Climate calculation with focus on the environmental aspect in relation to cost for the construction project "Landvetter Backa Västra”.

Master’s thesis in Design and Construction Project Management

Axel Svenningsson & Philip Svensson

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2023 www.chalmers.se

MASTER'S THESIS ACEX30

Climate calculation with focus on the environmental aspect in relation to cost for the construction project "Landvetter Backa Västra".

Master's thesis in Design and Construction Project Management

Axel Svenningsson
Philip Svensson

Department of Architecture and Civil Engineering
Division of Building Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023

Climate calculation with focus on the environmental aspect in relation to cost for Veidekke's construction project "Landvetter Backa Västra”.

Master’s Thesis in the Master’s programme Design and construction project management

Axel Svenningsson

Philip Svensson

Examensarbete ACEX30
Institutionen för arkitektur och samhällsbyggnadsteknik
Chalmers tekniska högskola, 2023

Department of Architecture and Civil Engineering
Division of Building Technology
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Cover:
An image displaying a construction project produced by the authors.
Department of Architecture and Civil Engineering.
Gothenburg, Sweden, 2023

Abstract

The greenhouse gases are currently the main cause of the increasing global warming, particularly due to carbon dioxide emissions. In Sweden, the construction and real estate sector accounts for 21% of greenhouse gas emissions, and Sweden has set a target to achieve net zero emissions of greenhouse gases by 2045. Against this background, the central part of the master's thesis will focus on climate impact, with a case study conducted on an ongoing road and construction project called 'Landvetter Backa Västra', and the aim of this project is to study the project's emissions using life cycle assessment (LCA). Veidekke's project involves constructing the road that leads to the new development area, a task that includes extensive blasting and challenging topography. In addition to blasting, the studied project includes tasks such as road construction with asphalt, concrete bridge construction, pipeline laying, and steel structures. The idea and direction for the thesis was jointly developed with Veidekke.

A literature review was conducted in the initial stages of the report using keyword searches in databases such as Google Scholar, Chalmers Library, and websites of government agencies. Information/data from the Landvetter Backa project was collected from a cost estimate calculated by Veidekke for the project. Five interviews were conducted, and two climate impact calculations were performed for the project using two different climate calculation tools based on data from the cost estimate. Anavitor and the Swedish transport administration have developed their respective climate calculation tools, which were used and compared in this report. Veidekke has a collaboration with Anavitor, and therefore, all calculations for alternative materials and fuels were based on results from Anavitor's carbon climate calculation tool.

The result for the total carbon dioxide emissions for the Landvetter Backa project was calculated to be 1926 tons of CO_2-eq using Anavitor's tool and 1665 tons of CO2-eq using the tool from the Swedish transportation administration. Diesel was the studied factor with the largest impact, accounting for over 50% in both climate calculations, followed by materials such as steel and concrete. Several materials with reducing CO_2-eq were presented in the results and were weighed together for the Landvetter Backa project, resulting in a 56% reduction in total CO2-eq but with a 24% increase in cost.

As this report also examines alternative environmentally friendlier solutions, it can be concluded that HVO100 would have reduced emissions by 47% for this project, but with a price increase by 26% per liter. Through research, it is also possible to note that both steel and concrete have more environmentally friendlier alternatives than the "standard product", where implementation of these alternatives could have reduced total emissions. Rock blasting, which is also studied in this report, currently does not have a good environmentally friendlier alternative in terms of reasonable cost and time increases.

Keywords: Carbon dioxide emissions, climate calculations, GWP, EPD, environment, emissions, Infrastructure industry, greenhouse gas.

Sammanfattning

Växthusgaserna är idag den främsta orsaken till den ökande globala uppvärmningen, särskilt på grund av utsläppen av koldioxid. I Sverige representerar bygg- och fastighetssektorn 21 % av växthusgasutsläppen och Sverige har satt upp målet att till år 2045 inte ha några nettoutsläpp av växthusgaser. Med denna bakgrund kommer den centrala delen av masteravhandlingen att fokusera på klimatpåverkan, där en fallstudie utförs på ett pågående väg- och byggprojekt som kallas "Landvetter Backa Västra" för att studera projektets utsläpp. Veidekke's projekt går ut på att man ska konstruera vägen som leder till det nya exploateringsområdet, en uppgift som innefattar mycket bergsprängning och tuffa höjdskillnader i geografin. Förutom bergsprängning inkluderar det studerade projektet uppgifter som vägbyggnad med asfalt, betongbrobyggnadsarbete, ledningsläggning och stålkonstruktioner. Idén och riktningen för avhandlingen har utvecklats av Veidekke's anställda tillsammans med studenterna.

En litteraturstudie tillämpades i ett tidigt skede av rapporten med hjälp av nyckelordsökningar i databaser så som Google Scholar, Chalmers Library och webbsidor för statliga myndigheter. Information/data från projektet Landvetter Backa samlades in från en kostnadskalkyl som Veidekke beräknat för projektet. För att besvara frågeställningarna, genomfördes fem intervjuer och två kilmatkalkyler som beräknades för projektet med två olika klimatkalkylsverktyg baserat på data från kostnadskalkylen. Anavitor och Trafikverket har utvecklat varsitt klimatkalkylsverktyg som användes och jämfördes i denna rapport. Veidekke har ett samarbete med Anavitor och därför har alla beräkningar för koldioxid reducerande åtgärder baserats på resultat från Anavitors klimatkalkylsverktyg.

Resultatet för det totala koldioxidutsläppet för projektet Landvetter Backa beräknades till 1926 ton CO_2-eq med Anavitor- och 1665 ton CO_2-eq med Trafikverkets klimatverktyg. Diesel var det drivmedel som hade störst påverkan med över 50 % i båda klimatkalkylerna, följt av material så som stål och betong. Ett flertal material och drivmedel med reducerande koldioxidpåverkan presenterades i resultatet och sammanvägdes för projektet Landvetter Backa, vilket reducerade det totala koldioxidutsläppet med 56 % men till följd av ett ökande pris med 24 %.

Då denna rapport även studerar alternativa miljövänliga lösningar kan man konstatera att HVO100 hade reducerat utsläppen med 47% för detta projekt, dock hade priset stigit med 26% per liter. Genom eftersökningar går det även att konstatera att både stål och betongen har miljövänligare alternativ än ”standardprodukten” där man med implementering av dessa hade kunnat sänka de totala utsläppen. Bergssprängning som även studeras i denna rapport har idag inget bra miljövänligt alternativ sett till rimliga kostnadsökningar och tidsökningar.

Nyckelord: Koldioxidutsläpp, klimatberäkningar, GWP, EPD, miljö, utsläpp, anläggningsbranschen, växthusgas.

Preface

This master thesis of 30 ECTS was carried out at the Department of Architecture and Civil Engineering as part of the master’s program Design and Construction Project Management, Chalmers University of Technology. This thesis has been written and contributed equally by Axel Svenningsson and Philip Svensson.

We would like to thank the examiner, the supervisors, Veidekke and everybody else who guided and advised us during our master thesis.

Gothenburg, June 2023 Axel Svenningsson & Philip Svensson

Table of content

List of tables

List of Figure

1.0 Introduction

The introduction of this master thesis consists of background, aim, limitations, and specification of issue under investigation.

1.1 Background

The greenhouse gases are the main reason for the increasing global warming, especially because of the emissions of carbon dioxide (Singh & Singh, 2012). Increasing global warming contribute to many negative outcomes and two are for example more frequent natural disasters and increasing sea level because of the ice is melting. 40 percent of the annual Co_2 emissions are represented by the built environment, where 27 percent comes from building operations and 13 percent from construction and materials (Architecture 2030, 2023). To be able to stop the increasing global warming potential, EU has come up with a European green deal (European commission). The deal says that by the year of 2030 at least 55 percent of the greenhouse gas emissions should be reduced compared to the levels of 1990 and by the year of 2050 there should be no net emissions of greenhouse gases.

In Sweden, the built- and real estate sector represents 21 percent of the greenhouse gas emissions (Boverket, 2023a). Sweden has established a goal saying that by the year of 2045 Sweden should have no net emissions of greenhouse gases, which is five years earlier compared to the European green deal (Naturvårdsverket, n.d.b). There have also been established some stage goals, by 2030 the emissions of greenhouse gases should be reduced by 63 percent and 75 percent by the year of 2040 compared to levels of 1990. At the beginning of 2022, there were some legal requirements regarding construction of new buildings in Sweden, which could be seen as one of many tools to meet the goals of no net emissions by 2045 (Boverket, 2022). From 1 January 2022, a climate declaration needs to be done and handed in before the construction of a new building. The reason for the new law is to create an understanding of the climate impact from the construction, which in turn could create opportunities for improvements to decrease the climate impact.

Looking at the house-building construction sector, it can be understood that it consists of several different certification systems. As mentioned, the Swedish National Board of Housing, Building and Planning (Boverket), also follows up on the sector's emissions with an annual compilation on behalf of the government (SFS 2012:546). In comparison with the “Road and infrastructure” construction sector, certification systems have not been available to the same extent and no equivalent system to monitoring exists today. After Sweden's parliament passed the goal of achieving net zero greenhouse gas emissions to the atmosphere by 2045, the road and infrastructure sector has been working more together to reach a fossil-free Sweden (Regeringen, 2016).

It can also be seen that initiatives are taken by clients such as the Swedish Transport Administration (Trafikverket), as they have started setting requirements for emissions to be reduced within projects. In accordance with Sweden's climate goals earlier mentioned, the Swedish Transport Administration also has a goal of being climate neutral in their infrastructure projects by 2045 (Swedish Transport Administration, 2021). For road and construction projects at the Swedish Transport Administration, climate calculations can now be used to calculate emissions and energy consumption through a calculation tool which they provide. A climate calculation program is a tool that calculates energy use and climate impact based on resource use and emission factors (LCA data). The results of the climate calculation could later be studied to see which factors can be improved and made more efficient to reduce emissions. Today there are many different tools and websites you can use for these calculations, not only the one provided by Swedish Transport Administration. But they all more or less have the same functions. In this thesis Veidekke will provide Anavitor as a climate calculation tool, and the tool from the Swedish Transport Administration with unrestricted access will be used to compare with.

The supervisor from industry for the master thesis is Veidekke Sverige AB. Veidekke Entreprenad AB is a Scandinavian construction and property company with its headquarters in Oslo. It began with road paving in Norway in 1936, but today the company builds roads, tunnels, bridges, and houses throughout the whole Scandinavia. Just as the construction sector in overall, Veidekke have the goal to be climate neutral by 2045 and they have already started to make progress to reach this. They claim that their job is both to reduce their own emissions where they can, but also to use their expertise and knowledge to reduce the climate impact of customers and suppliers (Veidekke, 2023).

With this background, the central part of the master thesis will focus on climate impact, where a case study is done on an ongoing road and construction project called "Landvetter Backa Västra" to study the project's CO_2-eq emissions. The idea and direction of the thesis have been developed by employees of Veidekke together with the authors.

1.2 Aim
The purpose of the master thesis is to analyse the major climate-impacting factors in a road and infrastructure project, and to discuss and highlight potential actions for emission reduction. The aim is to support Veidekke to become more knowledgeable about the topic and provide useful information for future work within sustainability.

1.3 Sustainability and Ethical concerns
This thesis has focus on sustainability and environmental concerns. The awareness around the world is increasing rapidly and environmental issues has led to increased needs for alternatives, which means it creates opportunities for companies to get competitive advantages. Proactive work towards harder regulations and laws also results in more sales and better image, according to Groza et al (2011).

The importance of ethical concerns when writing and conducting a thesis is vital. There are four ethical concerns considered and could be described as following, firstly, the thesis should not create any harm to the participants. Anonymity and privacy are used through the whole projects, but if its okey to use names and descriptions if it is done correctly and through acceptance. The second concern focus on informed consent, for example that before an interview being held, the question about recording and transcription is asked out loud. The third concern discuss invasion of privacy and focus on protection of personal information. The fourth principle discuss avoiding deception, which means that the interviewed are well known about the project and aim before the interview start (Bell et al., 2018).

1.4 Limitations
The study in this paper has been delimited to only investigate the CO_2-eq emissions from the product and construction phase. These phases constitute A1-A5 of the system boundaries from a life cycle perspective (LCA), which can be seen in Figure 1.

Product			Construc-tion		Use Stage							End of Life				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Demolition	Transport	Waste processing	Disposal	Re-use, recovery and recycling potential

Figure 1. System boundary, created by authors based on EN 15978.

Moreover, delimitations have been made regarding the number of material types studied in this paper. The four most frequently used material types used in the project Landvetter Backa Västra and two to three alternatives of each material type will be studied regarding the CO_2-eq emissions. The material types are concrete, asphalt, steel reinforcement and rock blasting. Regarding the transport of materials, it has been delimited to only investigate the Co_2-eq emissions from two different transport vehicles, which are tridem truck and tridem truck with trailer for transport of material. The fuel for the transport types has also been delimit to four alternatives, which are HVO, diesel, RME and electric. The calculations of CO_2-eq emissions from A1-A5 for each material and fuel will be calculated with Anavitor's and Swedish transport Administration's program.

1.5 Specification of issue under investigation

The master thesis uses a few questions to help the research reach the specified goals and aims.

- What material and transportation choices in a construction project negatively impact the environment the most today?
- What are alternative solutions to these negative environmental options and how does the cost of material and transportation choices change with more environmentally friendlier solutions?
- How does the climate calculation program which the Swedish transport Administration (Trafikverket) use differ from Anavitor?
- How can contractors and consultants influence clients to change/adapt their requests to support environmentally adapted solutions?

2. Theoretical part

The theory chapter creates the foundation for the result and discussion and include all different theories, concepts and terms needed. This section includes, among other, information about greenhouse gases, GWP, CO_2-eq, legal requirements, climate calculations, EPDs and different materials.

2.1 Greenhouse gases

Greenhouse gases are gases present in the Earth's atmosphere that trap heat and contribute to the greenhouse effect. The greenhouse effect is a natural process that helps to regulate the Earth's temperature by trapping heat from the sun and preventing it from escaping back into space. However, the increased emission of certain greenhouse gases from human activities such as the burning of fossil fuels and deforestation has led to an unnatural increase of the greenhouse effect, causing the Earth's average temperature to rise, and leading to global warming (Sovacool et al., 2021).

As seen in Figure 2, the most significant greenhouse gas in the U.S is carbon dioxide (CO2), which makes up about three-quarters of the total human-made greenhouse gas emissions. This data from the U.S is relevant as they are one of the most influential and driving countries which gives an understanding of how the overview could be for the rest of the world as well. Other important greenhouse gases include methane (CH4), nitrous oxide (N2O), and fluorinated gases. Greenhouse gas emissions are responsible for the warming of the Earth's atmosphere and have been linked to changes in rainfall patterns, rising sea levels, and more frequent extreme weather events. Reducing emissions of greenhouse gases is critical for mitigating the impacts of global warming and ensuring a sustainable future. This can be achieved by transitioning to cleaner forms of energy, improving energy efficiency, and reducing emissions from deforestation and agriculture. (Environmental Protection Agency, 2022A).

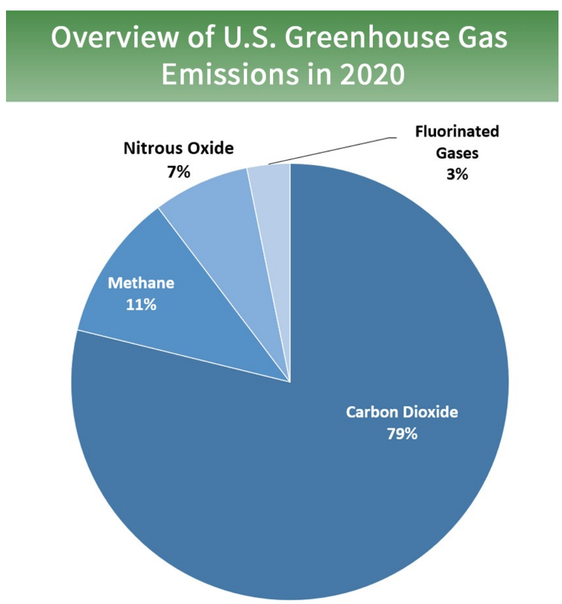


Figure 2. Overview of U.S Greenhouse gas emissions in 2020 from (United States Environmental Protection Agency, 2022A).

2.2 Global warming potential (GWP) and Carbon dioxide equivalent (CO_2-eq)

Global Warming Potential (GWP) is a measure of how much energy a greenhouse gas traps in the atmosphere compared to CO_2 over a specified period (usually 100 years). The higher the GWP value, the more heat the gas traps and the greater its impact on global warming. GWP is used to assess the climate impact of different greenhouse gases, such as carbon dioxide (CO_2), methane (CH4), and fluorinated gases (Rowberg, 2022).

GWP is expressed as a ratio of the heat trapped by a certain greenhouse gas to the heat trapped by an equivalent mass of CO_2. For example, methane has a GWP of 28, meaning it traps 28 times more heat than the same mass of CO_2 over a 100-year time frame. This makes it a potent contributor to global warming despite being present in much lower concentrations than CO_2. The use of GWP enables scientists, policymakers, and the public to understand and compare the relative potency of different greenhouse gases in contributing to global warming. This information can be used to prioritize actions aimed at mitigating their emissions and reducing their impact on the climate. However, it is important to note that GWP is a simplification of the complex processes involved in the Earth's climate system and does not account for all factors affecting global warming (Environmental Protection Agency, 2022B).

The CO_2- eq is the unit used to compare the greenhouse gases carbon dioxide, methane, nitrous oxide, and fluorinated gases (Boverket, 2023b). The unit CO_2- eq is calculated by multiplying million metric tons of a gas with the global warming potential (GWP) of the gas (Eurostat, 2017).

2.3 Legal requirements

In 2017, the Swedish government decided that Sweden will strive for zero net emissions of carbon dioxide by the year 2045 (Naturvårdsverket, n.d.a). In the built and construction industry, Fossilfritt Sverige has developed a strategy plan with industry related companies to lower the CO_2-eq emissions from the industry (Byggföretagen, 2023). 170 companies have signed up for the strategy plan (Fossilfritt Sverige, n.d.). The goal of the strategy plan is to reduce the CO_2-eq emissions by 50 % to 2030, 75 % to 2040 and achieve no net emissions by the year 2045 (Fossilfritt Sverige, 2018). Actions mentioned in the strategy plan to achieve these goals are for example pushing the government to establish legal requirements for the industry regarding CO_2-eq emissions and establishing requirements for climate declarations for new projects. However, legal requirements regarding climate declaration for new projects were established in the beginning of 2022 to increase the understanding of which materials are the largest contributor to the climate impact (Boverket, 2022).

Today there doesn't exist any legal requirement regarding CO_2-eq emissions in the product and construction phase for new construction projects in Sweden (Boverket, 2020). Boverket has suggested establishing a legal requirement regarding the CO_2-eq emissions of the phases A1-A5, which includes phases as production of the product, transport, and construction. The requirement is supposed come into legal force in 2027 and be adjusted 2035 and 2043. Moreover, the Swedish Transport Administration which is a large client of infrastructure projects in Sweden has come up with its own requirements regarding climate impacts of new projects (Trafikverket, 2023A). The requirements differ between projects depending on the economic value. Projects over 50 million includes requirements as percentual climate requirements, climate declaration and action plan for climate reduction and projects under 50 million includes climate requirements for specific materials.

2.4 Climate calculation

Under this paragraph general information about EPD, system boundary and different climate calculations tools are presented. There is also a more detailed description presented of the climate tool developed by the Swedish transportation administration and the climate tool developed by Anavitor.

2.4.1 General information and different tools

Today there are several different websites and software which all can calculate climate impacts. Except from Anavitor and The Swedish Transportation calculation tool there are for example following software:

- SimaPro: A complete sustainability assessment tool that assists in evaluating the environmental effects of goods and services over the course of their life cycles. Together with modules for various environmental effects, it has a module for calculating carbon footprints. Sustainability consultants and professionals frequently utilize SimaPro (SimaPro, n.d.).

- Ecoinvent: Ecoinvent is a life cycle analysis (LCA) and sustainability analysis database. It is commonly used for LCA studies and carbon footprint calculations and offers a comprehensive database of unit processes and systems for many economic sectors, including construction (ecoinvent, n.d)

- OpenLCA: An open-source software tool for life cycle assessment that can be used to calculate the environmental impacts of products, services, and organizations. It provides a range of features and modules, including a carbon footprint calculation module, making it a flexible and cost-effective option for organizations with in-house sustainability expertise (OpenLCA, 2022).

- BEES (Building for Environmental and Economic Sustainability) software: A life cycle assessment software tool specifically designed for the building industry, which includes a module for calculating the carbon footprint of building products and systems. It provides a focused and detailed tool for the building industry, allowing building professionals to assess the environmental impact of building products and systems throughout their life cycle (NIST, 2020).

Regardless of the tool used, the focus and goal are remarkably similar. Climate calculation tools focuses on determining the CO_2-eq emissions and the global footprint of an organization, project, or product. The tools consider several factors that contribute to the climate impact, including energy consumption, transportation, materials, fuels, life cycle, production processes, waste and so on. All these tools assist companies in identifying areas that can be improved with regards to environmental impact. The different platforms have different structures regarding costs for users, some websites provide free access while others have some type of monthly fee or similar.

2.4.2 EPD and System boundary

LCA stands for life cycle analysis, which is a method to determine the environmental impact during a product, process, or activity's lifetime (Pan et al., 2018). The environmental impact is often measured in CO_2-eq in a LCA assessment. System boundary is a component in a LCA assessment and is used to delimit and define the scope of the study. Lifespan, geographic scope, and life cycle stage are three components of the system boundary that need to be determined (Boverket, 2019A). In Sweden there exists a standard called 15978:2011, which is a tool that can be used to determine the scope of the LCA study (Boverket, 2019B). The standard 15978:2011 provides a Figure of which lifecycle phases that could be included in the study, see Figure 1.

However, the result from an LCA assessment for a single product can be used and presented in an environmental product declaration (EPD) (Boverket, 2019C). The content of an EPD is controlled by standards and can be delimited to only include specific parts of the product's life cycle. EPD is often used in lifecycle assessments for buildings, it makes it possible to gather and compare information about single products environmental impact.

2.4.3 Anavitor

Anavitor was founded in 2006 as a joint venture between Åkej AB and IVL (Swedish Environmental Institute) with the aim of providing a scientifically sound understanding of the environmental impact of materials and fuels used in the construction industry. As a result, Anavitor was developed as a one-of-a-kind environmental calculation software that calculates the Life Cycle Assessment (LCA) of a building project. This software is designed to help construction professionals make informed decisions about the environmental impact of their projects, regardless of the stage of development. By utilizing Anavitor, one can easily calculate the sustainability of their projects and contribute to a healthier planet (Anavitor, 2023).

Anavitor explain how to use their tool in a simplified version, see Figure 3. First anybody can import their calculations into the program through an XML, Excel or IFC file, but it's also possible to start a climate calculation from scratch where all materials and fuels are manually included. In this process it's possible to add some specific information about the project. After transforming the data into the program, it becomes possible to make some changes within materials, change scenarios or add some EPDs for example. Lastly, when finished with the program it's possible to create reports and analyses of the results (Anavitor, 2023).

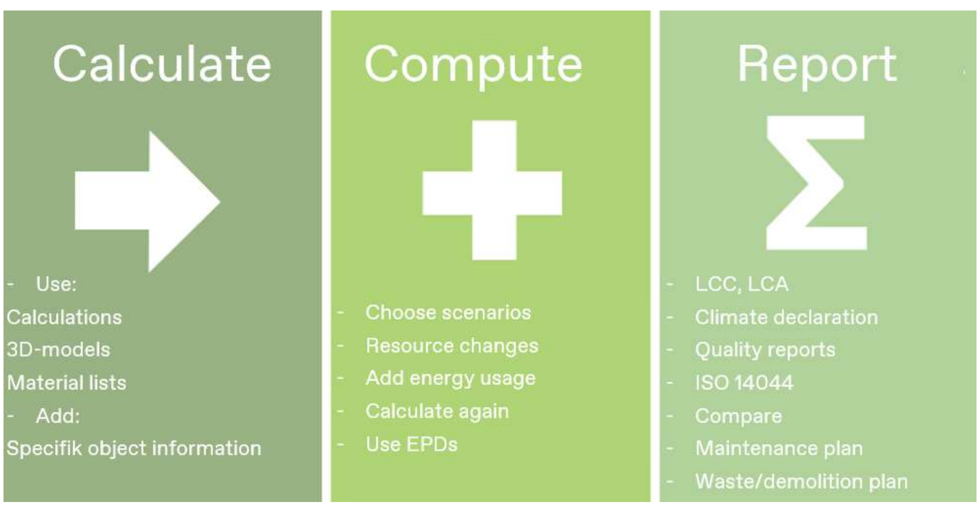


Figure 3. How to use Anavitor (Anavitor, 2023). Copyright 2023 processed from copyright holder, used with permission.

2.4.4 Climate tool provided by the Swedish Transport Administration (Trafikverket)

In 2013 the Swedish Transport Administration was requested by the government in Sweden to develop a national program to improve the infrastructure industry between the years 2014-2025 (Trafikverket, 2014). The Swedish Transport Administration created a tool to calculate climate calculation in conjunction with their work to create an improvement programme (Trafikverket, 2020A). The tool was named climate calculation version 1.0 and was constructed in Excel. One time a year an updated version of the tool was released and by the year of 2016 the tool was developed from being a tool in Excel to becoming a web application. The new format of the tool was the fourth version and got the name version 4.0. The tool has been updated totally seven times during the years and version 7.0 was released in 2020.

Moreover, the tool calculates the resource use and the emissions of carbon dioxide equivalent by applying the same method used in a life cycle analysis (Trafikverket, 2020A). Calculations are based on information from the economic calculations for the project, predetermined emissions factors by the Swedish transport administration gathered from EPDs and resource templates. Depending on the economic calculation level the tool has four different inputs for the calculations. The four inputs are named A, B, C and D. A, B and C are all for investment object and input D was added in the version 5.0 for maintenance object on base contract. Further, the level of the economic calculation depends on the extent of information, input A is used for economic calculations level 1-2 and input B is used for economic calculations level 3. Input C is designed to be used for climate calculations with varying extent of information and is therefore applicable to climate calculations with a varying level between 1-3.

2.5 Material

The environmental impact contributed from infrastructure projects are significant. Road and railway infrastructure are estimated to emit 1-2 million tons of CO_2-eq between the years 2014- 2025, which represents 5-10% of the total impact from vehicles, infrastructure, and traffic in Sweden. In investment projects, building materials such as concrete, steel reinforcements, and asphalt have the largest environmental impact. The crushing of rock and blasting, as well as changes in land use, also contribute to the environmental impact (Trafikverket, 2016). The study written by Trafikverket (2016) show how different materials and vehicles contribute to the climate impact. The study explains that the biggest factors contributing to carbon emissions generally are connected to machines and transportation, concrete, steel, and asphalt. To create an understanding of the requirements on different materials within a project, upcoming sections will highlight the various requirements set by the Swedish Transport Administration for projects with a size under 50 million SEK, which was previously mentioned in the theory section.

2.5.1 Concrete

Concrete is one of the most used materials in the construction industry, because of its benefits as for example strength and long lifetime (Skanska, n.d.). Legislations about a climate neutral Sweden by the year 2045, has put pressure on the development of concrete. The material concrete consists of three elements, which are cement, aggregate and water. Cement is a large contributor to the climate impact, since 8 % of the global carbon emissions and 3 % usage of the world's energy is associated with the production of cement (Sivakrishna, 2020). Concrete and cement are not the building material with the highest carbon emissions per kilogram, but due to the large demand and the high-volume consumption of the materials, it contributes to large quantities of CO_2-eq.

The Swedish Transport Administration who is a large actor in the construction industry in Sweden, has established specific requirements for cement and concrete, see Table 1 (Trafikverket, 2020B). The requirements apply for project under 50 million and is one step to enhance the development of a more environmentally friendlier cement and concrete. An organisation called Swedish concrete established year 2017-2018 an average value of carbon emissions measured in kg CO_2-eq /m3 from common concrete types used in Sweden, see Table 2 (SVENSK BETONG, 2022).

Material	**Unit**	**Output level**	**Demand 2020-2024**	**Demand 2025-2029**
Cement	CO_2-eq /kg	0,88	0,7	0,62
Concrete	CO_2-eq /kg	0,16	0,12	0,12

Table 1. The Swedish Transport Administrations requirements regarding CO_2-eq emissions per kilogram for cement and concrete for projects under 50 million, processed from (Trafikverket, 2020B).

However, Cementa, which is a large producer of cement in Sweden, has a goal to produce climate neutral cement by the year 2030 (Cementa, n.d.). Cementa working on developing an efficient method to use other materials as replacement for cement as binder. Materials that have been evaluated as replacement are fly ash and slag from the iron industry. According to Sivakrishna et al, (2020), using substitutes as for example fly ash, rice husk ash, slag from iron industry, etc to ordinary cement, has created the name green concrete and has shown a reduction up to 80 % of CO_2-eq emissions. Moreover, the climate reduction of concrete can be reduced by using waste materials such as plastic, glass ceramics, etc, as aggregate in the composition of concrete (Tucker et al, 2015). Swedish construction companies as Skanska, Thomasbetong, Swerock and Betongindustri are some companies that have develop their own concrete using these replacement materials to cement with focus to lower the environmental impact and CO_2-eq emissions from the concrete production, see Table 2. According to Skanska, the company has developed a concrete called green infrastructure concrete where up to 40 % of the CO_2-eq emissions are reduced by using slag as a complement and replacement material to cement (Skanska, 2023). Swerock has been able to reduce 50 % of their CO_2-eq emissions from their Eco-concrete by using Merit which is a slag product to lower the amount of cement (Swerock, n.d.). According to Löfgren (2022), fly ash has been used in Thomasbetong more environmentally friendlier concrete called Thomasgreen plus and has shown a reduction of up to 50 % in CO_2-eq emissions compared to industry standard. Furthermore, Cementa is also developing a method to collect and store the CO_2-eq emissions created during the production of cement (Cementa, n.d.).

Company/organisation	**Material**	**Percent reduction**	**Unit**	**Emissions**
Swedish concrete industry standard	Infrastructure concrete		CO_2-eq /kg	0,14 – 0,16
Skanska	Green infrastructure concrete	40 %	CO_2-eq /kg	0,084 – 0,096
Swerock	ECO-concrete	50 %	CO_2-eq /kg	0,07 – 0,08
Thomasbetong	Thomagreen plus	50 %	CO_2-eq /kg	0,07 – 0,08
Betongindusti	Infrastructure concrete	20 %	CO_2-eq /kg	0,112 – 0,128

Table 2. Comparison of a few environmentally friendlier concrete types and their CO_2-eq emissions factors, processed from (Swerock, n.d.; Löfgren, 2022; SVENSK BETONG, 2022; Skanska, 2023.; Betongindustri, 2023).

2.5.2 Asphalt

Asphalt is used for the top layer of road construction all over the world. The material consists of 91-97 % of stone aggregate and 3-9 % of a binder, which in most cases are bitumen (Liu et al, 2017). Bitumen is a fossil substance produced from oil and contributes negatively to the climate impact. Asphalt is constructed by heating and drying the mixture of materials. The process of heating and drying consumes a lot of energy in terms of fuel and constitutes up to 90 % of the total energy consumption of producing asphalt. The high volume of energy needed to heat and dry the mixture of materials contribute to climate impact in terms of CO_2-eq emissions. To enhance the development of reducing the carbon emissions emitted from the production of asphalt the Swedish Transport Administration has established requirements regarding CO_2-eq emissions per ton for different asphalt types used in project under 50 million, see Table 3 (Trafikverket, 2020B).

Asphalt type	Unit	Base level	Demand 2020, 15 % reduction	Demand 2025, 30 % reduction	Demand 2030, 50 % reduction
ABT & ABS	Kg CO_2-eq /ton	49	≤42	≤34	≤25
ABB & AG	Kg CO_2-eq /ton	43	≤37	≤30	≤22

Table 3. Requirements regarding CO_2-eq emissions per kilogram for different asphalt types from the Swedish Transport Administration for projects under 50 million, processed from (Trafikverket, 2020B).

Veidekke has applied new strategies to reduce the CO_2-eq emissions from producing asphalt (Veidekke, 2022A). Three manufactures in Sweden have been changed from being powered by fossil fuels to now being powered by renewable fuel as bio-oil. The change of fuel and an increased use of recycled asphalt has contributed to Veidekke having reduced 40 % of their CO_2-eq emissions connected to the manufacturing process compared to the Swedish transportation administration base level. Except from these changes, Veidekke has also developed an asphalt called LTA (low temperature asphalt) which has similar quality as normal asphalt but contribute to 10 – 15 % lower CO_2-eq emissions from the manufacturing process compared to the Swedish transportation administration base level (Veidekke 2022B). The reduction of CO_2-eq emissions is achieved by reducing the temperature by 20 – 30 degrees of the manufacturing process of asphalt. Veidekke Miljøasfalt pluss is one of the names of Veidekke's most environmentally friendlier asphalts, see Table 4.

Furthermore, Peab is another Swedish company who has come up with a method to lower the energy consumption needed to produce asphalt and therefore also lower the CO_2-eq emissions (PEAB, 2022). The new method has lowered the CO_2-eq emissions by 65 % from the production of asphalt since it was applied in 2015. The new production method uses biofuel for the processes of heating and drying, which has previously been done with fossil fuel. Moreover, has Peab also increased the use of recycled asphalt and lowered the production temperature as a method to lower CO_2-eq emissions. Eco-asphalt plus is the name of Peab's most environmentally friendlier asphalt, see Table 4. According to Chou (2015), can the use of reclaimed asphalt in asphalt production lower the energy use and the CO_2-eq emissions. Energy savings can be made with 16 % and CO_2-eq emissions can be lowered with 20 % if 30 % reclaimed asphalt is used in the production of asphalt.

Company	Asphalt type	Unit	CO_2-eq /ton
Veidekke Miljøasfalt pluss	Ab 11/Ab16	Kg CO_2-eq /ton	14.86
Veidekke Miljøasfalt pluss	Ska 16 PMP (ABT)	Kg CO_2-eq /ton	24.98
PEAB ECO-ASFALT Plus	AG (40% reclaimed asphalt pavement)	Kg CO_2-eq /ton	21.4
PEAB ECO-ASFALT Plus	ABT (40% reclaimed asphalt pavement)	Kg CO_2-eq /ton	26.5
PEAB ECO-ASFALT Plus	ABS (20% reclaimed asphalt pavement)	Kg CO_2-eq /ton	31.4
PEAB ECO-ASFALT Plus	ABB (30% reclaimed asphalt pavement)	Kg CO_2-eq /ton	23.8

Table 4. Comparison of several environmentally friendlier asphalt types, processed from (PEAB, 2018; Veidekke, 2022A; Veidekke, 2022B).

Moreover, new research has been made about replacement and complement substances to the binder bitumen used in asphalt mixture (Li, 2022). Research has shown that by adding wood powder to the mixture the CO_2-eq emissions can be lowered with up to 82,3 % and by adding AI(OH)3 or Mg(OH)2 can the reduction become as much as 97,9 %.

However, in 2020, there was a project in Habo in Sweden where a climate customized asphalt was used for a 1,7 kilometres road construction (Svevia, 2020). The customized asphalt included lignin as a complement to bitumen, biofuel was used for processes heating and drying, and reclaimed asphalt was used in the production. The mixture had a beneficial benefit on the climate impact and lowered the CO_2-eq emissions by 74 % compared to industry standard. Moreover, the use of lignin showed to increase the asphalt qualities in form of increasing the ability to resist wear from traffic. Peab and Veidekke are two other Swedish companies who also investigates the possibility of replacing bitumen with the rest substance lignin, which is a substance collected from the forest industry (PEAB, 2022 & Veidekke, 2022B)

2.5.3 Reinforcement (steel)

Steel is a critical component in construction, and there are various forms of fabricated steel used to complete a project. The main forms are reinforcement steel and structural steel, each with specific variants required for different projects (Steel Fabrication Services, 2019).

Structural steel is a vital and highly flexible building component that plays a key role in constructing the frames of buildings. Its versatility and strength make it an important material for various feats of engineering, from bridges, skyscrapers, and rails. Structural steel offers numerous benefits, such as its ability to withstand high loads, provide stability and support, and its ability to be moulded into any shape required for a project.
Reinforced steel is different from structural steel. It is often used with concrete and bricks to make the structure stronger. Reinforced steel gives the structure extra strength that concrete/bricks does not have, while concrete gives the structure strength to manage pressure. The combination of the two makes the structure stronger and more durable (Larsen et al., 2012).

SSAB (earlier "Svenskt Stål AB"), LKAB (Luossavaara-Kiirunavaara Aktiebolag), and Vattenfall have initiated HYBRIT (Hydrogen Breakthrough Ironmaking Technology) with the aim of collectively developing a carbon-neutral value chain to produce iron and steel, using only carbon-free electricity and hydrogen, thereby removing carbon dioxide emissions across the entire value chain. The HYBRIT technology replaces the conventional blast furnace process, which employs coal to eliminate oxygen from iron ore, with a direct reduction method utilizing carbon-free hydrogen generated from water through the utilization of carbon-free electricity sources. Instead of carbon dioxide, the process produces water vapor or steam (HYBRIT, 2022). This mentioned technique could establish the world's first carbon-free reduction of iron ore to iron sponge, a fundamental step towards the creation of carbon-free iron and steel production. The success of this endeavour necessitates research, advancement, and collaboration. With this technology they aim to create the conditions for carbon-free steel in the market by 2026. The HYBRIT Demonstration is expected to produce approximately 1.2 million tons of raw steel annually, equivalent to 25% of Sweden's total production. It has the potential to prevent the emission of 14.3 million tons of carbon dioxide equivalent greenhouse gases over the first 10 years of production (HYBRIT, 2022).

Looking at the best climate friendlier alternative being available today there are Celsa Steel Service, which are a Swedish steel producer who believes that green steel is the future of steel. The company is one of the pioneers in the work for more environmentally friendlier steel production. Currently, the company produces Europe's most environmentally friendlier steel, with emissions of 370 kilograms of CO_2-eq per ton of steel produced. With this number of emissions, they are well below the European average of 1030 kilograms of CO_2-eq per ton of steel produced equivalents. Celsa Steel Service works on several different fronts to keep emissions down. All steel is produced from recycled material and through investments in energy-efficient smelters and water-based electricity they have significantly reduced their carbon footprint. However, their latest innovation is an algorithm that calculates which raw material results in the least waste in production, which saves them waste material, increases production efficiency, and strengthens their competitiveness (Svenskt näringsliv, 2019).

If looking at the reinforcement steel from Celsa together with the Swedish Transport Administration (Trafikverket) requirement for amount of CO_2-eq per amount of steel, it could be understood that Celsa produces steel which cope with the requirements from the Swedish Transport Administration, see Table 5.

	Output level 2015.	**Contract finished 2020-2024.**	**Contract finished 2025- 2029.**
Requirement from the Swedish Transport Administration	No more than 1.03 kg CO_2-eq / kg of steel	No more than 0.72 kg CO_2-eq / kg of steel	No more than 0.52 kg CO_2-eq / kg of steel
Celsa Steel Service		0.37 CO_2-eq / kg of steel (Today)	
European average		1.03 CO_2-eq / kg of steel (Today)	

Table 5. Requirements from the Swedish Transport Administration (Trafikverket) considering CO_2-eq emissions and Celsa Steel Service standard emissions together with the European average, processed from (Trafikverket, 2020B; Svenskt näringsliv, 2019).

2.5.4 Rock blasting

Excavation and rock blasting work is common in many different industries, such as mining, construction, civil engineering and in agriculture for example. Focusing on the construction sector, rock blasting is mainly done to prepare the foundation work for the construction of buildings, to construct tunnels, to lay pipes, construct roads or to pull cables. Blasting work often involves various types of preparatory rock work, such as drilling and loading work (Arbetsmiljöverket, 2023).

Blasting in the construction sector typically involves a series of controlled explosions, with the use of precision timing and sequencing to create the desired effect. The goal is to break up the rock into small, manageable pieces that can be removed from the site. Conventional drilling and blasting are still the preferred methods for rock breakage due to their cost-effectiveness and efficiency. However, there are negative impacts associated with these methods, such as fly rock, ground vibrations, air overpressure, back-break, and gas emissions (Al-Bakri & Hefni, 2021). According to protected sources in the construction industry traditional rock blasting has a capacity of 700-900 m3 per day compared to a capacity of 100-150 m3 per day with hydraulic fracturing and wire sawing.

According to a study conducted by Al Agedi & Ibrahim (2010), energy consumption and carbon dioxide emissions during traditional rock blasting involve the amount of diesel used by the rock drilling rig machine as well as the number of explosives used for the actual blasting. During drilling, 0.11 liters of diesel are consumed per ton of rock with an average machine, which corresponds to 0,286 kg CO_2-eq emissions per ton of rock. During blasting, 2.3 kg of explosives are used per ton of rock which corresponds to 0.166 kg of CO_2-eq emissions per ton of rock, see Table 6.

Today the rock drilling machines which are used when rock blasting with explosives or fracturing over ground are driven by diesel. But, as late as September 2022 Epiroc have developed a drilling rig for over groundwork all electric driven, which they now try out in collaboration with Skanska in Sweden. Epiroc have already developed electrified machines for underground drilling rigs which help the process (Epiroc, 2022).

To reduce carbon dioxide emissions, there are alternative methods to the traditional blasting, such as: wire sawing, fragmentation with hydraulic hammers, hydraulic fracturing, fracturing with expanding agents, fracturing with water, and so on. The hydraulic alternatives could be seen as the most competitive cost wise compared to the traditional with explosive, but the advantage is that these methods also remove the explosive material. Wire sawing is time demanding and more appropriate when working in sensitive areas with restrictions considering sound and vibrations. (Benker & Göransson, 2020).

Type	**Unit**	**Emissions**
Traditional (drill + blasting) Diesel	Kg CO_2-eq/ton rock	0.286 + 0.166 = 0.452
Hydraulic alternatives (drill + Hydraulic) Diesel	Kg CO_2-eq/ton rock	0.286 + 0 = 0.286
Electrified drilling (drill + blasting)	Kg CO_2-eq/ton rock	0 + 0.166 = 0.166
Electrified drilling with hydraulic fracturing	Kg CO_2-eq/ton rock	0 + 0 = 0

Table 6. Average Kg CO_2-eq /ton rock, processed from (Al Agedi & Ibrahim, 2010; Benker & Göransson, 2020).

2.6 Transportation

This section discusses different transportation types and vehicles which are commonly used in construction projects. Information about excavators, dumping trucks and tridem trucks will be provided. This section also discusses the different fuel types of diesel, HVO100, and RME100/FAME100 considering their CO_2-eq emissions.

2.6.1 Excavators

An excavator is a heavy construction machine that is used for digging, demolition, and other earthmoving tasks. It typically consists of a long arm or boom with an attached bucket that can dig and moving substantial amounts of material such as soil, and rocks. Excavators are commonly used in construction, mining, and forestry operations, as well as in landscaping, road building, and utility work (Hajji & Lewis, 2017). There are diverse types of excavators, used for different tasks. For example, there are Crawler excavators, and these are large excavators that move on tracks, making them ideal for rough terrain and heavy-duty digging. Then there are wheeled excavators which are like crawler excavators, but they have wheels instead of tracks and they are often used for road and building construction. Another one is the long-reach excavator, and these are excavators with longer arms and booms, which make them ideal for deep digging. All these types also come in varied sizes, models, and capacities to optimize performance for suitable work.

The different excavators are often called by their weight, for example 15-ton, 30-ton or 50-ton crawler excavators and this could be seen or understood as the capacity it withholds and the size of the machine. The cost also differs between sizes and most often the bigger the excavator is, the more expensive it is, mostly connected to fuel consumption and maintenance (Al Agedi & Ibrahim, 2010).

2.6.2 Dumping truck

Dump trucks are primarily used in construction work to transport and load materials such as soil, gravel, stone, and other loose materials. They are typically equipped with large, sturdy tires and a tailgate that opens to empty the load. Just as excavators, dumping trucks come in varied sizes to fit the purpose of the projects, as well as the rising costs for bigger trucks (Veidekke, 2023).

2.6.3 Tridem truck with and without trailer

Trucks are used in construction work in several ways. They are primarily used to transport materials such as gravel, stone, sand, soil, asphalt, and concrete from one location to another. When materials need to be moved from or brought to, trucks can be used to transport them over longer distances. The trucks can be driven with or without trailer depending on many factors such as how much material is needed to be transported, construction site size (if there is enough space), costs etc. but the main thing is that a tridem truck with trailer naturally can bring more material per kilometre (Veidekke, 2023).

2.6.4 Vehicles emissions

However, the different machines and vehicles affect the climate differently. Down below in Table 7 and 8 it shows how these different machines can contribute to the global warming and how much CO_2-eq emissions they emit.

Machine	Liter/ hour	CO_2-eq /Liter	Kg CO_2-eq /H
Dumper A25 (diesel)	20	2.8	56
Crawler Excavator 13 ton (diesel)	6.4	2.8	18
Crawler Excavator 20 ton (diesel)	12.1	2.8	34

Table 7. Average emissions from machines, processed from (Persson, 2020; Bolinder, 2018).

Types of Tridem	kg CO_2-eq/Km
Tridem without trailer (diesel)	0.48
Tridem with trailer (diesel)	0.73

Table 8. Average climate impact of Tridem trucks for urban and rural areas, processed from (Trafikverket, 2023B).

2.6.5 Fuel

Diesel and gas have dominated the market for years and from a study it has shown that 86 % of all cars in Sweden in 2021 was powered by diesel or gas (Trafikanalys, 2022). Dumper, truck, excavator, loading machine etc. can be described as heavier vehicles and have for many years been primarily powered by diesel. In the same study for 2021, it showed that 97 % of all heavier trucks with a total weight over 3,5 tons are powered by diesel. The fuel diesel is a fossil fuel and is manufactured from oil by distillation in refineries (Stockholmsstad, 2022). In summary, two thirds of the total amount of fuel used in Sweden in 2021 is diesel.

The use of diesel has a negative climate impact and contributes to CO_2-eq emissions (Stockholmsstad, 2022). Because of the climate challenges the world is facing, the use of diesel needs to decrease or be improved. Sweden has established a regulation regarding the climate impact from diesel, at least 66 % reduction in climate impact by 2030. There have been developed methods to improve and reduce the climate impact from diesel (Binder, 2022). Two methods that are used in Sweden are FAME and HVO, these two methods can be produced in pure form but also as complements that are mixed into diesel. FAME is the shortening for fatty acid methyl esters and is produced from rapeseed. The pure form of FAME is called RME100 or FAME100. HVO is produced from vegetable oil and the pure form of it is called HVO100. According to Trafikverket (2023C), HVO100 is the fuel that has the lowest climate impact in the terms of CO_2-eq emissions, see Table 9.

Fuel type	Kg CO_2-eq /l
Diesel	2.8
RME100/FAME100	0.96
HVO100	0.39

Table 9. CO_2-eq liter for three different fuel types, processed from (Trafikverket, 2023C).

Unlike diesel, HVO100 is a renewable fuel but with the possibility to use in an ordinary diesel engine. Nearly 90 % reduction of climate impact has been shown with the use of HVO100 in a diesel engine (Koopmans, n.d.). According to Neste (2017), a comparison of HVO100 and diesel showed that the use of HVO100 reduced 4 % of the fuel consumption compared to ordinary diesel. However, the price for diesel, HVO100 and RME100 differ and HVO100 is the most expensive fuel and costs about 5 Swedish crowns more than diesel, which costed about 27 Swedish crowns in September 2022 (Binder, 2022). Before the war between Russia and Ukraine started the price between the three fuels only differed about 2 Swedish crowns. The war resulted in a price increase for all three fuels, but HVO100 had the largest increase and hasn't had the same reduction as the other since then. RME is the cheapest fuel and is about 3 Swedish crowns cheaper than diesel, though it is not possible for all diesel engines to use RME100 and regarding density and energy content it doesn't achieve the same quality as the other two.

Moreover, the use of electric vehicles in the construction industry is still under development and the use of it is limited (Hayers, 2022). Excavators with a weight under 5 tons are one of the machines where the electric development has come farthest. The battery size required for this type of machine isn't big, which enables faster charging. There is ongoing development for larger excavators, though is the size of the battery and the capacity of it two major challenges. Volvo has created an excavator named EC230 with the weight of 22 tons and 264 kWh capacity of the battery which enables 8 hours of work. The use of electric excavators has a zero net emissions of carbon emissions and it is also very preferable from the noise perspective (Hayers, 2022).

3. Methodology

This methodology chapter describes how the work have been structured. It includes how the climate calculation where performed, how the interviews and the data collection took form.

3.1 Method flowchart

The planned methodology process can be describe as shown in Figure 4. The process will start with a literature study followed by a flexible process where the climate calculations are conducted simultaneously as the interviews. As the climate calculations are comprehensive, they will be carried out during a longer lifespan.

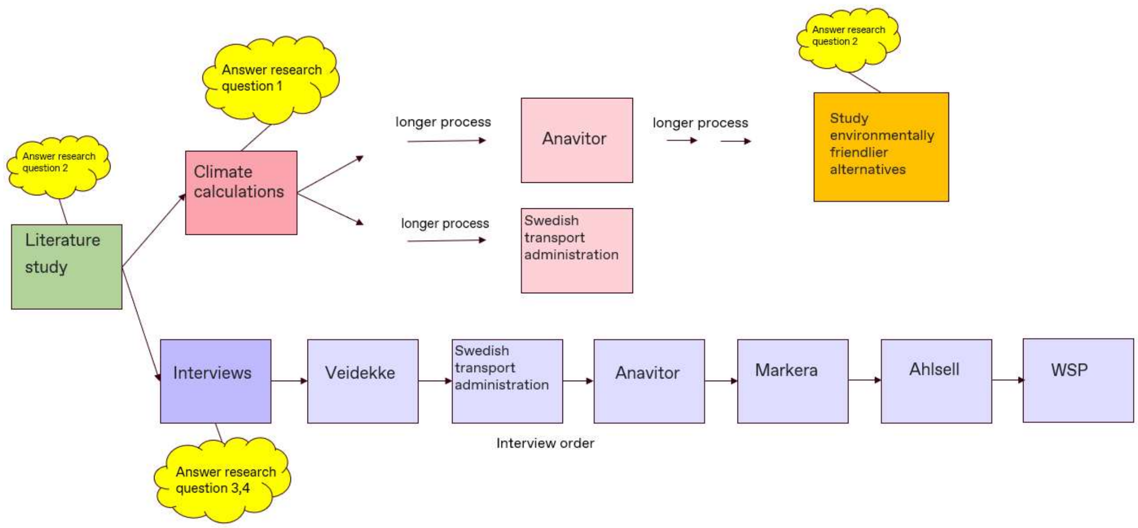


Figure 4. Flowchart for the method, created by authors.

3.2 Quantitative and qualitative study

This report focuses on a real infrastructure project named Landvetter Backa and to answer the research questions in this report the methodology entails both a qualitative study with interviews and a quantitative study with climate calculations (Lundberg, 2019). A literature study will be conducted to collect knowledge to design interview questions. The qualitative study will provide experiences and knowledge from people in the industry to the report and the quantitative study will provide numbers and statistics of how choose of material, fuels, transportation, construction method etc. contribute to climate impact.

3.3 Research quality

This paragraph will discuss the reports validity, trustworthiness, and reliability. Dependability, credibility, transferability, and confirmability are four aspects that trustworthiness can be divided into (Bell et al., 2018). Dependability can be compared with reliability and aims to verify the report/study consistent, which means that similar result should be achieved if the study was repeated. Since the result of this report will be based on climate calculation software with emissions factors based on EPDs, a similar result will be generated if the study is repeated and therefore dependability is achieved. Validity is the same as credibility and describes if the methods and the result of the study can be perceived as reliable. This will be achieved by conducting two climate calculations, which makes the result more reliable since the results generated from the software's will be compared. Furthermore, the perception of how the industry work to reduce the climate impact will be collected from interviews with employees in the industry, which contribute to a transferability to the study and a relevance to other studies. The last concept confirmability aims to verify that the study does not include or are based on any personal thoughts or bias. The result of this report achieves a neutrality because of several interviews will be applied.

3.4 Literature study

A literature study will be conducted to gather information about previous research regarding climate change, how the infrastructure industry is affected and how it adapts to todays and future environmental challenges. The literature study mainly answers the research question number two and will be conducted using keyword searches in databases such as Google Scholar, Chalmers Library, and websites of government agencies. Keywords as greenhouse gas, EPD, infrastructure industry, Global warming potential (GWP), Carbon dioxide equivalent (CO_2-eq), environment, emissions, climate calculations and potential requirements will be used in the databases. Moreover, will this literature study focus on previous research and the development of materials as concrete, asphalt, steel, and rock blasting. These materials are chosen to be further investigated since they all constitute a large part of the project Landvetter Backa. The CO_2-eq emissions of standard products of steel, asphalt, concrete and rock blasting will be presented, as well as two to three more environmentally friendlier alternatives with lower CO_2-eq emissions for each material. Further, the use and development of electric vehicles in the infrastructure industry as well as the use of alternative fuels to diesel such as HVO100 and RME100 will be studied and presented in the literature study. Finally, industry-relevant information about the use of climate calculations will be studied to gather information about which parameters the calculations depend on and to what extent it is used in the industry today.

3.5 Interviews

- The first interview for this project will be a semi-structured interview arranged with the regional manager Fredrik Indevall at Veidekke, to gather information about the contractor’s ability to influence and impact the client regarding environmental solutions, and to understand the decision-making process involved in choosing different machines/materials, etc, see appendix A. This interview will be arranged on teams and plans to take form in February 2023, and focuses on research question 4.

- There will be one semi-structured interview with the Swedish Transport Administration (Trafikverket) to gain understanding of how their climate tool works and how they want to be involved in influencing climate change, see appendix B. The interview was also conducted as it is of interest to understand if contractors can influence buyers to demand more environmentally friendlier options and not just focus on costs. This interview will be arranged with the investigator and climate calculation specialist Sofia Miliutenko Martin on Teams and plans to happen in March 2023, and focuses on research question 3 and 4.

- Semi-structured interview will be arranged with Ahsell, which is a material supplier company, to gain more understanding and answer indirectly to question 4. Questions will be created and applied to gather information about how the company work to reduce their products climate impact, how they work with EPDs and requirements regarding the existence of EPDs for products, etc. The interview will be arranged with Andrea Wästlund, sustainability strategy specialist, on Teams and plans to take form in April 2023.

- There will also be a semi-structured interview with Markera which is a consulting company to investigate how they work with the climate challenges and how much influence they have on their clients regarding more environmentally friendlier solutions as for example choose of materials and fuels, see appendix C. This interview will be arranged with the founders and owners of Markera Kent Sjöholm and Malin Arvidsson at their office and plans to take form in March 2023, and focuses on research question 4.

- There will be one interview with Anavitor. A semi-structured interview will be conducted to gain more knowledge about the tool and how it can be used to influence companies to focus more on sustainability and reduction of CO_2-e emissions, see appendix D. The interview will also focus on the program structure and their data collection, what they base their factors and numbers on. This interview also aims to gather information on other aspects such as user friendliness, collaborations with users, accessibility and so on. This interview will be arranged with Daniel Petersson, LCA- specialist, on Teams and plans to happen in Mars 2023, and focuses on research question 3.

- An interview will be arranged with WSP, which is a consulting company. The interview will be conducted as a semi structured interview and will consist of related questions as the interview with Markera, with a focus on how they work with climate challenges and the extent of their influence on their clients regarding proposals for new environmentally friendlier solutions. The aim with the interview is to interview a larger consulting company to compare the result with the result from the interview with Markera, which is a smaller consulting company. The interview will be arranged with Malin Domhagen, environmental- and sustainability consultant, on Teams and plans to happen in April 2023, and focuses on research question 4.

3.6 Climate calculations

An execution of climate calculation using the computer program Anavitor, provided by Veidekke will be performed. Veidekke work together with Anavitor and therefore will this study use their tool. With help from the climate calculations programs Anavitor and the Swedish transport administration the research questions 1 plans to be answered. As seen in Figure 5, the process will start by transferring the cost calculation of the project from MAP, which is the database Veidekke use when calculating costs, to the climate calculation program Anavitor to enable identification of the biggest negative climate factors. Anavitor have an automatic function to read in cost data and convert it into LCA data, but some extra work will be needed with various products, fuels and materials for which Anavitor lacks data but also to perfect the data-connections further. The work will be processed by researching about climate friendlier alternatives which affect the global warming less. Later, comparison between different options enables the research to proceed with the most suitable and lastly, the calculation of the project will be done again to see the new result. The climate calculations with alternative materials and fuels will only be performed with Anavitor when analysing the result.

Although Anavitor can transform the imported information into generic data there is need of manual data collection from EPDs and different product information, such as density, weight, and dimensions. Supervision meeting with employees from Anavitor will be needed to deal with different tasks and problems related to the program to perfect the calculations.

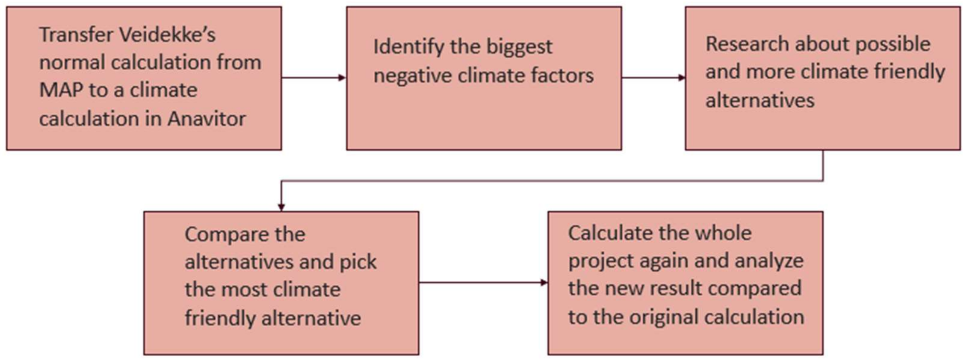


Figure 5. Climate calculation process, created by authors.

A comparison between the Swedish Transport Administration's (Trafikverket) climate tool and the Anavitor program used by Veidekke will be conducted to gain an understanding of how these differ and resemble each other. When performing the climate calculation in the tool provided by the Swedish transportation administration the import from MAP cannot be automated, instead all data must manually be included. When all the data have been collected and put into the program, then it is possible to calculate the total climate impact in CO_2-eq. The comparison will not intend to be in-depth, but primarily focus on the difference in the total amount of CO_2-eq emissions. Connected with the climate calculations, there will be need of some type of supervision meeting with employees from Trafikverket to solve and understand various aspects with their calculation program.

3.7 Studied environmentally friendlier alternatives.

In this report, more environmentally friendlier solutions will be studied to reduce the CO_2-eq emissions for Landvetter Backa, but also for the industry in general. The literature study conducted in this report will provide two to three more environmentally friendlier alternatives with lower CO_2-eq emissions for materials and fuels such as concrete, steel, rock blasting, asphalt, and diesel. These materials and fuels will be applied in Anavitor's climate calculation program to study the CO_2-eq reduction for the project Landvetter Backa. Further, project-specific environmentally friendlier solutions will be studied based on the results from the climate calculation programs for which factors contribute the most to CO_2-eq emissions. All alternative solutions will also be studied regarding their price impact.

3.8 Description of the studied project

The reference project for the case study is a Road and infrastructure construction project. Härryda municipality is developing Landvetter Backa so that all residents and newcomers to the area will have high standards for roads and streets, reinforced water and sewage networks, and access to fiber-based broadband networks (Härryda KOMMUN, 2022). Veidekke will construct the road leading to the new exploitation area, a task including a lot of rock blasting and tuff fluctuations in the geography. In Figure 6 one can see that there are "Etapp 1 & 2, and to clarify this study focus on "Etapp 1", the road. Other from rock blasting, the studied project includes tasks such as road building with asphalt, concrete bridge construction work, pipe laying, and steel constructions. The road construction will stretch for about one km, and to put things into perspective it can be stated that the project cost a bit less than 80 million kr, without stating the exact number.

To get a better understanding of the studied projects there will be close contact with employees from Veidekke working on site, both with site managers, supervisors, and calculators. As the studied project is an ongoing project, right as this thesis is conducted, there will be need of updated information exchange about different purchases and methods performed. The work is scheduled to be finished after about two years of time. The information exchange will be important because changes on site also affect the climate calculations. Site visits will also be carried out to create a better understanding of the studied project.

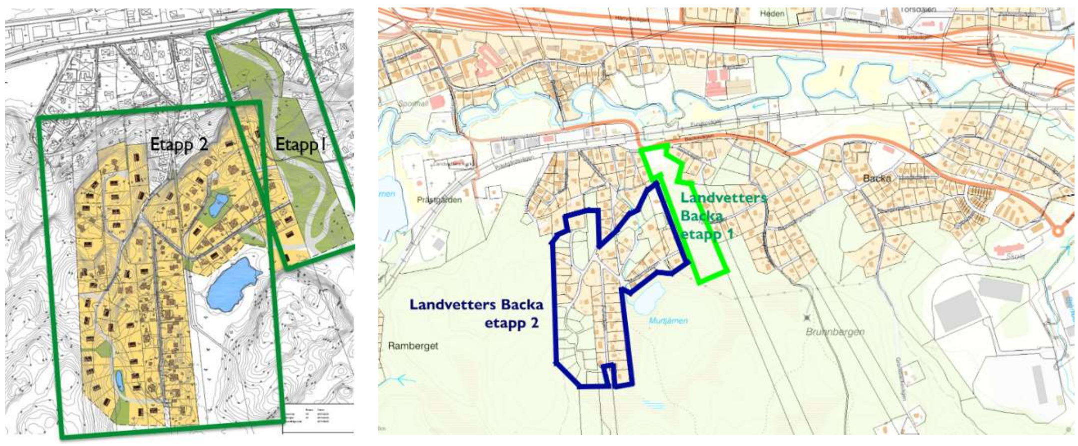


Figure 6. The development in Landvetter Backa, created by authors.

4. Result

This chapter presents the answer to each research question and is divided into three sections. The first section named climate calculations programs presents the calculated CO_2-eq emissions of project Landvetter Backa with the Swedish Transport Administrations and Anavitors climate calculations programs, followed by a comparison between the programs. Subheading two presents a comparison of standard materials and fuelscversus climate adapted materials and fuels, which is followed by a comparison of how three different transport fuels contribute to CO_2-eq emissions. The third and the last subheading answers to the research question of how the contractor and consultant can influence the client.

4.1 Climate calculations programs

These sections present the calculated CO_2-eq emissions for project Landvetter Backa by the Swedish Transport Administrations and Anavitors climate calculation programs.

4.1.1 Swedish Transport Administration (Trafikverket)

The total impact of CO_2-eq emission from the project Landvetter Backa as well as the impact from each material and fuel is presented in Figure 7. See appendix G for further results presented in a screenshot of the result in the climate calculation program. The Figure includes materials and fuels such as asphalt, concrete, rock blasting, steel, diesel, polytene and a rubric named other. Rock blasting includes only the dynamite. The rubric named "other" includes materials such as glass, wood, geotextile, and other materials that have too small contribution worth to mention.

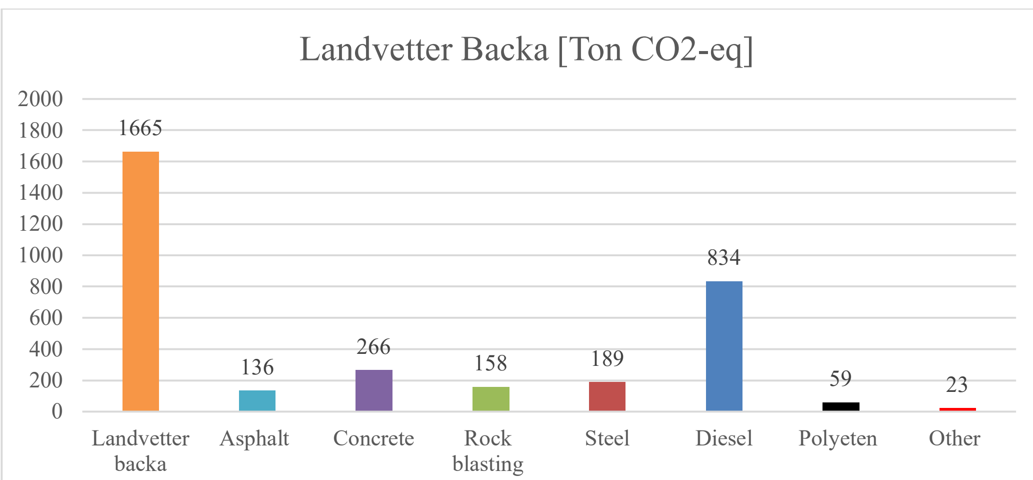


Figure 7. Calculated CO_2-eq emissions connected to the project Landvetter Backa by the Swedish Transport Administrations climate tool.

The total impact of CO_2-eq emissions calculated for project Landvetter Backa with the Swedish transport administration tool is 1665 ton CO_2-eq. Diesel is the fuel with highest impact at 834 ton CO_2-eq, followed by concrete at 266 ton CO_2-eq.

The total impact of each material and fuel in percentage calculated with the Swedish transport administrations programs is presented in Figure 8.

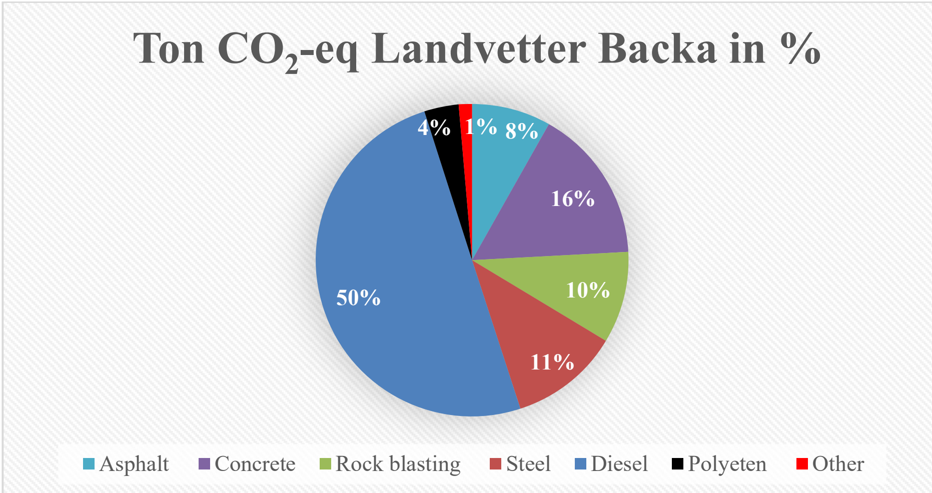


Figure 8. CO_2-eq emissions calculated by the Swedish Transport Administrations climate tool for project Landvetter Backa presented in percent.

Diesel contributes to 50 % of the CO_2-eq emissions for Landvetter Backa and the other materials impact differs between 1-16 %.

4.1.2 Anavitor

This section presents the calculated CO_2-eq emission by Anavitors climate calculations program. The total amount of CO_2-eq emissions emitted from the project Landvetter Backa and from varied materials and fuels are presented, see Figure 9. See appendix F for further result presented in a screenshot of the result in the climate calculation program. Different sorts of asphalt, steel, polytene and concrete are not considered separately, they are included into each material type. Rock blasting includes only the dynamite. Material type named "other" includes materials such as glass, wood, geotextile, and other materials that have too small contribution worth to mention.

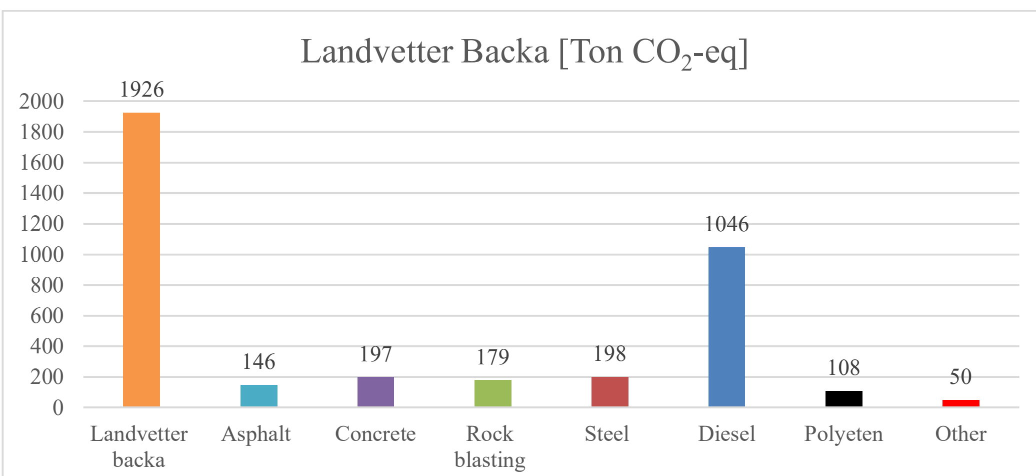


Figure 9. Calculated CO_2-eq emissions connected to the project Landvetter Backa by Anavitors climate tool.

The total impact of CO_2-eq for project Landvetter Backa calculated with Anavitors program is 1926 ton CO_2-eq. Diesel is the largest contributor of CO_2-eq for the project Landvetter Backa and contribute to 1046 ton CO_2-eq, followed by steel which emit 198 ton CO_2-eq. Except from the category other the material polytene has the lowest emissions of 108 ton CO_2-eq.

Figure 10 presents the percentage how much each material contributes to the total emitted CO_2-eq from Landvetter Backa.

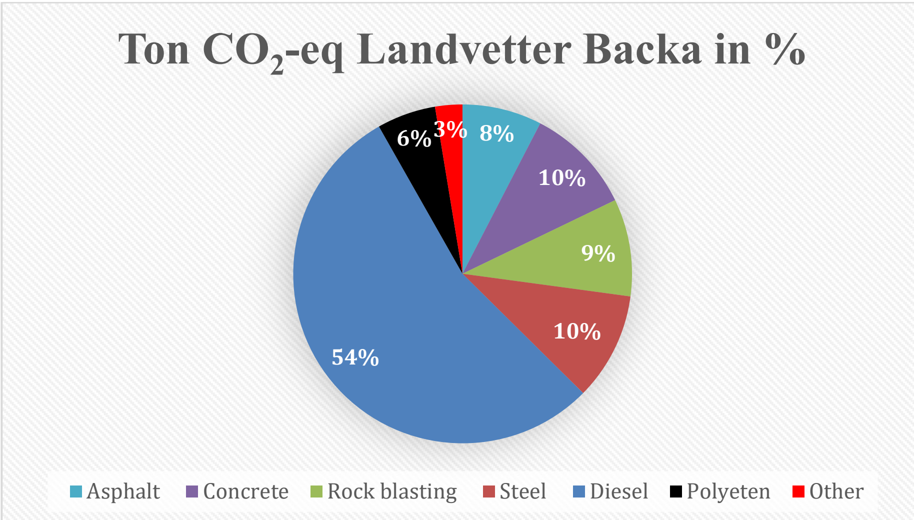


Figure 10. CO_2-eq emission calculated for the project Landvetter Backa in percentage by Anavitor.

Diesel has an impact of 54 % of the total emitted CO_2-eq from Landvetter Backa, which means that diesel has larger impact then all the other materials together. The other materials contribution differs between 10 to 3 percent.

4.1.3 Comparable values for CO_2-eq

To develop an understanding for the reader how much 1926 ton CO_2-eq is, a comparison is made to put the value in perspective to something more every day. The average emissions for cars in 2022 were measured to 135 g CO_2-eq/km, which is equivalent to a distance of 14 266 667 km to match the 1926 ton of CO_2-eq emitted from the project Landvetter Backa (Trafikverket, 2023D). To put that into perspective, one lap around the earth is about 40 000 km (NE, 2023). So, this project´s total CO_2-eq equal to 356 laps around the earth with the average car earlier mentioned for 2022.

4.1.4 Comparison between the climate calculation programs.

These sections compare the two studied climate calculation programs Anavitor and the Swedish Transportation Administration calculation tool, regarding aspects such as application, accessibility, user friendliness and ranges of EPDs. The information is based on interviews and experiences from working with the databases and can be seen in Table 10.

= Same
= Different

Information	Anavitor	The Swedish Transport Administration
Possibility to calculate climate calculations	Yes	Yes
Application	Software application	Web application
Accessibility	Windows	All operative systems
Numbers based on	IVL (Swedish environmental institute)	EPD and LCA studies from 2015
Based on one or several EPDs	Differ between materials, both one and several	Differ between materials, both one and several
Possibility to import files	Yes	No, under development
Types of files	Excel, IFC and sbXML	Future possibility; Excel
User friendlier	Yes	Yes
Developed and comprehensive	Good, widely developed, and broad range of materials	Ok, small range of materials
Range of EPD	Need improvement	Need improvement
Possibility to create reports	Yes	Yes
Experience from customer	Good	Ok, needs some improvements

Table 10. Comparison between the climate calculation programs.

Table 10 showcases that both programs can make a climate calculation for a project where the total CO_2-eq emissions presents. Where and how the applications can be used differ from each other, also where and how the generic data is imported from differ. Anavitor could be experienced beneficially because of its possibility to import different files into the program and because the advanced user experience, but both applications could be seen as user friendlier.

Anavitor explains in the interviews that the ambitions right now for them is to become a web interface, and for more people/organizations to start using the platform, but also to be sold in neighbouring countries. The Swedish Transport Administration explain in their interview that they are working on development and plan to release version 8.0 of the climate tool in 2024. The updates planned for version 8.0 include the inclusion of more material types, updating the emission factors to 2020 levels, and updating the templates for different building components. According to the Swedish Transport Administration there are also right now work in progress with the development of creating the possibility of importing an excel template structured in AMA format with quantities.

Information about the experience from customers regarding the programs user-friendliness and functions have been answered from the interviews with WSP, Markera and Anavitor, see appendix C, D, and I. Anavitor have in general received good feedback from their customers about their program. According to the interviews with WSP and Markera the Swedish transport administration's program needs to be improved and developed. The program needs to be developed regarding the range of materials included in the program, as well as the range and selection of units for materials.

4.2 Material and Transportation with alternative solutions

These sections present the results regarding the different studied materials and transportations solutions. With the results from Anavitors calculations, the studied materials are compared to more environmentally friendlier alternatives, both in emissions, but also cost wise.

4.2.1 Materials

This section present Table 11 which show the top 20 contributors to CO_2-eq emissions from the studied project Landvetter Backa Västra.

Name	kg CO2-ekv
Excavator crawler 45 ton	265 679
Dumper A25, load capacity 25t/10m3	184 227
Rock blasting	161 847
Truck and trailer, cargo cab. 34 tons/16m3	140 280
Excavator crawler 25 tons	123 562
Concrete C35/45 vct 0.45 S3 (16/27 sten), XC4, XD2, XS2, XF4	105 575
Concrete C40/50 vct 0.40 S3 (16 sten) XC4, XD3, XS3, XF4	73 474
Transport rock	50 330
PE-rör PE 100 SDR17 dim 400 x 18,7	48 894
Asphalt, ABT16 40 mm	43 001
Excavator wheels 15 tons	39 139
Transport rock	38 965
Asphalt, ABb16 50 mm	37 009
Asphalt, AG22 50 mm enl. offert	33 920
Reinforcement B 500 BT ILF	31 843
Noise reduction wall	30 875
Saferoad railing N2-W4 saferoad	28 990
Wicker fence with barbed wire	27 696
Stairway in steel	25 857
crushed rock 0-32	25 169

Table 11. Top 20 contributors to CO_2-eq emissions from the studied project.

From Table 11 it can be understood that the top 2 contributors both are diverse types of vehicles driven with diesel. Rock blasting also contribute a lot to the total amount of CO_2-eq. Concrete used for a bridge within the project and different types of used asphalt also affect the total emissions. The factors used to calculate varied materials are Anavitors generic standard numbers, which are based on IVLs updated database which gathers the most recent LCA studies and gives combined average number, according to Anavitor (2023).

4.2.2 Formulas, calculations

Formula 1. Percent reduction (%), describe how much more environmentally friendlier the alternative material choses are compared to the standard alternative. Formula 2 calculate how much the environmentally friendlier alternative material could lower the total amount of CO_2-eq in percentage for the whole project if replacing the standard material alternative. These formulas are used in Table 12, 13, 14, and 15.

Formula 1:

$$Percent\ \ reduction = 1 - (\text{"green alternative"/"standard alternative"})$$

Formula 2:

$$Total\ CO2\ emissions\ Landvetter\ Backa = 1 - \left(\frac{X - (Y - Z)}{X}\right)$$

X = 1926-ton CO_2-eq (Total CO_2-eq Landvetter Backa)
Y = Standard alternative total CO_2-eq Landvetter Backa
Z = Green alternative total CO_2-eq Landvetter Backa

4.2.3 Concrete

This section presents the results of concrete. Table 12 show diverse types of concrete studied with information about the emission per unit, the number of emissions the types affect the whole project, how much the environmentally friendlier alternatives lower the total emissions, but also the price per unit and price difference percentage wise between the standard product and the green alternative. See appendix J for further visualization in graph format. The price per unit is confidentially produced through help from different actors in the industry and could be seen as "average value" and approximate. The result regarding concrete doesn't not evaluate prefabricated concrete products.

Material	Unit	Kg CO_2-eq/unit	Percent reduction	Ton CO_2-eq Total Landvetter Backa	Total CO_2-eq emissions (%) Landvetter Backa	Price [kr/m^3]	Price difference %
Infrastructure Concrete (C40/50 vct 0,4)	Kg CO_2-eq /Ton	150		73	100 %	1340	
Infrastructure Green concrete (C40/50 vct 0,4)	Kg CO_2-eq /Ton	75	-50%	36.5	-2 %	1510	+11%
Infrastructure Concrete (C35/45 vct 0,4)	Kg CO_2-eq /Ton	160		106	100 %	1310	
Infrastructure Green concrete (C35/45 vct 0,4)	Kg CO_2-eq /Ton	80	-50%	53	-3 %	1490	+12%

Table 12. Results from the studied material, concrete.

The result show that the two green concrete alternatives can lower the CO_2-eq emissions per ton with 50%. Also, the green alternatives could lower the total CO_2-eq for the specific material in the studied project with 2% and with 3% each. Looking at the price, the more environmentally friendlier alternatives cost about 11-12% more than the industry standard product.

4.2.4 Asphalt

This section presents the results of asphalt. Table 13 show different types of asphalts studied with information about the emission per unit, the number of emissions the types affect the whole project, how much the environmentally friendlier alternatives lower the total emissions for the specific product, but also the price per unit and price difference percentage wise between the standard product and the green alternative. See appendix J for further visualization in graph format. The price per unit is confidentially produced through help from different actors in the industry and could be seen as "industry standard" and not exactly correct.

Material	Unit	Kg CO_2-eq /unit	Percent reduction	Ton CO_2-eq Total Landvetter Backa	Total CO_2-eq emissions (%) Landvetter Backa	Price [kr/ton]	Price difference %
Asphalt (ABT & ABS)	Kg CO_2-eq /Ton	42		65	100 %	2920	
Environmental friendlier asphalt (ABT & ABS)	Kg CO_2-eq /Ton	25	-40%	39	-1.3 %	3650	+25 %
Asphalt (ABB & AG)	Kg CO_2-eq /Ton	37		83	100 %	2760	
Environmental friendlier asphalt (ABB & AG)	Kg CO_2-eq /Ton	22	-41%	49	-1.8 %	3450	+25 %

Table 13. Results from the studied material, asphalt.

The result show that the two green asphalt alternatives can lower the CO_2-eq emissions per ton with about 40%. Also, the green alternatives could lower the total CO_2-eq for the specific material in the studied project with 1.3 and 1.8% each. Looking at the price, the more environmentally friendlier alternatives cost about 25% more than the industry standard product.

4.2.5 Steel

This section presents the results of reinforced steel. Table 14 show different types of reinforced steel studied with information about the emission per unit, the number of emissions the types affect the whole project, how much the environmentally friendlier alternatives lower the total emissions for the specific product, but also the price per unit and price difference percentage wise between the standard product and the green alternative. See appendix J for further visualization in graph format. The price per unit is confidentially produced through help from different actors in the industry and could be seen as "industry standard" and not exactly correct.

Material	Unit	Kg CO_2-eq /unit	Percent reduction	Ton CO_2-eq Total Landvetter Backa	Total CO_2-eq emissions (%) Landvetter Backa	Price [kr/ton]	Price difference %
Reinforced Steel	Kg CO_2-eq /Ton	720		48	100 %	8600	
Green reinforced steel	Kg CO_2-eq /Ton	370	-49%	24	-1.2 %	9600	+12 %
HYBRIT steel (future)	Kg CO_2-eq /Ton	0	-100%	0	-2.5 %	12 192	+42 %

Table 14. Results from the studied material, steel.

The result show that the green reinforced steel alternative can lower the CO_2-eq emissions per ton with about 49%, and that future HYBRIT alternative can lower the emissions with 100% (0 Kg CO_2-eq/Ton). Also, the green alternative could lower the total CO_2-eq for the specific material in the studied project with 1.2% and 2.5%. Looking at the price, the more environmentally friendlier alternative cost about 12% more than the industry standard product and the future HYBRIT alternatives about 42% more than the industry standard product.

4.2.6 Rock blasting (explosives)

This section presents the results of rock blasting, more specifically the material for explosives. Table 15 show explosive alternative and the hydraulic alternative combined with wire sawing with information about the emission per unit, the number of emissions the types affect the whole project, how much the environmentally friendlier alternatives lower the total emissions for the specific product, but also the price per unit and price difference percentage wise between the standard product and the green alternative. See appendix J for further visualization in graph format. The total cost for each method is based on several factors needed when performing rock blasting, see appendix E for further explanation. The price per unit is confidentially produced through help from different actors in the industry and could be seen as "industry standard" and not exactly correct.

Material	Unit	Kg CO_2-eq /unit	Percent reduction	Ton CO_2-eq Total Landvetter Backa	Total CO_2-eq emissions (%) Landvetter Backa	Cost per unit (kr/m3)	Price difference %
Explosives	Kg CO_2-eq /Ton Rock	0,166		179	100 %	140	
Hydraulic alternative combined with wire sawing (electric)	Kg CO_2-eq /Ton Rock	0	-100%	0	-9 %	2000	+1329%

Table 15. Results from the studied material, rock blasting (explosives).

The result show that the hydraulic alternative can lower the CO_2-eq emissions per ton with 100% (0 Kg CO_2-eq /Ton). Also, the green alternative could lower the total CO_2-eq for the specific material in the studied project with 9%. %. Table 15 show that the rock blasting, drilling + explosives cost about 140 kr/m3 and the rock blasting, drilling + wire sawing + hydraulic cost about 2000 kr/m3. Looking at the price, the more environmentally friendlier alternative cost about 1329% more than normal explosives for this project.

4.2.7 Transportation

This section presents a comparison of the transportation fuels diesel, RME100, HVO100 and Electric, see Table 16. See appendix J for further visualization in graph format. The comparison includes CO_2-eq emissions per unit, total CO_2-eq emissions for the Landvetter Backa and price per unit for each fuel type. Differences between the fuel types are also presented in percentage, with Diesel as the reference value.

Fuel	Unit	Kg CO_2-eq /unit	Percent reduction	Ton CO_2-eq Total Landvetter Backa	Total CO_2-eq emissions (%) Landvetter Backa	kr/l (2023-03-24)	Price difference %
Diesel	Kg CO_2-eq /l	2.8		1046	100 %	21.91	
RME100/FAME100	Kg CO_2-eq /l	0.96	-66%	356	-36 %	16.77	-23 %
HVO100	Kg CO_2-eq /l	0.39	-86%	146	-47 %	27.67	+26 %
Electric	Kg CO_2-eq /l	0	-100%	0	-54 %		

Table 16. Comparison of four types of fuels regarding CO_2-eq emissions and price.

The result from Table 16 shows that RME accounts for a reduction of 36 % of the total CO_2-eq emissions for Landvetter Backa, HVO100 accounts for a reduction of 47 % and electric accounts for a reduction of 54 %. The price for electric fuel has not been studied since electric infrastructure vehicles are limited on the market and are not used to any wider extent in today's infrastructure projects. RME100 is cheaper than diesel but it doesn't have the same qualities as diesel and is limited to specific vehicles. HVO100 is more expensive but can be used by most of the vehicles driven by diesel.

Four different vehicles used in the project Landvetter Backa are compared on what type of fuel they are driven by, how this fuel type impacts the total CO_2-eq emissions emitted from Landvetter Backa and how it impacts the cost, see Table 17 and Figure 11. The vehicles that are compared are Excavator, dumping truck, tridem without trailer and tridem with trailer and the fuel types are diesel, electric and HVO100. To clarify, the total ton CO_2-eq column is representing all different types of machines sizes but to simplify this calculation, one machine size of each vehicle type has been chosen to represent all sizes in the project regarding the price. A comparison of the electric fuel is only made for tridem truck without and with trailer. Excavator and dumping truck are not compared with electric since it is not common to use in today's projects because of its short operating time, which makes it hard to find numbers and prices for these two vehicle types to include in this report.

Vehicles	Unit	Kg CO_2-eq /unit	Ton CO_2-eq Total Landvetter Backa	Total Ton CO_2-eq emissions (%) Landvetter Backa	Price
Excavator (Capacity 20 ton) (Diesel)	Kg CO_2-eq /h	34	431	100 %	1350 kr/h
Excavator (Capacity 20 ton) (HVO100)	Kg CO_2-eq /h	4.7	60	-19 %	1750 kr/h
Dumping truck (Capacity 25 ton) (Diesel)	Kg CO_2-eq /h	56	184	100 %	1000 kr/h
Dumping truck (Capacity 25 ton) (HVO100)	Kg CO_2-eq /h	7.8	26	-8 %	1350 kr/h
Tridem truck with trailer (Capacity 34 ton) (Diesel)	Kg CO_2-eq /km	0.73	140	100 %	1400 kr/h
Tridem truck with trailer (Capacity 34 ton) (HVO100)	Kg CO_2-eq /km	0.1	20	-6 %	1800 kr/h
Tridem truck with trailer (Electric)	Kg CO_2-eq /km	0	0	-7 %	
Tridem truck without trailer (Capacity 17 ton) (Diesel)	Kg CO_2-eq /km	0.48	8	100 %	900 kr/h
Tridem truck without trailer (Capacity 17 ton) (HVO100)	Kg CO_2-eq /km	0.07	1	-0.36 %	1200 kr/h
Tridem truck without trailer (Capacity 13 ton) (Electric)	Kg CO_2-eq /km	0	0	-0.41 %	1100 kr/h

Table 17. Comparison of carbon emission and price for different vehicles driven by different fuel types.

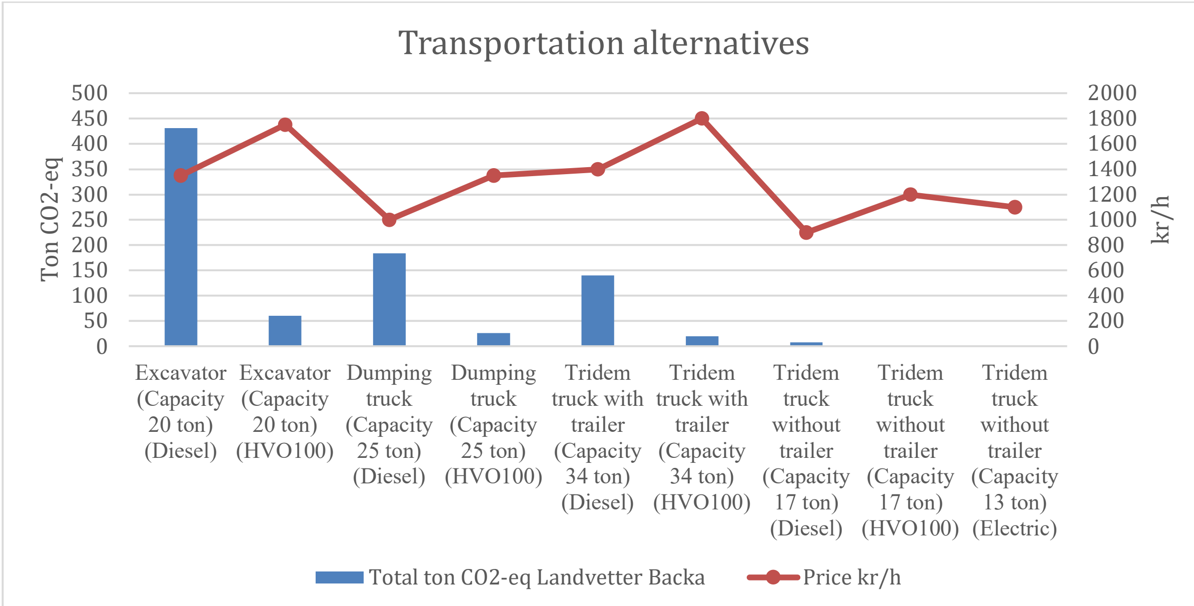


Figure 11. Transportation alternatives, two different y-axes.

The result shows a reduction in total ton CO_2-eq emissions for Landvetter Backa for all vehicles when HVO100 is applied, though with an increased price. The excavator accounts for a reduction of 19 % of CO_2-eq emissions when HVO is applied, which is also the largest reduction in percents among the vehicles. When electricity is applied for the tridem trucks, the percentage of reduction in total ton CO_2-eq emissions for Landvetter Backa for tridem truck with trailer increases by one percentage point, from 6 % to 7 %, compared to the use of HVO100 and 0.41 % reduction compared to Diesel truck without trailer. The tridem truck without trailer cost 1100 kr/h, but only have the capacity of 13 ton. According to Bellman Group (2023), the trucks have a range of about 18-25 miles before needing to recharge. From Figure 11, it can be understood that the diesel alternatives have considerable amounts of CO_2-eq emissions, also that the HVO100 alternatives have high costs per hour.

Further, a more detailed comparison has been made between tridem with trailer and tridem without trailer based on the Landvetter Backa project, see Table 18. The table presents the capacity per hour, total hour, total distance, and total kg CO_2-eq emissions for each type of tridem. The price difference in percent is also presented.

Type of Tridem	Capacity/hour	Total hour	Price difference (%)	Distance (km)	Total kg CO_2-eq	Difference (%)
Tridem without trailer	28.5	4 120		138 000	65 830	
Tridem with trailer	48	2 445	-8%	69 000	49 807	-24%

Table 18. Comparison of Tridem trucks and their difference of aspects.

Based on the results presented in Table 18, the CO_2-eq emissions decrease by 24 % and the price decreases by 8 % when using tridem with trailer for the Landvetter Backa project. Tridem with trailer accounts for a capacity per hour that is 68 % larger than tridem without trailer.

4.2.8 Combined result

This section presents a comparison of the total ton CO_2-eq emissions and price difference for the current status of project Landvetter Backa with a more environmentally friendlier alternative of project Landvetter Backa, see Table 19. The more environmentally friendlier alternative project is based on environmental adapted materials and fuels for diesel, steel (reinforcement), asphalt and concrete, see Tables 12, 13,14 and 16. The total price difference is just summarizing the costs for these materials and fuels alternatives and not the whole project. Rock blasting has been excluded from this comparison since the price difference has a significantly large increase, see Table 15.

Project alternative	Total Ton CO_2-eq emissions Landvetter Backa	Total Ton CO_2-eq emissions Landvetter Backa (%)	Price difference (%)
Current project status Landvetter Backa	1926	100 %	
Environmental friendlier project Landvetter Backa	842	-56 %	+24%

Table 19. Comparison of carbon emission and price for two projects alternative.

The environmental friendlier project reduces the total ton CO_2-eq emissions for Landvetter Backa with 56 %, though with a price increase of 24 %. The price isn't presented in any exact number instead an estimation. Moreover, the CO_2-eq emissions for Landvetter Backa can be reduced more if electric is used instead of HVO100, but it is not possible today because of further development is needed to address today's limitations with electric fuel.

4.2.9 Alternative solutions

As one of the research questions in this thesis focus on alternative solutions for negative environmental options an analysis of how a mobile crushing plant could theoretically replace an amount of the existing method. In the studied project today, there are a lot of rock blasting needed to be performed, and even though most of the material can be used on site as filling materials, there are about x-k tons of rock the project sells to a crushing facility. As the project is ongoing on site just as this thesis are written, there are constant changes. So, as this is written the involved managers in the project describe that they plan to hire a mobile crushing plant to crush some 0-150 but in what amounts and for how long time, is not decided yet. This analysis then focuses on what if the project hires a mobile crushing plant instead of buying x-k ton of crushing materials which will be used in different fractions within the project, and instead sell about x-k tons of rock. The analysis is performed both with a focus on climate impact, which can be seen in Figure 12, but also with a focus on price which can be seen in Table 20. This analysis is based on average prices, capacities, consumptions and confidentially produced through help from different actors in the industry. As some information about the project is confidential, the exact amounts are named as x.

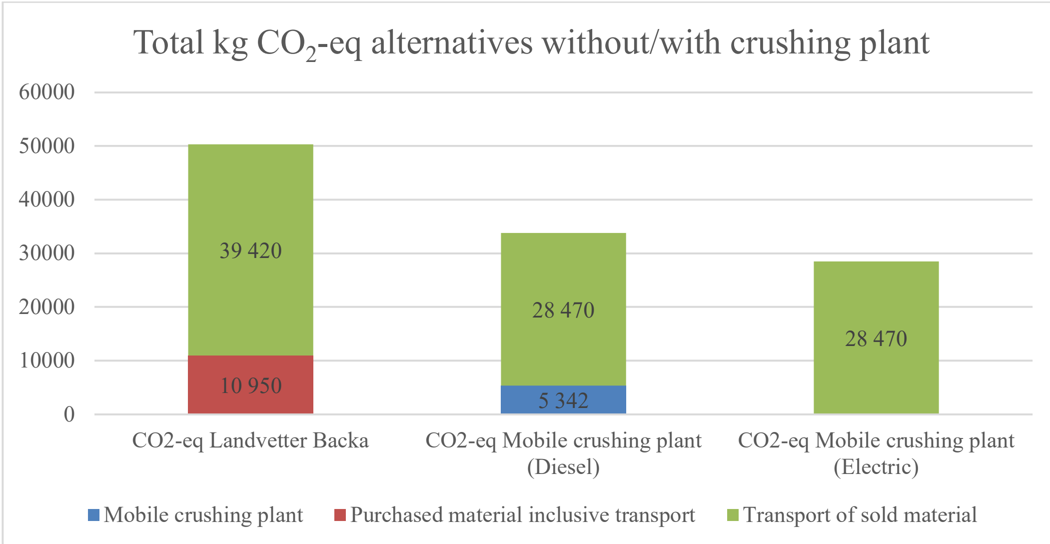


Figure 12. 12Comparison of CO_2-eq emissions between crushing plant powered by electricity versus diesel, as well as usage without a crushing plant.

Based on the numbers presented in Figure 12, Landvetter Backa accounts for 50 370 kg CO_2-eq when a mobile crushing plant is not used. The use of a diesel-powered mobile crushing plant accounts for 33 812 kg CO_2-eq and an electric-powered mobile crushing plant accounts for 28 470 kg CO_2-eq. The electric crushing plant reduces the impact of CO_2-eq emissions by 43 %, while the diesel powered one reduces the impact by 33 %.

The CO_2-eq presented in Figure 12 are approximated values and have been calculated with the formulas 3,4 and 5. These formulas are based on the variables in Table 20 and some confidential values named as x in the text above.

Mobile crushing plant characteristics	**Variable**
Consumption diesel	Ca 18 l/h
Emission factor diesel	2.8 kg CO_2-eq /l
Consumption electricity	Ca16 kw/h
Price per ton inclusive extra crushing	Ca 50 kr/ton

Table 200. Characteristics of mobile crushing plant, processed from (maskinmekano, 2023).

Formula 3:

$$Mobile\ cruishing\ plant = Consumption\ diesel \times Emissions\ factor\ diesel \times time\ consumption$$

Formula 4:

$$Purchased\ material\ inclusive\ transport = \frac{Planed\ amount\ of\ crushing\ material}{Tridem\ truck\ with\ trailer\ (capacity\ 34\ ton)} \times Distance \times Emission\ factor\ tridem\ truck\ with\ trailer$$

Formula 5:

$$Transport\ repurchased\ material = \frac{Transport\ repurchased\ material}{Tridem\ truck\ with\ trailer\ (capacity\ 34\ ton)} \times Distance \times Emission\ factor\ tridem\ truck\ with\ trailer$$

The total price as well as the price difference in percent for using a mobile crushing plant or not are presented in Table 21.

Moment	Ca total Price	Price difference
Landvetter Backa	3 350 000	100 %
Mobile crushing plant (Diesel)	1 700 000	-49 %

Table 211. Price comparison of using mobile crushing plant versus not using one.

The price presented in the table are calculated with formula 6 and using a mobile crushing plant shows a price reduction of 50 percent. Prices used in formula 6 to calculate the total price are confidential and therefore not presented in this report.

Formula 6:

$$Price = rent + purchased\ material\ inclusive\ transport - repurchased\ transport + transport\ cost\ repurchased\ material + operating\ cost$$

4.3 Encouragement for environmentally friendlier alternatives

This section discuss how contractors and consultants could influence clients to change their requests to support more environmentally adapted solutions. Also, this section discusses how the actors experience receptivity towards the clients and vice versa. Another thing being evaluated is the future outcome and how the industry might change towards a common goal of reaching a more sustainable industry.

4.3.1 Contractors viewpoint

To increase the contractor's ability to influence and discuss environmental factors with the client, Veidekke has initiated an approach called "Green customer meetings". The approach was implemented for the first time about a year ago and the focus is to enhance the dialogue between the contractor and client. An enhanced dialogue between the involved are supposed to enable a discussion of potential measures or proposals on how to work more sustainable. The green meetings can be arranged in separate phases of a project for example when the contractor is estimating a job, bidding for a job or when the contractor has won the job. To increase the contractor's possibility to influence the client, Veidekke argues that the contractor should be able to provide clear numbers, calculations and figures of how different materials, fuels and methods can decrease the carbon emissions. Furthermore, Veidekke argues that partnership contracts can enable a more open discussion with the client regarding more environmental sustainability and social sustainability.

The most common clients Veidekke works with are municipalities, private clients, and the Swedish Transport Administration. Veidekke believes it is easier to apply for green customer meetings with municipalities and private clients since it is easier to meet with the person who has the authority to make decisions. There is also often a greater ability to influence these two clients and get them to listen to proposals and ideas since they own their own wallet. The reception of ideas is often positive from the clients, though can it be limited because of a strict budget. However, the Swedish Transport Administration is a large organization with distinct roles and services and therefore it can be hard to meet the person with the right authority. Further, the Swedish Transport Administration creates requirements and incentives for projects which can be challenging for the contractors to change or have an impact on. Therefore, it is preferable if the contractor gets involved in an early stage of a project with the Swedish Transport Administration as client, to increase the possibility to influence and make changes. Each year, there is a meeting held by the Swedish Transport Administration where upcoming projects are presented and companies in the industry are invited to listen and discuss different alternatives. The companies are enabled to discuss more environmentally friendlier alternatives and proposals with project managers represented by the Swedish Transport Administration.

Green customer meetings have recently been implemented and for the upcoming years Veidekke wants to increase the use of it to increase the contractor's ability to influence. Veidekke argues about the importance of discussing environmentally friendlier alternatives since the more it is discussed and noticed the more it will enhance and increase the development process.

4.3.2 Consultants viewpoint

From a consulting viewpoint, Markera argues that that they as consultants don't have too many possibilities to influence clients in general regarding supporting environmentally adapted solutions. Markera, who works a lot towards the Swedish Transport Administration, explains that when it comes to materials and execution, they are limited by the regulations of the Swedish Transport Administration. They explain that they cannot invent their own materials to use, such as environmentally friendlier concrete, without the Transport Administration making an exception for or allowing such a choice of material. Further on Markera mean that their greatest opportunity is to create the best possible design for the project, with the most optimized construction and a mass balance. This is mainly what Markera focus on, but the environment is intertwined with the costs in this case. If the project is done well and as cheaply as possible, it will usually be more environmentally efficient, according to the interviewed. WSP have a similar viewpoint as Markera, it can be hard to influence the clients fully, but there still are possibilities to do so a bit depending on who the clients are but also depending on the specific projects and assignments. According to WSP it is easier to help with changes when contractors have bonus aspects in their contracts, then it automatically becomes easier to change different aspects and materials into more environmentally friendlier.

Even though Markera and WSP works with the Swedish Transport Administration mostly, they also work with different clients such as municipalities, contractors, industries, energy companies and so on. Markera explains that these clients are often more open and willing to try different solutions which they present. WSP instead argues that it often depends on person level what clients are easiest to influence regarding alternative solutions. As consultants most often are procured from cheapest price it can be hard to have space to affect the clients with environmentally friendlier solutions, according to Markera. However, in a contract with a variable price, Markera explains that they can be more creative and more orientated to environmentally friendlier solutions compared to a fixed price. When it comes to a fixed price, their goal is to do the work as quickly and cheaply as possible, which means that we follow exactly what is stated in the contract, but of course with professionalism. WSP explain that they have a lot of internal goals and focus on environment and sustainability which motivate them to try implementing more suitable options in their daily work towards customers. Further on, Markera explains that it is not always easy to work with the Swedish Transport Administration as it is such a large company and organization, therefore it becomes hard to get in contact with right persons. Talking about future possibilities both WSP and Markera argues that the demands for more environmentally friendlier alternatives can only increase, and they feel like things are happening. Until now, and even now, the biggest focus has been on the cost of things, but hopefully in a few years, the focus may be on sustainability, even before cost, according to the interviewed.

4.3.3 Clients viewpoint

From a client's viewpoint, the Swedish Transport Administration explain that they are very receptive to various proposals for improvements, suggestions, and ideas from contractors and consultants. The Swedish Transport Administration explain that the people working with especially climate calculations are easy to reach through email and phone, where they gladly receive feedback. Further on, the interviewed explain that they try to consider all types of contractors and consultants in the industry, but of course there is a limit to how quickly and how much they can delve into things, and even if they are receptive to proposals, it does not mean that Swedish Transport Administration can adjust everything. Examples from the Swedish Transport Administration on how they work with receptivity could be that companies submit feedback on various emission factors that they do not find consistent with what is currently being used by the Swedish Transport Administration, or that the default values are not perceived as correct. Then the Swedish Transport Administration explain that they take this information into account ant try to find a better alternative. Talking about the future, the interviewed explain that there are now increased dialogues being created between actors, and the interest is increasing rapidly regarding climate and environmental alternatives within projects. Lastly, discussing price and future challenges, the Swedish Transport Administration explain that they need to find the right balance between price and emissions. They cannot set too high requirements, as contractors won't be able to calculate and win projects. At the same time, the Swedish Transport Administration wants to push for development and achieve the environmental goals set for the future.

5. Discussion

The discussion section dives deeper into this thesis result with focus to answer the stated research questions.

5.1 Simplifications and generalizations

Duo to this report is based on a real project, certain information has not been able to present. Prices for material products from material suppliers has shown to be a sensitive issue. There are suppliers who do not wish to share their prices, which have made it impossible to present any exact prices in this report. The prices presented in this report are either estimated or presented in percent to avoid disclosing the exact prices. However, prices differ constantly and depends on several factors, which justify the method of estimating the prices.

Moreover, there has been made simplifications for the calculations of CO_2-eq for the materials and machines in the project Landvetter Backa due to time limitation. The calculations for asphalt have been simplified to two types of asphalt representing all the asphalt types used in the project. This simplification has been made based on information from the theory on how the Swedish transport administration presents its requirements regarding CO_2-eq emissions from asphalt. The concrete has also been simplified to two types and all the precast concrete has been excluded from the calculations due to low impact. The project consists of several types of steel with different emissions factors, though has a simplification been made to only calculate the CO_2-eq emissions from reinforcement in this report. Various sizes of excavator, tridem truck and dumpers are used in the Landvetter Backa project. Due to time limitations, it has not been possible to calculate prices for each type and size of machine. To simplify this calculation, one machine size of each vehicle type has been chosen to represent all sizes in the project. The simplifications that have been made do not affect the carbon dioxide emissions, but only the price conditions, which are considered to have no impact on the quality of the report as prices are constantly changing.

5.2 The materials and transportation choices which affect the studied construction project the most.

Anavitor's climate calculation program and the Swedish transport administration's climate calculation program calculated different values for the total CO_2-eq emissions for the project Landvetter Backa. The result from Anavitor's tool was 15.6 % larger than the result generated from the Swedish transport administration's tool. Further, the ranking of materials and fuels also differed between the results, but both results showed that diesel accounted for at least 50 % of the total CO_2-eq emissions. Ranking of materials such as concrete and steel differed between the tools, but these two materials were top 3 in both tools. The reason the result differs between the tools depends on the tools are based on different emissions factors as well as Anavitor includes more parameters, since the whole cost calculations was imported to the tool. Materials, fuels and work tasks need to be manually imported to the Swedish transport administration's climate tool, which creates uncertainty to include all factors. However, the order of material with the largest CO_2-eq impact depends on the project type, location, and scope. For this project there was a need of a large amount of rock blasting, which contributed to a large amount of excavation work for the blasted rock material. The excavation is done by vehicles as excavator, dumper and tridem with truck, which all are powered by diesel. According to Anavitor's climate tool, diesel accounted for 54 % of the total CO_2-eq emissions from the project, which is largely represented by the large amount of excavation work. Projects located on flat surfaces with for example moraine as foundation and lower amount of excavation work due to rock blasting isn't necessary are likely to have a lower proportion of diesel emissions. Further, the project type is crucial in determining what type and amount of material that are needed. For example, a project that involves a lot of concrete will have a substantial percentage of emissions from concrete.

5.3 Some alternative solutions for negatively environmentally friendlier choices in a project.

This section discusses the advantages with a mobile crushing plant, but also alternatives for rock blasting and fuels.

5.3.1 Mobile crushing plant

An evaluation regarding using a mobile crushing plant for the project Landvetter Backa has been made in the report, since diesel accounted for a high percentage of the total emissions due to the large amounts of excavation work. The use of a mobile crushing plant enables to reuse material on the construction site which reduce the number of transports in and out from the site. The comparison has been made with two different types of crushing plant, one powered by diesel and one powered by electric. For the project Landvetter Backa the crushing plants powered by diesel versus electric showed a reduction of 33 % versus 43 % of the total CO_2-eq. The price has only been compared for the crushing plant powered by diesel since it is the most common to use on the market. Further, a reduction of 50 % of the total price is achieved by using a mobile crushing plant powered by diesel. This does not mean that it is always profitable to use a mobile crushing plant, there needs to be a high demand of rock blasting, excavation of blasted rock material as well as a demand for purchased crushed materials. The mobile crushing plant also require a lot of space for the machine and storage of crushed material, which needs to be considered. In this project, the required space is achieved. In the Landvetter Backa project, calculations have been made for the rental of a mobile crushing plant, but at the time of writing this report, no decision had yet been made. In the future, it would be interesting to study the breakeven point of when it is profitable versus not to use a mobile crushing plant.

5.3.2 Rock blasting

In the theory section 2.5.4, two alternative solutions to traditional rock blasting with explosives were presented. These two methods were hydraulic fracturing and wire sawing, both methods were described as time-consuming but with the advantage of reducing carbon dioxide emissions. The result in this report shows a reduction of the total CO_2-eq emissions for the project Landvetter Backa with 9 % when using hydraulic fracturing and wire sawing. According to conversations with rock blasting companies in relation to collect prices, methods as hydraulic fracturing and wire sawing has been described as methods to be used for smaller scale. It was neither possible to only use wire sawing or hydraulic fracturing for the Landvetter Backa project, instead a combination of the methods was needed. Further, the price increase by 1327 % when using hydraulic fracturing and wire sawing for project Landvetter Backa. The reason to the significantly increase in price depends on the capacity of blasted rock per day is lower, traditional rock blasting has a capacity of 700-900 m3 per day compared to a capacity of 100-150 m3 per day with hydraulic fracturing and wire sawing. This alternative method to lower the CO_2-eq emissions for a project with a large demand of rock blasting is not a reasonable solution because of the large price increase and the lower capacity per day which contribute to a longer construction time. Therefore, when the combination of more environmentally friendlier material was combined for the project Landvetter Backa in the result the traditional rock blasting alternative was chosen despite the higher CO_2-eq emissions. However, the theory mentioned other negative impacts associated with traditional rock blasting such as fly rock, ground vibrations, air overpressure, back-break and gas emissions, though hasn't neither of these factors been included in the result of this report. The reason these factors has been excluded is because of this report focus only on the CO_2-eq emissions.

5.3.3 Fuels

Moreover, this report studies alternative fuels to diesel such as HVO100 and RME100, as well as the development and use of electric machines in the infrastructure industry. These methods have been studied based on CO_2-eq emissions and cost. All three alternative fuel types generated lower CO_2-eq emissions but in favour to Electric followed by HVO100. The cost of electric fuel has been excluded from the study since the use of electric vehicles are limited in the infrastructure industry and therefore hard to find prices for. Further, the theory as well as the result showed an increase in price for HVO100 and decrease in price for RME100 compared to diesel (Binder, 2022). Despite RME100 having a lower CO_2-eq impact and cost compared to diesel it hasn't been mentioned in the interviews as a common alternative to diesel in the infrastructure industry. According to Binder (2022), HVO100 can be used in all diesel vehicles and RME100 is limited to vehicles with approval because of its distinct properties of diesel. According to Fredrik at Veidekke, there has been concerns about the use of HVO because of it can clog the machines and that it will become a shortage of supply in relation to the war in Europe, though hasn't neither of these concerns been any problem to Veidekke. In the Landvetter Backa project, HVO100 can reduce the total CO_2-eq emissions of the project by 47 %, though at an increased price of 26 %. The major challenge with HVO100 is to convince the client to be willing to pay more to reduce the CO_2-eq emissions. The interviews conducted in this report indicate that price is the most decisive factor, but some clients are open to new innovations but are limited to budget. The development of innovation to lower the CO_2-eq emissions has increased in the last year in relation to new laws and to meet the requirements the Swedish transport administration plans for. The new requirements put demand on use of electric vehicles, which according to Fredrik can be a challenge since the electric vehicles are not used on a large scale in today's construction industry due to its short battery lifetime. Electric vehicles can lower the CO_2-eq emissions by almost 100% and the transition of electric cars has grown the last years. To increase the use of electric vehicles as tridem truck, dumper, and excavator, there needs be developed a battery with sufficiently long battery capacity to handle an 8-hour workday. From the result it could be understood that the electric 13-ton tridem truck have a range of 18-25 miles. These two aspects will affect the time pressure a lot because it can't transport as much material per transportation trip and it can't have the same effectivity, as it need to be recharged several times a day if used during the whole workday. However, if the diesel was replaced by electric fuel for the project Landvetter Backa the total CO_2-eq emissions for the project would be reduced by 54 %, which must be seen as a theoretical percentage rate. Because of the limitations in the market, it hadn't been possible to change all diesel machines to electric machines.

From the result it can be understood that tridem trucks with or without trailer have significant differences in total CO_2-eq emissions. This come about because tridem trucks with trailer can carry more tons of material than a tridem without trailer naturally. Even though a truck with trailer cost more per hour, the total amount of hours needed becomes lower and therefore both cost and CO_2-eq emissions reduces. Important to remember is that a tridem truck with trailer have negative aspects which this comparison does not deal with. A tridem truck with trailer becomes much longer and therefore clumsier and worse turning radius, so in project located in tight areas in bigger cities for example it might just not be an alternative and forces the projects to drive tridem truck without trailers.

5.4 How the climate programs Anavitor and Swedish transport administration differ.

After analysing and working with the two calculation tools Anavitor and the one from the Swedish transportation administration it becomes clear that they use different emission factors in several cases. This means if creating a climate calculation for a project you will get different numbers from the two programs. Anavitor base their factors and generic data on IVLs numbers, but also enable a good change to import different EPDs from the market to replace these generic values (Anavitor, 2023). One disadvantage related to the emission factors with Anavitor is that it's not possible to change the factors for the generic data on your own. However, this function is possible within the calculation tool provided by the Swedish transportation administration.

Although Anavitor can transform the imported information into generic data, the database is not fully developed yet which mean there is need of manually data collection from EPDs and different product information. This work is not necessary if someone only want a general understanding of the project but important if the calculation should come out as true and close to reality as possible. Because Anavitor have not yet fully developed their calculation program, especially for road and infrastructure projects, weekly supervisions where needed with their employees to deal with different task. Connected with the climate calculations, there were also one supervision meeting with employees from the Swedish transportation administration to solve and understand different aspects with their calculation program. In general, it can be understood that the calculation tool provided by the Swedish Transportation administration is not fully developed and lack more advanced calculation possibilities.

Another thing which is important to understand is that Anavitor more easily include all things in a project if it is registered from the beginning. So, when the export is done from MAP (the cost calculation program) and imported into Anavitor, nothing is forgotten. Compared to the program which the Swedish transportation administration provide, where you have to include all little and big things on your own, which easily leads to less things being included in the calculations. Also, the database which the Swedish transportation Administration provide doesn't give the creator a lot of options for different material or dimensions to choose from. If the database doesn't have what you are looking for, manual work has to be done where exact numbers on specific data needs to be provided, and sometimes it can even be hard finding the right information from different suppliers and manufacturers which mean the calculation in the end doesn't give accurate values for the related CO_2-eq. However, this doesn't necessary mean that the tool isn't good, in the end it actually creates an acceptable climate calculation.

In this work, we decided not to modify the emission factors in the program of the Swedish Transport Administration, in order to accurately compare the actual difference between the software. Although there were some factors that could be considered outdated and inaccurate, we chose to use the generic data that is provided by the database. One of the generic factors that varies between the programs is the value for diesel. Considering that diesel accounts for 54% of the total CO_2-eq emissions in this project, even minor differences in the programs can significantly affect the total emissions.

5.5 How different actors in the constructions sector could influence each other.

From the interviews with both Markera and WSP, one can understand that it can be difficult for consultants to motivate and influence clients to think more sustainably and choose more climate-friendlier options. In the interview with Markera, who explains that they are a slightly smaller consulting firm, it is clear that they experience it as somewhat more difficult and sometimes impossible to influence clients, especially tough clients like the Swedish transportation administration. Although WSP may find it difficult to get proposals through, it is understood from the interviews that they still find it a little more manageable, but it also depends more on the individual person who works as the client.

Veidekke explains that as a contractor, they find it easier to influence clients such as municipalities or private actors, rather than the Swedish transportation administration. This is also understood to be a similar experience by both Markera and WSP. The Swedish transportation administration is a large and strong organization with established structures and requirements, which makes it more difficult to reach them.

From the interview with the wholesaler company Ahlsell, which works extensively in the construction industry and has a wide range of products from various suppliers, it was understood how the work with EPDs functions. The interviewee explains that the construction industry has been a little behind in the development of EPDs for quite some time, and still is, but they see that the development has increased significantly in just the last year.

In order for the industry to easily produce accurate climate calculations, it is necessary for suppliers to provide credible and useful EPDs or similar reports. However, as Ahlsell points out, this is a costly process that many suppliers are reluctant to undertake, especially smaller companies. If the requirements from laws and regulations were more stringent, it would force suppliers to do so. Alternatively, contractors could advance this process by choosing to only purchase products with specific data, even if it costs a little more. However, as long as contracts are driven by the lowest price, this is difficult to justify, given the already intense competition in the industry.

5.6 The future outcome, viewed by the studied actors in the construction sector.

In summary, according to the interviewees in this study, the future of the construction industry looks increasingly bright. A major driving force in achieving the climate goals in this industry is the Swedish transportation administration, of which they are aware. In the interview, they emphasize that they are working hard to find the right balance between economy and development in order to meet and push entrepreneurs, and they are aware that they need to lead the industry towards the climate goals of becoming carbon-neutral by 2040. This actually confirms Veidekke's, WSP's, and Markera's views on the matter, as all three actors argue that the clients, particularly the Swedish transportation administration, determine the pace of development as they set the final requirements and level to aim for. Ahlsell emphasizes that legal requirements and regulations from the EU are the biggest driving force, which can be compared to the others since the Swedish transportation administration is state-controlled and follows EU regulations. Although everyone agrees that it will take some time to make all the necessary changes, everyone has good faith that the future looks brighter and that climate issues are a major focus area right now. However, what the various actors emphasize is that while they want and need to focus on the environment and development, everything ultimately falls back on the need to make money; therefore, it must be economically viable to work sustainably.

Although much of the responsibility lies with the clients, this does not mean that the other actors are insignificant. Veidekke's work with green customer meetings is an example of how entrepreneurs can work to influence development and take responsibility by having open dialogues about what is reasonable and where development opportunities exist. Similarly, WSP shows how consultants can work proactively by having clear internal goals at the company level where they work sustainably. An example of this is that WSP is a member of the organization and process "science-based targets," where they are accepted by the organization and constantly monitored by a committee to confirm that they are working towards carbon neutrality and complying with the demands of the Paris Agreement.

6. Conclusion

To conclude this master thesis, short, summarized answers to the studied research questions will be answered. The answers and conclusions are based on the results in combination with the theory.

1. **What material and transportation choices in a construction project negatively impact the environment the most today?**

The factors with the largest carbon dioxide impact in a construction project depend on the type, scope, and location of the project. Diesel has the largest impact of carbon dioxide emissions in the Landvetter Backa project and accounts for over 50 % of the total emissions. The conclusion of the result and theory is that diesel is used in most phases applied in a construction project, therefore diesel will be a central contributor to carbon dioxide emissions in all projects. Further, concrete and steel are ranked as top 3 factors with largest impact and constitute about 10 % of the total carbon emissions from Landvetter Backa. Rock blasting has a significant impact on the total carbon emissions for Landvetter Backa, due to the type and location of the project requires a large amount of rock blasting.

2. **What are alternative solutions to these negative environmental options and how does the cost of material and transportation choices change with more environmentally friendlier solutions?**

HVO100 is a good alternative fuel to diesel as it would reduce the emissions of this project by 47% but increase the total costs by 26%. The costs are slightly higher as HVO100 is about 6 SEK/liter more expensive than diesel. Both concrete and steel have more environmentally friendlier alternatives available on the market today, with concrete that is adapted for construction and has 50% lower environmental impact (Kg CO2-eq / Ton) than the standard product, and reinforcement with approximately 40% lower climate impact (Kg CO2-eq / Ton). Similar to HVO100, the price range for these environmentally friendlier materials is higher per ton. Considering Landvetter Backa and its large amount of rock blasting, unfortunately, there are no good alternatives to standard drilling and blasting materials that would compete on a reasonable level in terms of cost and time.

3. **How does the climate calculation program which Swedish transport Administration (Trafikverket) use differ from Anavitor?**

The climate calculations programs are based on different emissions factors for materials and fuels. Anavitor's emissions factors are based on data from IVL, and the transport administration base their emissions factors on EPDs from 2015. The function to import EPDs is available for both programs, though provides the transport administration program even the ability to change the emissions factors manually. Further, Anavitor achieves a higher level of security in including all project data, since it is designed to be able to import files such as cost calculations. Compared to the Swedish transport administration program which requires all data to be manually inserted and is also limited to a certain number of material options. The conclusion is that Anavitor is more developed and has higher user friendliness, but both programs have advantages and disadvantages and need to be further developed.

4. **How can contractors and consultants influence clients to change/adapt their requests to support environmentally adapted solutions?**

It's not always easy to influence and persuade clients to change their requests and specifications to become more environmentally friendlier. Both contractors and consultants claim that it's easier to influence private clients or municipalities to think more sustainably, while it may be more challenging to influence the Swedish transportation administration as they are such a large organization with clear and strict guidelines. Both Veidekke and WSP suggest that it's easiest to influence clients at an early stage, through initiatives such as 'green client meetings' or effective communication before the design phase.

Future research

To conclude, this report presents the materials and fuels with the largest carbon dioxide impact in a construction project, alternative material and fuel options, differences between climate calculation programs and how various actors can influence each other regarding improvements to reduce the carbon emissions. For future research, it requires development for electric fuel or an alternative method to reduce the use of diesel. The current methods of rock blasting are limited and needs further research, as well as all materials need to be further developed to reach as close to net zero emissions as possible.

References:

Al Agedi, B., & Ibrahim, M. (2010). Energiförbrukning och utsläpp av koldioxid vid byggande av väg. Mälardalens Högskola. https://www.diva-portal.org/smash/get/diva2:310515/FULLTEXT01.pdf

Al-Bakri, A. & Hefni, M. (2021). A review of some nonexplosive alternative methods to conventional rock blasting. Open Geosciences, 13(1), 431-442. https://doi.org/10.1515/geo-2020-0245

Anavitor. (2023). DET ÄR LÄTT ATT RÄKNA GRÖNT. Retrieved February 3, 2023, from https://www.anavitor.se/Hem

Apif M. Hajji & Michael P. Lewis. (2017). How to estimate green house gas (GHG) emissions from an excavator by using CAT's performance chart", AIP Conference Proceedings 1887, 020047. https://doi.org/10.1063/1.5003530

Arbetsmiljöverket (2023, February 3). Sprängarbete. Retrieved February 16, 2023, from https://www.av.se/produktion-industri-och-logistik/sprangarbete

Architecture 2030. (2023). WHY THE BUILT ENVIRONMENT?. (https://architecture2030.org/why-the-building-sector/

Bell, E., Bryman, A. and Harley, B., 2018. Business research methods. 5th ed. New York: Oxford University Press.

Bellmangroup. (2023). Bellmans testar eldriven lastbil!. https://bellmangroup.se/bellmans-testar-eldriven-lastbil/

Benker, M., & Göransson, S. (2020). Alternativ till konventionell ovanjordsprängning i tätbebyggda områden (ISRN UTH-INGUTB-EX-B-2020/026-SE). Uppsala universitet. https://www.diva-portal.org/smash/get/diva2:1443100/FULLTEXT01.pdf

Binder, T. (2022). HVO100 - analys av nuläge och framtida utveckling. Svenska miljöinstitut. https://www.diva-portal.org/smash/get/diva2:1714447/FULLTEXT01.pdf

Bolinder, E. (2018). Klimatpåverkan från arbetsfordon i byggproduktion. *https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8955259&fileOId=8955261*

Boverket. (2023a, 9 January). Miljöindikationer – aktuell status. https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljoindikatorer---aktuell-status/

Boverket. (2023b, 9 January). Utsläpp av växthusgaser från bygg- och fastighetssektorn. Utsläpp av växthusgaser från bygg- och fastighetssektorn - Boverket

Boverket. (2022, 28 October). Vad byggnadsnämnderna behöver veta om klimatdeklarationer. https://www.boverket.se/sv/klimatdeklaration/om-klimatdeklaration/pbl-och-klimatdeklarationer/vad-byggnadsnamnderna-behover-veta-om-klimatdeklarationer/

Boverket. (2020). Utveckling av regler om klimatdeklaration av byggnader (2020:13). Utveckling av regler om klimatdeklaration av byggnader - förslag på färdplan och gränsvärden (boverket.se)

Boverket. (2019A, 20 February). Metodval för LCA. Metodval för LCA - Boverket

Boverket. (2019B, 20 February). Standarder for LCA. Standarder för LCA - Boverket

Boverket. (2019C, 20 February). Mer om miljövarudeklarationer för byggprodukter (EPD). Mer om miljövarudeklaration för byggprodukter (EPD) - Boverket

Byggföretagen. (2023). Färdplanerna viktiga i ny klimathandlingsplan. https://byggforetagen.se/2023/01/fardplanerna-viktiga-i-ny-klimathandlingsplan/

Cementa. (n.d.) Nollvision för koldioxid. Nollvision för koldioxid | Cementa

Chou, C., & Lee, N. (2015). Assessment of life cycle energy saving and carbon reduction of using reclaimed asphalt concrete. Environmental sustainability in transportation infrastructure. https://doi.org/10.1061/9780784479285.017

Ecoinvent. (n.d). About ecoinvent. Retrieved February 3, 2023, from https://ecoinvent.org/the-ecoinvent-association/

Environmental Protection Agency. (2022A, May 16). *Overview of Greenhouse Gases*. EPA. Retrieved February 1, 2023, from https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Environmental Protection Agency. (2022B, May 5. *Understanding Global Warming potentials. EPA.* Retrieved February 1, 2023, from https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

European Commission. (2019). A European Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Eurostat. (2017, 9 March). Glossary: Carbon dioxide equivalent. Glossary:Carbon dioxide equivalent - Statistics Explained (europa.eu)

Fossilfritt Sverige. (n.d.). Bygg- och anläggningssektorn. Bygg- och anläggningssektorn - Fossilfritt Sverige

Fossilfritt Sverige. (2018). Färdplan för fossilfri konkurrenskraft. Fardplan_for_fossilfri_bygg-_och_anlaggningssektor_20181228-1.pdf (byggforetagen.se)

GHG Protocol. (n.d.). About Us. Retrieved February 3, 2023, from https://ghgprotocol.org/about-us

Ghosh, A., & Chatterjee, A. (2008). Ironmaking and Steelmaking: Theory and Practice (1st ed.). Prentice-Hall of India Pvt.Ltd.

Groza, M. D., Pronschinske, M. R., & Walker, M. (2011). Perceived Organizational Motives and Consumer Responses to Proactive and Reactive CSR. Journal of Business Ethics, 102(4), 639-652.

Hayers, M. (2022). Volvo shows 22 tonne electric excavator. Construction Europe. Volvo shows 22 tonne electric excavator - Construction Europe (construction-europe.com)

HYBRIT (2022, June 22). HYBRIT Demonstration. https://www.hybritdevelopment.se/hybrit-demonstration/

Härryda kommun. (2022, November 21). Utvecklingen I Landvetter Backa. Utvecklingen i Landvetters Backa - Härryda kommun. Retrieved February 1, 2023, from https://www.harryda.se/byggaboochmiljo/aktuellabyggprojekt/landvetter/utvecklingenilandvettersbacka.4.414de20a182e90df9d2a5a1.html

Jorden. (n.d.). In Nationalencyklopedin. Retrieved May 4, 2023, from https://www.ne.se/uppslagsverk/encyklopedi/l%C3%A5ng/jorden

Kalander, C. (2014). Planer för transportsystemet 2014 – 2025. Trafikverket. https://trafikverket.ineko.se/Files/sv-SE/10799/RelatedFiles/2014_039_planer_for_transportsystemet_2014_2025_samlad_beskrivning_av_forslagen_till_nationell_plan_och_lansplaner.pdf

Koopmans, L. (n.d.) Allt du behöver veta om HVO100. Volvo. https://www.volvocars.com/se/edit/artikel/allt-om-hvo100

Larsen, K. P., Poulsen, P. N., & Nielsen, L. O. (2012). Limit Analysis of 3D Reinforced Concrete Beam Elements. Journal of Engineering Mechanics, 138(3), 286–296. https://doi.org/10.1061/(asce)em.1943-7889.0000326

Li, X., Yuan, F., Shen, J., Jia, J., & Gao, j. (2022). Application of wood powder for asphalt Co2 emissions reduction. Journal of cleaner production, 375. https://doi.org/10.1016/j.jclepro.2022.134127

Liu, S., Shukla, A., & Nandra, T. (2017). Technological, environmental and economic aspects of Asphalt recycling for road construction. Renewable and sustainable energy reviews, 75, 879-893. https://doi.org/10.1016/j.rser.2016.10.080

Lundberg, E. (2019). Att skriva uppsats med kvantitativ ansats. [powerPoint-presentation]. Göteborgs Universitet. file:///C:/Users/phili/Downloads/kvant%20uppsats2019%20(1).pdf

Löfgren, I. (2022). Först med klimatförbättrad betong, nu med en anläggningsbetong som ger 50% lägre klimatavtryck. Thomasbetong. Först med klimatförbättrad betong, nu med en anläggningsbetong som ger 50% lägre klimatavtryck (thomasbetong.se)

Maskin mekano. (2023). Minska ditt CO2 avtryck. https://www.maskinmekano.se/sorteringsverk/eldrift?fbclid=IwAR2AHBqNUF_4OPtWFcBM-unvuHggyhZ0qcFLsFO8hP8QEgarE7dGngpZQLo

Naturvårdsverket. (n.d.a). Sveriges klimatmål och klimatpolitiska ramverk. (https://www.naturvardsverket.se/amnesomraden/klimatomstallningen/sveriges-klimatarbete/sveriges-klimatmal-och-klimatpolitiska-ramverk/

Naturvårdsverket. (n.d.b). Däför blir det varmare. Växthusgaser - Därför blir det varmare (naturvardsverket.se)

Naturskyddsföreningen. (2021, 9 June). Hur fungerar växthuseffekten? Hur fungerar växthuseffekten? - Naturskyddsföreningen (naturskyddsforeningen.se)

NESTE. (2017). Optimering för HVO minskar bränsleförbrukningen och utsläppen. https://www.neste.se/optimering-f%C3%B6r-hvo-minskar-br%C3%A4nslef%C3%B6rbrukningen-och-utsl%C3%A4ppen

NIST. (2020). BEES. Retrieved February 3, 2023, from https://www.nist.gov/services-resources/software/bees

OpenLCA. (2022). Why we started the development of openLCA. Retrieved February 3, 2023, from https://www.openlca.org/the-idea/

Pan, W., Li, K., & Teng, Y. (2018). Rethinking system boundaries of the life cycle carbon emissions of buildings. Renewable and sustainable energy reviews, 90, 379-390. https://doi.org/10.1016/j.rser.2018.03.057

PEAB. (2022). 65 procent lägre koldioxidutsläpp när Peab asfalt summerar. 65 procent lägre koldioxidutsläpp när Peab Asfalt summerar - Peab (cision.com)

PEAB. (2018). ECO-Asfalt plus [EPD]. https://api.environdec.com/api/v1/EPDLibrary/Files/c6ff82fb-6406-4c87-a723-f51c6ce7b822/Data

Persson, J. (2020). Utsläpp av koldioxid vid transporter av bergmaterial i projektet trängslet. *https://www.diva-portal.org/smash/get/diva2:1535395/FULLTEXT01.pdf*

Regeringen. (2016). Regeringens proposition (Rapport nr. 146). https://www.regeringen.se/49fe25/contentassets/480ed767687b4b7ba6c960f9c1d4857f/ett-klimatpolitiskt-ramverk-for-sverige-prop.-201617146

Rowberg, K. (2022). Global Warming Potential. Salem Press Encyclopedia of Science.

SFS 2012:546. Förordning (2012:546) med instruktion för Boverket. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-2012546-med-instruktion-for-boverket_sfs-2012-546

SimaPro. (n.d.). About SimaPro. Retrieved February 3, 2023, from https://simapro.com/

Singh, R, B & Singh O. (2012). Study of Impacts of Global Warming on Climate Change: Rise in Sea Level and Disaster Frequency. Global Warming - Impacts and Future Perspectives. InTech. DOI: 10.5772/50464.

Sivakrishma, A., Adesina, A., Awoyera, P.O., & Rajesh Kumar, K. (2020) Green concrete: A review of recent developments. Materialstoday: PROCEEDINGS, 27(1), 54-58. https://doi.org/10.1016/j.matpr.2019.08.202

Skanska. (n.d.) Grön betong – för en hållbar framtid. PowerPoint-presentation (skanska.se)

Skanska. (2023). Grön betong. Grön betong låg klimatpåverkan | skanska.se

Sovacool, B. K., Griffiths, S., Kim, J., & Bazilian, M. (2021). Climate change and industrial F-gases: A critical and systematic review of developments, sociotechnical systems and policy options for reducing synthetic greenhouse gas emissions. Renewable and Sustainable Energy Reviews, 141. https://doi.org/10.1016/j.rser.2021.110759

Steel Fabrication Services. (2019, 14 January). What Is the Difference Between Reinforced and Structural Steel?. https://steelfabservices.com.au/what-is-the-difference-between-reinforced-and-structural-steel/

Stockholmsstad. (2022). Diesel. https://hallbart.stockholm/lar-dig-mer/drivmedel-klimat/diesel/

Svenskt Näringsliv (2019, October 1). Europas mest miljövänliga stål finns i Halmstad. https://www.svensktnaringsliv.se/regioner/halland/europas-mest-miljovanliga-stal-finns-i-halmstad_1137534.html

SVENSK BETONG. (2022). Vägledning klimatförbättrad betong (Publication No. 2) Vagledning_Utgava_2_Webb.pdf (svenskbetong.se)

Svevia. (2020). Asfalt med lägre klimatpåverkan. Lignin, asfalt med lägre klimatpåverkan - Svevia

Swedish Standards Institute. (2011). SS-EN 15978:2011 [Figure 1]. https://www.sis.se/api/document/get/82222

SWEROCK. (n.d.). ECO-Betong. ECO-Betong - betong med lägre klimatpåverkan | Swerock - Swerock

Toller, S. (2020). Klimatkalkyl – Beräkning av infrastrukturens klimatpåverkan och energianvändning i ett livscykelperspektiv. Trafikverket. https://bransch.trafikverket.se/contentassets/eb8e472550374d7b91a4032918687069/klimatkalkyl-rapport-v-7.0.pdf

Trafikanalys. (2022). Fordon i län och kommuner 2021. Sveriges officiella statistik. https://www.trafa.se/globalassets/statistik/vagtrafik/fordon/2022/fordon-i-lan-och-kommuner-2021.pdf

Trafikverket. (2023A). Klimatkrav. Klimatkrav - Bransch (trafikverket.se)

Trafikverket. (2023B). Hur mycket släpper olika fordonstyper ut?. https://bransch.trafikverket.se/for-dig-i-branschen/miljo---for-dig-i-branschen/Luft/Dokument-och-lankar-om-luft/handbok-for-vagtrafikens-luftfororeningar/

Trafikverket. (2023C). Klimatkalkyl (version 7.0) [Software]. Trafikverket. https://klimatkalkyl.trafikverket.se/

Trafikverket. (2023D). Vägtrafikens utsläpp 2022. Retrieved from https://bransch.trafikverket.se/contentassets/01e7ada729cf48f2977873379b306d45/pm-vagtrafikens-utslapp-2022.pdf

Trafikverket. (2020A). Klimatkalkyl för vägarbeten. Retrieved from https://bransch.trafikverket.se/contentassets/eb8e472550374d7b91a4032918687069/klimatkalkyl-rapport-v-7.0.pdf

Trafikverket. (2020B, 8 maj). Klimatkrav för kommuner och regioner, retrieved from 5 maj 2020 [Video]. YouTube. https://www.youtube.com/watch?v=6kqAO6KnAkY&list=PLCYiAAOUWtV-V2nWUIjAkb3cWIER40NHP&index=1)

Trafikverket. (2014). Planer för transportsystemet 2014–2025. Retrieved from https://trafikverket.ineko.se/Files/sv-SE/10799/RelatedFiles/2014_039_planer_for_transportsystemet_2014_2025_samlad_beskrivning_av_forslagen_till_nationell_plan_och_lansplaner.pdf

Turk, J., Cotic, Z., Miladenovic, A., & Sajna, A. (2015). Environmental evaluation of green concretes versus conventional concrete by means of LCA. Waste Management, 45, 194-205. https://doi.org/10.1016/j.wasman.2015.06.035

Tyrens. (2020). Förslag på klimatkrav för beläggning. *Rapportmall stående (trafikverket.se)*

Veidekke. (2022A). Lågtemperaturasfalt, viktigt på vägen mot hållbarhet. https://www.veidekke.se/aktuellt/reportage/lagtemperaturasfalt-viktigt-pa-vagen-mot-hallbarhet/

Veidekke. (2022B). Veidekke ställer om till lågtemperaturasfalt. Veidekke ställer om till lågtemperaturasfalt

Veidekke Industri. (2020A). Environmental Product Declaration (EPD) for Ab-11 and Ab-16 70/100 Plus Environmental Asphalt from Veidekke [PDF]. EPD-Norge. Retrieved from https://www.epd-norge.no/getfile.php/1324959-1668421634/EPDer/Byggevarer/Asfalt/NEPD-3652-2592_Veidekke--Ab-11-og-Ab16--70-100-Miljoasfalt-pluss.pdf

Veidekke Industri. (2020B). Environmental Product Declaration (EPD) for Ska-16 PMB Plus Environmental Asphalt from Veidekke [PDF]. EPD-Norge. Retrieved from https://www.epd-norge.no/getfile.php/1324914-1668421427/EPDer/Byggevarer/Asfalt/NEPD-3645-2599_Veidekke-Ska-16-PMB-Miljoasfalt-pluss.pdf

Appendix

Appendix A: Interview with the Regional Manager Fredrik Indevall (Veidekke)

1. **How can the entrepreneur influence clients such as the Swedish Transport Administration (Trafikverket) to demand more environmentally friendlier alternatives to reduce the climate impact of projects**?

Veidekke has initiated a program called "Green Customer Meetings" where they meet with clients either when they are bidding for a job, estimating a job, or in a more open format to discuss potential measures or proposals on how to work more sustainably. This is a relatively innovative approach that Veidekke has been implementing for about a year to create better dialogue with clients. When it comes to Trafikverket, it may be more challenging to apply these meetings as it is a large organization with many separate roles and services. With Trafikverket, it may be more feasible to participate in a market dialogue before a project with a buyer, project manager, or construction manager to discuss environmental work, etc. However, if they have already written their requirements and incentives at this point, it can be challenging to make any changes. Therefore, if looking at Trafikverket, the entrepreneur wants to get involved at an early stage to influence the contracts more easily. Trafikverket also holds an annual meeting where they invite companies in the industry to discuss and present upcoming projects and create dialogue. Here, there is an opportunity to talk to different project managers and present proposals on how to work more sustainably and environmentally friendlier.

- **Generally, or even at the material level?**

Both generally and at the material level. Being able to present clear numbers and calculations is believed to be truly clear and good. If one can provide specific proposals on how to avoid driving long distances with excavated material, use more environmentally friendlier fuels, or better manage crushed material within projects to reduce transportation, these are good things to bring up.

2. **What are the other types of clients that Veidekke works with and can influence towards a more sustainable approach?**

Other clients that Veidekke works with can be municipalities or private clients such as Volvo, among others. It is somewhat easier to apply "Green Customer Meetings" with these clients since they are easier to reach and to meet with the people who make decisions regarding various projects. The idea behind these meetings is to maintain a relatively open dialogue where Veidekke can present both general ideas and proposals on how to work more sustainably, but there is also an opportunity to go into more detail, such as materials and fuels. They want to be concrete and provide figures on how much CO_2-eq can be saved if one chooses one material or the other, etc. Of course, clients get excited when they explain how cost savings can be made by building in a particular way, but at the same time, they are interested in being able to show that they are building sustainably and environmentally friendlier as it is their ambition and promotes them well outwardly. With these types of clients, it may be somewhat easier to have green customer meetings throughout the timeline, both in a preventive sense but also if they have been assigned a job. They own their own wallet, and therefore it may be easier to get them to listen to ideas and proposals.

- **What kind of requirements do these clients have?**

These clients do not always have environmental requirements from the beginning, while sometimes they may have different incentives, and sometimes they may refer to Trafikverket's requirements in their contracts. Generally, it can be said that there have not been many different environmental requirements from these clients. Often, if there have been any environmental requirements, it has not been difficult to meet them.

3. **How is the reception from the clients when the proposals are presented?**

I think the reception is positive. You can tell that the people who participate in the meetings are listening and interested. And when you have partnership contracts, you already discuss a lot of these issues, which is good, not just environmental sustainability but also social sustainability. However, it depends a bit on who the client is and how strict their budget is. If they already have a fixed budget, it can be more difficult to influence them.

4. **Has this work been done before or is it new to have a dialogue with clients about a more sustainable approach?**

Green customer meetings started last year. In previous projects, we have seen that clients have had requirements for, for example, green reinforcement or green concrete, and then we have to calculate that. We have also had collaboration projects on, for example, E20 where we jointly decided to use green steel and green reinforcement for a specific bridge, but also looked at opportunities to reuse materials by introducing a sorting plant. When it comes to alternative solutions, money is often involved, but it may also be necessary to have a different solution. We had a client where we were supposed to build a bridge, but they had not applied for a water permit and therefore could not build the bridge. It was resolved by being able to excavate the pipes at the bottom, and thus we did not have to build a bridge. There is a lot of CO_2-eq in a bridge, and it was also cheaper not to build it. By participating in collaborative projects, we discuss different solutions, and even if the exact amount saved is not specified, we find alternatives that make it better. In one project, there was very thick material in the PE pipes for water, and we looked at the possibility of reducing the thickness and thus reducing half of the plastic volume, which would have saved a lot. In this case, this pipeline was to be connected to another pipeline that had this thickness, which meant that we could not change the thickness because it would have affected the connection. The important thing is that we can discuss the possibility of making changes.

5. **What motivates Veidekke to work towards influencing clients, what type of benefit do they see in this?**

There are at least two reasons that motivate Veidekke. One reason is that if we become good at this and it is demanded in the contracts, we will be evaluated not only for our ability to build productively and with the right quality, but also sustainably. If we become better at this, we will be able to compete with our competitors and thus score high points, which will enable us to win contracts.

The second reason is that when we compare CO_2-eq emissions and we change reinforcement, concrete, or something else, it can actually result in increased costs. In terms of running accounts, this can lead to increased revenue for us in the end.

6. **What type of contract is most advantageous for being able to influence the client while making it as profitable for the company as possible?**

I believe collaboration is the easiest approach, and that brings us to either a fixed zero or a fixed one, and much of it is about getting to know the organization of the other party. You need to plan, find smart solutions, create schedules for everything, and in doing so, you build trust in each other and take the time to talk about things in a better way, making it easier.

Then I believe that these refineries or industries in general make good money but usually get a bad reputation in the media because of the environment. They also have strict requirements on themselves, and if they can show that they are saving on things and present calculations that prove it, it is probably quite easy for them to accept an increased cost.

Trafikverket, which is a huge client, is difficult to influence in individual projects, but over time they will shift their focus because it is necessary.

7. **How do you see the future and the development of requirements for more environmentally friendlier alternatives and climate impact?**

For the future, we will definitely see a change, but it depends a bit on whether you think short or long-term. The Swedish Transport Administration has talked about introducing requirements that almost no pilot project can meet, which would make it difficult for us and other companies to submit bids today. The reason for this is that the machines that are being demanded do not exist today. The requirements will drive us to look at more alternatives than we do today. We purchased around 20 electric excavators, 20-25 tons, with batteries in Norway 3-4 years ago. The electric battery in the excavators lasted for 3-4 hours, which resulted in a not-so-good evaluation. However, the requirements will mean that more money is invested in development, which may result in batteries being developed that can last for an entire day, but someone has to try it out.

Development and requirements: There have been improvements in the construction site facilities, such as better insulated and tightly sealed modular buildings. In these buildings, there are now also electric radiators, air heat pumps, and all lighting is always in automatic mode. The lighting is turned off when no one is present, as previously seen on construction sites where floodlights are left on even when no one is there. We also see that HVO is increasingly being used as fuel and electric cars are becoming more common for service vehicles.

8. **Other questions.**

- **Are initiatives like sheds and cars driven by the company itself or are they requirements from external sources?**

The requirement for cars comes from external sources; soon, 50% of the cars must be electric. It's not always a requirement, but as the topic is being discussed more, development is increasing. We also have internal requirements where the board has stated that we are part of the solution to climate change and that action must be taken. Doing nothing is not an option; if we propose a project and get approval from the board, we must show what we can do for the environment. We have goals for our operations and have curves to follow, and we are doing very well in that regard. We switched from fossil fuels to biofuels at our asphalt plants, resulting in a 50% reduction in emissions, and some became electric. New asphalt alternatives have also been developed, where the temperature of the asphalt was reduced from 100 to 70 degrees, saving energy needed to heat up the asphalt.

- **We talked about fuel earlier, how much HVO is being used today? Are there any requirements from, for example, the Swedish Transport Administration regarding HVO?**

There may be requirements for it. I don't have a percentage, but in the beginning, it was challenging to use HVO because it clogged up the machines, and the warranty did not apply. There is always some initial fear, but I think we have moved past that. Today, we have subcontractors who use HVO in all their machines, and we work closely with them. When the war broke out in Ukraine, there was concern that we would not be able to get enough HVO, but that didn't happen.

There are good examples of reusing demolition materials for other purposes. One example is when large, prefabricated beams were demolished and then used to build a staircase by stacking them as steps, avoiding the need to transport them to a landfill or demolish them. Norway aims to crush all demolished concrete within 1-2 years and reuse it by mixing it into new concrete. Veidekke also looking at how to handle contaminated soil, which is both expensive and complicated to determine where to place the material. In these cases, we are considering the possibility of washing the soil to remove contaminants and potentially reuse the material. This solution could also reduce the transport distance of the material.

- **When it comes to green customer meetings, who takes the initiative to contact the client? What role do they play?**

It is rarely a project manager, as they are usually out in the field. In most cases, it's me or a site manager, along with an environmental business developer, but there may also be cases where a project manager goes with us.

Appendix B: Interview with the investigator and climate calculation specialist Sofia Miliutenko Martin (Trafikverket)

1. **What are Trafikverket figures and data based on? Is it different industry standard or something else?'**

Trafikverket's climate tool (Klimatkalkyl) primarily uses data from EPDs (Environmental Product Declarations), but in some cases data is also retrieved from open databases and life cycle assessment studies. The emission factors used in the tool correspond to values from 2015 in most cases, except for the emission factors for fuel, which correspond to values from year 2017.

- **Is the data and figures retrieved from a specific EPD, or is it retrieved from several EPDs to calculate an average?**

Within a year, an updated version with updated emission factors will be released in Klimatkalkyl with values that correspond year 2020. Since there were not as many EPDs available in 2015, some materials are only based on one EPD, such as concrete for instance. For some materials, an average value is used, such as steel. The tool specifies what the emission factor is based on for each data point. To use updated information, it is possible to change the emission factor in the tool and refer to your own EPD.

2. **Is it possible to import cost estimates into the Traffic Administration's climate tool so that it automatically links different resources and materials? If so, through which software programs?**

It's not possible to do it 100% automatically. We had a project with a consulting company that helped us to create a support tool in Excel. This tool is intended to serve as a support for mapping and grouping data that should be used as input in Klimatkalkyl, because it takes a very long time to enter everything manually into the tool. This Excel file can be downloaded here: Klimatkalkyl – infrastrukturens klimatpåverkan och energianvändning i ett livscykelperspektiv - Bransch (trafikverket.se)

- **Does it matter which version of the Traffic Administration's climate tool one has access to upload a cost estimate? For example, converting a cost estimate file to an XML file to make it downloadable to the tool?**

No, it doesn't matter. The support tool mentioned above is based on AMA codes and can be used to facilitate work in the climate calculation tool, but it is not possible to upload a cost estimate directly to Klimatkalkyl at the moment.

3. **How does it work when the Traffic Administration procures the client for a job, do you yourselves create a basis and a template in the climate tool, or does it differ depending on the type of contract?**

As a starting point, Trafikverket creates a basis, but it depends on the project. The basis is designed as a template in Trafikverket's climate tool, which provides contractors with the opportunity to compare their improvements to the baseline. There may be exceptions that depend on the project and follow relatively strict guidelines. More details can be found in

TDOK 2015:0480:
https://trvdokument.trafikverket.se/Versioner.aspx?spid=5481&dokumentId=TDOK%202015%3a0480

- **Does it matter what type of contract it is, for example, a turnkey contract or a performance contract?**

Yes, it does matter what type of contract it is, as there are different requirements that are clearly presented in our guidelines- TDOK 2015:0480: https://trvdokument.trafikverket.se/Versioner.aspx?spid=5481&dokumentId=TDOK%202015%3a0480) .

An example of the breakdown of the requirements can be at the planning stage or in the development of tender documents.
There are also guidelines for climate calculations, which show, for example, how to use climate calculations in different phases of the project. See TDOK 2015:0007: https://trvdokument.trafikverket.se/Versioner.aspx?spid=5059&dokumentId=TDOK%202015%3a0007

4. **What is the future of the Traffic Administration's climate tool, and what are the ambitions for the tool going forward?**

We are currently working on development and plan to release version 8 of the climate tool in 2024. The updates planned for version 8 include the inclusion of more material types, updating the emission factors to 2020 levels, and updating the templates for different building components. We have received feedback about improvement of our data for the templates for building components, with some being considered underestimated or overestimated. These updates take relatively long time as they need to be checked multiple times. There are also plans to make some improvements in templates for operation and maintenance of infrastructure. We want to make templates for operation and maintenance more similar to how the tool is designed for building components and make it more flexible.

5. **What does the collaboration generally look like with different contractors in the industry in terms of the environment and emissions? How receptive is Trafikverket to different proposals and ideas from contractors such as Veidekke, Skanska, PEAB?**

Trafikverket is very receptive to various proposals for improvements, suggestions, and ideas from contractors. We who work with climate calculations and tools have an email address (klimatkalkyl@trafikverket.se) where we gladly receive feedback. We really try to consider all types of feedback from contractors and consultants in the industry, but of course there is a limit to how quickly and how much we can delve into things, and even if we are receptive to proposals, it does not mean that we can adjust everything.

- **Do you have any concrete examples of how contractors can/want to influence Trafikverket's climate policies?**

Concrete examples could be that companies submit feedback on various emission factors that they do not find consistent with what is currently being used by Trafikverket, or that the default values are not perceived as correct. Trafikverket performs several projects periodically, where contractors, consultants and suppliers have an opportunity to provide their feedback with regards to Trafikverkets climate requirements, and incentives, as well as suggest improvement opportunities. So, in summary, we have and want to have ongoing cooperation with contractors, consultants, and suppliers.

- **How has the development with this looked in general over the years?**

Since we started imposing more climate requirements in 2016, there has been a gradual increase in demands and interest regarding climate requirements. There are now more dialogues being created between actors, and the interest is increasing rapidly. Going forward there will be more demands on the production and use of EPDs or similar verification documents.

6. **What is preventing Trafikverket from setting even tougher requirements (CO_2-eq emissions on different materials) for contractors?**

Trafikverket needs to find the right balance. We cannot set too high requirements, which might be impossible to reach for contractors. At the same time, Trafikverket wants to push for development and achieve the environmental goals set for the future.

- **In terms of costs, if the requirements become tougher, won't the projects become more expensive? How do you feel about that?**

If Trafikverket is to achieve its goal of zero emissions by 2040, the requirements must become tougher, and this is something Trafikverket budgets for to a certain extent.

7. **Regarding the different requirements for projects under 50 million, what are the different values based on? For projects over 50 million, what are the requirements based on?**

The values are based on a long-term plan to achieve Trafikverket's climate goal of zero emissions by 2040. Therefore, we need a plan to push development towards climate neutrality. As we discussed earlier, we need to find the right balance because we cannot set too high requirements at once, making it impossible for contractors to reach those goals. These requirements were also created through a dialogue with the industry to see what opportunities they have, etc. The requirements were also determined based on 2015 EPD levels and LCA analyses. But setting requirements is not an exact science and there is no exact formula for the approach, so it is important to find a reasonable level through dialogue.

8. **If we want to compare to the starting point of 2015, how is it done in practice?**

In Trafikverket's climate calculation, the values currently in place are 2015 reference values. So, if you want to compare to the 2015 reference values, you adjust the emission factors to project-specific values that should be verified by EPDs, and then you get the difference directly.

Appendix C: Interview with the LCA-specialist Daniel Petersson (Anavitor)

1. **What are Anavitor's figures and data based on? Are they based on industry standards or something else?**

The data that Anavitor connects its resources to is based on data from IVL, the Swedish Environmental Research Institute. The data is adapted to Nordic conditions and is continuously worked on, which means that it is updated on a daily basis. IVL, in turn, bases their values on updated industry standards. They currently have more developed values for the building industry and unfortunately have not yet come as far with the facility side. Anavitor is connected to the Building Sector's Resource Hub, which the industry has developed. The suppliers, in turn, should have the ability to update their declarations and EPDs against this "hub," and Anavitor should be connected to the latest information. However, this does not always work smoothly, and sometimes it may be necessary to request EPDs that the hub has not yet uploaded through Anavitor. This means that IVL reviews the request, and if approved, an update is made, and the data can then be used in the program. Anavitor's generic data is based on an average that IVL simply produces. This does not mean that Anavitor is locked into only using IVL, but it is currently used extensively.

- **What type of data would you say is a little behind in terms of daily updates?**

Since IVL has been more adapted to the building side, the facility industry is a bit behind in terms of daily updates. But some concrete examples could be diverse types of construction vehicles such as excavators and dump trucks. Otherwise, asphalt and concrete materials are much more developed and updated, with information that can be easily downloaded.

2. **Which software programs, such as MAP, can be imported into Anavitor?**

Skanska uses a program called SPIK, where they can also export their cost estimate through an XML file to Anavitor. Another example is Wikell's section data, which can also be exported as an XML file to Anavitor. In general, Anavitor can import from any program as long as it can be sent as an XML file, but also Excel files. Currently, work is also underway to easily import IFC files.

3. **Do you compare or evaluate the Swedish Transport Administration's climate calculation tool with Anavitor?**

Generally, we at Anavitor don't look at the Swedish Transport Administration's tool. The data is open, so we at Anavitor can look at it, but since there is no "API" that is open or at least available to Anavitor, we cannot take in and compare the data that the Swedish Transport Administration's tool uses. "API" is a small program that allows databases to talk to each other.

4. **How do you work to load EPDs into Anavitor? Is it not something that happens automatically?**

As previously discussed, Anavitor largely relies on IVL to handle and retrieve various EPDs. This means that Anavitor should automatically have the latest versions available in the database. However, sometimes this transition does not occur smoothly, and it may be necessary to request a specific EPD in Anavitor, which means that the request is forwarded to IVL, which in turn makes an update.

- **How do you feel about the range of EPDs available on the facility side?**

It varies, there is a lot of data available on the market, but the facility side is generally still lagging in development.

- **Do you have any contact with material suppliers in general?**

Previously, this contact could be made to some extent, but today, it is more IVL that handles this part.

5. **Who are your main customers? Do you only work with the contractor, or can you also work with the client?**

In most cases, we work with the contractor, but we also work with the client on occasion. Examples of clients we work with are municipalities. If you look at IFC, you want to get involved as early as possible and then it's the architects and engineers who use the software, but most of the time it's the contractors because they are the ones who are responsible for everything until it is handed over to the client and they have control over all costs.

- **How do you work with your customers and what does the collaboration/process generally look like?**

We provide the software, and our collaboration is to give the customer the ability to perform a credible LCA analysis.

- **In what way do you work with the client?**

Architects and engineers have their models and calculations and, in those cases, where we work with the client, we make the connections and calculations. This is not something we aim for, but we want it to become a natural part of the architect's work. The best scenario would be for the architect to do their part and then hand it over to the contractor who would then pass it on to the client.

- **How receptive are you to improvement suggestions from your customers?**

Large customers can drive development themselves, and we are fully receptive as long as it complies with the rules. We have a large customer who has developed Anavitor a lot and adapted the program to their company. As we get more customers, we may create a base version and allow larger customers to have an impact. Right now, we're not that big, so we do most of what's requested.

6. **Does Anavitor support all types of computers, or does it have to be Windows?**

For Anavitor to work, Windows is required, alternatively an emulator can be used to run the program on another operating system. However, the ArchiCAD version may only work on Mac initially. Currently, we are working a lot on developing a web-based interface, which will not depend on the operating system used. The first version should be ready by the end of the year, and hopefully, there will be a beta version available after the summer.

7. **How has the response from customers been for Anavitor?**

It varies and depends on how familiar one is with the tool. Anavitor is actually an easy-to-use tool that can become extraordinarily complex depending on how one works with it. You input your calculation and connect it to your environmental resources for calculation, but then there are many things around it that can make it complicated. I find that it varies, for example, calculators generally find the program relatively easy to understand as it looks right now, but someone who only works with the environment may perceive it as a lot of information and repetition.

8. **What are the ambitions for Anavitor's climate tool in the future?**

The ambitions right now are for it to become a web interface, and for more people/organizations to start using it and for it to be sold in neighbouring countries.

Appendix D: Consultants Kent Sjöholm and Malin Arvidsson (Markera)

1. **How can consultants such as Markera influence clients such as the Swedish Transport Administration to impose stricter requirements on the use of environmentally friendlier alternatives to reduce the climate impact of projects?**

When it comes to materials and execution, we are limited by the regulations of the Swedish Transport Administration. We cannot invent our own materials to use, such as environmentally friendlier concrete, without the Transport Administration making an exception for or allowing such a choice of material. Our greatest opportunity is to create the best possible design for the project, with the most optimized construction and a mass balance. This is mainly what we excel at, but the environment is intertwined with the costs in this case. If the project is done well and as cheaply as possible, it will usually be more environmentally efficient. Materials and machinery are not within our control, as they are part of the contractual requirements that come from the Transport Administration.

- **Do you think the client would be receptive if you pushed for an environmental improvement, such as a choice of material?**

It varies depending on whether the client is the Swedish Transport Administration, a municipality, or a private entity. The Swedish Transport Administration is difficult to influence because they follow their regulations. Municipalities are often more open and willing to try different solutions that we present.

- **Does the Swedish Transport Administration discuss with you before presenting a new material or method to be used to reduce environmental impact?**

No, they do not. They may have discussions with a larger consulting firm.

2. **How does the process work when clients procure consultants and designers?**

It is mainly about who can offer the lowest price. The contract can be either a fixed or variable price, and this is determined by the client.

- **How do the different types of contracts differ, and which type of contract is most advantageous for influencing the client?**

No, we cannot influence anything until the contract type has been determined. However, in a contract with a variable price, one can be more creative compared to a fixed price. When it comes to a fixed price, our goal is to do it as quickly and cheaply as possible, which means that we follow exactly what is stated in the contract.

- **How much background information do you receive from the client, such as the Swedish Transport Administration?**

It varies, it can be very detailed information, but also limited in the form of only an overview. The advantage of less information is that it creates more opportunities for us compared to a detailed description that we must strictly follow. All projects are different, not just because of the physical environment but also because of cultural values, the project team, and how the procurement is designed.

3. **Apart from Trafikverket, what other clients do you often work with?**

Trafikverket is our major client, but in addition to them, we work with clients such as Mölndal municipality, Härryda, Gothenburg municipality, and Veidekke. In most cases, our clients are either Trafikverket or different municipalities.

- **Do you mainly work in the Gothenburg area or how far do your boundaries stretch?**

After Covid, it has become possible for us to work over larger areas in Sweden as we do not need to be physically present in the same way as before. For example, we have a project in Uppsala.

4. **Do you have any examples of things that clients often want help with in including in contracts in terms of environmental requirements and sustainability?**

Trafikverket has templates where their environmental requirements are presented, and we follow up on their environmental requirements.

- **Do you feel that contractors meet the environmental requirements set in the contracts currently? Or do you feel that harder requirements could have been set and that the contractors would have been able to meet them as well?**

It's difficult to answer that, as we do not see this directly. However, we do make carbon calculations that the contractor must adhere to, and in some projects reduce emissions by 30%, which I do not see as a major challenge for the contractor if they are a bit creative. More requirements have started to come, but they are relatively difficult to measure.

- **If there is a sensitive area that you feel should not be disturbed, do you perceive the client, such as Trafikverket, as cooperative in these matters?**

It is a balancing act that involves weighing interests against each other, weighing costs against environmental impact and intrusion into valuable areas. This is something that the entire project team needs to work on together. However, we can only say what we think, but it is always the client, in this case Trafikverket, that has the final say. We have been involved in projects where we have proposed an alternative, but where the client did not follow our alternative and chose another option to save money.
How cooperative the client is depending largely on the person representing the client in that particular project. Generally, municipalities have a bit more freedom, but they also usually have a lower budget to adhere to. We have also experienced that contractors usually have a greater influence on the client than we as consultants have regarding the impact of various material choices.

5. **How do you experience the functionality of Trafikverket's climate calculation tool?**

The experience is essentially that the tool is not yet complete. There are many missing features, and it is not easy to work with the software. It feels like the tool was not created by someone knowledgeable in the industry who understands how quantity listings and AMA work, or how things are priced. Additionally, we find that the units often may not be logical or correspond to reality.

- **Do you feel that Trafikverket is receptive to opportunities for improvement with the program or helpful when needed?**

It is not always easy to work with Trafikverket as it is such a large company and organization, but the problem really lies in the fact that their database is not fully developed, and the structure does not work. We have talked to them about the tool before, but there is not much that can be done. If they want us to provide quantities in the tool, we will solve it, but it is difficult to say how accurate everything is in relation to reality.

- **How long have you been using Trafikverket's climate calculation tool?**

Since it was first introduced. You can wish that it would have been a bit more developed by now, but they do send out updates every year, so progress is being made.

6. **Do you notice that clients want to work more sustainably and introduce more sustainability requirements compared to previous years?**

Yes, we do. They have goals they want to achieve, of course, and the overall mindset is becoming more sustainable. We see that they adjust material choices slightly and place more demands on the emissions of materials.

7. **What motivates Markera as a consultant to work to influence clients, what type of gain is seen in this?**

As consultants, we don't get any added value from doing good things, because we are judged on the lowest price. Unfortunately, there is no incentive for us where we receive bonuses if we come up with more sustainable alternatives or similar. Then there is a motivation within the company to do an excellent job and show good work or that we have found a more sustainable alternative. At Markera, we also want to follow the debate and development, to show our expertise in what we are doing.

8. **How do you see the future and development of demands for more environmentally friendlier alternatives and climate impact?**

Well, the demands for more environmentally friendlier alternatives can only increase and it feels like things are happening. Until now, and even now, the biggest focus has been on the cost of things, but hopefully in a few years, the focus may be on sustainability, even before cost.

- **Do you think that in the future, you as consultants can influence the clients to work more sustainably and implement stricter requirements?**

Since Markera is not as large as WSP, for example, it may be costly to have someone working in this way exclusively, but certainly in the future, it may be easier to influence clients to think more environmentally friendlier. But since especially Trafikverket is so large and strong, they always have the final say, and they decide in the way they want.

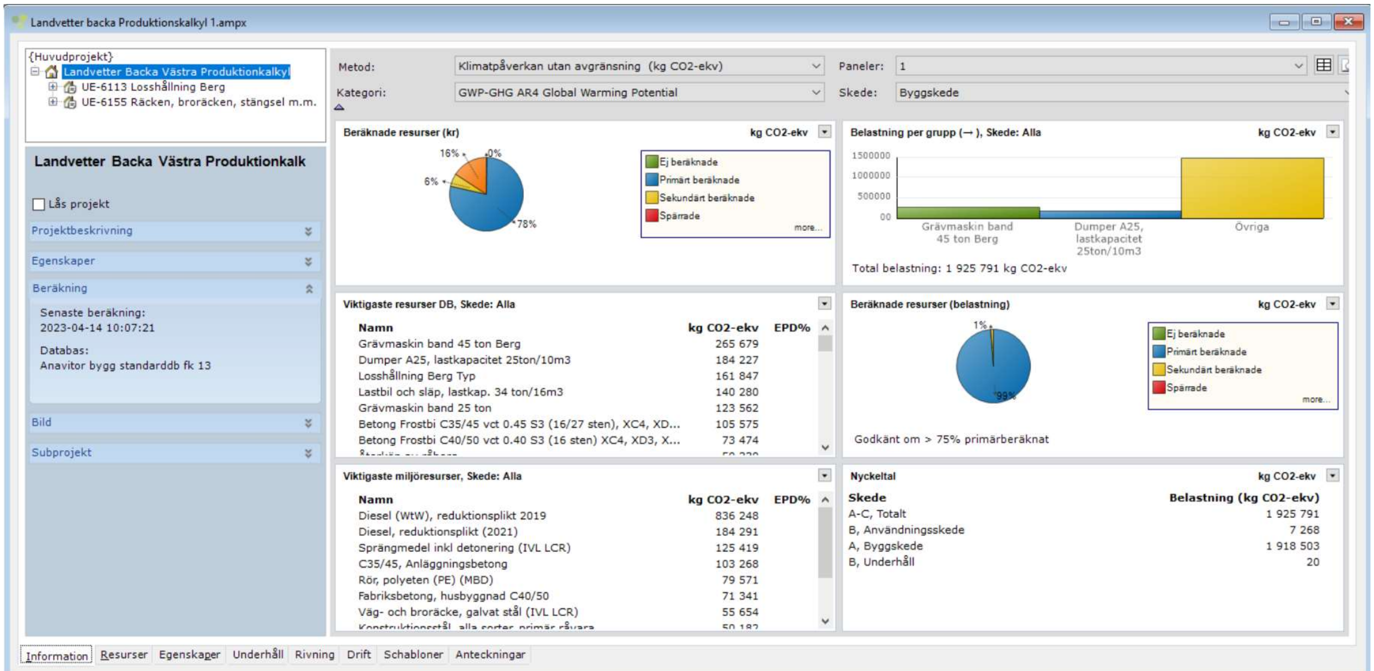
9. **Do you have any other considerations related to the environment and sustainability?**

One should not forget maintenance, operation, and sustainability. Sometimes one can be fixated on the amount of climate impact a certain product has during production but forgets how long the product lasts. Let's say you compare a pipe bridge to a concrete bridge, sure, you see that the pipe bridge is cheaper and may have less climate impact. But then you notice that the pipes rust much faster and the operation is not maintained, which means that you still must replace them in a short time, which then increases the climate impact.

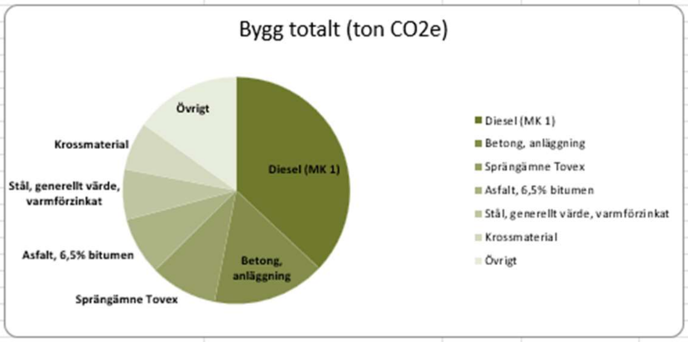
Appendix E: Cost factors to consider when rock blasting with different methods.

Rock blasting, with explosives	Rock blasting, with wire sawing and hydraulic alternative
Rock blasting, for roads (kr/m3)	Wire sawing traditional (kr/m2)
Rocks surface area <1m (kr/m2)	Wire sawing Blind cut (kr/m2)
Rocks surface area >1m (kr/m2)	Hydraulic alternative with wire sawing as basis (kr/m3)
Blasted slope surface class 1 (kr/m2)	
Blasted slope surface class 2 (kr/m2)	
Blasted excavated bottom class 1 (kr/m2)	
Rocks surface area, pipe pit (kr/m2)	
Extra cost depending on type of lighter (kr/m2)	

Appendix F: Result from Anavitor



Appendix G: Result from the Swedish transport administrations climate tool



Resultat till diagram

Diesel (MK 1)	613,006457
Betong, anläggning	266,3139744
Sprängämne Tovex	158,12444
Asfalt, 6,5% bitumen	135,9643404
Stål, generellt värde, varmförzinkat	118,774708
Krossmaterial	114,0264
Övrigt	250,3729417

Resultat till SEB (Totalt från alla ingående klimatkalkyler)	
Bygg totalt	
Klimat (ton CO2e)	1664,623393
Energi (GWh)	7,247065535
Bygg & reinvest + Drift & Underhåll per år	
Klimat (ton CO2e/år)	27,02793765
Energi (GWh/år)	0,135518044

Kalkyler

		Resultat					
Information:		Klimat (ton CO2e)			Energi (GJ)		
Mapp	**Kalkyl**	Bygg totalt	Bygg & reinvest/år	Drift & Underhåll/år	Bygg totalt	Bygg & reinvest/år	Drift & Underhåll/år
	Totalt:	1664,62339	27,02793765	0	26089,43592	487,8649569	0
Landvetter Backa_20230209_0912_2023(	Landvetter Backa_20230209_0912_2023(	1664,62339	27,02793765	0	26089,43592	487,8649569	0

Bidrag från Material och Arbetsmoment

	Klimat (ton CO2e)			Energi (GJ)		
	Bygg totalt	Bygg & reinvest/år	Drift & Underhåll/år	Bygg totalt	Bygg & reinvest/år	Drift & Underhåll/år
Diesel (MK 1)	613,01	7,86	0,00	9468,76	121,42	0,00
Betong, anläggning	266,31	3,39	0,00	848,03	10,98	0,00
Sprängämne Tovex	158,12	1,98	0,00	1402,24	17,53	0,00
Asfalt, 6,5% bitumen	135,96	3,40	0,00	8435,34	210,88	0,00
Stål, generellt värde, varmförzinkat	118,77	5,14	0,00	1320,23	57,13	0,00
Krossmaterial	114,03	1,43	0,00	1710,40	21,38	0,00
Avskogning	106,59	1,33	0,00	0,00	0,00	0,00
Polyeten, HDPE	59,28	1,48	0,00	1063,82	26,60	0,00
Stål, rostfritt stål och rostfri armering	36,72	0,31	0,00	539,58	4,50	0,00
Stål, armeringsstänger	33,62	0,43	0,00	533,08	6,86	0,00
Geotextil, PP textil	11,06	0,14	0,00	557,45	6,97	0,00
Annat material	2,71	0,03	0,00	0,00	0,00	0,00
Trä	0,25	0,01	0,00	85,71	2,05	0,00
Cement (CEM I)	0,14	0,00	0,00	0,61	0,01	0,00
Massor	0,00	0,00	0,00	0,00	0,00	0,00
El, ursprungsmärkt förnybar (inköpt av Tr.	0,00	0,00	0,00	0,00	0,00	0,00
Jord	0,00	0,00	0,00	0,00	0,00	0,00
Stål, generellt värde	0,00	0,00	0,00	0,00	0,00	0,00
Glas, härdat	0,00	0,00	0,00	0,00	0,00	0,00

Appendix H: Interview with the sustainability strategy specialist Andrea Wästlund (Ahlsell)

1. **Does Ahlsell have internal goals related to the environment and sustainability? How do you work towards developing a more environmentally friendlier assortment?**

Ahlsell currently has internal goals that are being updated. We are working with something called science-based targets, which is a way to align emissions goals with the Paris Agreement. This is done by setting an ambition to achieve net zero carbon dioxide emissions by a certain time, and then determining more stringent emissions targets to achieve this ambition. In our case, our ambition is for our entire value chain to achieve net zero carbon dioxide emissions by 2045. The targets determined are verified by a third party to ensure they are in line with the Paris Agreement. We are currently in the process of setting these targets and aim to announce them in the fall. We have had other climate goals for a long time, primarily related to scope 1 and scope 2 emissions, which we have been working on for a long time. It has long been believed that the major emissions are in the transportation sector, and therefore a lot of effort has been put into that, but since we entered into science-based targets, we have seen that the major emissions are in our products and services. Scope 1 and scope 2 emissions that we have worked on extensively in the past have been found to constitute a small part of the total emissions, which has required a significant shift in focus. When it comes to sustainability goals, baseline data is required to set benchmarks, but when this data is not available, the focus shifts and step 1 becomes to collect data.
One challenge we face is to increase revenue while reducing emissions, as these have previously gone hand in hand. For us, it is important to be able to show our customers which materials are most sustainable, but ultimately it is up to the customer to choose to invest in more sustainable products. If we can provide our customers with updates on the emissions generated by products and offer alternative products, emissions are likely to decrease.
In addition to these goals, we also have goals related to waste, social sustainability, health and safety, supply chain, and human rights. The climate goal is currently a top priority.

- **Does Ahlsell have a goal for all the products it sells to have EPDs?**

We do not have an official external goal for this, but it is being discussed internally, although no percentage has been determined. Ahlsell offers approximately 1.5 million products, and not all products are suitable for an Environmental Product Declaration (EPD). We strive to obtain as many EPDs as possible for our products, and a percentage for this will be determined in the future.

2. **How does Ahlsell work to develop EPDs, both for in-house manufactured products (if applicable), but also for products from other suppliers?**

We have a line of private label products, but we do not manufacture our own goods. We import products from suppliers and then put our brand name on them. We are responsible for obtaining environmental data for these products in collaboration with our suppliers to create EPDs. Creating an EPD costs approximately SEK 150.000 to 300.000, and since we have around 30.000 private label products, it is not feasible to create an EPD for all of them. We have searched the market for various tools related to EPD creation and have explored the possibility of using EPD generators to make the process more efficient.
Ahlsell also sells products sourced from branded suppliers, and for these products, the suppliers themselves are responsible for providing environmental data such as EPDs. Larger suppliers have understood the importance of providing environmental data such as EPDs for

their products, while smaller suppliers have not made as much progress in this area. We have not yet decided how to proceed with EPD requirements, as it could potentially mean that a significant portion of our products would no longer be sellable. We believe that the most important thing is to have a product range where there are EPDs available for products in each category so that customers have the option to choose.

3. **How is the availability of EPDs from other suppliers perceived today?**

Overall, only a small percentage of products have an EPD. Larger product suppliers are aware of the importance of EPDs, and some already have EPDs for 80% of their product line, while others have set goals but are still in the early stages. However, smaller suppliers are often confused about the development and importance of EPDs. There is no legal requirement for EPDs, and the EU has not yet determined the format for reporting carbon emissions. It is the market that has driven the development of EPDs.

4. **Does Ahlsell impose any environmental and sustainability requirements on suppliers today, including with regard to the development of EPDs?**

Ahlsell has requirements for suppliers to follow their code of conduct. There are also some legal requirements, but these are more general. Ahlsell also demands certain product data and product information. However, it can be difficult to always follow up on the data that suppliers present and ensure that it is completely accurate. The industry as a whole need to develop further in this area, and people working with these issues need more knowledge on the subject.

5. **How does Ahlsell perceive that different contractors are requesting EPDs on products? Has it increased in recent years?**

Since I started at Ahlsell five months ago, it has really escalated both in Sweden and Norway. In Norway, they were already demanding and working with EPDs to some extent, but now as they increasingly work with climate declarations, which drives the issue forward, and as larger companies set their own climate goals and need this data to a greater extent, the question is pushed forward.

- **How do you think EPDs generally affect the market?**

Increased demand for EPDs can lead to some increase in costs for products. The price does not actually increase because we develop EPDs, but it may mean that with increased understanding of the product itself, one realizes that some action needs to be taken because the product itself has high environmental impacts. These changes can in turn affect production and thus price increases. Since we at Ahlsell are so large and have different conditions compared to other smaller wholesalers, the picture may look different. If even smaller companies need to develop expensive EPDs, they may need to add some cost to the products. Right now, EPDs are the best available option on the market for comparing different products with each other, but there are also many disadvantages to it. It is possible to develop EPDs from only general values and data without being so product-specific and realistic as possible, which can lead to some misleading information. So, the industry needs to identify this problem and take action to get the best possible result. It does not work to just sit and wait for it to become perfect. Then, an EPD is really better than nothing because it standardizes and regulates a lot anyway.

6. **How do you think the future looks for suppliers, how much harder requirements will it be with regard to environmental impact, the development of EPDs, etc.?**

Probably, legislation will become tougher and environmental requirements will increase. What the EU decides will affect a lot of what everyone else needs to relate to. However, there is still much that is unclear, which is unfortunate because one would need to be able to prepare more for what is to come in order to have the opportunity to meet future legal requirements. But, it will look vastly different in five years, in terms of what product information one needs to be able to deliver, and so on.

It is also not entirely certain that EPDs will be the solution and meet future requirements from the EU and legislation. Having a dialogue with suppliers to ensure that there is the opportunity to be a little flexible so that one can get the right output when needed is important.

Appendix I: Interview with the environmental- and sustainability consultant Malin Domhagen (WSP)

1. **How can consultants such as WSP influence clients such as the Swedish Transport Administration to impose stricter requirements to use environmentally friendlier alternatives and reduce the carbon footprint of projects?**

As consultants, we can suggest alternative solutions for different materials, design proposals, or any other aspect of a project, but in the end, the clients have the final say. Depending on the assignment, the specifications may be truly clear, making it challenging to implement alternative solutions.

- **Can you provide any concrete examples of this?**

One project we worked on involved locks. Alternative solutions were proposed that could have reduced the carbon footprint, but the clients were determined to stick to the traditional method. In another project, we found alternative materials for a set of piles, allowing us to maintain quality while reducing the carbon footprint.

- **Is there motivation on your part to make changes that can benefit the environment?**

If the contracts for the projects are written in a way that offers bonuses for reducing carbon emissions by a certain percentage, there is certainly motivation to achieve this goal. Additionally, WSP has internal environmental goals, and we aim to help customers find sustainable solutions while being an innovative leader in the industry. There are also personal motivations among individual employees who prioritize environmental and climate issues.

2. **What type of contract is most advantageous to influence the client while also being profitable for the company?**

I am not entirely familiar with how different contracts can affect the relationship with the clients. The projects I have worked on recently have been a total contract and a project where we develop the basis for the tender documents. If there are bonuses, as is often the case in total contracts, it can be advantageous as we have the opportunity to influence more. When working in the early stages of a project, there may be more opportunities to influence alternative solutions, but it ultimately depends on the clients and how determined they are to maintain a specific approach.

3. **In addition to the Swedish Transport Administration, what other clients do you often work with?**

We work with various actors in society, including energy companies, Vattenfall, clients in the concrete and steel industry, and material suppliers, among others. As one of Sweden's largest consulting firms, we have expertise in many different areas of society.

- **Do you notice a difference in how different clients work with sustainability and environmental requirements? Do you notice a difference in how receptive they are to introducing more sustainability requirements in contracts?**

Yes, there is a clear difference depending on the client. Sometimes, clients and customers are highly focused on the environment, and this is evident. Generally, the construction sector shows significant interest in environmental issues. Compared to the industry, they may be lagging. It can be difficult to say that the focus is on different contracts; rather, it is related to the different assignments themselves.

4. **Do you have any examples of things that clients often want help with including in contracts in terms of environmental requirements and sustainability?**

Often, customers want help developing various types of carbon calculations or baseline reports. It may also be the case that clients want help identifying the parts of a project that have the greatest impact.

- **When you have identified what affects the projects the most, do you also provide alternative solutions?**

It depends on what the assignment is. Often, the customer just wants the analysis and report where the various environmental problems have been identified. Then WSP can provide tips, depending on which part of the organization has the assignment, as we usually only present the data. However, it could be the case that after we present the results, the clients come back with an alternative idea, and then we could recalculate the carbon calculation and identify any differences.

- **What software do you use for this?**

Swedish transport administration tool, SimaPro, OneClickLCA, and to some extent, our own Excel files. I find that all of these tool's work relatively well, but there are certainly opportunities for development with all of them.

.

- **Do you feel that contractors are meeting the environmental requirements in contracts today? Or do you feel that even stricter requirements could have been set and that contractors could have solved them too?**

In terms of the construction industry, I think that contractors are meeting the requirements that are set. The problems could rather lie in the consequences of using alternative materials or methods, which can lead to increased production times, which can negatively affect projects. Costs may also be affected, of course.

5. **Do you notice that clients are increasingly interested in working more sustainably and implementing more sustainability requirements compared to previous years?**

Yes, absolutely. Over the past 2 years, there has been a clear increase in demand. The Swedish Transport Administration (Trafikverket) has relatively strict requirements on how to reduce their climate impact, which they need to incorporate into their projects. There is also a growing interest from other customers in understanding the carbon footprint of products or services. I work a lot with environmental impact assessments (MKB) and permit processes, and I've noticed that the requirements from authorities have become stricter, with more emphasis on reporting energy efficiency changes, climate impact, and environmental goal impacts. In summary, the willingness to work more sustainably is coming from all sectors within the industry.

- **Are there products and alternative solutions available to meet the requirements set for projects?**

It can be challenging, but in the construction industry, there are environmentally friendlier materials available on the market today, such as Celsa steel, which has lower carbon emissions. However, there are limitations in terms of availability, which may restrict the ability of everyone to use a specific type of material. There are also other challenges, for example, I've heard of a project that used ECO concrete, which had different curing times and affected the project's timeline.

6. **What motivates WSP as a consultant to work towards influencing clients, and what type of benefits do they see in this?**

Internally at WSP, we have goals to work more sustainably and reduce carbon impact in projects. We are also part of a process called science-based targets, which is an organization that companies can join. The company must then have climate goals and ambitions to reduce their carbon impact based on scientific data, in order to achieve the 2-1.5-degree target or the net-zero target. This is then reviewed by a committee to ensure that the goals are based on scientific evidence and that the company is doing its part to achieve the Paris Agreement. By being part of this process, it creates a driving force within WSP to achieve these goals.

7. **How do you see the future and the development of requirements for more environmentally friendlier alternatives and climate impact?**

I believe that Trafikverket, being a large client, has a significant role in the development of reducing carbon impact, as their requirements are reflected in the projects and dictate material choices, among other things. One challenge will be to produce enough environmentally friendlier materials in relation to what needs to be built, so that the sustainability goals can be met. However, another challenge that arises from this is how costs will be affected. We have also noticed recently that there are projects at the company level that are pushing forward with sustainability initiatives even if it is not driven from the top. I believe that large companies and politics play a significant role in driving sustainability and carbon reduction forward. In Sweden, where the lowest price is often the determining factor, there needs to be incentives or requirements from larger actors to drive development forward and invest in more sustainable solutions.

8. **Additional, data, etc.**

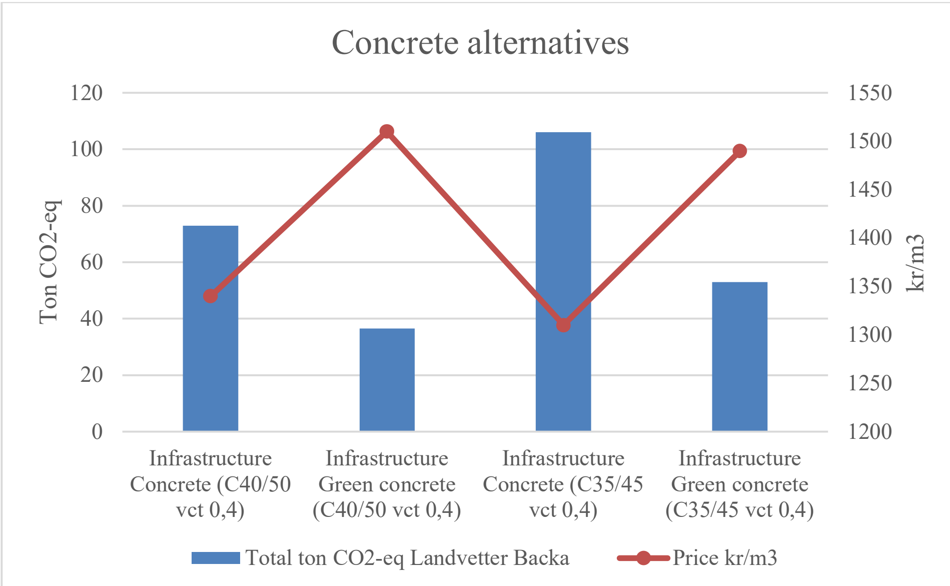
Climate calculations are based on the background information provided by GESS, and there may be issues with the availability of information, uncertainties around the quantities provided, and the type of datasets used, including their age, which can impact the accuracy of the calculations. This creates a challenge in obtaining as accurate calculations as possible.

- **How is the process of developing EPDs (Environmental Product Declarations) conducted? Is it a costly process for companies?**

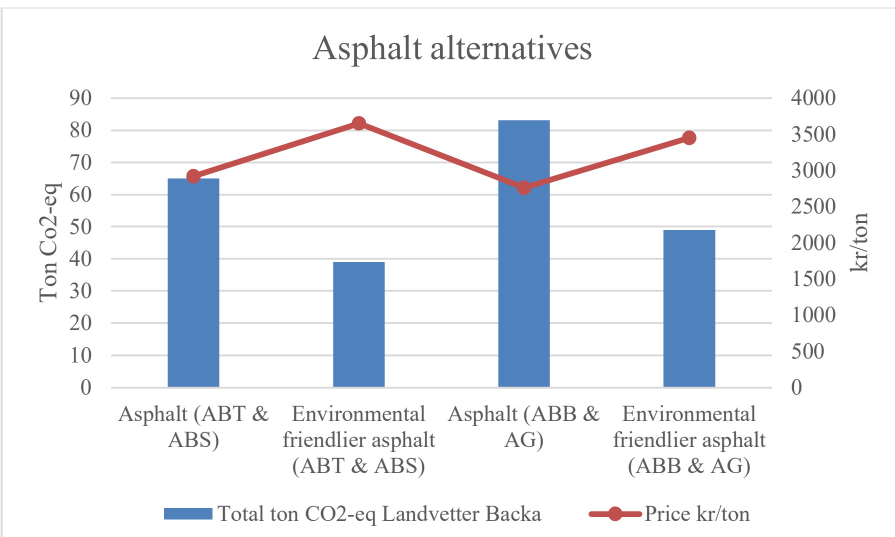
We use Sima Pro for our calculations and Ecoinvent as the database, but there are more specific databases available depending on the products being assessed. Developing EPDs can be relatively costly for companies, and there is a shortage of personnel with the ability to perform the calculations and review them. The estimated time to create an EPD is about six months.

Appendix J: Material alternatives

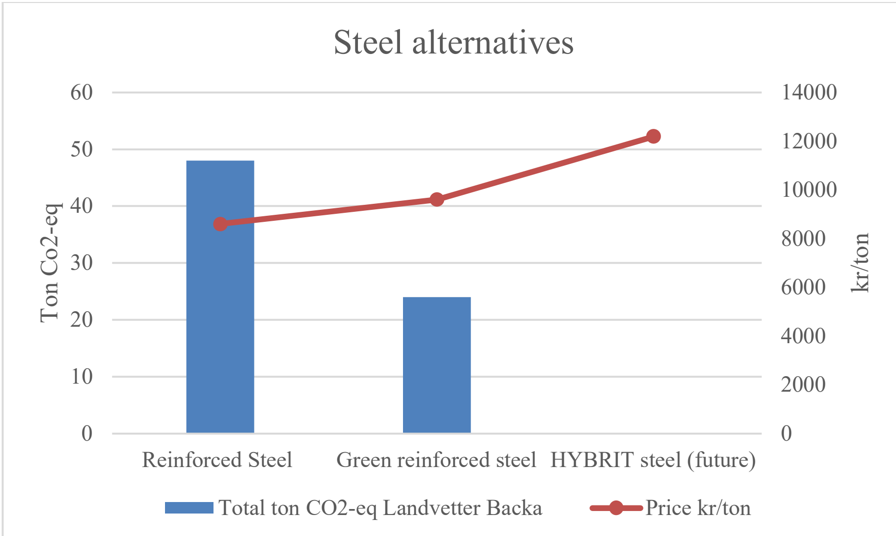
Concrete:



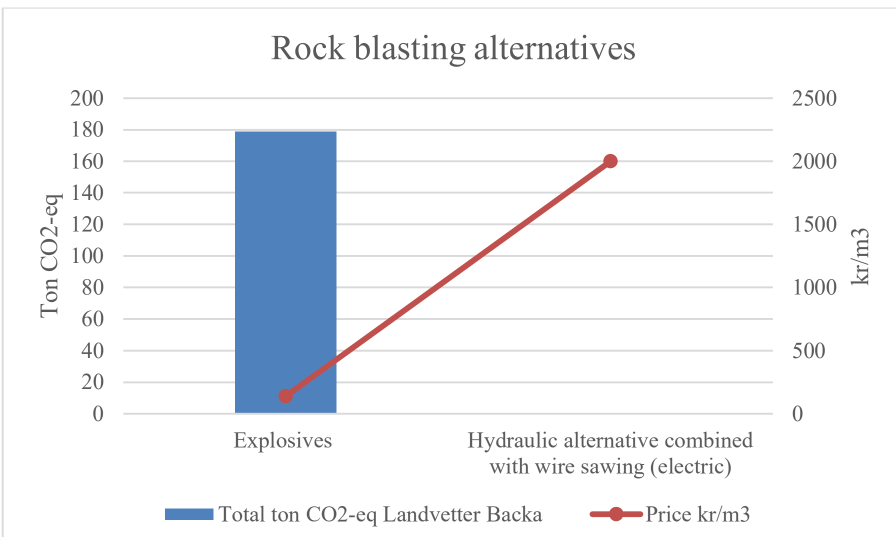
Asphalt:



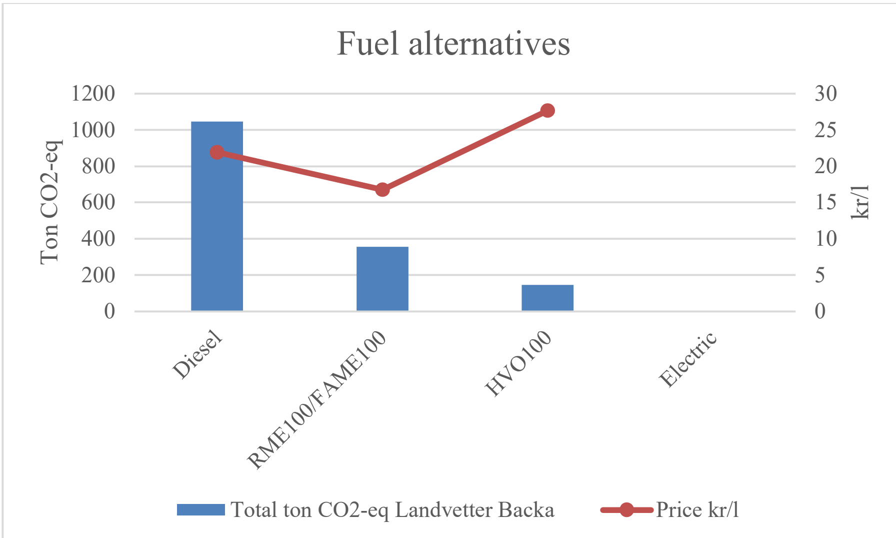
Steel:



Rock blasting:



Fuel:



Fuel alternatives
Ton CO2-eq
kr/l
1200
1000
800
600
400
200
0
30
25
20
15
10
5
0
Diesel
RME100/FAME100
HVO100
Electric
Total ton CO2-eq Landvetter Backa
Price kr/l

CHALMERS
UNIVERSITY OF TECHNOLOGY