Data Driven Analysis of Construction Site Electrification in Oslo, Norway[1]

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Abstract. Construction sites are a main source of direct greenhouse gas (GHG) emissions, and electrification of construction machinery is a key strategy for emission reduction. In response to the Paris Agreement, Oslo aims for all public construction sites to be emission-free by 2025 and private construction sites by 2030. This paper examines the role of electric construction machinery in reducing GHG emissions from construction sites in Oslo, Norway. The study identifies 409 public construction sites in Oslo (2014-2024), and analyses data from 175 electric public construction sites from 2020 to 2024, detailing the use of electric construction machinery and their impact on GHG emissions. A comprehensive methodology was employed to gather data from various agencies, harmonise energy use data to a common unit (kWh), and apply national energy and GHG emission conversion factors. Across 2020-2024, 66 fully electrified construction sites were observed, 512 distinct electric construction machinery models were identified, and the avoided GHG emissions are estimated to be around 15 800 tCO_{2e} compared to a baseline diesel scenario. This transition has engaged contractors of all sizes. Challenges in data collection and future directions for achieving emission-free construction sites are discussed, emphasizing the need for systematic data management and collaboration among different stakeholders.

Keywords: Electrification, Construction Site, Construction Machinery, GHG Emissions, Construction Site Data

1 Introduction

According to the United Nations' (UN) Intergovernmental Panel on Climate Change (IPCC), buildings were responsible for 21% of greenhouse gas (GHG) emissions and 31 % of energy use in 2021 [1]. With the induction of the Paris agreement, EU nations are striving to cut GHG emissions by 43 % by 2030 [2]. In Norway, it is estimated that ca. 2 100 tCO_{2eq} are generated annually from construction sites, the majority of which comes from the combustion of diesel in construction machinery, which also contributes to local noise and air pollution [3]. Desouza et al. [4] modelled nitrous oxide (NOx) emissions from non-road mobile machinery (NRMM) in the UK and found that NOx emissions are 39 % higher than previously estimated. Li et al. [5] examined air pollutant emissions from NRMM in Beijing and found that emissions decreased annually by 13

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% from 2015-2019, and that machines with average power above 75 kW accounted for 67-78 % of total emissions. Sparrevik et al. [6] investigated the potential for reducing emissions from NRMM through disruptive innovations and found that current regulations and activities have not yet reduced emissions, and that a sociotechnical ecosystem change is required for a successful transition.

In 2019, Oslo introduced standard climate and environment requirements and criteria in public tenders to reduce GHG emissions from construction sites [7]. In 2020, Oslo's GHG emissions were around 1 million tCO_{2eq}, whereby ca. 150 000 tCO_{2eq} arose from NRMM [8]. Oslo has nearly achieved their ambition for all municipal construction sites being emission free by 2025. In Oslo's 2025 climate budget, it is estimated that a further 18 500 tCO_{2eq}/year can be saved from using electric construction machinery on construction sites [9]. The city of Oslo is now working towards the goal of all private construction sites being emission free by 2030. In 2023, Wiik et al. [10] found that Oslo had approximately 90 construction sites that used electric or fossil-free construction machinery from 2019-2022 and identified 133 unique electric construction machinery on the Norwegian market. This paper provides an updated data driven overview of electric construction machinery, and electric construction sites in Oslo including the rate of electrification, energy and power demands, and GHG emissions saved.

2 Methodology

The methodology consists of mapping, collection, screening, and analysis of construction site data from agencies in Oslo municipality. An initial mapping of Oslo municipality identified 19 of 50 agencies with construction activities, of which 6 agencies had available construction site data. One-to-one meetings were arranged with each of the 6 agencies to identify construction works and facilitate data collection. Of these, two were subsequently excluded from the process due to lack of data. The agencies with accessible data were the Agency for Urban Environment (Bymiljøetaten, BYM), the Fornebu Metro Line (Fornebubanen, FOB), Oslobygg (Oslobygg, OBF), and the Agency for Water and Wastewater Services (Vann- og avløpsetaten, VAV). In all, 409 construction sites were identified from 2017 to 2024. The analysis was limited to 2020-2024 since projects before 2020 were fossil-free and did not use electric construction machinery. This reduced the number of construction sites to 175, see Fig. 1. Construction types included cycle paths, fire stations, health and care buildings, metro stations, offices, parks, schools, nurseries, service buildings, sports halls, street upgrades, swimming pools, tunnels, and water and sewage works.

For each project, detailed information was gathered on project characteristics (e.g. project name, type, phase, location, construction duration), available energy and power at the construction site, planned activities, timeline, and construction machinery (e.g. make and model, size and energy carrier, energy and power usage, operation and charging hours). Total energy use per energy carrier and charging logistics plans were also collected. In addition, information on the electric construction machinery emerging on the market were collected and supplemented with data from Bellona's database, the Norwegian Association of Machine Wholesalers (MGF), the International Trade Fair for Construction Machinery, Building Material Machines, Mining Machines, Construction Vehicles and Construction Equipment (BAUMA), California Air Resources Board's (CARB) database, and the Norwegian Road and Construction trade fair [11–13]. Thousands of data points were gathered with varying scope (e.g. direct on-site energy use, construction machinery energy use, heating, drying, and lighting, and mass transport energy use) from a wide variety of sources (e.g. reports (.pdf, .doc), excel sheets, advanced metering systems (AMS), and digital tools (e.g. Fremby, Powersite, and Qlik)) and with different data quality resolutions (e.g. annually, monthly, daily, hourly, minutely) and units (e.g. $kgCO_{2e}$, km, tkm, kWh, kg, litre, m^3).

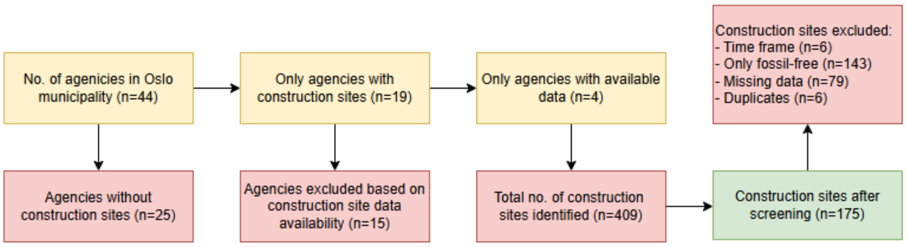

Fig 1. Flow diagram showing the construction site data screening procedure.

Follow-up meetings were then carried out with each agency to ensure data quality. These meetings were supplemented with information from energy partners, contractors, and digital tool providers, and quality assured against annual reports from Oslo municipality. Data gaps were supplemented with project information from news clippings, site visits, and stakeholder dialogue. A proxy construction machinery of a similar type and size was selected if not specified.

All the data was gathered and structured into two databases: a construction site database, and a construction machinery database. The gathered data was subsequently harmonised to make sure data was reported in the same format and converted to the same unit (kWh). Energy unit conversion factors from the Norwegian Environment Agency (NEA) were used for diesel: 10.08 kWh/l, hydrotreated vegetable oil (HVO) diesel: 8.9936 kWh/l, biogas: 10.038 kWh/l and 14 kWh/kg, and propane: 6.912 kWh/kg [14]. It was assumed that construction machinery operates for on average 5 hours a day, when this was not specified. GHG emissions were calculated by multiplying with GHG emission factors from the NEA for diesel: 0.265 $kgCO_{2e}$/kWh, HVO diesel: 0.28 $kgCO_{2e}$/kWh, biogas: 0.001 $kgCO_{2e}$/kWh, propane: 0.23 $kgCO_{2e}$/kWh. Electricity has no direct GHG emissions and is therefore set to zero. The results from the two databases were made available through public interactive dashboards [15]. While the dashboards provide access to the processed data, the aim of this paper is to provide the underlying methodology, analysis, and interpretations that are not included in the dashboards.

3 Results

The results from the construction machinery database identify 512 distinct electric construction machinery models used across 175 construction sites. These represent 18 different types of construction machinery, dominated by excavators (164), and wheel loaders (160). Other commonly used types included dumpers (41), vibroplates (41), rollers (20), pavers (19), trucks (14), and demolition robots (12). Less frequent types included compressors (7), generators (7), heat and dryers (7), concrete trucks (6), concrete truck mixers (5), graders (5), and a small number of specialised machines such as an asphalt cutter (1), carrier machine (1), chipper (1), and mix spreader (1).

The results from the construction site database are shown in Fig. 2-5. Fig. 2 shows the 175 construction sites identified from 2020-2024 using electric construction machinery, whereby 66 construction sites were fully electric. The results are organised by agency (BYM, FOB, OBF and VAV), project type, and project duration. VAV had the largest portfolio of electric construction sites (54 %), followed by BYM (26 %), OBF (15 %) and FOB (5 %). Construction periods ranged from 1 to 59 months, with an average project duration of 14 months. Most construction projects were either new (67 %), or rehabilitation (32 %) projects, mainly comprising of water and sewage works (54 %), parks (10 %), or schools and nurseries (8 %). Average energy demand was ca. 614 MWh per construction site, with peak power demands ranging from 30 - 800 kW.

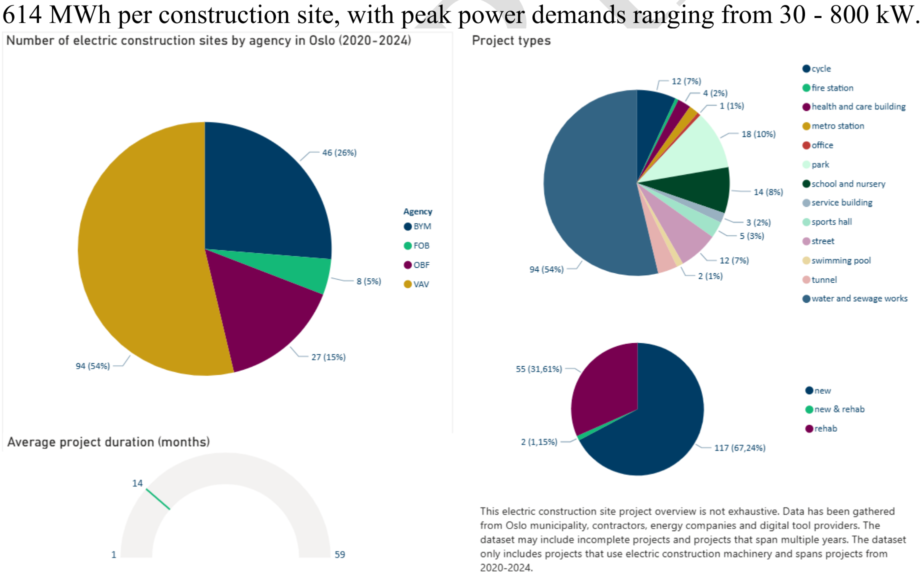

Fig 2. An overview of Oslo's electric construction sites, by agency (upper left), project type (upper right), and duration (lower left).

Fig. 3 shows that the rate of electrification of construction machinery has steadily increased to over 80 % in 2024. The average number of electric construction machinery used per project has varied between 5-8 from 2020-2024. The data shows on average 2000 machine hours per project, giving ca. 250-400 hours per machine. Based on the reported energy data, an estimated 15 800 tCO_{2e} were avoided by using electric construction machinery from 2020-2024. Fig. 4 shows the distribution of electric construction projects between small, medium and large contractors per year. In all, 46 unique contractors were identified to have worked on electric construction sites in Oslo. Of these contractors, 27 % were large organisations (over 250 employees or over 500 million NOK in annual turnover), 53 % were medium organisations (50 - 250 employees or 100 - 500 million NOK in annual turnover), and 20 % were small organisations (less than 10-50 employees or had an annual turnover of less than 100 million NOK). Fig. 5 shows the spread of electric construction sites in Oslo by agency from 2020-2024 by location (map) and by year (bar chart).

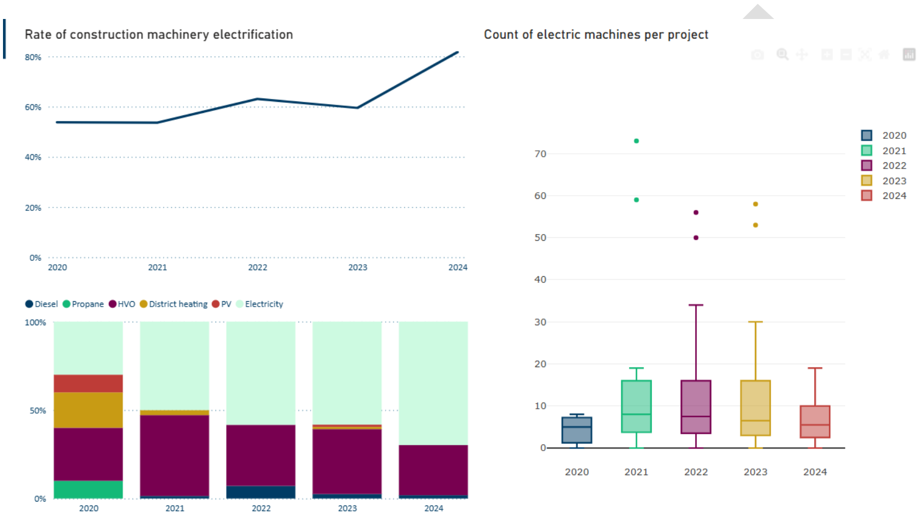

Fig 3. An overview of the rate of construction machinery electrification (upper left) and share of energy source per year (lower left), and the distribution of electric construction machinery on Oslo's construction sites per year (right).

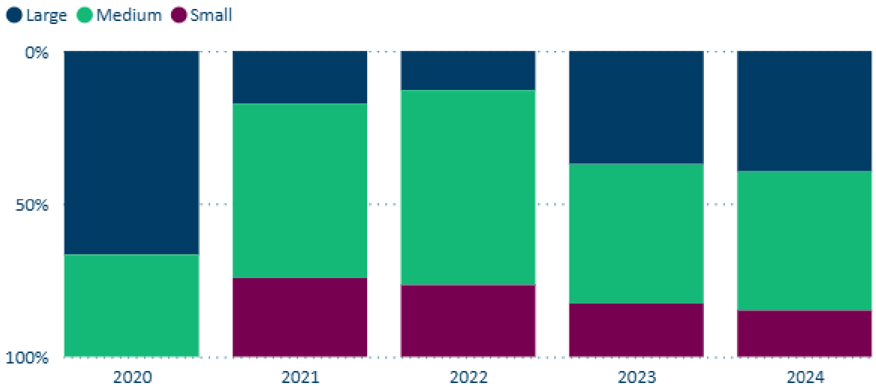

Fig 4. The distribution of electric construction projects between small, medium and large contractors per year.

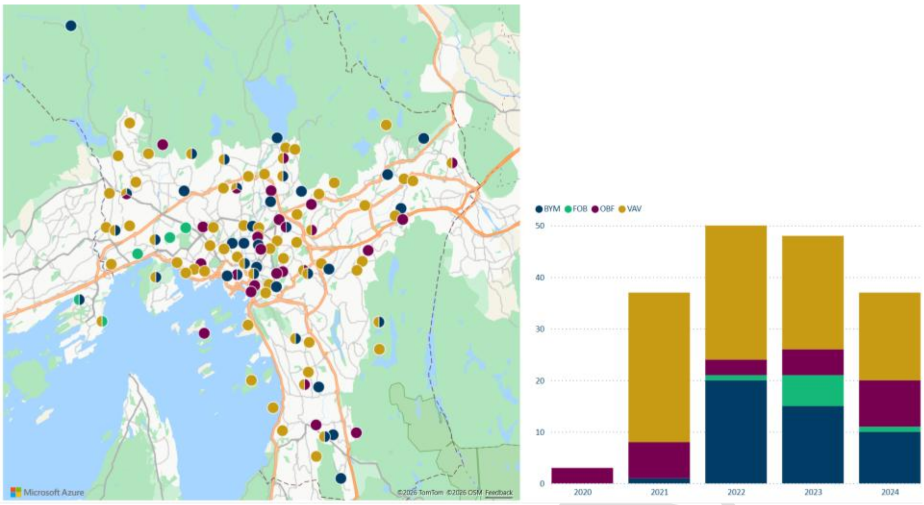

Fig 5. The spread of electric construction sites in Oslo by agency according to location (left) and year (right).

4 Discussion

The results show a clear increase in electrification of construction sites in Oslo, driven primarily by municipal climate ambitions and the strategic use of procurement criteria, together with financial incentives from Enova. This experience demonstrates that electrifying construction machinery is technically feasible in real projects and that public procurement can accelerate adoption across the construction industry. VAV has the most electric construction sites and were the first agency to reach emission-free. Their projects are spread across the whole city, and are typically cycle paths, street upgrades, or water and sewage works characterised by a shorter construction period (10 months) and fewer construction machinery (<5). Other cities can learn from Oslo and prioritise electrification of these project types first. Nationally, electric construction machinery availability is growing exponentially and is available in a range of size classes (Fig. 6). Battery technology dominates the market, with some stationary cable machines, and the emergence of some larger hydrogen construction machinery (over 20t). In 2025, electric construction machinery accounted for ca. 8 % of all new construction machinery sales in Norway despite a general decline in diesel construction machinery sales, see Fig. 7 [13]. Comparable international developments highlight similar trends, for example, recent studies from China show high market penetration rates of electric lifting platforms and forklifts in 2023 reached 90 % and 64 %, respectively, with monthly sales of electric loaders exceeding a thousand units [16]. The broad participation of contactors in Oslo, from small to large, indicates that the transition is industry wide. The estimated 15 800 tCO_{2e} savings from 2020-2024 show the significant emission reduction potential of electrification.

Despite strong progress, reporting and data quality remain a main barrier for accurate monitoring and scaling. Fragmented systems across agencies lead to inconsistent scopes, formats, and temporal resolutions. Data sources originated from manual excel templates to automatic reporting and monitoring tools, with limited information on charging losses, seasonal variations, and distinctions between daytime (DC) and nighttime (AC) charging which further complicated evaluation. Unclear data ownership, different internal authorisation procedures, and GDPR requirements introduced additional steps. Establishing a harmonised and transparent digital system for data collection, evaluation, and follow up, shared across the construction value chain, is therefore important for evaluation, planning and policy follow up.

Current electrification efforts focus primarily on construction machinery and direct GHG emissions. A clear description of which activities are included under the electrification of emission free construction sites, and an expanded scope covering a broader set of construction site activities, will help to avoid problem shifting. Integrating infrastructure data (e.g. grid connections, battery containers, and chargers) will help get a better overview of energy and power demands and charging logistics. Although the cost of electrification is not covered in this study, gathering data on additional costs and developing a harmonised cost calculation method would support economic assessment. Since one of the main goals of electrification is environmental impact reduction, systematic documentation of environmental performance using life cycle assessment (LCA) procedures is also important. Relevant standards, such as the Norwegian technical specification SN/TS 3770 for emission free construction sites, can provide useful background [17]. Construction site waste reduction activities and emission free construction site activities are currently addressed separately. Aligning these activities in the future can help identify environmental hotspots and measures that reduce overall impacts. Finally, early planning and involvement of stakeholders is important to align expectations, allocate resources, and establish data collection and sharing mechanisms from project start. Updating this study with more complete and harmonised data will improve understanding, further development needs, and opportunities for knowledge sharing.

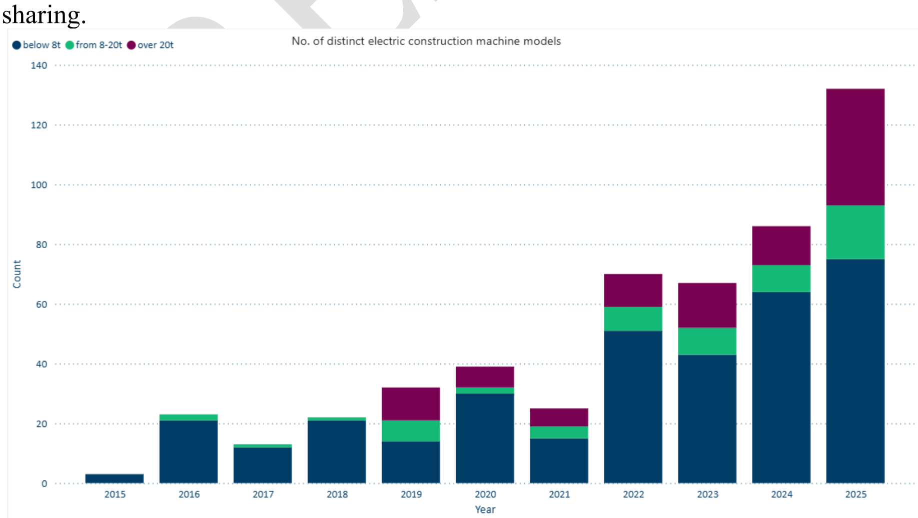

Fig 6. Annual number of distinct electric construction machine models entering the market.

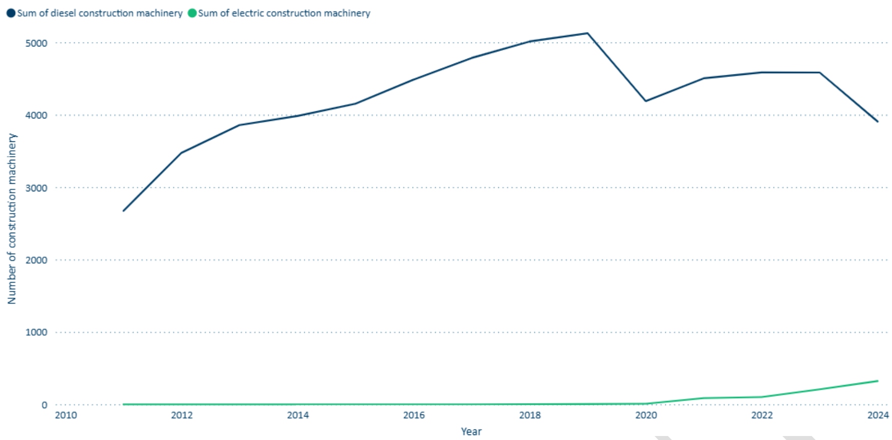

Fig 7. Annual number of construction machinery sold in Norway [13].

5 Conclusions

The transition towards electric construction machinery and the implementation of emission-free construction sites in Oslo represents a significant step towards decarbonisation. The data collected highlights the growing availability and adoption of electric machinery, resulting in substantial reductions in GHG emissions. As Oslo continues to lead by example, nearly achieving its goal of all public construction sites being emission-free by 2025, it sets a benchmark for other cities and private actors to follow. The challenges identified in data collection and the need for standard routines amongst stakeholders underscores the importance of systematic data collection and monitoring approaches to achieve emission-free construction sites. By sharing insights and best practices, Oslo can inspire other urban areas to implement similar initiatives, fostering a collective effort towards an electric construction industry.

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