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Is it possible to achieve waste free construction sites in Norway?

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Is it possible to achieve waste free construction sites in Norway?

Selamawit Mamo Fufa[1,*], [1]Christoffer Venås, [1]Marianne Kjendseth Wiik

[1]SINTEF Community, Børrestuveien 3, NO-037 Oslo, Norway

*Email: Selamawit.fufa@sintef.no

Abstract. The construction industry is one of the world's largest consumers of energy (ca. 40%) and natural resources (ca. 40%). Norwegian statistical data shows that waste from construction, rehabilitation and demolition is steadily increasing. Norway alone generated approximately 1.9 million tonnes of waste in 2017, around 1% more construction waste compared to 2016. Of this, only 34% of the waste was recycled, which is 8% less than in 2016, and 34% below the EU's requirements (70% reuse and recovery of all non-hazardous construction and demolition waste). There are on-going initiatives in Norway to address this and realise 'waste free' construction sites, with an ambition to contribute towards global, national and regional environmental impact reduction targets. The aim of this paper is to discuss challenges and opportunities for waste free construction sites in Norway and lessons learnt from Norwegian fossil and emission free construction sites. This paper concludes that Norwegian waste-free construction is ambitious but possible.

Keywords: Construction site, Construction waste, Emission free, Waste free construction, Zero waste construction.

1.Introduction

Construction sites represent between 5-10% of total emissions in cities [6]. In Oslo, the emissions relating to construction sites are approximately 7% of the city's total emissions1. The construction phase emissions occur during the early stages of a building's life cycle, and given the magnitude, one can question whether new construction can contribute to reaching environmental goals, no matter how energy efficient buildings are during operation [1]. This shows the importance of minimising embodied construction emissions. Today most Norwegian construction sites generates 40-60 kg/m2 waste [15]. Several projects have set a goal of waste generation below 25 kg/m2. However, the construction industry has identified several challenges to reduce today's levels of waste to a significantly lower level. One major challenge is related to complex projects that involve many stakeholders with different needs and practices. Waste reduction requires extensive planning throughout the project period and close collaboration between different actors, which is both time and resource intensive. Human factors, such as perceptions, attitudes, behaviours and expectations of the involved multiple stakeholders is another key barrier. Most actors in the construction industry are unsure of the profitability and environmental

[1] https://www.smartcitiesworld.net/news/news/cities-commit-to-clean-construction-to-cut-building-emissions-by-up-to-44-per-cent--4665

benefits of waste reduction measures. It is cheaper to buy new materials and easier to send leftovers to waste treatment facilities. Waste reduction and reuse of products are key principles in the waste prevention and management hierarchy to reduce waste, emissions (from production, transport and waste treatment of additional new products) and the potential adverse impacts of waste on environment and health. A recent Nordic study shows a significant positive environmental impact by reducing the resource usage by 20%, which is equivalent to 900,000 tonnes of GHG emissions, and a potential social and financial benefits for private companies equivalent to 1.7% annual growth [13]. Reducing waste from construction sites will play a major role in fulfilling local, regional, national and global environmental goals, while addressing several of the UN sustainable development goals (such as SDG 11 Sustainable cities and communities; SDG12 Responsible production and consumption and SDG13 Climate action and waste and pollution reduction impacts).

The aim of this study is to evaluate and discuss the challenges and opportunities for waste free construction sites in Norway; as well as review the lessons learnt from Norwegian fossil and emission free construction sites and discuss how emission reduction measures can enable waste free construction. This paper starts by outlining the background and definitions. It then presents four Norwegian case studies in addition to the planned and actual waste generation results. This is followed by a discussion on challenges, opportunities and lessons learnt before presenting concluding remarks.

2.Background

The Norwegian construction sector is a front runner in taking responsibility for setting environmental goals which enable the industry to develop low emission solutions and the utilisation of transparent data and communication schemes to follow building performance (such as BREEAM [3] and EPDs [2]). There is a growing interest in Norway on fossil and emission free construction site activities [1][5][7][10][17]. Oslo municipality is the main driver behind this initiative and requires all public construction projects to be fossil (as a minimum requirement) or emission free since 2017. Oslo municipality use public procurement as a tool, by setting achievable ambitious requirements in competition tenders. This enables the rapid development and implementation of new market-oriented fossil and emission free solutions.

Currently, there are no legal requirements for waste reduction from construction sites. Existing requirements made by authorities and builders are passive and focus on waste sorting, and not on waste prevention or reduction. The construction industry has now taken the lead to address waste challenges through a joint initiative called "waste free construction site"[3]. Eleven key public builders have gathered in this initiative to identify challenges and opportunities, motivate the development of new solutions and facilitate public support schemes for innovative projects with targets for waste reduction. The initiative also plans to initiate a new requirement for waste free construction sites by 2022.

The term waste free and zero waste are often used interchangeably when discussing waste from building sites. A waste free construction site is a construction site that does not generate any waste in any of its construction site activities. However, some actors in Norway have used the concept of waste-free construction sites for achieving less than 40 kg/m2 of waste. In order to harmonise definitions, the Norwegian waste-free construction site initiative define waste free construction sites as construction sites that do not have any waste from construction site activities (including the production of the materials). The scope of the definition is limited to waste from construction of new buildings and focuses on five construction waste fractions, namely wood, gypsum, plastic, packaging and pipes. [12].

However, achieving zero waste from construction sites is challenging. Bærum municipality has taken the first steps by focusing on one of the waste fractions and is working towards smart packaging solutions to achieve no packaging waste [4]. Similarly, Stavanger and Sandnes municipalities are also underway to acquire two pilot projects where waste reduction is a priority [16].

[2] https://www.epd-norge.no/?lang=en_GB
[3] https://innovativeanskaffelser.no/avfallsfrie-byggeplasser/

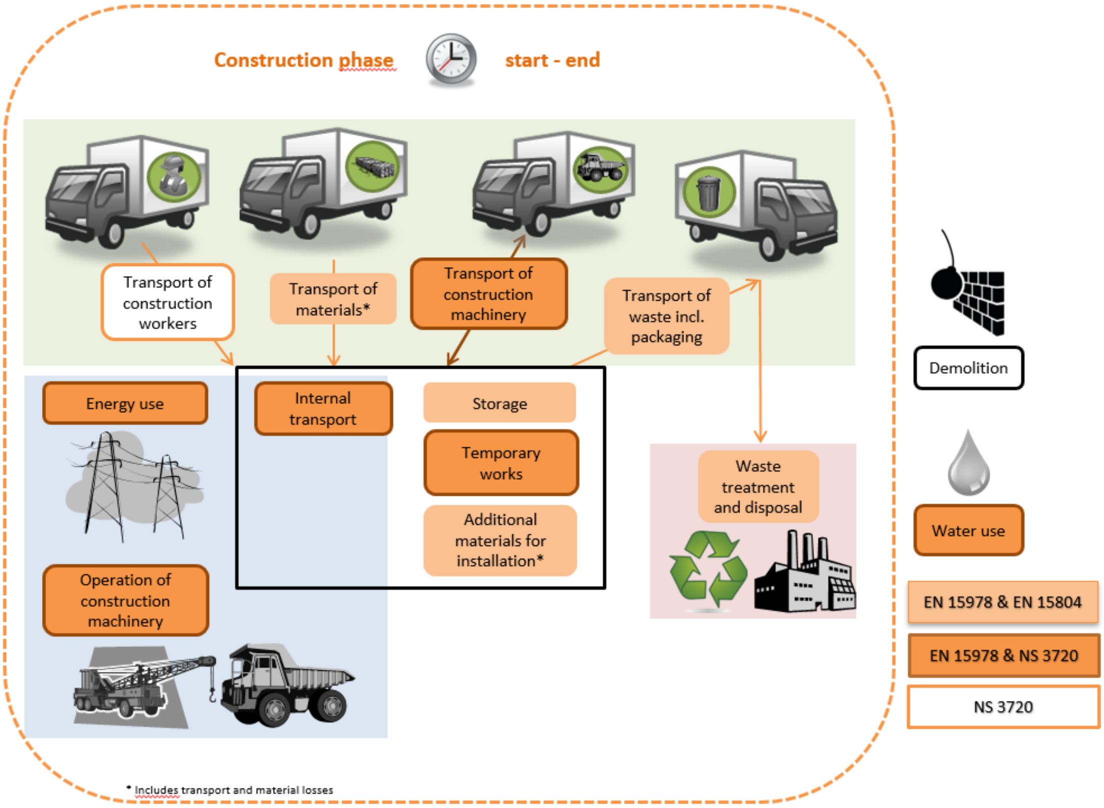

Figure 1: System boundary for emission free construction sites (Fufa, Wiik, Mellegård, & Andresen, 2019).

Waste is one component under construction site activities, and waste free construction sites support the development of emission free construction sites. The joint initiative sees that similar, in-depth work is needed to realise waste free construction sites. In spring 2019, contractors and suppliers have shown an interest in developing new collaborative waste reduction solutions through a series of dialogue meetings under the joint initiative for waste free building sites network [12]. However, they also expect transparent and achievable requirements in the procurement process and incentives to support new cost-intensive innovative working methods.

3.Materials and methods

This study follows the construction phase of four Norwegian building case studies (Campus Evenstad, in Hedmark, Lia nursery school in Oslo, as well as a small and a large construction site in Bærum). The methodology involves collecting data on waste plans, waste generation and waste sorting, visiting the construction sites, and performing qualitative interviews with key stakeholders. The two Bærum construction sites are on-going projects, whilst Campus Evenstad was completed in 2016 and Lia nursery school in 2017.

The two Bærum construction sites are traditional construction sites which are selected by Bærum municipality for a qualitative study to investigate the current practice of the ongoing "smart packaging construction sites" project. The small construction project is for a new social service building with a total floor area of 1500m^2 over three floors. The building consists of a traditional construction with a steel load-bearing frame and hollow deck concrete slabs. The large construction project is also for a new social service building with a total floor area of 17000m^2 consisting of several smaller buildings over two to three floors. The buildings consist of solid wood construction with either a brick facade or treated wood panels. The aim is to understand the importance of packaging and packaging waste in construction and to contribute to the parallel development of waste-free construction sites. Interviews have been carried out with the construction manager and supervisor. In addition, a group interview with the suppliers has been conducted.

In contrast, Campus Evenstad and Lia nursery school have implemented solutions aiming to achieve low emission construction sites. Campus Evenstad consists of an administration and educational school building with a total floor area of 1141m^2. The building consists of a solid wood construction, wood fibre insulation, and an untreated timber cladding. It was the most ambitious pilot project from the Norwegian ZEB research centre, which compensates the emissions related to materials "M", operation "O" and construction "C" through on-site renewable energy generation (ZEB-COM) [9][17]. Whilst Lia nursery school is the first fossil free construction site in Norway and has been awarded as Norway's most environmentally friendly nursery school in 2018 [11]. The total floor area is 1600m^2. The construction consists of prefabricated timber elements with timber interior and exterior cladding, hollow core concrete slabs, and light weight concrete roof elements.

Figure 2: Visualisation of Campus Evenstad (left, by Ola Roald Arkitekter) and photograph of Lia nursery school (right, by SINTEF).

Both Campus Evenstad and Lia nursery school evaluate emissions from the following construction site activities: transport of building materials; transport and operation of construction machineries; waste management including transport of waste from construction site activities to the treatment facilities, waste processing (recycling or incineration) and waste disposal; energy use; temporary works and person transport (see Figure 1). All demolition works and waste belong to the previous life cycle and are not included in the analysis. The waste data was collected from the waste plan filled out by contractor. Further detailed information about the two case studies can be found in [7][11][17].

4.Results

Table 1 presents the type and amount of construction waste planned for, generated and sorted on-site from the four case studies. The total waste generated per m^2 total floor area results are 27.1 kg/m^2 for Campus Evenstad, 32.1 kg/m^2 for Lia nursery school, 10.3 kg/m^2 for Bærum small and 24.3 kg/m^2 for Bærum large. More than 80% of total waste generated in Campus Evenstad is sorted and consists of untreated wood (47%), mixed waste (20.1%), concrete (16.2%) metals (11.8%) and gypsum (3.2%), whilst in Lia nursey school more than 82.5% of total waste is sorted and consists of untreated wood (47%), mixed waste (17.5%), gypsum (14.9%), metals (6.7%), paper (6.4%) and plastic (5.8%). In Bærum small, 64% of total waste is sorted and consists of untreated wood (52%), gypsum (27%), plastic (8%), mixed waste (8%) and mineral wool insulation (3%). In Bærum large, 86% of total waste is sorted and consist of gypsum (34%), untreated wood (29%), mixed waste (14%), concrete (11%) and plastic (4%).

Table 1. Total planned and actual construction waste for four Norwegian construction sites.

Type of building	Evenstad*	Lia nursery	Bærum small**	Bærum large**

Total floor area (m^2)	1141	1600		1500		17000	
Construction Waste (kg)	Planned	Planned	Actual	Planned	Actual	Planned	Actual
- Untreated wood	14522	29030	28140	17000	8060	147650	120700
- Paper, cardboard and carton	365	1500	3840	2000	-	14770	6240
- Glass	130	0	0	0	-	0	-
- Iron and other metals	3640	7061	3980	7000	340	29530	15170
- Gypsum based materials	1000	10199	8900	8000	4200	73830	141010
- Plastic	30	1850	3440	4000	1160	7380	16310
- Concrete, brick, Leca and other heavy building materials	5000	15000	0	15000	-	147650	45440
- Electric and electronic waste	10	0	0	500	-	1480	1148.5
- Mineral wool insulation	0	0	0	900	500	1480	6900
- Mixed construction waste	6200	6136	9920	6000	1200	36910	58530
- Hazardous or special waste	21	0	1040	600		1480	1057
Total construction waste	**30918**	**71476**	**59260**	**61000**	**15460**	**462160**	**412505.5**
Total construction waste - sorted	24697	65340	48300	55000	14260	425250	353975.5
Total construction waste generated per total floor area (kg/m^2)	**27.1**	**38.7**	**32.1**	**40.7**	**10.3**	**27.2**	**24.3**
Sorting fraction (%)	80	91	82.5	90	92	92	86

NB: Packaging waste is included under 'wood', 'plastic' and 'paper, cardboard and carton' fractions.
* The actual waste data for Evenstad was not available at the time of writing this paper.
**At the time of writing this paper, the Bærum construction sites were under the final stages of construction and will have some additional wastes from internal finishes (e.g. gypsum, cardboard, plastic) not accounted for here.

The interviews with the construction site personnel in Bærum projects provided insight to the practical implications of waste requirements and potential packaging waste measures. Both projects in Bærum focus solely on sorting on-site, and not on waste reduction. The informants did not have strong beliefs in the ability of achieving packaging-free construction or waste free construction and questioned the profitability and environmental benefits of leaving today's practice. Substantial changes in current working methods, giving less flexibility for on-site operations and better planning of the construction logistic activities are described as important measures for potential waste reduction solutions. The need for public procurement and stricter requirements from public authorities was also highlighted as the most important drivers for change in the future.

5.Discussion

From the results, it is possible to see that all case studies have managed to reduce the total construction waste generated per total floor area, excluding Campus Evenstad since data on actual waste generated was not available. Lia nursery school and Bærum large have not been able to meet their planned sorting fractions, and it may be considered that this is a consequence of reducing 'sortable' waste. On the other hand, Bærum small has been able to improve its sorting fraction. Through interviews, it was found that since Bærum small is a smaller project with a less complex structure and has a site layout with available dry and safe temporary storage for materials. This enables easy implementation of good waste management practices, where sub-contractors and suppliers followed-up to ensure good sorting practices.

The Norwegian waste free construction site initiative's definition limits the scope to waste from construction of new buildings and focuses initially on five construction waste fractions: wood, gypsum, plastic, packaging and pipes [12]. It is interesting to note that all case studies have high fractions of waste from untreated wood, gypsum and plastic, as well as mixed construction waste and concrete. Packaging wastes are integrated under untreated wood, paper, cardboard and carton and plastic, whilst pipe wastes are integrated under iron and other metals and plastic. Developing a stepwise ambition level definition, such as in the Norwegian ZEB research centre for zero emission buildings [9] or in the emission free construction site project (Figure 1), can be a useful approach to realising waste free construction site ambitions. Recommendations include establishing a waste free construction site ambition definition system using benchmarks for total construction waste generated per total floor area, sorting fractions and the waste hierarchy system. This will highlight the amount of waste generated from the construction process and the treatment method used for waste generated. It will also enable stakeholders to identify measures for reducing waste and increase the fraction of waste material recovered. This approach will help harmonise the definition of waste free construction and facilitate for transparent communication of results between construction projects. However, in order to establish benchmark values, either national statistics or a larger body of case studies is required.

More time and resources were used in the early project phases for the planning of both Campus Evenstad and Lia nursery school, in order to create a common understanding of the project ambitions and discuss potential measures and challenges to achieve low emission construction sites. There was a close cooperation between actors, whereby the ambition for low emission construction, concepts, lessons from previous experiences, accessibility of machineries and equipment in the market, and potential challenges and opportunities were discussed at an early stage. This enabled both projects to achieve their ambitions. As waste is one part of construction activities, both case studies consider ambitious waste minimisation targets (for example using prefabricated elements in Lia and use of locally available low carbon materials in Campus Evenstad). The two Bærum construction projects focus on delivering projects on time and budget without spending more time in the early planning. For example, the marginal higher cost of using pre-cut gypsum boards in Bærum small, and the risk of longer delivery times in Bærum large was described as the reasons why traditional methods were chosen. Furthermore, the informant believed that the most important success criterion for waste reduction would be to ensure an optimal quantity in stock, continuously produce properly and with good quality and avoiding temporary storage of materials. It is recommended that all construction projects should deliver a waste plan, containing the total amount and type of onsite construction waste that is going to be generated during the construction period to local authorities before construction starts. The waste plan can then be used as a tool during the construction phase to actively reduce and sort waste fractions. Through interviews it was confirmed that waste plans are not actively used to plan waste operations or used to follow up waste generation during construction. The need for digitized tools to plan and follow-up waste during construction has been discussed.

Green public procurement is common practice in the Norwegian building sector, whereby the public sector uses its position in the market to set strong demands on developers, contractors and suppliers. Oslo municipality sets a good example in setting requirements for fossil and emission free building sites to reduce ca. 30% of the city's total construction site emissions. Lia nursery school was the first construction site to implement the fossil free construction site ambition. The lessons learnt from this project were then used in other fossil free and emission free construction sites around Norway. This can also be used as a reference when setting requirements for waste free construction sites. Setting clear, measurable and realistic environmental requirements or targets and incentives in the procurement process encourages different stakeholders to consider new and innovative solutions. Lack of knowledge and experience amongst stakeholders, high costs and lack of access to waste-free solutions are considered as important barriers across the case studies. There is a need to replace traditional solutions based on linear thinking and consider new technologies and methods aimed at optimising operations.

Early planning with consideration of external factors, collaboration and good dialogue between all stakeholders involved (to share knowledge, expertise and other resources) and choices of construction methods (such as prefabricated elements and modules) are the main factors which enable all projects to achieve their ambitions. Purchase of pre-cut and prefabricated materials/elements in the desired dimension, effective utilisation of areas, efficient construction site lay out, on-time and efficient delivery (to reduce unnecessary movement and storage of materials), proper material handling with dry and clean storage areas if temporary material storage is needed (to avoid material damage) are some measures that should be considered. An agreement with suppliers to return packaging, more on-time delivery of materials without packaging, bulk deliveries to avoid unnecessary use of small packaging are some examples of packaging waste reduction measures which can be implemented in current practice. The economic and environmental consequences of each waste reduction measures should be considered to make informed choices.

There is a need for developing circular supply value chain systems, with new working methods, allowing close collaboration between different stakeholders for the successful realisation of waste free construction sites. There is also a need to develop practical solutions, new ways of working profitably, develop competence, collect best practices through pilots, and create a platform for the dissemination of knowledge and information between different actors. Combining theoretical and practical knowledge through pilot testing, documentation of practical advancements and best practices from different projects will help to fill the current knowledge gap. There is a need to develop and apply research-based knowledge and methodologies which enable the evaluation of potential cost savings, environmental and social benefits when choosing different waste reduction measures. Using a life cycle thinking approach is central to evaluate the sustainability of these solutions. Performing cradle-to-grave life cycle assessment will enable to avoid problem shifting from one life cycle phase to another or from one environmental indicator to another. Governmental involvement is central to strengthen incentives, further develop regulations and promote public and private procurements. Upcoming new requirements should be realistic, transparent, measurable, comparable and incentivised so that ambitious actors can develop and implement innovative solutions. It is also important to provide recommendations based on lessons learnt for procurement procedures, regulations and incentives for the realisation of waste free construction sites. Lessons learnt from previous and on-going projects on fossil or emission free construction sites can be used as an example.

6.Conclusions

This study has presented the findings from four Norwegian construction sites. The results show that achieving absolute zero waste may be challenging to achieve soon but is possible. It requires new digitalised waste reduction solutions, good early planning, new working methods and close collaboration between actors to create a closed circular supply chain. There is also a need for harmonised ambition levels, definitions and system boundaries which enable stakeholders to evaluate, document and follow up waste reduction measures. The study also highlights considerable scope of work for further analysis.

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