SUND & BÆLT

ANALYSES OF NEW ISLAND HARBOUR AT TÅRS

CALCULATION OF CO_2-EMISSIONS

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CONTENT

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1 Introduction

The project site is located near Tårs in Langelandsbælt, Denmark. The objective is to establish an offshore ferry harbour on an artificial island, approximately 3.5 km from Lolland into the Langslandsbælt, which can reduce the travelling time all year round on the Spodsbjerg-Tårs crossing.

The proposed harbour location and its area is shown in Figure 1-1.

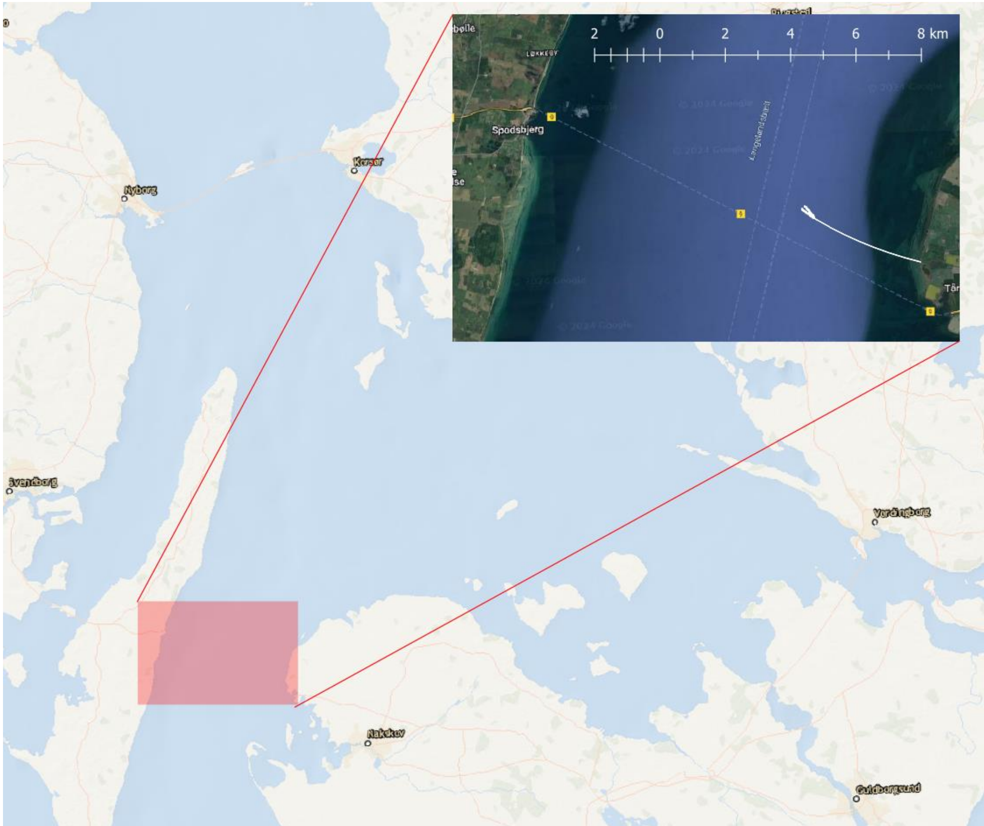

Figure 1-1 Location of Tårs Ferry Harbour in Langelandsbælt.

This Technical note provides calculations of CO_2-emissions for the construction of the offshore ferry harbour, embankment and bridges for six scenarios of the island harbour as presented in Table 1-1.

The assessment is based on the quantities for the six scenarios which are presented in ref. /1/. The construction method is generally the same for the six scenarios. The CO_2-emissions of the analysed construction components are summarized below:

› Quay structures (quay, ferry berth and duc d'albes) incl. quay equipment

› Rockworks for harbour (revetments, breakwaters and breakwater heads)

› Reclamation work with sand

› Pavements, fences, signs, wiring and lighting for the hinterlands

› Utility works – electric supply to the harbour (installation of a 20 kV electric cabling) and water supply to the harbour (installation of cable ducts containing pulled water pipes)

› Buildings (ticketing facilities and waiting area)

› Low concrete bridges (B1 and B2)

› Rockworks for the embankment

› Connecting road from Route 9 to the landfall of the access road to the harbour

Table 1-1 The six scenarios which are assessed for the establishment of the offshore harbour. Scenario 1 is the basis scenario. Parameters which are changed for different scenarios compared to the basis scenario are marked in ***bold.***

Scenario	Layout[1]	Bicycle lane[2] (Yes/No)	Bridge span[3] [m]	Pile diameter[4] [m]	# piles per bridge element [-]	Length of bridge from the harbour[5] [m]	Length of bridge from shore[6] [m]	Length of embankment [m]	Combined length of access road [m]
1 (Basis)	3	Yes	25	0.8	3	800	600	2,100	3,500
2	3	**No**	25	0.8	3	800	600	2,100	3,500
3	3	Yes	25	0.8	3	**600**	600	**2,300**	3,500
4	3	Yes	25	0.8	3	**3,500**	**-**	**-**	3,500
5	3	Yes	25	0.8	3	**450**	600	**1,575**	**2,625**[7]
6	**2**	Yes	25	0.8	3	800	600	2,100	3,500

[1] *Layout 2: The harbour entrance is oriented towards NW. Layout 3: The harbour entrance is oriented towards N.*

[2] *If bridges and embankment are established with a bicycle road (13 m wide bridge/embankment) or without a bicycle road (9.2 m wide bridge/embankment).*

[3] *The bridge span between each support.*

[4] *The diameter of the piles from the bridge elements to the foundation.*

[5] *Length of the bridge between offshore harbour and embankment, B1.*

[6] *Length of the bridge from shore and out to the embankment, B2.*

[7] *The offshore harbour is placed closer to shore at a water depth of approximately 5-5,5 m.*

2 Methodology

The assessment is based on an estimated climate impact or Global Warming Potential (GWP), which is an expression of the emissions of CO_2, and other greenhouse gases measured in CO_2-equivalents (CO_2e) during the construction and operations phases.

A life cycle assessment (LCA) methodology was applied to calculate the carbon footprint, following internationally recognized standards including ISO 14040, ref. /2/, and ISO 14044, ref. /3/, which define the principles and framework for LCA; DS/EN 17472, ref. /4/, which focuses on sustainability assessment in construction projects; and DS/EN 15804, ref. /5/, which pertains to environmental product declarations for construction materials.

The background processes used in the applied Excel-based tool are majorly based on InfraLCA V3.18 database, ref. /6/, which has been designed to evaluate the environmental impacts of infrastructure and construction projects. InfraLCA has been developed by the Danish Road Agency (Vejdirektoratet), under the Ministry of Transport, and focuses on Danish and Scandinavian infrastructure context.

2.1 Life cycle phases

The CO_2-emission analysis is based on LCA, where climate impact (CO_2e) is included as the sole environmental impact category. As the primary scope of the analyses for the new island harbour is the construction phase, the CO_2-calculations are carried out for the life cycle phases A1–A5: the production phase (A1–A3) and the construction phase, including transport and installation (A4–A5). The life cycle phases are illustrated in Table 2-1.

Table 2-1 Life cycle phases included in system boundary.

Produktion			Byggeproces		Brug							Endt levetid				Udenfor systemgrænse
Råmaterialer	Transport	Fremstilling	Transport til byggeplads	Indbygning/ Energiforbrug samt transport fra byggeplads	Brug	Vedligehold	Reparation	Udskiftning	Renovering	Energiforbrug	Vandforbrug	Nedrivning	Transport	Affaldsbehandling	Bortskaffelse	Genbrug og genanvendelse
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

Note: MND = module not declared

2.2 Environmental emission data sources

Construction materials and process emission factors, density values, energy and fuel consumption, as well as transportation emissions were primarily sourced from InfraLCA V3.18. In cases where data was not available, third-party verified Environmental Product Declarations (EPDs), EU reports and Ecoinvent LCA-database were used as valid alternatives for background emission data sources. Table 2-2 provides an overview sample of the data sources which were not available in InfraLCA V3.18.

Table 2-2 Overview of data sources for emission factors other than InfraLCA.

Materials	Emission factor source
Extra aggressive C40/50 concrete	Fehmarnbelt link project experience
Steel reinforcement, 80% recycled	Fehmarnbelt link project experience
Paving stones (10 cm thickness)	Product EPD; Geography: DK; Publisher: Dansk Beton
20 kV cable (1c500 Al) 20 KV cable (3c500 Al)	Product EPD; Geography: SE; Publisher: NKT
Administration building and ticketing system/building	TRIS - European Commission, Building Regulations Directive (EU) 2015/1535. Building emission benchmark for construction of new buildings
Marine dredged aggregates (sand extraction)	Product EPD; Geography: DK; Publisher: NCC
Electrical - substation/transformer station	Ecoinvent v 3.11 - Cut-off, market for transformers, high & low voltage use

2.3 Modes of transport and distances

The mode of transport of dredged marine aggregates (sand) and blasted rocks is modelled as open-sea transport via ships/coasters. The mode of transport of other materials and components such as concrete, steel, pipes and electrical cables are primarily modelled with road transport using 26-tonnes diesel truck, and for larger materials 36-40 tonnes diesel truck. The transport data input was sourced from internal experience with other projects and project specific information, and where data was unavailable, default distances from InfraLCA V3.18, and EPDs were accordingly applied. Table 2-3 shows a sample of external transport data sources.

Table 2-3 Overview of transport data sources other than project specific.

Materials	Distance (km)	Source
Steel reinforcement	1500	InfraLCA V3.18
PE 100, Ø64 mm pipes,	1561	
Connecting road on shore, Type 4 T4	102	
Geotextile	113	Internal experience
20 kV Cable (1c500 Al)	700	NKT EPD
20 kV Cable (3c500 Al)	700	NKT EPD
Transformer 10/20 and 20/10 kV	1500	Assumed to be sourced from Germany

2.4 Main assumptions

Detailed assumptions are listed below:

- Background data is based on InfraLCA. Where data are missing, these are covered and complemented based on similar infrastructure harbour projects or 3rd party verified sources.

- The constructions components of lighting (belysning) and surface drainage (overfladeafvanding) are currently excluded as further dimension data is required for the carbon estimations. However, CO_2 emissions will be similar for the six scenarios.

- Data on machinery diesel consumption for the installation of structural steel (A5) for quay structures was not available. Diesel consumption for the installation of structural steel is, however, assessed as neglectable compared to the production of structural steel.

- Diesel consumption data for site operations (A5) involving the blasted rocks (sprængsten) in embankment and harbour was not available. Therefore, soil backfilling diesel consumption data from InfraLCA V3.18 was used as a proxy.

- The structural design data for buildings is not available at this phase of the project. Emission intensities for buildings are based on the building regulation benchmarks for new structures, as provided by TRIS – European Commission, ref. /7/. These benchmarks offer aggregated minimum emissions values for the A1–A3 and A4–A5 phases. Therefore, it is assumed that the carbon contribution of A4 and A5 individually corresponds to half of the total A4–A5 benchmark value.

- Road Type 4 (T4) cross section quantities were calculated based on the dimensions specified in the Vejdirektoratet’s catalogue (chapter 8) for hot-mix asphalt, as outlined in "Dimensionering - Befæstelser og forstærkningsbelægninger", ref. /8/.

- All CO_2 calculations include an additional 15% contingency buffer in order to cover any potential underestimations, due to data assumptions and limitations at the current project stage.

3 Results

Overall, the results indicate that the highest CO_2-emissions come from the manufacturing and production phase of materials (A1–A3), followed by the transport phase to the project site (A4). The lowest contribution comes from the installation and construction phase (A5). This suggests that the CO_2-footprint is primarily driven by the production and supply of materials, rather than the fuel consumption associated with on-site construction activities. Figure 3-1 below summarizes the CO_2 emissions across the six scenarios, broken down by life cycle phase including 15% contingency.

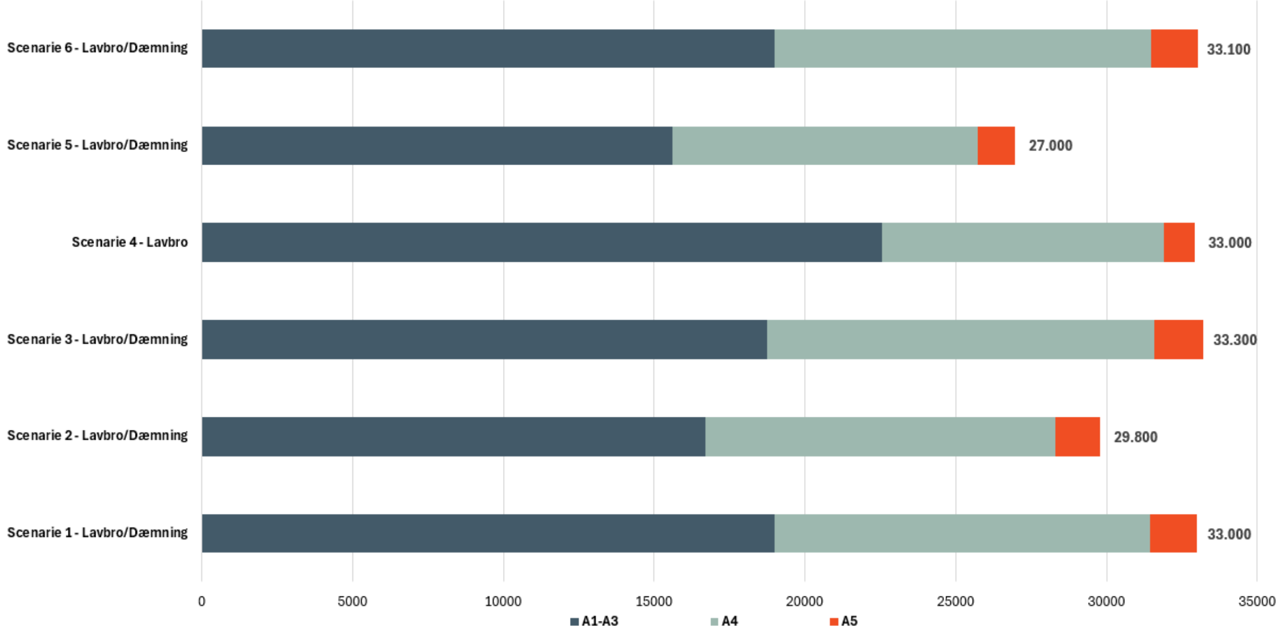

Figure 3-1 Tårs new island harbour scenarios, CO_2-footprint based on lifecycle phases.

All six scenarios demonstrate relatively similar CO_2 emission performance, indicating no significant differences in the construction components, as the input material quantities are largely comparable. However, some variations in CO_2 emissions arise due to differences in the construction of concrete bridges and embankment rockworks across the scenarios.

Scenario 1 (baseline) and Scenario 6 have approximately the same total CO_2 emissions—around 33,000 tonnes CO_2e. This similarity is attributed to the comparable quantities of materials used in the construction of project components. Scenario 4 also results in similar emissions, although it requires significantly larger quantities of concrete and steel for the construction of a long low bridge, but rockworks are much less presented in this scenario without a large central embankment. As a result, the transport phase contributes more to the total emissions in Scenarios 1 and 6.

Scenario 5, with the offshore harbour located closer to shore, and Scenario 2, which omits the bicycle lane, are the least carbon-intensive, with emissions of 27,000 and 29,800 tonnes CO_2e, respectively. This is primarily due to reduced material inputs, especially in the construction of concrete bridges and embankment rockworks.

In contrast, Scenario 3 is the most carbon-intensive, with total emissions of 33,300 tonnes CO_2e. This is primarily due to generally higher input material quantities compared to the other scenarios, as well as increased fuel consumption at the construction site, particularly for embankment rockworks.

In order to appreciate the magnitude of the emissions impact, Figure 3-2 and Figure 3-3 show the CO_2-emissions contribution from the various construction components for each of the six scenarios.

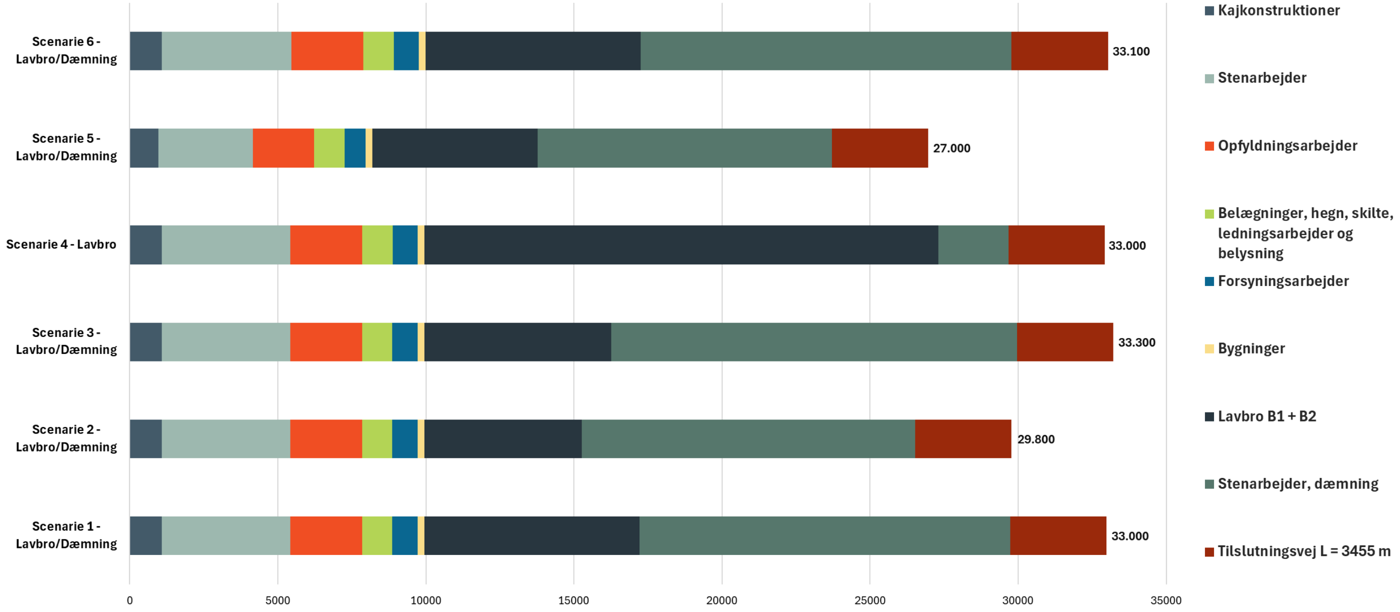

Figure 3-2 Tårs new island harbour scenarios, CO_2-emissions per construction component.

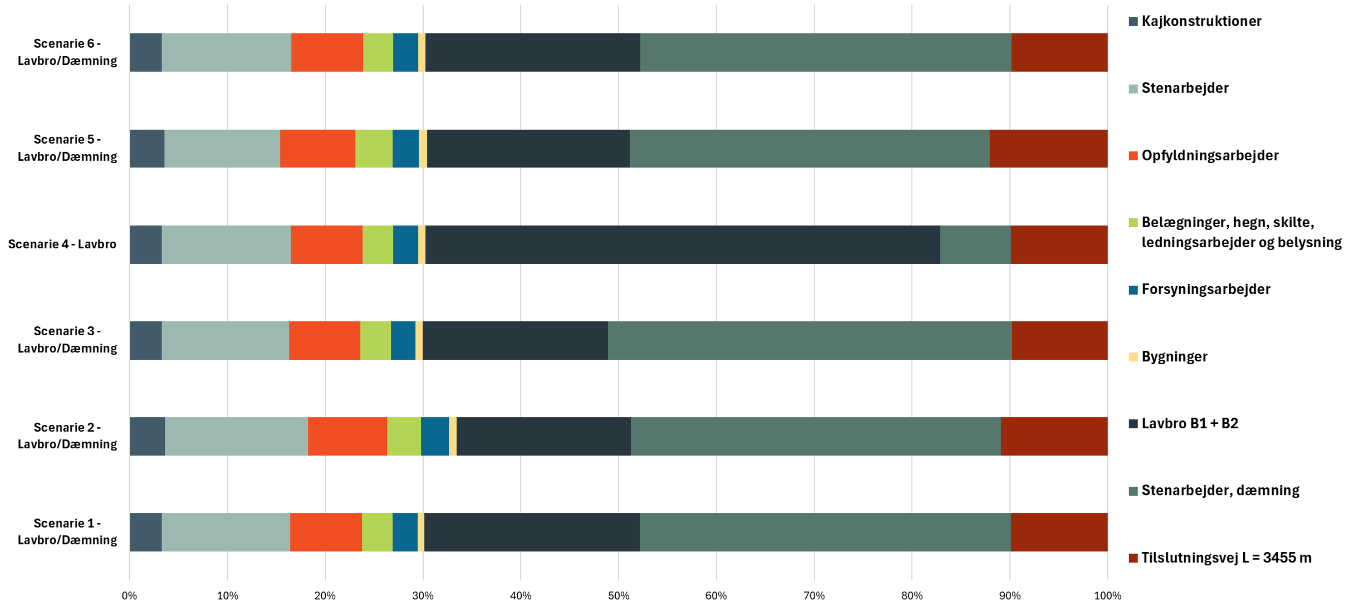

Figure 3-3 Tårs new island harbour scenarios, CO_2-emissions percentage contribution per construction component.

Identifying the carbon emission hotspots across the different construction work components within the project provides valuable insights into where efforts should be focused when reducing the overall carbon footprint. It is essential to understand which construction materials are the primary contributors to these emissions.

Figure 3-4 summarizes the CO_2-footprint of various construction material with percentage contribution to overall emissions for the baseline scenario (Scenario 1). Similar proportional trends are observed across the other scenarios, except for Scenario 4, where higher quantities of steel and concrete are used, and less rocks are required.

When evaluating the CO_2-footprint per unit mass, steel and concrete exhibit significantly higher impacts compared to other materials such as rocks and marine sand. Nonetheless, long-distance transportation of rocks and fossil fuel consumption involved in sand handling are also major contributors to the overall emissions. Furthermore, significantly large quantities of rocks are required for the construction of the offshore harbour compared to steel and concrete.

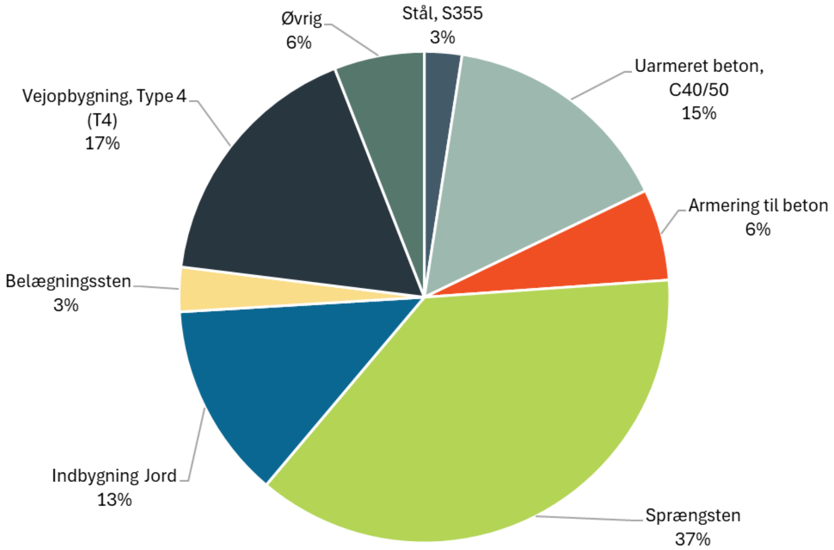

Figure 3-4 *Construction materials CO_2-emissions percentage contribution to scenario 1 (baseline).*

4 Conclusions

The CO_2-emissions performance of the six different scenarios range from 27,000 to 33,300 tonnes CO_2e, the highest being for scenario 3 due to higher input material quantities compared to the other scenarios, as well as increased fuel consumption at the construction site, particularly for embankment rockworks. The lowest emitter is scenario 5, which uses the least of materials from all other scenarios due to the harbour being located closer to shore compared to the other scenarios.

When looking at emission sources from construction materials, concrete and steel (structural and reinforcement steel) have a large embodied-impact from production, while emissions related to other materials such as rocks and sand are due to fossil fuel consumption used for transport and handling.

Overall, these results highlight an opportunity to look into construction materials and design optimization and requirements to create a strategic roadmap for carbon emissions targets at later development stages of the project.

5 References

/1/ **COWI**
A258774-HAV-TEK-11 Mængder og anlægsbudget
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/2/ **International Organization for Standardization**
ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework
Edition 2, 2006.

/3/ **International Organization for Standardization**
ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines
Edition 1, 2006.

/4/ **Dansk Standard**
DS/EN 17472:2022 Sustainability of construction works - Sustainability assessment of civil engineering works - Calculation methods
2022.

/5/ **Dansk Standard**
DS/EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
2019.

/6/ **Vejdirektoratet**
InfraLCA Version 3.18
Online: https://www.vejdirektoratet.dk/infralca, 2025.

/7/ **TRIS - European Commission**
Notification Detail - Order amending the Order on Building Regulations 2018
Online: https://technical-regulation-information-system.ec.europa.eu/en/notification/26461, 2024.

/8/ **Vejdirektoratet**
Dimensionering - Befæstelser og forstærkningsbelægninger
2022.

Appendix A Detailed results

Table A-1 Tårs new island harbour scenarios, CO_2e footprint based on lifecycle phases.

Project lifecycle phases	A1-A3 (Material production)	A4 (transport)	A5 (Construction)	Total carbon footprint (tons CO_2e) *
Scenario 1 - Lavbro/Dæmning	18,990	12,443	1,557	33,000
Scenario 2 - Lavbro/Dæmning	16,701	11,618	1,456	29,800
Scenario 3 - Lavbro/Dæmning	18,741	12,850	1,620	33,300
Scenario 4 - Lavbro	22,566	9,340	1,019	33,000
Scenario 5 - Lavbro/Dæmning	15,600	10,133	1,224	27,000
Scenari0 6 - Lavbro/Dæmning	19,001	12,472	1,558	33,100

**Total emissions are rounded up to nearest hundred*

Table A-2 Tårs new island harbour scenarios, CO_2e emissions per construction component.

Konstruktions-komponenter	Scenarie 1 - Lavbro/ Dæmning	Scenarie 2 - Lavbro/ Dæmning	Scenarie 3 - Lavbro/ Dæmning	Scenarie 4 - Lavbro	Scenarie 5 - Lavbro/ Dæmning	Scenarie 6 - Lavbro/ Dæmning
Kajkonstruktioner	1,085	1,085	1,085	1,085	964	1,085
	3%	4%	3%	3%	4%	3%
Stenarbejder	4,343	4,343	4,343	4,343	3,188	4,383
	13%	15%	13%	13%	12%	13%
Opfyldningsarbejder	2,415	2,415	2,415	2,415	2,070	2,415
	7%	8%	7%	7%	8%	7%
Belægninger, hegn, skilte, ledning-sarbejder og belysning	1,029	1,029	1,029	1,035	1,029	1,029
	3%	3%	3%	3%	4%	3%
Forsyningsarbejder	843	843	843	843	714	843
	3%	3%	3%	3%	3%	3%
Bygninger	237	237	237	237	237	237
	0,72%	0,80%	0,71%	0,72%	0,88%	0,72%
Lavbro B1 + B2	7,259	5,311	6,299	17,341	5,579	7,259
	22%	18%	18,92%	53%	21%	22%
Stenarbejder, dæmning	12,526	11,260	13,708	2,380	9,923	12,526
	38%	38%	41,17%	7%	37%	38%
Tilslutningsvej	3,253	3,253	3,253	3,253	3,253	3,253
	10%	11%	9,77%	10%	12%	10%
Samlede klimapåvirkning (tons CO_2e)*	33,000	29,800	33,300	33,000	27,000	33,100

**Total emissions are rounded up to nearest hundred*

Table A-3 Construction materials CO_2-emissions percentage contribution to scenario 1 (baseline).

Material	Carbon footprint (tons CO_2e)	Percentage contribution
Stål, S355	814	2%
Uarmeret beton, C40/50	5,080	15%
Armering til beton (stål Y550)	1,985	6%
Sprængsten	12,295	37%
Indbygning/opfyldning med sand	4,255	13%
Belægningssten	964	3%
Vejopbygning, Type 4 (T4)	5,633	17%
Øvrig	1,964	6%
Total Sum*	33,000	100%

**Total emissions are rounded up to nearest hundred*