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Environmental impact assessment of on-site and off-site construction logistics activities – A case study analysis from Norway

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Environmental impact assessment of on-site and off-site construction logistics activities – A case study analysis from Norway

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Abstract. Construction site activities are one of the main contributors to GHG emissions in the construction industry. There are several on-going initiatives on finding low and zero emission solutions for reducing GHG emission from construction sites. The objective of this paper is to investigate the emission reduction potential from fossil and emission free on-site and off-site construction logistic activities based on actual data collected from a case study from Oslo. The paper firstly presents definitions and step wise approach for fossil free and emission free construction site activities. Then, GHG emission calculation from the logistic activities using LCA methods and scenario analysis to evaluate the environmental performance of fossil and emission free solutions considered in the selected case study. The results illustrated the GHG emission reduction potential from electrification of construction machineries and transport of material, collaboration between construction site for more efficient use and reuse of excavated masses, modal shift for transport of materials as well as the importance of clear description of the system boundary and background data. Availability of electric machinery, electrified means of transport and sufficient electricity supply, lack of requirements for low-emission material transport solutions, lack of data for LCA studies are identified as some challenges. Moreover, the study highlighted the potential contribution of increased demand for emission free solutions through public procurement to facilitate a change in the industry by overcoming these barriers.

Key words: Construction logistics, GHG emission, Embodied energy, Norwegian case study, scenario analysis

1. Introduction

The global construction sector accounts for ca. 23% of the total GHG emissions, where the construction site accounts for ca. 5.5% of the emissions [1]. In Oslo, the construction sites account for 7% of the city's total emission, without accounting the GHG emissions from transport of people and goods [2]. In 2017, the transport of goods by lorries within Oslo accounts with ca. 19% of the GHG emissions related to construction activities [3]. The City of Oslo has set an ambitious goal of reducing direct GHG emissions by 52% by 2023 and by 95% in 2030 compared to 2009 levels [4]. To achieve this, the municipality set requirements, among others, for all public procurement of municipally owned construction sites to be fossil free and thereafter emission free by 2025. In addition to only considering zero emission machinery, which is the common trend in Norway, the city aims for all goods transport within the city, including the heavy-duty transport, to be driven by zero-emission or sustainable renewable fuels by 2030.

The electrification of on-site construction activities highlights the importance of better planning and more efficient both on-site and off-site construction logistic activities. Better planning of material deliveries to and from Norwegian construction sites and higher utilisation of the vehicle capacity is estimated to reduce the emissions by 50%, or app. 280 000 tons CO_2 of the yearly emissions [5]. Such developments will greatly influence the operation of the construction sites within the city borders, leading way for a transformed clean construction logistic in the low-emission society by 2030. However, unclear demands for construction logistic solutions in the tender, lack of awareness or reluctance to consider logistic solutions with an impression of avoiding additional cost with little value, inefficient supply chain due to lack of data and planning, in balance between the cost and benefits, inefficient logistics on-site and lack of planning and coordination between projects and among stakeholders involved in the project are some of the challenges ,6]. These problems can lead to negative effects such as more transport, materials losses, high costs, congestion on and around construction sites, lack of space, safety and delays.

The MIMIC project [8] has been able to develop solutions to support cities and construction companies in the planning and management of construction logistics to improve mobility and reduce negative environmental impacts. Together with partners from Austria, Belgium, Norway and Sweden, MIMIC has developed: 1) construction logistics scenarios and strategies to increase knowledge of construction logistics [9], 2) stakeholder analysis [10] and construction logistics serious game [11] to identify needs and facilitate discussions, 3) impact assessment framework to evaluate the environmental, economic and social performance of on-site and off-site construction logistics [12], 4) simulation and optimisation models to assess construction logistics solutions, 5) design policy and legal framework requirements [13], and 6) a smart governance concept for integrating construction logistic solutions, impact assessment and policy framework developed through the project in the urban planning process [14]. This paper is one of the outputs of MIMIC project with focus on implementation of the impact assessment method using the data collected from the demonstration pilot in Norway. The objective of this paper is to investigate the emission reduction potential from construction logistic activities of a case study using a life cycle assessment method. The paper evaluates the main emission sources of construction logistic activities, and scenario analysis to evaluate the environmental performance of fossil free and emission free solutions.

2. Background

This section gives an overview of construction logistic activities, fossil and emission free construction site definitions and system boundaries, and a step wise approach for achieving clean construction.

2.1 Construction logistic activities

Construction logistics is the interface between the supply chain process (hierarchical process at strategic, tactical and operative planning levels) and the construction process (at different project phases) [9]. Construction logistics focus on coordinating materials and resource flows to, on and from the construction site [15]. Thus, it covers the transport activities to and from site (including transport of materials, masses, waste, machineries and workers and referred as off-site construction logistic activities) as well as on-site activities (including operation of construction machineries, storage and installation of materials, consumption of auxiliary/temporary installations and materials and waste flows referred as on-site logistic activities).

2.2 Definitions and system boundaries

The terms emission free and fossil free construction site are often used interchangeably. A clear definition and description of the activities covered in these definitions is important to create a common

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understanding and support transparent communication. Here is a harmonized definition of the two terms [16]:

- *Fossil free construction site* is a construction site that does not use any fossil fuels (like diesel or propane) in any of its on-site activities. Fossil free construction site often replaced fossil fuel with bioenergy and biofuels or alternative zero emission renewable energy resources (such as electricity and hydrogen).
- *Emission free construction site* is a construction site that does not have any direct GHG and NOx emissions from its construction activities. Use of electric or hydrogen powered construction machinery, electricity or district heating for temporary heating and drying, use of zero emission vehicle transport to, from and at building sites for transport of machinery, construction products, waste and construction workers are some examples of emission free alternatives.

The system boundary for construction site activities are represented by life cycle module A4, transport from production to construction site and A5, construction site installation processes following the life cycle modular principles [17,18]. However, there is some difference between the construction site activities included under the modular life cycle principle in EN 15804 [19] for construction products EPD, EN 15978 [17] for buildings and NS 3720 [18] Norwegian standard for GHG emission calculation for buildings (See Annex A). In this paper, a harmonised system boundary for the following construction site activities are including in accordance with [16,20]: the use and operation of construction machinery, energy use, internal transport, storage, temporary works, additional materials for the assembly of building products and elements, transport of materials and products, transport of construction machinery, transport of waste and masses, transport of construction workers, waste treatment and disposal operations for waste generated during construction activities.

2.3 Stepwise approach

Achieving emission free construction site, including all construction site activities is challenging. Most projects use the term fossil free or emission free without specifying the construction site activities considered in the project. Thus, a stepwise approach for fossil and emission free construction site ambition level definition, with a description of construction site activities considered in the analysis (see Figure 1), is presented for transparently reporting and communicating fossil and emission free construction sites.

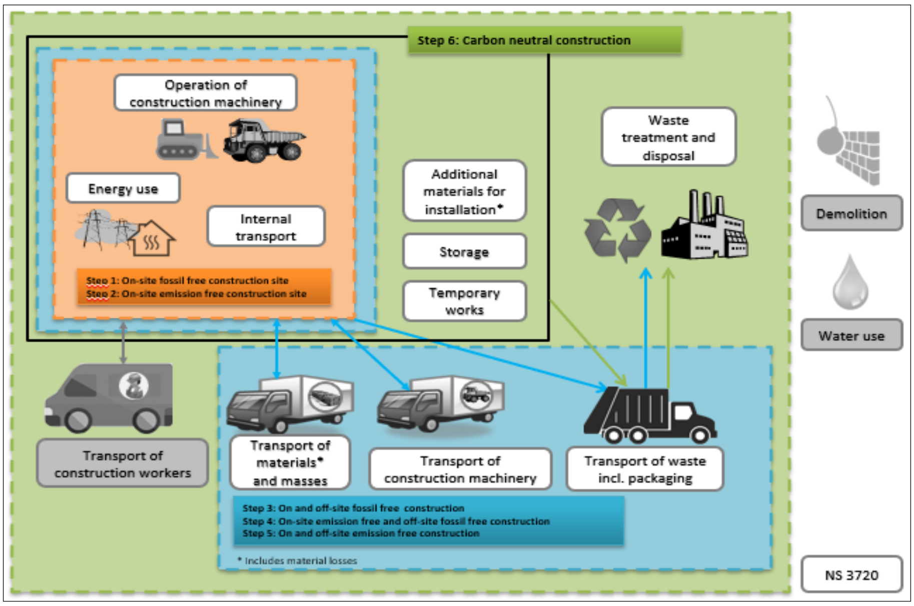

Figure 1 System boundary for stepwise emission free construction site ambition level definition. Adopted from [16]

The stepwise approach starts with fossil-free as a minimum ambition, to carbon neutral construction step by step by electrifying and using other zero-emission solutions for the different activities as described below.

- *Step 1*: *on-site fossil free construction site* - including fossil free internal transport, operation of construction machineries and on-site energy use.
- *Step 2*: *on-site emission free construction site* - including emission free internal transport, operation of construction machineries and on-site energy use.
- *Step 3*: *on-site and off-site fossil free construction site* - including activities descried under step 1 and fossil free transport of machinery, materials, masses, people, and waste to and from construction site activities.
- *Step 4*: *on-site emission free and off-site fossil free construction site* - including activities described under step 2 and fossil free transport of machinery, materials, masses, people, and waste to and from construction site activities.
- *Step 5*: *on-site and off-site emission free construction site* - including activities described under step 2 and emission free transport of machinery, materials, masses, , and waste to and from construction site activities.
- *Step 6*: *carbon neutral construction site*: including emission free solutions and/or carbon compensation measures for all construction site activities shown in Figure 1, including zero-emission solutions for waste treatment, low or no resource use for installations activities (temporary works, storage and auxiliary materials).

It should be noted here that, it might be difficult to include all the activities described under each step, i.e., only some activities described under each step can be fulfilled by projects. For e.g., with an ambition of achieving step 2- on-site emission free construction site, the focus can be using emission free machinery and internal transport. In this case, the system boundaries for the activities covered under each step should be clearly described.

3. Methodology

The methodology used in this study include a description of the case study considered, the LCA methodology used to evaluate the environmental performance of construction logistics activities and scenarios considered to evaluate the emission reduction potential of fossil and emission free solutions.

3.1 Case study

In MIMIC project, demonstration pilots from the four project partners countries (Norway, Sweden, Belgium, and Austria) are used to test the framework and methods developed within the project. In this study, the case study from Norway is used to test and demonstrate the impact assessment method for on-site and off-site construction logistics , 21]. The selected case study is the new main Emergency Ward in Oslo, “Oslo Storbylegevakt”. The emergency ward centrally situated app. 6 km north of the city centre in an old hospital area under decommissioning, will host several health services in addition to emergency functions. The gross floor area of the building is planned to be 27 000 m^2, with a heated area of ca. 23 000 m^2. There is an additional underground parking garage of about 5 500 m^2. Construction started in March 2020, with groundwork and foundation and superstructure work (and data collection) going until April 2021. The building is planned to be fully finished in April 2023. The environmental ambitions for the construction site are fossil free construction site (substituting diesel with HVO biodiesel) and testing a large 38-ton electric excavator (Step 1 ambition level (Figure 1)). The building is going to be BREEAM-NOR Excellent certified, and to meet the energy-efficient passive house standard. For a minor part of the slab construction, reuse of 27 hollow-core concrete slab elements from the old, decommissioned Government Quarter in Oslo were also pilot tested and installed in December

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2020. Logistic solutions such as digital scheduling, planning system for transports and material deliveries and time restrictions for intermediate storage on site (max. 14 days) are also considered.

3.2 LCA methodology

The environmental impact assessment was conducted following the life cycle assessment (LCA) framework developed through the MIMIC project [12,22]. The goal of the LCA study is to evaluate the environmental impact of construction logistic activities. The system boundary includes A4 and A5 life cycle stages. Transport of masses, transport of materials, transport and treatment of waste (Construction and demolition waste), operation of mobile and stationary machinery and energy use are construction logistics activities included in the analysis. Even if demolition waste is not part of the construction site system boundary (Figure 1), it is included in the analysis of this study to investigate the contribution of the demolition process. The scope of the study is also limited to activities related to groundwork and foundation and superstructure building elements. That means, the impact from the construction of other building parts is not included in the analysis. GHG emissions and embodied energy, assessed using non-renewable cumulative energy demand (CED), are indicators used to evaluate the environmental impact from the constructions site activities. Both direct and indirect emissions are included in the analysis. The inventory data was collected from construction site from March 2020 – April 2021 for the initial phase of the construction of groundwork and foundation and superstructure. The background emission factor for means of transport used to transport materials to the construction site (A4), means of transport for transport of waste-to-waste treatment facilities (A5) and emission factor per waste treatment type are taken from a generic database (Ecoinvent V3.1 [23]). The emission factors for energy and fuel use in A5 are taken from NS 3720, NS-EN 16258 [24] or generic database (Ecoinvent v3.1).

3.3 Scenarios

Scenario analysis was conducted to evaluate the emission reduction potential of alternative fossil and emission free construction site solutions. Base case scenario (for activities considered in the project) and three other alternative realistic scenarios (Alternative 1-3) have been evaluated for machinery, mass transport and material transport activities (Table 1). The scenarios, including the base case, are evaluated against alternative 1 to evaluate the potential embodied emission and energy reduction potential of fossil free and emission free solutions.

Table 1 Scenarios for machinery, mass transport and material transport activities

Scenarios	**Machinery**	**Mass transport**	**Material transport**
Base case scenario (Base case)	Use of 90% biodiesel and 10% electricity driven machinery	Use of 71% Biodiesel and 29% diesel driven vehicle for transport of mass	Transport of materials using road and barge transport
Worst case (Alternative 1)	Use of 100% diesel driven machinery	Use of 100% diesel driven vehicle for transport of mass	Transport of materials using road transport
Fossil free solution (Alternative 2)	Use of 100% biodiesel driven machinery	Use of 100% biodiesel driven vehicle for transport of mass	Transport of materials using road, barge, and rail transport
Emission free solutions (Alternative 3)	Use of 100% electricity driven machinery	Use of 100% electricity driven vehicle for transport of mass	

4. Results

This section presents the results from embodied GHG emissions, embodied energy and the findings from different scenarios.

4.1 Embodied GHG emissions and energy

Table 1 shows the total and per square embodied GHG emission and non-renewable CED results from the construction site activities during the groundwork and foundation, and superstructure construction phases.

IOP Conf. Series: Earth and Environmental Science 1196 (2023) 012048 doi:10.1088/1755-1315/1196/1/012048

Table 2 GHG emission and non-renewable CED results

Construction site activities	Total GHG emissions and non-renewable CED		GHG emissions and non-renewable CED per m2	
	GHG emissions (tCO2eq)	Total non-renewable CED (GJ)	GHG emissions (tCO2eq/m2)	Non-renewable CED (GJ/m2)
Energy use	12	154	0.44	0.006
Machinery	244	2113	9.14	0.079
Mass transport	659	7092	24.69	0.266
Material transport	581	5145	21.76	0.193
Construction waste	0	2	0.00	0.000
Demolition waste	75	1130	2.79	0.042
Total	1571	15636	59	0.59

The results show that the largest contributor to the total GHG emissions is mass transport (with ca. 42%) followed by material transport (ca. 37%), machinery (16%). Whilst the contribution from demolition waste (5%), energy use (15%) and construction waste (0,01%) is relatively lower. Here it should be noticed that the impact from all mass transport is included, however only transport of materials used for groundwork and foundation and superstructure is included in the analysis. Similarly, only impacts from energy use and construction waste during these energy-intensive phases are investigated. The non-renewable CED results show significant contribution from mass transport (45%) and material transport (33%) due to the use of fossil driven means of transport. Whilst the percentage contribution of machineries is relatively lower (14%), due to the use of biodiesel and electric driven machineries. The demolition waste contributed 7% to the total non-renewable CED result, mainly from the use of transport of waste to the waste treatment facilities.

4.2 Scenario evaluation

The GHG emission and non-renewable CED results of base case scenarios, and scenarios with alternative fossil and emission free solutions for machinery, mass transport and material transport are presented in Figure 2-4.

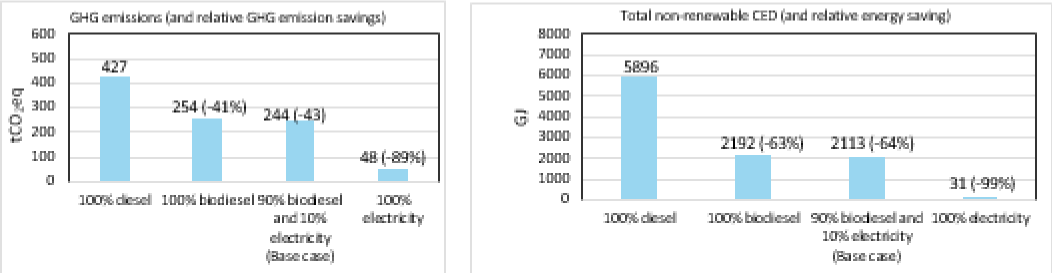


Figure 2 GHG emission (left) and non-renewable CED (right) results and relative savings compared to alternative 1 from scenarios considered for machinery

The results for alternative energy use for machinery scenario (Figure 2) illustrated that compared to the use of diesel driven machinery, the project (Base case scenario) able to reduce ca. 43% and 64% of the total GHG emissions and non-renewable CED, respectively, by using biodiesel and electricity driven machinery when available. The result also illustrated that electrifying all machinery would enable to reduce ca. 89% and 99% of the total GHG emission and non-renewable CED.

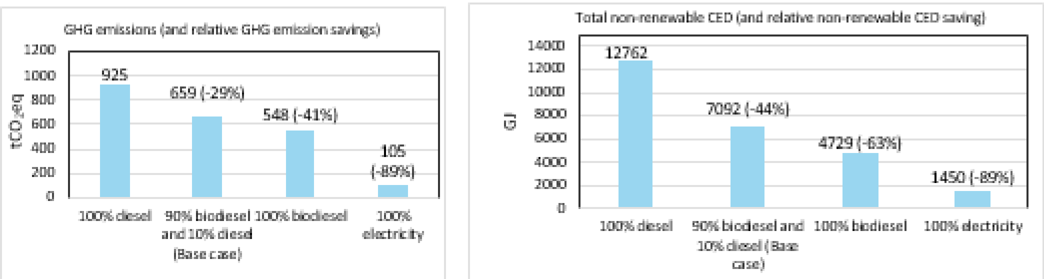
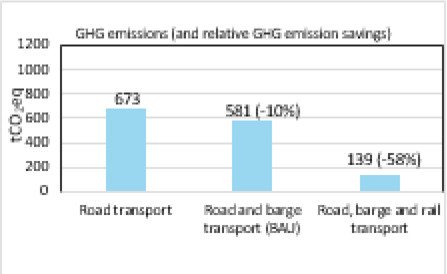


Figure 3 GHG emission (left) and non-renewable CED (right) results and relative savings compared to alternative 1 from scenarios considered for mass transport

The results for alternative energy use for mass transport scenario (Figure 3) illustrated that compared to the use of diesel driven means of transport, the project (Base case scenario) able to reduce ca. 29% and 44% of GHG emissions and non-renewable CED, respectively. The project would have further reduced GHG emissions and non-renewable CED by ca. 41% and 63%, respectively by use of 100% biodiesel driven machinery and ca 89% of GHG emission and non-renewable CED by electrifying all means of mass transport.



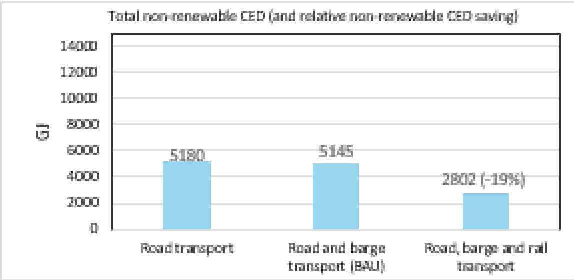


Figure 4 GHG emission and non-renewable CED results from scenarios considered for material transport

The results for alternative modal shift for transport of materials scenario (Figure 4) illustrated that compared to transport of construction materials by road, the project (Base case scenario) able to reduce ca. 10% of GHG emissions by transport of some materials using barge. Use of a combination of possible road, barge and rail material transport would enable to reduce ca. 58% and 19% of GHG emission and non-renewable CED, respectively.

5. Discussions

This section discusses the main factors which influence the embodied GHG emissions and non-renewable CED results.

5.1 On-site and off-site construction logistics

This study included both direct and indirect embodied energy and emissions from on-site and off-site construction logistic activities. The results illustrated significant contribution of off-site logistic activities from transport of mass and construction materials. However, the common practice today is evaluation and reporting of direct GHG emissions from on-site construction logistic activities. With increase implementation of fossil and emission free on-site construction logistics activities, the GHG emissions stems from the off-site activities becomes very significant. Therefore, it is important to find emission free solutions for both on-site and off-site activities to reduce the overall embodied energy and emissions.

5.2 Construction logistics activities

Machinery: Use of biodiesel and electricity (when possible) driven construction machinery was the target in Oslo emergency ward project. During the groundwork and foundation and superstructure construction phases, only one 38-ton electric digger was used. Which resulted in using 12 conventional (driven on biofuel) of 13 diggers, out of a total of 15 machineries. Lack of available electric machinery and sufficient electricity supply were some of the challenges to use more electric machineries. The result from scenario analysis illustrated, however, the significant impact reduction potential from electrification of machineries. Incentives for supporting mass production of electric machineries and use of machine parks to make electric machineries available can be a solution.

Mass transport: In Oslo emergency ward, ca. 130 000 m^2 excavated masses have been transported mainly by road using biodiesel driven vehicles. The scenario analysis shows significant embodied energy and emission reductions by using electric vehicles. Current electric lorries available in Oslo can transport masses of around 10 m^3 (about half of conventional lorries for this purpose) and can only travel about 50km and this would be a practical issue to solve (cost-efficiently) for such a large amount of excavated mass. The use of consolidation centers/mass hubs and better collaboration between nearby construction sites could give efficient reuse of excavated masses and reduce transport distance, that could also enable the use of electric vehicles for mass transport in the future. Modal shift (to boat or rail) might be necessary to consider in combination with mass hubs to treat all (also contaminated masses) in the Oslo region without using conventional lorry transport. In this case, possibly more excavated mass could have been reused on the site to reduce the transport to the site. However, almost half (about 48%) of the mass transported to the site came from a nearby storage facility, located within 19 km. The average distance for masses transported to the site was 40 km. As much more mass was transported from the site, the possibility of reusing mass is limited. The excavated mass transported from the site makes up 91% of the transportation work, and the excavated mass of good quality has mainly been used in other construction projects in the region. 61% of the quality masses was used as fill in a construction project 95 km away. A smaller share of this was transported to the port (21% of this mass), cutting the road transport distance to 28 km. The remainder transported only by road makes up 54% of the total fuel consumption related to the road transport of mass. All embodied energy and GHG emissions related to transport of mass to regional construction projects was allocated to the current case project, which could be a matter of further discussion. The shift in the requirements of the municipality towards including mass transport, and not only focusing on the on-site emissions, is supported by these results. The specific focus on mass transports in the tenders is important, and further focus on the (typically long-distance) heavy transports will be important to cut embodied energy and emissions in future projects.

Material transport: The environmental impact from transport of heavy materials, such as prefabricated concrete slab, would have been reducing by using barge or rail. The benefit from reuse of concrete slab is not visible in the construction phase impact assessment study as only the impact from transport of the reused concrete slab is included in the analysis (under A4 life cycle stages) due to the scope of the analysis. Including the whole life cycle assessment will enable to give a good overview of benefits from reused materials and other resource efficiency measures.

Waste: The GHG emission from demolition is relatively significant in comparison with construction waste. This is because the construction waste included only the waste from construction of groundwork and foundation and superstructure building elements. From demolition waste, brick, concrete heavy building materials, are the most waste fractions, followed by polluted brick, metals and mixed waste. With the progress of construction process, the amount of waste from different waste fraction is expected to increase. In Norway, waste from building and construction site represented about 25% of the total national waste. Out of these, the waste from new construction represented ca. 34% whilst the demolition and rehabilitation waste rep-resented 39% and 29%, respectively [25]. This shows the significance of the waste from construction, demolition and rehabilitation activities. There are national waste free construction site initiatives aiming to reduce the waste from new building construction site [26]. EN 15978 and NS3720 excluded demolition waste, referring that as outside the system boundary. However, it is important to include demolition waste during the analysis of construction phase to show its significance. This may encourage waste reduction through more rehabilitation than demolition, increasing reuse, as well as better waste treatment measures (e.g., increasing recycling).

5.3 Technological developments
In Oslo emergency ward project, use of machineries driven by biodiesel and electricity (when available), digital transport scheduling for just in time delivery, incentivized direct delivery, and separate road for delivery vehicles to avoid traffic are some of construction logistics measures considered. The scenario analysis in this study shows potential of electrification in achieving emission free construction logistics. However, the current assessment shows the need to go beyond electrification of on-site construction logistics by considering electrification of off-site construction logistics activities.

It is also important to consider other construction logistic solutions such as utilization of terminals (consolidation centers, nearby delivery areas, cooperative logistics), pooling of machinery (machine park), milk round delivery (deliveries for several sites on one route), regulatory measures (load or size restrictions, strict delivery booking rules) and eco-logistics (anti-idling, training, raise awareness)[24]. Certification schemes, such as BREAM-NOR, are one of the drivers for sustainable developments in Norway. Incorporation of credits in certification schemes can encourage construction logistics solutions. By assigning a logistic coordinator early in the project phase, construction logistics solutions can be considered throughout the project phase [7]. Then, testing and implementation of relevant solutions can be ensured.

5.4 Public procurement

Through the purchasing power in the building stock the city owns, the City of Oslo has been a leader in using fossil free, and emission free construction strategies [28]. By developing procurement procedures with market dialogue and new award criteria for evaluation of tenders, there are now an increasing stock of electric machinery in Oslo, and a lot of these machines in use (in addition to several electric lorries for mass transport). The current focus of the award criteria (for construction projects) is on emission free on-site machinery and emission free and biogas lorries for mass transport. Six of Norway's biggest cities has followed Oslo in setting similar goals, to implement emission free construction requirements in all public project by 2025 and both public and private projects by 2030 [28]. In parallel with this current development, it is important that the procurement procedures are developed to stimulate more efficient logistics, as well as targeting the material transports more clearly. The current assessment shows the need for more collaboration and better planning to achieve electrification and short transports of mass and shows that awarding low-emission (larger) material transports could be important to cut the embodied energy and emissions in construction projects. This could be important in the further development of the procurement procedures in the region. The implementation of new requirements, in cooperation with the contractor and the building owner in the current case, shows some of the potential of innovative public procurement for reducing emissions in construction projects.

5.5 Inventory and background data

The result from LCA is mainly dependent on the quality of inventory data and the background impact factors used in the analysis. The finding from this study identified that data collection from construction logistic activities is challenging. There is on-going activity for establishing a data collection system for on-site construction logistic activities, such as energy use, machinery, and mass transport. This is due to the need to evaluate and follow up the requirements for fossil free and emission free construction site activities set by municipalities. However, getting material transport inventory data is still challenging. The significance of the embodied energy and emission results from material transport show the importance of including the impact from transport of materials. A combination of bill of quantities from BIM and transport data from transport service providers can be a good source of data. The source and quality of emission factor for diesel, biodiesel and electricity is another challenge identified in this study. Even if biodiesel is commonly used solutions for fulfilling fossil free construction site requirements, uncertainties in the source of biodiesel and emission factors used can put the environmental performance analysis of biodiesel into question. Thus, it's important to report the actual biofuel used and harmonized background emission factors to increase transparency and get an overview of the actual impact of using biodiesel. Since the future is electrification, it is also important to agree on the source of emission factors for electricity. It should be noted here that this study is limited to the construction phases of groundwork and foundation and superstructure building elements. Future studies are encouraged to evaluate the potential impact from the whole construction phase.

6. Conclusion

This paper has evaluated the environmental performance of fossil and emission free construction site solutions from groundwork and superstructure phases of a Norwegian case study. The results from the case study show the importance of combining electrification with efficient logistic measures and clear description of system boundaries for fossil and emission free construction site activities. The study also highlighted main technical barriers related to availability of electric machinery, and electrical infrastructure and logistical challenges for large projects where many diggers have to be used for excavation, lack of collaboration between construction sites for more efficient use and reuse of excavated mass and lack of electrification and consideration of better logistical solutions (e.g. modal shifts for material transport like heavy materials like concrete and prefabricated concrete slab). Increased demand for emission free solutions through public procurement is identified as a potential contributor towards realization of the 2030 emission free construction site targets. This comparative assessment can be used as a practical reference for further evaluation of the remaining activities in the project.

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Appendix 1

Construction phase activities	**EN 15804**	**EN 15978**	**NS 3720**
A4 Transportation from the production gate to the construction site, including any transport, intermediate storage, and distribution;	✓	✓	✓
A4 Transport of construction equipment (cranes, scaffolding, etc) to and from the site;	✗	✓	✓[a]
A4 Transport of materials and masses to and from the site;	✗	✗	✓[a]
A4 All impacts and aspects related to losses due to transportation (including the production, transport and waste management of products and materials damaged or lost during transport);	✗	✓	✓
A4-A5 Storage of products, including provision of heating, cooling, humidity control, etc;	✓	✓[a]	✓
A4-A5 wastage of construction products (additional production processes to compensate for the loss of wastage of products);	✓	✓	✓
A4-A5 Waste processing of the waste from product packaging and product wastage during the construction processes up to the end-of-waste state or disposal of final residues;	✓	✗	✗
A5 Installation of the product into the building including manufacturing and transportation of ancillary materials and any energy or water required for installation or operation of the construction site. It also includes on-site to the product;	✓	✗	✗
A5 Ground works and landscaping;	✗	✓	✓
A5 Transport of materials, products, waste and equipment within the site;	✗	✓	✓[b]
A5Temporary works, including temporary works located off-site as necessary for the construction installation process;	✗	✓	✓
A5 Onsite production and transformation of a product;	✗	✓	✓
A5 Provision of heating, cooling, ventilation, humidity control etc. during the construction process;	✗	✓	✓
A5 mobile and stationary works machines, including fuel, used at building site;	✗	✗	✓
A5 Installation of the products into the building including ancillary materials not counted in the EPD of the products e.g. releasing agents in formworks for concrete, formworks discarded at the end of the project;	✗	✓	✓
A5 Water use for cooling of the construction machinery or onsite cleaning;	✗	✓	✓
A5 Waste management processes of other waste generated on the construction site. This includes all processes (including transportation from the building site) until final disposal or until end of waste state is reached;	✗	✓	✓

a includes transport of materials, masses and equipment's to and from the building site. This is referred as A5 in EN 15978

b Transport of masses is also included.

c This is not included in the GHG calculation for the new building. However, if the purpose of the calculation is to compare various alternative development solutions, and only one of the solutions involves demolition, demolition must nevertheless be included.