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Final report on the LCA-LCCA-online tool including a meaningful user manual

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Call 2020: Resource Efficiency and the Circular Economy



**D4.1 - Final report on the LCA-LCCA-
online tool including a meaningful user
manual**

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1 Introduction

In 2020, road transportation accounted for 24% of the total carbon dioxide emissions in the European Union. Most of the carbon emissions within the transportation sector are associated with vehicle operation, followed by infrastructure construction and maintenance. Roadside equipment, like noise and safety barriers, has a limited impact. Nonetheless, road infrastructure construction necessitates significant use of natural resources and leads to huge waste production. The PROCEEDR project, financed by the CEDR Transnational Road Research Programme Call 2020 Resource Efficiency and Circular Economy, has developed a software tool to assist National Road Administrations (NRAs) and manufacturers of roadside equipment in discovering innovative and sustainable solutions, thereby facilitating the shift from a linear to a circular economy in the realm of roadside infrastructure.

This report first aims to give an overview of the tool's objectives and the areas where it can be effectively employed. Subsequently, it will describe the tool structure, providing a step-by-step guide to assist the user in navigating its functionalities and ends with suggestions for potential improvements.

2 Tool's objectives and users

The PROCEEDR tool is designed to assess the resource efficiency and circularity potential of roadside noise and safety barriers through the application of Life Cycle Assessment (LCA), Life Cycle Cost Assessment (LCCA), and a newly developed Circularity Indicator (CI). The assessment scope encompasses the entire life cycle, from production and transportation of the raw materials over construction, and maintenance of noise and safety barriers to replacement, waste processing, and recycling/downcycling.

As a result, the PROCEEDR tool can be used by:

- Project leads or consultants at National Road Authorities (NRAs) to compare different barrier solutions for specific lengths/areas and to evaluate their environmental impact and circularity potential. It serves as a valuable resource for assessing both existing barriers as well as new projects.
- Manufacturers and designers of roadside equipment to conduct a comprehensive environmental impact assessment and explore the circularity potential, aiding in the identification of areas for optimization and facilitating comparisons between different design alternatives.

3 Tool Structure

The following section presents and explains the navigation through the tool’s drop-down tabs in the same order that a user would experience it.

3.1 Start page

Of the various types of roadside infrastructure equipment, the life cycle assessment and circularity indication were conducted on noise and safety barriers. Therefore, to begin the project, the user must select the specific barrier they wish to proceed with (Figure 1).

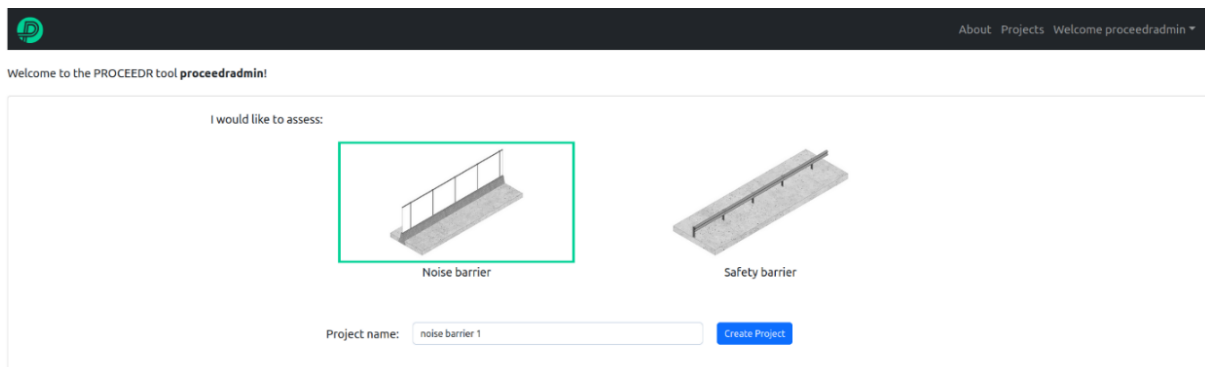


Figure 1 PROCEEDR tool start page

3.2 Defining a project

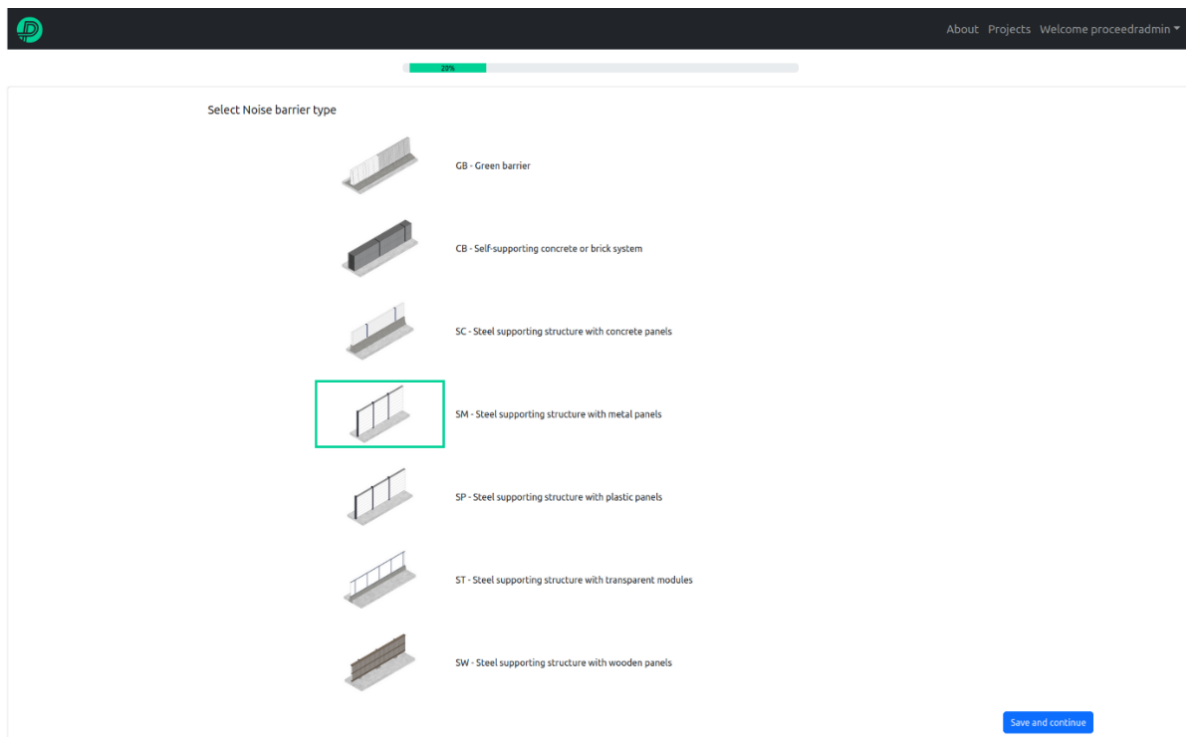
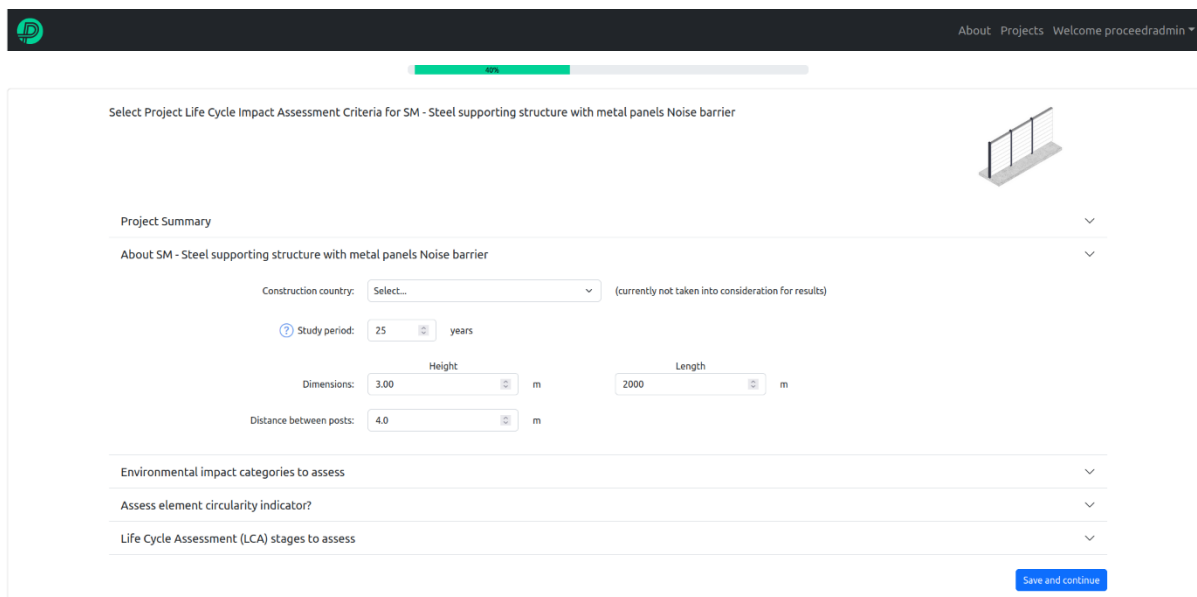


Figure 2 Selecting noise barrier type

For each barrier, there are several predefined types to choose from, based on common barriers in Europe (D1.2¹). Figure 2 shows the various types of noise barriers.

Each barrier includes default data on materials and their quantities, compiled from expert estimations and European Environmental Product Declarations (EPDs) available also in D2.2¹. The user can modify material quantities with specific product information.

After selecting the barrier, the user must choose the project-specific values (Figure 3). The dimensions, height (for noise barriers), and length of the barriers represent the area or length under evaluation for the overall environmental impact assessment. The study period, distinct from the project lifetime, indicates the period in which environmental impacts and costs associated with production, replacement, maintenance, transportation, and waste treatment will be assessed². Although the user can define each element's lifetime individually, the study period corresponds to the foundation lifetime.



Select Project Life Cycle Impact Assessment Criteria for SM - Steel supporting structure with metal panels Noise barrier

Project Summary

About SM - Steel supporting structure with metal panels Noise barrier

Construction country: Select... (currently not taken into consideration for results)

Study period: 25 years

Dimensions: Height 3.00 m, Length 2000 m, Distance between posts: 4.0 m

Environmental impact categories to assess

Assess element circularity indicator?

Life Cycle Assessment (LCA) stages to assess

Save and continue

Figure 3 Project definition

3.3 Environmental impact categories

In this tab, the user can choose to assess from 13 environmental impact categories (Figure 4) including: Total global warming potential (GWP-total), Fossil global warming potential (GWP-fossil), Biogenic global warming potential (GWP-biogenic), Land use and land use change global warming potential (GWP-Luluc), Depletion potential of the stratospheric ozone layer (ODP), Formation potential of tropospheric ozone (POCP), Acidification potential (AP), Freshwater eutrophication potential (EP-freshwater), Marine eutrophication potential (EP-marine), Terrestrial eutrophication potential (EP-terrestrial), Water depletion potential (WDP), Abiotic depletion potential for fossil resources (ADP-fossil), and Abiotic depletion potential for

¹ <https://proceedr.project.cedr.eu/publications/>

² For more realistic results, it is advisable to select a study period that is equal to or longer than the lifetime of the elements. If the chosen study period is shorter than the elements' lifetime, the calculation of the associated environmental impact will be limited to that short period. In such cases, A1-A3 will encompass the entire environmental impacts of material production, while B4 will indicate negative values corresponding to the elements' lifetime, which is not included in the study.

non-fossil resources (ADP-Minerals & Metals).

Although the tool defaults to measuring the total global warming potential (GWP-total), the user can activate other environmental impact categories as needed.

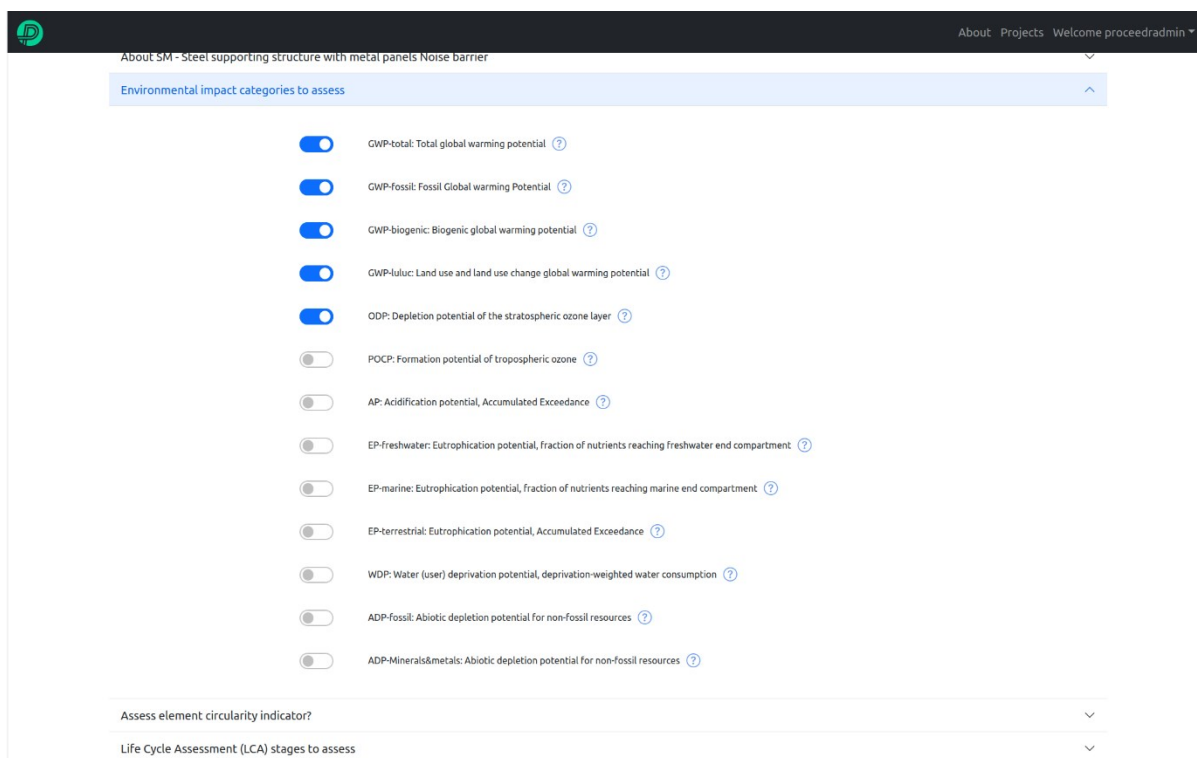


Figure 4 Selecting environmental impact category to assess

If the user is unfamiliar with the environmental impact categories or any other terms in different tabs, clicking on the question mark will prompt a pop-up box to appear on the screen, offering additional information or images for clarification (Figure 5).

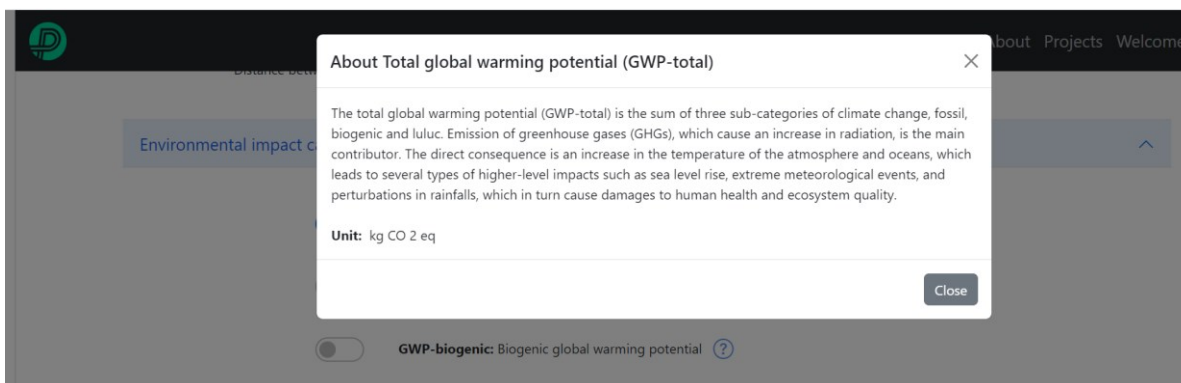


Figure 5 A pop-up information box

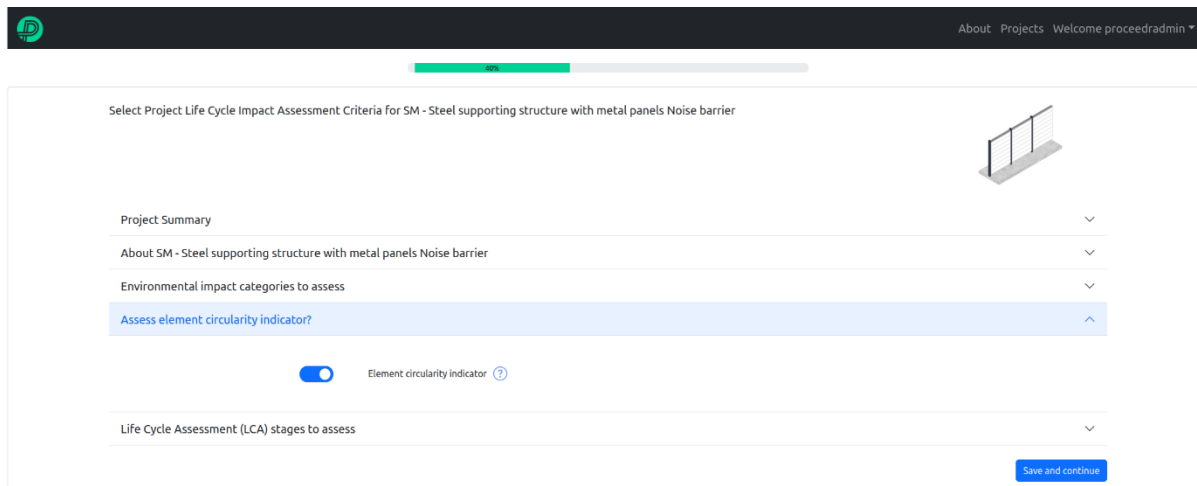


Figure 6 Circularity indicator

Upon enabling the element circularity indicator (Figure 6), the tool evaluates it for each defined element (foundation, structural posts, acoustic elements or railing). The circularity indicator (CI) is a numerical assessment of an element's circularity. This number ranges from 0 to 1, from totally linear to circular. The assessment criteria include the linear flow index of the material (virgin, secondary and bio-based material input and output) and the utility of the product (how long and intensely a product is going to be used in comparison with average similar products).

3.4 Life cycle stages

This tool enables the user to assess all relevant life cycle stages (cradle to cradle) for noise and safety barriers (irrelevant life cycle stages for these products have been excluded) and the potential environmental impacts and costs. If the user wishes to evaluate specific life stages, they can disable the others in this tab (Figure 7). These stages include: production (A1-A3) involving virgin and secondary material extraction, processing, manufacturing, and transportation within and up to manufacturing; construction (A4-A5) encompassing transportation and installation; maintenance (B2) involving regular cleaning; replacement (B4) after the element's lifespan; deconstruction and transportation (C1-C2) for disassembly and transport to recycling or disposal centres; and potential benefits (D) derived from material or energy recovery beyond the product system boundaries.

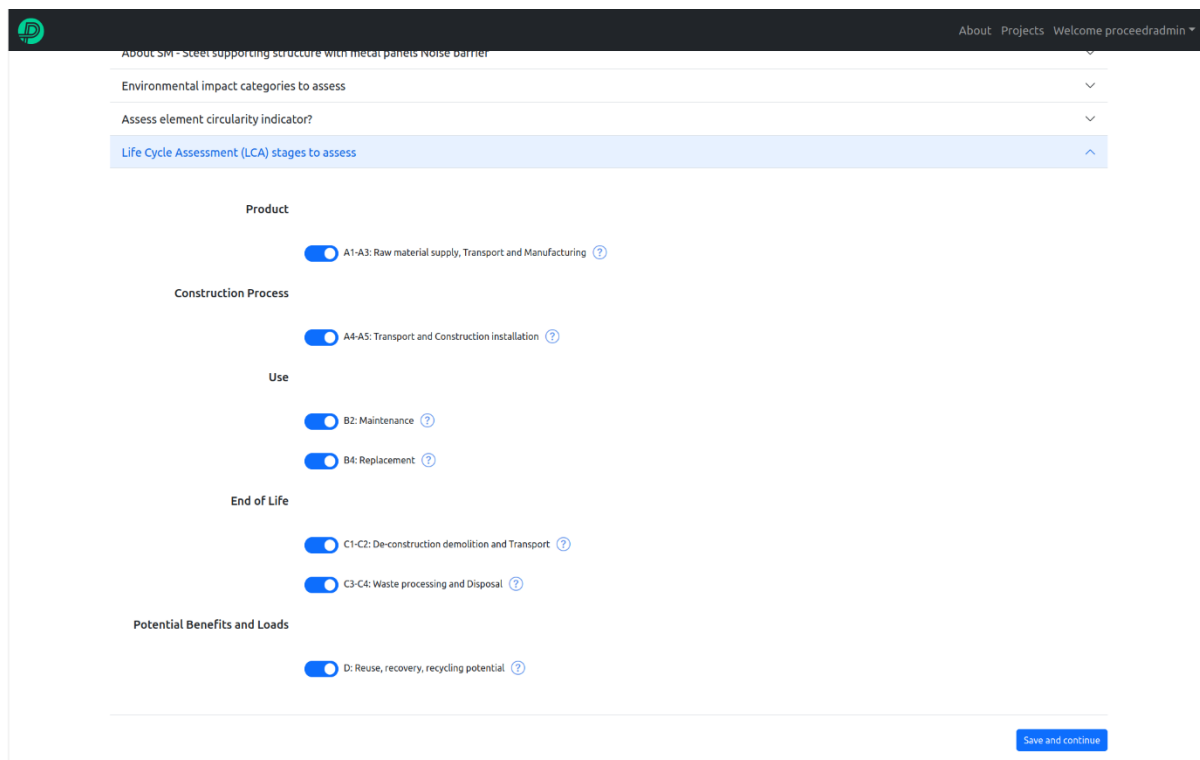
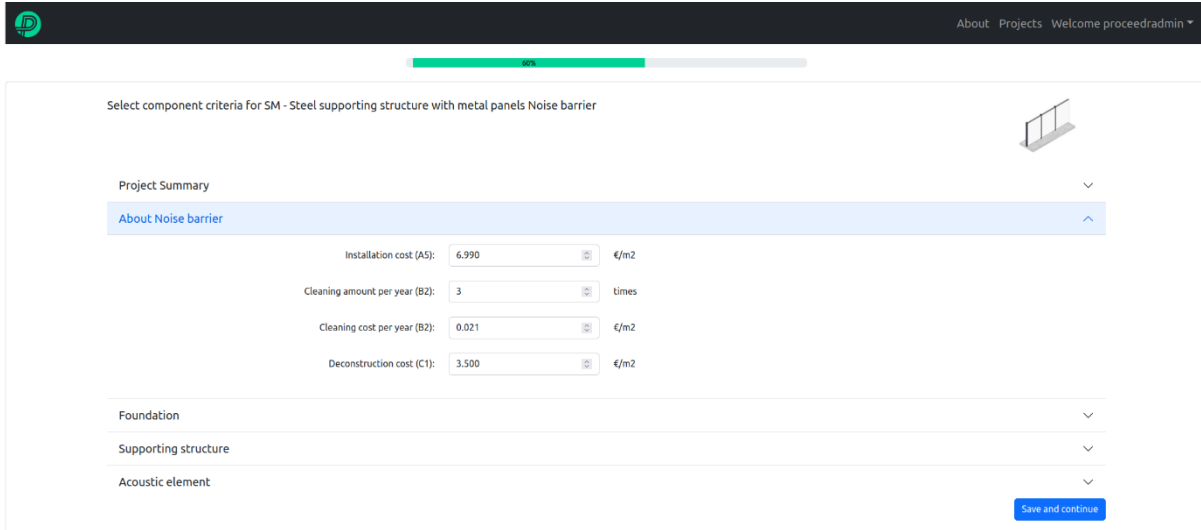


Figure 7 Selecting life cycle stages to assess

3.5 Barrier specific data

After defining the project scope and selecting the environmental impact categories to be assessed, the user can enter specific data or continue with the provided default data for the entire barrier and each element (e.g., foundation, structural posts, and acoustic panels) in the respective tabs. The user has the option to save and continue with default values or input their own data.

For instance, when including the installation (A5), maintenance (B2), and deconstruction (C1) stages, the user can view and modify values related to the cost of each process or the frequency of cleanings (for maintenance) (Figure 8).



Select component criteria for SM - Steel supporting structure with metal panels Noise barrier

Project Summary

About Noise barrier

Installation cost (A5):	<input type="text" value="6.990"/>	€/m2
Cleaning amount per year (B2):	<input type="text" value="3"/>	times
Cleaning cost per year (B2):	<input type="text" value="0.021"/>	€/m2
Deconstruction cost (C1):	<input type="text" value="3.500"/>	€/m2

Foundation

Supporting structure

Acoustic element

Save and continue

Figure 8 Entire barrier's relevant values

3.6 Material production and end-of-life

For noise barriers, the user can navigate through three tabs: foundation, structural posts, and acoustic elements (for safety barriers, there are only two: structural posts and railing) to select materials, quantities, and other values. The separation of elements, apart from having different lifetimes, allows the user to assess the environmental impact of installing a barrier on an existing foundation.

Selecting any of these tabs, such as the foundation (Figure 9), reveals sub-tabs (Construction materials and Transport modes) with values concerning the life cycle stages for which the user wants to assess their impacts. It is important to note that certain dependencies exist between life cycle stages and between life cycle stages and circularity indicators. For instance, even if the user chooses not to assess stages A1-A3 initially, they have to provide values for these stages, as the other stages are reliant on the materials produced in the initial stages. Similarly, to evaluate the circularity indicator of a barrier, the user must contain the production (A1-A3) and end-of-life (C3-C4) stages, even if they initially were not selected.

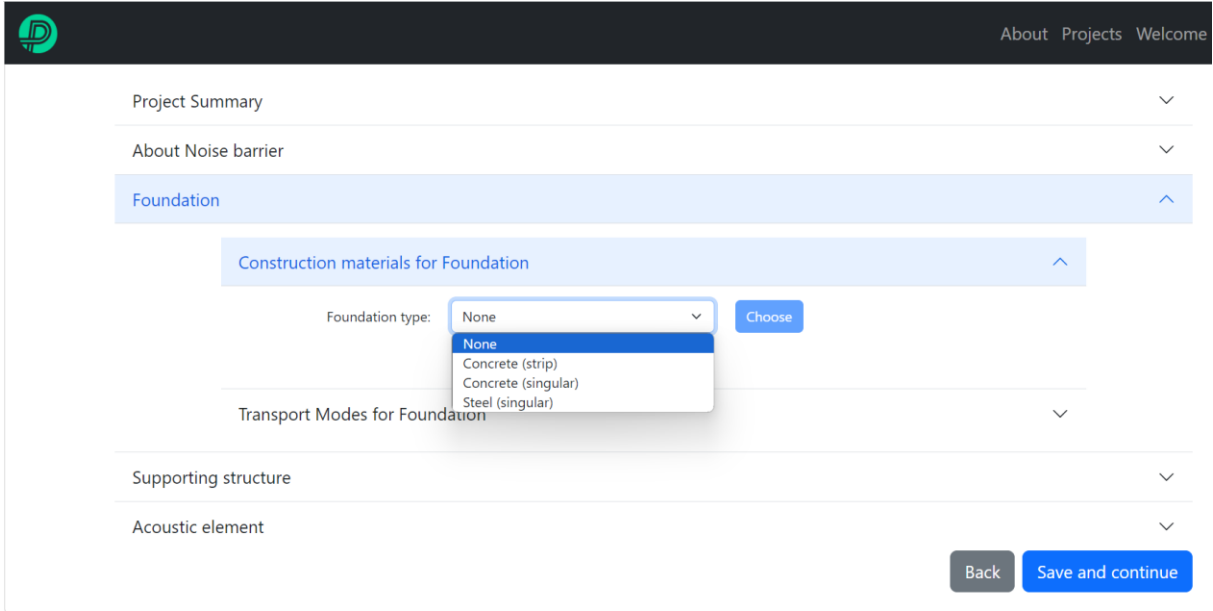


Figure 9 Element type selection

For the specific barrier type selected by the user (e.g., SM-steel structure with metal panels), a list of different elements, such as various foundations, structural posts, and acoustic panels, is available (Figure 9). Selecting each element reveals a list of materials associated to the element, along with their default quantities and costs (Figure 10). The user can adjust the dimensions, density, and costs of these elements as needed.

Precast concrete element strip ^

About Precast concrete element strip:

Density:	<input type="text" value="2400,00000"/>	kg/m ³
Section area:	<input type="text" value="0,3100000000"/>	m ²
Length (strip foundation)/ Height (singular foundation):	<input type="text" value="4,0000000000"/>	m

Raw material supply, Transport and Manufacturing for Precast concrete element strip (A1-A3):

Material Cost:	<input type="text" value="0,40"/>	€/kg
Material virginity:	<input type="text" value="70,00"/>	%

Waste processing, disposal and circularity for Precast concrete element strip (C3-C4):

Disposal cost:	<input type="text" value="0,032"/>	€/kg
Recycle/Downcycle for secondary use:	<input type="text" value="40,00"/>	%

Reuse, recovery, recycling potential for Precast concrete element strip (D):

Virgin material production cost:	<input type="text" value="0,43"/>	€/kg
Recycle/Downcycle cost:	<input type="text" value="0,34"/>	€/kg

Figure 10 Materials production and end of life inputs

The percentage of “Material Virginity” indicates the proportion of materials being used for the first time in the production stage, and the “Recycling/Downcycling” percentage represents the amount of materials, after reaching its end-of-life, that will be recovered for secondary use in the same or other industries rather than being disposed of (e.g. via landfill or incineration). Although these percentages are initially estimated based on various manufacturers' reports and scientific articles (see D2.2¹), the user can edit them if they possess more advanced knowledge about specific materials. Defining these values properly allows a more accurate assessment of environmental impacts, as the energy consumption during virgin material extraction and processing differs from that during processing for secondary use after the end of life. Additionally, these values are required for evaluating product circularity and module D (potential benefits and loads).

3.7 Transportation

After the selection of materials, for each element the user needs to select the transportation modes and distance from the manufacturing place to the installation site (A4) and from the installation site to the waste treatment or recycling centre (C1) (Figure 11). The default transportation mode is set to “Lorry, unspecified”, representing an average value for different types of transportation lorries with average emissions in Europe. The tool also offers a drop-down list of different transportation modes, including various lorry sizes and emission

¹ <https://proceedr.project.cedr.eu/publications/>

categories (EURO 3, 4, 5, and 6), train, ferry, and plane, for the user to select from (Figure 12). Additionally, the user can input transportation distance and cost instead of relying on default values.

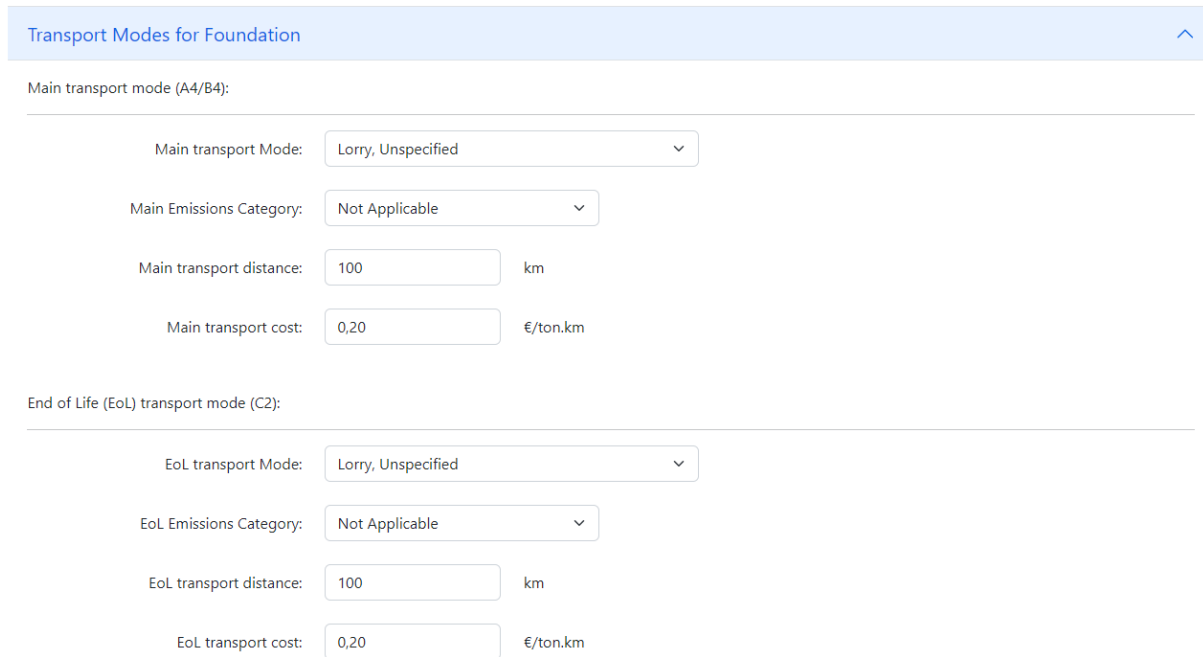


Figure 11 Transportation inputs

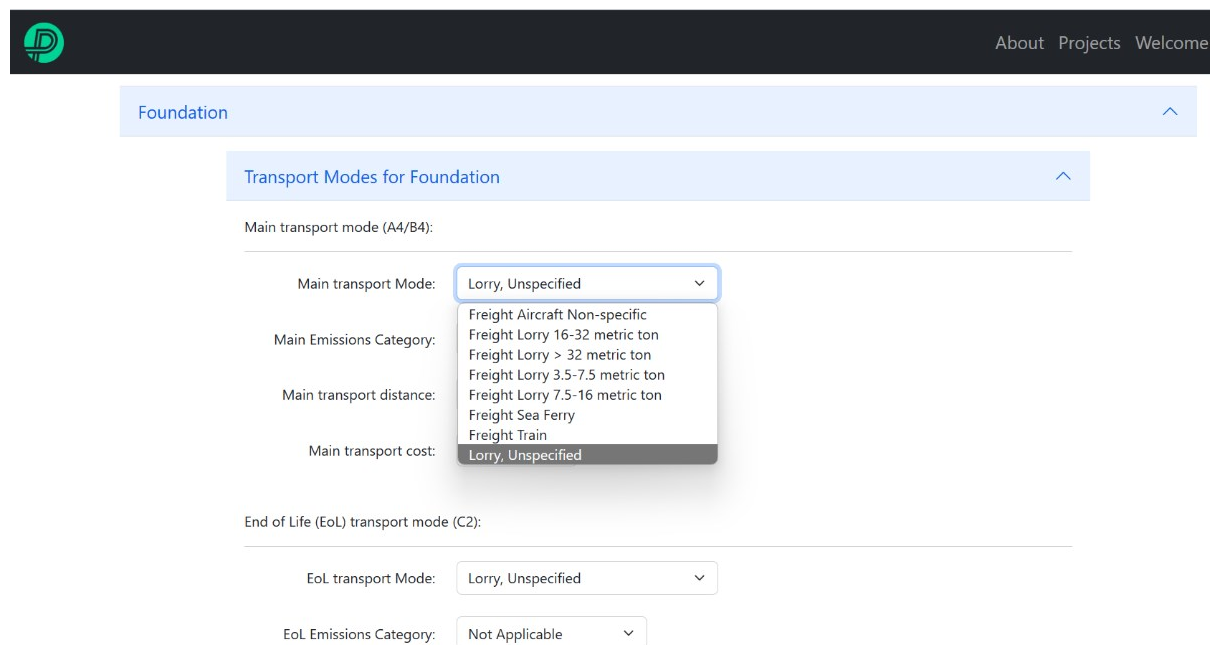


Figure 12 Transportation modes

3.8 Project Summary

After defining all elements, the user is presented with the project summary page, a part of

which is illustrated in Figure 13. The user can review all the values before proceeding to the result tabs and change them (Edit values button) if required.

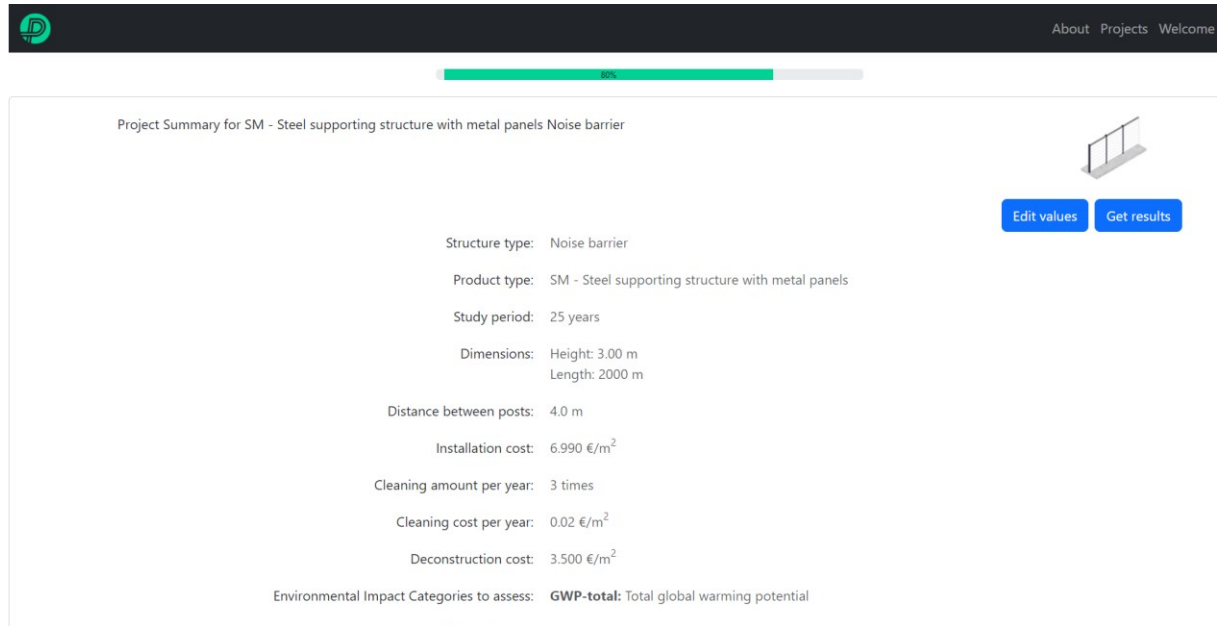


Figure 13 Part of Project's summary

3.9 Results

The first tab in the result section illustrates the total global warming potential gannt chart for a defined functional unit in each life cycle stage (Figure 14). This presentation allows the user to identify the most significant contributing stages and potential areas for improvement. The functional unit is a quantification of the product or project based on its performance. In the case of noise barriers, it is defined as one square meter (m²) during the project study period, while for safety barriers, it is defined as one meter (m) during the study period.

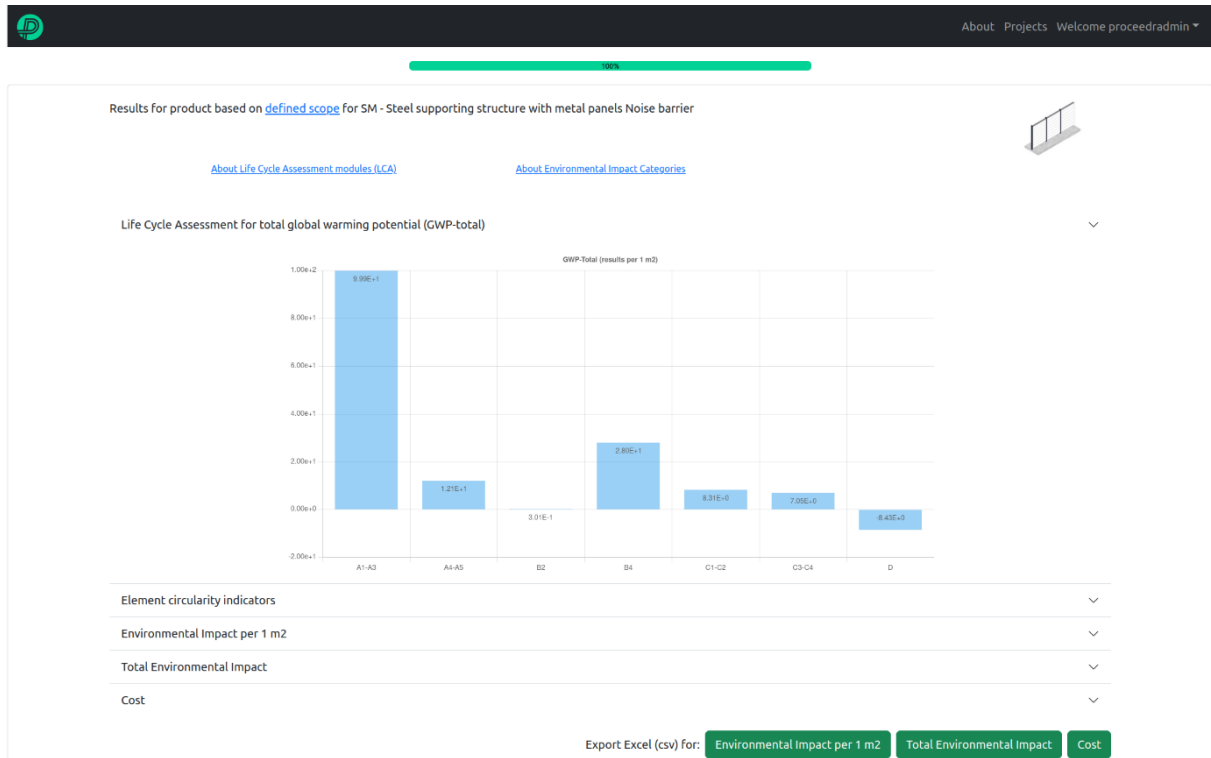


Figure 14 GWP-total per life cycle stages and functional unit

The circularity indicator tab presents the circularity potential of each defined element (Figure 15), as previously mentioned, ranging from a linear representation (0) to a fully circular representation (1). It is important to note that this indicator directly correlates with the element's lifetime, secondary and biobased input, and recyclable and biobased output. Thus, it is not a fixed representative value for the element, and it can change by changing the lifetime and the amount of used, virgin and disposed material.

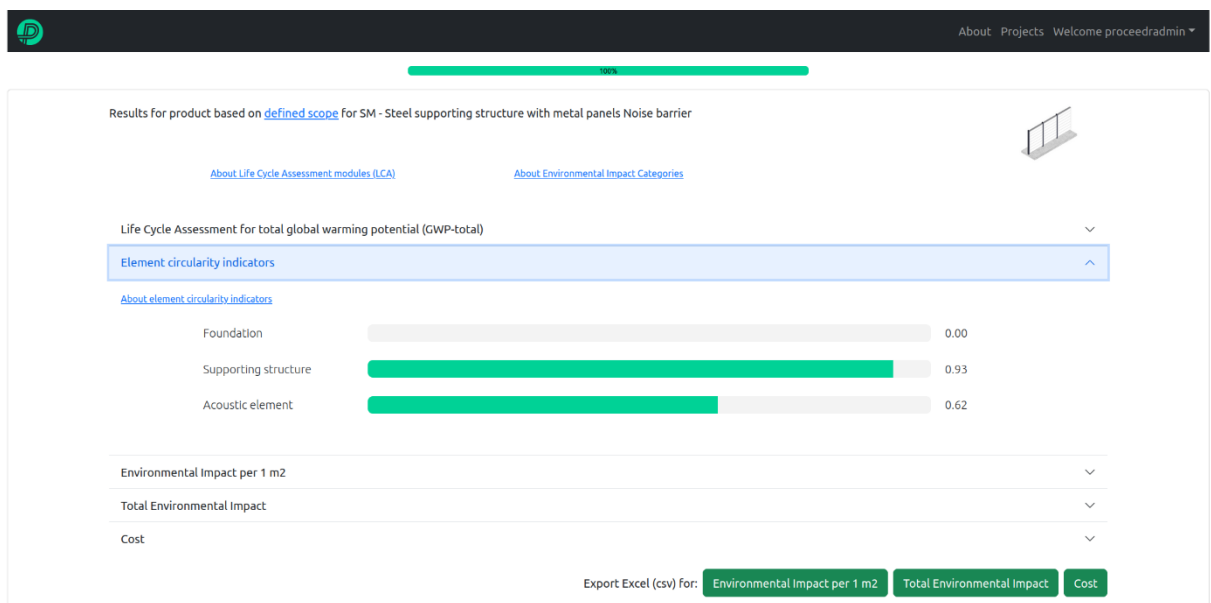


Figure 15 Element circularity indicators

Potential environmental impacts and costs are presented per functional unit (Figure 16 and Figure 18) and for the entire project (Figure 17 and Figure 18). The separation of these results enables the user both to assess the overall environmental impact of the entire project and allows the comparison between different barriers of the same type based on the same reference.

Additionally, the user has the option to export each table result to an Excel file using the green button located at the bottom.

The evaluation of environmental impacts and costs is based on average European data, supplemented by global data in cases where European data is unavailable. The Ecoinvent 3.9.1 database serves as the primary data source and OpenLCA version 2.0 as the source software (the chosen material and process from the database for each material is presented in D2.21).

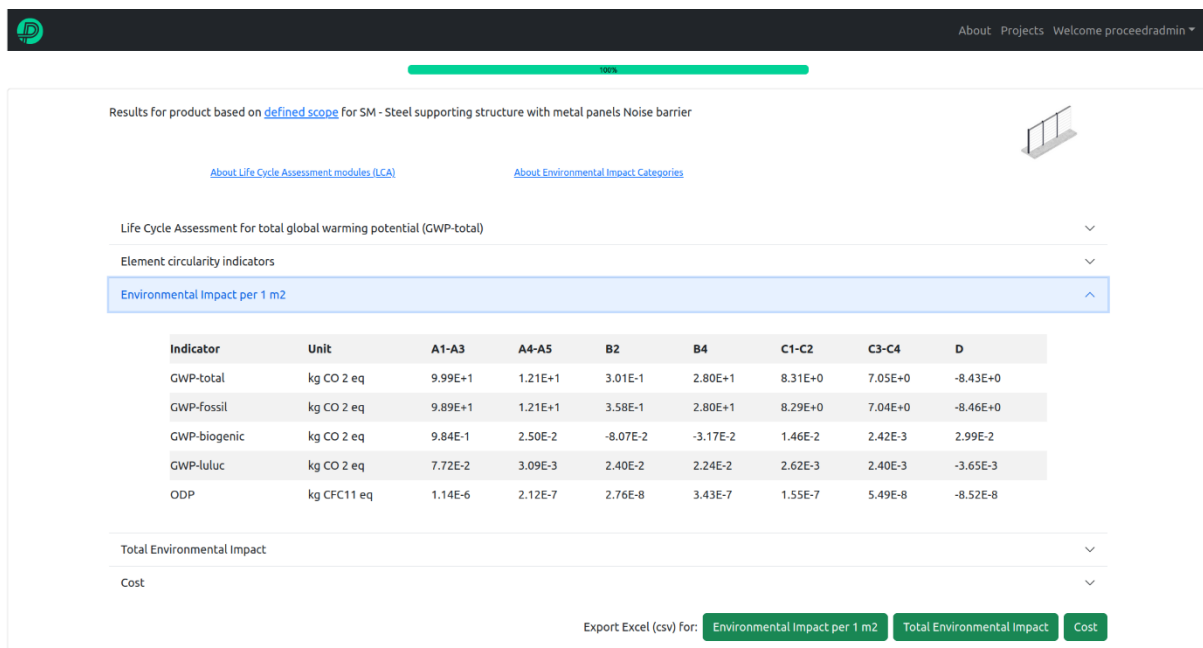


Figure 16 Environmental impacts potential per life cycle stages and functional unit

¹ <https://proceedr.project.cedr.eu/publications/>

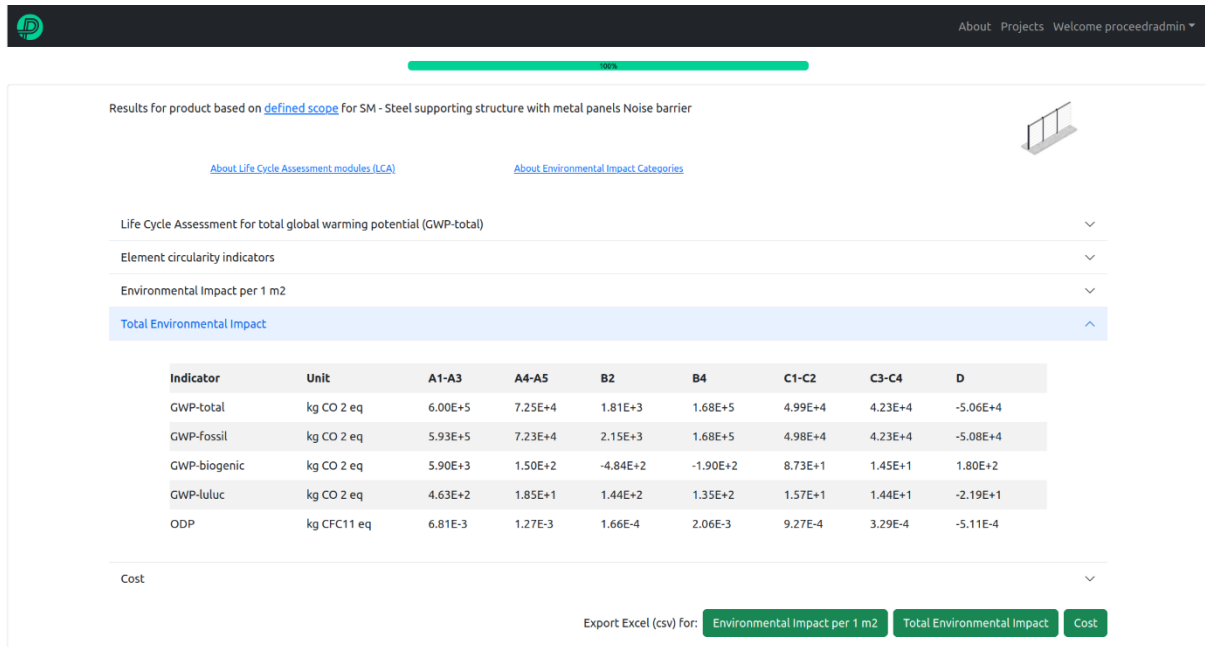


Figure 17 Total environmental impacts potential per life cycle stages

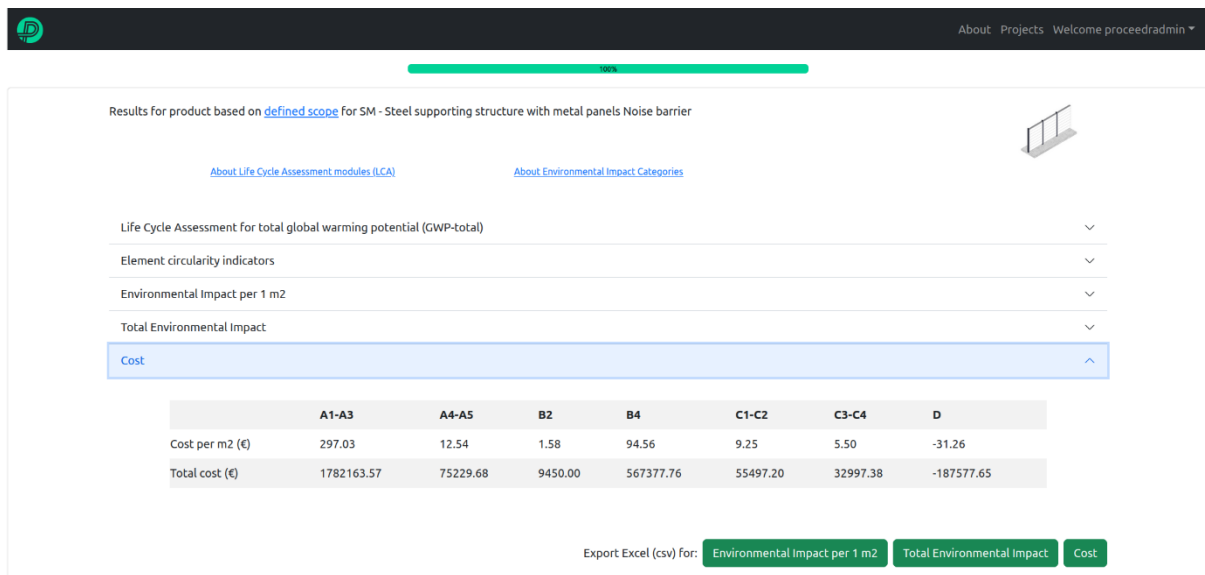


Figure 18 Life cycle cost potential

4 Potential for future improvement

The tool serves various users, from environmental specialists to those with limited knowledge of Life Cycle Assessment. It currently relies on general global or European average data from the Ecoinvent 3.9.1 database to calculate environmental impact emissions. Currently, the tool does not allow the user to overwrite the environmental impact emissions for individual materials or processes. Also, while the user can modify the quantity and composition of existing materials, the tool does not support the creation of new materials or barriers. Providing these options would enable environmental experts greater flexibility in assessing the environmental footprint of specific products or in different geographic regions but was outside the scope of the PROCEEDR project.

While the 'export to Excel' function allows the user to compare the results of different barriers based on the same functional unit in Excel files, it is important to note that comparing results within the tool in the current version is not possible. This functionality may be considered in a possible extension of the PROCEEDR tool.

In order to facilitate the development within time and resource constraints, the tool simplifies all potential end-of-life scenarios into two categories: disposal and recycling/downcycling. For the disposal scenario, the tool primarily considers landfill or incineration based on material type, as detailed in Deliverable 2.2. It accounts for closed-loop recycling as the first option in the recycling/downcycling category. If closed-loop recycling is not feasible, the tool assumes alternative recovery treatments such as energy or material recovery for other industries, as outlined in Deliverable 2.2. The amount of material which is not going to be recycled/downcycled will be disposed of. However, for materials like plastic, multiple recovery scenarios are possible. While a portion of the material may be directed towards closed-loop recycling, the remainder may undergo energy recovery rather than disposal. Therefore, incorporating more detailed end-of-life scenarios would lead to more accurate and realistic outputs. Moreover, allowing the user to define their own environmental impacts from material recovery processes or end-of-life treatments could be considered as an additional feature.

Various methodologies exist for evaluating the circularity potentials of products or services. The applied approach assesses the circularity of individual elements based on their constituent materials. However, evaluating the circularity potential of the entire barrier may be influenced by additional factors, such as the disassembly of the elements, which can be challenging to quantify and may vary across manufacturers. This aspect could be considered for future research. Furthermore, the current tool categorizes materials into two groups: bio-based and non-bio-based (and non-bio-based into virgin or secondary) categories, simplifying the formulation. However, it's worth noting that certain materials may be partially bio-based, and accounting for this aspect can slightly impact the results.