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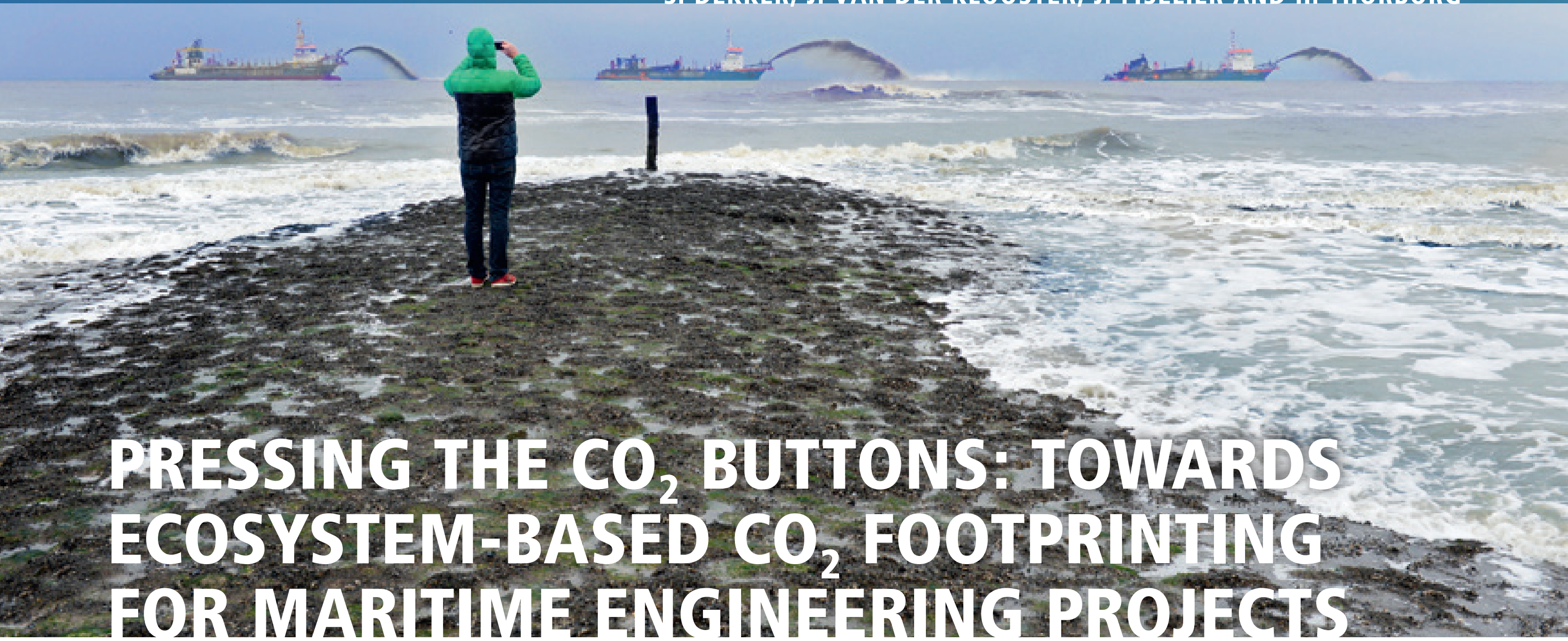

PRESSING THE CO_2 BUTTONS: TOWARDS ECOSYSTEM-BASED CO_2 FOOTPRINTING FOR MARITIME ENGINEERING PROJECTS

ABSTRACT

'Building with Nature' is a programme carried out by EcoShape (www.ecoshape.nl), a consortium of private parties, government organisations and research institutes. It involves disciplines from natural sciences, technology and social sciences to successfully operate in the continuum between nature, engineering and society. In the Building with Nature programme, specific attention is devoted to using nature and natural processes in designing, building and managing maritime engineering projects. The CO_2-related aspects of such projects must also be taken into account. For that reason the Building with Nature (BwN) initiative includes the development of a programme that focuses on ecosystem-based CO_2 footprinting. The objective is to identify and use the 'CO_2 buttons' involved in maritime engineering projects – such as coastal and embankment reinforcement and land reclamation projects – so that engineers can take decisions in the design stage that will positively affect the CO_2 footprint.

INTRODUCTION

Excavation uses an enormous amount of energy. Dredging, even in the context of 'Building with Nature' (BwN) projects, involves high emissions, including CO_2 emissions. Although the dredging industry is already working with more energy-efficient vessels that emit less CO_2 for every cubic metre excavated, maritime engineering designs could offer more CO_2-efficient solutions by implementing even more efficient execution methods or by creating precisely the right conditions for sequestering CO_2 in the ecosystem where the project is being constructed.

For that reason the 'Building with Nature' (BwN) initiative includes the development of a programme that focusses on ecosystem-based CO_2 footprinting. The Building with Nature innovation programme is committed to the integration of infrastructure, nature and society in new or alternative forms of engineering that meet the global need for intelligent and sustainable solutions. The programme is carried out by EcoShape (www.ecoshape.nl), a consortium of private parties, government organisations and research institutes. It involves disciplines from natural sciences, technology and social sciences to successfully operate in the continuum between nature, engineering and society.

Above: Dredging for embankment reinforcement at Camperduin, on the Dutch coast. Since fuel consumption is one of the main cost factors during dredging, the sector is developing more energy-efficient vessels and trying to use cleaner fuels to reduce CO_2 emissions.

The objective of BwN in relation to CO_2 is to identify and use the 'CO_2 buttons' involved in maritime engineering projects, such as coastal and embankment reinforcement and land reclamation projects, so that engineers can take decisions in the design stage that will positively affect the CO_2 footprint.

CO_2 FOOTPRINTING PROGRAMME

The essence of the ecosystem-based CO_2 footprinting programme is that the design phase examines not only the equipment used, but also the emissions throughout the entire chain: it takes into consideration the CO_2 balance of the execution and the sandpit as well as the changes in the ecosystem initiated by the project.

For example, BwN solutions are often based on the use of natural systems, such as tidal marshes, mangrove forests and willow thickets. Such systems are also referred to as Blue Carbon Systems. Blue Carbon Systems are those in which the carbon stored by coastal and ocean ecosystems, such as tidal

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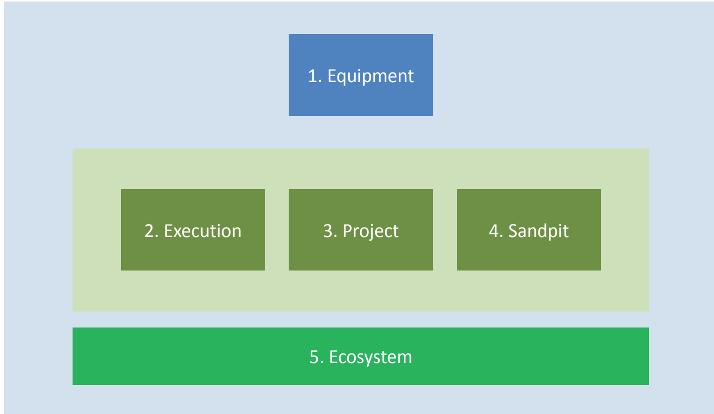


Figure 1. Wet Maritime Engineering Project Emission Factors.

marshes, mangroves and seagrasses, remove carbon from the atmosphere and ocean and store it in plants and/or deposit it in the sediment below them by natural processes.

These coastal ecosystems are very efficient at sequestering and storing carbon and thus Blue Carbon Systems account for a significant portion of the CO_2 sequestration by the world's oceans. Maintaining, restoring and developing such systems affects CO_2 sequestration during projects.

EMISSION FACTORS

Building upon the BwN Design Guidelines (see De Vriend and Van Koningsveld 2012), a distinction can be made between five important emission factors in order to significantly contribute to reducing the CO_2 footprint of wet maritime engineering projects (see Figure 1):

1. the equipment deployed,
2. execution,
3. the project,
4. the sandpit, and
5. the ecosystem in which the project is located.

Designers can only influence factors 2, 3 and 4 (the 'CO_2 buttons'). Factor 1 should be considered an autonomous trend in the dredging sector and factor 5 represents the natural system with which the project interacts.

Equipment

This refers to the dredging sector's efforts to develop more energy-efficient vessels and to use cleaner fuels in order to reduce CO_2 emissions. This efficiency-oriented effort is largely cost-driven, since a substantial part of the costs associated with dredging projects relates to fuel use.

The average economic lifetime of a dredging vessel is 25-30 years. Therefore, dredging vessels are not replaced frequently. So although older vessels are often upgraded and updated in certain ways, emissions reductions are lagging behind. In recent years the trend away from heavy fuel oil towards gas oil has been a response to the pressure exerted by international laws and regulations on the industry to switch to cleaner fuels. For example, the first experiments with biodiesel are currently underway. All in all, expectations are that developments in the fields of equipment and fuels could result in emission reductions of 10-15% over the next few decades.

Execution

This 'button' refers to the efficient (or more efficient) deployment of equipment and thus reduced fuel use. Dredging companies are already making this change 'organically' because it directly affects costs. For example, optimisation in execution is being sought, primarily in collaboration with customers, through such measures as reusing materials and reducing transport distances - solutions, which relatively speaking, involve direct placement rather than pressurised sand delivery and make it possible to use larger vessels and use them much more efficiently.

It must be kept in mind, however, that the use of dredging equipment – and the related emissions – are largely determined by the local physical conditions, such as the hardness of bed sediment, and the availability of equipment which partly depends on which projects are on offer around the world. The recent initiative known as "slow steaming" is aimed at making the mobilisation and demobilisation of vessels more energy efficient by sailing between projects at lower speeds. There are also programmes underway for the smarter deployment of dry excavation equipment (dumpers, bulldozers, shovels and excavators).

Furthermore, the degree to which degradable organic substances and nutrients are released during execution, such as when a hopper is being loaded, can impact a project's CO_2 footprint. Whether silt and the nutrients it contains are released into the environment or whether the fine-grained materials flow back into the sandpit is entirely dependent on the dredging method.

The Project

A project can be developed so that it requires less sand, perhaps by seeking a thorough balance between the construction and maintenance phases, between hard and soft elements, and the reuse of materials within a project. Using Blue Carbon Systems for sequestering CO_2 is another possibility for actively sequestering more CO_2. In this respect, consideration may be given to using natural systems, such as salt marshes, mangroves, as well as cultivating dunes and willow thickets.

The Sandpit

At the outset, this button relates to the selection of the extraction area and the sailing distance between the extraction area and the project site – an emission factor that cannot be ignored. A sandpit, however, also creates a potential storage site for silt and organic substances, and thus for CO_2 as well. Location, orientation, form and method of extraction from the sandpit impact the quantity of silt that is captured, both during and after extraction (Figure 2).

The effects a sandpit has on the CO_2 is still largely unmapped territory and it is a factor that merits attention in BwN's ecosystem-based CO_2 footprinting programme. Organic substances take various forms, from fully inert to dead algae that can still be actively degraded. Most of the organic substances

Figure 2. Twenty million cubic metres of sand were placed on the Dutch coastline to strengthen the Hondsbossche and Pettemer Sea Defences in north-western Holland. The sailing distance to and from the extraction site must also be considered in evaluating the $C0_2$ footprint.

that are released from deeper sediment layers during dredging are no longer degradable.

Ecosystem

This button refers to the interaction between a project, execution, sandpit and the ecosystem where the project is located. Nutrients released by activities such as dredging stimulate the growth of algae that absorb atmospheric CO_2. These algae are ultimately deposited with the silt in the salt marshes where the CO_2 is then sequestered. A land reclamation project can create a lee zone behind which a mangrove forest can develop and, in turn, where CO_2 can be sequestered. A substitution situation could also arise however: silt that is deposited in a sandpit will no longer be available for the later development of a salt marsh.

THE DUTCH SUSTAINABLE INFRASTRUCTURE PROJECTS PROGRAMME

In the context of the Dutch Sustainable Infrastructure Projects programme (http://duurzaamgww.nl/index.php/actueel/greendeal/?lang=en), customers and market parties, including contractors, have begun using several tools intended to result in reduced emissions. The CO_2 performance ladder and DuboCalc are examples of such tools.

The CO_2 Performance Ladder

The CO_2 performance ladder focusses on more energy-efficient business operations, with the higher rungs on the ladder – corresponding to higher energy efficiency goals – resulting in a higher award advantage (notional discount) on tender prices. At the same time, however, the higher the rung, the more efforts a business must make to reduce CO_2 emissions.

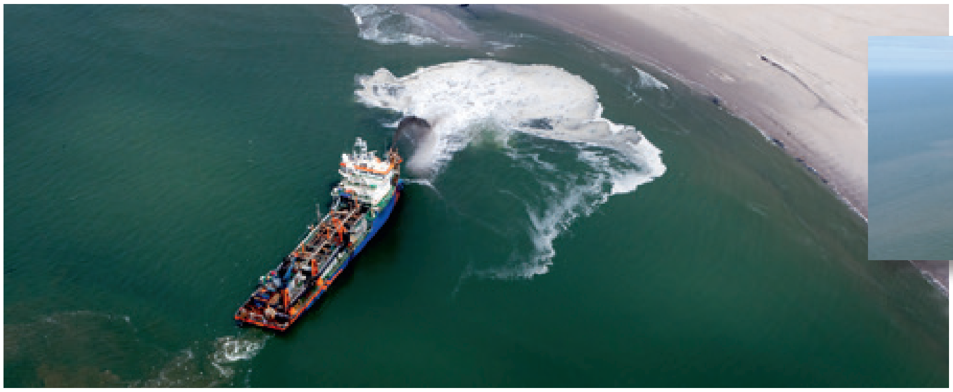
DuboCalc

DuboCalc, which focusses on materials and energy use in projects, supplements the business operations-oriented "CO_2 performance ladder". The CO_2 performance ladder is an instrument to stimulate companies participating in procurement to be aware of their CO_2 emissions in their own business operations and in the performance of projects. This involves in particular saving energy, using materials efficiently and using renewable energy. The principle behind the ladder is that efforts are rewarded: a higher score on the ladder means a concrete advantage in the tendering process, in the form of a notional discount on the tender price. DuboCalc is a tool that can be used to calculate the environmental costs of materials over their entire life cycle and the cost of fuels. The outcome of such a calculation with DuboCalc may lead to the above-mentioned notional discount on tender prices.

DuboCalc is not yet an effective tool for "wet" maritime engineering projects because it lacks sector-specific components, such as the ability to calculate the effects of design and operation of the sandpit on the CO_2 footprint and the interaction between the ecosystem and the Blue Carbon Systems deployed there. The purpose of the BwN programme on ecosystem-based CO_2 footprinting is to meet the need for such a tool.

BwN DESIGN TOOL

Execution, the project and the sandpit are the 'CO_2 buttons' that maritime engineering project designers can "press". In this respect,



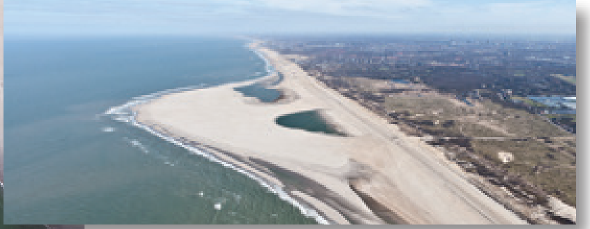


Figure 3. Left, the so-called Sand Motor being built along the coast of the Netherlands and right, an aerial view of the completed Sand Motor project.

it is important to realise that one of these buttons cannot be pressed without affecting the others. For example, execution is dependent on the amount of soil a project requires, but also on the equipment the contractor deploys. The combination of equipment deployment, project and sandpit impacts the environment, and vice versa.

Steps are currently being taken within BwN to develop a design tool that focusses on these buttons. To that end, a partnership has been formed between two dredging companies (Boskalis and Van Oord), NGOs (The North Sea Foundation and the Wetlands International Foundation), engineering and consulting firms (Arcadis, Royal HaskoningDHV and Witteveen+Bos) and Deltares, a Dutch institute for applied research in the field of water, subsurface and infrastructure. The goal is to be able to develop and construct maritime engineering projects that leave a much smaller CO_2 footprint over their entire lifecycle than they would have with conventional design and construction methods.

Figure 4. An exploratory survey into the recovery of mangrove forests in Indonesia.

The envisaged design tool is based on an accessible spreadsheet application that will offer engineers a simple method for calculating CO_2 footprints based on key figures. The tool will consist of the following components:

- A design sheet that makes connections between emission factors and design variables, such as the translation of a design into sand volumes, dredging techniques and sailing distances, and the dimensions and sediment properties of a sandpit and the use (and reuse) of materials.
- A database of key emission figures for the use of materials, types of organic substances, Blue Carbon Systems, and so on.
- A computation sheet for calculating CO_2/ GHG (greenhouse gas) footprints and performing sensitivity analyses that take any substitution effects into account.
- A dashboard that displays key results, such as the total lifecycle footprint, and compares project alternatives based on both emissions and costs.

Creating such a design tool has required a thorough survey of the professional literature to identify any gaps in knowledge (regarding such issues as the effect sandpits have on project footprints) and the possibilities for the targeted deployment of Blue Carbon Systems for CO_2 sequestration.

The results of the literature survey will be used to establish an analysis framework for measurements in four marine engineering projects:

- the reinforcement of the Hondsbossche and Pettemer Sea Defence (located in the north-western part of the Netherlands) (Figure 2),
- the Sand Engine (an innovative method for coastal protection, located at the west coast of the Netherlands) (Figure 3),
- the Houtribdijk EcoShape pilot project; Houtribdijk is actually a dam located in the centre of the Netherlands, and
- an exploratory survey into the recovery of mangrove forests in Indonesia (Figure 4).

CONCLUSIONS

The results of the measurements in the four marine engineering projects being studied will enable the BwN team to add missing data to the first demo version of the new design tool. A more developed design tool can then be applied to other similar projects or further developed for other types of projects and situations. Ultimately, the aim is to achieve a 20% smaller CO_2 footprint over the lifecycle of maritime engineering projects constructed after 2020.

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