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A mapping of electric construction machinery and electric construction sites in Norway

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Abstract. The Norwegian construction industry is responsible for ca. 2.2 million tonnes CO_{2eq} in 2021. The rise in GHG emissions, noise and air pollution in the built environment is becoming a potential hazard due to the large growth of construction activities within cities. As a response, actors from the Norwegian construction industry have converted diesel construction machinery to electric operation to reduce these impacts. As a result, the electric construction machinery market in Norway has grown exponentially. However, access to electric construction machinery varies greatly. The aim of this paper is to map the available electric construction machinery on the Norwegian market as first steps towards creating a database of electric construction machinery for subsequent energy and power demand modelling of fully electric construction sites. This paper also maps the regional differences in construction machine availability through mapping the known public construction sites in Norway that use electric construction machinery.

1. Introduction

The construction industry is responsible for 23% of global greenhouse gas (GHG) emissions, whereby 5.5% relate to construction site activities, predominantly from the combustion of fossil fuels for the operation of construction machinery [1,2]. The Norwegian construction industry was responsible for ca. 2.2 million tonnes CO_{2eq} in 2021 [3]. The rise in GHG emissions, noise, and air pollution in the built environment is becoming a potential hazard due to the large growth of construction activities [4]. As a result, an increasing number of countries are committing to net-zero carbon goals and setting strict environmental regulations in efforts to limit global climate change [5,6]. With the rapid decarbonisation of electricity grids, electrification is an inevitable trend used in many sectors to reduce carbon emissions, the construction industry included [7]. As a response, actors from the Norwegian construction industry have been converting diesel construction machinery to electric operations to reduce these impacts [8]. In 2021, seven of the largest municipalities in Norway signed a declaration that all public tenders for construction sites will be emission free by 2025, and that by 2030 all construction activities in cities (also private) will be emission free. These municipalities have been a driving force for electrification, as contractors are rewarded for supplying zero-emission construction machinery [9]. Such initiatives have created a demand for electric machinery, which has led to significant developments in the electric construction machinery market in Norway. As a result, the electric construction machinery market in Norway has grown exponentially. However, access to electric construction machinery varies greatly and the electrification of construction machinery faces a range of challenges such as high cost of batteries, lack of charging infrastructure, demand for trained workforces, and limited grid capacity on the supply

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side [10]. Previous studies have shown that electric construction machinery can reduce GHG emissions by up to 95 %, as well as reduce other pollutants such as particulate matter, nitrous oxides, sulfur dioxide and noise pollution, thus improving local air quality and public health [11]. 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 [12]. Construction is a high-risk industry for noise-related ill health [13].

The aim of this paper is to map the available electric construction machinery on the Norwegian market, as well as to map regional differences in construction machine availability through mapping public construction sites in Norway that use electric construction machinery.

2. Background

In 2017, Oslo municipality required all public construction sites to be fossil free. In 2018, some of the first prototype electric excavators were developed, and tested on construction sites in Oslo [14]. In 2020, the first electric construction machinery database was developed by environmental organisation, Bellona, to supply contractors with sufficient information about the available electric construction machinery on the Norwegian market [15]. The database includes electric alternatives for different machine types: 1 backhoe loader, 1 battery technology, 5 cement mixer, 3 crawler cranes, 5 dumpers, 1 drilling rig, 7 energy storage systems, 1 forklift, 4 handlers, 3 rammers, 18 small excavators, 11 standard excavators, 3 tandem rollers, 2 track loaders, 4 vibrator plates, 15 wheel loaders.

In response, the Norwegian machine wholesalers' association (MGF) [16] established a database to give an up-to-date overview of their member's dealings with emission free machines and solutions. MGF's database identifies eight electric machine types, including excavators, wheel loaders, dumpers, crushing and screening plants, mining and tunnelling machines, sweepers, trucks, asphalt paver, and other small machines. One other project has mapped the use of electric construction machinery in the Oslo region from 2017 - 2022, for Viken, Oslo and Vestfold-Telemark counties [17]. The project loans electric construction machinery to interested parties for up to four weeks. This allows construction workers to test machinery before they decide to invest themselves. The project's electric machine fleet includes excavators, dumpers, wheel loaders, mobile cranes, telescopic loaders, demolition robots, stampers, and vibrator plates.

C40 cities is a network of mayors from nearly 100 world-leading cities. Through the network the mayors of Oslo, Los Angeles, Mexico City and Budapest have pledged to halve GHG emissions from all construction activities by 2030 [18]. The EU DG Grow Big Buyers Initiative has a working group on Zero Emission Construction Sites consisting of Amsterdam, Brussels, Budapest, Copenhagen, Helsinki, Lisbon, Oslo, Trondheim, and Vienna [1]. The Big Buyers Initiative has published a joint statement of Demand for Emission free Construction Site Machinery. This includes requirements for emission free construction machinery in 20% and 50% of public projects from 2025 and 2030 respectively [19].

3. Method

The scientific methodology firstly involves identifying electric construction machinery on the Norwegian market and gathering technical specifications from manufacturers. This is achieved by compiling existing databases from Bellona and MGF into one database and supplementing with new construction machinery data from manufacturer's websites. The scope excludes heavy-duty transport, equipment, battery and packs, hydrogen generators, and hybrid (diesel/electric) machines. Data collected includes information on machine type, make, model, technology (i.e., battery/cable), machine weight in tonnes (t), battery capacity (kWh), operational time (hr), power use (kW), as well as charging characteristics. Secondly, a mapping of the public construction projects in Norway that use electric construction machinery is carried out to ascertain the geographical distribution in Norway. This is achieved by collecting information on construction site location, year of construction, and type of electric construction machinery used in all the Norwegian environmental agency's Klimasats projects [20], and supplementing with previous mappings of Oslo's electric construction sites [10], and Viken's machine rental project [17]. The data collected from Viken was aggregated for the project duration 2017

- 2022, so efforts have been made to disaggregate the data to a yearly basis based on percentages supplied by the project manager. It should be noted that few projects are fully electrified, and the degree of electric construction machinery used varies. The data is plotted on a map to visualise the regional distribution of public electric construction projects. GHG emissions from the use of electric construction machinery is outside the scope of this paper since there are no direct GHG emissions from electric construction machinery, and the Norwegian electricity grid is characterised by a very low GHG emission factor (24 gCO_2e/kWh) since electricity is generated from approximately 98% hydropower [21]. Emissions are still low even if electricity exchange with the rest of Europe is considered, as in the zero emission building (ZEB) emission factor for the national electricity mix (130 gCO_2e/kWh) [22]. In comparison, diesel has an emission factor of 3.32 $kgCO_2e$/litre [21]. Previous studies have shown that up to a 95% reduction in GHG emissions can be achieved when diesel construction machinery is replaced with electric equivalents [8, 10, 14].

4. Results

In total, this study maps 133 unique electric construction machinery including 14 different machine types, see Figure 1. Of these machines, 100 are < 8 t, 10 are between 8 – 20 t, and 23 are > 20 t. Excavators are the most common type of electric construction machinery with 37 unique types ranging from 1 – 56 t. The machine database shows that battery capacity ranges from 0.79 – 600 kWh. Manufacturers report battery-electric machines can operate for 0.5 - 8 hours at a time (4.8 hours on average) before requiring 0.5 - 8 hours charging time (1.9 hours on average). Power demands when charging at night range from 0.2 – 50 kW, whilst rapid charging requires 0.3 – 150 kW. In total, 256 public construction projects used electric construction machinery in Norway during 2017-2022, see Figure 2 and Table 1 for regional distribution. Viken (46 %) and Oslo (36 %) have the highest shares of electric construction projects.

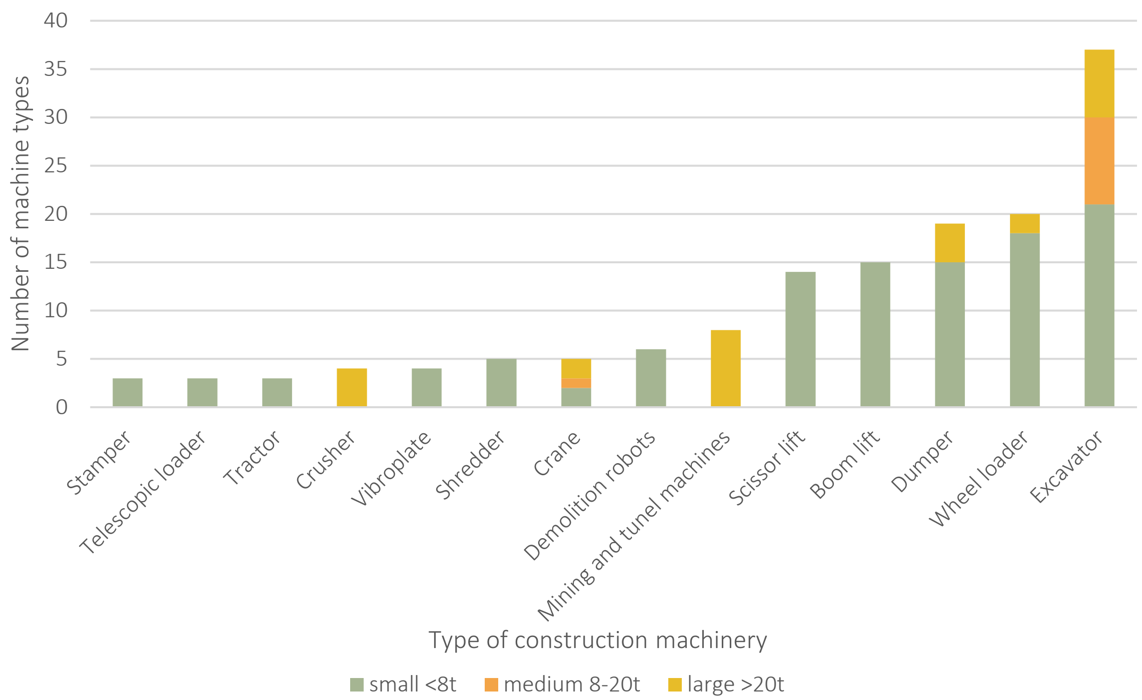

Figure 1. Number of electric construction machinery and weight class (tonnes) available on the Norwegian market in 2022.

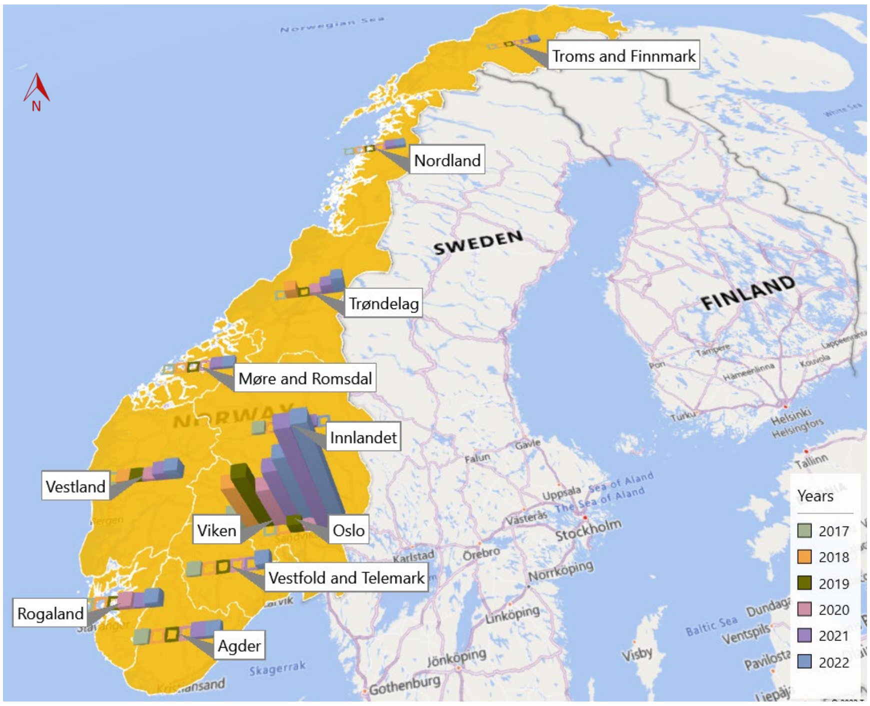

Figure 2. Map of public construction projects that use electric construction machinery in Norway 2017–2022.

Table 1. Number of public construction projects that use electric construction machinery in Norway 2017-2022.

County	2017	2018	2019	2020	2021	2022	*Total*	*%*
Agder	1	0	0	0	2	2	*5*	*2*
Innlandet	1	0	1	0	1	0	*3*	*1*
Møre and Romsdal	0	0	0	0	1	1	*2*	*1*
Nordland	0	0	0	0	1	1	*2*	*1*
Oslo	0	0	4	2	43	44	*93*	*36*
Rogaland	0	0	0	2	1	3	*6*	*2*
Troms and Finnmark	0	0	0	0	0	1	*1*	*0,4*
Trøndelag	0	3	0	1	3	5	*12*	*5*
Vestfold and Telemark	1	0	0	0	0	3	*4*	*2*
Vestland	0	1	1	1	3	4	*10*	*4*
Viken	6	19	23	17	24	29	*118*	*46*
National total	***9***	***23***	***29***	***23***	***79***	***93***	***256***	***100***

5. Discussion

Some assumptions and limitations were made when collecting data for the construction machinery database and public construction sites. In some cases, data was fragmented, averaged, or missing. The mapping overview may be incomplete since electric construction machinery and projects are under constant, rapid development. Best efforts have therefore been made to avoid accidentally missing data or double-counting machinery or projects. One aspect that made data collection difficult is that the technical specifications for electric construction machinery are not standardised. Not all suppliers or manufacturers provide the same kind of data, and there is no specific technical data framework for the reporting of electric construction machinery. Options such as fast charging are not usually reported for all machines. Often technical specification details are difficult to find and understand, can easily be misinterpreted or missing data. In some cases, it was unclear if reported charging times are based on normal or rapid charging. Technical specifications are often decided under laboratory conditions, and do not consider the impact of external factors such as weather conditions, temperature, construction activity, or driver's behavior which may influence the performance of construction machinery. Our findings highlight that there is a need for standardised reporting of electric construction machinery technical specifications. Standard reporting will make it easier to use construction machinery data in dimensioning energy and power demands of construction sites and make it easier for contractors to compare different construction machinery technical specifications.

The gathered electric construction machinery database shows that many of the battery electric construction machinery have shorter operating times than the average working day and require rapid daytime charging. Large construction machinery also requires higher energy and power demands than smaller construction machinery. Power and energy demands will increase when multiple electric construction machinery operate at the same time. In terms of significance for the built environment, this entails a need for better energy infrastructure to support electric construction activities. The results highlight the disparity in geographical distribution of electric construction machinery used on construction sites in Norway, and indicates some of the challenges faced with large-scale, implementation of electric construction sites despite a large range of electric construction machinery being made available on the Norwegian market. One noticeable trend from Figure 1 is that manufacturers electrify small construction machinery first, often starting with excavators, wheel loaders or dumpers. The results also show that stationary construction machinery often use cables, whilst mobile machinery are often battery driven. Some cable construction machinery also have a small onboard battery to allow for some mobility without a cable connection. There is also a correlation between construction machinery weight (t) and battery capacity (kWh), in that the larger the machine the higher the power demand. It is therefore important for manufacturers to prioritise the electrification of larger machinery as large machinery often have a larger share of emissions since they consume larger quantities of energy. The results show a slower uptake of electric construction sites in Northern Norway. Reasons for this can be explained by limited access to electric construction machinery, less requirements for emission free construction, small, remote communities separated by longer transport distances with limited energy infrastructure, and small actors with limited funds for investing in electric machines with high capital costs. It may also be explained by the level of planned developments in and around Norway. There may for example be a higher level of public construction projects in large cities to the south of Norway. It may alternatively be explained by the differences in regional and national requirements and climate ambitions. Many of the larger cities have established goals on emission free construction sites, however there are currently no national requirements. The results may also be skewed by Viken's rental project since construction machinery is leased for up to 4 weeks at a time, meaning a higher turnover of construction projects being reported. Viken also covers a much larger geographical area compared to Oslo, which may also explain the higher number of public construction projects that use electric construction machinery.

The construction market in Norway is currently not large enough for global manufacturers to reorganise and begin large scale series production of electrical construction machinery. A larger market is needed, and this is dependent on more cities and nations implementing requirements for emission free construction. This mapping is useful as it can be used by Norwegian public authorities to target regions and implement measures or incentives for further electrification.

This study provides scope for further work. Firstly, the mapping can be expanded to an international market and to include private electric construction projects, electric heavy-duty vehicles, hydrogen construction machinery, and mobile renewable energy equipment such as battery containers or hydrogen generators that facilitate for emission free construction sites. The mapping could also be expanded to ascertain the degree of electrification in construction projects, e.g., percentage of operational machine hours that use electric solutions. Secondly, the construction machinery database are the first steps towards creating a database of electric construction machinery for subsequent energy and power demand modelling of fully electric construction sites. Being able to model energy and power demands is useful for project owners and contractors who are planning to use electric construction machinery. A next logical step can be to gather experiences from pilot testing to generate load profiles for different types of construction machinery carrying out different construction activities (driving, excavating, lifting etc.). Such further work will provide a better foundation for contractors to accurately dimension energy and power demands based on real conditions.

6. Conclusion

This paper maps the available electric construction machinery on the Norwegian market and maps regional differences in availability. The construction machinery mapping is useful for contractors since it presents the first steps towards creating a database of electric construction machinery for subsequent energy and power demand modelling of fully electric construction sites. The construction site mapping is useful for public authorities in identifying barriers and success factors in the rapid implementation of electric construction sites on a nationwide scale. Lessons learnt from this article are transferable to other countries that are interested in implementing electric construction sites.

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