

Construction Carbon Footprint Analysis of Breakwaters and Sea Walls

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Publications

A nature-based solution: the Icelandic-type berm breakwater

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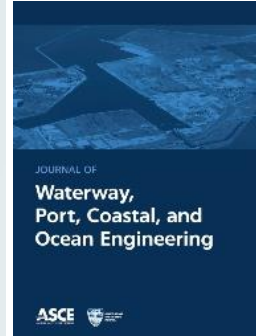
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Icelandic-Type Berm Breakwater: A Nature-Based Structure with a Low Carbon Footprint

Authors: Majid Eskafi , Sigurdur Sigurdarson , Bjorgvin Brynjarsson , and Kjartan Eliasson | [AUTHOR AFFILIATIONS](#)

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• Abstract

Introduction

Icelandic-Type Berm
Breakwater

Methods

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for NBS

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Data Availability
Statement

Acknowledgments

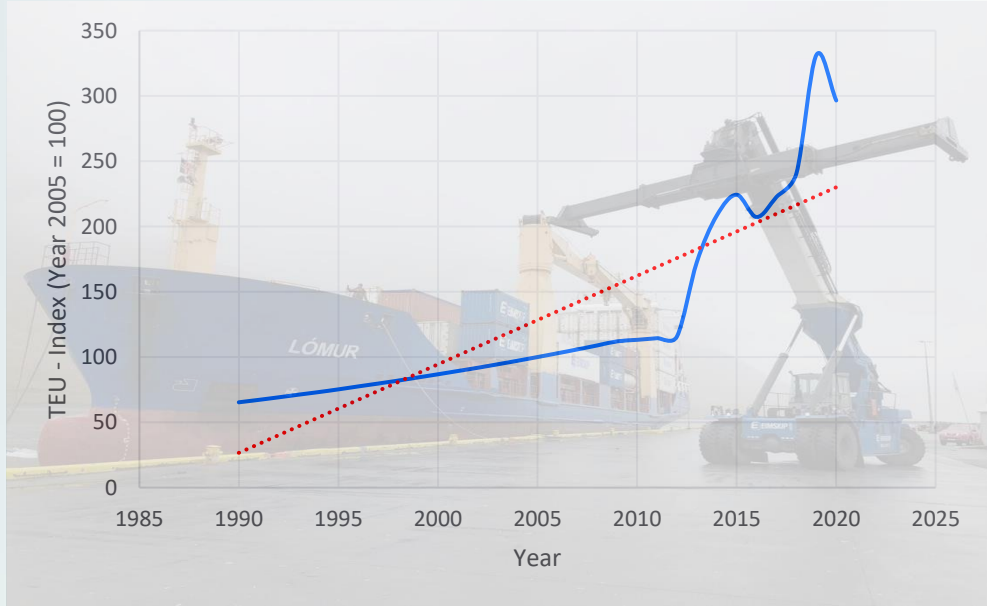
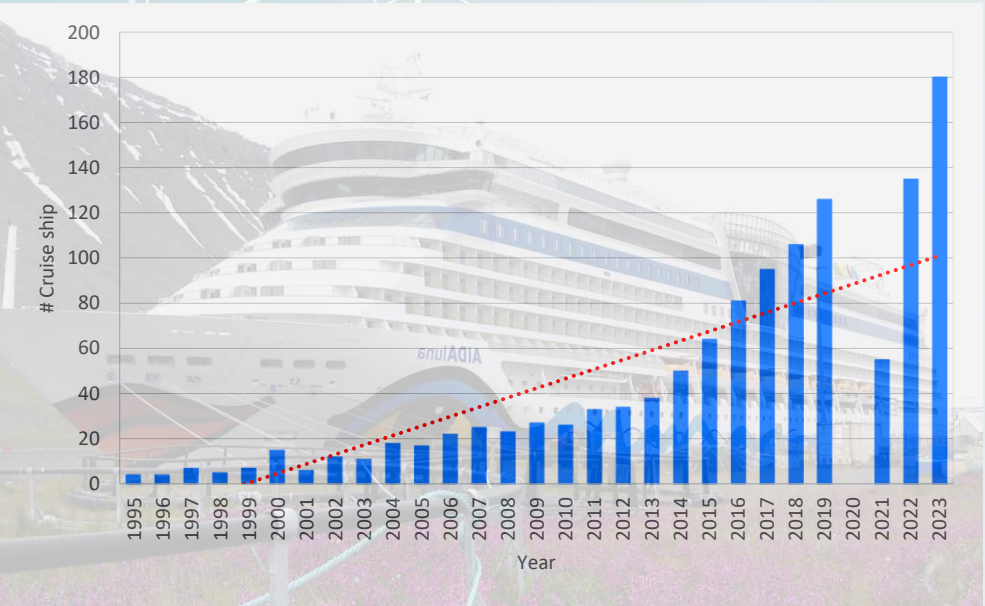
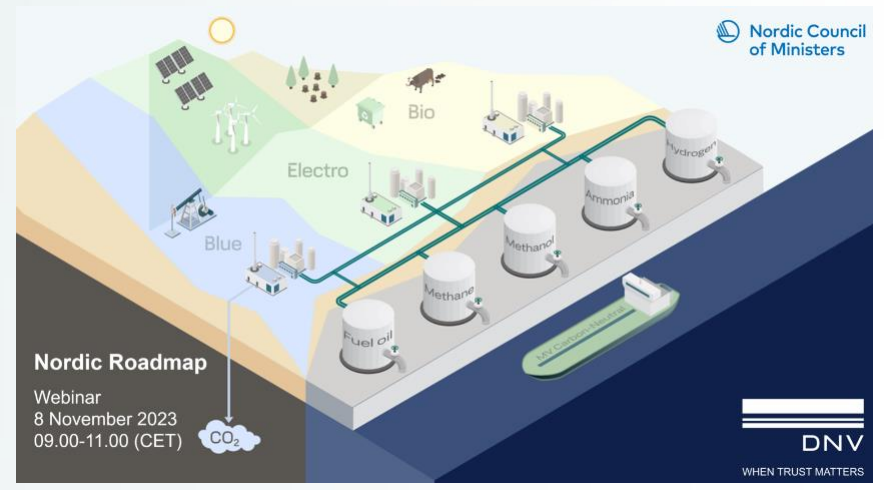
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Abstract

With the ever-increasing emphasis on climate change and sustainability, there is growing interest in using environmentally friendly coastal structures. In addition to engineering and cost factors, the construction global warming potential (GWP) can and should be an influencing factor in the selection and design of the structures. Therefore, knowledge of construction GWP facilitates informed decision-making in coastal projects to achieve climate goals. Considering the number of Icelandic-type berm breakwater (IceBB) structures worldwide, this structure's design method is commonly accepted in coastal protection projects. In this paper, the construction process of an IceBB was assessed for its GWP and compared with concrete armor unit protection of a conventional rubble mound breakwater (ConRMB). The assessment and comparison were made for constructing a breakwater to protect the port of Thorlakshofn in southwest Iceland. The life cycle assessment (LCA) methodology was applied to calculate the construction carbon footprint of the structures using GaBi software, version 10.6.1. Using the International Union for Conservation of Nature (IUCN) criteria for nature-based solutions (NBS) and based on the existing literature, the characteristics of IceBB were briefly explored. The results showed that the construction of IceBB has a lower GWP than ConRMB, mainly due to using natural rock armor instead of concrete armor units. Furthermore, the results indicated that IceBB characteristics meet the IUCN criteria for NBS and thus can be granted as a (hard) NBS coastal structure. Acknowledging the advantages of IceBB, adopting this structure in coastal protection projects could meaningfully contribute to climate change mitigating policies.



Development in Port Sectors



Brownfield and Greenfield Port Development

- **Ministry of the Environment, Energy and Climate**
Carbon neutrality before 2040 under the Paris Agreement
- **Icelandic Road and Coastal Administration**
Reduction in the construction carbon footprint of projects
- **Housing and construction agency**
Life Cycle Assessments (LCA) for new structures according to ISO 14040 and ISO14044



Fréttir

Uppbygging hafnarinnar opnar á ótal tækifæri

Framkvæmdir í Þorlákshöfn

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Research Question

Is there any environmentally friendly coastal structure?

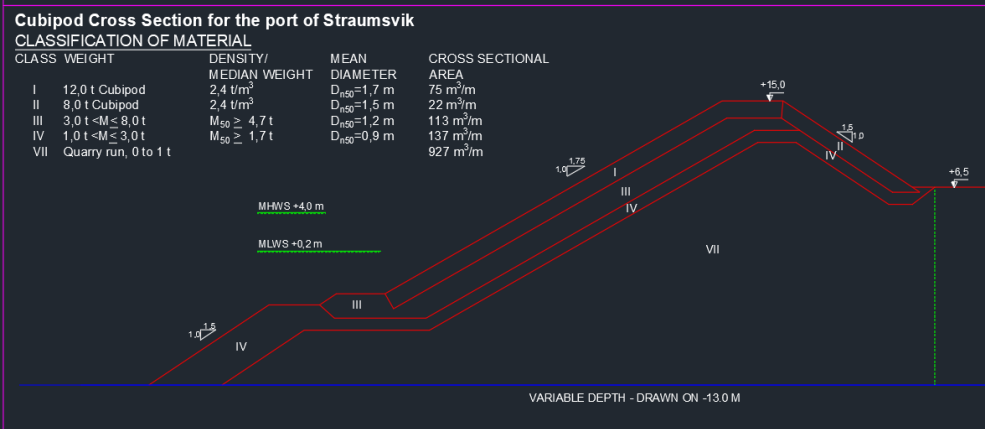
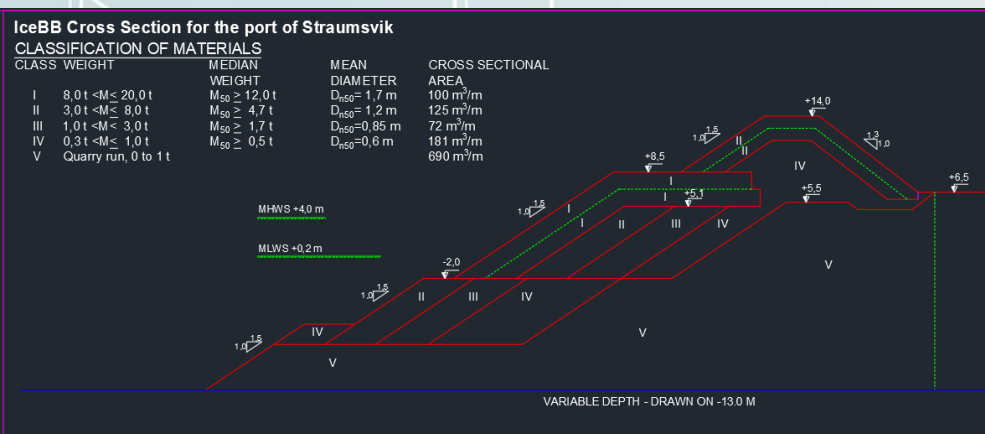


LCA of different scenarios:

1. Protection of the port of Thorlakshofn
 - a) Extend the existing breakwater with an IceBB
 - b) Extend the existing breakwater with a ConRMB

 2. Protection of the port of Straumsvik
 - a) Construct a new IceBB
 - b) Construct a new ConRMB
-
- ✓ Icelandic-type berm breakwater (IceBB)
 - ✓ Concrete armor units conventional rubble mound breakwater (ConRMB)

IceBB and ConRMB



IceBB:

- Preliminary design is based on potential quarries
- Final design is tailored to fit the selected quarry, the design wave load, available construction equipment, and transport routes.
- Narrow-graded armorstone classes:
 1. Higher permeability and wave energy absorption
 2. More stability
 3. Lower wave penetration into the ports, and less wave overtopping
 4. Lower wave reflection from the trunk and head of the structure

Method

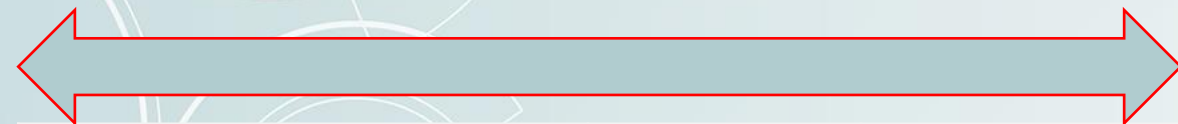
Life Cycle Assessments (LCA)

- GaBi software from Sphera

- CF can be calculated as:

$$CF = \sum_{i=1}^n e_{t,i} \times quantity_i$$

- where n is the number phase/activity, and $e_{t,i}$ is the specific amount of CO₂ phase/activity per quantity.



Cradle-to-Grave				
Cradle-to-Site				
Cradle-to-Gate				
Procurement/production of materials	Transport to site	Construction on site	Operation/maintenance	Disposal

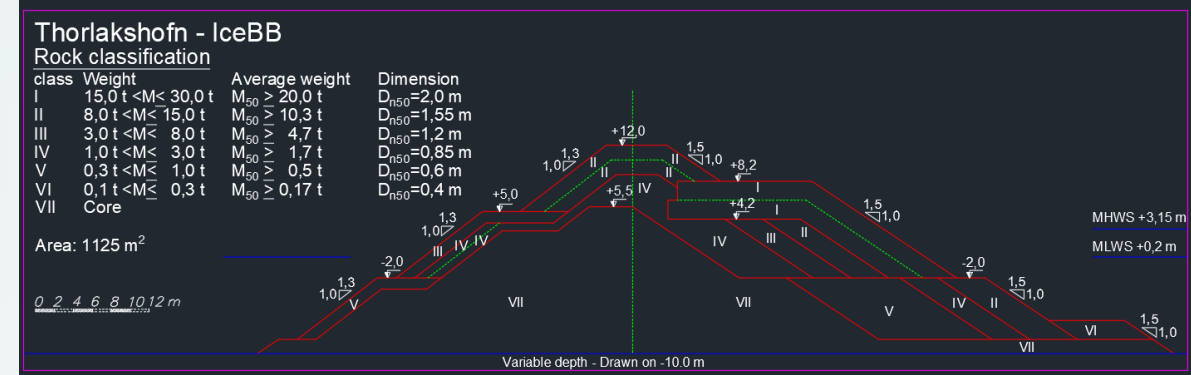
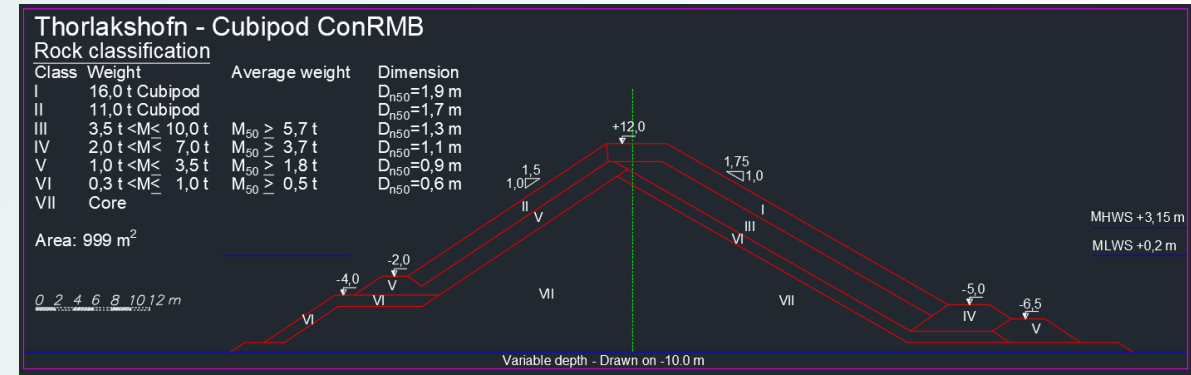
Case studies



Port of Straumsvik



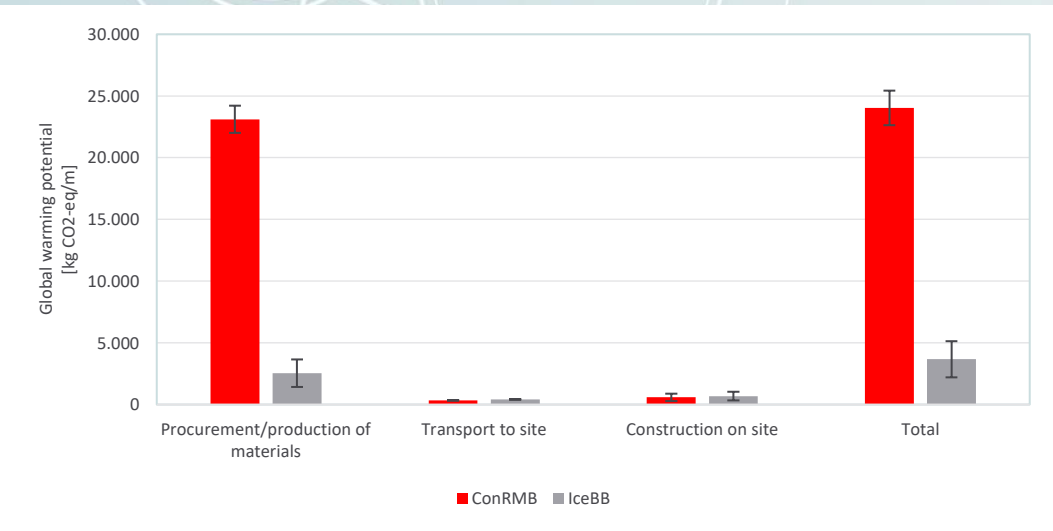
Port of Thorlakshofn



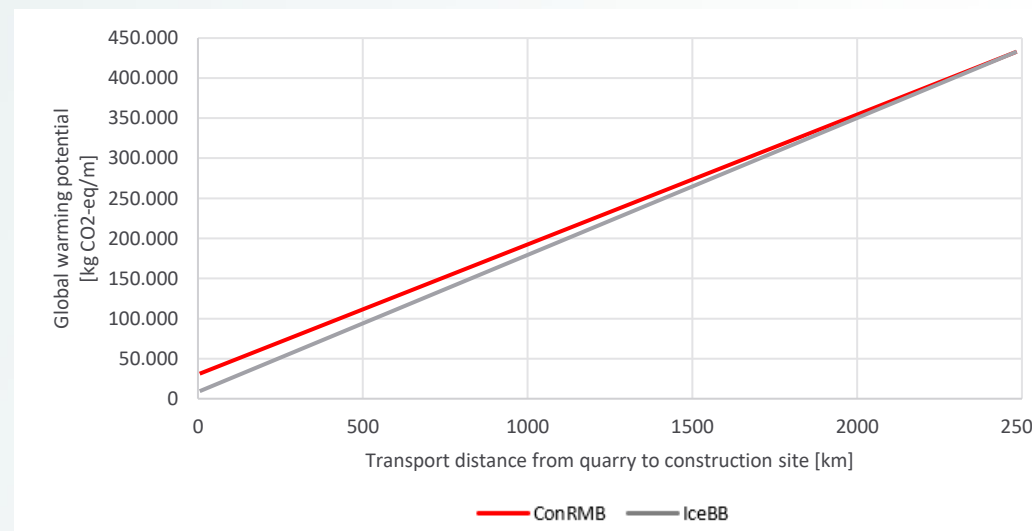
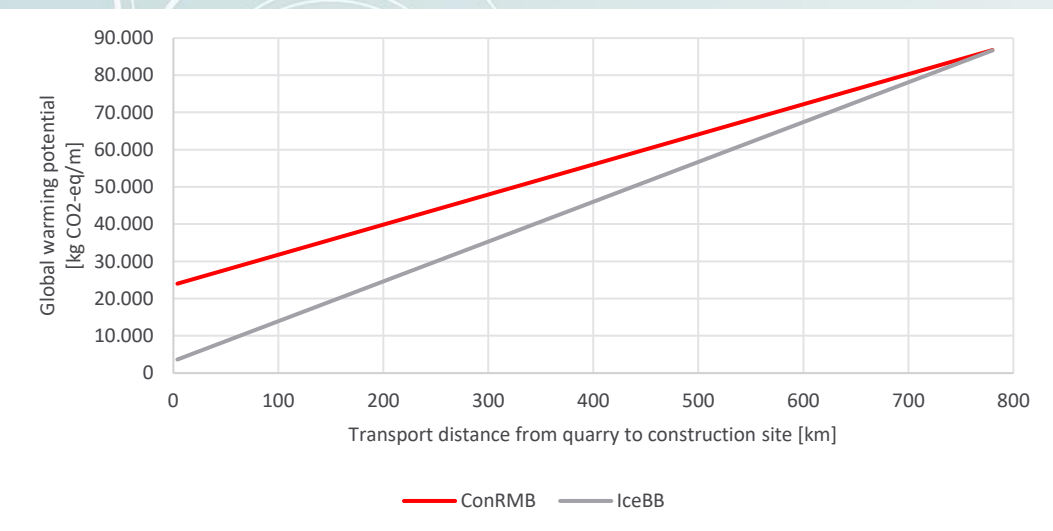
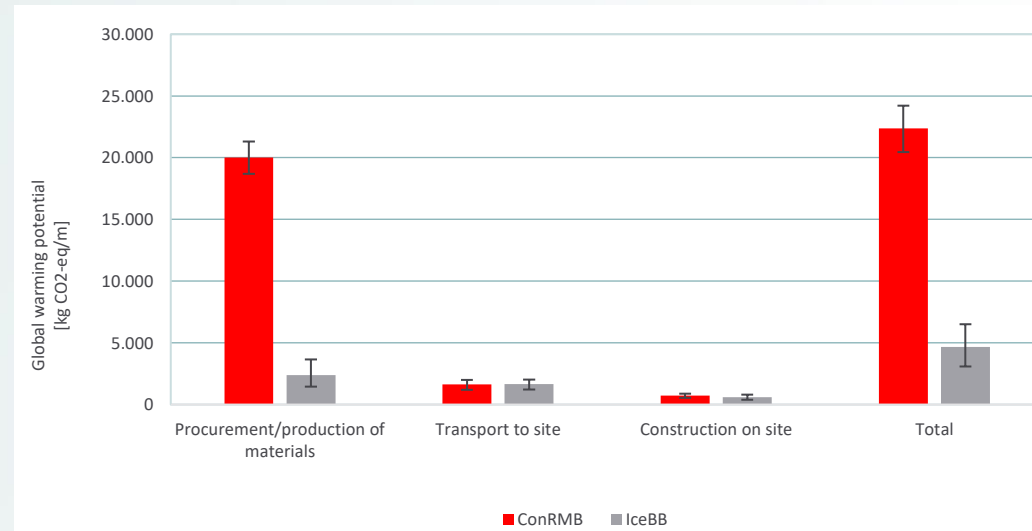
Results



Port of Thorlakshofn



Port of Straumsvik



Results

International Union for Conservation of Nature (IUCN) for Nature-Based Solution (NBS)

IUCN criteria	IceBB
1. NBS effectively address societal challenges.	✓
2. Design of NBS is informed by scale.	✓
3. NBS results in a net gain to biodiversity and ecosystem integrity	✓
4. NBS are economically viable.	✓
5. NBS is based on inclusive, transparent, and empowering governance processes	✓
6. NBS equitably balance trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits.	✓
7. NBS have managed adaptively, based on evidence.	✓
8. NBS are sustainable and mainstreamed within an appropriate jurisdictional context.	✓

Concluding remarks

- Carbon accounting has become a requirement for engineering option appraisal.
- The construction Global Warming Potential (GWP) factor of berm breakwaters based on a reliable LCA method was presented.
- The results show that the construction of IceBB has a relatively low GWP as it is made entirely from natural rock.
- IceBB can be used as an example of a hard NBS coastal structure, as
 1. It has a relatively low construction GWP
 2. Fulfills the IUCN criteria for NBS

Concluding remarks

- The results provide support for informed decision-making in port and coastal protection projects to reduce the construction CF by:
 1. Using rock armor units where both rock armor units and concrete armor units are options to be used.
 2. Using greener fuel in the construction process of IceBB since its major construction CF is from fuel consumption.
- Acknowledging the advantages of IceBB, adoption of this structure in port and coastal protection projects could further contribute to climate change mitigating policies.

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- Þorlákshöfn Port Authority (Þorlákshöfn)



Thank you for your attention

