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# Towards emission free construction sites in Northern Norway: Results from a regional survey

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**Abstract**. The concept of emission free construction sites (EFCS) has emerged as a prioritised measure to reduce greenhouse gas emissions from Norwegian construction activities. EFCS have been evaluated through several pilot projects in Southern Norway, whilst none are found in Northern Norway. This study aims to investigate the major barriers and success factors for developing EFCS-projects in Northern Norway through a digital survey amongst construction industry representatives. The results indicate that major barriers for EFCS implementation are related to limited access and capacity of electricity and power supply, and limited availability and high costs of emission free technologies. Similar challenges are identified from EFCS projects in Southern Norway, making the cold climate, poor infrastructure, and remote conditions in Northern Norway an amplifier of these challenges. The identified success factors are to a large extent aligned with the major barriers, emphasizing improved power supply and charging infrastructure, as well as increased availability of emission free technologies. Predictable and equal requirement specifications in public tenders that reward those who invest in emission free technology are requested, emphasizing the importance of implementing requirements. Further work is needed to gather experience from EFCS pilots in cold and remote areas.

## 1. Introduction

23 % of global greenhouse gas (GHG) emissions arise from the construction sector [1]. In 2021, the Norwegian construction industry emitted approximately 2.2 million tonnes of GHG emissions, which accounts for 3,4 % of the total emissions in Norway [2]. The main source of these GHG emissions is the combustion of fossil fuels in construction machinery [3]. In line with fulfilling the emission reduction obligations of the Paris Agreement, Norwegian authorities have initiated several climate actions to reduce GHG emissions. This includes fossil free construction sites (FFCS) and emission free construction sites (EFCS), which have emerged as prioritized emission reduction measures within the Norwegian construction industry. FFCS are a first step towards EFCS as it allows for direct substitution of conventional diesel with biofuels (e.g., HVO biodiesel), while EFCS involves only the use of energy sources that do not lead to direct GHG or NOx emissions (e.g., electricity or hydrogen). Norway, and Oslo in particular, have been forerunners in the adaptation of emission free technologies in construction [4]. Seven of the largest municipalities in Norway have signed a declaration that all public tenders will require EFCS by 2025, and that by 2030 all construction activities in cities (including private construction) will be emission free [5]. However, as requirements for FFCS and EFCS are implemented by regional authorities, there has been limited application outside the larger

cities. Whilst EFCS have been evaluated through several pilots in Southern Norway [5], there are no completed EFCS pilots in Northern Norway.

Traditionally, efforts to reduce GHG emissions from buildings have focused on reducing the operational phase emissions [6]. Today, we witness a shift from standard buildings, to low- and zero-energy buildings, and even zero-emission buildings [7,8]. Once buildings are designed to be energy- and material efficient, the relative contribution of the GHG emissions during construction to total GHG emissions will increase. A previous study found that roughly half of the construction phase GHG emission came from construction machinery [8]. EFCS can also bring several benefits beyond emissions reduction. Amongst these are healthier working environments with less pollutants and noise for both construction workers and neighbors. Emissions of other pollutants ($NO_x$, $SO_x$, and particulate matter) and noise from construction machinery can have a significant negative impact on the health of construction workers and citizens [9], and the construction industry in the United Kingdom is responsible for the largest annual number of occupational cancer cases, with around 8 % of these directly related to diesel engine exhaust emissions [10]. Other benefits of EFCS include increased energy efficiency of electric equipment and lower maintenance and operational costs compared to conventional construction machinery. In addition, the benefits of EFCS may extend to other sectors using similar equipment, e.g., the mining industry.

The objective of this study is to investigate major barriers and success factors for developing EFCS-projects in Northern Norway.

## 2. Background

The Nordic Arctic climate is characterised by extreme seasons, high temperature and precipitation variations, a strong gradient in latitude solar, and UV radiation [11]. Several action plans show that developments in the Arctic have been a priority in the Norwegian Government's agenda, including a focus on the reduction of GHG emissions via transition to green transport, energy, and construction [12]. At the regional level, different municipalities are establishing their own missions regarding the green transition [13]. One challenge of the Arctic region is the cold climate with variable sunlight hours through the year, and consequently increased energy demand for heat, light, and transport [14]. The severity of the climate can decrease the cost-effectiveness of renewable solutions, and the cold climate has a direct influence on the performance of electric construction machines regarding their operation and charging time [15]. Another challenge is related to the geographic distribution of these regions, which have a large number of small, remote communities separated by significant distances, which makes the development of energy and power infrastructures more demanding [14]. Delivering construction machines and materials can be expensive and lead to high carbon footprints. The transition to a more sustainable construction sector can be demanding for small actors as investment in emission-free machines and equipment is expensive. As a result, Norway, Sweden, and Finland are planning to establish a joint-collaboration platform for sustainable construction in cold climates [16]. In Oslo, contractors, suppliers, and manufacturers have actively taken initiative to advance zero-emission machinery powered by batteries, fuel cells or direct electrification. Oslo is part of the C40 network, which through its Clean Construction Declaration pledged the mayors of Oslo, Los Angeles, Mexico City, and Budapest to halve GHG emissions from all construction activities by 2030 [17]. Oslo municipality is also an active member of the EU DG Grow Big Buyers Initiative (an initiative by the European Commission for promoting collaboration between big public buyers in implementing strategic public procurement for sustainable solutions), which has a working group on Zero Emission Construction Sites [18]. Oslo municipality has been a driving force by rewarding suppliers who offer zero-emission construction technologies through public tender. Such initiatives have created a demand for emission-free construction machines in the Norwegian market.

## 3. Methodology

The study applies mixed methods research design through a combination of qualitative and quantitative data collection and analysis, namely a digital survey and a literature review. The survey questions were prepared based on a literature review conducted on previous EFCS projects in Norway [19,20]. The literature review draws upon transferable experiences and lessons learnt from previous pilot projects. The survey was conducted using SurveyMonkey. The link to the survey was distributed by email to approximately 350 representatives from the construction industry in Northern Norway. Table 1 specifies the number of survey respondents per stakeholder group. The survey consists of sixteen multiple-choice questions and nine open-ended questions. The respondents were asked to give input on relevant barriers, success factors, and potential negative consequences related to the implementation of EFCS. The respondents were asked to consider two predefined lists of potential barriers and construction site activities, ranging them in terms of importance and degree of difficulty for implementing EFCS. The survey was conducted from 24.11.2022 to 19.12.2022. Respondents conducted the survey digitally, using on average ten minutes to complete the survey.

Open-ended responses were coded using Dedoose software (v. 9.0.84) for mixed methods research. The coding of open-ended responses was done according to 'barrier categories', which were defined based on the content of responses. Results from multiple-choice questions are visualised in tables.

**Table 1.** Overview of survey respondents across stakeholder groups

| Stakeholder group | Number of respondents |
|---|---|
| Machine contractors | 17 |
| Building contractors | 19 |
| Public developers | 20 |
| Transmission system operator (TSO) | 1 |
| Consultants | 7 |
| Machine and equipment suppliers | 6 |
| Total | 70 |

## 4. Results

Table 2 shows how the respondents view the implementation of different predefined construction activities in EFCS projects. Heavy-duty transport (of masses, construction machinery, and building materials) and operation of construction machinery are regarded as the most challenging activities. Demolition is amongst the top three most challenging activities when results for 'a little difficult' and 'very difficult' are combined. Transport of personnel and internal transport are considered as the least challenging, since over half of the respondent's regard these as 'unproblematic'.

**Table 2.** Ranking of predefined construction site activities in terms of the perceived degree of difficulty when implementing in EFCS projects (n=number of respondents).

| # | Activitiy | Unproblematic | A little difficult | Very difficult | n |
|---|---|---|---|---|---|
| 1 | Mass transport | 6 % | 31 % | 63 % | (51) |
| 2 | Transport of construction machinery | 6 % | 31 % | 63 % | (48) |
| 3 | Operation of construction machinery | 18 % | 29 % | 53 % | (51) |
| 4 | Transport of building materials | 12 % | 42 % | 46 % | (51) |
| 5 | Transport of wastes | 18 % | 49 % | 33 % | (51) |
| 6 | Demolition | 8 % | 60 % | 32 % | (50) |
| 7 | Energy use (e.g., heating) | 37 % | 48 % | 15 % | (54) |
| 8 | Supplementary materials and installation | 26 % | 62 % | 12 % | (42) |
| 9 | Temporary works (e.g., barracks) | 45 % | 43 % | 12 % | (51) |
| 10 | Transport of personnel | 61 % | 32 % | 7 % | (57) |
| 11 | Internal transport | 50 % | 45 % | 5 % | (56) |

Some variations are observed across the stakeholder groups. For instance, public developers do not emphasise transport of construction machinery or transport of building materials as 'very difficult'. Similarly, suppliers are less concerned with mass transport and operation of construction machinery.

Further, building and machine contractors regard internal transport as 'unproblematic', compared to the other stakeholder groups.

Table 3 shows how the respondents' regard potential barriers for conducting EFCS in Northern Norway. While the results of potential barriers indicate a certain spread in terms of importance, it is worth noting that all barriers are viewed as either 'important' or 'very important' by more than half of the respondents. The most emphasised barriers are related to limited power supply for charging, and challenges related to acquiring infrastructure for provisional power, as well as the availability and costs of construction machinery and heavy-duty vehicles.

**Table 3.** Ranking of potential barriers in a predefined barrier list. The values reflect the share of respondents answering either 'important' or 'very important' to the respective barriers (n=number of respondents).

| # | Barrier | Value | n |
|---|---|---|---|
| 1 | Limitations in the power grid can lead to increased charging times | 77 % | (56) |
| 2 | Challenging process of obtaining provisional power (may lead to delays) | 74 % | (61) |
| 3 | Electric construction machines are too expensive | 74 % | (53) |
| 4 | Limited availability/long delivery time for emission free construction machinery | 74 % | (54) |
| 5 | Limited availability/long delivery time for emission free heavy-duty vehicles | 72 % | (54) |
| 6 | Electric heavy-duty vehicles are too expensive | 70 % | (54) |
| 7 | Electric construction machines do not have sufficient energy or power supply to last full working days | 69 % | (54) |
| 8 | Electric heavy-duty vehicles do not have sufficient energy or power supply to last full working days | 65 % | (54) |
| 9 | Challenging planning of power supply and use | 63 % | (59) |
| 10 | Use of cable-battery construction machines can present on-site logistics challenges | 62 % | (53) |
| 11 | Public developers lacks competence on defining procurements | 63 % | (59) |
| 12 | Long distances to disposal sites may lead to using vehicles on biofuels of fossil fuels | 62 % | (52) |
| 13 | The industry lacks competence on planning EFCS | 62 % | (58) |
| 14 | Limited availability/long delivery time for emission free energy solutions (e.g., heating) | 61 % | (56) |
| 15 | The industry lacks competence on using emission free technologies | 59 % | (59) |
| 16 | Different machines require different charging systems | 58 % | (52) |
| 17 | Electric construction machines can handle less weight/load than conventional machines | 50 % | (54) |

## 5. Discussions

This paper presents findings from a regional survey of major barriers and success factors for EFCS, obtaining a response rate of 20 % amongst 350 industry representatives in Northern Norway. The response rate is considered adequate for the given purpose, and the selection is considered to reflect a diversified regional construction industry. Some of the stakeholder groups have few respondents, primarily the transmission system operator (TSO) group, but the number of TSOs in the region is also limited. The online survey approach has some inherent limitations, amongst these that the data collection is based on self-reporting, and that we do not control who choose to participate in the survey. A rigid structure, for instance the use of predefined lists, may limit the depth of responses. However, the respondents were given opportunity to elaborate or clarify their answers, which might reduce this potential pitfall.

One of the top-mentioned barriers is access to energy and is highly emphasised by all stakeholder groups, except public developers. The energy-related challenges are concerned with underdeveloped infrastructure, limited power supply and capacity for charging electric construction machinery. Availability of emission free technology is another significant barrier mentioned by all stakeholder groups except suppliers, with an emphasis on the availability of electric construction machinery. Access to electric heavy-duty vehicles and equipment are also mentioned as challenges. The cost of electric construction machinery is highly emphasised by contractors and public developers. It is noted that barriers relating to availability and cost of emission free technology is mentioned by all stakeholders, except for suppliers. The supplier's main emphasis is related to access to energy, as well as asking for "*reassurance that public developers do not deviate from requirement specifications for* *emission free machinery*", which is related to a contractor stating that it will be "*very unfortunate if requirements are not followed up*". Construction operations in the Arctic is perceived as an additional barrier across stakeholder groups. This barrier is related to remote areas with long distances and underdeveloped infrastructure, accompanied by a cold climate reducing available construction time and affecting battery capacity of machinery.

The identified success factors for EFCS are to a large extent aligned with the major barriers pointed to above. For instance, the success factors for energy related barriers are oriented around establishing improved power supply and charging infrastructure, also emphasising the importance of early planning and facilitation of power supply. Contractors suggest an extended construction period to provide sufficient time to establish necessary infrastructure during rigging phase. The suppliers suggest expanding district heating infrastructure, describing it as a major advantage in bigger cities. Consultants and public developers mention alternative energy sources like hydrogen and ammonia as potential solutions to solve a limited power supply. Increased availability is the main success factor related to emission free construction machinery and equipment. In addition, the TSO highlights EFCS pilot projects and investment funding through public support schemes as an opportunity for contractors to upgrade their machine park. The ability of construction machinery to last long working hours is highlighted by machine contractors and public developers, in addition to sufficient range of heavy-duty vehicles. Further, all stakeholder groups mention more generic success factors involving governmental regulations and facilitation, collaboration and awareness raising, as well as economic incentives to cover the extra cost of EFCS. The importance of collaboration across stakeholders is highlighted by a building contractor stating that the transition to EFCS "*must be solved in close collaboration with the client"*, while a machine contractor states that "*no dialogue exits between private and public sector"*. Requirement specification in public procurements is another frequently mentioned success factor. This involves a joint effort across all public developers, providing equal and predictable conditions for contractors. One of the consultants asks for requirements which are "*designed to 'force' suppliers to deliver [emission free equipment]"*, while a supplier argue that the industry must "*start using the [emission free] equipment without having a fossil alternative"*. The introduction of stricter environmental requirements in building and infrastructure projects is, however, handled by regional authorities, making larger cities the forefront of EFCS pilot projects. The commitment for carrying out EFCS is lacking in rural areas, made evident by a smaller municipality stating that "*the commitment is not secured in political or administrative management"*. There is a lack of internal plans for carrying out EFCS and smaller actors could benefit from external support and guidelines. A need for greater competence in the field of EFCS is mentioned by all stakeholder groups.

The perceived negative consequences of EFCS are mostly related to the extra costs compared to conventional construction. It is described as a capital-intensive transition and both building contractors, machine contractors, and public developers are worried they will not be able to sustain the extra costs of EFCS. The same stakeholder groups expect lower initiation and completion of construction projects, potentially leading to loss of competence and jobs in the local area. A supplier describes EFCS as "*almost impossible outside the bigger cities*" and a consultant is worried EFCS may lead to exclusion of certain parts of the market as smaller actors do not have the same financial muscles as larger contracting companies. Both machine contractors and public developers mention that there will be a surplus of relatively new fossil construction machinery, which will lose considerable value and potentially be exported out of the country. However, several stakeholders amongst suppliers and machine contractors, as well as a contractor and the TSO, do not emphasise any specific negative consequences of EFCS implementation.

Similar barriers and success factors pointed to in this study are reported for EFCS in major European cities [21], as well as identified from EFCS pilot projects in Southern Norway emphasising the availability of energy supply, charging infrastructure, and efficient logistic solutions [19,20]. Related, the TSO argue that EFCS "*should not be more challenging than in southern parts of Norway*." Nevertheless, the cold climate, poorly developed infrastructure, and long distances in Northern Norway may potentially serve as an amplifier of these challenges, at least in the most remote areas. It seems that those with knowledge might be more optimistic, e.g., contractors do not think internal transport is a problem and suppliers do not think access to machinery is a problem. A first step in that sense would be to start collaborate/talk to each other.

## 6. Conclusion

This study investigates the perceived major barriers and success factors for emission free construction sites in Northern Norway. While this study is limited to a survey analysis geographically bound to Northern Norway, the results are supported by findings from the southern parts of the country, where EFCS are relatively well established. Thus, the results may be relevant and interesting for other regions and countries. Further work is needed to gather experience from EFCS pilot projects in cold and remote areas, and a mapping of the regional energy infrastructure may be of interests. Future studies could also consider a wider survey at a national, Nordic, or European level.

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