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Stenca Pipe Thermal Insulation: Comparative Life Cycle Assessment

Technical summary

July 2022

Made for

Stenca Solutions

Project:

STENCA PIPE THERMAL INSULATION

ABOUT REFLOW

ReFlow is a Danish environmental consultancy company with a focus on measuring, documenting, and reducing the environmental footprint of products and processes. Life cycle assessment practitioners at ReFlow have rich experience in evaluating industrial products and systems and providing decision support.

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Executive summary

Stenca aims to position its products as environmentally friendly options, with the ambition of getting a baseline knowledge of the impacts of its products and improving them to offer greener solutions. To determine the preferable environmental attributes of the Stenca Pipe/tank compared to other technologies available in the market, a life cycle assessment was conducted. The assessment was performed for the four following products: Stenca Pipe/tank, stone wool, cellular glass, and pyrogel.

The study is intended for compliance with the ISO 14040/ILCD approach. It was modeled by providing thermal insulance corresponding to 1.0 m^2K/W to 1 m^2 of substrate's flat surface for a lifetime of 30 years. The life cycle inventory was built with a cradle-to-grave perspective. SimaPro software was used to model the assessment, together with Ecoinvent 3.8 library, including all impact categories from the ReCiPe 2016 Midpoint Hierarchist method.

The assessment shows that the Stenca Pipe product has a carbon footprint of 8.67 kg CO_2 eq, performing better in all impact categories, compared to the other three assessed products. The life cycle stage contributing the most to the climate impact is the manufacturing stage with 6.40 kg CO_2 eq, while the most impacting parameter was found to be polyol with a carbon footprint of 6.04 kg CO_2 eq.

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1. Introduction

Stenca aims to position its products as environmentally friendly options, with the ambition of providing a product that meets the demand of customers in need of greener solutions. To determine the preferable environmental attributes of the Stenca Pipe/tank compared to other technologies available in the market, life cycle thinking is required.

Life cycle assessment (LCA) is an internationally standardized method for quantifying and estimating resource consumption, environmental and health impacts related to a product or system. LCA serves as a key tool for identifying environmental impacts when implementing sustainable solutions, so that any "burden shifting" within different environmental impact categories or within life cycle stages does not take place.

The life cycle assessment framework is defined by the ISO 14040 and ISO 14044/ILCD approach (ISO 2006a, 2006b), the steps followed are: goal and scope definition, inventory analysis, impact assessment and interpretation.

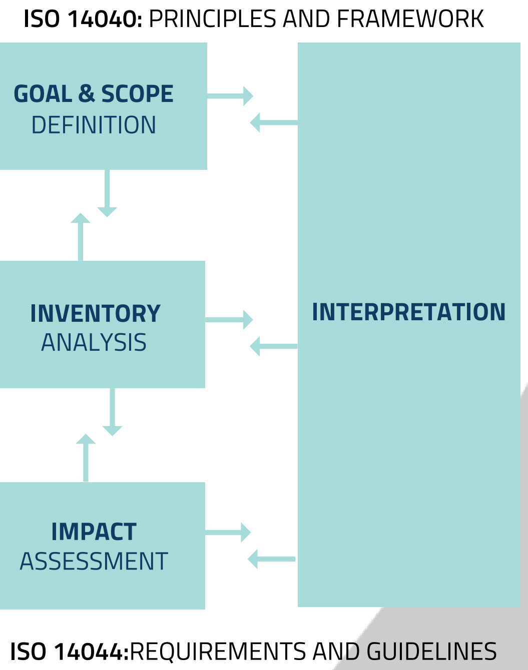

Figure 1 ISO 14040 framework for LCA

2. Goal and scope definition

The Goal and scope definition aims to address the presumed purpose of the life cycle analysis, as well as the definition of the product(s) to be assessed, functional unit and reference flow for the analysis. The object of assessment is a cradle-to-grave assessment of four products used for insulation: Stenca Pipe/tank, stone wool, cellular glass and pyrogel. The study intended for compliance with the ISO 14040/ILCD approach.

To set the basis for the life cycle inventory analysis and the impact assessment modeling, the functional unit and the reference flow is decided from the function of the four products being assessed. The functional unit defines the specific function of the insulation solutions, following the ISO Standards and the ILCD Framework. The functional unit for this assessment is defined as:

"Provide thermal insulance corresponding to 1.0 m^2 K/W to 1 m^2 of substrate's flat surface for a lifetime of 30 years"

Based on the above definition of the functional unit, the actual amount of each of the materials can be calculated using the following equation:

$$R.F. = R \times \lambda_{design} \times d \times A$$

Where:

R is the thermal resistance as 1 m^2 x K/W;
λ is the thermal conductivity measured as W/m x K ($\lambda_{design} = \lambda_{declared}$);
d is the density of the insulation product in kg/m^3 ;
A is the area in m^2, here 1m^2;
K is temperature in ^oK;
W is Watt.

The reference flow with the respective amount of material to be installed can be calculated (Table 1)

The system boundaries of this assessment consider the following life cycle stages: manufacturing, distribution, and disposal, therefore being a cradle-to-grave assessment. The use stage was not considered, as no elementary flows or emissions are accounted for, and the avoidance of impacts for the four materials is the same according to the functional unit.

Table 1. Reference flows (in kg) necessary to provide a thermal resistance of 1 m2K/W for a period of 30 years

Material	Density (kg/m^3)	λ value (W/m K)	Reference flow (kg)	Composition (kg)
Stenca Pipe	120	0.021	2.7	2.52 (insulation material) 0.18 (outer coat)
Cellular glass	115	0.051	5.865	5.865 (insulation material)
Stone wool	128	0.0403	5.158	5.158 (insulation material)
Pyrogel	200	0.0204	4.079	4.079 (insulation material)

3. Inventory analysis

The inventory analysis is the second step of an LCA, in which the product systems are modeled, and elementary flow data is collected for all processes in the system and scaled according to the reference flows previously defined. Extensive research was undergone, basing the life cycle inventory on a combination of primary data provided by Stenca, Environmental Product Declarations directly from suppliers of the three remaining insulation materials, and secondary data e.g. literature data. The background processes depicting the supply chain of process inputs and waste were modelled with data from Ecoinvent 3.8 database (attributional; allocation at the point of substitution) (Wernet et al., 2016).

Manufacturing: The manufacturing stage of the Stenca Pipe was modeled using information provided directly by Stenca[1] , specifically with the quantities of raw materials, manufacturing electricity and waste flows. On the other hand, the elementary flows for cellular glass, stone wool and pyrogel were extracted from environmental product declarations provided by manufacturers of each of the respective insulation materials (Peters et al., 2021) (Kofod et al., 2022) (Hill, C., 2015).

Distribution: The distribution stage, the main transportation scenario, was assumed to be from each of the manufacturing locations to an average distance to Bergen, Norway and Stavanger, Norway. The products were first assumed to be transported by lorry to the closest port and then transported in a ferry (when manufacturing factory was in Denmark) or container ship (for rest of the world) to the destination.

Use: The use stage considers any materials needed when installing the insulation products to the substrate's surface, without considering the substrate. For Stenca, the model includes a sealant based on MS polymer and 3 plastic strips for 1 meter of pipe. While for the three other products, a metallic jacketing and metallic bands of stainless steel were considered according to Norsok standard R-004 (Standards Norway, 2006)

Disposal: The disposal stage was modeled using the municipal solid waste incinerator dataset with the Norwegian location from ecoinvent. This inventory contains 92.8% of average burnable waste and the rest consisting of inert (unburnable) parts. This dataset was selected as representative due that energy recovery was found to be the major method used for the treatment of waste from construction, rehabilitation and demolition of buildings by 2020 (Statistics Norway, 2020).

1. The provided primary data and bill of materials are confidential

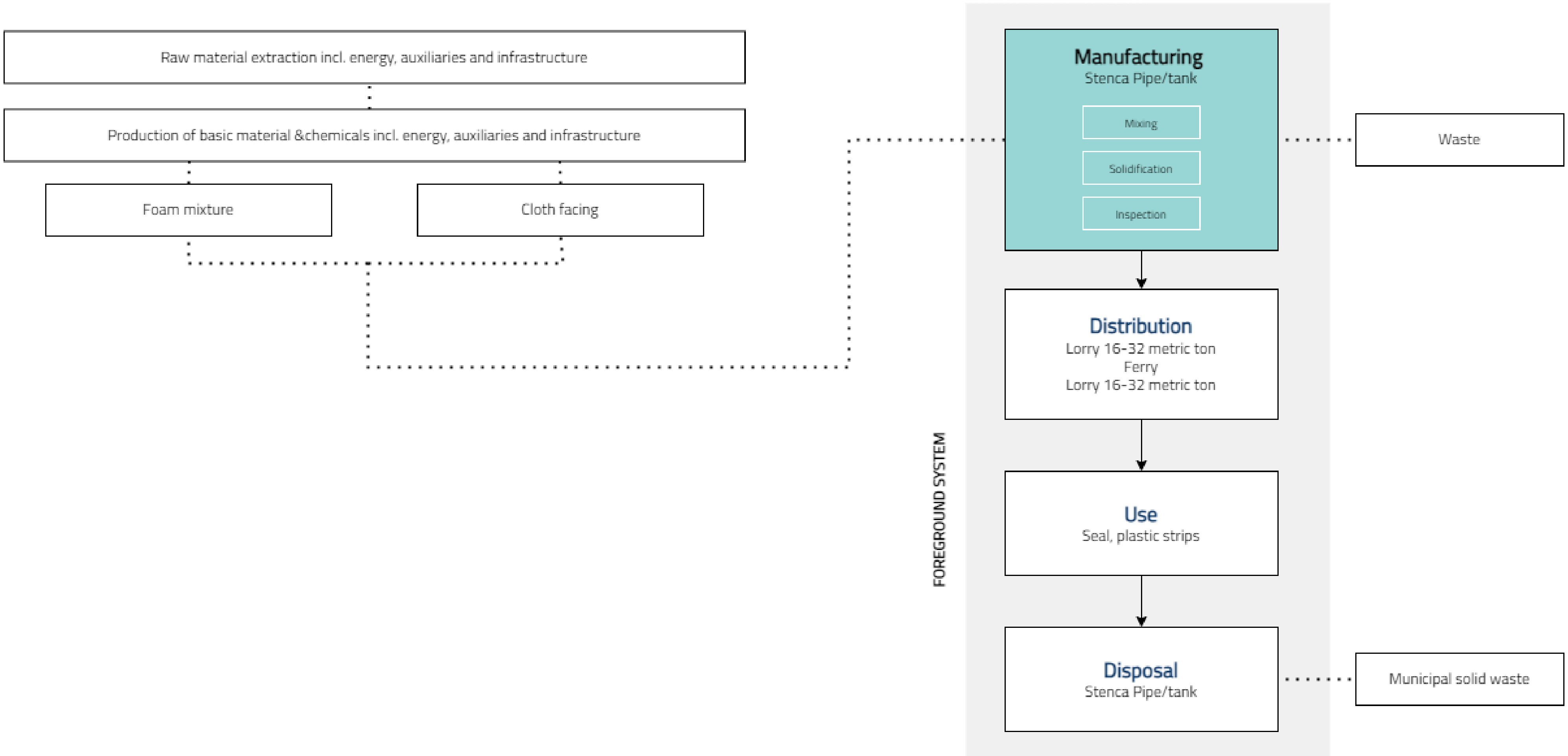

Figure 2. System boundaries of Stenca Pipe/tank including all foreground and background processes with its elementary flows

4. Life cycle assessment: Stenca Pipe Insulation

The impact assessment was performed in SimaPro v 9.3. (SimaPro, 2022). The impact assessment methodology chosen was ReCiPe 2016 (Hierarchist perspective; midpoint level) (Huijbregts et al., 2017). This section addresses the modeled life cycle of the different insulation materials, introducing the results of the life cycle scenarios and the individual life cycle stages and their impacts. The model investigates the environmental impacts per the previously defined reference flows (see Table 1), based on the functional unit of providing a thermal resistance of 1.0 m^2K/W to an area 1 m^2 of pipe. The life cycle results for the Stenca Pipe/Tank, cellular glass, stone wool and pyrogel are given in table 2.

Table 2. Characterized impact results for Stenca Pipe/tank, cellular glass , stone wool and pyrogel with the total impact contributions including the manufacturing, distribution and disposal stages.

Impact category	Unit	Objects of assessment			
		Stenca Pipe	*Cellular glass*	*Stone wool*	*Pyrogel*
Global warming	kg CO_2 eq	8.674	19.443	49.288	88.080
Stratospheric ozone depletion	kg CFC11 eq	3.85E-06	1.58E-05	4.34E-05	4.08E-05
Ionizing radiation	kBq Co-60 eq	0.151	13.177	8.504	22.192
Ozone formation, Human health	kg NO_x eq	0.020	0.036	0.095	0.128
Fine particulate matter formation	kg PM2.5 eq	0.013	0.027	0.052	0.221
Ozone formation, Terrestrial ecosystems	kg NO_x eq	0.021	0.037	0.096	0.131
Terrestrial acidification	kg SO_2 eq	0.028	0.046	0.126	0.251
Freshwater eutrophication	kg P eq	0.004	0.014	0.037	0.065
Marine eutrophication	kg N eq	0.001	0.001	0.003	0.005
Terrestrial ecotoxicity	kg 1,4-DCB	44.277	163.996	250.726	328.244
Freshwater ecotoxicity	kg 1,4-DCB	1.236	2.498	4.088	5.174
Marine ecotoxicity	kg 1,4-DCB	1.611	3.312	5.420	6.863
Human carcinogenic toxicity	kg 1,4-DCB	0.767	8.287	9.857	11.402
Human non-carcinogenic toxicity	kg 1,4-DCB	22.415	43.848	91.507	125.330
Land use	m^2a crop eq	0.148	1.565	7.152	2.239
Mineral resource scarcity	kg Cu eq	0.043	0.478	0.479	0.635
Fossil resource scarcity	kg oil eq	2.931	4.717	12.011	22.788
Water consumption	m^3	0.233	0.252	1.726	0.744

The color gradient should be interpreted in a category basis with the green color showing the lowest impact contribution and red the highest.

As it can be observed in table 2, the Stenca Pipe/tank showed a lower impact score in every impact category. In relation to global warming, the Stenca Pipe/tank resulted with a carbon footprint of 8.674 kg CO_2eq, while for the cellular glass, stone wool and pyrogel the carbon footprint was calculated to be 19.443 kg CO_2 eq, 49.288 kg CO_2eq and 88.080 kg CO_2 eq, respectively. Therefore showing a reduction up to 89%, when using the Stenca Pipe/tank compared with the insulation material that performed the worst in this assessment.

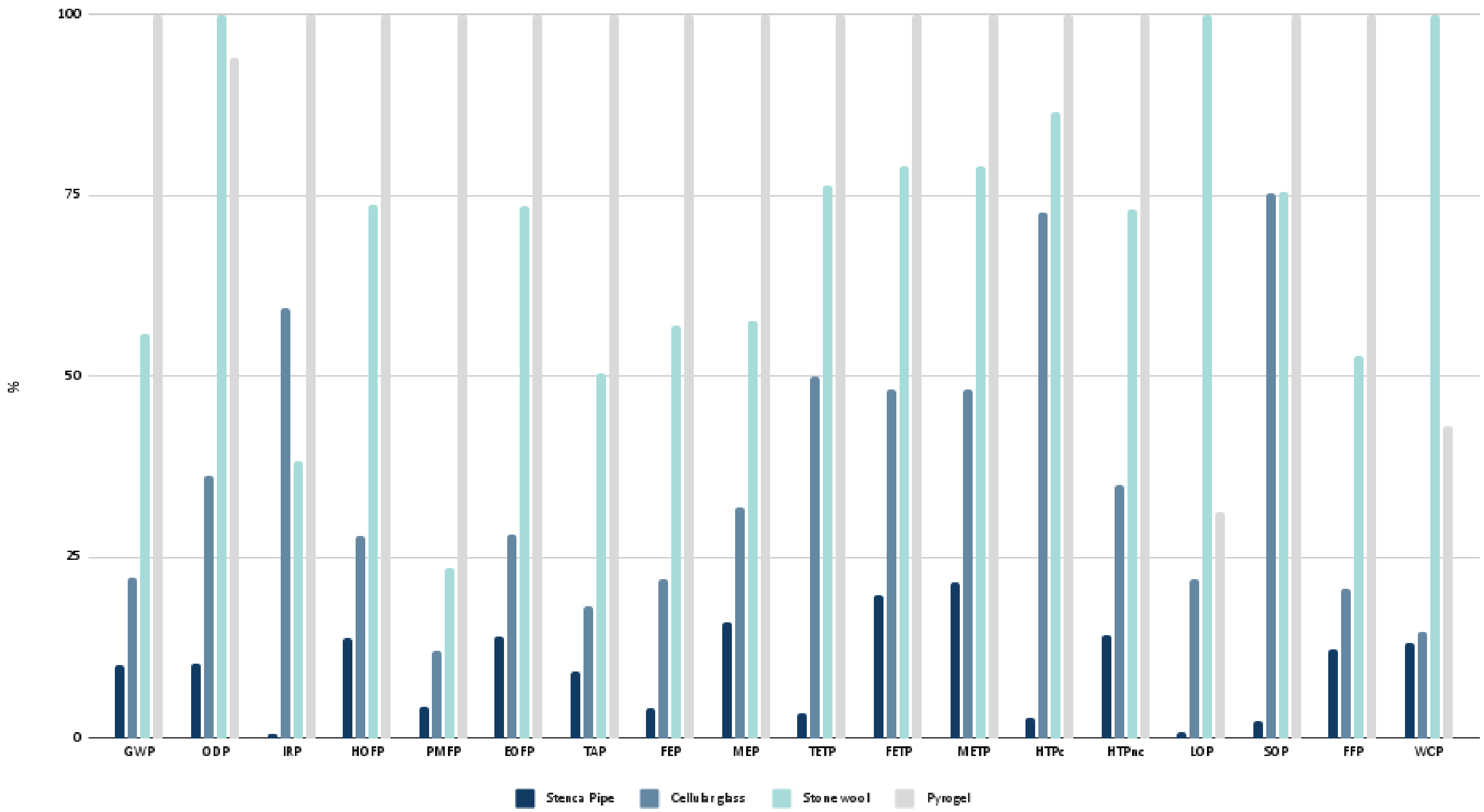

Figure 3. Characterized impact results with percent wise contribution to each impact category for life cycle of each product including manufacturing, distribution use and disposal life cycle stages

Additionally, an environmental hotspot analysis was conducted to identify the main parameters and processes contributing to the impacts of each of the life cycle stages, with an emphasis on the Stenca Pipe/tank.

Manufacturing stage

The manufacturing stage was found to be the main contributor stage to the potential global warming impact category, with almost 70% of the contributions regarding the whole life cycle. Assuming 2.7 kg of Stenca Pipe/tank from the reference flow, the total climate impact contribution from the manufacturing stage is 6.40 kg CO_2 eq, where the polyol is the most impactful parameter contributing 6.04 kg CO_2 eq.

Furthermore, the use of a recovered material[2] from another industrial process as a raw material of the manufacturing of the Stenca Pipe/tank provides environmental credits, related to the avoidance of the production of a primary material. The impact reduction is found to be 1.1 kg CO_2 eq. The results showed how the use of this material improves the environmental performance of the system.

Distribution stage

For the distribution stage, the Stenca Pipe was found to have a climate impact contribution of 0.25 kg CO_2 eq, consisting of 3% of the whole life cycle impacts. Compared to the other three products, the Stenca Pipe performed with the second to lowest impact, with cellular glass having the lowest global warming potential for distribution. This might be due to the difference of transportation methods used, as the Stenca Pipe uses mainly lorry transportation and ferry, while the cellular glass uses lorry transportation and container ship.

2. Confidential

Use stage

For the Stenca Pipe/tank, the total carbon footprint resulted in 0.497 kg CO_2 eq, with the seal contributing to almost 97% of the climate impact of this stage. As aforementioned, the cellular glass, stone wool and pyrogel use stage was modeled in accordance with NORSOK R-004 (Standards Norway, 2006), which requires the use of metal jacketing and metal bands made of stainless steel. In comparison to the Stenca Pipe, the carbon footprint of the use stage of the three products is 4.02 kg CO_2 eq, 6 times higher. This is due to the metal required to cover the pipes, while the Stenca pipe already includes an external coat, eliminating the need for the extra jacketing.

Disposal stage

For the disposal stage, the waste was modeled considering the transportation to the disposal site and its disposal on the municipal solid waste incinerator in Norway. The contribution of this stage to the total carbon impact of the Stenca Pipe is 18% (1.52 kg CO_2 eq). The disposal stage also represented 80% of the whole product's life cycle in the freshwater ecotoxicity, marine ecotoxicity and human non-carcinogenic impact categories.

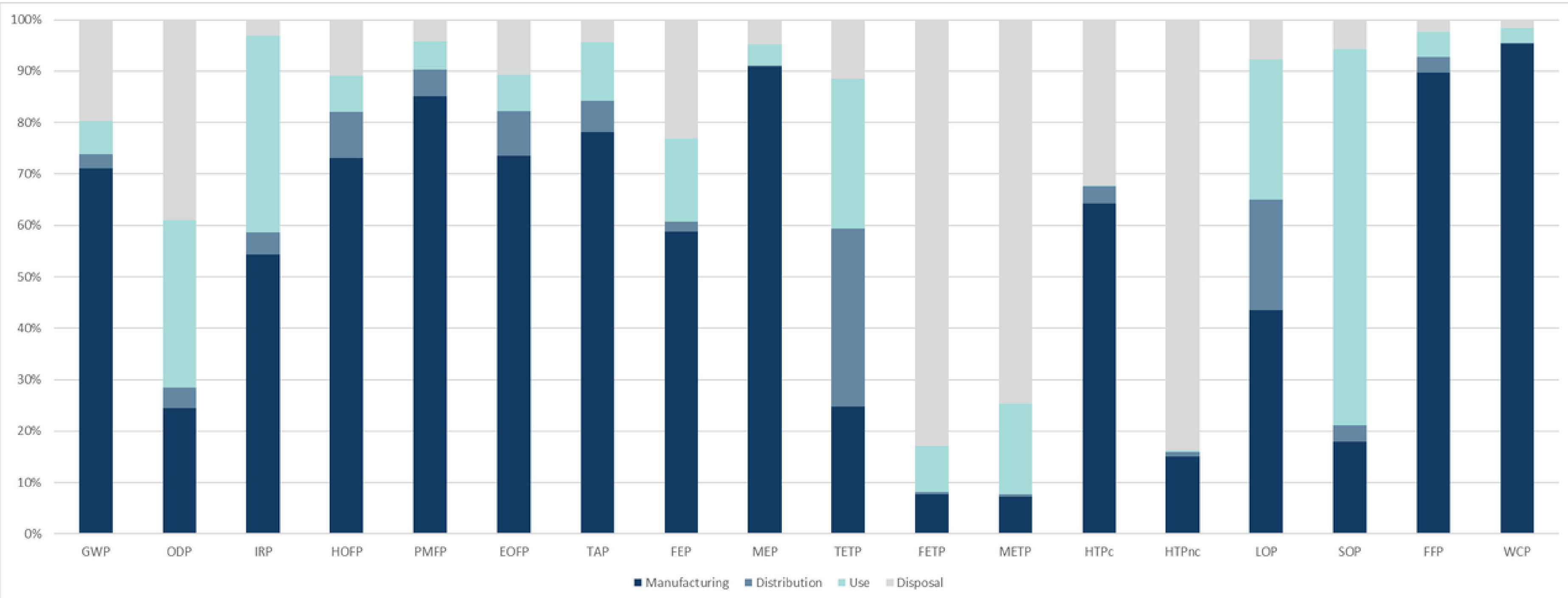

Figure 4. Impact assessment results of characterized results with percent wise contribution to each impact category for each life cycle stage of Stenca Pipe/tank

5. Conclusions

The intended application of this life cycle assessment was to quantify and compare the potential environmental impact related to four different insulation products: Stenca Pipe/tank, stone wool, cellular glass and pyrogel. The assessment aimed at investigating the environmental impacts related to the production distribution and disposal of each material, also conducting an environmental hotspot analysis to understand which processes contribute the most for each of the impact categories.

With the results of this LCA and scenarios, the comparison of the four different insulation system environmental performances and impacts indicates the advantages of the Stenca Pipe/tank. Firstly, the density and thermal conductivity of the Stenca Pipe/tank represents a favorable position as it requires less material to perform the function of providing a thermal resistance of 1.0 m^2 K/W. Consequently, the global warming impact results of the Stenca Pipe/tank showed the lowest impact compared to the three other assessed insulation products. Furthermore, the Stenca Pipe/tank performed better in all the evaluated impact categories compared to the modeled stone wool, cellular glass and pyrogel. The carbon footprint of the Stenca pipe/tank was found to be 8.674 kg CO_2 eq. The stage with the highest impact potential on global warming is the manufacturing stage and the polyol was the parameter with the highest impacts, representing 69% of the total impacts.

Facing the challenging needs to reach sustainable development in the offshore and marine industry, the potential to lower these environmental impacts, hereby up to 89% reduction of carbon emissions, can be retrieved by the industry by using the Stenca Pipe/tank.

However, this assessment was based on certain properties, such as density and thermal conductivity of specific products, which vary depending on the material/product used. Therefore products with other properties should be assessed, as these may change the results.

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