ZERO EMISSION CONSTRUCTION SITES

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ABOUT BELLONA

Bellona Europa is the Brussels-based branch of the Norwegian Bellona Foundation, an independent non-profit organisation working on the environmental, climate and social issues of our time. We aim to identify, promote and help implement realisable solutions for the protection of nature, the environment and health. To achieve these goals, Bellona continues to work with – and against – relevant actors and stakeholders both nationally, and internationally.

OUR ORGANISATION
Bellona was founded in 1986 in Oslo, Norway, as an environmental action group. Still headquartered in Oslo, we have since expanded with offices in Brussels, Murmansk and St. Petersburg. Our team consists of about 65 employees with diverse professional backgrounds in communication, engineering, ecology, economics, geosciences, law, physics, and political and social sciences.

SOLUTION-ORIENTED APPROACH
Our solution-oriented approach to climate issues follows the evaluation of existing options, assessment of associated challenges and promotion of identified solutions. Supported by the breadth of knowledge and skills of our experts, Bellona follows a holistic, trans-sectoral approach to assess the economics, climate impacts and technical feasibility of possible climate options.

COMMUNICATION AND COOPERATION
The challenges of climate action are complex and involve multiple influential actors and stakeholders; from national and supranational governments, to internationally operating billion-dollar companies, and the people living in respective regions and countries. To ensure collective action takes place and in the interest of society and the climate, it is crucial to retain open channels of communication. Bellona does not shy away from, and indeed seeks, the exchange with polluting industries, as well as civil society, academia and governments. We believe that the process of finding solutions to pollution from industries that are currently essential to our economy and the standard of living needs to involve them. Bellona is engaged on several platforms, where we aim to initiate discussion and fuel debate to identify the realisable climate solutions we need. We work jointly with scientific institutions on several European research projects, and follow close relationships with fellow climate NGOs across the globe.

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“Electrification is one of the most important solutions globally to cut emissions, use energy more efficiently, and create better cities. Zero emission construction sites fit perfectly in this picture. It is also a sector where public developers through their procurement can have a massive impact. Back in 2016 we started a collaboration with a municipal developer in Oslo to cut emissions from construction. Three years later we have the first site in which all machinery and equipment contribute zero emissions.

The progress over these few years—technological, operational, and political—has been astounding. It is now clear to see for all in this market that zero emission technology is the way forward.”

Frederic Hauge, Founder and CEO of The Bellona Foundation

“Cities and citizens can benefit from Zero Emission Construction, through improved air quality, less noise and a better environment for construction workers. There is a strong case for clean and healthy construction in cities. Oslo works together with C40, Bellona and many others to forward clean construction.”

Heidi Sørensen, Director, Climate Agency, The City of Oslo

“Construction is too often overlooked in the context of emissions globally. In Europe specifically, as this report shows, the industry is both a significant component of the region’s economy and a substantial source of greenhouse gas emissions, alongside other environmental impacts. For me, this represents a huge opportunity: electrification in this sector is not just transformative to how building sites operate, but is rapidly becoming possible.

The key to making zero emission construction sites a reality will be collaboration between industry, government, and city officials. Working together to share examples of success and to establish the framework for future projects is how we will close the gaps that currently exist on the path to electrified construction. That’s why, at Cummins we work hard to develop the best technology for the market.”

Julie Furber, Vice President – Electrified Power, Cummins Inc.
Construction is a key industrial sector, yet climate change and air pollution are critical threats to be addressed, with severe warnings from scientists. The construction industry therefore needs to evolve and contribute towards the shift to a sustainable society. Conventional methods currently contribute to both climate and air pollution. But it doesn’t have to be this way.

Innovative zero emission technologies are being developed for all sectors, including the construction sector. While a decade ago it might have been unthinkable to assume that anything bigger than a car would be electrified, technological development has defied expectations and brought solutions to a sector in desperate need for innovation. Electric construction machinery, powered by batteries or fuel-cells, offer substantial benefits to the climate and to human health, amongst a range of other benefits.

However, the availability of models is lacking. There is no demand for zero emission machinery and they are more expensive upfront. Public procurement is helping to change this, with the city of Oslo taking the lead. Large public buyers such as cities have the power to create demand for these machines, which present a benefit to the wider environment and to their own citizens. Setting ambitious, predictable targets for the reduction of emissions from construction sites is a way to encourage suppliers to innovate and develop this new market for zero emission construction machinery. Using their large procuring power, buyers can and should set climate demands in their tenders. This way we can ensure a better future for all.
INTRODUCTION

Construction plays a key role in society by maintaining and building new infrastructure, housing, offices, and public spaces. With global populations expected to increase to 8.6 billion and 9.8 billion by 2030 and 2050 respectively, and with major infrastructural changes to made in the meantime, there is little doubt that construction activity is set to increase. Meanwhile, atmospheric greenhouse gas concentrations are rising to alarming levels and emissions need to fall rapidly in order to keep global temperature increases below 1.5°C, in line with the Paris Agreement. In addition to this, increasing impacts of air and noise pollution on human health are exacerbating the need for a technological shift away from fossil fuel combustion. As such, it is important that an industry which plays a major role in the transition looks at how it can decarbonise itself.

The global construction industry contributes 23% of the world’s CO2 emissions across its entire supply chain. 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.

Construction machinery is essential in any construction project and it is vital that we find solutions to continue to use them without endangering the lives of workers, citizens and future generations. While the current stock of machinery is polluting, new and clean technologies are rapidly emerging and public buyers, such as cities, can play a key role in encouraging the development and deployment of these machines.

Using their vast public purchasing power, cities can create a new market and push manufacturers, contractors, and suppliers to adopt new technologies and methods to enable the construction industry to continue its vital work, without damaging our environment.

This report will propose definitions which can be adopted by contracting authorities in their public tenders and in statements, to provide further clarity. It will also set out the impacts of current machinery, due to their noise, air pollutants, and GHG emissions. There will be an outline of what cities plan to do to address the impacts of construction machinery. Market advances, drawn from public statements, will be listed to demonstrate that zero emission machinery exists and that contracting authorities should feel comfortable in setting ambitious environmental criteria in their tenders. The report will outline current EU policy developments on the topic of construction machinery emissions, to illustrate what the outlook for policy is likely to be in the coming years.
This report focuses on the machinery and equipment which is operated within the boundaries of a construction site. These machines are predominantly powered with the combustion of fossil fuels. There are many different parts of the construction sector which require decarbonisation efforts; however, the operation of construction machinery has thus far received relatively little attention.

The goal of this report is to enlighten all stakeholders involved in the construction industry as to the impact of conventional machinery and the benefits and opportunities of a technological shift to zero emissions. The hope is that this report will galvanise the support of big buyers such as public authorities and major contractors and change their procurement methods and operations so as to encourage the uptake of zero emission construction machinery and equipment.
DEFINITIONS

The following definitions should be adopted as widely as possible to reduce confusion and ensure a clear and succinct dialogue.

**Zero Emission Construction Site:**
A construction site in which construction activities are carried out exclusively with zero-emission construction machinery or equipment, and all transport of goods and people to and from the site using zero emission vehicles. The providence of the energy carrier is not included.

The terms Zero Emission and Emission Free can be used interchangeably. To avoid confusion, this report only refers to Zero Emission.

**Zero Emission Construction Machinery and Equipment:**
Machinery or equipment which does not emit pollutants at the point of use. The providence of the energy carrier is not included.

These tend to use electricity or hydrogen as an energy carrier. The providence of the electricity or the hydrogen is not included in this definition. It will of course be necessary to also work on electricity to come from renewable sources and for hydrogen to be produced with additional renewable energy.

**Zero Emission Construction Logistics:**
The transport of goods and people to and from the site using zero emission vehicles.

As a contract, the term fossil-free construction site is also used in some projects. We define this in the following way:

**Fossil-Free Construction Site:**
A construction site which construction activities are carried out without the use of fossil fuel.

Generally, fossil-free is used for operations where conventional diesel fuel is replaced with biodiesel or biogas, fuels not of fossil origin. These cannot be termed zero emission fuels as the combustion of biofuels result in air pollutants being emitted locally.

In addition to construction machinery and logistics, materials are a major contributor to the carbon footprint of construction. Even though materials are in scope for this report, we include the definition below for further discussion.

**Net-Zero Carbon Construction Materials:**
Construction material with close to zero direct or indirect CO₂ emissions.

For more information on the decarbonisation of construction materials please refer to our report ‘Industry’s Guide to Climate Action’.

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1 The reason for not including electricity production emissions is that the focus here is on emissions from the demand-side. In the transition towards a zero emission society based on renewable energy it is paramount to develop zero emission solutions on the supply and demand side simultaneously.
EMISSIONS FROM CONSTRUCTION SITES

The climate crisis is gaining in intensity at an alarming rate. Recently, the UK’s Met Office confirmed that all 10 of the country’s hottest years have occurred since 2002. The IPCC has produced several Special Reports in the past couple of years outlining the urgency and necessity of reducing emissions. In the meantime, the Arctic is facing increasing temperature anomalies, with the European Space Agency measuring anomalies of up to 13°C compared to the 1981-2010 average. In light of the increasing manifestation of anthropogenic impact on the climate, it is time to radically reduce greenhouse gas emissions. The best time to reduce emissions is yesterday, the second best time is now. This means every single activity which emits GHGs needs to contribute towards this global effort to prevent climate breakdown. This of course includes the emissions from construction machinery.

The European Union estimates that 100 MtCO2e are emitted annually from Non-Road Mobile Machinery in Europe. This includes construction machinery, inland waterway transport, railcars and locomotives, and agriculture machinery.
There is varying information about the exact GHG emissions of construction machinery. This section outlines the existing literature to provide a better picture.

Only 16 of the EU’s 28 Member States report the specific emissions from construction machinery, with Italy and France the most significant omissions from the statistics. Yet according to their emission inventories, construction machinery in these 16 EU countries emitted 20 MtCO$_2$e from construction machinery in 2017. This is higher than the total emissions of 5 EU Member States: Slovenia, Luxembourg, Cyprus, Latvia and Malta. Not all countries report this data, therefore actual overall emissions of construction machinery in the EU is certainly higher. Countries not reporting their emissions are Cyprus, Czechia, Estonia, France, Greece, Ireland, Italy, Malta, Poland, Portugal, Romania and Slovakia. Extrapolating from known emissions, the estimated total emissions of construction machinery in the EU are almost 40 MtCO$_2$e. This is higher than 8 EU countries. This would mean construction machinery also emits more than Croatia, Estonia and Lithuania. The data is available in the annex.

A DNV GL report commissioned by Oslo’s Climate Agency, estimates that between 120 and 240 Mt of CO$_2$e come from construction sites in the C40 cities. The Greater London Authority reports that in Greater London alone, construction machinery accounts for 150 000 tons of CO$_2$.

A study for Volvo’s Construction Climate Challenge estimates that 25% of the carbon emitted from infrastructural projects in Sweden comes from fuel consumption. This would include both transport of materials, as well as the operations on the site.

Several academic studies have been made to assess the environmental impact of machinery in construction. One study looking at the construction of two skyscrapers found that the foundation phase requires the most intense use of machinery, since much of the work requires earthmoving equipment. During this phase of a project, it is estimated that 19% of GHG emissions come from equipment use. This would imply that the foundation phase of a construction project requires specific attention when it comes to planning for the reduction of emissions from machinery. The carbon footprint of machinery during the foundation phase amounts to approximately 51kgCO$_2$e/m$^2$. This concurs with DNV GL, which finds that 37kgCO$_2$e/m$^2$ is emitted by machinery during an entire construction project.
According to the European Environmental Agency, air pollution is the most significant environmental factor affecting human health. In the EU, approximately 400'000 people die prematurely due to air pollution every year. The World Health Organisation estimates that every year 4.2 million people die prematurely around the world due to air pollution. PM is known to penetrate deep into the body via blood vessels, causing cardiovascular, cerebrovascular, and respiratory diseases. There are also increasing concerns, without conclusive evidence as of yet, over ultrafine particles (UFPs) which penetrate even deeper into the body than larger particulate matter. This is to say that potential effects of air pollution are likely to extend beyond what we currently measure and understand.

However, we already know that air pollution is a major health risk. Air pollution disproportionately affects young and old citizens who are more sensitive to air pollutants, and poor and marginalised communities, who are more likely to be exposed to air pollutants. It is also important to note that air pollution can be very localised. Similarly, to being exposed to noise, air pollution can be short and intense, or mild and extensive.

Long-term exposure to relatively mild levels of air pollution can still have harmful long-term effects on human health, just as short-term exposure to high levels of pollution can have immediate effects. The WHO makes it clear that, despite setting recommendations for pollution limits, there is no such thing as a 'safe level' level of exposure to air pollutants, since any exposure is negative to human health. The WHO states:

“The lower the levels of air pollution, the better the cardiovascular and respiratory health of the population will be, both long- and short-term.”

Critically, air pollution is a burden to public health systems, which do not receive funding or compensation from those responsible for emitting air pollutants. While it is very difficult to quantify the exact costs, this is a clear violation of the “polluter pays” principle, which is a fundamental aspect of the European Union’s treaties. It is essential that the public health crisis resulting from air pollution be addressed by tackling the root cause, namely by eliminating emissions of air pollutants.
Construction machinery is a significant contributor to air pollution, particularly in urban areas where air pollution is already a problem. Much like conventional road vehicles, the combustion of fossil fuels to power the machinery results in the emission of air pollutants, particularly, NO\textsubscript{x}, CO, and PM. In recent years, efforts have been made to address this, for instance by enforcing emission standards and mandating the use of filters. However, it is impossible to eliminate the emissions of air pollutants whilst burning fossil fuels. As such, while construction machinery continues to be fuelled in such a way, their use will continue to impact the health of citizens, particularly of workers on the site and of people working or residing nearby. The Trades Union Congress lists the following occupations as those most exposed to diesel exhaust: professional drivers, including buses, trains, lorries, fork lifts, tractors and cars, those who work in warehouses, garages, construction workers, seafarers, underground workers, maintenance workers, and anyone who is in an enclosed space near a diesel engine, such as administrative staff. In the UK in 2005, the Health and Safety Executive found that each year more than 230 construction workers die from cancers caused by exposure to diesel fumes, the highest amount of all the sectors examined.

In London, 9% of PM\textsubscript{2.5}, 4% of PM\textsubscript{10}, and 6% of NO\textsubscript{x} emissions come from the exhaust fumes of construction machinery. Amsterdam estimates that 10% of NO\textsubscript{x} and 4% of Particulate Matter concentrations are due to construction machinery. As cities become increasingly aware of air pollution impacts and turn to ‘Low Emission Zones’ and alternatives to conventionally-fuelled transport, construction machinery has remained relatively unregulated. They are frequently omitted from Low Emission Zones, which regulate the access and operation of vehicles within designated areas. In fact, the International Council on Clean Transportation warns that, in light of increasing legislation and efforts to clean up road vehicles, the share of emissions coming from non-road machines is likely to increase and “become the dominant source of air pollution in the world.”

Due to the emissions of air pollutants, conventional machinery is used in a restrictive way when work must be carried out indoors. Using such machinery in tunnels and basements, for example, often requires multiple operators working in shifts, so as to avoid overexposure to dangerous air quality. Switching to zero emission machinery therefore provides an added benefit to contractors and workers, who may use their equipment more efficiently and in more applications.

Thankfully, cities are catching on and looking into how they can reduce air pollution from machinery. More information about city initiatives is available on pages 21-29.
Exposure to noise is a general health hazard in the workplace. Hearing loss accounts for approximately 10% of compensation for occupational diseases in the European Union. Tinnitus is a common hearing dysfunction resulting from prolonged exposure to noises. Some impacts on hearing can be the result of prolonged exposure to ‘ear-safe’ levels of noise. This is obviously the case of construction workers, who are in the near-daily presence of machinery producing loud noises of various sources. This can impact cardiovascular function (hypertension, changes to blood pressure and/or heart rate), changes in breathing, annoyance, sleep, physical health and mental health. A study on the impact of construction noise in Beijing estimated that the social cost to the city is around €2 million for large projects, primarily due to sleep disruption. This did not include further economic impacts on local businesses such as hotels and restaurants, which can expect reduced income if they are near noisy construction sites.

Noise can also affect the operations on the construction site. Difficulty in communicating as a result of noise often leads to operator mistakes. Due to the exposure to noise, workers are often required to wear protective headgear to reduce their exposure. However, the EU OSHA states, “fatal accidents have been reported that involved backup manoeuvres on construction sites, even when the vehicles had functional sound alarms complying with current regulations”. While regulations do their best to reduce the impact of noise, the fact of the matter is that the full extent of the impact cannot be avoided and efforts must be made to reduce noise from construction sites as opposed to measures to adapt to it.

**HOW MUCH DOES CONSTRUCTION MACHINERY CONTRIBUTE TO NOISE?**

**Impact Noise**

Noise from impact can occur from the use of jackhammers, dump trucks, drilling machines, piling machines, cement cutters, electric saws, tamping machines and welding machines, as well as hand tools such as sledgehammers and drills. These machines also produce vibrations which can also affect human health. Impact noise tends to come in repeated short bursts lasting several seconds. At latest assessment, the noise from impact occurring from construction operation cannot be avoided and is not within the scope of this report. Unfortunately, construction sites will always be noisy to some degree due to impact noise.

**Engine Noise**

Noise from the engine is usually lower than impact noise. The United States Federal Highway Administration lists the noise levels of various types of construction machinery, both impact and non-impact. Most measurements for non-impact machinery lie within the legal noise range for the EU, which is set between 80-85dB. Nonetheless, despite being compliant with legal requirements, as noted above, prolonged exposure to noise also affects human health. Unlike impact noise, engine noise is constant, which presents a health hazard when exposed for long periods of time. Wearing protective hearing gear is necessary in these cases, which helps mitigate the health impact, but makes communication more difficult and can increase the likelihood of accidents and damage.
BENEFITS OF ZERO EMISSION CONSTRUCTION MACHINERY

1. GHG Emissions Reduction
2. No Direct Air Pollution
3. Less Noise Pollution
4. Lower Running Costs
5. Opportunity for EU Innovation
REDUCES GHG EMISSIONS

Firstly, zero emission machinery has substantially less GHG emissions than conventional machinery. Using average OECD carbon intensity of electricity production, emissions of electric equipment are approximately 40% lower than diesel machinery over its lifetime. With renewables expected to become the dominant form of power generation over the next decades, lifetime emissions will continue to fall. Unfortunately, the climate impact has been severely overlooked in legislation and has left the sector without guidance or the political need for innovation to address this. In the context of the climate urgency in real terms, and the Paris Agreement and the EU’s climate goals in political terms, it is clear that the GHG emissions from construction machinery must be eliminated as quickly as possible. While zero emission machinery is not yet strictly zero emission along the whole lifecycle, it already presents emissions and energy savings when compared to machinery using an internal combustion engine. The efficiency of the electric powertrain and the reduction of emissions from the energy sector therefore make zero emission machinery viable technologies to address the emissions from this necessary activity. Furthermore, in conjunction with lower emissions in the production of electricity and hydrogen, it is possible for construction sites to be zero emission along the entire supply chain. It is critical to note that efficiency improvements in diesel engines will never result in zero emissions.

NO DIRECT AIR POLLUTION

Secondly, there is no direct air pollution from the use of zero emission machinery. This presents obvious benefits to both construction workers, which are highly exposed to conventional diesel fumes, and to the general population, which is increasingly exposed to and aware of the health risks of air pollution. An added bonus of this lack of air pollutants is that the equipment can be used indoors, such as tunnels and basements, with much less restrictions than conventional machinery. This improves workers’ health as well and opens new possibilities for the use of equipment.
LESS NOISE POLLUTION

Thirdly, zero emission equipment produces significantly less noise and vibration. All manufacturers of zero emission machinery advertise substantial reductions in these areas. This again reduces the impact on workers’ health and reduces nuisance to those living and working in the vicinity. Less noise opens up the possibility of working at night time if necessary and is conducive to a much better living environment for all involved. Noise from the engine is significantly reduced when changing the powertrain. A video of the world’s first zero emission construction site, in Oslo, showcases the silence of electric machinery. The YouTube show *Fully Charged*, which reviews electric vehicles, tested a JCB 1-ton electric excavator and emphasised the low noise levels of the machine. JCB confirmed on the show that a ‘beep’ noise was inserted at ignition because otherwise operators would not be able to tell that the excavator is on. Indeed, noise at the operator station is reportedly 10 dB less than the diesel version. Exposure to 85dB can cause permanent damage to hearing, whereas the impact below 75dB is negligible. Reducing the noise of construction machinery and equipment can have a positive effect on the operations on-site, not only by reducing the likelihood of operator miscommunication and subsequent accidents, but also improving the wellbeing of construction workers. Reducing the noise of a construction site presents a benefit to society as a whole, by improving work conditions, reducing noise-induced health impacts, and ensuring a better environment altogether.

Credit: Felix Features
LOWER RUNNING COSTS

The evidence suggests that a shift from diesel to electricity provides much lower operational and maintenance costs. This shift will reduce dependence on oil, thus insulating contractors from the high volatility of oil prices while also reduce oil imports and improving energy security. Annually, the EU spends around €17 billion a month on energy imports. Furthermore, electricity as a fuel is cheaper and the motors are more efficient at transferring the energy into motive power. These machines also have fewer moving parts and require less maintenance, avoiding the need for oil changes and replacing air filters. For this reason, it is assumed that electric machinery has 50% longer lifetime than diesel machinery. A 25-ton diesel excavator consumes approximately 284,000 L of diesel. Depending on the price of diesel and of electricity, an electric 25-ton excavator produces fuel cost savings of between €100,000 to €240,000 over the lifetime of the machine.

OPPORTUNITY FOR EU INNOVATION

The development of new technologies for construction machinery opens up an opportunity for the EU to take the lead in the innovation of the sector. Many large manufacturers already exist and need to adapt to the future economy. Doing so sooner rather than later is essential and delaying such a transition will only damage EU industry. The European car industry has infamously delayed action on climate change and is now paying the price, with future estimates banking on US and Chinese firms to take the lead. As such, the EU currently has the opportunity to be a first-mover in this field and ensure that it remains a global leader when it comes to the manufacture of construction machinery.
Zero emission equipment is not yet perfect and arguments are made against their use: they are still more expensive to purchase than diesel machines; the energy supply to the site needs to be sufficient to provide the extra power for the machinery; there aren’t as many models available on the market; contractors do not yet have the experience to operate this machinery. However, these challenges must be overcome to enable the construction industry to contribute to a sustainable future.

Public authorities can play a key role in overcoming these challenges by using their financial muscle. The substantial amounts of money they spend on construction projects can be used to reward sustainable and innovative practices. Using public procurement as a tool for innovation has gained traction in the EU, and construction is a prime sector for this. The purpose is to create large market demand for products which are not yet fully commercially viable. Public authorities can use their role as a large buyer to set targets for the market to comply. They can also shoulder additional risk and spend a little extra money, for the sake of helping to develop or test a solution.

It is suggested that new zero emission equipment is approximately 20-30% more expensive than a new conventional machine, while retrofitting of some machines can be about 3 times more expensive. The high capital cost is a substantial barrier to the uptake of zero emission technologies. This is largely due to the high price of batteries and smaller economies of scale. Nevertheless, as battery prices continue to fall and as global production ramps up to meet increased demand, the upfront cost is likely to fall as well. With large buyers issuing demands for zero emissions, manufacturers will inevitably comply.

The practicalities of deploying electric equipment are still being discovered. At this stage, one construction site in the world is fully operated by zero emission machinery. Progress is being made on this front, with several cities in Europe expressing interest in developing pilot projects, which will provide valuable lessons on what to do and what not to do when operating a zero emission construction site. These pilot projects are a key step in this transition. Quantifying the energy needs of electrifying the machinery and finding the best business model to encourage contractors to switch to zero emissions are important steps.

Nevertheless, public buyers can already incorporate zero emission equipment into their tenders which will provide visibility to the issue and already send a message to the market that emissions must be considered. Providing a bonus to tender applications which plan to use zero emission machinery will encourage contractors to use them as a way to get the edge over competitors. Changing the tender criteria altogether is an even better way of internalising external costs, such as air, noise and climate pollution. Using the Most Economically Advantageous Tender (MEAT) criterion is a way to ensure that other aspects such as pollution, quality of the work, social and innovative characteristics are included in the assessment. The city of Oslo has successfully implemented these criteria. More details on this are available below.
The Big Public Buyers Initiative is a platform for promoting and enabling collaboration between big public buyers on strategic public procurement to help drive the market for innovative goods and services. The main aim of the initiative is to enhance the uptake of strategic public procurement in Europe through partnerships with public buyers. The project is run collaboratively by ICLEI and Eurocities, who both have access to an extensive network of cities.

In this initial pilot phase, one of the three working groups is dedicated to ‘Zero Emission Construction Sites’, or ZEMCONS. The goal is to discuss the best available information, share best and worst practices, and look at ways of cooperating together. In the short-term, the Working Group plans to engage in a market dialogue and issue a joint statement of intent: that participating cities will go for zero emission technology on their construction sites by a certain date. This joint statement of intent will provide a strong signal to market players that in order to compete for large public tenders, such as those of large European cities, the use of zero emission machinery and equipment will be necessary in the near future. This should act as an incentive for early movers to accelerate their efforts and for laggards to react and catch up, applying much needed pressure on the sector to innovate.

This working group is primarily led by Copenhagen, Helsinki, Oslo, and Stockholm. Other European cities have expressed interest in the progress that has been made on the decarbonisation of construction machinery. These include, Amsterdam, Brussels, Budapest, Lisbon, Nantes, Trondheim. This list is set to grow substantially as more and more cities join the call for zero emission construction sites.

A notable outcome of this project is the facilitation of a market dialogue to help contracting entities and potential tender bidders understand how they can reduce emissions from construction site machinery.

Membership to all working groups of the Big Buyers Initiative is open to any large public buyer and Bellona encourages those interested to join. More information is available here: http://www.sustainable-procurement.org/big-buyers-initiative/

The C40 Mayors Summit, taking place in Copenhagen in October 2019, will act as the first Pan-European market dialogue on the topic of ‘Clean Construction’ between public buyers and market players. This event will provide a setting for cities to jointly promote the idea reducing emissions from construction sites, while allowing the relevant market players to express their concerns and showcase their latest technologies and solutions.
In the current political climate, cities have become the leaders of the global movement towards cutting emissions. Cities can influence around 70% of the world’s emissions and are home to 75% of Europeans. As such, they play a key role in the sustainable energy transition. Organisations such as C40 Cities, ICLEI and Eurocities are taking large steps towards decarbonisation and are creating better environments to live in. Aiming to protect citizens from noise and air pollution, several cities have established Low Emission Zones (LEZs), where urban access for some polluting road vehicles is restricted or deterred. As of 2019, there are 250 LEZs in the EU.

Zero Emission Zones (ZEZs) go even a step further, banning all internal combustion engine vehicles including hybrids. In ZEZs only all-electric vehicles and fully electric public transport is allowed, making walking, and cycling in these zones a more pleasant experience. Up to now only an Ultra-Low Emission Zone (ULEZ) has been introduced in London (see below), which will hopefully encourage other cities to follow the lead and establish LEZs, ULEZs and even ZEZs in the near future. While LEZs are generally confined to road vehicles the next step to ensure the wellbeing of city dwellers would be to include other sectors which are big emitters into these zonal regulations.

Several cities are coming to grips with the negative climate and health impact of conventional construction equipment. In this section we list the European cities which have made and will continue to make significant progress in striving towards reducing emissions from construction sites.
Oslo is very much a leader when it comes to Zero Emission Construction Sites. As a first-mover on the topic, the decisions that the city takes are likely to set tone for all future efforts to decarbonise construction sites. Cities will seek to learn from Oslo’s best practices and mistakes, and will shoulder less economic burden as a result of Oslo’s willingness to take a risk. The impact of Oslo’s work is likely to be reproduced in other cities around the world.

In the Norwegian capital, emissions from construction vehicles and machinery account for 7% of total emissions. In the meantime, the city also plans to reduce emissions by 95% by 2030 – one of the most ambitious climate targets to date – which is why the city is working on reducing emissions from public and private construction sites. As a first step, Omsorgsbygg Oslo KF, Oslo’s municipal developer for building kindergartens, nursing homes, fire stations and emergency rooms, among others, took the lead in 2016 - in collaboration with Bellona - and set a public procurement standard for its tenders, aiming for fossil-free construction sites. This change required a relatively simple adjustment for contractors: switching from diesel to biodiesel. As a result, all new construction procured by Omsorgsbygg was set to this standard, demonstrating the role of using procurement standards to push the market towards cleaner technologies. This change was so successful that the city of Oslo set fossil-free construction as a minimum requirement for all public works in the city, to reduce GHG emissions.

The shift proved too simple for Omsorgsbygg. Over the course of 2016 the conversation shifted from fossil-free towards zero emissions as a target, and Omsorgsbygg developed a new criterion for all tenders: “What can be run electric, shall be run electric.” As there were few electric solutions available this criterion had little immediate impact – however, it was certainly taken note of in the market. Several more market dialogues were held in 2017 and 2018 to prepare the market for the public procurement of zero emission solutions. And in 2018 both municipal developer Omsorgsbygg and Oslo municipal agency Bymiljøetaten unveiled plans for the procurement of a zero emission construction site. The street upgrading project of Bymiljøetaten started 2 September 2019 (see p.24)

**CHANGES IN 2019**

Based on the efforts in the two announced pilot projects, Oslo municipality decided to revise its procurement policies. In line with their 2030 targets, Oslo has decided to push the market further and ask all future construction projects to use zero emission machinery and vehicles. In 2019, tender requirements were changed to reflect this. The plan will ensure emissions reductions from construction projects, ensure predictability, and ensure innovation and market development of zero emission machinery. As of October 2019, all of the city’s publicly procured construction projects will have a minimum requirement for fossil-free construction. However, by 2025 all of Oslo’s public construction sites will operate zero emission machinery and zero emission transport of materials and workers to the site. This is a significant step, which demonstrates the city’s commitment to making zero emission construction sites a universal reality and sends a clear signal to market players that they must work on developing new solutions before their competitors if they want to win any public tender put forward by the city.
CHANGES IN 2019

Furthermore, Oslo’s construction budget is not-insignificant 10 billion NOK a year (1 billion EUR a year). Norwegian companies are already feeling the pressure; failing to comply with these standards will mean missing out on extremely large projects. This has resulted in several new machines being developed, simply due to this change in procurement rules. For projects worth 50 million NOK (5 million EUR) or above, the minimum requirement is zero emission heating and drying equipment, mainly used for drying concrete. For projects worth 5 million or above, contractors which specify the use of zero emission machinery and/or heavy duty vehicles are given a ‘bonus’ when it comes to the award criteria.

Oslo has recently changed the criteria for which to evaluate the contractors, providing additional weighting on environmental criteria. The new requirements adopted by the City Government imply that the evaluation of a tender application awards environmental performance:

GUIDELINES:
The award criteria for Environment shall as a minimum have 20% weighting for building and construction competitions (as a main rule, the Environment criterion should be weighted 30%). Minimum 50% of the total weighting for Environment shall be attributed to construction machinery and transport to/from the building/construction site. This only relates to the sub-criteria related to the award criteria for Environment, comprising direct emissions from building/construction machinery and transport in connection with building/construction work, and which shall represent minimum 50% of the award criteria for Environment, which in turn shall be weighted as minimum 20% of the entire weighting.

The other sub-criteria under the award criteria for Environment may, for example, relate to greenhouse gas emissions from production of materials (LCA/EPD), geographic location, the building’s energy consumption, measures to prevent acute pollution during construction, extra protection of biotopes, greenhouse gas estimates for the entire life cycle or other relevant factors for the building/construction project in question.

If there are no plans to add on further environmental requirements, the environmental requirements for building/construction work may be assigned a higher weight.

In situations with strict minimum requirements on the environment, such as requirements for zero-emissions construction sites or strict minimum requirements on the building’s environmental performance throughout its life cycle, the award criteria for Environment may be assigned a lower weight or ignored.

Figure 1: Information Source: Oslo Klimaetaten
This change in procurement methods for construction projects affects many different departments of the Oslo government. All of Oslo’s municipal undertakings and agencies, for example Omsorgsbygg, the Municipal Undertaking for Social Service Buildings; Oslo Havn, the city’s port authority; Boligbygg, the Municipal Undertaking for Social Housing; Kultur og idrettsbygg, the Municipal Undertaking for Cultural and Sports Facilities; and Undervisningsbygg, the Municipal Undertaking for Educational Buildings and Property, must abide by the new rules. These organisations are collectively responsible for a large share of the city’s construction work, which is expected to be worth well above 1 billion EUR a year for the next 4 years. The regulation also states that from 2025 all construction work commissioned by the city should be zero emission, and this is included as a formal contractual requirement in all contracts from 2019 onwards. The new regulation provides ample proof to the market that the city is serious in its mission to tackle emissions from construction sites and that the market will need to develop solutions to be able to compete for these valuable contracts. Bellona has partnered with manufacturers and the Oslo City Council within the so-called pilot-e projects to produce zero emission diggers, concrete mixers, and pumps. The use of electric diggers in Oslo is expected to save around 100,000 tons of CO2 every year. Veidekke, a construction company, estimates that replacing a conventional 25-ton excavator with an electric model reduces emissions by roughly 52 tonnes of CO2 a year. A Swedish study estimates that the production of a 300kWh battery needed for such a machine would emit about the same as using a conventional excavator for a year. There is a complementary project for zero emission transport of cement from the production facility to the refining facility. As such, collaboration between local policymakers, industrial actors, and civil society is helping to develop innovative technologies to comply with Oslo’s procurement standards.

THE WORLD’S FIRST ZERO EMISSION CONSTRUCTION SITE

OLAV V GATE: CASE STUDY

On the 2nd of September 2019, Oslo initiated the world’s first zero emission construction site after several years of planning. The project, run by Bymiljøetaten, Oslo’s Agency for Urban Development, to pedestrianise a section of the street was chosen for its ideal location and high visibility, one of the city’s most used streets and near the National Theatre and City Hall. The requirement for an entirely zero emission site, set by the tender, was purposely beyond what the market could offer at the time. Nevertheless, the suppliers came through and delivered 4 electric machines to operate on the site, 3 powered by batteries and 1 powered directly through an electrical cable. The equipment used to supply energy is regular. The cable-powered machine requires more current than the battery powered ones.

Olav V Gate Simulation; Credit: Bymiljøetaten
The tender process for the Olav V Gate project was split into several processes. A critical aspect of this procurement was that before publication of the tender, the Agency engaged with several suppliers to inform them and gather information on the available technology. Secondly, through a dialogue with four different contractors they determined which machines were needed. The market research revealed that these machines could be delivered, but that the availability was limited and the lead-time could be up to six months. Subsequently, a tender was published for the procurement of zero emission machinery and agreed a concession contract with a rental company that would acquire the machines from the suppliers, such as NASTA. The concession contract allows for these machines to be used in construction tenders. The tender for the construction project was published on the basis that the machines from the first tender be used in the project. In this way, the development of the equipment was expedited and the contractors had no choice but to operate the site on zero emission machines.

Given this is a pilot project, the tender is somewhat unusual. The contracting agency is footing the energy bill and ensuring the electricity is available. Since there is a lack of information about the exact energy requirements of operating a full site with zero emission machinery, this helps reduce the economic risks for the contractor and provides vital data for all future projects. Since the site eliminates the consumption of fuel, this acts as an extra incentive for the contractors, who may be wary of operating a site in unfamiliar circumstances. This also means the contractor does not need to worry about providing the right amount of energy to site. Of course, the city acknowledges that this is not a sustainable model but is an essential step in understanding how to properly operate a construction site without emissions. It is assumed that once more data is available on energy consumption, requirements and costs, and contractors are more familiar with operations of such a site, the city will proceed with issuing tenders in a more conventional way.

NASTA worked in cooperation with its partner Hitachi to develop electric construction equipment, in the knowledge that these machines will be necessary to compete for Oslo’s extensive construction project in the very near future. Hitachi developed the ZE85 electric excavator with Kiesel and the ZE160LC with NASTA, both of which are being used for this innovative project. The other electric machines used on the site are a Kramer 5055e, and a Caterpillar 323F Z-line.
AMSTERDAM

Amsterdam’s final draft of the Clean Air Action Plan aims to bring the whole city to zero emissions by 2030. Regarding mobile machinery and generators for construction, Amsterdam is investigating how it may eliminate emissions by 2025. The city is planning on reducing emissions from mobile machinery such as diggers and excavators by setting low-emission criteria in tenders and awarding contracts which show sufficient ambition. In the future, the city of Amsterdam plans to investigate the possibility of banning diesel generators in certain areas, and other ways to encourage the use of clean machinery in construction projects.

BERLIN

The German capital expects ‘substantial construction activities’ towards 2050, with a population growth of about 250 000 people. Furthermore, due to the city’s efforts to improve energy efficiency in buildings, Berlin wants to increase the rate of renovation from 1%. Meanwhile, in a survey run for the city 28% of respondents were concerned about the pollution coming from construction sites.

Indeed, 4% of the city’s PM10 comes directly from construction NRMM exhaust. Therefore, the city plans to require Stage V machinery as a minimum from 2020 onwards. Yet there are no plans to go beyond this towards zero emissions. The upcoming Clean Air Plan for the should look into how to eliminate emissions from construction machinery.

COPENHAGEN

Copenhagen expects to grow by nearly 110 000 people by 2025 and has put its focus on the energy efficiency of buildings throughout their existence rather than the construction process. Through mapping, the city has discovered that procurement of craft such as construction and maintenance and the facilities’ management is responsible for half of the CO2-emissions coming from transport. As part of its climate strategy to become climate neutral by 2025, the city has committed to build all new municipality buildings and to renovate existing buildings according to low energy principles. A low energy building is characterised by having an energy-efficient design and technical features allowing it to maintain living standards with low energy. The city mainly focuses on new building’s energy consumption to be as low as possible by setting the right requirements. The fulfilment of these requirements will be also taken into consideration when giving construction permits.

Copenhagen is also a leading member of the Big Buyer’s Initiative, and hosted the first Pan-European market dialogue on Clean Construction. At the C40 Summit in Copenhagen, Jørgen Abildgaard from the City of Copenhagen announced that the city aims to be fossil free by 2023. The city’s climate plan states that it “is prepared to participate in demonstration projects in the area of construction” and will implement procurement strategies with a focus on the construction sector. Suppliers should be ready to adapt to likely upcoming changes and look out for opportunities to participate in potential pilot projects.
**HELSINKI**

The city is one of the fastest growing in Europe and is planning to invest vast sums of money on new construction. The Real Estate Strategy will look at how the city manages its own real estate. In the case of Helsinki, heating accounts for more than 50% of the city’s emissions. Therefore, in terms of construction and buildings, their focus lies on investing in energy renovations which have proven to reduce emissions by 80%. Currently, the city is finding ways to bring private house owners to renovate their houses. Helsinki has set a target for 2020 where 100% of the city’s procurement processes will include environmental criteria. For construction machinery, Helsinki is likely to change its tendering criteria, as expressed in its Carbon Neutral Action Plan, “In the emissions reductions of heavy traffic and machinery, the tendering criteria are key.” It is still unclear what these criteria will be and if this will be included in the Real Estate Strategy. However, it is likely that requirements will be similar to those of Oslo.

**LONDON**

Just like any other metropolitan city, air pollution is one of the major challenges London is facing. Construction machinery emissions in London are estimated to be 7% of NO\textsubscript{x} emissions, 4% of PM\textsubscript{10} emissions and 8% of PM\textsubscript{2.5}. As opposed to what one might think, more PM\textsubscript{2.5} emissions come from construction machinery exhaust than from construction dust. To reduce the construction sector’s impact on the capital’s air quality, the city has set limits on emissions coming from heavy duty vehicles for driving within the London Low Emission Zone (LEZ). To further tackle this issue, the city has announced it will establish an ultra-low emission zone in central London by 2020. Additionally, for the same year, there are a few regulations which will have to be followed by engines for 37kW-560kW on sites in London, which all target the final goal of having zero emissions from construction machinery throughout London by 2040. The city is planning on meeting these requirements by “re-organising non-road mobile machinery fleet and replacing equipment which does not meet these standards” amongst other.

The city lacks the direct powers to regulate the sector and has therefore only issued guidance on a NRMM Low Emission Zone. However, the guidance essentially reflects existing European legislation, with the addition of a zero emission target by 2040. The Mayor of London is working to increase enforcement powers and will seek to review its standards to deliver the largest possible improvements. With the information available in this report, it is clear that more can be done in the British capital.
PARIS

The city recently published its Climate Action Plan where they state construction sites and quarries in the Île-de-France region are responsible for 18% of PM10 particle emissions, 11% of PM2.5 particle emissions, and 3% of nitrous oxide (NOx) emissions in the region. The city plans to implement a Clean Worksite Charter supported by the French Atmospheric Protection Plan for all construction sites in the Paris area. Thus, project stakeholders can commit to reducing emissions from their construction sites by following the requirements. The city commits to reducing emissions from diesel machinery, without further stating how it plans to do so except for promoting the use of electric instead of diesel generators.

The city also has ‘accompanying actions’ to reduce emissions from construction sites. However, these are non-legal and are limited to the use of particulate filters. No plans are currently being made to fully eliminate emissions from construction sites.

ROTTERDAM

In Rotterdam, emissions from the transportation of construction materials are extremely high, accounting for over 95% of total emissions caused by the transportation of goods. Therefore, since 2015, Rotterdam has a sustainable procurement approach for construction materials based on the use of environmental product declarations (EPD's). Suppliers who can prove alignment with the EPDs, receive a reduction in the bid price. Rotterdam has done very necessary work in developing this form of green deal, giving the right sustainability framework for transport and logistic activities as well as setting low-emission standards for vehicles and machinery used in construction tenders.

ZÜRICH

The Swiss city is highest ranked city of the Soot Free Cities ranking when it comes to NRMM emissions management, a ranking which evaluates 23 European cities regarding the technical, economic but also sustainable transport measures they are taking to address air pollution. In terms of emissions from non-road mobile machinery the city is requiring large diesel-powered machinery to be equipped with a particle filter. This accounts for public as well a private construction sites. New construction machinery is only allowed to enter the Swiss market if they are in line with strict requirements. This falls short of Oslo and London which have both set clear targets for elimination of emissions. A revision of the city’s plans should include more ambitious plans for NRMMs.
Construction and plant machinery accounts for 5% of the city’s GHG emissions. In 2014, the city’s total energy consumption was 270 GWh, with diesel being 95% of the fuels used. As one of the pioneers in tackling emissions from NRMMs, Stockholm has been running a programme since 1999, where contractors are obliged to comply with certain environmental guidelines. In order to obtain an allowance to bid for a contract, machinery engines used for the construction project either needs to meet the specific emission standards or be retrofitted accordingly. In its Climate Plan, the city presented an action plan for using fossil-free fuel for the construction machinery which is used. The city plans to do through the procurement of transport and other services, setting criteria for environmental performance and encouraging the consolidation of goods. Stockholm’s target is for the construction sector to be fossil-free by 2040.

Nevertheless, a report commissioned by the city to plan the transition to fossil fuel-free machinery recommends a short-term switch to HVO. However, the report also states that this is not a long-term, warning of supply issues. Another finding is that temporary financial support of electrically-powered machinery is likely to lead to commercially viable technology once financial support is dropped. The report stated that the same would not be applicable for ICE machinery running on fossil free fuels. When looking at project costs, the report found that switching to a hybrid machine would only increase the overall cost of a construction project by 0.27%, despite the purchase price being 25% higher than a conventional machine, partially offset by lower operational costs.

**SUMMARY OF CITIES’ STEPS**

- Adjustment for contractors i.e. switching from diesel to Hydrogenated Vegetable Oil (HVO)
- Setting a minimum requirement for zero emission construction
- Giving bonuses for applying award criteria
- Giving environmental aspects a high importance when evaluating tender applications
- Developing a test project for a zero emission construction site
- Partner with relevant partners to develop zero emission machinery
- Collaboration between local policy-makers, industrial actors, and civil society
- Setting up low/zero emission zones
- Re-organising NRMMs and replacing machinery which doesn’t meet standards
- Requiring particle filters for diesel vehicles and machinery
- Requirements for market entry
- Reduction in the bid price for exemplary construction projects
- Building and renovating according to low energy principles
10 TIPS FOR CITIES TO MAKE CONSTRUCTION SITES EMISSION FREE

1. Set a clear goal that all the municipality’s own construction sites should be emission-free as quickly as possible, and no later than 2025
Clear targets allow contractors, suppliers, and rental companies to plan long-term, invest in zero-emission machinery and equipment, and avoid bad investment in fossil technology.

2. Invite stakeholders as early as possible to a dialogue, to discuss possible barriers and solutions
Perhaps it turns out that the solutions are more accessible than you thought.

3. Create a market for emission-free construction machinery
Use award criteria and promote the consideration of emission-free construction site when competing for construction and construction projects.

4. Ensure that the municipality’s plans, guidelines and framework conditions build up on the overall goal of emission-free construction sites
The goals must be followed up in strategies and plans when developing the municipality’s building stock, in planning processes, and in budget processes for new buildings and infrastructure developments in the municipality.

5. Clarify the project’s approximate energy and power requirements early on so that the energy supply can be planned and put in place early in the construction process
Involve grid companies, suppliers and contractors. Are there plans to invest in zero-emission infrastructure for transport in the area and can there be possible synergies? Engage in market dialogue if there is uncertainty about what the grid companies and the market can offer, and how to tender the contract.

6. Set technology-neutral requirements that encourage competition and innovation
Let the market compete to offer the best and cheapest solutions to make the municipality’s construction sites emission-free.

7. Relieve risk where possible
The municipalities should consider relieving risk from market players, until they gain more experience in zero emission construction. Predictable and long-term frameworks and goals are important. Think about how you can help make it easier for a business to get a stake in zero emissions.

8. Favour the ones who take that little extra step
Use the award criteria to favour those who go further. Provide bonus points to those who offer innovative climate-friendly solutions. Also think of smart planning of work tasks and logistics, and give smart solutions emphasis on the competition for the assignment.

9. Participate actively in forums where you can learn from other municipalities - and where they can learn from you
Build expertise, learn from own and others’ experiences. Participate in meetings arranged, under the European Commission’s ‘Big Buyers Initiative’, attend the C40 Mayors’ Summit.

10. Take the step - and follow up!

These tips were jointly developed by Bellona, EFO, Nelfo and the Oslo Climate Agency.
CURRENT POLICY ADVANCES

Given the urgency of climate action, it is clear that policy needs to play a role in pushing and pulling the industry towards methods and practices which are compatible with the aims of the Paris Agreement. The topic of construction site emissions is still in relative infancy compared to more salient issues, such as road transport. This means that there is no overarching policy at EU or national level which addresses this particular issue directly. Those policies that do touch upon construction machinery specifically do not do so sufficiently to address the climate and human health challenge.

In light of the European Commission’s strategic long-term plan to address climate change, with the aim to reach net-zero emissions by 2050, the EU is set to become a leader when it comes to progressive policy on climate change mitigation. However, there are still policy gaps in addressing the emissions from various economic sectors, one of which is the regulation of greenhouse gas emissions from Non-Road Mobile Machinery (NRMMs).

ENERGY TAXATION DIRECTIVE

The Energy Taxation Directive (ETD) sets minimum tax thresholds for various types of energy, such as diesel, petrol and electricity, with some notable exemptions in international shipping and aviation. The ETD has not been revised since 2003 and is now severely inadequate in light of the necessary technological and societal transitions which need to occur in the coming years, since the tax rates are to the detriment of electricity used for motive power. Due to the European Council’s decision-making process, which requires unanimity on tax matters, efforts to revise the ETD have stalled for the better part of a decade. However, a renewed sense of optimism has emerged from President-elect Ursula von der Leyen’s letters to her designated Commissioners for Climate and Transport.

Given the efficiency of electric motors in comparison to internal combustion engines, the shift to zero emission mobility and machinery would benefit from ensuring that taxes on electricity used as a ‘fuel’ are lower than taxes for fossil fuels used in transport. This would provide an additional incentive for a shift to cleaner technologies.
On the 13th of March 2019, the European Parliament approved a resolution calling of the European Union to be more ambitious when it comes to tackling air pollution. The resulting declaration, ‘Europe that protects: Clean air for all’ stresses the impact of air pollution on human health and that 90% of European city dwellers are exposed to “levels of air pollution deemed damaging to human health”.

The following key point is also made in the declaration

“Calls on the Commission to address emissions from construction site machinery beyond the NRMM Regulation by conducting an impact assessment on the potential of zero-emission construction machinery in cutting air- and noise-pollution levels, and moreover its possible inclusion in future revisions of relevant EU legislation;”

Therefore, the European Commission will need to produce an impact assessment, as stated above, which is a critical component of its legislative proposals. Bellona strongly supports this call and urges the Commission to act upon the European Parliament’s request. The impact assessment should also consider the contribution of zero emission machinery to climate mitigation goals to ensure coherence amongst environmental targets.

NRMM REGULATION (2016/1628)

The Non-Road Mobile Machinery Regulation is the most relevant piece of legislation at the European level on this topic. The EU has regulated NRMM emissions since 1997, with this legislative file being the latest and likely the last to regulate NRMM emissions in this way. Applicable since January 1st 2017, it serves to incrementally reduce air pollutant emissions from NRMMs, including construction machinery, with the intention of “stimulating innovation, improving air quality, reducing health costs and increasing life expectancy”. The NRMM Regulation only addresses carbon monoxide (CO), total hydrocarbons (HC), oxides of nitrogen (NOx) and particulate matter (PM), thereby ignoring the climate impact of fossil fuel combustion and the noise impact of internal combustion engines. On January 1st 2019, the regulation entered into its final phase, the application of Stage V emission standards for all sales, which vastly reduces the emissions of the gaseous and particulate pollutants listed above, namely by reducing PM limits by 97% and HC and NOx limits by 94% compared to the Stage I rules established in 1997 (Figure 2).

![Figure 2: Emission limits from Stage I to Stage V for HC+NOx and PM. Source: ICCT](image-url)
Despite this progress in regulating emissions, the omission of GHGs is a significant one. There is the possibility of a trade-off between reducing air pollutants and GHGs. This implies that the reduction of air pollutants from conventional construction machinery beyond a certain point may result in higher GHG emissions, which is counterproductive. Given the extent to which the NRMM Regulation pushes for reductions in air pollutant emissions, it is clear that the next logical step is to demand an elimination of pollutant emissions. However, this will require a technological shift towards different powertrains and fuels. Switching to a different combustion fuel, such as specific biofuels like sustainably sourced HVO and cleanly produced biogas, offers only a somewhat viable intermediate solution, but there are significant concerns relating to the impact on the environment and the scalability of such a solution. Electrification via fuel cells and batteries appear to offer the best alternative when it comes to air pollution and GHG emissions, with the added benefit of reductions in noise and operational costs.

Furthermore, while the latest stage of the NRMM Regulation is stringent on air pollutants, it is only applicable to new machinery entering the market as of January 2019. However, machinery tends be used for several thousand hours before being scrapped. Depending on the machinery type and the usage factor, machinery can continue to be used for the better part of a decade. As such, one would expect the market to be almost entirely compliant to Stage V requirements in more than 15 years. Without policy changes, those 15 years will see old machinery with lax emission standards continue to be used, while GHG emissions continue to go unregulated. As such, new policy regulating the GHG emissions of NRMM is urgently needed.

The NRMM Regulation is clearly inadequate to fully address the scale of the human health and climate challenge with which we are faced. It goes far, but not nearly far enough. There is a need for policies which both push and pull the market towards cleaner technologies, by creating a demand for clean machinery and curtail the production and use of ‘unclean’ machinery in line with Europe’s climate and air pollution goals. As such, Bellona calls on the relevant authorities at the city, regional, national and European levels to go beyond the requirements of the NRMM Regulation and implement strategies which reduce air pollutant and greenhouse gas emissions to zero. It is Bellona’s opinion that public authorities should use their procuring power and establish minimum environmental criteria that go beyond the NRMM Regulation, which is now standard. The NRMM Regulation is a base from which to build upon.
The Clean Vehicles Directive (CVD) sets procurement targets for public authorities in Member States to purchase “clean vehicles”. The revision of this Directive took effect on August 20th 2019. Once transposed into national law, the CVD will push public authorities to procure a certain percentage of their new vehicles in compliance with environmental requirements set out in the Directive. During the negotiations, Bellona pushed heavily for the inclusion of construction site machinery. In the absence of industry support and public awareness, this was not successful. However, the preamble states the following:

“By 31 December 2027, the Commission should review the implementation of Directive 2009/33/EC. That review should be accompanied, where appropriate, by a legislative proposal to amend that Directive for the period after 2030, including for the setting of new ambitious targets and the extension of the scope to other categories of vehicles, such as L-category vehicles and construction site machinery.”

As such, this gives a clear indication that after 2030, contracting authorities in the EU will likely be required to procure clean construction machinery. Nonetheless, given current trends in electrification and the urgency of climate action, such a delay is both unnecessary and unwarranted.

Therefore, Bellona urges Member States to go beyond the requirements of the Directives when transposing into national law. In transposing the Directive, as a minimum, national policy should provide a strong bonus to bids to tenders which plan to use zero emission machinery. At the project level, contracting entities and authorities should shape tenders so that contractors may compete on lowest possible emissions from construction activity, creating a direct link between investment in zero emission technology and better performance in bid evaluations. Additionally, they should consider setting minimum tender requirements for construction projects, such as the use of fossil-free machinery leading to zero-emission.
CURRENT MARKET ADVANCES

Several manufacturers have realised that the construction sector is evolving and are taking on new technologies which support the of transitioning away from combustion engines, much like the automotive industry. As such, a growing number of companies are developing electric machinery ranging from excavators to truck cement mixers.

HITACHI NASTA

The Norwegian Hitachi retailer Nasta has retrofitted a range of machines for electric drive. Most recently they have developed two battery-driven excavators, which can both be operated in battery or cable mode. The ZE19 mini excavator has a running time of 2.5h while the ZE85 compact excavator can be used for 4 hours straight. The on-board charger allows the excavators to fully charge in 1 to 2 hours, whereby the ZE85 also has a fast charging option, reducing the charging time to 45 minutes. The life cycle analysis of the excavators confirms that the amount of emissions is reduced by 40 tCO2 per year offering a significant advantage to conventional diesel models.

The ZE85 is the electric excavator which is being used at the first zero emission construction site in Oslo (see p.24,25).

PON EQUIPMENT

CAT, a global giant in the manufacturing business offers an array of machinery ranging from agricultural to marine machinery. The Norwegian CAT retailer, Pon, has taken a leading role, both in the CAT group and in the industry in general. Pon Equipment took it upon itself to build the first large-scale electric excavator, a 26-tonner with a massive 300kWh Battery that weighs 3.4 tons and lasts 5 to 7 hours. The extraordinary machine was even said to be the “Tesla of heavy construction machinery”. The Norwegian construction company Veidekke has been involved in the development, and has contracted for 8 excavators. Øivind Larsen, Veidekke’s construction director, said the single machine will reduce their CO2 emissions by 52 tonnes. In addition, Pon CAT has developed a kit which will allow retrofitting for other models. Pon has also stated the ambition to develop several new types of electric machines every year going forward.
Volvo is a leading international manufacturer of construction equipment and has announced to launch an electric range of compact wheel loader and compact excavators in 2020 which will replace diesel models entirely. At the bauma fair in Munich, Volvo presented its first commercial zero-emission electric compact excavator and wheel loader. The manufacturer claims that the new electric models deliver zero exhaust emissions, significantly reduce noise, energy costs and maintenance requirements while also improving efficiency.

The German manufacturer Liebherr has developed a fully electric concrete mixer truck which is now part of their construction machinery range. Both versions of the truck – hybrid and the fully electric- are capable of mixing and transporting all types of concrete and also show full flexibility for all drive types. Liebherr has recently developed the world’s first battery powered drilling rig. The LB16 has an operating time of 10 and a charging time of 7 hours and has the capacity to operate weight up to 55t.

At this year’s Bauma, Cummins also displayed a prototype mini excavator, which is powered by the newly developed Cummins BM4.4E flexible battery modules with 4.4 kWh each. The prototype is capable of charging in under 3 hours and operating a full work shift. The modular design can also be applied to other applications and duty cycles. Cummins sees an opportunity for more battery-powered excavators to be used in urban and sub-urban areas because of its advantage of eliminating emissions and reducing noise.
Suncar HK has developed three electric versions of Takeuchi excavators, the TB216E (1.6 t), the TB260E (7 t) and the TB1140E (16 t). They advertise 2.5 times higher energy efficiency, 90% less CO2e emissions, 50% reduction in ‘loudness’, 70% lower energy costs, and a run time of between 4-8h with 1h charging time.

Wacker Neuson has an array of zero emission compact construction equipment. The Munich-based company offers a range of products which are either hybrid or fully-electric. Wacker Neuson produce electric wheel dumper and electric mini excavator, both with integrated 180-degree seat rotation, and a battery-powered rammer. A key innovation has been the development of a battery which can be used to power 7 of their exhaust-free machines. This saves costs, storage space and logistical efforts, as changing the battery doesn’t require any specific tools nor much time.

Asia’s top construction equipment maker Komatsu developed its first zero-emission electric digger. The model has the proportions of a 4.7-ton mini excavator and uses the same battery as other Komatsu forklifts and can last up to six hours.

JCB has recently developed an electric excavator, which can also be used as a driller when replacing the bucket for a different tool. In the YouTube show Fully Charged, which reviews electric vehicles, the machine was tested. The presenter highlighter its low noise level, long battery life, and overall performance with very positive results.

Wierda Hybrid has developed an electric PTO which can be used for different purposes, depending on the application used. Despite the PTO being hybrid, the battery life is 5 hours meaning that it can be easily operated as zero emission. If the construction site has an additional requirement for zero emissions the PTO would have to operate on electric mode only.
Volvo has also started an initiative called "The Construction Climate Change" which aims "to promote sustainability throughout the construction industry value chain, from extraction and production of building materials, construction and utilisation, to demolition and recycling." Recently, the CCC started a research project, aiming to test the potential in electrifying the equipment in a mining quarry. This project saw a reduction in CO2 emissions of 95% as well as a reduction in overall costs by up to 25%.

The International Council on Mining & Metals has announced a plan to eliminate GHG emissions from surface machinery by 2040. The Innovation of Cleaner Safer Vehicles programme counts with the support of Caterpillar, Cummins, Epiroc, GE, Hexagon Mining, Hitachi Construction Machinery, Komatsu Ltd, Liebherr, MacLean Engineering, PBE Group, Sandvik Mining and Rock Technology. One of the goals of the programme will be to promote operational and technological innovation towards zero emission mining machinery.

Kuhn Schweitz retrofitted the eDumper, building the world’s largest dumper and EV in general. The machine is equipped with a regenerative braking system enabling it to charge when it drives downhill. This extends the periods between charges. In certain applications, the regenerative braking can prevent the need to charge altogether.

Another company which has specialised in retrofitting diesel machinery is Green Machine, a New York-based manufacturer of battery drive systems for construction and industrial application. They have replaced the regular diesel engine of the Komatsu excavator with a lithium-ion battery which matches the performance of the regular excavator while offering a 100% cleaner, 90% cheaper and 50% quieter operation.

In parallel to this report we will be releasing a catalogue on our website listing all currently available zero-emission construction machinery to our knowledge. The list will be periodically updated to provide buyers and contractors with a useful tool and to further encourage the uptake and development of zero emission machinery.
Zero emission construction sites depend on new types of machinery run on other energy carriers than diesel or natural gas. This means that the energy supply on-site must be replaced – but what this zero emission energy supply should look like is not yet defined.

It is almost certain that there will be a combination of technologies at work. Direct power supplied to a machine. Batteries, as buffers, and for tools and machines without cable. District heating, where this exists, to supply heat for e.g. drying out and hardening concrete structures. Hydrogen (H\textsubscript{2}) for use in fuel cells, which can supply both electricity and heat. Ammonia (NH\textsubscript{3}) as another and more efficient carrier of hydrogen. On top of these different energy solutions there must be some sort of coordinating system that enables smart operations and efficient use of energy.

Direct power, batteries, and district heating are today in regular use in construction sites – in small scale, for certain uses. At a zero emission site the scale is different. A mid-size excavator might require 100 kW in full operating mode. If a concrete truck arrives to pour concrete and hooks up to the energy supply, it may draw another 80 kW. A concrete pumping truck might draw double the amount. The challenge is to develop a system that fulfils the energy supply in all stages of a construction project, but does not overinvest in infrastructure, building more capacity than what is needed when construction is completed. Flexibility is paramount.

Certain technical questions need to be worked out – some general, some project specific. What kind of grid capacity is needed for the finished building? How can it be used most efficiently? How can batteries provide a buffer towards the grid, and what size must they be? What is the most efficient way of supplying major amounts of heat, when needed?

Then there are new roles and responsibilities, new interfaces. Who manages the power system, when it is integral to every operation on the construction site? Who handles the actual cable connections, when high voltages are involved? How are machines monitored and usage information handled? How deep can traditional power and grid companies be involved, and are there gaps where new roles need to be defined?

As the issue of energy supply is the easiest, most common objection to zero emission construction sites, a Bellona-initiated project aims to look into these issues. By gathering data from actual construction projects, and estimating energy demand for equivalent electric machinery, some issues and solutions may crystallize. The project group consists of Omsorgsbygg Oslo KF, Oslo Climate Agency, Elektroforeningen, Nelfo, Ramirent, and Hafslund Nett. Results will be published in a Bellona Brief.

Electric construction machinery operating in urban or sub-urban areas can more easily have access to charging spots. A solution for more remote construction sites are energy storage systems. Tangent, a UK based Energy Technology company, builds micro-grids for off-grid and grid-edge applications. The units which can include energy from renewable sources, diesel gen-sets and/or energy sources can also vary in size from between 10kWh to 100MW, depending on the site’s needs. The units can hybridise diesel generators but also micro grids which supply PV, gen-sets and batteries.
HOW WE GOT OUR DATA

Within the United Nations Framework Convention of Climate Change (UNFCCC), developed countries are obliged to report their GHG emissions on an annual basis, based on recommendations issued by the Intergovernmental Panel on Climate Change (IPCC). The IPCC gathers scientists across the planet to summarise the latest findings on climate change science, adaptation, and mitigation. A specific category, 1.A.2.g.vii, exists to report emissions from construction non-road machinery, which includes most types of construction machinery. Most EU countries report their emissions from construction machinery in this way, but some do not. Whether all follow the same methodology is not clear. However, the numbers below are a good indication of the emissions from the combustion of fuel for construction machinery. Estimates for GHG emissions from construction machinery is usually based on proxy information. The database is updated annually and numbers are often retroactively updated. The numbers below are current as of the date of publication. A positive step in the right direction would be for all emissions reporting authorities to account the GHG emissions from construction site machinery as a separate category and to use a similar methodology.

Cities tend to gather data by combining a top-down and a bottom-up approach. The top-down approach collects broad emissions data on a particular fuel type for instance. In the meantime, the bottom-up approach collects information on employment, machinery usage and emissions factors to determine when and where those emissions happened.
The data is taken from the UNFCCC’s detailed inventory.

*These countries do not report their emissions from construction NRMM in the designated category. Therefore, their emissions are estimated based on how much construction NRMM contributes to national emissions as a percentage. For sake of simplicity, the average share for is used (1.06%). The variables and unknowns mean this estimate is purely indicative.
BIBLIOGRAPHY


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