Decarbonization and Reuse of foundations in the construction stage
More than recycling, reduction, substitution and the energy transition

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ABSTRACT

Decarbonization and reuse of foundations in the construction stage has a huge impact for contractors with regards to the tender stage, project management and planning. The tender stage becomes more complex because there are more selection criteria to comply with, where in the past it used to be about planning and budget only. The reuse of foundation introduces uncertainty with regards to budget and planning. In order to implement reuse of deep foundations on a larger scale there is a need for more open dialogue between clients, contractors and engineers and other contract formats with appropriate risk allocation. The most significant potential for decarbonization of foundations is (in the implementation of reuse) in the design and design optimization because in this stage it is possible to influence (raw) material usage (Scope 3). The way current projects are documented can have a huge impact of the decarbonization and re-use potential of future projects.

Introduction / Decarbonization and the Contractor

This paper gives an overview of the impact of the implementation of decarbonization and reuse of foundations for a contractor in the construction stage. This paper was written to form the basis for a keynote lecture on this subject for "The Conference on Foundation Decarbonization and Re-use" March 21-23, 2023 Amsterdam, Netherlands.

In the past, the two (most important) criteria for a contractor were budget and planning apart from safety. In the present much more criteria are evaluated for procurement and contractor selection. In more and more projects, the carbon footprint of the project and emissions during the construction stage are important criteria not only for selection of the winning tender bid but also to decide on "go" or "no go" for the execution of the project before the procurement or tender process even starts. The expectation is that the list of evaluation criteria will become longer in the (near future) because of climate goals, which are set for 2030 and 2050 (Carbon Net Zero) and require more reduction and even negative CO_2 footprints for compensation of other projects or activities. Reuse and future reusability of foundations are important criteria to reach those climate goals. (Future) implementation of criteria makes tendering and execution of projects more complex for contractors and obviously for their clients too. Since the most significant potential for decarbonization of foundations is in materials usage, the largest impact can be made in the design stage. A design optimization can reduce dimensions of or the number of foundation elements, and the execution of pile tests is a helpful tool to validate these reductions. Furthermore, the reuse of existing foundation elements can be implemented in the design, and again pile testing is a very helpful tool and, in some case, the only means for validation.

Reuse of Foundations and the Contractor

"What was built in the past can help us reduce our carbon footprint today and in the future." The foundation structure that remains in the ground after demolition of the upper structure can, if in good condition and of sufficient capacity, be used to carry a new upper structure. Condition and capacity can, in some cases, be determined from existing construction records and as-built data, and validated by pile (load) testing. This sounds quite simple, however it is not. Reuse of foundations can have a huge impact for a contractor, and makes tender and project management more complicated because it introduces

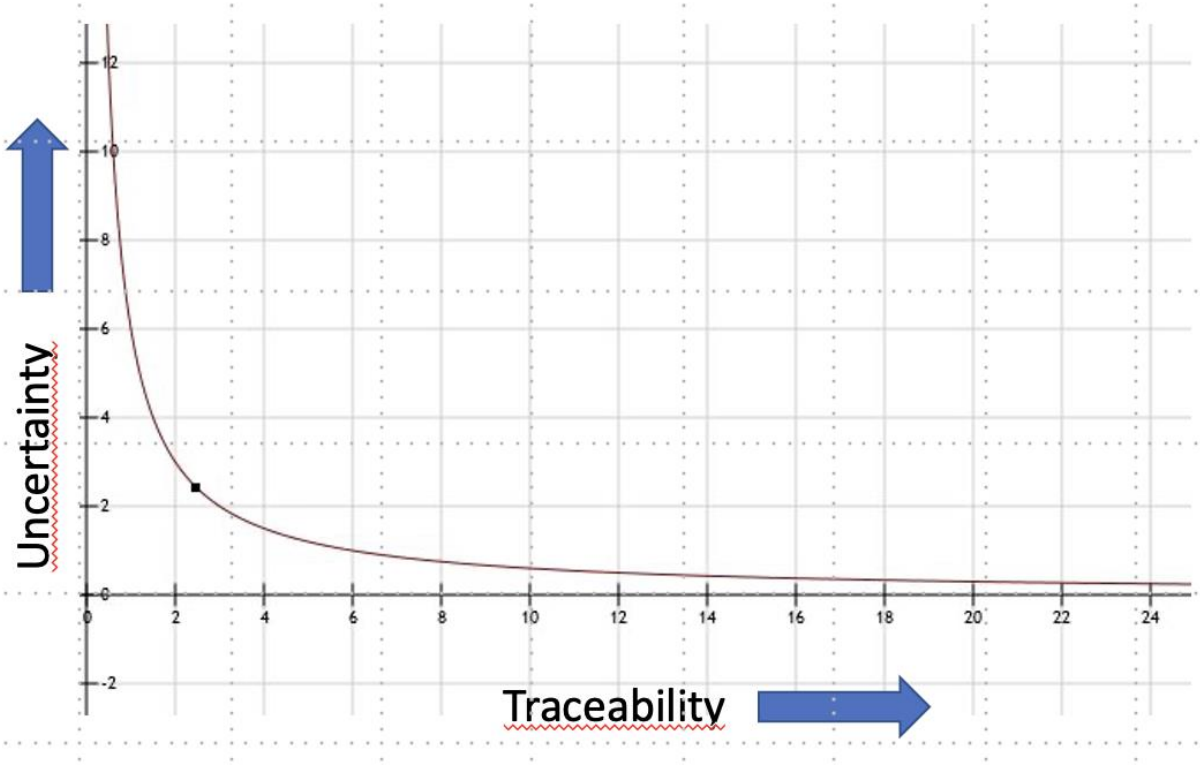
uncertainty in budget and planning, and actually requires another construction culture especially when we also want to introduce future reusability.

The first thought that comes to mind when talking about reuse of foundations is that this should have a positive impact on the client's budget. For the contractor it introduces (more) uncertainty in the first place. Questions that come to mind are:

- What will it cost to make the existing foundation fit for another service life?
- Can all foundation elements be used or do we need to replace some of them?
- What do we find when we start digging?
- What time is required for inspection?

Due to these queries, among others, budgeting and planning of a project is much more difficult and uncertain than for a completely new structure for a project with a simple construction contract or even a Design and Build contract in which (new) ground conditions are a client's risk.

Material certificates, construction records, as-built drawings, and old and new ground investigations can be very helpful to reduce the uncertainty for the contractor (and the client), while sufficient and valid data can help the engineer to better determine the condition and capacity upfront and it will make inspection and testing plannable. In short, traceability reduces uncertainty.



Where in the past (and even today) contractors and their clients may have doubted the necessity of keeping good construction records and delivering proper as-built drawings to their clients or pushing the contractors to do so. We now see that future reusability of foundations heavily depends on traceability of that what was made.

To implement reuse of foundations and plan for future reusability of foundations a change of

construction culture is required:

- Other contract formats
- Different risk allocation
- More open dialogue; and
- The recognition of necessity of traceability

In this way we can achieve that: “What is built today, can help us reduce our carbon footprint in the future,” or in other words: future decarbonization by making foundations reusable. Important to mention is that if the first two items are implemented, this does not mean that numbers three and four are immediately achieved. How these can be achieved, ultimately is not in the domain of decarbonization and reuse but rather in the domain of culture – and change management.

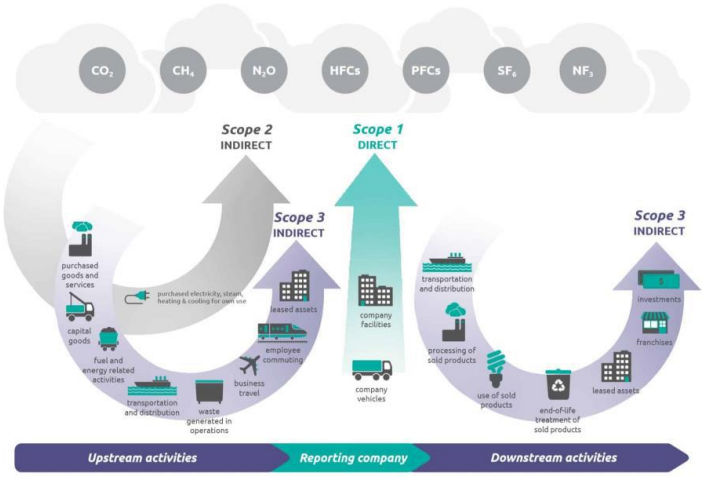
Tenders and Procurement

More and more tenders (at least in Netherlands and UK) have other awarding criteria than price, and apart from safety, most of these criteria are linked to sustainability. Examples are a comparison between carbon footprints of offers that give a fictive discount on pricing, requirements with regards to the CO_2 footprint of the tender offers, or to the CO_2 performance of the company itself, like for example the “CO_2 performance ladder” in the Netherlands.

In order to have access to a tender, a minimum certification level is set. If companies are certified at a higher level than this threshold this can lead to a so-called fictive discount for the client, i.e., the company is allowed to submit a higher bid, of which the fictive discount is deduced before evaluation of all submissions in the tender.

The CO2 Performance Ladder as a procurement instrument uses the ‘power of procurement’ to (1) direct investments towards a low carbon economy, and (2) encourage companies who participate in tenders to stimulate their CO2 awareness and reduction in their organization, projects and supply chain. It creates a competitive advantage for sustainable organizations and is in accordance with European procurement law.

As of the first level, companies are required the have insight in their own CO_2 footprint, i.e., their CO_2 emissions as per scope 1 and 2 of the Greenhouse Gas Protocol and report conform ISO 14064-1, as of level 4 and 5 insight in scope 3 emissions of CO_2 is a requirement.



Scope 1 Direct Emissions from the activities of an organization or under their control. Including fuel combustion on site such as gas boilers, fleet vehicles and air-conditioning leaks.
Scope 2 Indirect Emissions from energy purchased and used by the organization.
Scope 3 All Other Indirect Emissions from activities of the organization, occurring from sources that they do not own or control. These are usually the greatest share of the carbon footprint, covering emissions associated with business travel, procurement, waste and water.

Source GHG protocol

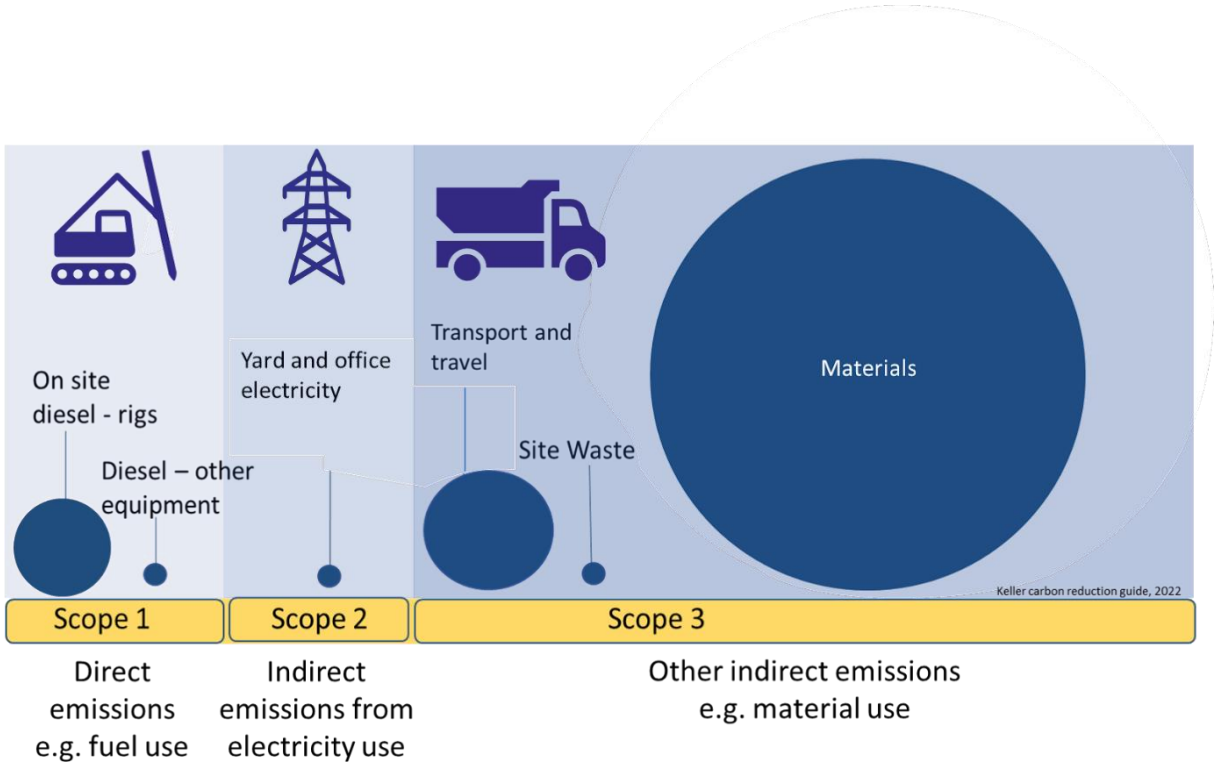
Although reduction or alternative materials (Scope 3) have to most effect on a project's carbon footprint. Most tender incentives for contractors aim at Scope 1 and 2. This is where a contractor not responsible for design has most influence.

Examples of reduction measure for the respective scopes are:

Scope 1) Reduction of fuel consumption on construction sites, by using modern low consumption engines and switch to solar powered site offices.

Scope 2) Switch to certified green electricity providers and reduce procurement of energy by building or renovating sustainable offices

Scope 3) Collaborate with value chain partners in order to reduce the use of raw materials in products and designs and optimize logistics.



Source Keller

Various organizations provide software to map and measure companies' or projects' CO2 footprints and to do lifecycle analyses (LCA) for products. Furthermore, suppliers of construction materials also provide LCAs of their products

The Geotechnical Carbon Calculator is a tool developed by EFFC and DFI which allows contractors, designers and clients to assess the carbon footprint of their projects and evaluate alternative methods of execution on CO2 emissions.

Furthermore, there can be requirements for logistics or requirements for emissions like nitrogen deposition. Examples of these are given in the next chapters, Decarbonization of Construction Sites and Evolution of Equipment. Furthermore, it is important to mention the Aerius Calculator software package which is provided in the Netherlands in order to calculate the nitrogen deposition of a project during construction and during its service lifetime.

Decarbonization of Construction Sites

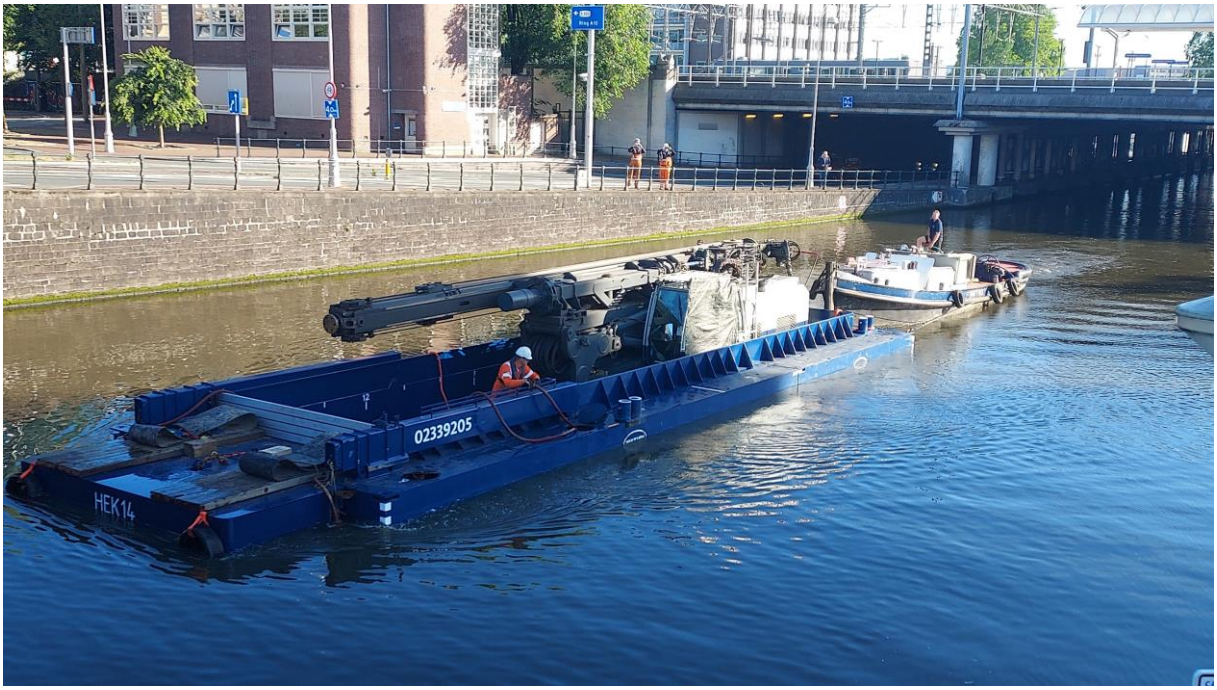
In the city of Amsterdam, a lot of examples of decarbonization of projects and especially decarbonization of construction sites can be seen over the past years. A couple of interesting examples are highlighted in this chapter.

The first example is the construction of underground bicycle storage at Beursplein. This project, which was delivered in 2018, had some special requirements for execution. Due to limited storage on the construction site itself, materials were all delivered just-in-time from a logistics hub at the city limits. On top of that there were no empty trucks leaving the site. There was always construction waste or tools that were ready for transportation away from the site after a delivery.

Another project requirement was a limited number of vehicle movements in which all vehicles from luxury cars to vans and lorries counted equal. Carpooling by construction workers and using public transport to reach the site were incentivized in this way.

This example is not only a good representation of how a carbon footprint reduction is achieved with efficient logistics, it also is a good example of how to increase traffic safety in the city centre by reducing project-related vehicle movements.

Comparable requirements are set for various canal wall replacement and renovation projects along the inner-city canal ring. Truck payload and axle load limitations make it very difficult or even impossible to reach these projects with materials or construction machinery. This is why transportation via the canals itself is becoming the new standard for city centre construction projects. On top of that, in some areas, electric navigation is becoming mandatory.



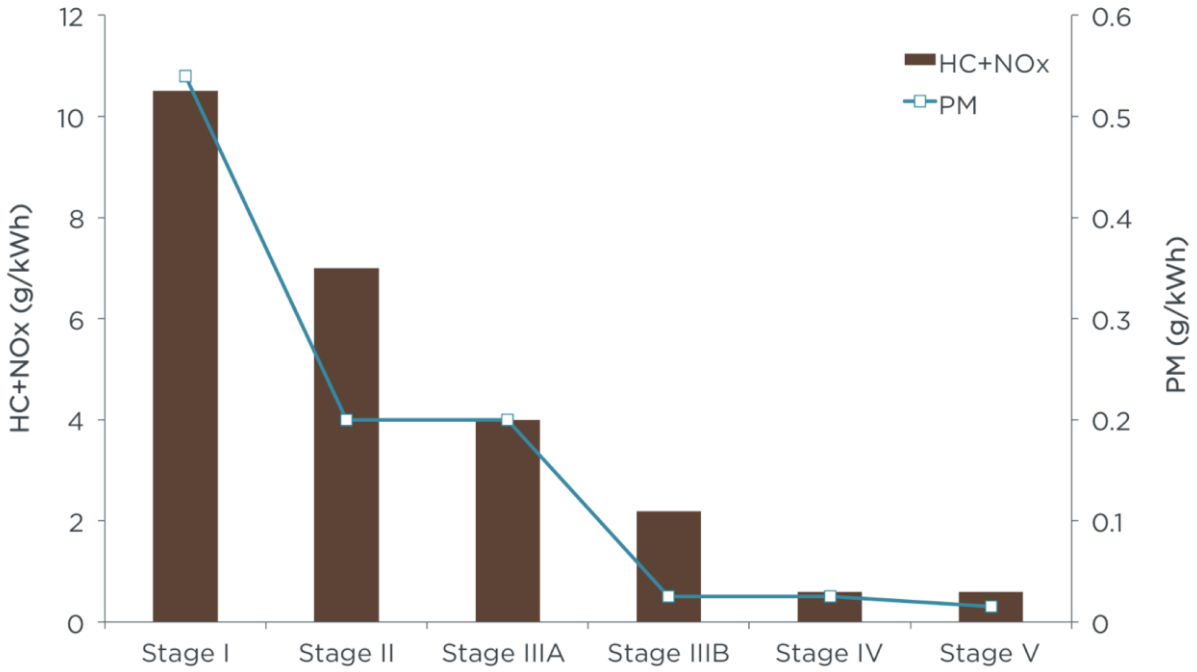
Another generic requirement is usage of a Logistics HUB instead of storage of construction materials on the construction site. When storage is available on the construction site most suppliers or rather their logistics partners provide construction sites with materials using full-sized, articulated truck trailer combinations that cause traffic congestion in the inner city, while most times these full size combinations are not fully loaded when they come in and will in turn leave the construction site empty. If contractors use logistics partners for “last mile logistics optimization,” smaller trucks provide the materials just-in-time to the construction sites, and this can be done even after working hours in order to have the materials in place when the new working day starts. And, as already mentioned in the Beursplein bicycle storage project, these trucks will not leave the construction site empty but with waste materials or other items to return back to the logistics HUB.

With regards construction site electricity, diesel generators are more and more replaced by hybrid generators with solar panels, site cabins with solar panels on the roof, and even mobile wind turbines — especially in old city centres with limited grid capacity or remote places where off-grid solutions are required. Furthermore, battery containers provide a solution to work off-grid for a shorter period or to upgrade the grid capacity when used as a so-called “peak shaver.”

Evolution of Equipment

As mentioned before, most decarbonization is achieved by reduction or elimination of material usage (scope 3). However, in order to reach Net Zero Carbon by 2050, to reduce direct emissions and, for example, reduce nitrogen deposition, scope 1 and 2 emissions should be dealt with as well. In the Introduction chapter and the chapter on Reuse of Foundations and the Contractor, a culture change was

already mentioned as a requirement. If we look at decarbonization through the use of modern equipment this is also the case. In the past (sub)contractors (especially piling companies) used to overhaul heavy construction machinery multiple times before a (piling) rig reached the end of its service lifetime. In this way it was quite common that a rig was used for 2 to 3 decades. However, over the past few years, when decarbonization or reduction of emissions became an important factor for companies because of project requirements or a company certification (CO_2 Performance ladder), old engines are not overhauled another time but are replaced by modern Stage IV or Stage V engines (Europe or Tier for USA) especially the engines that were over 560 kW and did not have a classification before the introduction of stage V in 2016 and became mandatory for most machinery in 2019 and 2021.



Other solutions to reduce emissions and to decarbonize are the use of HVO synthetic diesel or the use of an extra filter unit at the exhaust of the machine, for example the NO-NOX filter, which is provided by Volker Wessels in the Netherlands or Denox by Bredenoord. These solutions are most effective on engine classes < Stage 5.

One step further is full electrification and or a hybrid solution, for all types and capacity classes of construction machinery as well as piling equipment where hydraulic-electric or full electric solutions have been introduced by most construction machinery manufacturers — some with onboard (exchangeable) battery packs, others which can either use a diesel generator a battery or a direct connection to the grid.

The most important limitations for going full electric are:

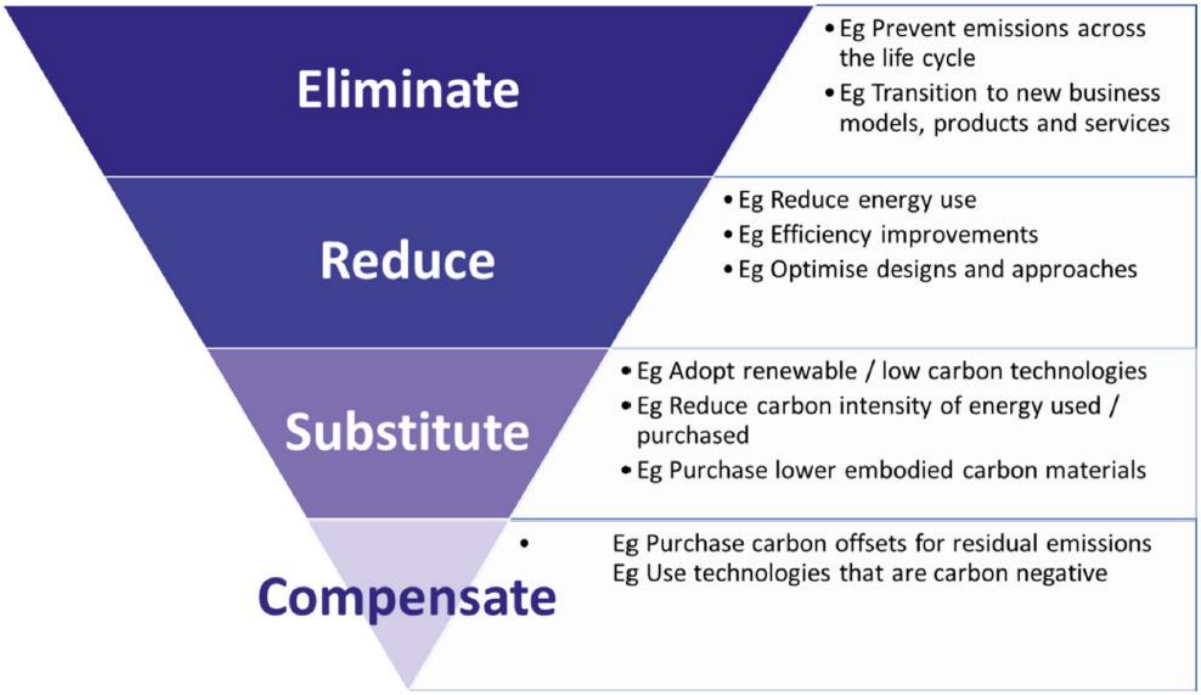
- Available charging infrastructure
- Local power grid capacity
- The investment itself

That these issues will be dealt with in the near future seems to be quite certain. For a river flood

protection project in Netherlands, the contractor combination is investing in a construction machinery charging facility along the A15 Freeway.

The Role of Other Stakeholders

Other stakeholders in the process of decarbonization and reuse of foundations that are not yet mentioned in this paper, nor part of the chain like clients and engineers, are industry associations and governmental organizations, for example. The latter are there to set long term goals to provide (international) rules and legislation in order to create a level playing field, set common language and give basic guidance like, for example the 17 Sustainable Development Goals of the United Nations. Industry associations like the European Federation for Foundation Companies (EFFC) the Deep Foundation Institute (DFI) or NVAF (Dutch member organization of EFFC) have their sustainability working groups to evaluate the consequences of legislation on behalf of their members, give feedback to (local) governmental organizations and work on more specific guidance for their members.



Conclusions and Recommendations

Elimination of scope 3 materials has the largest potential for decarbonization. This justifies design optimization and reuse of existing structures.

The impact of decarbonization and reuse of foundations in the construction stage for a contractor is far more than some extra works in the field. It introduces uncertainty in budget and planning and there is need for a change of construction culture to implement it on a larger scale. Especially when foundations that are built today should be prepared for future reusability. A key success factor is traceability by keeping good construction records and as-built drawings.

Apart from the execution of reuse of foundation in projects, contractors can influence their scope 1 & 2 emissions, although reduction or even elimination of these emissions have far less impact than what can be achieved in scope 3. These emissions shall also be dealt with to ultimately reach net zero carbon and to fulfill other requirements like the reduction or elimination of nitrogen deposition.

More information and sources:

SCI Network :: The Dutch CO2 performance ladder, Prorail, The Netherlands (sci-network.eu)

What is the Ladder (co2-prestatieladder.nl)

Greenhouse Gas Protocol | (ghgprotocol.org)

https://www.geotechnicalcarboncalculator.com/

https://www.un.org/en/climatechange/net-zero-coalition

https://www.cece.eu/environment/exhaust-emissions#:~:text=The%20stage%20V%20regulation%20extends,particulate%20number%20limits%20(PN).

https://windpowernl.com/2022/12/09/watthub-charging-facility-powered-by-renewable-energy-opens-in-the-netherlands/