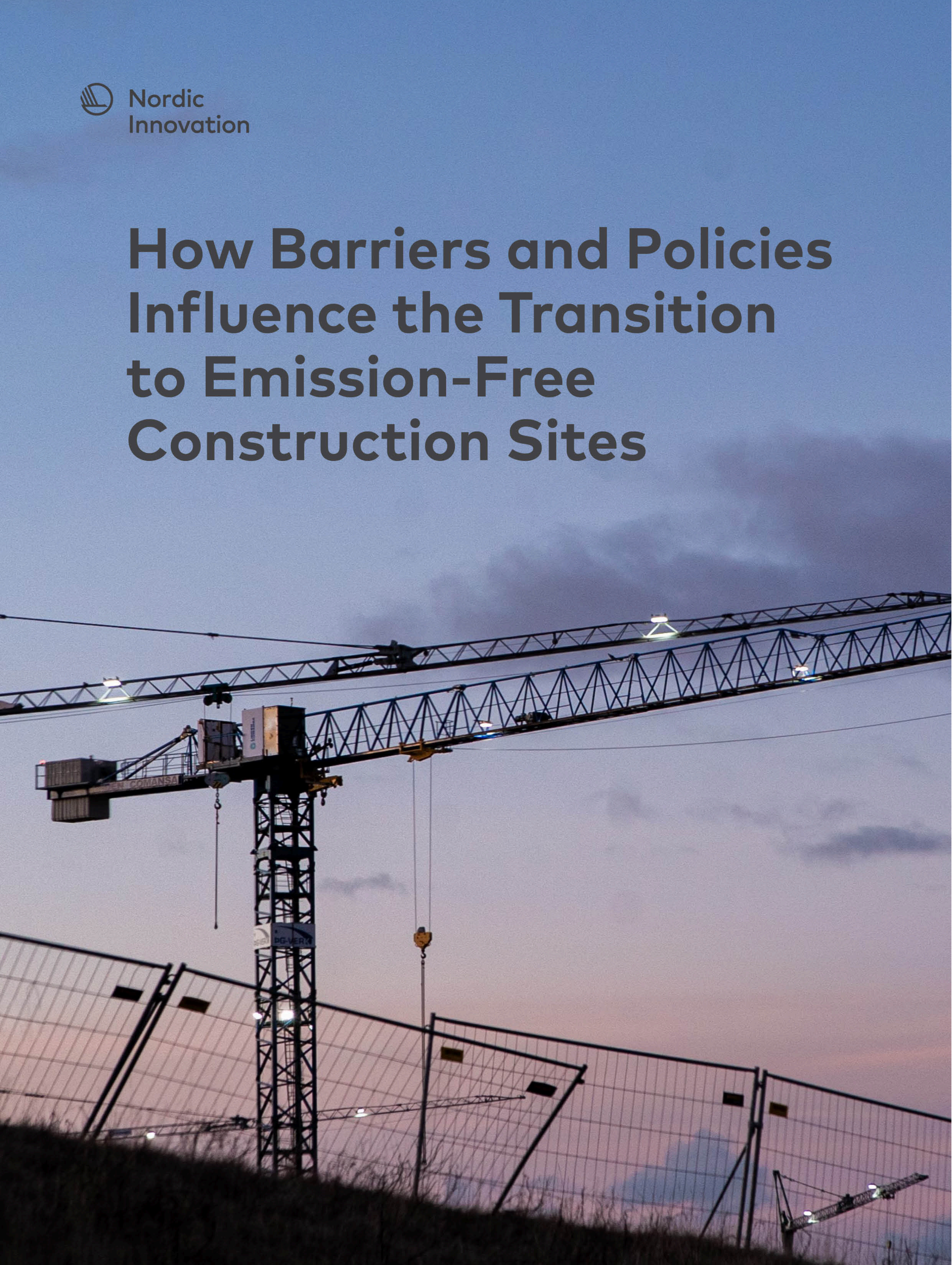
Nordic Innovation

How Barriers and Policies Influence the Transition to Emission-Free Construction Sites



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Preface

This project is part of the Nordic Sustainable Construction programme initiated by the Nordic Ministers for Construction and Housing and funded by Nordic Innovation. The programme contributes to the Nordic Council of Ministers' Vision 2030 by supporting the Nordics in becoming the leading region in sustainable and competitive construction and housing with minimal impact on the environment and climate.

The programme supports the green transition of the Nordic construction sector by creating and sharing new knowledge, initiating debates in the sector, creating networks, workshops, and best practice cases, and helping to harmonise Nordic regulations on the climate impact of buildings.

The programme runs from 2021 to 2024 and consists of the following focus areas:

- Work Package 1 – Nordic Harmonisation of Life Cycle Assessment
- Work Package 2 – Circular Business Models and Procurement
- Work Package 3 – Sustainable Construction Materials and Architecture
- Work Package 4 – Emission-free Construction Sites
- Work Package 5 – Programme Secretariat and Capacity-building Activities for Increased Reuse of Construction Materials

This report is one of the Work Package 4 deliverables.

The work has been carried out by a multidisciplinary working group with participants from Green Building Council in Iceland in collaboration with the Icelandic Ministry of Infrastructure, the Housing and Construction Authority of Iceland, and the University of Iceland. The Icelandic Ministry of Infrastructure is the responsible party.

For more information on Nordic Sustainable Construction, visit our website at https://nordicsustainableconstruction.com/

Summary

The objective of the Nordics to take the lead in a sustainable and competitive construction and building sector comes with an ambition to reduce the environmental and climate impact of construction. Authorities at all levels must lead the way and remove any barriers that might hinder the transition to a cleaner construction sector.

This report identifies and categorises the barriers to implementing emission-free construction sites. It is based on published research, stakeholder dialogue, and insights from pilot projects. The findings are further supported by a survey in which stakeholders rated the impact of these barriers and provided additional feedback. The report highlights key obstacles across four main categories: policy and regulatory barriers, financial barriers, technological barriers, and systemic barriers. However, it also sheds light on encouraging progress and emerging solutions that indicate a growing momentum in the industry.

Policy and regulatory barriers

- **Regulatory gaps and political inaction** – the lack of strong, unified regulations that mandate the reporting and reduction of emissions on construction sites and slow political responses have delayed progress towards achieving emission-free construction.
- **Unconducive standards and building codes** – regulation that hinders development towards achieving emission-free construction sites.

Financial barriers

- **Higher initial cost** – emission-free construction methods are still more expensive than traditional methods, and projects may take longer due to technological constraints.
- **Project duration** – new technologies result in projects taking longer and costing more.

- **Waste reduction** – although reducing waste can lower costs, there may be upfront expenses associated with waste management techniques.
- **Finance** – financiers need to prioritise environmental performance over financial gains and provide access to financing for low-emissions projects and equipment.
- **Risk** – innovation, such as the implementation of emission reductions in any form, is inherently risky.
- **Procurement** – stakeholders have pointed out that systems for awarding contracts based on low emissions must not be tailored to one technology, such as battery electric machinery, since that could hinder development beyond what is currently available.

Technological barriers

- **Limitations of biofuels** – HVO and biodiesel are only sustainable alternatives when the raw material is waste, such as used cooking oil or waste animal fat.
- **Availability of machinery and equipment** – availability is one of the barriers most often mentioned in discussions with stakeholders.
- **Uncertainty about performance and development** – the construction industry rarely allows experimentation, as unfamiliar technology can lead to unforeseen issues, increasing costs and delays.
- **Charging bottlenecks** – construction in new areas can be delayed due to the development of grid infrastructure, while in older urban areas the electric grid may already be at full capacity.
- **Hydrogen infrastructure** – although hydrogen is produced in most of the Nordic countries, there is very limited distribution infrastructure for customers in transport and construction.
- **Waste infrastructure** – many construction sites lack proper storage, leaving materials exposed and vulnerable to damage.

Systemic barriers

- **Speed and timeline constraints** – time constraints in projects discourage the adoption of new methods, with short-term costs being prioritised over long-term sustainability benefits.
- **Process complexity and integration issues** – the involvement of multiple contractors, subcontractors, suppliers, and stakeholders with diverse backgrounds and requirements makes implementing project-wide changes difficult, emphasising the need for collaboration.
- **Lack of data and measurement challenges** – reliable data is essential for achieving emissions-reduction targets, enabling stakeholders to make informed decisions.

- **Lack of knowledge and resistance to change** – many remain unaware of the impact of construction site emissions and the available ways to reduce them.
- **Current economic structure** – although renovating and reusing buildings reduces emissions by avoiding demolition and new construction, economic models often favour new builds.

The findings in this report emphasise the urgent need to address persistent barriers while building on the positive progress already made. The integration of LCA into regulatory frameworks and applying harmonised limit values on emissions in the Nordics is an excellent example of this progress. Successful actions of municipalities have demonstrated that emissions can effectively be reduced in construction. While pilot projects highlight barriers, they also provide new knowledge and set the stage for further success.

Policymakers and industry stakeholders must continue to work together to develop unified regulations, prioritise financing for sustainable projects, and invest in the necessary technological and systemic infrastructure.

By removing obstacles and scaling up proven solutions, the Nordic countries can lead the way in creating a sustainable, competitive, and emission-free construction sector. This report aims to inspire action by showcasing both the challenges that remain and the promising developments that pave the way forward.

1. Introduction

The transition to emission-free construction sites is a critical step towards reducing greenhouse gas emissions in the building sector. Although numerous studies address barriers to sustainable construction, the specific challenges of emission-free sites require further investigation. This report maps out the barriers to implementing emission-free construction sites. Key obstacles are categorised into four main areas: **Policy and regulatory barriers**, **financial barriers**, **technical barriers**, and **systemic barriers**. Each section examines specific challenges within these categories, including regulatory gaps, high initial costs, technology limitations, and resistance to change within the industry. By understanding these challenges, stakeholders can devise practical solutions to accelerate decarbonisation in construction.

The report also presents findings from a survey sent to a broad range of stakeholders. In this survey, participants rated the impact of various identified barriers and could suggest additional challenges they felt were significant. This combined approach provides a detailed view of the obstacles slowing progress towards achieving emission-free construction.

1.1 Overview

This report outlines the main barriers that stakeholders face when implementing emission-free construction sites. The barriers are interrelated and may fall into more than one of the categories listed below.

The main categories of barriers to emission-free construction include:

- Policy and regulatory
- Financial
- Technological
- Systemic

The intended audience of this report includes policymakers, regulators, financial institutions, industry professionals, developers, and other stakeholders who can address these overarching barriers to emission-free construction practices.

1.2 Background

There is a clear and undeniable need for sustainable construction practices to reduce greenhouse gas (GHG) emissions from the construction sector. There are many opportunities to reduce emissions throughout the lifetime of a building. One key area is during the construction phase. Replacing fossil fuel-powered machinery and vehicles with electric or low-carbon alternatives, reducing transportation of building materials, reducing waste, and reducing energy use related to construction sites all offer significant potential for reducing emissions. However, these solutions are not being implemented at the rate needed for the rapid reduction in GHGs required to limit global warming to 1.5 degrees. Several barriers exist relating to finance, technology, knowledge, skills, attitudes, market, and other systemic barriers. There are many studies examining the barriers to sustainable construction, which may also be barriers to emission-free construction. However, the specifics of emission-free construction sites are relatively new, and the precise factors that hinder these projects need to be examined in order to identify how to overcome them.

1.3 Methods

This report is built on content analysis (desk research), information gathered from conversations with professionals in the construction industry, and an online survey. Content analysis drew on reports, articles, and expert insights to identify barriers to emission-free construction. Meetings and events took place throughout the project, involving conversations with well over 30 different stakeholders that revealed the obstacles they faced when attempting to implement emission-free construction practices. Several barriers were identified based on the content analysis and dialogue with stakeholders. A short survey was then created for construction professionals to rank these barriers in order of impact on the implementation of emission-free construction sites. This report compiles the results from the above investigations to identify barriers that need to be addressed not only by the construction sector but also suppliers, financiers, utility companies, local and national authorities, and other key stakeholders.

2. Policy and regulatory barriers

Regulatory and policy frameworks play a critical role in shaping the adoption of emission-free practices on construction sites. This chapter starts with an overview of policies and regulations in the Nordic countries and the EU, and the following section will discuss how these can hinder the reduction of emissions at construction sites.

Unclear regulations, insufficient financial incentives, and a lack of supportive standards are major barriers to reducing emissions at construction sites. These barriers inhibit the transition to emission-free practices by failing to provide the necessary framework to encourage, support, and reward stakeholders for reducing emissions. Certain existing regulations may also slow down or prevent the reduction of emissions from construction sites. In the words of Signe Wenneberg, a Danish author, journalist, and climate activist:

"If all actors in the sector were bound by the Paris-compliant legislation, they would not have to compete with the ones willing to offer the cheap and unsustainable solutions to their clients." [1]

2.1 Overview of policies and regulations in the Nordic countries and the EU

The EU has implemented regulations to curb emissions from various types of mobile machinery. The Non-Road Mobile Machinery (NRMM) Directive targets emissions from construction equipment and other non-road vehicles, setting strict limits on particulate matter and nitrogen oxides. Separately, the EU's Euro standards regulate emissions from heavy-duty vehicles such as trucks and buses with the aim of reducing pollutants such as CO, NO_X, and PM. However, it's important to note that these directives do not currently address CO_2 emissions and climate impact.

The report "Policies Enabling the Reuse of Construction Products in the Nordics"[2] outlines the regulatory environment in the Nordic countries and the EU. Obstacles to reuse in each Nordic country include conflicting building regulations criteria, technical requirements, a lack of economic incentives, and ambiguous reuse targets. However, the reuse of building materials is one way of reducing emissions from construction sites by reducing waste.

The EU has shifted its focus from solely considering a building's operational energy performance to a broader, whole-life carbon approach. This involves evaluating a building's environmental impact from its initial construction to its eventual demolition. This shift is reflected in new and revised EU frameworks and policies such as Level(s), the European Taxonomy, the Renovation Wave, the Transition Pathway for Construction, the European Green Deal, updates to the Construction Products Regulation, the Energy Performance of Buildings Directive, the Ecodesign Directive, and the Waste Framework Directive. These policies encourage reduced emissions during construction and increased reuse of construction materials.

Some Nordic countries have taken these concepts further by imposing specific emissions limits for construction sites, targeting energy use and waste reduction. All the Nordic countries have set goals for minimising waste and maximising reuse rates. The Nordic countries also have general legislation for environmental protection that limits pollution from industrial activities, including construction. However, greenhouse gas emissions are not targeted specifically in this context.

Many municipalities, in the Nordics and beyond, have taken the initiative to reduce emissions from construction projects. These actions include committing to fossil-free construction, setting targets, establishing low emissions requirements at the tender stage, designating low-emission or low-noise zones, supporting pilot projects, and providing subsidies for electric machinery. The following table, 2.1, provides examples of municipal-level policies that have been implemented in Nordic cities to support emission-free construction.

Table 2.1. Examples of municipal-level policies in the Nordics and initiatives to promote emission-free construction sites. See: **Clean Construction Policy Explorer**[3]

City	Policy or initiative	Steps towards emission-free construction sites
Copenhagen, Denmark	Climate RoadMap 2017-2020	From 2020, increased use of sustainable biofuels in the city's on- and off-road machinery.
Helsinki, Espoo, Vantaa, and Turku, Finland	Green Deal Agreement	Aim to have fossil-free construction sites by 2025, with 20% of these sites using electricity, biogas, or hydrogen as fuel sources. To have at least 50% of all construction sites powered by these fuel sources by 2030.
Oslo, Norway	Oslo Fossil-free Construction	Requirements for fossil-free construction sites. The city subsidises the purchase, lease, or rental of battery containers on zero-emission construction sites.
	Pilot Project – Olav Vs Gate	One of the first emission-free construction sites in the world.
	Central Municipal Building Tender Criteria	Tenders for building projects weigh environmental performance at 30%, and of that 30%, 50% is geared towards low-emissions machinery, with requirements for fossil-free machinery.
	City-wide Targets for Construction Site Emissions	By 2025, all municipal construction sites will have zero emissions, and by 2030, this will include all construction sites (including private sites) within the city.
Stockholm, Sweden	Strategy for a fossil-free Stockholm	Commitment to a fossil-free Stockholm by 2040, including a focus on construction machinery.
Stockholm, Malmö, and Gothenburg, Sweden	Common Environmental Requirements for Contractors	20% of energy used in machinery and transport must come from renewable sources.
Copenhagen, Denmark Oslo, Norway Stockholm, Sweden	Commitment to clean construction	Pledge to reduce air pollution and GHG emissions from construction sites.

2.2 Regulatory Gaps and Political Inaction

This chapter addresses how a lack of strong, unified regulations and slow political responses have delayed progress towards emission-free construction. Regulatory gaps, inconsistent policies, and political inaction are key barriers to sustainable transformation in the construction sector.

The lack of specific regulations that mandate the reporting and reduction of emissions on construction sites is a critical barrier. Without clear requirements for disclosing emissions from material transport (A4) and construction activities (A5), there is no strong external motivation for clients or contractors. As a result, many fail to adopt emission-reduction measures.

The focus of most Nordic building codes is on energy efficiency during the building's operational phase, with less direct emphasis on reducing emissions during the construction phase and from material transport. For example, emissions from transportation are often not addressed in building regulations, despite the logistics of moving construction materials being a significant source of carbon emissions.

While some countries, such as Denmark, have introduced climate requirements for new construction, these measures often fall short due to high thresholds and limited applicability. For example, Denmark's CO_2 limit from 2023 of 12 kg CO_2e/m^2/year is applied only to buildings over 1,000 m^2 and is approximately 20% greater than the average building's emissions. Although future reductions were planned, industry experts argued that these targets were insufficient to meet the goals of the Paris Agreement. In response, more than 600 companies signed the *Reduction Roadmap* initiative, advocating for prioritising environmental impact over short-term growth.[4] This likely influenced Denmark's decision in 2024 to reduce the limit to 7.1 kg CO_2e/m^2/year, expand the types of buildings covered, and address emissions from construction sites.[5] However, the new limits remain less stringent than those recommended by the *Reduction Roadmap*.

Regulatory coverage within climate requirements can be inconsistent. For example, emission regulations may apply only to large buildings, leaving smaller structures unregulated. This lack of comprehensive coverage allows significant emissions sources to go unchecked, contributing to a slower transition towards sustainable practices.

Moreover, limit values for construction emissions are primarily focused on buildings, leaving out infrastructure such as roads, railways, and utilities, which are significant contributors to emissions. Expanding Life Cycle Assessment (LCA) principles to these sectors could play a crucial role in reducing overall environmental impact, yet these measures are not yet systematically applied.

Furthermore, without supportive policies such as market-based incentives, the adoption of emission-free alternatives remains slow. Although many stakeholders such as contractors and logistics providers express an interest in low-emission options, they face high costs and little financial reward for early adoption.

For contractors interested in emission-free construction, uneven competition remains a concern. In some cases, companies that invest in emission-free equipment find themselves outbid by competitors using older, inefficient diesel machinery. To level the playing field, policies are needed that apply the same emissions standards and incentives across all contractors. Additionally, concerns about electricity access at remote work sites indicate a need for infrastructure support to enable zero-emission operations.

"We'd like to invest in-low emission equipment, but other contractors could outbid us with old and inefficient diesel machines" **– contractor in Iceland**

On a global level, the Paris Agreement remains the most comprehensive international framework to combat climate change. Yet it does not specify the responsibilities of individual countries for achieving the 1.5°C limit, resulting in inconsistent national policies. Climate scientist and professor Johan Rockström, known for his research on planetary boundaries, emphasises that:

"We cannot succeed in delivering on the Paris Accord unless we adopt a full planetary boundary framework. We need to come back into the safe operating space, and it won't be enough to just phase out coal, oil, and gas." [6]

Focusing solely on phasing out fossil fuels will be insufficient; policies must also address broader consumption patterns and structural emissions sources, such as those in construction. Moreover, policies must be consistent so that the industry can invest in emission reductions without risk.

National governments must establish emissions-related regulations and industry-specific policies to support comprehensive decarbonisation. The study "Overcoming Barriers to Supply Chain Decarbonization"[7] highlights the need for governmental policies to guide businesses and reduce resistance from stakeholders. Businesses rely on clear policy guidance to take effective action. In addition, regulatory pressure reduces resistance to getting other stakeholders on board with carbon neutrality initiatives.

2.3 Unconducive standards and building codes

The construction sector's regulatory focus remains primarily on safety, quality, and durability, often excluding climate considerations. While these standards are essential, they overlook the broader environmental impact of the construction process itself, which, if left unchanged, could permanently affect both climate resilience and human safety. Building codes and standards often lag behind technological advancements, presenting barriers to the adoption of innovative, sustainable materials and practices. It is therefore important to develop regulations in line with contemporary science given the high likelihood of increased extreme weather events and in order to reduce construction projects that contribute to climate change. Regulatory differences across regions create additional hurdles in implementing and standardising low-emission construction practices.

An example of a regulation that hinders development towards emission-free construction sites is strict road weight restrictions that limit the load capacity of trucks. This is particularly problematic for electric vehicles. Electric trucks are heavier than their diesel counterparts due to their battery weight. The approval of new construction technologies, including emission-free machinery, often requires rigorous testing and certification to meet safety and performance standards. While necessary for quality assurance, these processes can take a long time to complete.

In the Nordic region, while building codes generally align with emissions-reduction targets due to a keen focus on sustainability, significant barriers remain. Complex regulations around material use and waste management hinder material reuse, resulting in unnecessary disposal and increased waste-related emissions (module A5 in LCA). There are examples where policies favour new construction over renovation, such as where levies apply to renovations but not to new buildings during the construction phase. This creates a financial disincentive for renovation projects despite their lower environmental impact.

The EU's Non-Road Mobile Machinery (NRMM) directive imposes strict emission standards for machinery used in construction and other industries, with the latest Stage V standards reducing local emissions. However, while the directive has lowered emissions at construction sites, it also requires more frequent investment in new machinery, which increases production emissions in manufacturing countries. This highlights the complex balance between reducing emissions locally and managing global production emissions, as more frequent machinery updates may unintentionally increase emissions on a global scale.

Current legislative practices are concentrated on a business-as-usual approach and increasing consumption with a focus on small incremental improvements instead of considering the absolute carbon budgets of the Paris Agreement which, if they are to be met, need to be aligned with a reduction in the overall consumption of goods. "If you haven't consumed something 'sustainable', you cannot be sustainable, in the government's definition," says Pasi Aalto, Centre Director NTNU Wood, Department of Architecture and Technology, Norwegian University of Science and Technology, highlighting how restrictive definitions of sustainability can hinder broader environmental impact.[8]

3. Financial barrier

Cost is often seen as a major barrier to decarbonisation in the construction industry. Several different companies and stakeholders are involved in construction projects, and they all need to make the business case for investing in resources to make construction sites emissions-free.[9][10] The need for upfront investment and the availability of machinery and vehicles powered by clean energy sources are often the first obstacles. Once this equipment is obtained, there can be additional barriers that prolong project duration and increase complexity, which also translate into higher costs. Additionally, the lack of access to finance can hinder progress on emissions-free construction since financial institutions often prioritise financial gain over environmental performance, and project tenders may reward the bidder with the lowest costs. Often, there is an absence of incentives to invest in emissions-free equipment, practices and projects, and emissions-free ambitions are not integrated into business models.

"...construction companies are not going to make the move unless their customers require it." – Building owner-operator

This chapter will explore the barriers related to higher costs for stakeholders, including the costs due to low-emission machinery and vehicles, waste management, and longer project durations, as well as barriers related to finance, increased risk, and the role of procurement agencies.

3.1 Initial cost of machinery and vehicles

There is an additional cost when purchasing new low-carbon equipment, such as battery electric machinery, clean fuels for diesel machinery, or retrofitting machinery to use low-carbon fuels. The high cost of emission-free machinery and vehicles is frequently cited as one of the top barriers to emission-free construction sites.[11][12][13] New emission-free equipment may cost 20% to 30% more than conventional equipment, and retrofitting existing equipment could cost three times as much. Fossil-free fuels, such as HVO, are often expensive compared to conventional diesel and may be limited in supply.

Not only is there a higher cost for the contractor when buying or retrofitting machinery and equipment, but it will also cost local, regional, and national governments more due to the infrastructure improvements needed to support the initiatives necessary to implement emission-free construction sites.[14] Infrastructure for charging vehicles will need to be developed regionally, and the electricity supply and grid will also need to be improved.

This was highlighted in an interview with staff from companies in the energy sector:

> ***"There are already subsidies for the purchase of equipment, but there is a lack of subsidies for infrastructure development, e.g. to strengthen the electric lines in the town."***

Although low-emission construction machinery and heavy-duty vehicles are more expensive than conventional diesel machinery and vehicles, over time the running costs of electric machinery can be less than diesel in terms of fuel and maintenance costs. Some studies have found that the cost is currently not that much more than for conventional projects. For example, the additional costs for low-emission construction sites in Helsinki between 2020 and 2022 were around 0.53% more (EUR 230,000).[15] A study in 2020 by CE Delft in The Netherlands found that it would cost around 5% more if all of the vehicles and tools on a construction site were battery-electric powered. Moreover, they predicted that the total costs of a zero-emissions construction site would be comparable to a conventional site using diesel by 2030.[16]

Solutions/successful examples:

- As part of its Clean and Emissions-Free Covenant, the Dutch government offers subsidies for buying emissions-free equipment, retrofitting existing equipment, and for innovative and experimental projects.[17]
- The city of Oslo subsidises the purchase, lease, or rental of battery containers on zero-emission construction sites.[18]

3.2 Project duration

The machinery and methods currently used to reduce emissions on construction sites may prolong the construction time and, therefore, cost more. Limited availability and longer delivery times for both emission-free construction machinery and heavy-duty vehicles are often noted as some of the top barriers to emissions-free construction.[19] Longer lead times when ordering electric vehicles and equipment can significantly delay projects. For example, it could take up to 18 months to fulfil an order for an electric vehicle or piece of equipment compared to 6 months to fulfil an order for the same type of vehicle or piece of equipment with a diesel engine.[20] The limited supply of biofuels and delivery logistics may also lead to delays. Electrical equipment and vehicles do not have enough power to last all day, which has been cited as a significant barrier by construction professionals, and one which can lead to the use of fossil fuels to complete projects. Technical malfunctions with new equipment can also cause delays. There may be a learning curve for workers when using new equipment and following new workflows, which can also prolong a project. The infrastructure necessary to support the electrification of both transport and machinery will take time to develop and depends on interactions between the sector and many different stakeholders.[21] Constraints in the charging grid can increase charging times, again prolonging the duration of projects. A limited choice of local suppliers can increase the need to import materials, which extends a project's timeline and increases cost and risk.[22][23][24]

3.3. Reducing waste

Although reducing waste on the construction site can decrease overall costs for construction projects, there may be some upfront expenses associated with waste management techniques. Beginning at the design stage, there may be higher fees for designing a project to have less waste. Using prefabricated or modular components has been shown to reduce waste compared to conventional building techniques. For example, there is less potential for mistakes such as cutting materials to the wrong dimensions, which reduces both waste and material costs. However, there can be higher costs associated with purchasing these units and more cost and complexity related to the transport of these units. Workers also need to be skilled in this type of construction, but although an initial investment in training may be necessary, this type of construction is often quicker which can save on labour costs in the long run. The availability of modular and prefabricated units may also be a barrier since manufacturing plants that produce these units require higher initial capital investment, and regional suppliers may be unable to fulfil orders for large projects, which could lead to delays or hybrid construction techniques. Clients and financial institutions may be less familiar with modular and prefabricated components and, therefore, less willing to purchase or finance these projects.[25][26][27][28]

On the worksite, other upfront costs associated with proper waste management techniques include providing an adequate sorting area, training staff to sort waste, and having proper storage facilities for materials to reduce loss. Although both EU and national legislation and targets seek to reduce construction waste, many of the Nordic countries have yet to meet these targets when it comes to the rates of reuse, recovery, or recycling of construction and demolition waste. Cost can be a major driving force when it comes to recycling or reusing materials on the construction site as landfilling, backfilling, or energy recovery can work out cheaper than recycling. Moreover, the availability of inexpensive raw materials hinders reuse since it is often cheaper to buy new materials over recycled ones, and the market for recycled materials is not yet well-developed. The cost of selective demolition and preparing materials for reuse can be higher than that of conventional methods, and there can be additional costs for storing materials. However, it has to be noted that there are projects in the Nordic countries proving the contrary. Some consider separating waste to be time-consuming and are reluctant to separate materials with low economic value. Transportation costs for waste management can be high in areas where recycling plants are located far from construction sites and where landfill costs are low.[29][30]

3.4 Finance

Access to finance and financial support is a key factor on the path to implementing emission-free construction sites. Incentives and requirements to reduce emissions on construction sites are necessary to ensure that stakeholders act on this goal.[31][32] Financiers need to prioritise environmental performance over financial gains and provide access to financing for low-emissions projects and equipment. Difficulties in accessing finance are a major barrier to emission-free construction. Financiers provide loans and investments directly to construction projects and indirectly through loans and investments in the supply chain, so there is great potential to support emission-free construction projects. Although financial institutions can set lending criteria requiring low-carbon construction practices, the financial sector mainly prioritises short-term monetary gains over the environmental performance of projects. The lack of collaboration between the financial sector and the construction sector results in a lack of data, standardisation in reporting, and standard value appraisal for sustainable buildings, which makes it difficult for financiers to assess a project's environmental performance.

"In the finance sector, there is a lack of the knowledge and skills needed to understand sustainability disclosures and reporting related to the built environment and on how to use these results to drive investment, promote low-carbon construction, and create a business case while building trust within the market. Also, the culture and mindset of the finance sector create a barrier to zero-emission construction sites since this sector has mostly solely focused on a strong monetary return on investment over environmental performance." [33]

3.5 Risk

Innovation, such as the implementation of emission reductions in any form, is inherently risky. This is especially negative for the financing of construction projects. [34] New methods in construction pose an added risk. There is an increased risk of delays or unforeseen costs. The availability of low-carbon or electrical equipment varies across Europe, which increases both prices and risk. There is also the unknown potential of hydrogen. The uncertain investment perspective results in contractors hesitating to invest due to the lack of certainty for future projects using zero-emission equipment.[35][36] Financial institutions may be tentative about the risk of financing new equipment or projects using non-traditional methods. Although not a new method, modular construction projects which can reduce onsite emissions may be able only to achieve project financing for 40% to 50% of the project with a higher upfront payment required. In traditional construction projects, however, developers may be able to obtain financing for up to 80% of the project.

"It's quite normal to be sceptical of new technologies, and economics is one of the big concerns." – Gabriel Wergeland Krog, Project Manager, Fossil-free Machines Norway[37]

The lack of trust and collaboration between stakeholders to take on the increased risk associated with sustainable construction practices is a barrier to emissions-free construction.

The impact of climate change also poses an increased risk for insurance providers, who could instead base their risk assessments on the positive impact of reduced emissions.

To combat the lack of hybrid and electric vehicles and machinery available in the market, incentives and requirements throughout the supply chain could reassure contractors that the higher upfront investment will pay off. The public sector can use its status as a major buyer to reward sustainable construction practices, increase market demand for emission-free equipment, and take on the additional risk and cost of emission-free equipment.[38]

3.6 Procurement

To support the green transition, authorities have financial schemes such as green public procurement and grants for low-emission equipment and projects. Procurement agencies must balance setting the requirements for emissions reductions neither too high nor too low, since setting requirements too high may push smaller companies out of the market or increase the risk of failed bids. Setting the requirements too low risks not achieving the significant reductions in emissions required and could lead to only incremental changes and lock-in effects.[39] The Netherlands and other countries such as Denmark and Belgium have established subsidy schemes to promote the adoption of zero-emission equipment. However, these subsidies alone are not enough without clear, binding regulations to push the sector towards quicker adoption.[40] More private sector-driven construction projects than public sector-driven construction are contributing to this prioritisation of financial gain over sustainable construction practices. Procurement requirements are not harmonised throughout the Nordic countries, which could be a barrier for companies that work across this region. The inconsistencies in tender requirements between institutions and municipalities within the same country can also be an obstacle.

Stakeholders have pointed out that systems for awarding contracts based on low emissions must not be tailored to one technology, such as battery electric machinery, since that could hinder development beyond what is currently available. Relating criteria to specific technology can also be problematic when projects span many years due to the fast pace of development. Flexible procurement strategies can allow for innovation and help prevent technological lock-in. Depending on the context (i.e. access to renewable energy, proximity to waste disposal) of construction project's location, different solutions may be more or less applicable.

Procurers can address the apprehension that companies or other stakeholders may have about investing in emission-free construction equipment by creating predictable demand and aligning procurement strategies with a timeline for the transition to emission-free practices.

4. Technological barriers

Emission- and fossil-free construction sites are based in part on improved technologies in energy and waste handling. A promising development in the electrification of passenger cars prompted the transition from fossil fuel-powered vehicles to battery-electric technology. The technologies, batteries, and biofuels currently deployed do not meet all the demands of the construction industry for emission-free energy. Although biofuel has been an alternative to fossil fuel in construction for some time, it has limitations. Experience gained from the first years in the electrification of vehicles and machinery in construction shows there are barriers, such as limited availability and insufficient energy infrastructure. While there may be barriers, there is potential for improvement. Although energy usage on construction sites is generally not monitored closely, such measurements must be a basis for development in the area.[41] The reduction of material waste and increased reuse come with technological issues and there are challenges to be overcome in this regard.

4.1 Limitations of biofuels

Fossil-free construction sites can use drop-in biofuels such as biodiesel and HVO for existing diesel engines.[42] Biofuels are very efficient for heating and drying. Wood chips are often used for heating in the Nordics. Biodiesel is also a good option for conventional diesel heaters. Although biofuels are not emission-free, greenhouse gas emissions are drastically reduced compared to fossil fuels. There are no technical issues associated with the use of HVO as it meets the same standards as conventional diesel. Biodiesel is preferred as a blend of fossil diesel. HVO and biodiesel are only sustainable alternatives when the raw material is waste, such as used cooking oil or waste animal fat.

Road vehicles and construction machinery have traditionally been available with natural gas powertrains. Biomethane is a direct replacement as a fuel in these vehicles. The production of biomethane is usually based on the fermentation of easily degradable biomass. The biodegradable fraction of municipal solid waste is often used as a raw material.

The current technology used in biofuel production requires biological raw material that is already limited in quantity.[43] A massive increase in the use of biofuels in the construction industry is, therefore, not currently a viable option. Developments in biofuel technology may pave the way for using other raw material that is more abundant and can be sourced sustainably.

4.2 Availability of machinery and equipment

The availability of emission-free machinery is repeatedly mentioned in interviews with people in construction companies. The general opinion is that although battery electric lightweight machinery and trucks can be sourced, the lead times are long. Heavier equipment is still not available in emission-free variants.

Cleancon, a Nordic project on clean construction, collated experience from several pilot projects with low-emission machinery.[44] One of many interesting results was that there is considerable demand for emission-free machinery, exacerbating the issue of poor availability. A similar conclusion was reached in a conference held by Leap to Zero in the Netherlands.[45]

"The biggest challenge is the lack of production of zero-emission machinery in factories. Currently, there is limited availability of zero-emission equipment worldwide."

Hydrogen is a promising fuel that can be used with fuel cells or in combustion engines. It is considered a better choice than batteries for heavy trucks and machinery as more energy can be stored on board. Commercial hydrogen equipment is generally limited to small power generators. Trucks and mobile machinery are generally available only as special test cases.

4.3 Uncertainty about performance and development

New technology brings change to established processes in the construction industry. New knowledge and experience have to be built up in all phases of construction. Added to this, there is uncertainty around what the new technology will be and how it will perform.

The construction industry normally does not have much room for experimentation. The same applies to investment in expensive equipment. The financial risk is typically the first barrier that contracting companies see when investing in emission-free equipment. Applying unfamiliar technology on a construction site can also cause unforeseen problems, resulting in additional costs and delays.

They also consider the likelihood of unforeseen problems with the technology if there is a slight chance that it will cause added problems.

Interviews with contractors highlight uncertainties that hinder the adoption of new emission-free technologies. They feel that the performance of the new equipment is not well-proven. Even if power and range are equal to conventional equipment, maintenance costs and practical lifespan are uncertain until more experience is gained.[46] One of these uncertainties is battery capacity; some manufacturers recommend that only about 80% to 90% of battery capacity is used in order to increase lifespan. Stakeholders are often uncertain about the effective usable range of new emission-free equipment, as well as cold weather performance.[47][48]

There are also concerns about obsolescence, with new technologies rapidly replacing the first generation of emission-free machinery.[49] Distributors and other equipment specialists point out that batteries are not the final emission-free solution. An example of the fast pace of development is a pilot production run of 200 heavy trucks running on hydrogen. The majority of the trucks will be delivered to customers in Norway and Iceland in 2025.[50]

4.4 Charging bottlenecks

Issues regarding the charging of battery electric vehicles and machinery on construction sites are a recurring theme in surveys and interviews.

Charging large battery electric machines and vehicles requires powerful grid connections and contractors often cite this as a limiting factor. Getting a connection to a new construction site can be problematic due to utility providers' traditional processes. Construction in new areas can be delayed due to the development of grid infrastructure, while in older urban areas the electric grid may already be at full capacity.[51][52]

High capacity chargers are used for battery electric machinery and the power drawn from the utility grid may be more than the building under construction will ultimately require.[53] It is important to plan grid connections and charging schedules carefully, which is difficult when combined with the introduction of new technology.[54]

4.5 Hydrogen infrastructure

As mentioned above, hydrogen is a promising fuel for heavy construction equipment and the technology is already available. Heavy vehicles and equipment using hydrogen are available today. These are, however, not as numerous as their battery electric counterparts.

Simple access to existing grid infrastructure has helped battery electric vehicles to gain popularity and lowered production costs. Although hydrogen is produced in most of the Nordic countries, there is very limited distribution infrastructure for customers in transport and construction.[55] Perhaps the most important barrier to the deployment of hydrogen trucks is the lack of infrastructure.[56]

The production of hydrogen is typically centralised in large units, employing electrolysis or methane reforming. Hydrogen is usually transported using trucks, either pressurised or liquified. Vehicles receive the fuel at hydrogen refuelling stations (HRS).

> ***"It is likely that increased hydrogen infrastructure deployment and, in addition, the potential availability of mobile HRSs will be a key success criterion for the first deployment stage of NRMM"* – Next Nordic Green Transport Wave - Large Vehicles[57]**

Road transport requires hydrogen refuelling stations at strategically chosen locations in the transport system. Non-road machinery at construction sites needs fuel to be delivered to the site. This requires solutions where hydrogen is transported to the site and dispensed directly to machinery.

Solutions/successful examples:

- A manufacturer of hydrogen construction equipment offers a mobile hydrogen refuelling station.[58]

4.6 Waste infrastructure

Although design and planning before the start of a construction project can significantly reduce waste from construction sites, it cannot be eliminated entirely. Proper organisation and suitable facilities are crucial for minimising damage to materials on site, although various barriers often hinder these efforts. As a result, construction projects still produce waste such as packaging, leftover materials, off-cuts, and used auxiliary materials.

"In fact, building material is as valuable today as it was in ancient times. We just don't respect it as much, and we find it easier to replace it with newly sourced material, even though we are surrounded by possibilities." [59]

A major source of waste on construction sites comes from materials being damaged before they are even used. Materials often arrive too early or too late. When they arrive too early, they may need to be stored on site for extended periods, often in unsuitable conditions, increasing the risk of damage from weather such as rain, snow, or humidity. Late arrivals disrupt workflow, resulting in rushed handling and increasing the chance of damage. Many construction sites lack adequate storage space for materials. Without designated areas, materials are often left in open spaces where they can be damaged by construction machinery or accidental collisions. In some cases, materials must be moved repeatedly to make room for ongoing work, further increasing the likelihood of damage. Late arrivals are often due to logistical and organisational barriers, including poor communication and co-ordination between suppliers, transporters, and site managers, which can lead to mismatched schedules and improper handling. The lack of simple and accessible digital tools to track materials, ease communications, and ensure the quality and safety of stored materials is a significant barrier.

Once waste is generated, managing it effectively presents additional challenges. Materials that do not end up used in construction should, if possible, be reused. If reuse is not possible, recycling into a high-value product is preferred. The sorting and recycling of construction waste on site pose several challenges, particularly in terms of infrastructure and logistics. Construction sites often lack space for all the containers needed to sort different types of waste. Containers are typically large to minimise the frequency of pickups, but this creates spatial challenges, especially at smaller or more crowded sites. Without adequate sorting options, materials that could be recycled or reused are often mixed with general waste. The size and design of current sorting containers limit their usability on compact sites. There is a need for technical innovations, such as compact sorting systems or modular containers, which take up less space without requiring more frequent collections. Furthermore, many sites lack digital tools to track materials and organise waste effectively, making it difficult to monitor reusable items and ensure proper sorting.

Earthworks pose another challenge, as they generate large amounts of reusable construction aggregates as well as soil that is unsuitable for construction.[60][61] The conventional solution is to transport materials to landfills and quarries that are understandably located outside urban construction areas. Research has shown that planning and organising stocks of earth materials locally can reduce transportation and resulting emissions.

5. Systemic barriers

This chapter looks at the systemic barriers that make it difficult to reduce emissions from construction sites. These barriers are built into the industry and society and affect processes. They include issues such as the fast pace of construction projects, gaps in data and measurement, a lack of knowledge and communication, resistance to change, and complexity.

These barriers often overlap, making it even harder to implement emission-free construction. For example, not knowing enough about new technologies can lead to resistance, and the fast pace of the construction can lead to fewer opportunities for dialogue. These barriers are shaped by cultural habits, regulatory gaps, and the deep-rooted ways in which the construction industry operates. Matti Kuittinen, Associate Professor in the Department of Architecture at Aalto University, argues that we need a profound value shift when discussing sustainable architecture.

"What we need now is a new enlightenment, similar to the European enlightenment in the late 18th century, when strong shifting values spread in society. This is wishful thinking, but at times I think I can see it happening in the actions and thinking of the younger generation." [62]

5.1. Speed and timeline constraints

Reducing emissions from construction sites requires additional processes which need to fit into the typical timeline in construction projects. For example, establishing grid connections and improving the on-site utilisation of building materials and energy are essential yet time-consuming steps. Time constraints in projects can limit the willingness to integrate new methods and technologies that might initially slow the process.

The speed of the construction process poses a significant barrier, which can be a consequence of financial barriers (see Chapter 3) since more time usually means more costs. It can also be a consequence of knowledge gaps since stakeholders need to realise that additional time is needed for certain aspects when reducing emissions at a work site, especially when experience needs to be gained in new methods.

The fast pace of construction projects can also increase the distance between different actors, reducing opportunities for dialogue. That can create misunderstandings or disbelief among subcontractors when they first encounter the project's functional requirements and design specifications.[63]

Ultimately, prioritising short-term gains over long-term sustainability not only impedes efforts to reduce emissions but can also lead to higher costs in the future.

5.2 Process complexity and integration issues

The construction industry is known for the complexity of its processes, which create significant challenges for implementing new innovative practices such as emission reductions. Involving multiple contractors, subcontractors, suppliers, and various stakeholders across different phases of a project with different backgrounds and requirements makes it difficult to implement changes which affect the entire project. Each contractor and subcontractor may follow different standards and practices and have their own interests to protect. For example, a contractor may prioritise cost efficiency over sustainability, whereas the client may be focused on achieving carbon neutrality. Aligning these goals across multiple parties adds layers of complexity.

Emission-reduction practices in construction require changes in different systems within the industry. This often involves integrating multiple new technologies at the same time, such as electric machinery, renewable energy sources, programmes to improve transportation performance, etc. These technologies are interconnected, meaning a change in one area affects another, slowing down work when there is a need to try different technologies. This requires co-ordination between stakeholders such as equipment suppliers, energy providers, and site managers.

In building projects with a high degree of innovation and development, the lack of communication can make it difficult to achieve the goal of reducing emissions. With new methods, there is often a need to adjust and improve solutions directly on the building site. This requires an understanding of the intentions behind the new methods and project plans within the team working on site. This further requires collaboration between design teams, who understand the intention of the work, and the on-site teams, who execute the project.[64]

However, communication gaps between stakeholders remain a significant barrier, such as between those who understand the project's intent and those who execute the work. A recent paper highlights the gap between theoretical knowledge and on-site practices, and underscores that collaboration among stakeholders and policymakers is not just beneficial but crucial for driving meaningful progress in reducing the construction sector's environmental footprint.[65]

Solutions/successful examples:

To achieve fossil-free or emission-free construction sites, it is essential to prioritise practical co-operation among stakeholders, establish precise requirements and goals, and foster open sharing of knowledge, experiences, and methods for implementation and documentation. These findings were identified during the construction phase of two Norwegian zero-emission construction sites, providing a pathway to success in similar projects.[66]

5.3 Data and measurement challenges

Accurately measuring and tracking emissions is essential for reducing the environmental impact of construction sites, yet several systemic barriers complicate this task. Without reliable data, achieving emission-reduction goals remains challenging, as stakeholders lack the insights to make informed, effective decisions. As Harpa Birgisdóttir, Professor at Aalborg University, states:

"Municipalities need to know what the climate effect is when deciding on new construction, compared to the effects of reuse or renovation." [67]

A significant barrier is the lack of a clear, standardised way to collect and report data on emissions from various construction activities. While Life Cycle Assessment (LCA) systems help guide what data should be collected, there is still no consistent method for collecting it. Without standard approaches, comparing emissions across projects or setting clear goals becomes difficult, which slows progress in reducing emissions.

Another challenge is the complexity of measuring emissions accurately at construction sites. Although some emissions data is gathered during building certifications such as BREEAM or LEED, this data is often limited and not used effectively for broader sustainability goals.[68] Instead, it is primarily focused on meeting certification requirements rather than providing a comprehensive emissions database for use across the industry.

Once data is collected, it also needs to be processed into accurate averages for each LCA module. Although the Nordic countries have some estimated emissions data, this data needs to be more precise. Significant gaps have been found between estimated and actual emissions in life cycle studies across the Nordic countries. For example, a study from Norway showed a 44% difference between estimated and actual emissions, mostly related to the use of construction machinery.[69] Other studies show that actual emissions from waste management are often much higher than initially estimated.[70]

Currently, the same estimated emissions value is used for many building types, but more accurate average data for each specific building type is needed. Creating precise data for each building type will allow for more accurate and meaningful comparisons and insights.

Overcoming these data and measurement challenges will require better technology and regulatory support.

5.4 Lack of knowledge and resistance to change

New methods in construction require time, effort, and a willingness to learn, as well as collaboration at all levels in the industry. Awareness of new practices is crucial, yet a typical barrier is the lack of knowledge and experience among stakeholders, as highlighted in a study on two Norwegian low-emission construction sites.[71] Many stakeholders lack training and skills in these areas, which limits their ability to apply low-emission methods. New technologies often require specialised training, yet these programmes are currently limited and difficult to find. Although awareness of low-carbon strategies is growing, stakeholders often don't fully understand how to apply these strategies in practice. Many remain unaware of the impact of construction site emissions and the available ways to reduce them. This knowledge gap slows the adoption of emissions-reduction practices and contributes to hesitancy, ultimately holding back progress towards achieving emission-free construction.

A report on *Overcoming Barriers to Supply Chain Decarbonization: Case Studies of First Movers* [72] identified knowledge-related obstacles such as "lack of awareness", "lack of expertise", and a "resistant mindset". These barriers also affect efforts to achieve emission-free construction sites. According to the report, resistance persists because some organisations do not see the shift to carbon neutrality as urgent or essential. This reluctance can be due to a lack of awareness about emissions-related environmental issues, disbelief or a belief that proposed measures will have minimal effect on the overall outcome, leading to low motivation for decarbonisation efforts.

The construction industry is typically conservative and relies on established methods, with cultural resistance to new sustainable technologies. Contractors often doubt the feasibility of emission-free transportation, questioning the reliability of electric vehicles and alternative fuel technologies. Without confidence in the availability, reliability, and cost-effectiveness of these solutions, many stick with conventional methods that produce emissions. Concerns about upfront costs, project delays, and limited knowledge of long-term benefits also hinder adoption. This lack of understanding and resistance to change leads many stakeholders to view emission reduction strategies negatively.[73]

In some cases, communication breakdowns lead to evident problems on site. For example, during the construction of the Lia Nursery School, the plan was to use biodiesel in large construction machinery, but the machines arrived on site with their tanks filled with diesel.[74]

5.5 Current economic structure

As highlighted in previous reports from the Nordic Sustainable Construction project, building less is the most effective way to reduce emissions from construction sites. By focusing on better utilising existing buildings – renovating and reusing structures as a whole – we can prevent the need for demolition and new construction, which reduces both embodied and operational emissions. However, the current economic model often favours new construction over the reuse or renovation of existing buildings. This growth-focused economy, particularly in its drive to increase GDP, poses a significant barrier to reducing emissions, not only in construction but across various sectors.

"I think that the first structural move is to really consider why we build. This includes the question of whether we have to build anything at all. Failing to ask this basic question is probably the main obstacle to understanding the structure of legal matters at the level of the first intuitive thought of building. That gut feeling saying that 'we need to build' comes with an economy that tells us to get rid of what is there so that we can build new. It is almost a philosophical task to challenge the current go-to solution, where we 'build our way out of each problem'." [75]

As Kai Reaver, Head of Architecture and Chief Advisor at the Norwegian Architecture Association, NAL, highlights in an interview, the core question is why we need to build. This "build-to-solve" mindset, driven by growth-focused economies, replaces existing structures instead of repurposing them, prioritising short-term gains over environmental sustainability. The traditional "linear economy" of construction extract, use, discard continues to dominate because it aligns with business models prioritising quick returns. Renovation and reuse face hurdles such as complex regulations, unpredictable costs, and limited incentives, further reinforced by policies favouring new builds.

One consequence of this growth-driven mindset is the so-called rebound effect. While energy use per square metre has decreased through efficiency gains, overall energy consumption per person and household has actually increased. This is due to larger heated areas, more electronic devices, and the tendency to consume more when things become efficient and cheaper. An example of a possible rebound effect at the construction site is if recycling processes become highly efficient, some companies may generate more waste with the assumption that it can be effectively reused or recycled, reducing the incentive to minimise waste generation in the first place.

As Harpa Birgisdóttir points out in a recent article, tackling environmental impact is not just about technological solutions; it requires a societal shift in what we value. Reducing environmental impact means rethinking our perception of consumption and space, and considering sufficiency as a core principle in construction.[76]

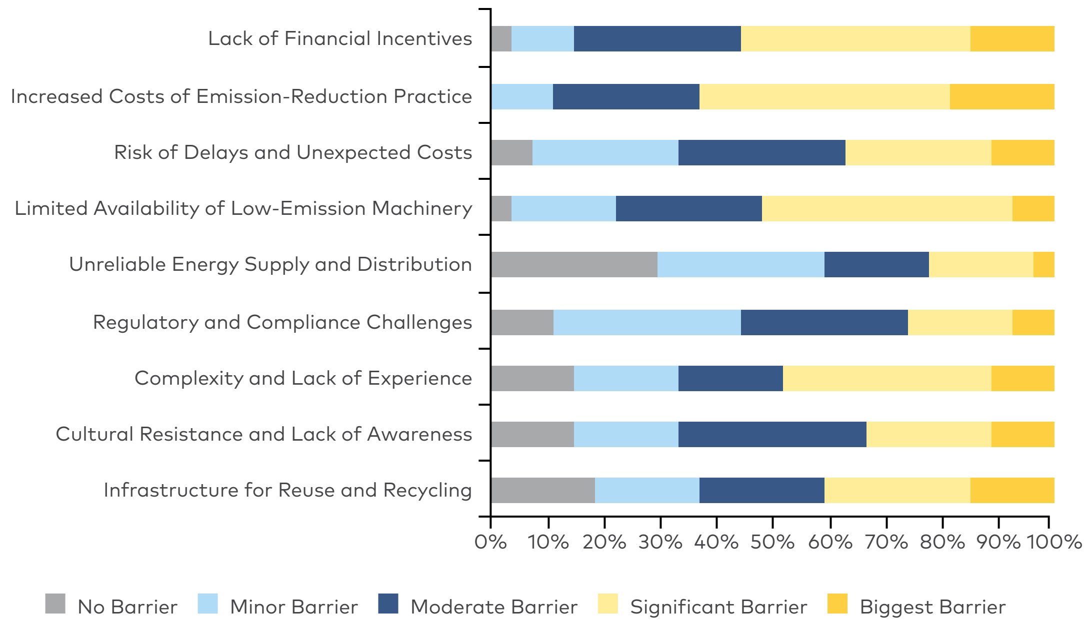
In addition, while some strategies and innovations appear sustainable, they are often undermined by the pressures of the growth economy. Many approaches that seem eco-friendly, such as energy-efficient buildings or "green" certifications, often encourage increased construction and the same unsustainable consumption patterns. This misalignment reveals the urgent need to shift from supporting growth to adopting sustainable practices built on principles of sufficiency and respect for the planet's limits.[77]

6. Industry survey

In addition to the content analysis and conversations with stakeholders, a short, informal survey was created based on the barriers that were identified. The survey was distributed online through the Nordic Sustainable Construction site and its LinkedIn page, through the newsletter of the Emission-free Construction Site project, and on social media groups such as LinkedIn and Facebook. Although the survey is not generalisable due to the small number of responses received, it offers a snapshot into what some construction industry professionals are currently perceiving as minor and significant barriers to emission-free construction sites.

Despite the low number of responses, there was a good balance of respondents from different professions within the construction industry. Responses were received from building owners and operators, on-site construction workers, designers, architects and engineers, and office workers at a construction company.

The majority of the respondents thought that there was a need to reduce emissions from construction sites. Those who responded "No" or "Maybe/I don't know" were mainly building owners or operators and on-site construction workers.



Over half of the respondents thought increased costs, lack of financial incentives, and limited availability of low-emissions machinery were significant or the biggest barriers to emission-free construction sites. Unreliable energy supply and distribution were seen as not being a barrier or as being a minor barrier by more than half of the respondents, and just under half saw regulatory and compliance challenges as not being a barrier or as being a minor barrier. Nearly 25% of respondents felt no need to reduce emissions, indicating potential cultural or knowledge-related barriers. Additional barriers that respondents noted were:

- lack of interest
- lack of demand from customers
- emission-free equipment being less reliable, not lasting the whole day, and long charging times

7. Bringing it together

Throughout the *Emission-free Construction Sites* project, the importance of dialogue between stakeholders has been repeatedly emphasised. Lack of communication appears as a barrier in several areas throughout this report. It appears in the context of logistical and organisational barriers on site, leading to mismatched schedules and improper handling of building materials. It also emerges when new methods are implemented, as a lack of communication between those who understand the project's goals and those who execute the work creates challenges.

Many of the barriers identified in this report are closely tied to time and cost pressures in the construction industry, including the lack of communication. Time constraints are often driven by the need to keep costs low as longer projects means increased costs. This focus on completing projects quickly and cheaply limits the ability to adopt new technologies or practices that could reduce emissions.

The high upfront cost of emission-free machinery and the time needed to adapt to these new technologies make it challenging to shift away from traditional methods. Similarly, delays in building the infrastructure needed for electric or hydrogen-powered equipment stem from the reluctance to invest in systems that may not deliver immediate financial returns.

The underlying reason for these challenges is the current economic structure, which prioritises fast and cost-efficient construction. This same structure often favours building new rather than reusing or renovating, even though reusing buildings would significantly reduce emissions. The focus on short-term cost savings and growth makes it challenging to shift towards more sustainable practices.

Overcoming these barriers will require not just technological and financial solutions but also a broader rethinking of priorities in the construction industry to make sustainability a central goal.

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