, help to report the environmental impact for building materials, concrete and wood included. There are signs of local authorities, like Umeå and Göteborg, are implementing these measures on local levels, which should increase the use of the measures and reporting of the environmental impact of both concrete and wood. Building a wooden frame instead of building a concrete frame lowers the environmental impact from 141 tonne CO_2e to 40 tonne CO_2e for the A1-A3 phase, which is a 71,6 % reduction in environmental impact. When the A4 phase is included, the transportation of the wooden frame, compared to the concrete frame, has a 0 %, 2,4 % and 19 % less environmental impact for 10 km, 100 km and 1000 km respectively if the transportation method is by train instead of by truck. When comparing transportation (A4), transportation by truck has 85 % higher environmental impact compared to transportation by train. Knowing the environmental impact based on transportation method, choosing transportation with lower environmental impact can generate greater use of green technology for transportation which is enabling the possibility to accomplish the SDG 9.4 target.

SDG 12.7, Responsible consumption and production

Public procurement with requirements of environmental impacts is practised for Sweden to reach sustainable development. Requirements of a conscious choice of concrete and wood can be made through public procurement, and this can lead to that public procurement can be used to promote sustainable development in the building sector. Requirements for methods of transportation is also important to include due to the A4 phase of LCA has a significant influence on the environmental impact, especially for concrete. Public procurement will then be in line with accomplishing the SDG 12 as well as fulfilling parts of new laws like Boverket's climate declaration. However, the SDG target 12.7 can only be reached if developers like Umeå and Göteborg act and, for example, ask for LCAs of frames made from different materials.

SDG 13.2, Climate action

The climate policy framework enables the ability to adapt and mitigate the impacts of climate change for Sweden. Environmental impact requirements in public procurement and planning strategies on a local level to lower CO_2e-emissions in the building sector are in use and are being more and more integrated. Upcoming laws like Boverket's climate declaration and use of LCA is a sign of strategies being integrated to lower the environmental impact. Requirements of transport method in policy and plans, like transporting materials by train instead of a truck when it is possible as a requirement in public procurement, can help to lower the environmental impact for the A4 phase and this will then also be a step towards sustainable development and the accomplishment of SDG 13.2.

SDG 15.2, Life on land

The forest as a resource is a valuable ecosystem service in Sweden that needs good management. Sweden has an authority, Skogsstyrelsen, for management of the forests that can help the accomplishment of the SDG 15.2. However, Sweden has two goals that are viewed as equal when it comes to forestry politics, a production goal (SkogsSverige, 2019) and a biodiversity goal (Naturvårdsverket, 2020). The production goal says that the forest should be managed efficiently and responsibly to produce a sustainable and good return. The owner of the forest has the responsibility, but also the freedom, to decide on the use of what the forest produces. The responsibility with freedom, however, might interfere with the biodiversity goal that says that biodiversity and genetic variation must be secured (SkogsSverige, 2019) if the goals are seen as equal. This possible interference is something to keep in mind if the number of buildings with domestic wood frames in Sweden is increased due to that the wooden frame has a lower environmental impact than the BAU and the climate improved concrete frames.

SDG 17.14, Partnership for the goals

The impacts of the use of concrete and wood for the frame can through national goals like the 16 environmental quality objectives, extended use of planning tools like Boverket's climate declaration and LCA enhance the policy coherence of sustainable development for the building sector. Synergies are generated because the policies are connected. The score for both climate actions assessed in this study when using the Goal interaction scoring-method implies multiple synergy effects. The positive scores for both of the assessed climate actions should, therefore, make it possible to accomplish the SDG 17.14.

5.4.2 Matrix

The results in figure 9 show that the climate improved concrete frame gets the sum 0 and is in a neutral state; the domestic wood frame generates synergies with a score of +8. Since the climate improved concrete frame gets the score 0, and the domestic wood frame gets the score +8 it indicates that the domestic wood frame should generate more synergy effects than the frame made of climate improved concrete. Scores that significantly stands out from the rest on the horizontal axis could imply that there is a problem area that needs to be focused on. Looking at the frame made of climate improved concrete, the sum indicates that there are no conflicts due to the sum. However, the low scores for SDG target 9.4, SDG target 13.2 and SDG target 15.2 might indicate that these areas need to be focused on to get if wanted, a higher sum for the particular climate action. The reference scenario, BAU, gets the score -6 and indicates that both the climate improved concrete frame and the domestic wooden frame have a greater chance of accomplishing the SDG targets.

6 Conclusion

The climate action *Conscious material choice for the frame* generates synergies for the wooden frame for the chosen SDG targets when using the Goal Interaction Scoring-method. The climate improved concrete does not generate synergies but either conflict for the chosen SDG targets. Therefore, both material choices for the frame should not prevent the accomplishment of the SDG targets. Both the climate improved concrete frame and the domestic wood frame get higher scores compared to the BAU scenario, which gets a negative score that indicates conflicts. Therefore, according to the Goal Interaction Scoring-method, continuing using standard concrete for the building frame might prevent accomplishing the SDG targets. However, the wooden frame generates more synergies than the climate improved concrete frame. Choosing a wooden frame (A1-A3) and train as the transportation method (A4) for longer distances have the lowest environmental impact and generate most synergies.

The wooden frame has the lowest environmental impact for the two materials assessed. The transportation method plays a big role in the environmental impact of the A4 phase for longer distances. At the shortest distance assessed in this study, 10 km, the transportation method (train or truck) does not have a significant difference in environmental impact. Increasing the rate of buildings with domestic wood frames should lower the climate impact of buildings to a greater extent than using climate improved concrete for the building frames.

7 Future research

Future research on how the climate action *Conscious material choice for the frame* is affecting the accomplishment of the SDG targets could include the whole A-phase, meaning that the phase A5 (construction and installation) could be included. Furthermore, the LCA could assess the entire life cycle, phase A-C, of the material chosen for the frame to get the total environmental impact. Another parameter to include in future studies could be the environmental impact of other materials used to support the frame, like steel. Since there are no economic calculations, with or without construction time included, in this study the economic parameter, as well as the time parameter, could be included in future studies of material choices for the frame.

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Appendix A

A1 The Sustainable Development Goals

All of the SDGs and their definitions are found in table 11 in this appendix.

Table 11. The Sustainable development goals (SDGs) with their symbol image and their definitions (cited from the United Nations, 2020c).

	Goal	Definition
	No poverty	End poverty in all its forms everywhere.
	Zero hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
	Good health and well-being	Ensure healthy lives and promote well-being for all ages.
	Quality education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
	Gender equality	Achieve gender equality and empower all women and girls.

6 CLEAN WATER AND SANITATION	**Clean water and sanitation**	Ensure availability and sustainable management of water and sanitation for all.
7 AFFORDABLE AND CLEAN ENERGY	**Affordable and clean energy**	Ensure access to affordable, reliable, sustainable and modern energy for all.
8 DECENT WORK AND ECONOMIC GROWTH	**Decent work and economic growth**	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	**Industry, innovation and infrastructure**	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.
10 REDUCED INEQUALITIES	**Reduced inequalities**	Reduce inequality within and among countries.
11 SUSTAINABLE CITIES AND COMMUNITIES	**Sustainable cities and communities**	Make cities and human settlements inclusive, safe, resilient and sustainable.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	**Responsible consumption and production**	Ensure sustainable consumption production patterns.

13 CLIMATE ACTION	**Climate action**	Take urgent action to combat climate change and its impacts.
14 LIFE BELOW WATER	**Life below water**	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
15 LIFE ON LAND	**Life on land**	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss.
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	**Peace, justice and strong institutions**	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
17 PARTNERSHIPS FOR THE GOALS	**Partnership for the goals**	Strengthen the means of implementation and revitalise the global Partnership for sustainable development.