Development requirements for ZE construction equipment & markets

This document aims to summarize the design requirements for zero emission machinery that emerged from the real world experience gained by front-runners in the Netherlands since 2020. We also add the lessons learned on the development of the market in the Netherlands and in which way it benefits the transition towards Zero Emission constructions.

Emissieloos Netwerk Infra (ENI) is the Dutch ecosystem wherein about 45 front-running companies from throughout the Zero Emission (ZE) value chain in the infrastructure construction market combine their knowledge and experience. We estimate several hundred heavy-duty ZE machines are in operation today in the most diverse circumstances. ENI exists to accelerate the development of ZE construction in the Netherlands in a sustainable and affordable manner, focusing on heavy-duty machinery on land.

It is paramount to understand that an electric machine is not just a new model but changes the users way of working and cost structure in unexpected and profound ways.

Nonetheless, there is no better way towards the necessary transition towards a more sustainable sector apparent today.

The Netherlands, 15-07-2024

Emissieloos Netwerk Infra

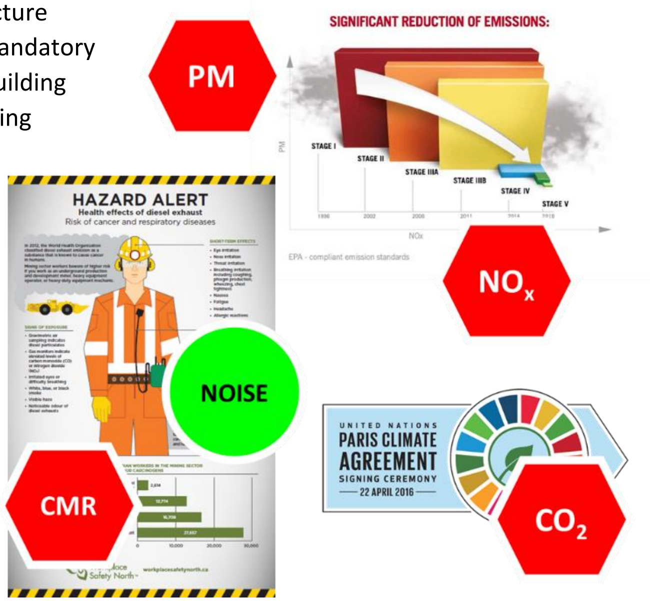
ENI today is an ecosystem of ~45 front runners from throughout the whole value chain.

Working to realise the zero-emission construction site by 2026 in the infrastructure market

Focus on heavy duty machines >125kW.

Background of Dutch market developments

Zero emission construction, specifically in the Dutch infrastructure sector, is an urgent necessity. **NOx emission** reductions are mandatory for a multitude of projects in order to obtain nature related building permits[i]. This can often only be achieved by substantially limiting emissions through the use of fully electric construction equipment. The reduction of Particulate Matter (**PM) emissions**[ii] is a similar concern in build-up areas whereas the reduction of **CO_2 emissions** is an internationally agreed necessity[iii]. On top of that the Dutch Labor Authority[iv] is intensifying its efforts to eliminate the exposure of construction workers to Diesel Engine Emissions because they are a **carcinogenic** substance (CMR) and the Dutch government classifies diesel as a Substance of Very High Concern (SVHC)[v].



As a bonus, ZE machines are substantially quieter than combustion engines. That increases health & safety on the job site and it **reduces noise stress** in the vicinity.

The Dutch government has introduced a roadmap in 2023 to have all public infrastructure work carried out zero emission by 2035 at the latest[vi], with an increasing number of projects already requiring varying degrees of ZE equipment today. Congestion on the electric grid in the Netherlands is dire and complicates ZE constructions. Nonetheless, this only means that clean autonomous electricity generation and energy logistics will play a pivotal role in powering the construction site[vii].

In short, the Dutch infrastructure sector is moving fast towards a mandatory zero emission future. We also see that other European countries experience the same pressures that shape this Dutch development, although they are mostly in an earlier stage than the Netherlands is in.

Diesel combustion causes four different emission problems and zero emission is the only answer to address them simultaneously.

Not using ZE machines in the Netherlands can mean not building at all.

Consequence of ZE work for contractors

The transition towards ZE construction is not only concerned with the type of machinery used, but a host of related consequences that are highly depending on the machine design, the location, availability of ZE equipment and the type of work required. Where the availability of machines will resolve over time, the other issues will remain dominant factors in the costs of and needed actions for ZE construction in every individual project.

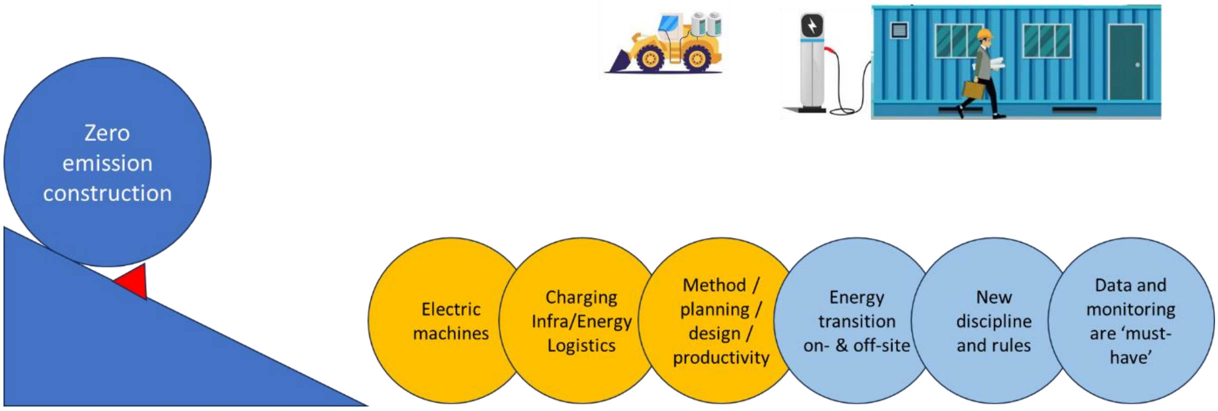


Illustration: The use of electric machines triggers a multitude of consequences on site as much as in the rest of the contractors organization.

Some examples: Machine design is a direct driver for the choice of charging equipment and energy logistics. Fixed batteries for instance require machines to be transported daily to a grid-connected charging point or need autonomous power generation or movable battery containers right next to the machine.

Another draw-back occurs with machines having insufficient battery capacity for a full working day. They reduce the productivity of that piece of equipment including the whole crew of workers connected to that machine. Furthermore, a machine with too little battery capacity is incompatible to work within a larger interdepending fleet of machinery like it is the case in large-scale earth moving or asphalt projects.

For operational dependability we see the majority of the converted heavy duty machines today using exchangeable/swappable batteries, especially with immobile machines. Although they require higher capital expenditures they safeguard continuous operation throughout the day, even in several shifts if needed.

New cost drivers emerged, business models change

Where daily rates for construction equipment were quite static in the past, being driven by mainly the costs for the machine, operator and fuel consumption, we now have strongly varying daily rates based on ZE related costs that were unknown before. They heavily depend on location, number of ZE machines and energy demand. It can be the case that ZE induced costs like energy logistics, charging infrastructure and productivity loss are higher than the bare daily rates of the ZE machine. Productivity per workday can be considered the highest risk to cost effective constructions.

It is important to remember that the **new cost drivers are depending on circumstances at the jobsite** and may vary greatly from project to project.

In short, the new cost drivers are:

- Machine rate *(one-off decision based on TCO)*
- **Energy logistics**, literally transporting energy or machines for the sake of charging or refuelling*
- Costs for charging or refuelling* infrastructure **equipment** and collection of energy and usage **data**
- Possible loss of **productivity per workday** of machine and work crew

(* fuel in this context refers not to diesel but hydrogen carriers, which carries substantial costs for infrastructure and logistics)

Especially for smaller construction companies, investments are a real burden to switch to ZE machinery. Although the ability to charge the required daily rate to clients is much more relevant to the Total Cost of Ownership (TCO) than up-front investments, financing investments is a real problem to many smaller companies.

In order to address that problem, ENI sees several levers for manufacturers (OEM), dealers and financiers to optimize TCOs and reduce investment burdens:

- **Factory build** instead of conversion reduces production costs and thus investments
- **Separated residual values of machine vs batteries** open up new finance and business models
- **Optimizing energy efficiency** per unit of output is paramount
- **Multiple functions and tools** on one machine reduce the required number of machines (This is already a standard way of working in the Netherlands but not necessarily elsewhere)

(Design) requirements for a successful and sustainable ZE technology transition

We have learned from experience that charging infrastructure, machine data and new competencies on the construction site are essential to make ZE construction work properly. For OEM parties we summarize the most urgent lessons learned below in three broad topics: *reliability*, *compatibility* and *future proof* development.

Also for OEMs we see that this transition will work better if a new way of cooperation amongst industry players is adopted. Where end users and supply chain partners work hard to **cooperate pre-competitively** with each other in ENI, we urge OEMs and their supply chain partners to do the same on an international scale.

Users of machinery urgently request the industry to break down barriers for a rapid transition towards ZE, and not create new ones.

Reliability in operations:

- **Full working days** must be guaranteed to reliably plan and calculate costs
  - “We cannot rely on charging during lunch…”
  - A rule of thumb: immobile off-grid machines are often easier to operate with (double sets of) swappable batteries
  - Charging speed of machinery must keep in step with the increasing speed of charging equipment, e.g. to enable long working days or double shifts.
- **Operators need to** (learn to) **trust** their machine and state of charge
- **Risks/Safety** requirements are different than for diesel machines. Also due to unfamiliarity of workers with high voltage appliances this needs special attention.
- **Service and warranties** need to remain OEM worthy, and even better in the early adoption phase.
- **Trouble shooting** (like troubles with charging) involves multiple parties and must not become a ‘blame-game’.

Compatibility across platforms and time:

- **Standardization of hardware and software** is crucial. Machines must be **interoperable** across every single model of charging equipment in the market and vice versa. The best way to ensure that now and in the future appears to be compliance with the **ISO 15118** standards and adherence to established (automotive) connector standards: **CCS, Mennekes Type 2 and eventually MCS**. After all, constructions take place in temporary and ever changing multi-brand environments.
- Equipment needs to **support smart charging** like postponed charging and dynamic load balancing.
- Standardisation is also demanded on **battery design** so that e.g. swappable batteries can be used in different types and even brands of machinery, or owned machines might be used with rented batteries.

- **Machine and charging data** must be easily extractable and generically incorporated in third party monitoring software (closed systems must become open, see our SCEB advice for initial guidance).
- **Machinery design:** Future generations of batteries should fit into current machines for upgrading and lifespan prolongation.
- **Software must not make hardware obsolete**: backwards compatibility is essential with long lived assets like construction equipment.

Future proof machines:

- **A battery is a machine in itself:** consider battery and machine as different assets
  - Batteries have a different lifespan and lifecycle than the machine whilst being of substantial value = different business cases are possible.
  - Fast technology development generates the wish to upgrade battery technology before end-of-life of the machine.
  - Various battery models for the same machine would increase the possibilities to economically chose the right version for the job (compare with short/long range models in cars).
  - Batteries can have secondary uses like buffering or energy trading whilst not used in machinery.
- **Need to sustainably manage materials**: Refuse, reduce, reuse, recycle, sustainably produce.
  - Fully closed/circular systems for batteries are required: 2nd and 3rd life applications of batteries and cells before recycling raw materials.
  - Eliminating conflict and hazardous materials in machines and batteries is part of this transition towards a sustainable construction industry.
  - Sustainable material mining and processing is essential, we must not repeat the history of environmental and social devastation in the upcoming era of electric power.
  - There are several ways to **minimize material requirements per unit of work output,** not only storage capacity on board! OEMs and end users need to balance materials demand with performance requirements.
    - OEMs have a task to make machines as **energy efficient as possible** while batteries will increase their performance.
    - Within the charging infrastructure there are choices to be made by designers and users alike. e.g. batteries solely for transporting electricity from a grid connection to a machine doubles the material footprint as two charging cycles are needed to 'fuel up' one machine, unnecessarily degrading an extra battery in the process.

Lessons learned on development requirements for (public) clients

As said, this transition benefits enormously from cooperation across traditional boundaries. Therefore, we share the most essential lessons learned in relation to the clients we work with in our markets.

The construction sector, and in particular the infrastructure market, is dominated by public clients. Their rules can make or break this transition. At ENI, we have worked extensively with (public) clients to share perspectives, understand each other better and cooperatively find the best way to accelerate the transition. We see that they can support the transition better if they assume *different roles* than in traditional, transactional markets. Above all, *predictability* of future ZE demand gives markets a solid base to invest and accelerate the transition.

Different roles:

- Clients have several ways to foster the transition.
  - **Buying power.** Clients can utilize their buying power to demand ZE construction. Furthermore, they can help to minimize machine hours through design choices (refuse to build).
  - **Policy power.** Clients can, to a certain extent, shape policies that foster the transition. Especially public clients and communities of buyers can enforce change within the sector

through policies and finance. E.g. calculating emission prices, reducing fossil subsidies or financially stimulating innovation.

- **Connections.** On an operational level, clients can support ZE constructions by cooperating on charging or energy logistics. On an (inter-)national level, clients can cooperate and consolidate their efforts in multiple ways, first and foremost by learning from each other.

Predictability is key to change markets:

- **Give a clear, binding growth path** in ZE work for the next 5-10 years. In order to stimulate investments there must be a perspective for entrepreneurs on returns in the future.
- **Cooperate with other clients on uniformity and scale.** Uniformity in requirements put in place for construction companies and other market players is a key quality to ease the transition. If every client invents another set of rules and criteria, the market cannot function effectively and efficiently. Furthermore, the demand for ZE constructions must be big enough to keep the available machines in operation. Otherwise it undermines the expectations of users and jeopardizes the willingness to invest.
- **Reserve budget** to finance this. We have the experience that subsidies are an inferior instrument compared to policies and legislation, but if subsidies are used they are more effective on the client side than on the end-user side. (see the ENI animation on cost drivers for elaboration[viii])
- **Play an active role** in energy infrastructure development. E.g. dedicated charging areas in a certain location could be used by contractors working for all clients in that vicinity. Or preparing for a grid connection prior to putting work on the market helps to reduce overall costs.
- **Cooperate with your contractors**, build flexibility in contracts in times you need to still learn how to do ZE constructions. Failures will happen, learn from it and prevent repetition elsewhere.

If the price of diesel would include environmental and health degradation costs, we would probably already have done the transition towards ZE by now.

Further sources of information

ENI has developed several other guiding documents for the development and use of electric equipment on the construction site. Those were based on the experts input within the ENI network and serve as a starting point to be build upon in the various industries. Consider them as a summary of end user requirements.

See our website for more information, guidelines and advice documents:
https://www.emissieloosnetwerkinfra.nl/english

Footnotes:

[i] Bouwvrijstelling stikstof van tafel, maar geen algehele bouwstop - Raad van State (Dutch, Supreme Court ruling on necessity to demonstrate NOx deposition limits in N2000 nature reserves.)

[ii] Netherlands (urbanaccessregulations.eu) (An overview of Dutch cities with specific environmental zones rules. Already relevant for construction related transport, mobile machinery is increasingly considered.)

[iii] The Paris Agreement | UNFCCC (The most cited international agreement on reducing climate change through cutting emissions of CO_2 equivalents.)

[iv] Werkinstructie Blootstelling aan dieselmotoremissies (DME) | Richtlijn | Nederlandse Arbeidsinspectie (nlarbeidsinspectie.nl) (Dutch, The Dutch Labour Authority has issued guidelines in 2023 on the prevention of exposure to Diesel Engine Emissions, including a list of construction machinery that is expected to be electrified.)

[v] Totale ZZS-lijst | Risico's van stoffen (rivm.nl) (Dutch, CAS number 68334-30-5 is included in the SVHC list of the Dutch National Institute for Public Health and the Environment (RIVM) due to its ingredients)

[vi] Het convenant SEB - SEB | Routekaart schoon en emissieloos bouwen (opwegnaarseb.nl) (Dutch, official convenant and road map towards ZE construction)

[vii] Sterke groei van elektrisch bouwen verwacht • ElaadNL (Dutch, Outlook 2024 report. Elaad is a foundation set up by grid operators to facilitate standardization around charging vehicles and construction equipment)

[viii] https://youtu.be/GA9Ln8FAM1M (ENI has made several animations to explain various lessons learned. In this video we highlight the new cost drivers and why ZE constructions is not more expensive but internalizes costs that normally are passed on to other parts of society)