Real World Insights into the emerging discipline of Zero Emission Constructions

Emissieloos Netwerk Infra, December 2022

Who is ENI?

"Emissieloos Netwerk Infra" (ENI - Zero Emission Network Infrastructure) is a foundation with some 45 member organisations representing an ecosystem of front runners in the energy transition in the Dutch construction sector. We focus on heavy machinery (> 125kW) used in the infrastructure market and want to achieve acceptable (societal) costs for working emission free by 2026. Members of this ecosystem are construction companies, OEM equipment importers, ZE conversion companies, energy companies, ZE technology manufacturers, rental companies and financial services organisations. Commitment to investing in relevant technology as well as knowledge sharing is conditional to becoming a member of ENI. We maintain relations with government bodies, infrastructure purchasing organisations as well as industry associations, research institutes and other NGO's.

With this paper, we want to disseminate the experiences and insights that have been produced in the last two years to help parties in other countries to learn from those ZE pioneers. We specifically address the OEM manufacturer community, electricity utilities companies and public purchasers of construction works to take those valuable real-life insights on board. We tried to keep it short and simple, although this means to compromise on some nuances that must be made. Please do not hesitate to contact us in case you would like to hear more about any particular topic.

ENI conference Sep 2022

“There is no alternative to going Zero Emissions - for several reasons”

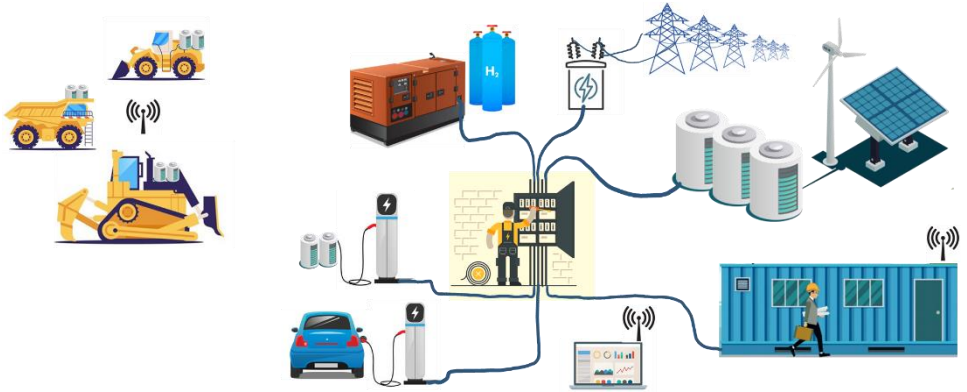
Transitioning towards ZE constructions is the only viable solution to mitigate CO_2 emissions and their negative impact on climate. But it simultaneously eliminates NOx deposition on nature reserves (a huge and current problem in the Netherlands), general health impacts through air pollution (many municipalities and governmental bodies are restricting urban emissions for this reason) and the health and safety requirements to protect workers from carcinogenic diesel engine emissions (diesel is a Substance of Very High Concern). No technology that can be combined with a combustion engine delivers on all four challenges. The electrified construction machine – coupled with various green energy sources and energy carriers – is the Zero Emission future this sector moves towards. `

“There is no future for combustion engines”

Time and again, we see machines being developed with combustion engines that run on Hydrogen. They are proclaimed as green, but in our experience have no future for several reasons: First, combustion of hydrogen can still release NOx, which is an especially big problem in the Netherlands, but damages nature everywhere. Secondly, the availability of fossil free hydrogen is utterly small and will be needed for industrial processes that lack alternatives for H_2 as feedstock or fuel. (We don’t even go into fossil based H_2, it’s worse than diesel) Hence, green H_2 is something of a last resort to store and transport energy in the construction sector. Thirdly, a combustion engine needs about 2,5 times more energy than a 1st generation electrified machine to perform the same work. Using H_2 instead of diesel fuel does not change the fact that combustion engines burn more energy for excess heat than they convert into actual work.

“ZE construction is about much more than just a machine”

ENI was founded in 2020 by three construction companies united in a dyke reconstruction project with zero emission ambitions. They quickly realized that the development of ZE heavy machinery cannot be seen in isolation of its context. Using ZE equipment has implications for energy logistics, work planning, contracting, Health & Safety management and the realization of grid connections amongst other aspects. There is even a new profession emerging: the ‘Chief Installation Officer’ on the job site. Hence we found ourselves in the middle of a technological and relational transition in order to achieve the energy transition. By 2022, we perceive the energy availability on site as a much bigger challenge than the development of ZE machinery. We also found that risk taking and cooperation across organisations and sectors is essential.

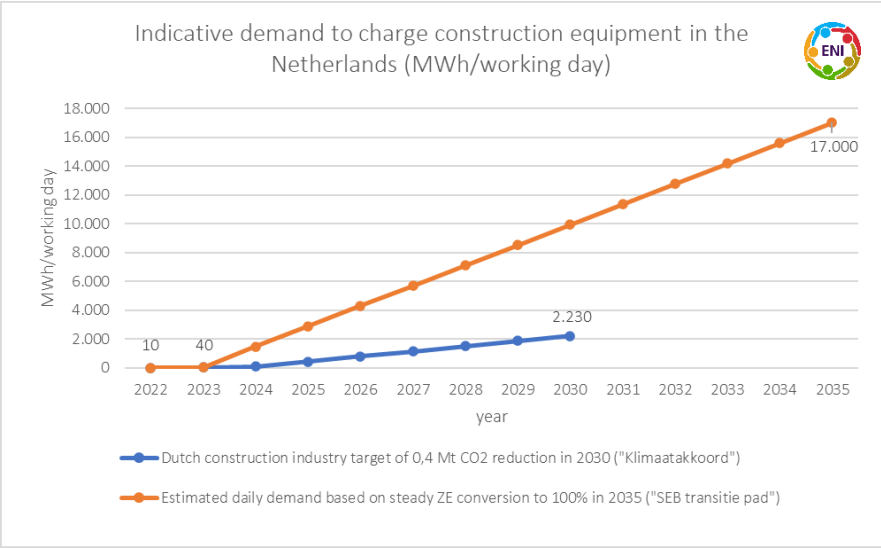


Visualisation of a ZE construction site

“Grid connections are always first choice but won’t do the job alone”

The energy consumption of a single 30-ton excavator exceeds 470 kWh a day. That is comparable to fast charging 7 electric passenger cars each night. Imagine 5 ZE machines in one place and you are looking at a serious energy demand of 2,3 MWh each night. The lowest figures estimate some 50.000 pieces of construction machinery in the Netherlands (some say 115.000). So as an educated guess we might be looking at 17.000 MWh of additional electricity demand each working day. Given current grid congestion levels and lack of technical personnel to build more capacity, the electricity demand for construction work will not be met by grid connections alone. So we expect that energy generation on the job site will remain a pillar of the construction industry – it just needs to go zero emission as well. Spreading the charging of batteries across different locations and hence grid connections or local power sources will deliver the flexibility needed to ensure that all machines are ready to go the next morning.

This energy supply switch is challenging: To comply with the climate green deal (p67, Dutch) for the Dutch construction sector (0,4 Mt CO_2 emissions reduction form equipment by 2030) we will need to replace about 613.000 litres of diesel per day with 2.230 MWh of green electricity. This is still shy of the pace we would need to adopt to get all construction equipment electrified by 2035 – a goal implied by the transition path (Dutch) put forward by the Dutch government.



Of course, emission reduction targets can also be met by not using construction equipment at all. Such a scenario sounds implausible at the moment, but so did the suggestion to lock down a whole country for an infectious disease just 3 years ago. The world is changing rapidly and with it the priorities put on climate mitigation such as emission reductions. That is why ENI works hard to safeguard the vital constructions sector in a zero emissions future.

“OEM: Maximise global CO_2 reduction per unit of development money”

The first generation heavy machinery has been electrified. Zero Emission excavators, asphalt paving machines, rollers and cranes have been converted into electrified versions and are operational. First time misses and expensive experiments are a necessary part of this development that has been spearheaded by committed users that initiated this. Now we know how to make those machines work. It is time to turn to the OEM’s (Original Equipment Manufacturers) to churn out larger series of ZE machines. But construction equipment is very diverse. So it is important to focus on machine types that create high impact per Euro invested in development: high volume machines and those types that reduce emissions substantially on a fleet level need to be prioritized to drive down costs as well as emissions as fast as possible. Within the ENI ecosystem, earthmoving equipment is a number one priority, followed by foundation and asphalt machinery as well as power generation equipment.

ENI animation on ZE construction and energy mix

“Immobile machines need exchangeable batteries”

Charging a machine daily is more of a challenge than building one. Working in a place with small, temporary grid connections or none at all often creates the need to import energy from outside the job site. Exchangeable batteries are therefore the better standard for immobile machinery like crawlers. The machines are often situated too far away from any grid connection (on site or not) to move there at the end of the day. Instead, energy should be brought to the machine in exchangeable batteries that slot into place on the machine itself. Would one use a mobile battery to transport energy to a machine with fixed batteries, charging the same kWh would occur twice: into the intermittent vessel like a battery container and then into the on-board batteries. That creates not only unnecessary losses during charging, but also demands the double amount of charging time and additional manhandling. Also it will deteriorate two batteries instead of one, causing double the amount of materials lost at end of life. With mobile machines fixed batteries might work in some cases.

“Battery capacity needs to be tuned to the maximum diesel consumption at 4kWh per litre”

When converting machines to ZE, the rule of thumb is that you need 4 kWh electricity per litre diesel consumed; that makes an electrified engine 60% more efficient! In the design of 1st generation batteries the average fuel consumption has been used to calculate battery capacity. However, real life experience shows that with heavy duty usage that is insufficient for a full working day. This constraint can make it impossible to use ZE machines in concert with diesel engines. Battery capacity needs to be tuned to the maximum diesel consumption to ensure a full working day without swapping or reloading batteries. The ‘kWh per litre' ratio however should also improve with next generation machinery: e.g. electric motors instead of hydraulic pistons. That will result in a smaller battery needed to deliver power for a full working day. Energy efficiency must therefore be a basic design principle to reduce battery capacity. This is also critical to address constraints around the availability of battery raw materials in general.

"Energy harvest maximisation will be key and needs versatile energy storage and logistics"

Given the huge additional demand of electricity – for constructions as much as for industry, logistics and passenger cars – we will need to tune all renewable energy generation to maximising the harvest of green kWh. Commercial windmills and solar parks will need to produce at all times and store whatever energy cannot be fed into the grid. But also decentralised renewable sources like PV panels and small scale windmills at construction sites are becoming commonplace. In order to let them harvest energy at every possible moment, storage and transportation come into focus as another strategic dimension to make a ZE construction site work. Again, exchangeable batteries will help a lot but storing energy in hydrogen, formic acid and other carriers needs to become normal as well. Learning from divers ecosystems in nature we stress that a high level of diversity in energy production and storage will deliver a high overall robustness of the energy supply system. Decentralisation, mobilisation and diversification are key aspects of a successful and secure ZE future in the construction industry.

Mobile windmill and PV installation at construction site

"Technology standards will accelerate ZE development – subsidies are more likely to delay it"

In May 2022, the Dutch government issued a first round of innovation subsidy (SSEB) to encourage companies to buy ZE construction equipment. The applications added up to a 10-fold of the available budget on the first day and subsidies where allocated by lottery – initially 39 applications were granted. There were no checks and balances to focus this development money on e.g. machine types with a large share in nationwide emissions or machines that are not yet commercially available. The regulation even stipulated that purchase agreements must be allowed to be terminated if no grant was forthcoming. It also postponed earlier commitments by companies to jointly develop and purchase 5 types of ZE machines – 51 pieces in total; buyers naturally held their horses as soon as the subsidy was announced. Just a portion of those early commitments were drawn in the subsidy lottery. The next round opens 12 months later with no market stimulation to innovate in the meantime.

By design, the market will in most cases wait on a chance to receive money for nothing, letting subsidies appear to be a welcomed government intervention. In reality, it wastes taxpayers' money and time in the transition. Regulated standards and lawful limits on technology on the other side make markets move along swiftly. That was proven to be the case in the ZE automotive sector (Dutch) and all evidence indicates it works likewise for construction equipment. With one exception: the buying power of governments in the infrastructure market is close to complete. 'The government' basically is the infrastructure market. So money not spent on ineffective subsidies could easily be channelled to top up procurement budgets for infrastructure work. Because ZE construction is more expensive than conventional construction work as long as environmental external costs of fossil fuel usage are still out of the calculation (e.g. in the form of CO_2 budgets, NO_x damage and Health & Safety measures).

“This energy transition transcends competition and client – contractor stereotypes”

We see a substantial shift in market relations as conditional to a successful technology and energy transition as is underway in the construction sector. ZE machine development, scale up of manufacturing and standardisation of equipment must leapfrog conventional market dynamics. In the Netherlands we see that change occurring today, be it with baby steps and setbacks: Competing construction companies are uniting procurement efforts to share development costs, OEMs cooperate with conversion companies that service various brands with standardised ZE components, clients start to arrange a grid connection before any contractor is selected and agree to develop ZE machinery during projects instead of demanding them up front.

The members of the ENI ecosystem and other front running organisations are demonstrating how ZE construction is becoming reality. Not in the last instance, the Netherlands is ahead on this curve due to its national NOx deposition problems that create unravelled urgency. However, greenhouse gas emissions, NOx deposition, air pollution and health and safety requirements are impacting people and markets around the world.

We hope to speed up this development by publishing these insights. Other tools and papers relating to the experiences and insights we collected through ENI members are available on our website.

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