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Translation rating to impact categories

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Cover page

This report presents the translation of the DuneFront sustainability rating system into quantifiable environmental impact indicators aligned with established Life Cycle Assessment (LCA) methodologies. It is a key step in Work Package 8 (WP8), which focuses on assessing the environmental performance of hybrid blue-grey infrastructures such as dune-dike systems across selected European coastal demonstrator sites.

In Deliverable D8.1, the project introduced a dedicated rating system to qualitatively assess hybrid infrastructure solutions across categories such as material use, climate resilience, biodiversity, water management, and land regeneration. However, to support robust comparison with conventional alternatives and ensure alignment with EU policy frameworks, it is essential to translate these qualitative sustainability criteria into measurable Life Cycle Impact Assessment (LCIA) categories.

D8.2 addresses this need by mapping each rating sub-criterion to relevant LCIA categories such as: global warming potential (GWP), Abiotic depletion potential (ADP), Water depletion, Eutrophication and acidification, Land Use, Human and Ecotoxicity.

The mapping process was based on internationally recognized methods (e.g., EN 15804, ISO 14040/44), supported by reliable data sources, including Environmental Product Declarations (EPDs), the Ecoinvent v3.8 database, and LCA tools such as SimaPro and One Click LCA. Where direct quantification was not possible within the present scope, such as for ecosystem services or social co-benefits, proxy indicators or qualitative flags were proposed.

This deliverable also provides guidance for future analysis, including optional normalization and weighting strategies. It builds the methodological foundation for the upcoming D8.3, which will deliver a complete life cycle inventory (LCI) analysis of selected demonstrator sites. The translation of rating criteria into LCIA categories enables more transparent, data-driven comparisons across coastal protection strategies, and supports integration with planning and policy tools such as the DuneFront Decision Support System (WP14).

By making the (environmental) impacts of nature-based and hybrid solutions measurable and comparable, D8.2 contributes to improved design, evaluation, and policy uptake of sustainable coastal infrastructure. It directly supports European Green Deal priorities and the integration of Nature-based Solutions into climate adaptation strategies.

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List of abbreviations

Abbreviation	Explanation
WP	Work Package
D	Deliverable
LCA	Life cycle assessment
LCIA	Life cycle impact assessment
EPD	Environmental product declaration
ADP	Abiotic depletion potential
GWP	Global warming potential
NbS	Nature-based solutions
AP	Acidification potential
EP	Eutrophication potential
LCI	Life cycle inventory

1. Introduction

Hybrid dune dike infrastructure is increasingly recognized for its potential to address coastal climate challenges while delivering ecological and social co-benefits. The DuneFront project supports the development and assessment of such Nature-based solutions (NbS), focusing on sustainability, biodiversity integration, and resilience under future environmental stressors.

As part of Work Package 8, we introduced the rating system in Deliverable 8.1 (D8.1) to evaluate the environmental and sustainability performance of hybrid dune-dike infrastructure. This rating system offers a structured and holistic view of sustainability, with its qualitative limits allowing for direct integration with established life cycle assessment (LCA) tools and frameworks.

This deliverable addresses the gap by translating the DuneFront rating criteria into quantitative Life Cycle Impact Assessment (LCIA) categories. These impact categories, such as Global warming potential (GWP), abiotic depletion potential (ADP), and water depletion, are widely used in environmental product declaration (EPDs) and LCA software tools. The goal is to bridge the conceptual framework of sustainability with data-driven decision-making tools used in environmental engineering, coastal management, and infrastructure design.

This translation facilitates the consistent evaluation of demonstrator sites within DuneFront, allowing for comparison with conventional solutions and providing a solid basis for the upcoming inventory-based assessments (D8.3). It also enhances transparency, reproducibility, and policy relevance by aligning the DuneFront methodology with international standards, such as ISO 14040/44 and EN 15804.

2. Assessment Methodology

The purpose of this deliverable is to translate systematically the qualitative sustainability criteria defined in the DuneFront rating system (D8.1) into quantitative environmental impact categories used in LCA. This process ensures compatibility with recognized LCA methodologies and enables measurable evaluation of blue-grey dune-dike infrastructure performance.

2.1 Review and structure of DuneFront rating criteria

The rating system includes several sustainability categories tailored to hybrid dune-dike infrastructure, such as:

Material and construction practices, climate resilience, water and energy management, biodiversity and ecosystem restoration, land use and site regeneration, pollution prevention,

monitoring, and maintenance. Each of these categories contains multiple sub-criteria or performance indicators. For example, the materials and construction category includes criteria such as the use of recycled content, low-impact materials, and the durability of components. To translate the rating system into measurable environmental impacts, we systematically evaluated each sub-criterion, considering these questions:

- 1- Does this criterion result in a quantifiable environmental effect? Like CO₂ emissions from material use.
- 2- Is there a well-established LCIA category that corresponds to this criterion? For example, the use of recycled materials relates to ADP, while vegetation restoration might connect with land use or biodiversity impact proxies.
- 3- If the criterion is qualitative or indirect, can it be linked to a proxy metric or scoring method? Like stakeholder engagement or ecosystem services, they may not fit within conventional LCIA categories but can still be tracked through complementary indicators.

By answering these questions, we can classify each criterion into one of three categories: quantifiable via existing LCA methods (GWP, ADP), indirectly quantifiable through proxies or assumptions, and Non-quantifiable but relevant for narrative reporting or qualitative assessment.

2.2 Selection of relevant LCIA methods and categories

LCIA categories were selected based on their compatibility with infrastructure assessment and their availability in widely used LCA tools, such as SimaPro. To ensure consistency and relevance to coastal infrastructure, the following selection criteria were applied:

Applicability to infrastructure and construction materials, the selected impact categories needed to be sensitive to the types of materials and processes used in hybrid dune-dike systems (concrete, plastic geotextile, excavation, plant materials).

Availability in mainstream LCA tools and databases.

Relevance to environmental and climate objectives, categories had to reflect key ecological concerns associated with DuneFront goals, such as preserving biodiversity, conserving water, reducing greenhouse gas emissions, and managing land sustainably.

Based on these criteria, we selected the following LCIA categories presented in Table 1:

Table 1: Selected Life Cycle Impact Assessment (LCIA) Categories Used to Quantify Environmental Impacts in the DuneFront Rating System

Impact Category	Description	Unit	Main Sources
Global Warming Potential (GWP)	Climate change impacts from greenhouse gas emissions	kg CO ₂ equivalent	IPCC, EN 15804
Abiotic Depletion (ADP)	Use of non-renewable natural resources (minerals land metals, e.g. sand and concrete use)	kg Sb equivalent	CML, EF 3.0
Water Depletion	Consumption of freshwater resources	m ³	ReCiPe, EF 3.0
Eutrophication Potential (EP)	Nutrient emissions causing water body degradation (e.g., algae blooms)	kg PO ₄ equivalent	CML, ReCiPe
Acidification Potential (AP)	Emissions causing acid rain and soil/water acidification	kg SO ₂ equivalent	ReCiPe, CML
Land Use	Physical occupation or transformation of land	m ² ·year (or PDF·m ² ·yr)	ReCiPe, EF 3.0
Human/Ecotoxicity Potential	Impact of toxic emissions on human health and ecosystems	kg 1,4-DCB equivalent	USEtox, ReCiPe

These categories enable DuneFront infrastructure projects to be assessed not only for general sustainability goals but also in terms of specific, measurable environmental impacts. Where direct quantification was not possible (e.g., biodiversity restoration or social value), we flagged those categories for proxy-based or qualitative assessment, to be explored in future deliverables.

3. Mapping rating criteria to LCIA indicators

This part involved directly linking each sub-criterion of the DuneFront rating system to one or more quantitative LCIA categories selected in the previous section. This mapping created the foundation for converting the DuneFront rating framework into measurable environmental performance indicators. The process was carried out in diverse stages:

3.1.1 Analyse each rating sub-criterion

Each sub-criterion under the DuneFront categories (e.g., use of recycled content, stormwater infiltration, biodiversity restoration) was examined to determine whether it could be :

- Directly translated into an LCIA impact (GWP from CO₂ emissions)
- Indirectly linked using proxy values or representative metrics (land use as a proxy for ecosystem services)
- Non-quantifiable, meaning it would remain as a qualitative performance measure or narrative input.

3.1.2 Assign corresponding LCIA category and units

For each mappable criterion, a corresponding LCIA impact category was assigned. For example:

- ✓ “Recycled content in construction materials”: Abiotic Depletion Potential (ADP), expressed in kg Sb eq, because using recycled materials reduces the need for virgin resource extraction.
- ✓ “CO₂ emissions reduction from low-impact processes”: Global Warming Potential (GWP), measured in kg CO₂ eq, using emission factors from databases like Ecoinvent or EPDs.
- ✓ “Use of water-saving landscaping”: Water Depletion, measured in m³, based on construction and operational water use.
- ✓ “Vegetation cover for dune stabilization”: Land Use (m²·year), with qualitative linkage to biodiversity benefits.

3.1.3 Create a consolidated mapping table

To complete the mapping process, a consolidated table was developed that links each sub-criterion of the DuneFront rating system to its corresponding Life Cycle Impact Assessment (LCIA) category (see Table 2). It serves as a practical reference for translating qualitative sustainability objectives into quantifiable environmental indicators. The table also highlights where proxy indicators or qualitative approaches are necessary, particularly for criteria related to biodiversity and ecosystem services.

Table 2: Mapping of DuneFront Rating Criteria to Life Cycle Impact Assessment (LCIA) Categories

DuneFront Rating Category	Sub-Criterion	Mapped LCIA Category	Unit	Primary Data Source	Notes
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Materials & Construction	Use of recycled materials	Abiotic Depletion Potential (ADP)	kg Sb eq.	Ecoinvent / EN15804 EPDs	Reduces demand for virgin resources
	Energy-efficient equipment	Global Warming Potential (GWP)	kg CO ₂ eq.	SimaPro / One Click LCA	Based on fuel/electricity use per machinery type
	Durable, low-maintenance materials	ADP, GWP	kg Sb eq., kg CO ₂ eq.	EPDs / Manufacturer LCA data	Longer lifespan reduces replacement cycles
Climate Resilience	CO ₂ reduction in design	Global Warming Potential (GWP)	kg CO ₂ eq.	LCA emissions calculation	Avoided emissions from optimized designs
	Flood protection function (qualitative)	Land Use / Ecosystem Services (proxy)	–	Proxy indicators	Proxy metric to be defined in D8.3 or WP14
Water Management	Stormwater retention and infiltration	Water Depletion	m ³	Project-specific LCA inputs	Reduces demand for potable water
	Runoff quality improvements	Eutrophication, Human Toxicity	kg PO ₄ eq. / kg 1,4-DCB eq.	ReCiPe / USEtox	Related to nutrient and contaminant discharge
Biodiversity & Ecosystems	Habitat restoration	Land Use / Qualitative biodiversity proxy	m ² ·year / index	SITES, LEED, project GIS data	Proxy scoring under development
	Native vegetation use	Land Use, GWP (carbon uptake)	m ² ·year / kg	NDVI/remote sensing data	Accounts for both stabilizing

			CO ₂ eq.		function and carbon sink
Pollution Prevention	Non-toxic construction materials	Human/Ecotoxicity (HTP, TETP)	kg 1,4- DCB eq.	USEtox, MSDS	Substitution of hazardous compounds
Land Use & Regeneration	Brownfield site redevelopment	Land Use Change	m ² -year	Spatial LCA / GIS layers	Redevelopment avoids new greenfield impact
Energy Use	Renewable energy for site operation	GWP / Primary Energy Demand	kg CO ₂ eq. / MJ	LCI database	GHG intensity based on grid mix
Monitoring & Maintenance	Low-impact maintenance practices	GWP / AP	kg CO ₂ eq. / kg SO ₂ eq.	Fuel consumption models	Includes machinery, fuel, and maintenance intervals

This table enables users of the DuneFront rating system to assign quantitative environmental scores to infrastructure projects, allowing them to compare options based on actual environmental impacts rather than subjective ratings alone.

3.2 Use of environmental product declarations and LCA databases

To support the translation of rating criteria into quantifiable environmental impacts, reliable data sources were used to ensure accuracy and consistency. Specifically, Environmental Product Declarations (EPDs) served as a primary reference for material-specific ecological profiles. EPDs offer standardized and third-party verified LCA data for construction materials, including emissions, energy use, and resource depletion, typically based on EN 15804. In addition to EPDs, Life Cycle Inventory (LCI) data were sourced from the following databases and tools:

- ✓ Ecoinvent v3.8, a widely accepted international LCI database.
- ✓ One Click LCA, especially its construction-sector default datasets.
- ✓ SimaPro, using predefined process chains for materials commonly used in hybrid dune-dike infrastructures, such as concrete, basalt aggregates, plastic geotextiles, and vegetation systems.

3.3 Guidance for normalization and weighting

The DuneFront rating system developed in Deliverable D8.1 already incorporates a structured weighting system for sustainability categories. These weights were determined based on expert judgment, stakeholder consultation, and policy relevance, and are used to calculate the overall rating score of hybrid blue–grey infrastructure solutions.

Although the primary objective of this report is to establish a mapping between sustainability criteria and LCIA categories, additional guidance was developed for potential normalization and weighting of results, which can support consistent comparison across different demonstrator or design scenarios. To aid analysts using the DuneFront framework:

- Normalization of LCIA results, using reference values such as EU or global average impacts (per capita or per square meter) of infrastructure, to allow comparability across sites and scales.
- Sensitivity testing of weighting, to explore how different impact categories (e.g., GWP, Water Depletion, Land Use) might influence project rankings under varied policy or climate scenarios.
- Consider regional adjustments for normalization values, especially for water depletion or land use, where local sensitivity may affect interpretation.

4. Conclusion

This deliverable has advanced the DuneFront sustainability assessment framework by translating its qualitative rating criteria into quantitative Life Cycle Impact Assessment (LCIA) categories. By establishing these links, Deliverable D8.2 creates a functional bridge between the conceptual evaluation of hybrid dune–dike infrastructures and their measurable environmental performance, utilizing standardized LCA methods.

The selected LCIA categories, such as Global Warming Potential, Abiotic Depletion, and Water Depletion, reflect the most critical environmental concerns related to infrastructure development and are supported by established data sources like Ecoinvent, EPDs, and sector-specific LCA tools. For each rating criterion, this deliverable identifies whether it can be quantified directly, approximated via proxies, or considered through qualitative reporting, ensuring a transparent and structured approach.

This translation supports multiple goals:

- It strengthens the credibility and objectivity of the DuneFront rating system.
- It prepares the groundwork for future assessments in Deliverable D8.3, where actual material flows and inventory data from demonstrator sites will be analyzed.



- It facilitates alignment with international standards and sustainability reporting frameworks, enabling broader policy relevance and stakeholder engagement.

While some limitations remain, particularly in quantifying ecosystem services and long-term social benefits, this framework enables consistent scoring, comparison, and decision support across different project types and geography.