bigbuyers
for climate & environment

an initiative of the Zero-emission Construction Sites working group of the **Big Buyers for Climate & Environment**

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Public Procurement of Zero-emission Construction Sites

Lessons learnt from the Big Buyers for Climate & Environment working group

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The Big Buyers working group on Zero-emission Construction Sites

Under the Big Buyers for Climate & Environment Initiative[1], a working group on Zero-Emission Construction Sites has brought together public authorities from across Europe to promote zero-emission construction sites, focussing on alternatives to traditionally diesel-fuelled non-road mobile machinery (NRMM) used to carry out construction works (such as diggers, excavators and wheel loaders). These entities have worked together to develop and pilot sustainable procurement approaches to encourage market innovation and reduce the environmental impact of construction activities. The group began collaborating in April 2019, and was relaunched in April 2021 with expanded participation. Joint activities have included capacity building, market dialogues, and learning-by-doing through pilot procurements with fossil- and emission-free machinery and on-site power supply. Although they share a common ambition for a low carbon future, the participating entities are in different stages of the transition to clean construction works - a diversity that reflects the wider European context and strengthens the exchange among them. Seven public authorities in this group are either planning pilot projects, running pilot projects, using a mix of fossil free and zero emission machinery, or beginning to incorporate the procurement of zero emission construction sites as part of their business as usual operations. These are Oslo, Copenhagen, Helsinki, Vantaa, Eindhoven, Barcelona and Neukolln District (Berlin).

Big Buyers Zero-emission Construction Sites working group participants:

- City of Oslo
- Andalusian Housing Agency
- City of Barcelona
- City of Copenhagen
- Danish Building & Properties Agency
- Danish Road Directorate
- City of Eindhoven
- City of Helsinki
- Lyse
- District of Neukolln (Berlin)
- Rijkswaterstaat
- City of Stockholm
- Swedish Transport Administration
- City of Vantaa

Affiliated entities:

- Motiva
- Bellona Foundation
- C40 Clean Construction Programme
- SINTEF

[1] The Big Buyers Initiative is funded by the European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. The sole responsibility for any error or omissions lies with the editor. The content does not necessarily reflect the opinion of the European Commission. The European Commission is also not responsible for any use that may be made of the information contained herein.

Contents:

Public Procurement of Zero-emission Construction Sites

1. Executive Summary

The Big Buyers Working Group on Zero Emission Construction Sites has carried out intensive work focussing on how its members can contribute to the transition away from fossil fuel powered construction machinery. A significant amount of focus has been on the technologies used to power construction site machinery, the availability of which is increasing but still uneven across European countries.

Through several rounds of market dialogue the group was able to hear directly from leading manufacturers what new, non-fossil technologies have been developed, and what is likely to be available in the near future. Similarly, the members of the working group were able to ask their own questions and provide insights into how developments in their organisations' strategies related to the climate emergency may ultimately affect demand. In acknowledgement of the need for the industry to have clear and predictable demand for its innovations, the working group developed a Joint Statement of Demand. This document lays out the ambitions of the signatories and indicates a clear appetite for more zero emission machinery to be made available.

To support the transition further, the working group collaborated with each other and shared best practices on how to procure construction projects which use low and zero emission machinery. As this is a topic which is well suited to test of concept through pilot projects, further advanced members of the working group shared tender criteria for other members to apply to their own circumstances. Pilot projects also provided excellent opportunities for study visits, which were combined with in person market engagement and working group meetings.

As the work of the group developed, and as the sector has evolved, additional subject matter areas and topics for the future became apparent. In order to use more electric machinery, the electricity grid and ways of working will need to be able to support this. More work within the group will be needed in the form of market dialogue and technical expertise to understand what developments will be needed to allow cities and public authorities to make their construction sites emission free.

In addition, the group has observed how there are varying levels of organisational support for zero emission construction sites across the members, with less support making it harder for ZEMCONS to be implemented. To ensure a holistic approach is taken to support the decarbonisation of construction sites, the group will also work on supporting an enabling framework for ZEMCONS, thinking how policy can support the transition, as well as demonstrating that transitioning construction sites away from fossil fuels can play a role in achieving an organisations wider environmental objectives.

Construction site emissions in context

Conventional construction works are a notable source of emissions both locally and globally. The construction industry contributes 36% of global energy use and

39%[1] of GHG emissions, and approximately 5.5% of these emissions come directly from activities on construction sites—predominantly through the combustion of fossil fuels to power machinery and equipment. It is estimated that emissions from construction sites represented 5–10% of total production-based emissions in cities (DNV GL Energy, 2019). These emissions are local and thus have a greater impact on air and noise pollution in the city. For example, it has been estimated that 14.5% of PM2.5 matter in London is due to local construction sites (Bellona, 2019).

As the energy efficiency of building use has been ambitiously tackled over the past decade, the focus increasingly shifts to embodied carbon: the emissions footprint of material extraction, production, transport and construction works.

Clean versus conventional construction
Benefits of transitioning to emission-free construction sites include:

- Reduced global GHG (namely CO_2e) from burning of fossil fuels
- Reduced local air pollution (NOx, SOx, CO, PM)
- Safer and healthier working conditions due to less noise, dust and exhaust
- Reduced noise (up to 5 times less) and nuisance to area surrounding construction sites
- Opportunities for optimised planning and use of machinery through smart systems (digital monitoring, power sharing)

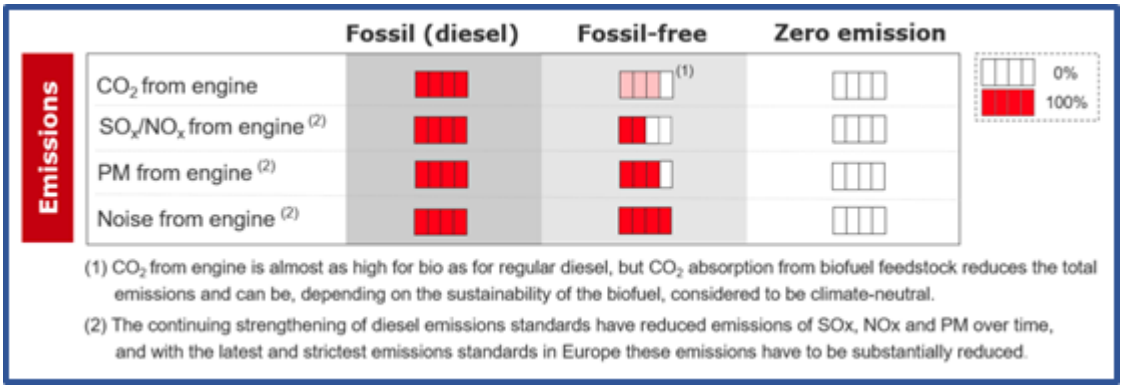

Figure 1: Perspectives on Zero-emission Construction - Oslo Climate Agency, 2019

What would it really be like to have emission-free works in urban centres? For a taste of the future, anecdotal experiences from Big Buyers cities Oslo and Copenhagen: In Oslo, children in a Kindergarten near to a park under renovation could take their naps outside thanks to the quiet electric excavators at work. On one Copenhagen civil works site, the quiet electric machines led to the city's Noise Department permitting longer hours worked, which decreased the project timeline by 50% overall and resulted in savings that compensated the 20% higher initial investment for emission-free equipment.

Future developments of ZEMCON technology include a variety of electric machinery, with varying reliance on batteries, and hydrogen. Developments not only involve the machines themselves but also how power can sustainably be provided to site.

[1] https://www.worldgbc.org/news-media/global-status-report-2017

How to procure emission-free construction works has focussed on sharing best practice tender documentation and has benefited greatly from the topic being one where pilot projects can be used as a low risk way of demonstrating proof of concept. In this way, many of the members of the working group have started on their journey towards ZEMCONS as business as usual.

2. Defining emission-free construction sites

A common understanding and definition of an emission-free site and the scope in question has been clearly asked for by market actors. For public procurements to ask for compliance with a fossil-free or emission-free approach in a construction contract, the scope of this must be clearly defined for all bidders. Likewise, the definition and goals laid out by the public authorities' procurement strategies are most effective in moving market actors and accelerating innovation when they are clear, consistent, specific, and reliable in a medium-term time horizon.

On the other hand, public authorities across Europe face diverse regional contexts - including availability of clean machinery and electricity, and know-how of local contractors - that may limit the scope of what is feasible to ask for in the short-term. There is a common denominator, however, and a clear direction of travel towards complete elimination of on-site emissions.

This publication uses the terms *'zero-emission'* or *'emission-free'* construction sites to refer to works in which there are no emissions from combustion engines within the construction site fence. Both electricity and heating on site may be considered within the definition of emission-free sites, although for the working group only non-road mobile machinery like wheel loaders, excavators, or mobile cranes, as well as any passenger vehicles on site and handheld tools were considered. The term 'fossil-free' construction sites refers to works in which there are no fossil-fuels (such as gas, oil or diesel) burned on-site to carry out the construction works; this includes the use of generators on site. For some, but not all, the definition of Fossil Free extends to electricity and heating. The limitation of scope to what is within the construction site fence *(see (1) in the figure below)* is to make this requirement as transparent, measurable and fair as possible - especially in the earliest stages of this transition.

Nonetheless, some buyers are already taking action to reduce emissions from additional related elements, such as heavy transport of construction materials to and from the site, lifecycle environmental impacts of construction materials, or a decarbonised power supply.

Figure 2: Applicable scope of emission-free construction sites

(1) Within the construction site fence:
- Operational use of machinery, vehicles and equipment on-site
- Generators on-site
- Transportation of materials, machines or people within/ around the site

(2) Beyond the construction site fence:
- Embodied emissions from extraction, manufacturing, and transportation of construction materials and machinery
- Production of electricity (and related power infrastructure, including batteries)
- Transportation of personnel, equipment or waste to and from the site
- Waste handling

It is critical that definitions used in setting out demands for cleaner construction works are technology-neutral as far as possible to avoid stifling innovation or limiting competition. Standards relevant to the industry, such as the European Commission's NRMM Stage Requirements, also provide harmonised definitions that may be used to specify the minimum environmental performance of machinery in procurements.

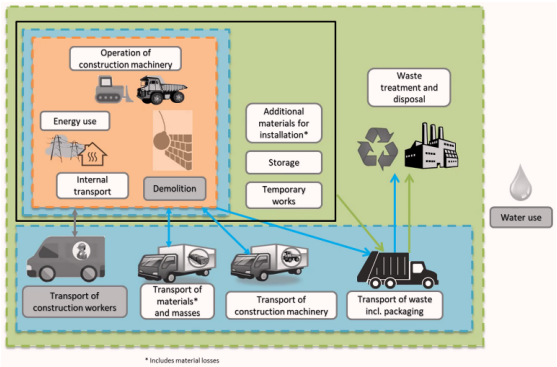

Figure 1 - ZEMCONS Working Group Scope

Shown in the image (Figure 1) is a concise summary of the scope of this report, first produced by SINTEF for Oslo, and what we mean by the construction site for the purposes of this project.

On-site machinery as a piece of the bigger picture

A focus on construction machinery is not exclusive of -but rather complementary to- other approaches to addressing the negative environmental and health impacts of conventional construction works, and ensuring that the sector develops in a forward-looking, attractive and sustainable way. Most involved entities are also working on a green and digital transition for the sector more broadly - for example, with approaches that also value material circularity, durability and aesthetic quality of buildings, and upskilling of construction workers.

3. State of the art in emission-free construction machinery in Europe

Since the inception of the working group in early 2019, the availability of emission-free NRMM has greatly increased in the European market - especially in the Nordics. Electric solutions for smaller machines (<2.5 tonnes) and handheld tools are generally available across the EU today. Large construction machine manufacturers and importers are increasingly publishing timelines for development and market release of emission-free models.

While there is increasing availability of emission-free options across Europe, as demonstrated by projects and pilots under way by members of the working group from Helsinki, to Barcelona, to Oslo, to Berlin, there is still more progress to be made. Industrial production lines for the heavier pieces of NRMM is required both to meet the growing demand, and to contribute to lower prices over time.

Transition fuels, such as biodiesel, are an option for public authorities who wish to reduce their reliance on fossil fuels. The use of biodiesel is reflected in the ambitions of the working group published in the Joint Statement of Demand whereby signatories commit to "requir[ing] fossil-free construction machinery in own public projects from 2025 [...] where available".

The working group has had numerous discussions with key industry players, including CECE, which have provided valuable insights into the overall direction of travel of the sector. In addition, the role that public procurers play in technological developments has been acknowledged by the market as shown in the quote below. It is clear that the interaction between buyer and supplier is a critical element in the transition to new fuel sources for NRMM.

"CECE believes in and strongly supports the transition to low or net zero CO2 energy carriers at acceptable costs for construction machinery. The sector and the equipment types are varied, complex and require multiple solutions for different situations, most of all in relation to machinery size and jobsite location. This is why CECE believes that no single technology can adequately provide decarbonisation for all conditions of jobsites. To that end, in our numerous interactions with the Big Buyers Initiative's ZEMCONS group, we have always shared the industry's decarbonisation roadmap, which is driven by innovation, incremental developments and market needs. In light of this, we have welcomed the role of public procurers in identifying and setting long-term CO2 reduction targets and lead by example in creating occasions of market dialogue with OEMs and CECE as their representative industry association."

Riccardo Viaggi, Secretary General of CECE, European Construction Equipment Manufacturers Association

Technological developments

The sector has seen rapid recent development of technologies in the past years, both in technologies designed to support non-fossil and electric NRMM, but also development of this machinery itself. Work carried out by the Bellona Foundation recently summarises the progress of machinery. Its online database shows the products available from various manufacturers, and its report entitled "Zero Emission Construction Sites Status 2019" presents a snapshot of the market, the technological challenges and policy solutions at the time of its writing.

Even in the intervening years further developments have been made and are summarised here. As part of the Big Buyers project, members of the working and followers groups have had the opportunity to engage with manufacturers through market engagement events to learn more about the advances that are being made.

Firstly, hybrid cable-battery systems are widely acknowledged to be a key part of the solution for the electrification and decarbonisation of construction sites. This technology has the ability to address the issues of peaks in energy demand (peak shaving), reducing the maximum demand for electricity at any given time while also enabling the use of electric machinery and ensuring minimal disruption to construction activities.

The hybrid cable-battery system is not the only way of using technology to ensure continuous power and to peak shave. Removable batteries and battery swapping are methods of achieving the same result. Power hubs on site also allow for peak shaving and can lower power costs by taking from the grid when costs are lowest.

Technologically similar, there is also the more traditional electric battery technology for large machinery which is most akin to the technological advances seen in the electrification of cars and other small personal transport modes. This solution requires greater capacity to that required for cars, but developments in battery technology are making this increasingly feasible.

Hydrogen solutions (combustion or fuel cell) can either be in the form of on-board H2 or as gensets for recharging battery or cable electric models. Hydrogen technology for construction site machinery is slightly further behind compared to applications such as road transport. This is largely due to road transport battery technologies being more developed and the fact that many hybrid vehicles are retrofitted. Ballard, one of the leaders in hydrogen technology, believes that its solutions are most applicable for fleets that start and end the day at the same

depot, such as buses and waste collection vehicles. It therefore recommends hydrogen gensets to power battery electric vehicles on site as an entry point to the use of this technology for construction applications.

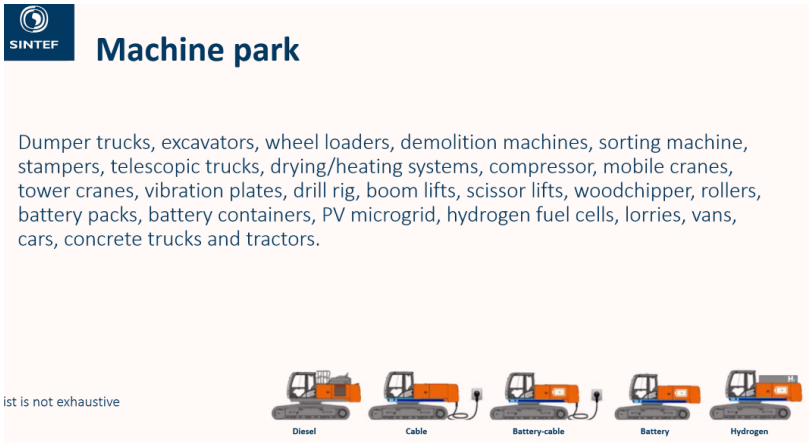

Figure 2 - Examples of Machine Technologies available

For further information on the availability of zero-emission construction machinery, see the Bellona Foundation's **Emission-free NRMM Database**, also available to sort by type of machinery.

Currently, there is no overarching policy at EU level that addresses greenhouse gas emissions from non-road mobile machinery and equipment, as it is not included in the Clean Vehicles Directive. The European Commission's latest NRMM Stage Requirements (Stage V, 2019) addresses carbon monoxide (CO), total hydrocarbons (HC), oxides of nitrogen (NO_x) and particulate matter (PM), but does not set limits for CO_2 emissions. There is potential for NRMM to be included in the recast of the Energy Performance of Buildings Directive (EPBD). Without a clear regulatory mandate at the EU level, suppliers are forced to await a clear signal from big buyers to demonstrate reliable demand for zero-emission NRMM solutions. For example, while The Netherlands is working hard to stimulate the uptake of clean and zero-emission mobile machinery, this is one of the big obstacles it faces. As the group evolves, it is clear that a focus on the enabling framework that would support the zero emission transition will be valuable to many members. It is expected that this work would look at European, Member State and Local levels.

4. Engaging market actors

For any highly innovative product or service, public procurers stand to benefit greatly from entering in dialogue with potential suppliers early on in the procurement process. Dialogues serve two primary purposes: First, they offer an opportunity for the public authority to clearly communicate their objective or ambition for the purchase, including any environmental or social targets, to the

potential tenderers. Second, they allow for the buyer to learn from market actors about availability and feasibility of requested products or services, including any potential issues with a particular criterion. Such a dialogue allows for public procurers to subsequently adjust and adapt their procurement approach, ensuring that there is sufficient market readiness to allow for fair competition and that their desired outcome can be achieved (or if not, scaling back to one that can).

Market innovation such as development, manufacturing and operation of emission-free construction machinery require substantial investment from market actors. To de-risk their investment, construction companies and machine manufacturers depend upon a clearly communicated signal of demand and transparent engagement and tender evaluation process from procurers. Approaches to market engagement can also be done locally, to see about the availability of emission-free NRMM and willingness of construction contractors to work with it, as well as to see if there is sufficient market readiness to use emission-free machinery as an award criteria or minimum requirement. Speaking with suppliers and contractors can also illuminate any potential changes to risks and responsibilities that could facilitate an accelerated piloting or uptake of these solutions - for example, if the public authority makes themselves responsible for the power supply needed to run electrified machines, or facilitates the interaction between the tenderers and the utility company providing the grid connections on-site.

The types of market actors relevant to a zero-emission construction site include primarily:

- **Construction contractors** - who will operate machinery to carry out the construction works. Contractors typically have numerous subcontractors, and may either have their own fleet of machinery or rent it for a specific job.
- **Machine suppliers** - who facilitate retrofitting conventional machines to emission-free standards, import internationally manufactured models for national markets, or rent equipment out for specific job sites.
- **Power providers** - typically utility companies with grid connections in urban areas, or potentially innovative on-site power hubs to store and shave peaks. Power must be de-risked to the extent possible, with the construction contractors and machine providers having confidence in the capacity to fuel the on-site equipment to peak performance in a clean and reliable way.

Market engagements can be made with actors from each of these types to ensure there is open dialogue on allocated responsibilities and capacity to mitigate risks. Additional involved actors may include a monitoring system (particularly for first pilots) or technology providers to optimise logistics and planning of machine use and recharging.

Since February 2020, Copenhagen has led a network of like minded public and private parties in the whole Danish value chain around a common ambition to move towards fossil- and/or emission free NRMM. The forum now consists of 60-70 key market actors. The purpose of the 3-4 sessions a year has been to facilitate common knowledge sharing between buyers and the market, making the market aware of forthcoming aspirations and opportunities, and giving the market the chance to present innovations in the sector. All relevant agendas around the introduction of fossil- and/or emission-free NRMM can be put

forward and external parties have been invited to present reports and findings of relevance.

This forum has helped Copenhagen as a buyer by being able to share possible new procurement demands and methods to the market before being introduced, during use and after to present evaluation to all. The other public as well as market actors and institutions have responded very positively to the forum and its relevance to promote the fossil- and/or emission free agenda. It has been beneficial for them to have knowledge about future demands, and to be able to comment on these to be ambitious but not too ambitious. Besides this, it is of common relevance to have an informed common knowledge sharing forum for all to participate in to share and learn about how to best promote this agenda.

5. Strategic public procurement - practical approaches

As the Working Group has developed, the following approaches have been taken by various members to incorporate their Zero Emission objectives into procurements. In the following section we set out the theory and provide examples of how these have been practically applied by the working group member.

1. ***Set ambition, align with organisation's strategies***
   For Zero Emission construction site goals to be realised, the ambition of the city/buyer organisation officers has to be matched at the political level. While the ability and extent of implementation will depend on the funding available to the city, officers will need to demonstrate that there is a clear link between broader climate and environmental objectives, and Zero Emission Construction Sites which can be used as a tool to achieve these goals.

In the Netherlands, Rijkswaterstaat the Dutch Directorate-General for Public Works and Water Management, developed a Circular Carbon Neutral Procurement Strategy 2050 which includes various pathways to achieve Zero Emission construction activities.

The inclusion of this in the strategy affords it political approval and ensures that all elements of the administration have a common goal to work towards.

2. ***Find out what is possible/ available with an early market dialogue***
   In such an innovative market, the scene changes quickly and is heterogeneous across European territories. It is therefore imperative to

start with a survey of what is possible and a communication of what ambition the contracting authority has. Dialogues are also an opportunity to uncover potential shifts in roles and responsibilities in comparison with a conventional construction site - so bringing together machine suppliers, construction contractors and power providers early on can avoid costly problems later.

Through this phase of the big buyers initiative, many of the Working Group participants have used market engagement activities as a way of determining what solutions are readily available in their region.. The purpose of this market engagement is not to limit ambition solely to what is currently practical, rather to highlight those technologies that can instantly be specified and identify areas that are being, and need to be, developed.

In Helsinki, for example, switching to renewable HVO diesel was shown to be a straightforward task, so too making the transition to using electric handheld tools. In addition there have been a number of pilots using smaller (4-5 tonnes) electric machines, but bigger machines are not currently available in Finland. In this case, market dialogue has been shown to be an effective tool for enabling Helsinki to begin making readily available changes, as well as identifying future developments that should be monitored until they are available in Finland.

3. ***Select appropriate pilot site***

   It has been found to be vital to choose the appropriate project to use as a pilot for zero emission contraction machinery. These pilots are very visible demonstrations of the benefits that a shift away from diesel and fossil fuels can bring. However, wrongly selected or implemented, they pose the risk of being a high profile failures and threaten political buy-in. To avoid this, appropriate sites and scopes of pilots are required.

Pilot Project at Olav V's Gate, Oslo.

To achieve its goal of a reduction of greenhouse gas emissions by 95% compared to 2009 levels by 2030, there are specific targets for emission reduction. By 2025, all construction sites on behalf of the municipality shall be emission-free (including also biogas). The upgrade in Olav Vs gate was a pilot project for zero emission site operation, and is an important step towards the transition which must come to the construction industry. Since construction began in September 2019, the site operation on Olav Vs gate has mainly utilised electrical machinery. Some processes required traditional machinery in order to ensure the necessary quality, such as the welding of membranes. Overall, the electrical machines perform equivalently to the diesel-operated machines, but produce both less noise and no on-site exhaust pollution.

By using electric construction machines, the project has saved 35 000 litres of diesel and 92 500 kg of CO2 equivalents (CO2e), compared to the use of regular machinery. The pilot project proved that using electric construction machines, in this case, is possible for almost all operations.

The electric excavators have overall proved to be the most successful of the machines, as these have performed equally to their diesel-operated counterparts. Provided there is a system for charging during any breaks, as well as during lunch and night time, the battery capacity is sufficient to function a full working day. Additionally, the reduced noise levels enable better on-site communication, which in turn improves health and safety for the labourers.

The project also utilised electric wheel loaders. These performed adequately at lightweight tasks, but for heavy loading and lifting, they were insufficient. The project therefore utilised a wheel loader operating on Hydrotreated Vegetable Oil (HVO) diesel 100 throughout the project period for the heaviest tasks.
There are several reasons why Olav V's gt was chosen as a good pilot project site for emission free construction:

- Centrally located, visible project – a busy street in the centre also requires special concern toward the public and the neighbouring businesses operating during the construction phase.
- Turning a car based street into pedestrian street – climate friendly construction fits well into the overall intentions of the project. In the lower part of the street there was also planned an innovative charging station for electric taxi cabs in Oslo, fitting well into this picture.
- Good access to electricity grid and other infrastructure.
- Oslo's general requirements were quite new and in need of practical use and testing, which made a good timing for choosing Olav V's gate.

(scale, location, complexity) E.g. reasonable size and complexity of works to set you up for success, public visibility and strong grid connection.

4. ***Secure (clean) power supply***

   The transition to Zero Emission Construction Sites requires the progressive use of cleaner and cleaner power supplies. Power could come from a variety of non-fossil fuel sources, in which case the sustainability credentials need checking as well as local distribution network and price stability, or from electricity. In the case of electricity, factors such as grid capacity and machine loads need analysing, as does the appropriateness of batteries for storage of extra power for recharging and peak shaving. The final option is hydrogen to which due consideration of safety for storage on site should be made, and whether gensets or in machine fuel cells would work best.

   All options have their advantages and disadvantages, ranging from how ready to use the technology is, to safety and appropriateness for a certain task or site. Through a range of market engagement exercises as part of the Big Buyers Initiative, ZEMCONS big buyers met with some of the key players in each technology operating in Europe.

In the case of Olav V's gt, electric machines were selected, as Oslo is a city with a well-established electricity grid, and Norwegian electricity is almost exclusively fuelled by hydro power, which ensures a very low carbon footprint, also in a life cycle perspective. The availability of machinery in the market was also an important factor, determining the choice of technical solutions and energy carriers.

5. ***Draft procurement documents & Get feedback on approach - from market and/or other experienced buyers***
   Ensure you're aligned to EU best practice and learn from others' experiences by getting feedback or basing your procurement criteria on tested ones. Evaluation and contract performance monitoring are also important to get right - to be fair, should be based on actual machinery use (not just allocation to the site) and on avoiding most contaminating models (large, diesel machines). Important to consider tradeoffs and balance among quality and all environmental criteria - including beyond ZEMCONS - and to set the award criteria weighting right to get market movement.


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6. ***Pilot procurement***
   Moving directly from fossil fuel powered construction sites to zero-emission ones is not a route that any members of the working group has taken. A clear lesson is that proof of concept through pilot projects is an important step for cities and public authorities. In this regard, the working group members shared their tender documents among themselves to enable procurement of pilot projects.

7. ***Measure and evaluate success***
   Zero-emission construction is still in early days - all data collected stand to greatly improve the collective understanding of how to best optimise energy use, plan for logistics around recharging and cabling of electric models on-sites, and to continue to build the case for how reduced noise and local air pollution make sites safer for construction workers and neighbours. Especially important to monitor lifecycle costs and economic indicators of emission-free machinery.

8. ***Identify barriers and adjust approach***
   As with all developments, surely there will be lessons learnt that can help to revise, adapt and improve the approach for the next contract. Barriers can be mitigated through collaboration with market actors and other public buyers. The initial barriers identified were related to the availability of electric machinery which was much less prevalent when the group first formed. While this issue is still very much real, particularly outside of the Nordics, significant work has been undertaken to engage with the market

and give a clear demonstration of predictable future demand, particularly through the development and signing of the Joint Statement of Demand.

As time went on, other issues came to light which, if unaddressed, may become barriers to the widespread adoption of zero emission construction sites. Broadly, these can be categorised into two groups, both of which will make good topics for future market engagement and knowledge building activities. Firstly, outstanding technical challenges related to a move towards electric or other zero emission fuels. These may include the availability of hydrogen as a fuel, and how it can be safely provided to sites, or ways in which operations can be structured so as to avoid overloading the city's electricity grid. Some work was done ((supported by the SINTEF report)) to consider peak shaving tactics, but more work with energy providers would likely benefit all members of the group, especially as ZEMCONS sites become more numerous and widespread.

Having an enabling framework to support individual cities and public authorities to implement more zero emission construction sites will also be key. As with other topics, this is an area where members of the working group have a range of experiences and are at different levels of development. As the group's work develops further, understanding the role that politicians and policy makers play, and understanding how the group can contribute to decision making will be vital in promoting

9. ***Embed emission-free NRMM into procurement strategy***
   To really reap the benefits of emission-free works and see accelerated market movement, embed ZEMCONS criteria into your standard construction contracting approach. The availability of emission-free NRMM models regionally as well as willing/ experienced contractors will respond notably to such a commitment from a big public buyer.

From fossil-fuel to near zero emission in only three years
The Agency for Water and Wastewater Services in Oslo started rewarding zero emission and biogas technologies (vehicles and machines) in construction work tenders from 2019. In only three years, they have seen a great shift in the bids. Today, Oslo water and wastewater construction sites use 80 % zero emission construction machines. More than 90 % of the dump truck transportation (mainly gravel, dirt and demolition waste) use electricity (47 %) or biogas (45%). The total amount of waste transported is around 500.000 tons a year.

6. Impacts of emission-free construction sites: cost and socio-environmental indicators

Construction activity is a huge contributor to greenhouse gas emissions of a city, and as a result, reducing these emissions can support wider climate ambitions and strategies.

As an example, in 2021, the City of Oslo saved more than 20 000 tonnes of CO2 from diesel used in municipal construction works (schools, kindergartens, nursing homes, road-, water and sewage infrastructure etc.), through electrification and sustainable biofuels. This is comparable to emissions from more than 10 000 fossil fuel based private cars.

This is a fantastic example of the carbon savings generated as a result of the transition away from diesel fuels. However, the benefits do not stop there. Local air quality, intrinsically linked to the type and quantity of tailpipe emissions improves, so too does the level of noise and particulate matter pollutants. As a result, the health and safety impacts of being on site for construction workers is reduced.

Future work will undoubtedly need to consider some of the trade offs associated with the technologies so far explored. For example, how can public procurement be used to minimise the social and environmental impacts of batteries, and how can contracting authorities address the embodied carbon impacts of retrofitting a diesel vehicle which may still have a significant operational life left.

An increase in cost may be assumed as a result of applying more stringent environmental criteria to construction site procurement. However, this may either be thought to be higher than in actually is, or deemed to be worthwhile considering the benefits that such sites deliver to a municipality. In Helsinki, in 2020-2021, the additional cost resulting from the low-emission criteria of competitive infrastructure contracts (fossil-freedom and Stage IIIB and Euro V classes) was on average 0.53%, or about 230,000 euros.[2]

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2 //efaidnbmnnnibpcajpcglclefindmkaj/https://www.theseus.fi/bitstream/handle/10024/751754/Luoto_Juuso.pdf?sequence=5

7. Outstanding challenges for procuring emission-free works

To transition from pilots to emission-free as standard practice on European construction sites, the following outstanding barriers must be addressed:

- **Limited availability of certain large electric NRMM, or limited awareness of large electric NRMM** and yet unknown potential of hydrogen. This causes high prices for equipment and more risk in planning and project management. Crucially, the availability of large electric NRMM varies significantly across Europe. In some countries availability is no longer the biggest barrier to implementation of emission-free works, but in others it certainly is.
    - This is a topic that the working group has focussed heavily on, undertaking 4 rounds of market engagement with manufacturers of numerous emerging technologies.
    - The Joint Statement of Demand signed by some members of the group and other committed public buyers aims to increase the availability of NRMM that can deliver on Zero Emission objectives, and to address the challenges of unpredictable demand. In short, these buyers, with budgets exceeding €4,5Bn, will procure Zero Emission construction projects and therefore have a clear need for machinery to enable this.
- Market actors depend upon **predictable demand** in order to invest in green innovation. To address this, procurers can link their purchasing strategy to a construction emission transition timeline, in line with the relevant climate action and carbon targets.

    - Procurers are increasingly making the link between their carbon or environmental strategies and policies, to the role that the construction sector can play. A great example of this is from Rijkswaterstaat.

    - In addition, the signing of the JSoD by a significant proportion of the Working Group, and wider sector indicate clearly the desire of public authorities to use non-fossil and zero-emission machinery. This is intended to reassure the market that demand will be there once machinery is consistently rolling off production lines.

    - The Finnish Green Deal[3] is another fantastic example of a group of public procurers joining forces to demonstrate a clear demand for machinery which can enable zero emission construction sites.

- **Optimisation of energy use and logistics on-site** is required to avoid excessive peak demand and unnecessary wastes of energy. Changes such as using mobile power hubs with large battery storage to limit drawing from the grid in peak hours, adjusted working hours to include machine charging breaks, or organising works to avoid unnecessary movement of machines across large sites or minimising excavation by design can help to save energy.
    - This poses a new challenge to procurers, project managers and for construction providers. It is vital that the operation of sites is structured in such a way as to smooth out the demand for energy as much as possible. As with most challenges, this has both technological and systematic solutions, for example using batteries or restructuring the working day.

- **Power supply** is key for a good business case. Power supply must be a priority and well-considered before selection of a pilot site. For instance if you are building an apartment building which will have garages that need EV chargers, you can bring the power for the construction site because ultimately this will be needed for the final product. The same is not necessarily true for a bridge being constructed in a remote location. In the procurement of a project, the appropriateness of the technology to deliver the works must be considered.

- **Charging infrastructure** requires cross-sectoral collaboration, and may compete as a priority with other renewable electricity system upgrades (e.g. district energy and stable residential supply). This may be increasingly less of a problem as EV charging infrastructure becomes more extensive, and renewable solutions decentralise supply.

- Capacity building of the **construction workforce** is needed for contractors to operate new machines - for example, for planning on-site logistics with consideration of charging cables and timetables.

[3]https://hnry.fi/en/emission-free-construction-sites-green-deal-agreement-for-sustainable-procurement/

- There is a need for an optimised on-site **data collection** methodology and benchmarking framework to evaluate the performance and success of emission-free construction sites. Though there are limited LCA studies on certain machine models, the proof of business case is not fully developed yet, and therefore conclusive documentation of pilot cases is crucial.

The relevance of these challenges varies across European regions. For example, in some countries, the electricity grid is largely decarbonised and clean and sufficient urban power supply is relatively feasible to secure. In areas with stronger public buyers networks regionally or nationally to align and advertise joint demand, there is more market movement to increase availability of emission-free NRMM.

8. Outlook & Recommendations for Europe

Zero-emissions construction sites may have seemed unattainable just a few years ago, but the market is moving very fast to make the necessary innovations. The transition is gathering speed, with a growing number of ambitious public buyers committing to emission-free construction in the form of a Joint Statement of Demand authored by the group. Knowledge exchange platforms such as the Big Buyers Initiative build capacity of public procurers to strategically leverage their purchasing power for innovation and sustainability. Nonetheless, construction is a notably conservative sector, and the change in market supply (e.g. to industrial factory production of emission-free NRMM models) relies on a stable and sizable demand.

The members of the Zero-Emission Construction Sites working group call on other contracting authorities to commit to action on reducing emissions and cleaning up construction sites, as only with aggregated demand can the necessary market innovation be accelerated. As described above, multi-level governance to support this transition will necessitate strong political support and dedicated financing to get pilots off the ground and thereafter normalise the approach across an organisation. To pave the way for others to follow suit, knowledge transfer mechanisms and capacity building can leverage the strategic purchasing power of public authorities. Finally, EU-level regulation on carbon emissions from construction machinery would undoubtedly accelerate market innovation and extend uptake of emission-free NRMM solutions.

The European Commission and national governments can support this agenda with dedicated:

- ***Research***

Research can contribute to further optimisation and scaling of emission-free NRMM. Technologies that enable large emission-free construction machinery, and especially use of many large electrified machines simultaneously on a site, are still in a research and development phase, with a need for greater testing and optimisation before becoming widely commercially available. Further research is especially needed for: (1) clean and peak-shaving power storage and provision on-site, (2) monitoring of operational emissions and noise levels of conventional

versus fossil- or emission-free machinery in different application contexts, (3) whole-life environmental and health impact assessments (including battery and machine sourcing, manufacturing, and end-of-life), and (4) digital systems to better plan and optimise machine use and logistics in construction works, to minimise energy demand.

- ***Funding***

Dedicated funding is needed at this early stage in the transition. At an EU-level, funding for collaboration platforms and knowledge exchange can greatly increase the dissemination and uptake of innovative approaches to procurement of emission-free construction works as piloted by cities like Oslo, Copenhagen, and Helsinki. Funding is also needed to build capacity of public procurers and enable demand aggregation (e.g. funding networks). Nationally or regionally, funding can be used to set up industry exchanges for furthering dialogue between key market actors like machine manufacturers or importers, construction contractors and local governments. Innovation funding can be used to support the ongoing Research & Development to develop high-performing emission-free machinery and power solutions, to better optimise machine use/ charging and site logistics, and to monitor economic and environmental impacts of emission-free sites.

- ***Policy & Regulation***

Environmental impacts of construction works can be incorporated into policy initiatives relating to the whole-life carbon agenda for the built environment, and transition pathway for a green and digital construction industry. Consideration of construction and buildings' embodied emissions (going beyond operational energy use) are increasingly incorporated into the European Commission's policy packages. Examples of this include Level(s), Construction Products Regulation, the recast on the EPBD, or the revision of the Green Public Procurement criteria for buildings. However, emissions from construction machinery represent a relatively small proportion of a building's whole-lifecycle impacts in comparison to other elements like material manufacturing or heating and cooling systems. While policies for whole life carbon of the built environment are very welcomed, they are not sufficiently targeted to accelerate a market shift for emission-free construction machinery.

Specifically for emissions on construction sites, the NRMM Regulation's Stage Requirements have been a key driver for reducing local air pollutants. Future stage requirements should work to reduce CO2e (which is currently left out of this regulation) and wholly eliminate acceptable air pollution from combustion engines, to usher in a clear market transition to emission-free machinery. It is expected that a regulatory mandate, would greatly speed up the production and availability of emission-free NRMM. Timely action is key, and in particular if NRMM regulation is linked to embodied carbon emissions for buildings, we cannot afford to set them far into the future. If no pollutant is tolerated from combustion engines, transitioning to fully electric vehicles will become the most economically viable option, rather than installing particle filters.

Annex: Additional resources

- BB ZEMCONS joint statement of demand
- BB ZEMCONS factsheets
- Bellona Factsheet on ZEMCONs
- NTNU? Market engagement guidance
- SINTEF Reports: Impact assessment and Survey
- Clean construction declaration - C40 Cities
- Clean Construction Policy Explorer - C40 Cities
- **Emission-free NRMM Database** - Bellona Foundation
- **Climate and environmental requirements for the City of Oslo's construction sites** - City of Oslo
- **Perspectives on Zero-emission Construction** - Climate Agency, City of Oslo
- **Reports** on the status of zero-emission construction in Europe - Bellona Foundation
- **Scandinavian Green Public Procurement Alliance on Non-road Mobile Machinery: Lessons Learned Report** - SGPPA

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Big Buyers for Climate & Environment

This guidance is based on the experiences and expertise of the members of the Big Buyers working group on zero-emission construction sites, active since May 2019. The Big Buyers Initiative is a European Commission platform for promoting collaboration between big public buyers in implementing strategic public procurement. By working together to aggregate demand and jointly approach market actors, public buyers can maximise their market power and impact, promoting the creation of new solutions more targeted to their needs.

ICLEI Europe and EUROCITIES are currently running the initiative on behalf of the European Commission, DG Internal Market, Industry Entrepreneurship and SMEs (DG GROW).

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