Climate impact of construction processes

A report from IVA and the Swedish Construction Federation
The goal of IVA’s project entitled An Energy Efficient Society is to use analysis, observations and recommendations to promote more efficient energy usage. The vision is 50 percent more efficient energy usage by 2050. The focus of the project has been a reduction in energy intensity, rather a general reduction in total energy usage.

The Energy Efficient Society project has analysed five sectors: Buildings, industry, transport, forestry & agriculture and services.

While preparing the report on buildings, a need was identified to study the energy usage and climate impact of construction processes as well. This sub-project entitled Climate Impact of Construction Processes was therefore launched and is a collaboration between IVA, the City of Stockholm and the Swedish Construction Federation. Construction projects have significant direct energy usage where energy efficiency improvements could be made, but there is also a significant indirect impact on the climate from the materials used. In this project we have therefore decided to focus on the climate impact of construction processes.

Our aim here, in addition to promoting further research, is to provide impetus for continued discussion and knowledge building as well as proactive measures to reduce the climate impact of construction processes and material production. We have sufficient knowledge today to take action. Decisions at the early stages are crucial and every construction investment decision-maker should conduct an analysis early on of the effects on the climate in an effort to understand the totality, and then seek alternative solutions with respect to design, choice of materials and methods. It is, however, important to have sound, fact-based information and assessments of the whole process before setting individual stipulations that could result in suboptimisation.

This study is aimed at all of the players in the construction process. A constructive dialogue could lead to significant improvements where public and private sector players, in their various roles, work to reduce climate impact.

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Summary

SUMMARY

Calculations indicate that the total climate impact of construction processes in Sweden is around 10 million tonnes of carbon dioxide equivalents per year, with a breakdown of around 4 million tonnes for housing projects and 6 million tonnes for civil engineering and public works. That is the same size as emissions from all of the cars in Sweden, and more than is generated by all lorries and buses.

A specific study has been carried out within the project to look at the climate impact of the construction process (upstream) relative to usage (downstream) in a multi-family concrete dwelling. The analysis indicates that the climate impact is as large in the construction of a building as in the building’s operation for a period of 50 years, where the energy supply is based on a “Nordic electricity mix” and a Swedish average for district heating. This is why it is important for there to be an increased focus on climate work in the construction process.

RECOMMENDATIONS

- A dialogue is needed between the sector’s various players, the authorities and the politicians so that political decisions are informed ones based on knowledge of the climate impact of the construction process.

- The Government should assign the relevant authorities, such as the Swedish Transport Administration and the Swedish National Board of Housing, Building and Planning, to develop procurement models in cooperation with the industry to reduce the climate impact in construction investments.
• Formas, Vinnova and other public sector research funders need to take the climate impact of the construction process into consideration when allocating funds for research and the knowledge dissemination.

• The construction industry and researchers need to work together to develop and standardise their methods so that all calculations are made based on the same criteria and yield comparable results.

• Construction clients, construction companies, project developers etc. must analyse and define the climate impact of the construction process so that they can identify their own role and thereby help to increase knowledge in the area.

• Local authorities should also pay attention to construction process climate issues in their planning and land allocation processes, which requires calculations to be made in the same way in order to be able to formulate fair and reasonable goals that can be followed up.
BACKGROUND

More than SEK 300 billion are invested every year in residential and non-residential properties, roads and railways, and various types of industrial facilities, but knowledge of the climate impact of these projects is limited among decision-makers.

A lot of effort is put into creating energy and climate efficient buildings, better vehicles and more efficient transport solutions. The debate is intense and the level of knowledge on the climate impact of the operational phase is growing.

On the other hand, the climate impact of the actual construction processes – from material extraction to finished building or facility – is seldom taken into account. Studies show that the climate impact is significant, but more work must be done to improve knowledge and awareness among the players in the sector.

IVA believes that this issue needs to be emphasised and substantiated with facts. This report aims to provide an overall picture of the climate impact of construction taking place in Sweden. Data for this study was limited in many areas, and it was therefore necessary to make many assumptions. However, the unavailability of some data does not diminish the importance of this issue. The studies that do exist all point in the same direction – the impact on the climate is substantial.

In order to determine which measures to implement, we need to know more about this area. Increased knowledge may help players in the industry take appropriate steps, and provide information upon which the relevant politicians and authorities can act.

One important task is to communicate the observations made by the work group in this area, some of which are based on the members’ own professional experience, but others are from topics discussed during the course of their work on the project. The observations have resulted in a series of recommendations aimed at politicians, government agencies and various players in the industry.

There is limited knowledge today about the total climate impact of production in construction projects in Sweden. The task here has been to attempt to present a picture of the situation at the national level based on various available sources. The data is rough, but it gives a rela-
Figure 2: The study covers both buildings and other construction projects.

Figure 3: Construction investments in 2012: SEK 309 billion and estimated maintenance of facilities of SEK 10–20 billion, totalling around SEK 325 billion.
Source: Swedish Construction Federation (B), prepared by ÅF.

Methods

We have chosen to look at the climate impact and include both the impact of energy usage in construction processes and carbon emissions from chemical processes in the production of various materials.

The analysis is based on the data available for 2012 as well as ongoing studies of the climate impact of various types of construction work and the construction of multi-family dwellings. Data has been obtained from the Swedish Transport Administration, the Swedish National Road and Transport Research Institute (VTI), the Swedish National Board of Housing, Building and
Planning, Statistics Sweden (SCB), the Swedish Construction Federation and the Swedish Environmental Research Institute (IVL). Data on how much is invested per year in the various sectors has been used to aggregate the information at the national level. The members of the Steering Committee have also brought their combined experience of construction processes, behaviour and structures to the process.

Part of the analysis is based on an ongoing, in-depth study of newly built multi-family dwellings in the Blå Jungfrun block in Hökarängen outside Stockholm, where detailed calculations have been made of the climate impact both upstream and downstream.

Not all emissions arise in Sweden. Imported construction materials also give rise to emissions during their production in other countries. The estimated climate impact here includes all input materials, regardless of whether or not they are produced in Sweden.

**CONSTRUCTION INVESTMENTS IN SWEDEN**

Construction investments amounted to around SEK 325 billion in 2012, which is equivalent to just under 9 percent of GDP. This includes new and reconstruction investments, as well as maintenance of properties and facilities. Properties includes everything from multi-family dwellings and single or two-family dwellings, to industrial buildings, office buildings and public premises. Facilities includes roads, railways and other facilities, such as water and sewage treatment plants, and electricity and thermal power stations.

Figure 3 shows the breakdown between different types of construction investments in 2012.

**ENVIRONMENTAL REPORT FROM THE SWEDISH NATIONAL BOARD OF HOUSING, BUILDING AND PLANNING**

In May 2014 the Swedish National Board of Housing, Building and Planning presented a report on the environmental impact from the construction and real estate industry, based on statistics from Statistics Sweden’s (SCB’s) environmental calculations. The analysis covers the climate impact from the construction of buildings, roads and railways and from property management. It does not include “other construction projects.” From these statistics it is possible to obtain figures for various industries, albeit not comprehensive ones.

According the Swedish National Board of Housing, Building and Planning’s (SCB’s) calculations, construction processes for buildings are responsible for emissions equivalent to 4 Mtons CO₂ eq., and for roads and railways around 2.1 Mtons CO₂ eq., i.e. a total of 6.1 Mtons CO₂ eq. in 2011.

To gain a complete picture, the emissions from other construction projects should be added. Emissions from these can be estimated at around 3 Mtons CO₂ eq., making a total of around 9 Mtons CO₂ eq. This is in the same range as the estimates arrived at in this sub-project, i.e. around 10 Mtons.

**BLÅ JUNGFRUN – A DETAILED EXAMPLE**

A detailed life-cycle analysis has been conducted of the climate impact of newly constructed multi-family dwellings in the Blå Jungfrun
Figure 4: Climate impact upstream and downstream, kg CO₂ eq./m² for Blå Jungfrun, based on the Nordic energy mix and average for Swedish district heating. The upstream data includes estimated amounts for groundwork and foundation work.
Source: KTH, IVL, prepared by the Steering Committee.

Figure 5: Climate impact from the construction process
Analysis of Blå Jungfrun shows that various materials account for 84 percent of the climate impact (including the foundations), while work processes and transport at the actual construction site account for 16 percent. Concrete has the most significant climate impact, both because cement production is an energy intensive process and chemical processes in production also generate carbon dioxide. The breakdown includes the building structures including foundations, but excluding groundwork, laying the foundations, road connections and services etc.
block in Hökarängen, 10 km south of Stockholm City. In the study the climate impact of the construction phase (upstream) and the operational phase (downstream) are compared. The calculations are based on international standards for life-cycle analysis. The analysis is presented in its entirety in a separate report.

The construction project was commissioned by the municipal housing company Svenska Bostäder and executed by Skanska under a general contract. The block consists of four multi-family dwellings with a total of 97 units consisting of 2–5 rooms and a kitchen. The total heated area is 11,003 m² Atemp (area in m² heated to more than 10°C). The construction project began in 2008 and the last tenants moved in autumn 2010. The buildings were planned to have very low specific energy usage and to meet the criteria for passive buildings. They are heated with district heating.

The buildings were constructed with a technique that can be considered typical for many of today’s multi-family dwellings. The main difference is that there are no garages.

Most multi-family dwellings are built in concrete, but now there is increasing interest in building them with a wooden frame. This provides a different distribution of the upstream and downstream climate impact.

The calculations made cover the building structures including the foundations. Land preparation and groundwork are therefore not taken into account. If these were to be included, the climate impact would increase by around 50 percent.

According to the calculations for Blå Jungfrun, the climate impact of building production (upstream) is around 350 kg CO₂/m² Atemp, of which 84 percent relates to materials used in the buildings, 13 percent to erecting the buildings and 3 percent to transports to the building site.

The climate impact from the total energy usage in operating the building for 50 years amounts to around 550 CO₂/m² Atemp, assuming average emissions for electricity and district heating (so-called Nordic energy mix, and the average for Swedish district heating). Household energy is included in the downstream calculation. The breakdown of climate impact upstream and downstream is therefore about 50/50, calculated over a 50-year period. The building will probably stand longer than that, but after 50 years extensive renovation will be necessary, which will again have an impact on the climate, from an albeit more limited construction process. Household energy is not normally taken into account in the energy performance of a building because the construction client cannot control the tenants’ energy usage. If household energy is excluded from the calculation, the breakdown of climate impact from construction processes relative to usage will be around 60/40.

Figure 4 shows the climate impact from construction processes compared to the average climate impact for the energy supply downstream. The ratio between upstream and downstream may differ for individual buildings depending on the type of energy used in the operational phase.
Climate impact

CLIMATE IMPACT FROM MULTI-FAMILY DWELLINGS

Figure 6: Cost items for investments in multi-family dwellings, total SEK 63 billion in 2012.
Source: Swedish Construction Federation.

The total amount invested in multi-family dwellings in Sweden was around SEK 63 billion in 2012, including land and VAT. Of the completed units within the multi-family dwellings, around half were in cooperative housing associations and half were rentals.

Figure 6 shows an approximate breakdown of the production costs for a multi-family dwelling, including land acquisition and VAT. The material costs account for around 30 percent and transportation to, and equipment for, the building sites account for just over 10 percent.

Data from, among other sources, the Blå Jungfrun block is used to produce general key ratios for climate impact from construction processes in the form of carbon emissions per invested SEK (CO₂/SEK). Data is also used from a recently published study of the climate impact of ten new multi-family dwellings, including groundwork (see figure 7). The average climate impact from their construction is around 550 kg CO₂/m² Accum. Based on this data, the total climate impact from multi-family dwellings per invested SEK is estimated at just under 30 ton CO₂/SEK m.

The estimated total climate impact from construction of multi-family dwellings is around 1.5 Mtons CO₂ per year, based on the data available today.
Figure 7: Climate impact kg CO$_2$/m$^2$ of heated surfaces, compiled from climate declarations from ten different multi-family dwellings, including the buildings and the ground contractors and construction processes. The climate impact is on average around 550 kg CO$_2$/m$^2$. The graph shows that the climate impact from construction processes can vary significantly from building to building. Source: Sustainable use of natural resources, IVL 2014.

Figure 8: Material composition by weight, for a house constructed from wood (based on Villa Ulrika, Småland and Växa from Myresjöhbus 1996). Concrete and macadam are used in the foundations. Total weight around 147 tonnes.
CLIMATE IMPACT FROM NON-RESIDENTIAL BUILDINGS

The term non-residential buildings covers a very heterogeneous group of buildings including everything from simple retail outlet buildings to more complex properties such as hospitals. The differences are also great within each category. There are, for example, schools in single-story wooden structures and education buildings that are advanced research facilities, simple offices or bank buildings with huge server halls.

Investments in non-residential buildings amounted to SEK 107 billion, of which 60 percent was through private investment and 40 percent public. Private sector investment is mainly in commercial properties and offices, while the public sector invests in school and hospitals etc.

Similar climate impact key ratios have been used as those for multi-family dwellings. There has been some compensation based on the assumption that the cost of land is lower. Many commercial properties, industrial premises and offices are located outside city centres, while homes are built where it is attractive live, i.e. in more expensive areas. Better data is needed in order to provide an accurate picture of the actual situation.

The total climate impact from construction processes for non-residential buildings is estimated at around 2–3 Mtons CO₂/year.

CLIMATE IMPACT FROM HOUSES

Around 10,000 houses (småhus – defined as single or two-family dwelling units) are built every year. Around 90 percent of all houses built in Sweden today are made of wood. The components are produced in a factory and assembled on a concrete foundation.

Knowledge about the climate impact of house production is limited. Data used in this study is taken from environmental product declarations (EPDs) produced by Myresjöhus in the mid-1990s.

Environmental product declarations are based on life-cycle analysis for buildings, including the foundations. Land preparation and groundwork are not included. These have a relatively high climate impact and use fossil fuels.

The buildings and construction techniques have not changed to any significant degree since the mid-1990s. The difference is mainly an increase in the amount of insulation materials in foundations, walls and roofs. Adjusting for this, the climate impact from house production is estimated at around 20 tons of CO₂ per house. Groundwork, which is not included in the environmental product declarations, must also be taken into account. Although there have been no available calculations for this, they could represent at least as much.

With these assumptions, the total climate impact from houses is estimated at 0.3–0.5 Mtons CO₂ per year.

Figure 8 shows the approximate material composition of a wooden house including the foundations.

CLIMATE IMPACT FROM OTHER CONSTRUCTION PROJECTS

Other construction projects are essentially all projects that are not residential or non-residential buildings. In this study, however, we mainly discuss roads and railways. These account for half of the total investments in construction projects in this category. Other examples are ports, airports, power stations and various types of industrial plants.
The extent of the climate impact from building new roads or railways depends to a very large extent on their route. Tunnels and bridges have a significantly higher climate impact per meter than roads on flat land. The terrain also plays a big role.

Thus, the climate impact of a project is determined at an early stage when decisions are made about the route of a road or railway. In general we can say that the climate impact is proportional to the size of the investment.

There are similarities between roads and railways in terms of which materials impact the climate. When constructing roads and railways, the input of steel, cement and asphalt, and management of excavated materials are the largest contributors to material-related greenhouse gas emissions (Swedish Transport Administration).

Climate impact from roads and railways
A few years ago a study was conducted by researchers at the Royal Institute of Technology...
(KTH) of the climate impact of road and rail projects. There has been no new, equivalent study since then. Greenhouse gas emissions from production and maintenance of roads and railways were estimated at 2.7–2.8 Mtons CO₂ equivalents per year.

Investments in roads and railways have increased by a couple of billion kronor since that study was conducted (varying from year to year from around SEK 36–38 billion/year to around SEK 38–40 billion/year, according to the Swedish Construction Federation and Statistics Sweden). Greenhouse gas emissions can therefore be assumed to be around 3 Mtons CO₂ eq.

The infrastructure for railways constitutes around 85 percent of the total climate impact of transportation (Swedish Transport Administration). If trains are run on renewable energy sources (or nuclear power), 100 percent of the climate impact can essentially be assigned to the infrastructure. For roads the situation is the reverse, see figure 9.

**The Bothnia Line example**
The Bothnia Line can be used as an example of a large railway project. When the Bothnia Line was to be built, comprehensive analysis was carried out of the environmental impact of the entire project by producing environmental product declarations (EPDs). These give detailed information on, for example, the climate impact from various parts of the construction process.

The total cost for the Bothnia Line was around SEK 17 billion. It is 190 km long and has 143 bridges and 16 tunnels with a total length of 25 km. The construction period was 11 years, from 1999 to 2010.

The total greenhouse gas emissions according to the EPDs were estimated at 2,800 tons CO₂/km, which makes a total of around 0.5 Mtons CO₂ for the Bothnia Line.

**The Swedish road network**
The Swedish road network consists of around 100,000 km of state roads, around 46,000 km of municipal streets and public roads, and 76,000 km of private roads, most of which are roads for forest vehicles.

The upstream climate impact from road construction depends largely on the type of road, and the type of terrain the road will pass through.

Figure 11 shows the climate impact from various types of road construction projects, excluding tunnels and bridges. Common to all the different types of roads is that producing and laying asphalt accounts for the largest portion of the energy usage.
Observations

THE CLIMATE IMPACT OF CONSTRUCTION PROCESSES IS SIGNIFICANT BUT KNOWLEDGE IS LIMITED.

The total climate impact from construction processes in Sweden amounts to around 10 Mtons CO₂ eq. per year, broken down as around 4 Mtons for building construction projects and 6 Mtons for other construction projects. This was equivalent to around 17 percent of Sweden’s reported greenhouse gas emissions in 2012, about the same amount as emissions from all cars in Sweden, and more than is generated by all lorries and buses.

There is an established perception that 15 percent of a building’s energy usage is in the production phase (upstream) and 85 percent in the building’s operational phase (downstream).

In this project calculations have been made of the breakdown of the upstream and downstream climate impacts and the picture is entirely different. In a MDU built in concrete, the construction process accounts for around 50 percent of the total climate impact during the building’s lifetime, estimated at 50 years.

Buildings are becoming more and more energy efficient and the energy used to operate and heat them consists largely of types of energy that have a low climate impact, in the form of electricity and district heating. Additionally, electricity usage is rendered more efficient through the increased use of heat pumps.

While development has been fast in terms of reducing the climate impact downstream, the climate impact has basically stood still or even increased in the construction processes, i.e. upstream. Essentially all construction equipment and machines (dumper trucks, excavators etc.) run on fossil fuels. To keep costs down, projects are often under considerable time pressure. This means that, for example, drying processes need to be speeded up, which results in higher energy usage and often diesel generators or electric dryers are used.

By improving energy efficiency, the energy distribution has been shifted so that a larger percentage is in the production phase, but above all the distribution of a building’s climate impact has been shifted upstream. Climate impact is now at least as big in the production phase as in the use of a building for a period of 50 years.

This is remarkable bearing in mind how today’s building regulations are designed. The Swedish Planning and Building Act and the Swedish National Board of Housing, Building and Planning’s building regulations essentially only regulate what happens during a building’s operational phase, i.e. downstream.

For construction projects (other than residential and non-residential buildings), the breakdown between upstream and downstream climate impact varies greatly between the different types of traffic, road, railway and air. The upstream climate impact per passenger km is about the same for road and rail, but in the operational phase the difference is significant. Climate impact from rail traffic is significantly lower per passenger km than for road traffic. For air traffic, almost all of the climate impact is in transportation.

WHY ARE THERE NOT STRICTER REQUIREMENTS WITH RESPECT TO CLIMATE MEASURES IN CONSTRUCTION PROJECTS?

Why isn’t the climate issue emphasised more in the construction process? Based on our observations, this is largely due to the perception
that the construction phase is of marginal importance relative to the operational phase, in both building construction projects and other construction projects. The actual construction project is perceived as a temporary process that ends the moment the building or road is finished. But when one construction project is completed the construction company starts the next one. In Sweden construction takes place for around SEK 325 billion a year, which is equivalent to about 9 percent of GDP. It cannot be described as a temporary activity.

The contractors deliver based on demand. A climate-efficient construction process does not provide any competitive advantage on the market and the building regulations only contain downstream energy performance requirements.

Construction projects have a long and complicated chain of decision-makers. Individual actors find it hard to see, and therefore take responsibility for, the whole process.

**LACK OF INSIGHT, METHODS AND KNOWLEDGE**

Knowledge about the climate impact of construction processes is limited among both politicians and public sector officials, as well as among private construction clients, contractors and suppliers. In the absence of knowledge and standardised tools, it is not possible to make the right planning decisions or to require climate performance in municipal land allocation. Researchers and specialists who have worked with the climate impact of construction processes have up to now focused on issues relating to methods and how calculations should be made, which is of fundamental importance in order to set standards for the future. But data and analysis also need to be produced on the total climate impact in order to generate more interest in the issue.
Recommendations

One overall recommendation is that the issue must be addressed by decision-makers in various sectors and at different levels in order to increase knowledge in the area. In a construction project there is a complicated chain of various actors, decision-makers, suppliers and executors. It is difficult for individual actors to get an overall picture and to implement measures on their own.

DIALOGUE IS NEEDED

- Clients, construction companies, project developers etc. need to analyse and define the climate impact of construction processes, so that they can identify their own role and thereby help to increase knowledge in this area.

- Industry associations need to put the issue on their agenda.

- A dialogue is needed between the sector’s actors, government agencies and politicians so that political decisions are made with knowledge about the climate impact of construction processes.

- Environmental standards must be communicated to every part of the chain, otherwise the chain will break.

THE PUBLIC SECTOR SHOULD LEAD THE WAY

- Municipal authorities should also pay attention to the climate issue in construction processes in planning and land allocation, which requires calculations to be made in the same way in order to draw up fair and reasonable goals that can be met.

- The Government should assign the relevant authorities, such as the Swedish Transport Administration and the Swedish National Board of Housing, Building and Planning, the task of developing procurement models in cooperation with industry players to stimulate a reduction in climate impact when investments are made.

- Methods should be nationwide so that they can be used by all players in Sweden.

PROCUREMENT AND MARKET FORCES NEED TO BE STIMULATED

- New production of buildings and facilities should in the future have a climate declaration for construction processes as well.

- As early as in their preliminary studies, private and public sector clients should ask for alternative methods of execution that have a lower climate impact.

- Materials suppliers should be encouraged to report the climate and energy impact of their products.

- In procurement, project-specific data must be used instead of average standard data to promote positive development. Better climate performance must provide a competitive advantage for the contractors focusing on the issue.
KNOWLEDGE AND METHODS NEED TO BE DEVELOPED

• The Swedish Research Council Formas, Vinnova and other government agencies providing research funding should take into account the climate impact of construction processes when allocating funds for research and knowledge dissemination.

• Before procurement stipulations can be put in place, a broader body of knowledge needs to be developed in the sector, otherwise there is a risk that inappropriate stipulations could lead to suboptimisation.

FOLLOW-UP MUST BE ONGOING

• The Swedish National Board of Housing, Building and Planning should be tasked by the Government to analyse with appropriate regularity both qualitative and quantitative development.

• The construction industry and researchers should work together to develop and standardise methods so that all calculations are carried out based on the same criteria and yield comparable results.

• Statistics Sweden should develop appropriate statistics that can be used to monitor development in the area.

DESIGN AND METHOD CHOICES

• Evaluate alternative design solutions and building methods, such as leaner designs, for climate-smart alternatives.

• Evaluate and develop materials and products with a lower climate impact in both production and usage, including maintenance.

• Locate buildings to optimise the use of existing infrastructure. Adapt the groundwork and construction work to minimise the transportation of excavated materials and material consumption.

MORE EFFICIENT CONSTRUCTION PROCESSES

• Work on reducing the climate impact at each individual construction site.

• Educate employees in climate-smart construction.

• Improve efficiency in material transportation to construction sites through smarter logistics solutions and chose transport solutions that use renewable fuels.

• Optimise the choice of materials and methods to reduce the climate impact of drying processes.

• Replace equipment run on petroleum and diesel with ones run on electricity.

• Turn lights off when they are not needed. Adapt according to need and use sensor-activated lighting.

• Use energy-efficient site huts. Use district heating and heat pumps wherever possible.
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