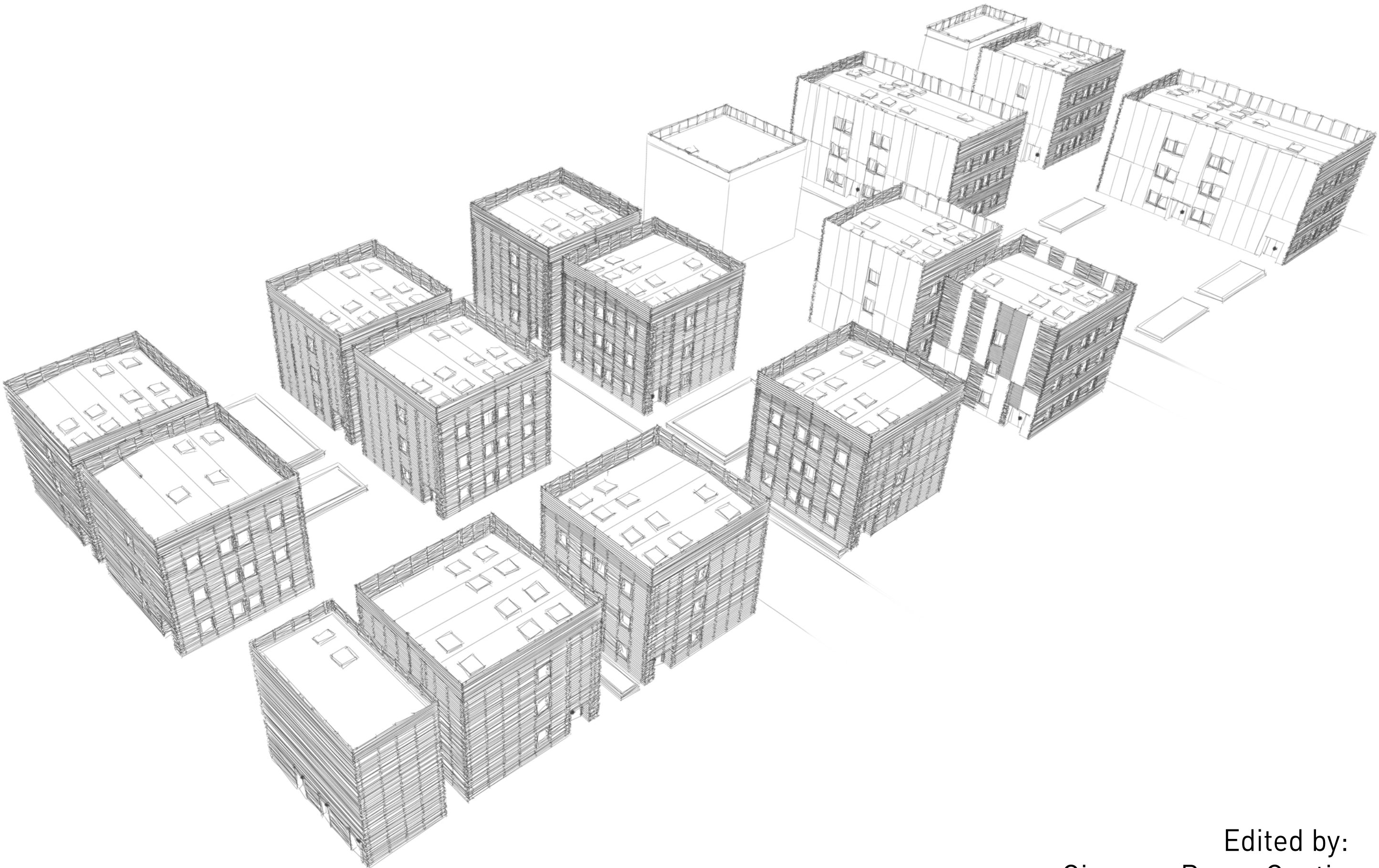
THE LOTUS PROJECT

when LCA and BIM approach work together

EXPLANATORY DOCUMENT



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INDEX

ABSTRACT

The increasing attention paid to the problem of pollution is inducing the construction sector to develop new design lines that take into consideration the environmental impact of buildings.

The most addressed topic in the design of buildings with low environmental impact is that of energy performance; although this topic is of primary importance for reducing the impact of buildings, it is equally important to consider the function and duration of the project. A design oriented to the duration of the building in fact allows a longer life of the building with a consequent gain in terms of environmental impact. The adaptability of the plants and the structure, the proposal of multiple functions or functional mixes and the use of technologies that facilitate the change of use of a building can extend the life of a building by preventing premature demolition of the work and lowering the need of new buildings.

The global exhibition that took place in Milan in 2015 was at the center of many controversies, in the construction and academic world, regarding the environmental impact and the reuse of the structures built for the event. The problems generally encountered are those relating to the construction of temporary buildings, which are not predisposed to withstand time, as well as the lack of a plan prior to the construction which envisaged a future use of the pavilions and clusters once the exhibition is finished.

The thesis aims to analyze, through the use of different analysis tools, the environmental impact of possible future choices considering different methods of intervention on part of the clusters in the area. The possible intervention scenarios will be assessed using a life cycle analysis and any choice required by the interventions will be justified through performance and comfort analysis and in compliance with current regulations to meet the minimum standards required by function.

The use of a BIM (Building Information Modeling) software provides an opportunity to improve the proposal since, once the model has been created, the export of information relating to all the project elements into other software, for the calculation of the LCA, energy performance and lighting and comfort, it is manageable and more complete.

In order to use a BIM approach, it is necessary to develop both the state of affair and the state of the project. Through the process of drafting the relief, databases relating to the elements and materials that compose it are created within the software, as well as the design geometry that allow future analyzes to be carried out without incurring in new modeling phases. The model used for the representation of the current state and for the various analyzes has a level of detail (LOD) LOD 300.

1. Introduction

1.1. Scope

The thesis considers the area and buildings pertinent to the "frutta e legumi" and "spezie" areas present at Expo 2015.

These two areas were intended for the creation of clusters aimed primarily at hosting states belonging to Asia, Africa and Oceania.

Following the analysis of the actual state of the buildings and considering the policies adopted in recent years in that area three possible methods of intervention have been selected for the clusters and areas analyzed:

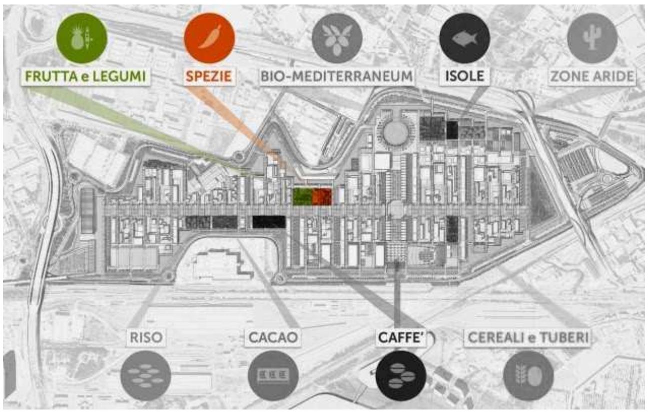


Fig. 01 – Type of cluster present in the Expo area

- retrofit of buildings to accommodate new on-site functions
- retrofit of buildings and move in a new area
- demolition and disposal of clusters

Retrofit of buildings to accommodate new on-site functions

In this first case, retrofitting buildings on site is considered in order to satisfy the new needs consequent to the change in function. The new policies applied to the site and the new projects in progress are considered in order to establish the functions of the buildings which will then be verified using the minimum parameters required by law for the specific function and analysis relating to visual and energy performance.

Retrofit of buildings and move in a new area

In the case considered, the necessity to retrofit the clusters is considered in addition to the need to move the structure in order to satisfy the necessities of the new chosen area. In order to partially reduce the environmental impact of the movement and consider an easily implementable scenario, the maximum radius analyzed for moving the building is 50 kilometers.

Demolition and disposal of clusters

In the last option the disposing of materials in case of demolition is foresee. The materials will be analyzed to determine the possible recycling or reuse actions to be taken and the resulting environmental impact. Actually, this is the option chosen in the case the option to obtain new space for the construction of new useful buildings in accordance with the MIND project is considered.

2. SDF (stato di fatto - state of affairs)

2.1. Area preface

2.1.1. Expo 2015

Expo 2015 was a World Expo hosted by the city of Milan, Italy. It was inaugurated on the first of May and closed on October 31. Milan hosted an exposition for the second time; the first was in 1906. Expo 2015's theme was "Feeding the Planet, Energy for life". Expo participants included 145 countries, three international organizations and several civil society organizations, corporations and non-governmental organizations (NGOs).

Fig. 02 – "Frutta e legumi" cluster during Expo

The design of the site was entrusted to experienced designers and young graduates working for Expo 2015 S.p.A. company, with the support of internationally renowned architects such as Stefano Boeri, Ricky Burdett and Jacques Herzog. These last few mentions, however, latter abandoned the project in 2011 after criticizing the purpose and the waste of money. The official presentation took place on April 26, 2010 under the name of Masterplan 2010. This masterplan, like all its later versions, is configured as a revision of a concept initially planned in 2009.

Fig. 03 – "Spezie" cluster during Expo

The area chosen for the event was in the north-western sector of Milan and was 90% located in the municipality of the capital and the remaining 10% in that of Rho. It occupies an area of 110 hectares adjacent to the new Fiera Milano exhibition center. The area was occupied, in the past, by industrial production plants and was then used both for agricultural use and for logistical plants.

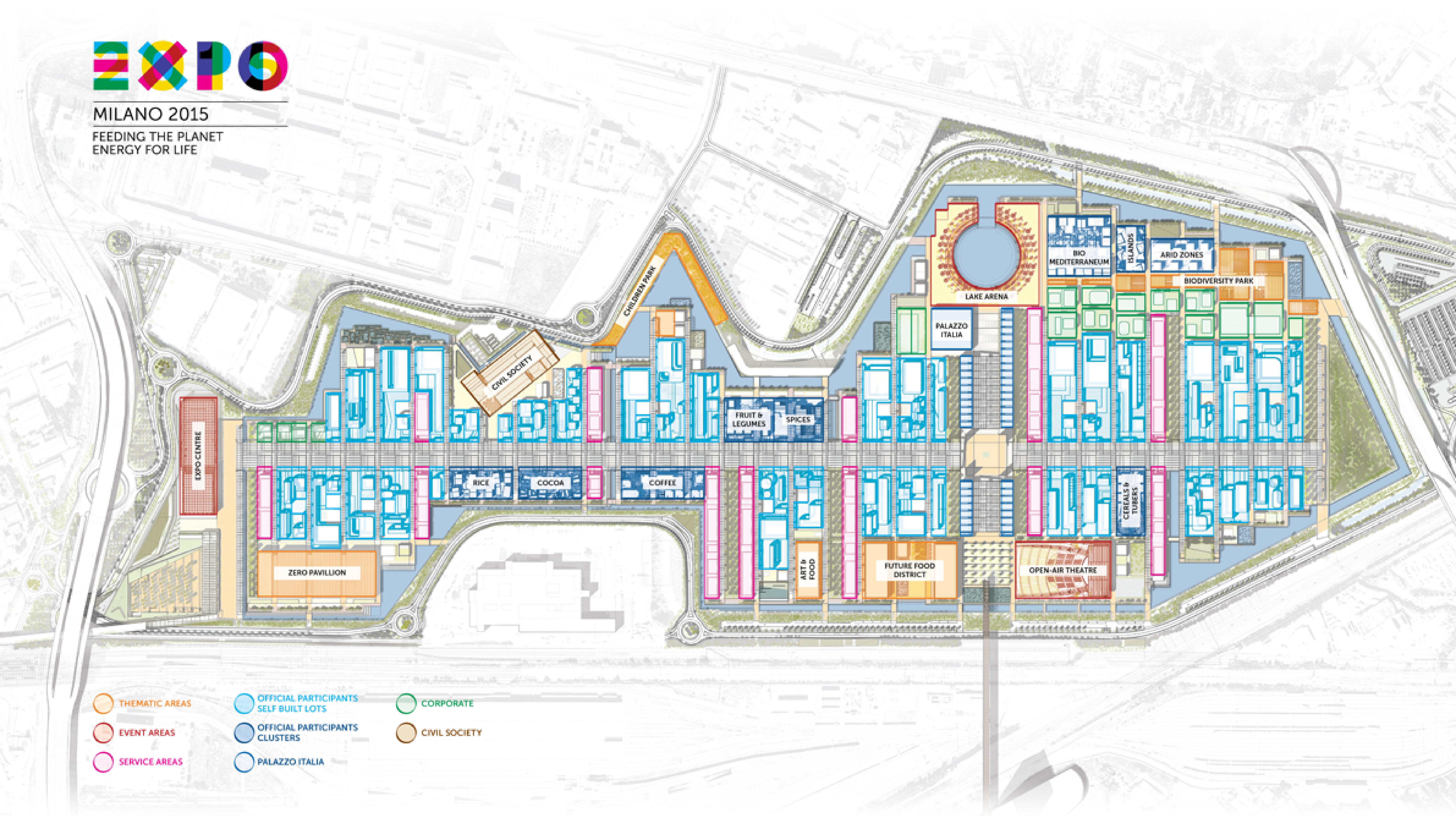
The exhibition area was organized as an island surrounded by a water channel and was structured in two perpendicular axes that recalls the two main streets of the ancient Roman cities, the Cardo and the Decumanus. According to a principle of homogeneity, all the pavilions of the various countries of the world overlooked the large Decumanus, the World Avenue, 1.5 km long and 35 meters wide; on the Cardo sides, 350 meters long, stood the structures of the Italian Pavilion which housed spaces dedicated to the Italian regions and provinces. At the intersection of the two axes was present the Piazza Italia, of 4 350 square meters. On the south side there is an open-air theater; named San Carlo, of approximately 10000 square meters for a total of 9000 seats. At the ends of the decumanus stood the Mediterranean Hill on one side and the Expo Center on the other. At the end of the cardo, on the north side, was present the Three of Life, a wood installation used for public event near Palazzo Italia, and as the symbol representing the whole Expo.

The participants exhibited their themes in individual pavilions built inside the area. In this edition, the possibility of grouping different countries was introduced, considering a single theme in order to encourage the demonstration of all countries. The pavilions that housed multiple countries united by a single theme were called clusters.

The building considered in the project belong to the latter category and was used to group the countries that have as a common resource the spices or the fruit and legumes.

EXPO MILANO 2015

FEEDING THE PLANET
ENERGY FOR LIFE



2.1.2. After the end

After the closure of the universal exhibition, the fate of the space has been swinging between abandonment and new owners; most of the pavilions were dismantled while the clusters remain present on the site. Expo area took the name of Experience, it hosted numerous initiatives: in 2016 and 2017 it allowed visitors to relive the experience of Expo in a reduced version, in 2018 it hosted mostly concerts.

Currently the project provides various policies in order to reevaluate the area and transform it into an innovation district. Arexpo is the company promoting the redevelopment project called MIND (Milano innovation district).

Today, the ex-Expo area becomes part of a project which has as its aim to establish a sustainable ecosystem able to bring out a new community and to represent an exemplary model for the future urban regeneration. The MIND project is characterized by a functional and social mix able to connect the community of the center of Milan and guarantee the union between the neighboring centers, thus becoming a strategic area for the country.

Fig. 04 – Fruit and legumes cluster after Expo

Fig. 04 – Spices cluster after Expo

2.2. The area nowadays

2.2.1. MIND project

The project is based on the creation of a functional mix that allows different relationships and collaborations between the chosen sectors in order to make the research more dynamic and create new opportunities for the companies that will be part of the project. The proposed macro-functions are:

- Institutions
- University
- Companies
- Startup
- Third sector

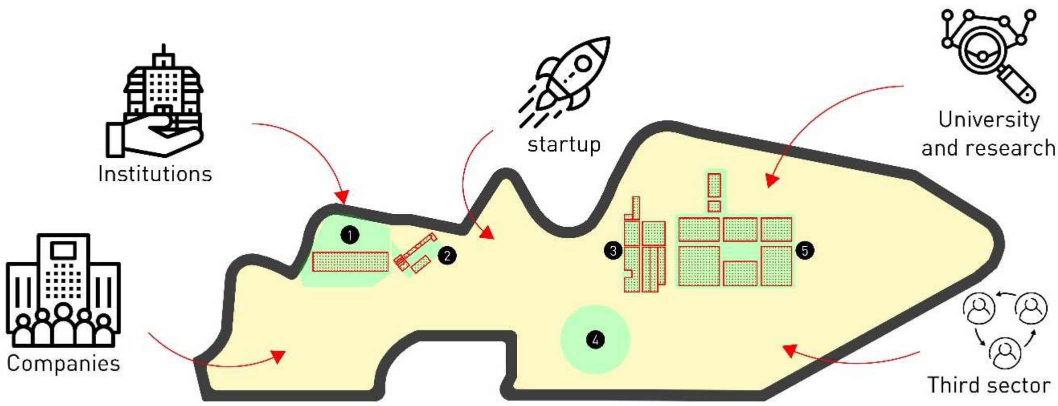


Fig. 05 – MIND macro-function scheme

The project involves the creation of a technological district that through the establishment of companies and services will lead to a re-functionalization of the area. In order to make the redevelopment area attractive, various public functions are already in the design process or construction phase: Galeazzi hospital, Human technopole, Statale university and Triulza foundation.

(1) Galeazzi hospital:

The aim of this project is to bring together excellences in the hospital sector in a single structure: orthopedic field of the IRCCS Galeazzi and the cardio-thoraco-vascular and bariatric experience of the Clinic Institute Sant' Ambrogio. The hospital will be built using the most modern and efficient solutions in terms of energy saving and environmental sustainability.

Total area - 50,000 mq

Plans planned - n. 16

Overall area - 150,000 mq

New building area - 20,000 mq

Parking and green - 30,000 mq

Fig. 06 – Render of the Galeazzi hospital

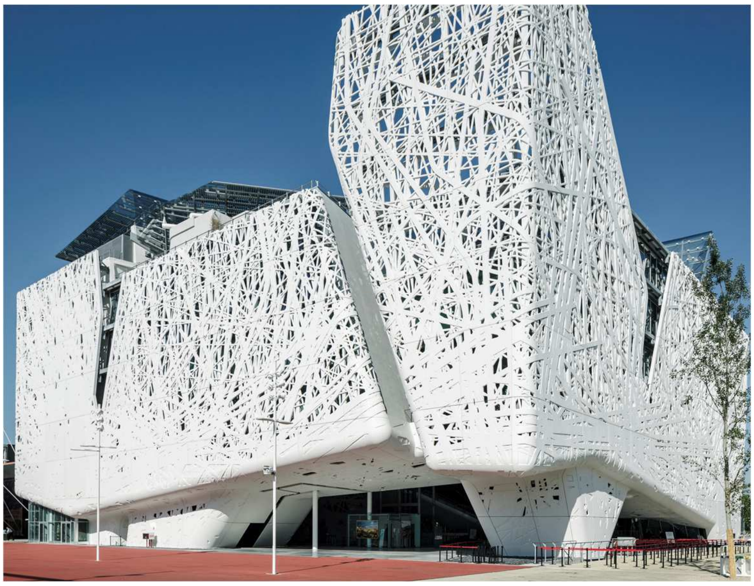


Fig. 07 – Actual headquarters of HT

(3)(4) Human technopole

The creation of a national and international hub that will connect universities, research institutes and hospitals. Human Technopole's mission is personalized medicine to combat cancer and neurodegenerative diseases using genomics, big data analysis, innovative diagnostics and new therapies. In 2023, the Institute will be fully operational, and 1500 people will work there.

Total area - 30.000 mq

Building planned - n.4

Support facility - n. 4

Research center - n. 7

(5) Statale university

The project is born from the idea of putting the scientific research and technology of the Statale university in the same area of Galeazzi hospital and Human Technopole, in order to guarantee an academic reality on par with the best world environments.

Total area – N.A.

Total guest – 20000

Total workers – 2300

Fig. 08 – Render of the Statale university

Fig. 09 – Render of the Triulza foundation site

(2) Triulza foundation

This organization represents the network of the main Italian authorities of the Third Sector. Following Expo, it's remained in Cascina Triulza to characterize the new science and knowledge park from the point of view of social innovation. The foundation will create a Lab-Hub for Social Innovation and Sustainable Development. The MIND project doesn't require modifications of the buildings already present in the area.

MIND will in fact be organized around a public and green spine that represents the main axis of shared spaces in a system of community places where daily life will be lived. The functions of the park will be combined within the green space thus defining a hybrid space unique in its kind.

Considering the principal function provided by the MIND project, the position of the structure and the dimension of the area intended for the project, the most suitable function is that of offices.

The offices will be adaptable to the various needs of use through the usage of building technologies useful for different modeling of the space and its functions. Considering the various proposals not yet developed in the MIND project, the creation of management or tertiary sector spaces can be used for: companies, startup and third sector.

The ground floor which will be developed as an office in the project will have to guarantee the possibility of hosting shops in order to respond, if required, to the design necessity developed in the preliminary masterplan presented in MIND.

2.2.2. Project Area

The project area considers the space occupied by the “frutti e legumi” clusters and the “spezie” clusters; the area has a size of about 8000 square meters. The overall area is divided into three different plates resulting from the divisions of the roads that enter the lot. The buildings considered has different structural system and technological solutions.

The different buildings that characterize the area have been divided into four categories considering the structural type and external finishes:

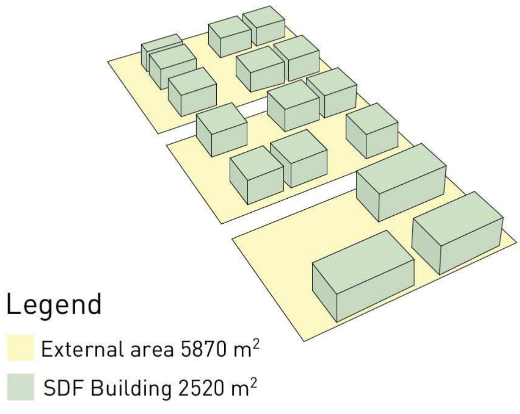


Fig. 10 – project area volumes scheme

- Typology 1:
  They are the main buildings of “frutta e legumi” area; these clusters have a wooden structure made up of portals and a ventilated facade with fir boards as a finishing layer.

- Typology 2:
  They are the main buildings of “spezie” area; these clusters have a wooden structure made up of portals and a ventilated facade with composite panels as a finishing layer.

- Typology 3:
  They are the service buildings for “frutta e legumi” area; these clusters have a steel structure and a ventilated facade with fir boards as a finishing layer.

- Typology 4:
  They are the service buildings for “spezie” area; these clusters have a steel structure and a ventilated facade with “tristrato” panels as a finishing layer.

Except for the service buildings which are smaller than the other clusters, the size of the pavilions and their internal organization are similar to each other.

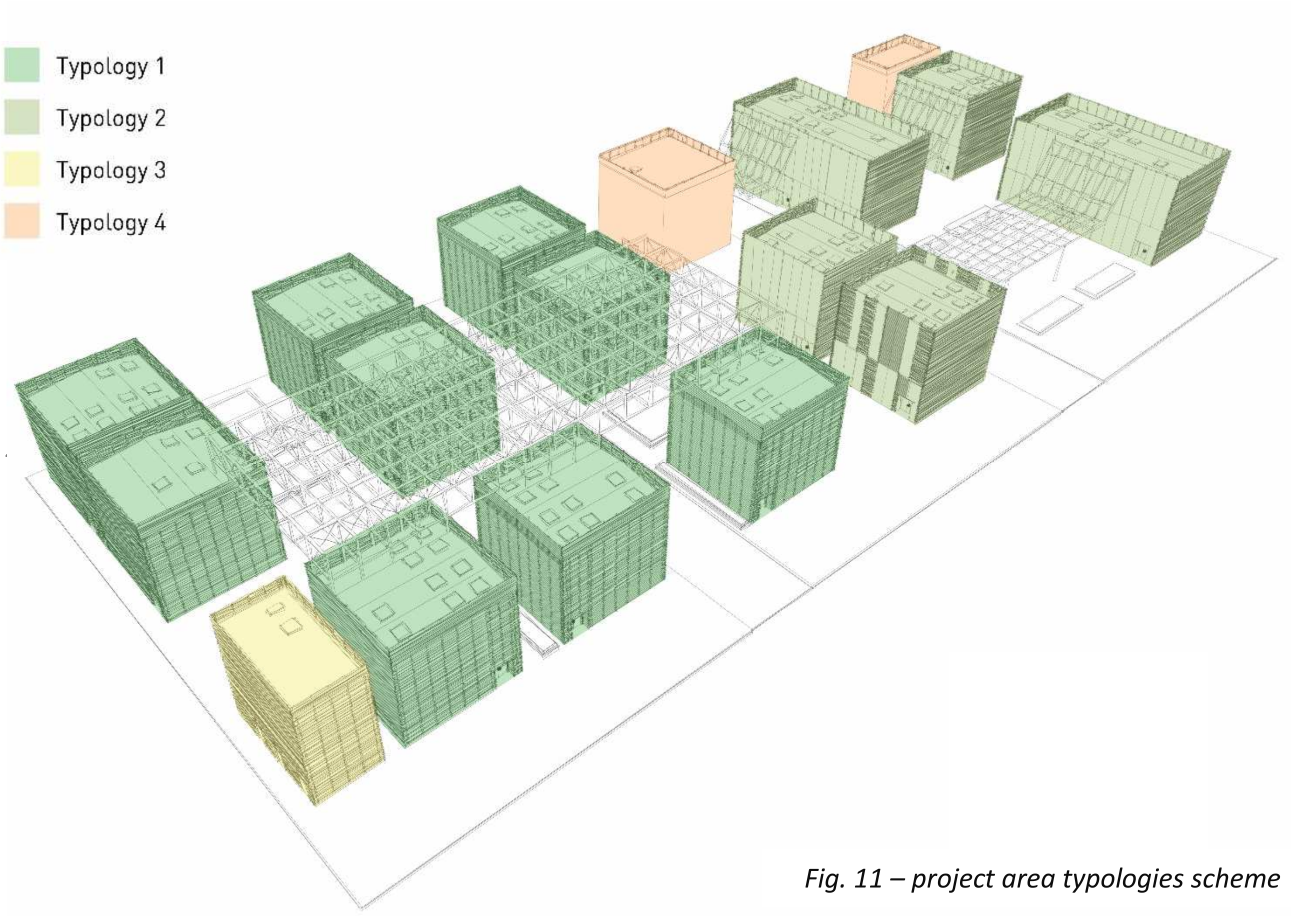


Fig. 11 – project area typologies scheme

2.3. Technical data

2.3.1. Building types

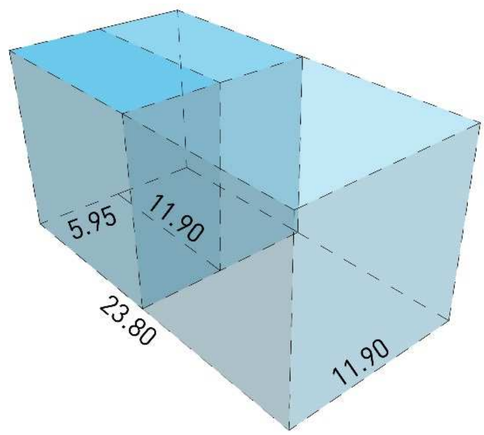


Fig. 12 – Cluster module scheme

All the buildings in the project have common properties in terms of size, structure and technological choices. Considering the volumes of the buildings, it is possible to recognize three typical sizes that are twice the size of each other. The vertical development of the building is 11.60 meters on three floors with similar heights.

The building has a rectangular plan and has a development of three floors connected by prefabricated wooden stairs. All the exhibition clusters have three entrances on the ground floor while for service clusters the entrances vary according to the internal distribution. The service clusters were used during the exhibition to contain all the systems necessary for the other clusters; all buildings of this type have a steel structure. It is possible to divide the spaces of the main pavilions into two different categories: service spaces, where it is possible to find vertical connections and toilets, and exhibition spaces with the larger extension in plan.

The service area has a false ceiling per floor, in order to facilitate the passage of the systems necessary for the operation of the building. The service part is equipped in most structures with an elevator that connects all floors of the cluster. The accessibility regulations relating to the service area are already satisfied in the current state. The toilets are present in all the structures on the first two floors while on the top floor it can be found only at the landing of the lift and stairs. The toilets have counter walls for the tanks required by the sanitary and this ones are repeated on each floor except for the last one.

The main rooms in each exhibition cluster (therefore excluding the service ones) are full height or developed on more floors than the scanning of the vertical connecting part. Although, even in this part of the buildings, the accessibility conditions are verified, it is necessary to rethink the distribution of spaces for the creation of new functions that will require a greater surface instead of having rooms at full height that are no longer useful. The lighting of the spaces at the top floor is entrusted to the skylights placed on the roof which are not sufficient to guarantee the minimum lighting parameters required, while in the case of exhibition spaces developed on the first two floors there is no natural light source.

In general, the building's distribution system requires a revision on several parts in order to make the spaces suitable for the function of offices. The floors must be extended in order to close the full-height spaces used for the exhibition and allow an increase in the space on the plan in order to accommodate more workstations and ensure rational use of the building. The false ceilings must in turn be apply in all spaces in order to guarantee the presence of the systems in all the rooms and to ensure greater adaptability of the spaces. Since in the next steps it will be necessary to insert layers of insulation in the walls and in the slab of the ground floor, the project involves the use of floating floors rather than false ceilings. The service area can be maintained in the current state since it’s already suitable for the new function after the arrangement of the spaces.

Analyzing the structures of the different pavilions, it is possible to distinguish steel and wooden structures, this distinction is repeated in the same way in primary and secondary buildings.

The wooden structures are characterized by wooden portals connected to the ground by means of metal hooks; on these portals were then added: beams for supporting the prefabricated floors, beams for connecting the different portals and diagonals (bracing) in wood for the stiffening of the structure. The secondary beams used on the roof were not installed with the construction of the structure but were present within the prefabricated roof package.

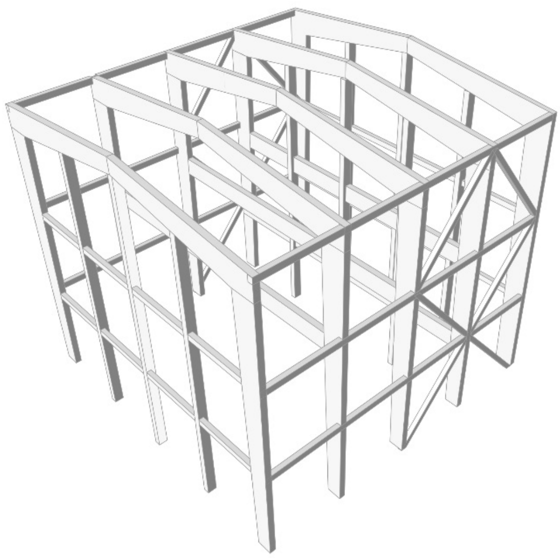


Fig. 13 – Axonometry of the wood structure

The metal structures are made by using profiles: IPE 240, UPN 180 and HEA 180. The structures are stiffened by the presence of a floor made of corrugated metal sheet and concrete; there are no bracing to guarantee further stiffening of the structure. The connections between the various profiles are made through the use of steel joints.

In the case of wooden structures, it is necessary to consider the need to extend the floors of the first and second floors with an increase in the loads acting on the structure. The structures are already prepared for this modification since all the profiles are oversized and the change in function decrease the forces acting on the structure.

Fig. 14 – Axonometry of the steel structure

The sub-structure made for the ventilated facade consists of steel transom with a hollow rectangular cross section connected to the main structure by means of steel hooks while the mullions that support the finishing layer are in fir. In the space used by the secondary structure there are also gutters and downspouts for the disposal of rainwater.

The stratigraphies used for the clusters are poorly performing and it is clear that they have been designed for a short duration. All the packages considered, except for those used in service buildings, contain many layers of wood or products derived from the latter, making the different materials more easily recyclable. Most of the stratigraphies are dry mounted, this aspect has made the assembly phase faster but can also be a positive element considering a future recycling of the building or part of it.

2.3.2. Highlighted problems

Considering the state of affairs, following the inspections carried out, it is possible to highlight a series of problems related to different aspect:

- Deterioration
- Insulation and energy performance
- Air change / illuminance ratio and illuminance comfort

Deterioration

Since the clusters were designed for a short period of time, the stratigraphies in addition to the lack of performance also present interstitial condensation problems. This aspect therefore requires intervention in the accommodation phase but has already caused damage to the materials used for the construction that arise, in the outer layers, degraded. The degraded materials not only require replacement, but it will not be possible to reuse or recycle them in the most effective way.

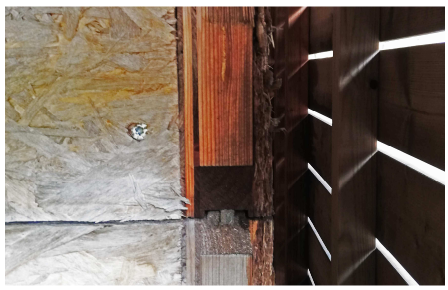


Fig. 15 – Deterioration problem

Insulation and energy performance

Fig. 16 – Deterioration problem

The insulation in many packages is not present and therefore does not respect the limits of the standard in the case of a reuse of the clusters. It is necessary to find a solution in order to respect the limits imposed by legislation and ensure a good energy performance of the building with the aim of reducing the environmental impact and ensuring the comfort of future users.

Air change / illuminance ratio and illuminance comfort

In order to ensure user comfort and design spaces suitable for future use, it is important to consider the lighting aspect; actually the structure does not meet the minimum input required by law on this topic since the clusters was designed to satisfy the exhibition space necessity. In order to meet the different needs required by the project functional assessment it will be necessary to analyze the actual situation and the different modification needed. The design of windows is also useful to increase natural ventilation and consequently to reduce the concentration of CO_2 present in the building during its use; during the planning phase it will be necessary to determine if the natural ventilation is sufficient to guarantee a low concentration of pollutants.

2.3.3. Functional assessment

Considering the principal macro-function provided by the MIND project, the position of the structure and the dimension of the area intended for the project, offices are the best function. The offices will be adaptable for the various needs of use through the usage of building technologies useful for different modeling of the space and its functions. Considering the proposals not yet developed in the MIND project, the creation of management or tertiary sector spaces can be utile for: companies, startup and third sector.

The ground floor which will be developed as an office in the project will have to guarantee the possibility of hosting shops in order to respond, if required, to the design necessity developed in the preliminary masterplan presented in MIND.

The technical volumes created to support the exhibition buildings will be kept the same in the spaces and will be subjected only to technological changes. The insulation layer will not be added to this building, the elements subjected to deterioration will be replaced with new material able to prevent the recurrence of these problems.

3. Strategies

3.1. Climate overview

Considering the Koppen-Geiger classification the climate is a CFA type (humid subtropical climate); this climate features hot and humid summer and cold winters. It is important from a design point of view to consider the climate of the area in order to choose the best design interventions both from an energy and visual point of view. From the design point of view, temperature is a critical factor; peaks of -7°C can be reached in winter, with an average low above 0°C. In summer, peak values of 34°C are registered, with an average of 22°C. These factors lead to the need of both high thermal insulations, to face rigid winter temperatures and have a more effective night cooling during summer, and natural ventilation to avoid the problem of overheating and reduce cooling loads. The existing buildings have light stratigraphies, consisting mainly of wood and air spaces that do not facilitate the achievement of high levels of thermal inertia. The design intervention will attempt to increase the insulation level of the buildings considering only marginally the thermal inertia of the building.

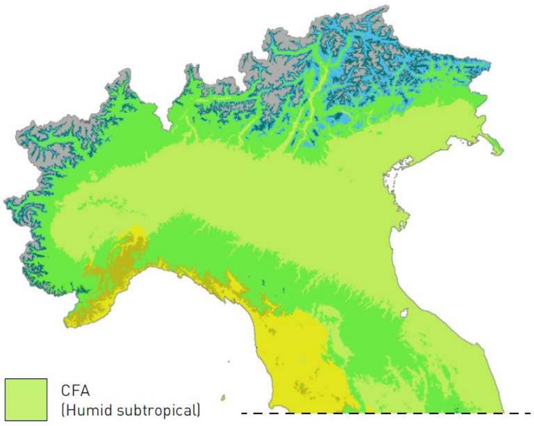


Fig. 17 – Koppen-Geiger map (shred)

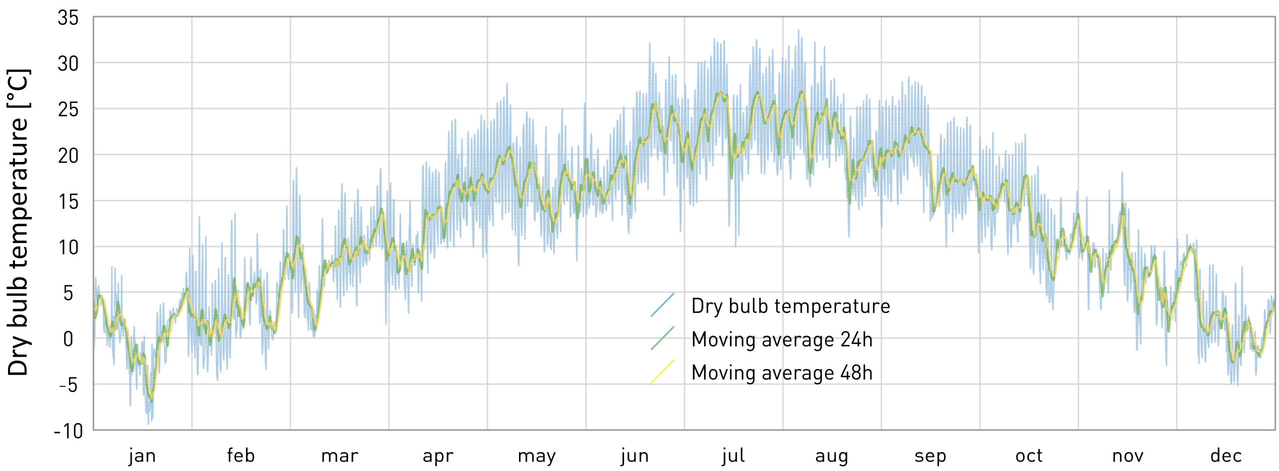


Fig. 18 – Dry bulb temperature chart (Milan weather)

Considering the visual aspect, it is important to consider natural lighting as a first resource to ensure good comfort inside the building. Since the intervention was applied to an existing building and partly due to the proximity of the various buildings, the improvement measures will still require a substantial aid of artificial light.

3.2. Actual strategies

The chapter takes into account the state of affairs [SDF] and the strategies that influence buildings today. The various aspects relating to the buildings and the critical issues that will be considered.

3.2.1. Summer case

Considering the summer period, the sun heats up the building and cause discomfort. The wall ventilation mitigates the overheating effect but due to the high temperature during summer and the people heat load the temperature inside the rooms doesn't respect the comfort limit. The section subject to ventilation is not closed due to the fir boars in the outer layer, for this reason the ventilation has a low effectiveness. The solar heat load and the high temperature increase the cooling load required by the building; the higher temperatures are reached in the upper floor. The use of the skylights is able to reduce part of the total load but not enough to avoid the use of a cooling system.

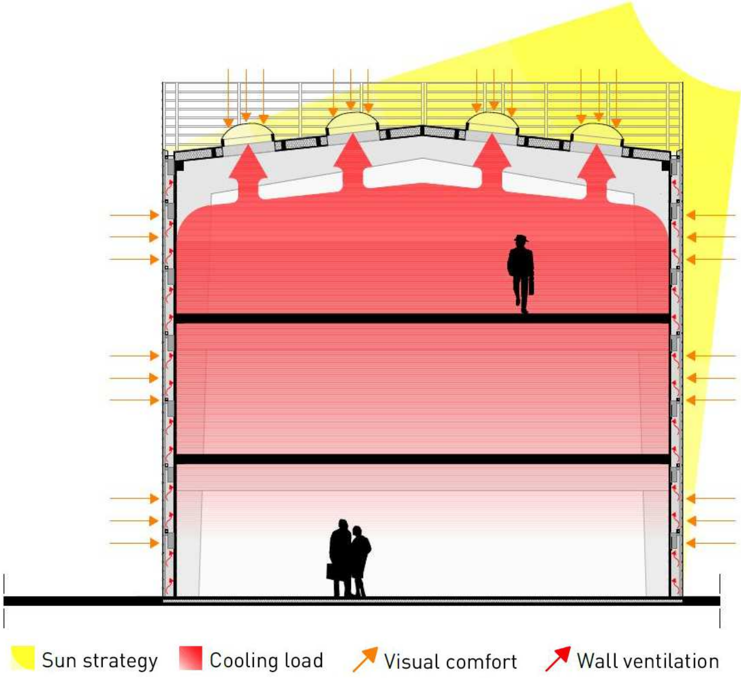


Fig. 19 – Actual summer case scheme

Visual comfort cannot be guarant state of affairs is insufficient and located only in the top floor. The ground floor and the first floor permanently require the use of artificial light to ensure a good visibility.

3.2.2. Winter case

The sun that heat up the building during the winter season represent a positive contribution to the heating load. The amount of energy gained from the sun in not sufficient to guarantee a thermal comfort inside the building due to the absence of insultation and the low use of glazed area. The low temperature during winter constitute a serious problem for this type of building, since the insulation is not present; the temperature inside the building doesn't respect the thermal comfort limit. The state of affair doesn't have a heating system due to the "temporary structure" concept. The ventilation present in the wall cause a decrease of the temperature in the internal layer that lead to an increased heating load and to condensation problems.

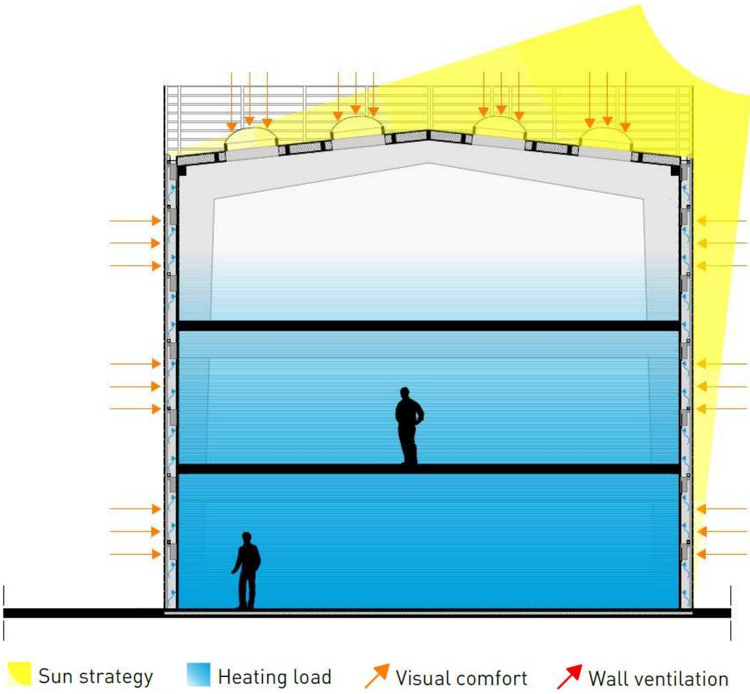


Fig. 20 – Actual winter case

Visual comfort, in winter, is even worse due to the reduced brightness of this period. The skylights are not able to provide the right amount of natural light at the top floor while the ground floor and the first floor are completely dark and require the use of artificial light during all this period.

3.3. Projected strategies

The chapter considers future strategies applicable to the building in order to improve its performance and ensure greater comfort for users.

3.3.1. Summer case

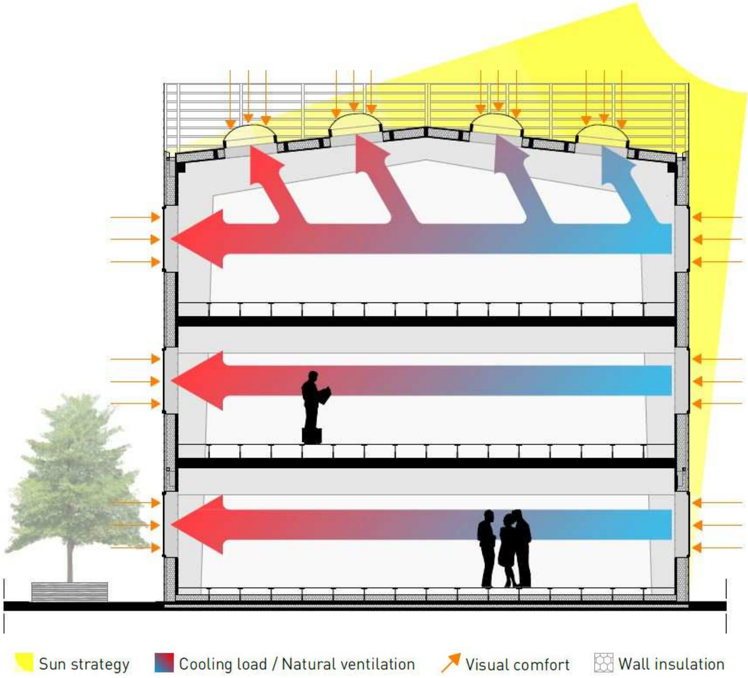


Fig. 21 – Projected summer case

The sun heats up the building and during the summer season will cause discomfort. The use of shading system can decrease the solar heat load, for the project is suggested the use of internal shading system (ex. curtains) in order to decrease the sustainability impact and maintain the original architecture. The solar heat load, the high temperature and the people heat load increase the temperature inside the building. A hybrid system that includes the use of a heat pump and natural ventilation can maintain the project comfort condition. Throughout the use of new glazed area for each floor the visual comfort can be increased in order to reduce the use of artificial light inside the building. Except for the top floor the use of artificial light will be required in reduced quantities.

Instead of the cavity used for ventilation there is an insulating layer in order to increase the performance of the building. An extra insulation layer for the slab at the ground floor is added.

3.3.2. Winter case

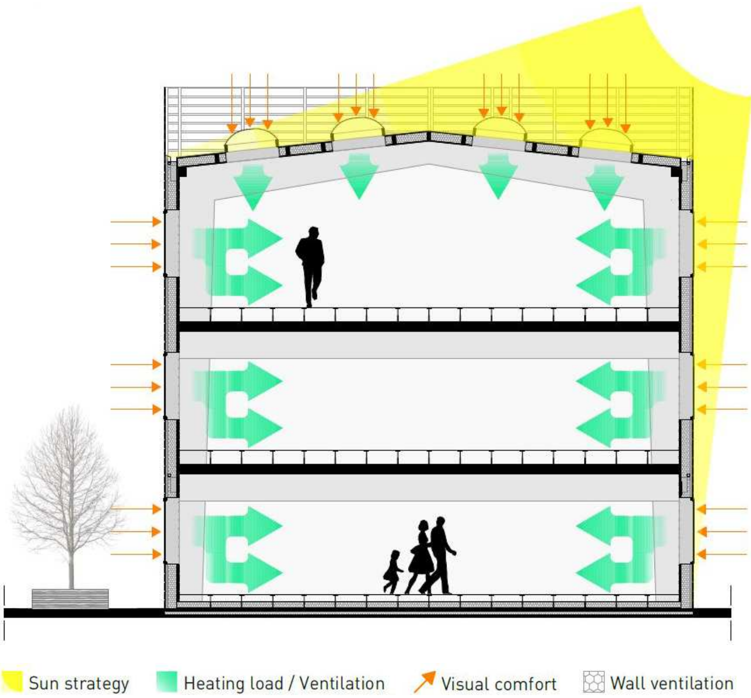


Fig. 22 – Projected summer case

The solar gain increased by the use of new glazed area and the heat pump work will permit the satisfaction of the temperature comfort conditions. The windows installed are used for the air-change when the system is not able to provide the correct amount of new air. The presence of the insulation drastically reduces the heating load of the building.

Visual comfort, in winter, is difficult to reach with the sole use of natural light due to the restrictions that the already built up clusters have. The new glazed surfaces guarantee a reduction in the artificial light demand, especially at the top floor. The presence of the new insulation guarantees a reduction of the heating load and permit to avoid the condensation problem.

3.4. Visual Performance analysis

In order to ensure proper comfort to the user of the buildings and meet the legal minimums required for the office function, it is necessary to add windows in the buildings analyzed. The analysis will verify the existing situation and the new configuration. The clusters considered are close to each others with small passages between the volumes; the proximity of the volumes excludes the possibility to add windows in some sides (the operation would exclude most of the possible light contribution). The skylights will be maintained and will ensure a greater luminosity on the top floor.

3.4.1. Windows module and properties

The windows used in the analysis will have standard dimensions and will be all the same since the analysis is aimed at verifying the amount of glass surface necessary to meet the needs of the buildings. Thanks to the analysis, it will be possible to obtain an approximate area of the glazed surface and consequently the number of windows which will then be considered in the life cycle assessment.

The dimensions chosen for the window module are 1.20 m wide and 1.50 m high. The choice to use only one type of module allows to have a rough estimation of the glass surfaces necessary for each room to meet the minimum performance and standards required. In the architectural design it will be possible to move or change the required areas by re-evaluating the minimums considered.

The windows used are double high solar gain Low-e, the properties related to this type of windows are:

Name	Thickness	T_{sol}	R_{sol1}	R_{sol2}	T_{vis}	R_{vis1}	R_{vis2}	T_{ir}	E_1	E_2	Cond
Clear	4.7 mm	0.796	0.074	0.074	0.888	0.082	0.082	0.000	0.840	0.840	1.00
Air	16.5 mm										
Low-e	4.7 mm	0.796	0.117	0.105	0.826	0.115	0.109	0.000	0.158	0.840	1.00

This type of windows helps the building in terms of energy performance since the bigger part of the summer solar heat is reflected outside and the winter heat supplied to the building is hold inside.

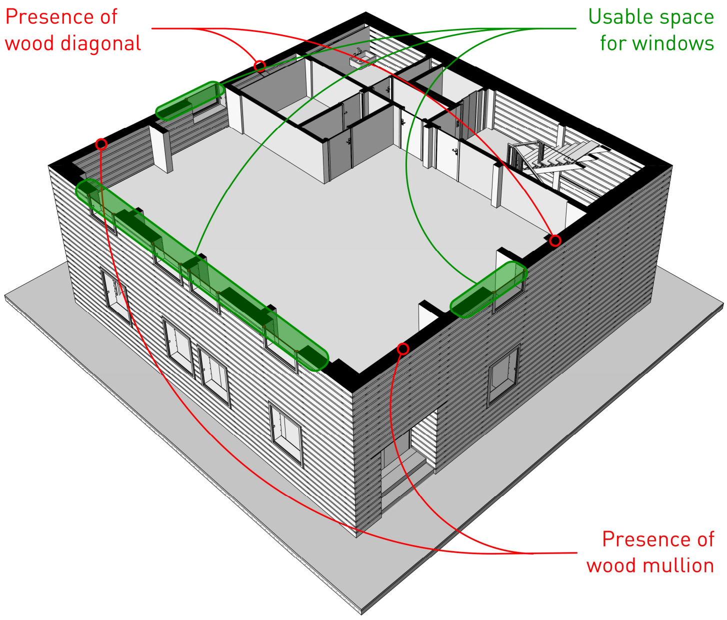


Fig. 23 – Usable space for windows scheme

3.4.2. Reference buildings

In order to perform the analysis, it is necessary to identify the buildings that will have the worst light conditions due to their position and exposure. Looking at the arrangement of the clusters, it is possible to identify two buildings with major problems caused by their proximity to other buildings: Building C typology 1 and Building D typology 1 (same situation for Building G typology 1). In the first case, due to the position, the east and west exposure is compromised by the presence of other buildings while for the second type the south side is covered and the east and west sides are partially covered in the case of sun with values of low azimuth (winter).

Considering the position of the spaces on the different levels it is possible to assume that on the ground floor the most unfavorable conditions will be present due to the shadows brought by the other buildings. On the first floor an improvement due to the height of the floor will be possible while on the higher floor the presence of skylights and a greater height will ensure higher lighting in all spaces.

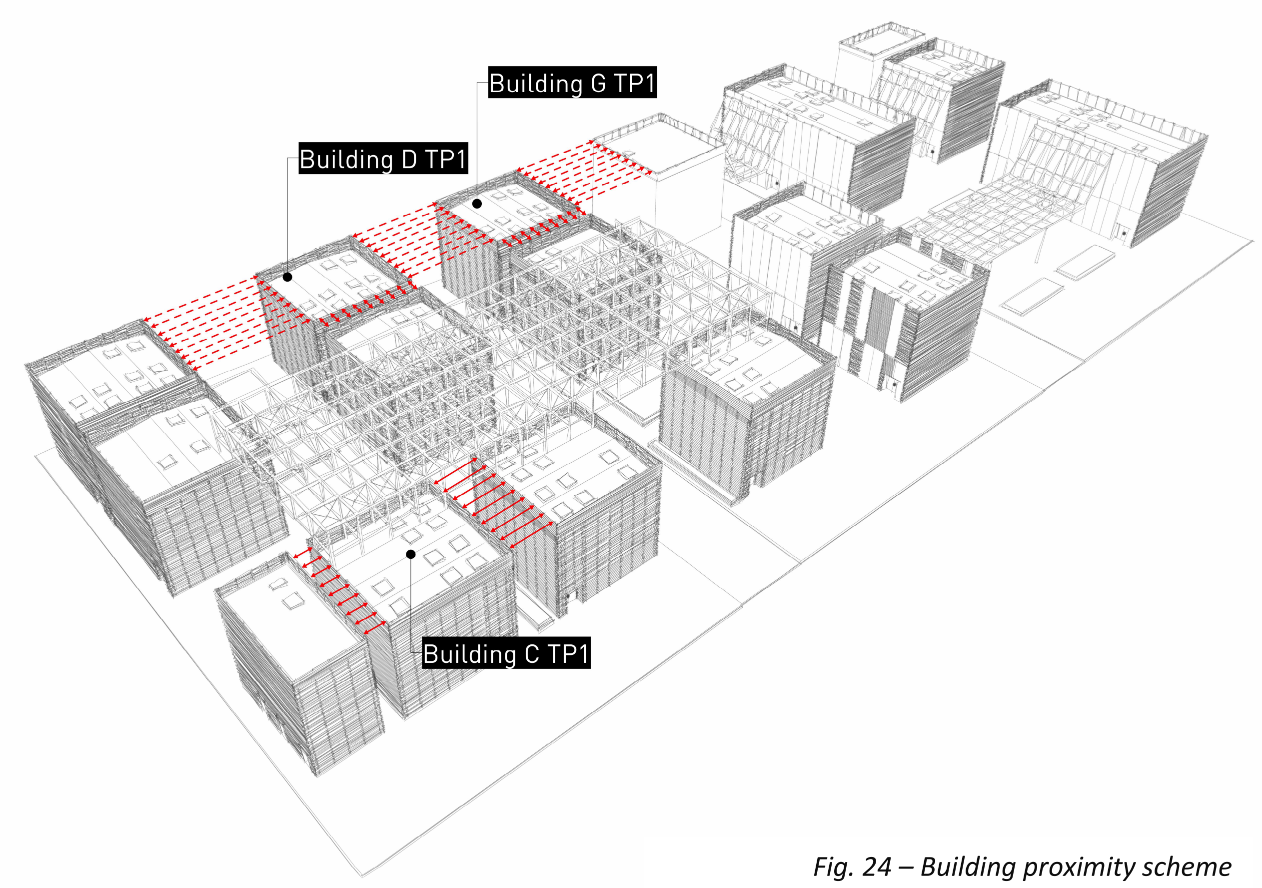


Fig. 24 – Building proximity scheme

3.4.3. Minimum area required from building regulations

The municipality of Milan provides in Art. 103 and 104 of the building regulations the minimum glazed area for the lighting and natural ventilation of the buildings. In the case considered, the verification limit is to be considered 1/10 of the net surface of the space under analysis.

Buildings used as technical spaces do not require a minimum of glazed area; this verification is applied to the two volume types of primary buildings: buildings with standard module (which characterize most clusters) and those with double module (present in two cases). The verification has to be considered valid for all the buildings having the same configuration of spaces and the same arrangement of windows (even if differently oriented). For the ground floor of buildings with standard module there are two types of configurations, the analysis considers the most unfavorable.

The position of the windows was decided considering the functions requiring ventilation and direct lighting, the geometry of the building and the structure present, especially the wooden diagonals of the primary structure, drastically reduce the spaces that can be used for the windows. The final result is therefore the optimal configuration chosen considering these limits.

Standard building [Building D Typology 1]

Floor	Space function	Floor Area	Ratio used	Windows module	Glazed area required
PT / P1 /P2	Function for the area considered	net area [mq]	from Building regulation	B [m] x H [m]	(Floor area) X (Ratio) [mq]
PT	Office/Retail	89.79	1/10	1.20 x 1.50	8.98
PT	W.C.*	7.17	-	1.20 x 1.50	-
P1	Office	77.50	1/10	1.20 x 1.50	7.75
P1	W.C. 1*	6.70	-	1.20 x 1.50	-
P1	W.C. 2*	6.51	-	1.20 x 1.50	-
P2	Office	78.71	1/10	1.20 x 1.50	7.87
P2	W.C.*	8.53	-	1.20 x 1.50	-

*all the W.C. are endowed of forced ventilation

Floor	Space function	Number of windows required	Windows projected
PT / P1 /P2	Function for the area considered	(Glazed area required) / (Windows module)	Windows present in the SDP
PT	Office/Retail	4.99	6
PT	W.C.*	-	-
P1	Office	4.31	6
P1	W.C. 1*	-	-
P1	W.C. 2*	-	-
P2	Office	4.37	6
P2	W.C.*	-	-

Double module [Building C Typology 2]

Floor	Space function	Floor Area	Ratio used	Windows module	Glazed area required
PT / P1 /P2	Function for the area considered	net area [mq]	from Building regulation	B [m] x H [m]	(Floor area) X (Ratio) [mq]
PT	Office/Retail	190.98	1/10	1.20 x 1.50	19.10
PT	W.C. 1*	6.88	-	1.20 x 1.50	-
PT	W.C. 2*	6.50	-	1.20 x 1.50	-
PT	Storage room	3.24	-	1.20 x 1.50	-
P1	Office	198.99	1/10	1.20 x 1.50	19.90
P1	W.C* 1	6.70	-	1.20 x 1.50	-
P1	W.C* 2	6.51	-	1.20 x 1.50	-
P2	Office	198.99	1/10	1.20 x 1.50	19.90
P2	W.C*	8.53	-	1.20 x 1.50	-

*all the W.C. are endowed of forced ventilation

Floor	Space function	Number of windows required	Windows projected
PT / P1 /P2	Function for the area considered	(Glazed area required) / (Windows module)	Windows present in the SDP
PT	Office/Retail	10.61	12
PT	W.C. 1*	-	-
PT	W.C. 2*	-	-
PT	Storage room	-	-
P1	Office	11.06	12
P1	W.C* 1	-	-
P1	W.C* 2	-	-
P2	Office	11.06	12
P2	W.C*	-	-

Fig. 25 – Minimum glazed area tables

Following the checks relating to the minimums required by the building regulations, it is possible to affirm that all buildings meet the imposed parameters.

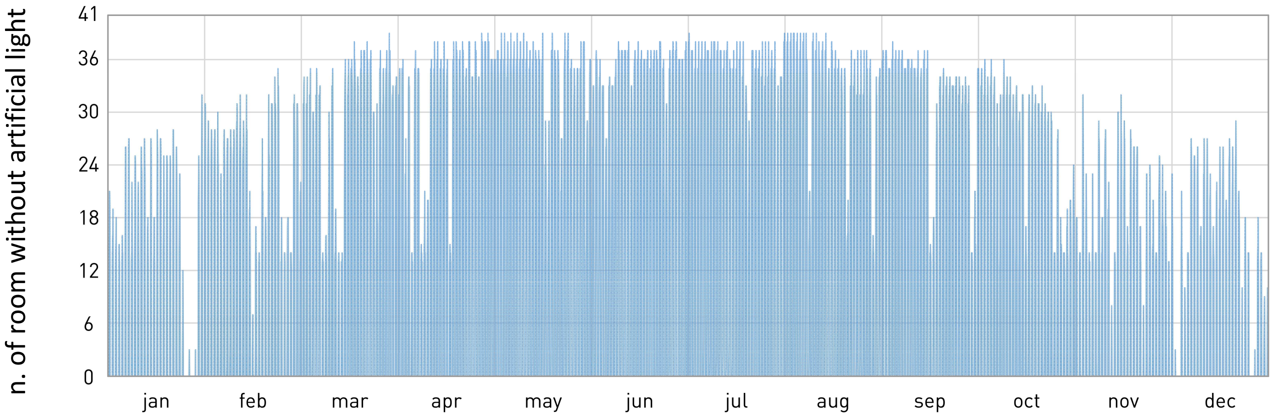
3.4.4. Daylight factor

Through the use of the software and the BIM models created, it is possible to calculate the Daylight factor for the different levels of the building. The area considered for each floor is that of the office or retail which requires correct lighting as it is the main function of each building. The other areas of the floor do not require a calculation of the lighting by law as they are secondary or service spaces. The buildings considered are those established in the chapter “3.4.2. Reference building”.

In the case of the state of affairs (SDF) the only floor considered is the highest one, this is because the other floors to date do not have glazed surfaces and are therefore currently not regular for the function envisaged by the project. EN 15193-1 and the DGNB protocol are taken into consideration for the evaluation of the results obtained, which provide recommended values for the daylight factor.

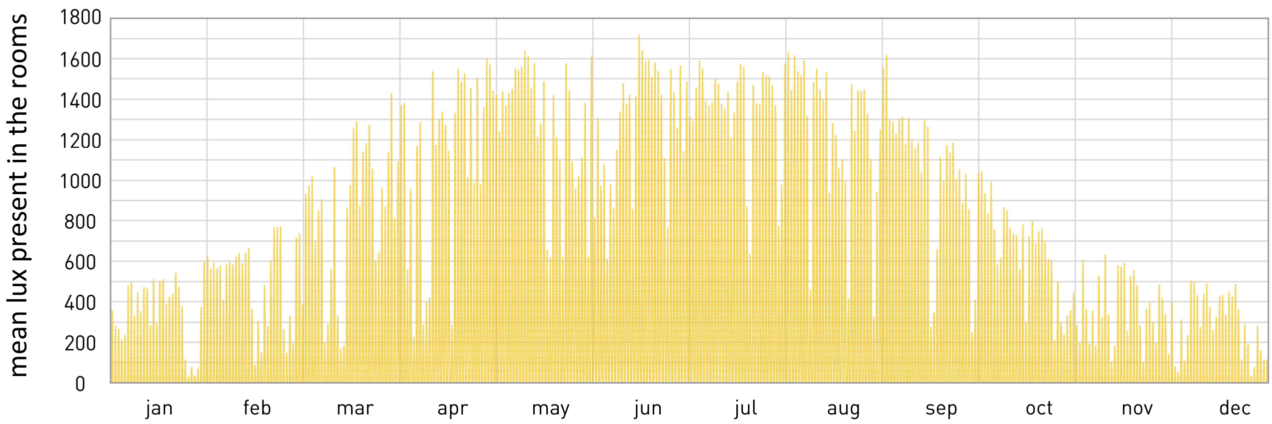
It is important to specify that this type of classification does not constitute an accurate estimate of the lighting in the work space as it is based on only one parameter for the classification but guarantees the possibility of summarily assessing the insertion of glass surfaces and estimating the lighting conditions interior of the spaces. The office and retail spaces are in any case supported by the use of artificial light in case of lack of daylight.

Fig. 26 – Room without artificial light chart

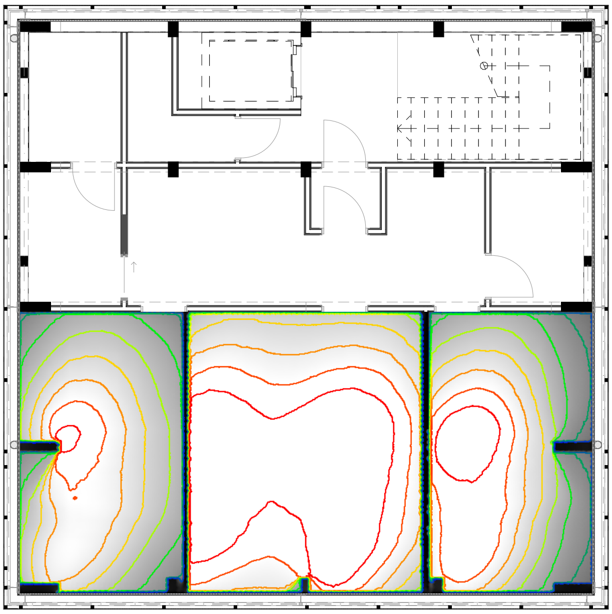


Considering the graph, it is possible to observe the number of rooms in which the light is turned off for each hour of the year. It is important to note that the presence of white spaces in the graph during the summer season tends to decrease, this is due to the longer duration of the days that allow to take advantage of the natural light for more hours.

Fig. 27 – Average quantity of lux present in rooms chart



The graph represents the average of lux present in the rooms analyzed during the whole year. The behavior of the graph is similar to the graph that represent the number of hours when the light is turned off since the two variables considered are closely connected.



SDF - 2nd floor

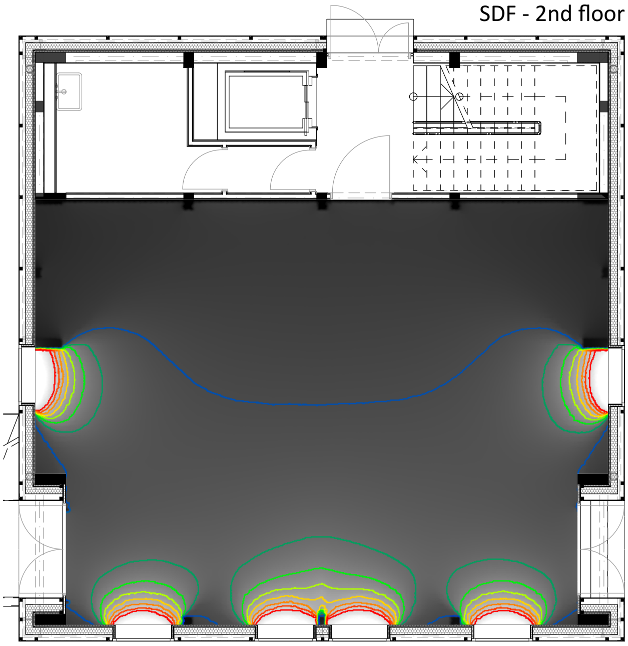
Visual analysis Building D - Typology 1

DF recommended	
Percentage	Condition
> 3%	very good
> 2%	medium
> 1%	slight
< 1%	none

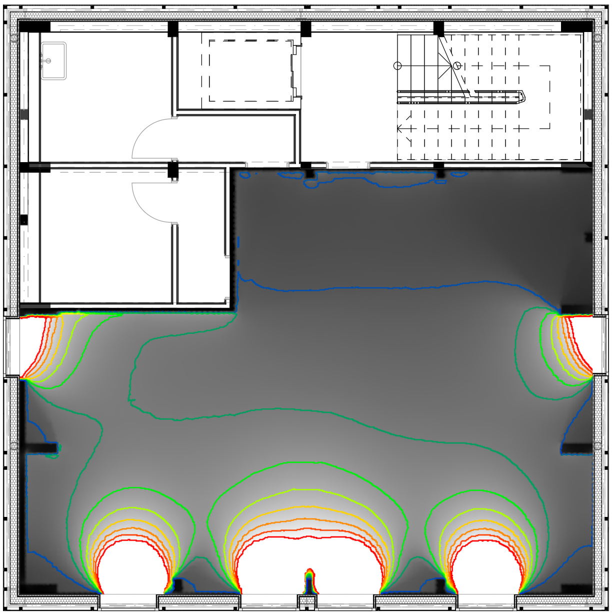
* from DGNB protocol

Daylight factor

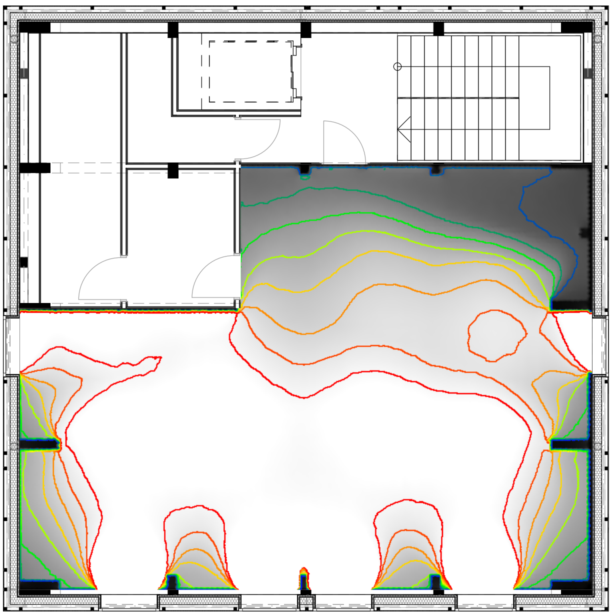
- 8.00
- 7.00
- 6.00
- 5.00
- 4.00
- 3.00
- 2.00
- 1.00



SDP - Ground floor



SDP - 1st floor



SDP - 2nd floor

From the result of the first simulation it is possible to see the difference between the various floors of the building. Considering the simulation of the state of affairs (SDF) is possible to affirm that the second floor had good values even before the intervention contrary to the other two levels which had no lighting due to the lack of windows. The results regarding the part of the project (SDP) are satisfactory despite the fact that the ground floor and the first floor will require the use of lighting some times during the year. It is necessary to remember that the interventions aimed at improving the light supply to an already built structure and for this reason the modification can't be fully effective like in a new building.

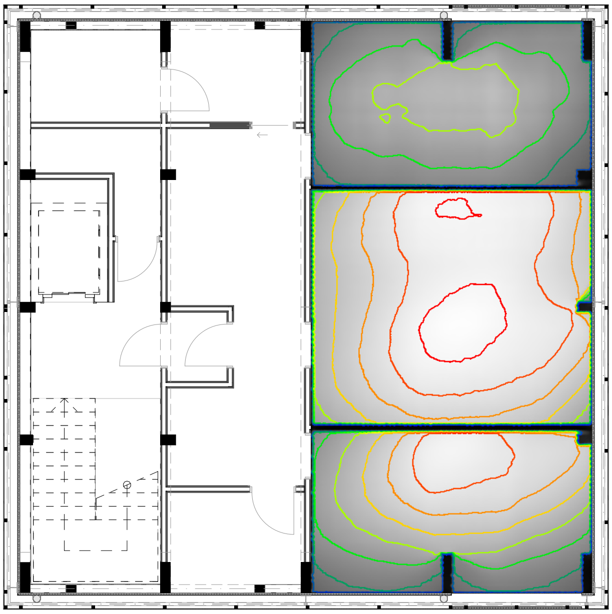
Visual analysis Building C - Typology 1

DF recommended	
Percentage	Condition
> 3%	very good
> 2%	medium
> 1%	slight
< 1%	none

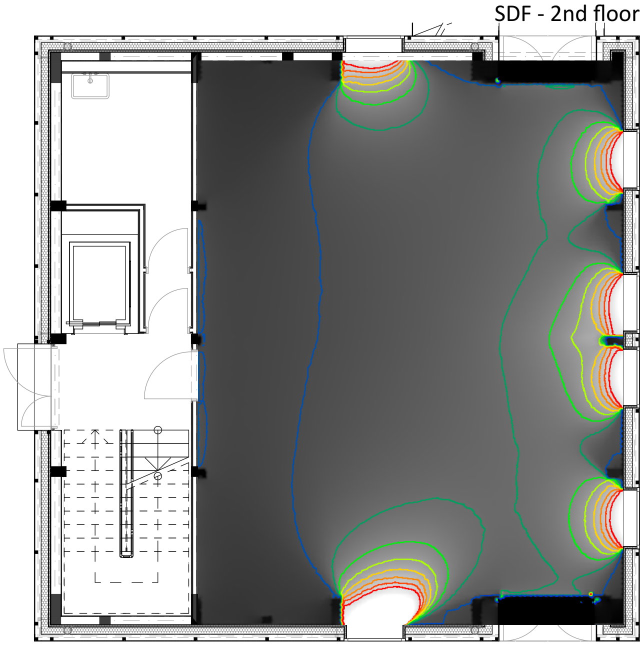
* from DGNB protocol

Daylight factor

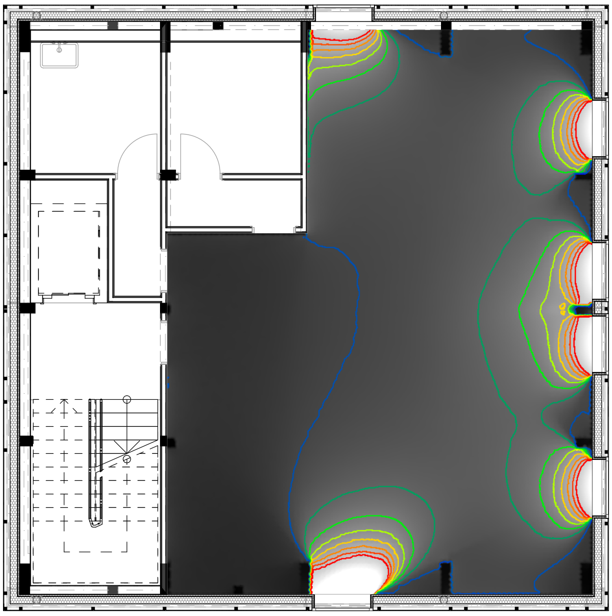
- 8.00
- 7.00
- 6.00
- 5.00
- 4.00
- 3.00
- 2.00
- 1.00



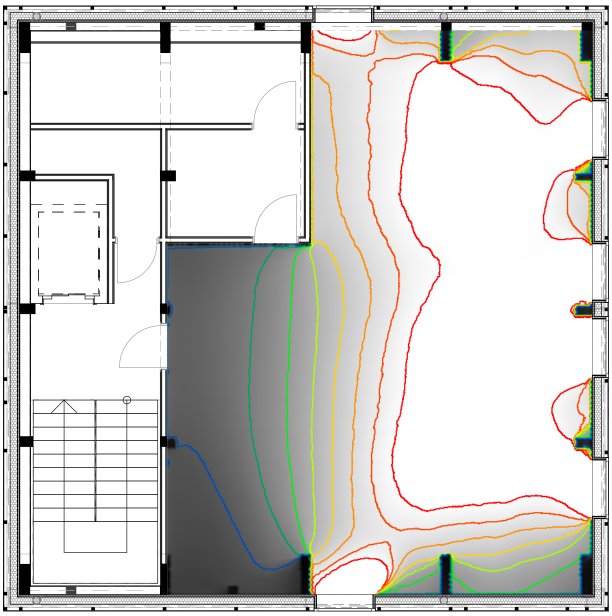
SDF - 2nd floor



SDP - Ground floor



SDP - 1st floor



SDP - 2nd floor

The second analysis allows to confirm what was observed in the first analysis. In the case of the second building analyzed it is possible to observe a slight improvement compared to the previous one due to the different exposure and the reduced presence of obstacles outside. In this case, in fact, there are only two buildings on the east and west side unlike the three buildings of the other geometry. The scanning of the floors also in this case is clearly visible with significant improvements with the increase in height and the presence of skylights on the top floor. As in the previous case, the first two floors of the building will require the use of artificial light several times throughout the year to ensure correct comfort for the users.

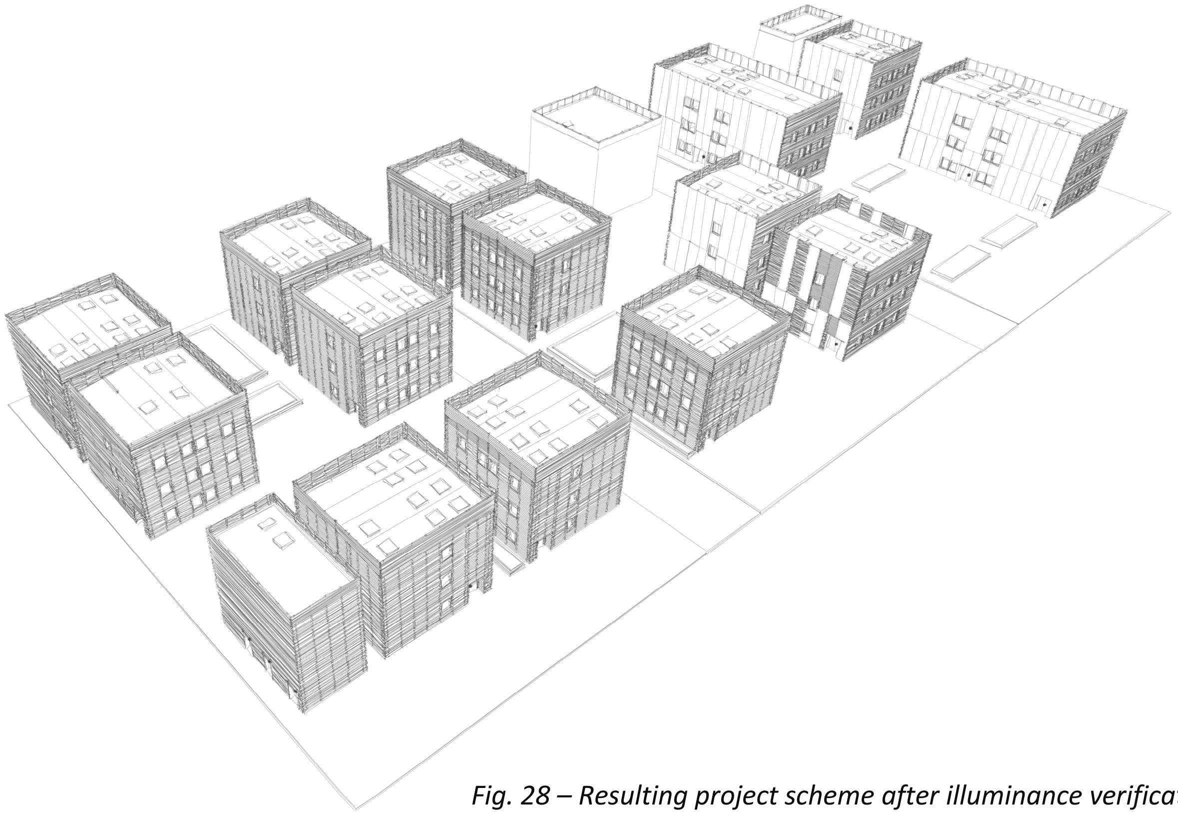


Fig. 28 – Resulting project scheme after illuminance verification

In conclusion, windows have been added to each primary building to guarantee the minimum required glass surfaces which are now respected for the office and retail function. Each floor has acceptable characteristics even if in the first two floors in order to favor the conditions of comfort for lighting is necessary the use of artificial lights. The changes made to the buildings were assessed with the help of simulations and at the same time considering favoring as much as possible the reduction of environmental impacts. The changes will be reconsidered in the phase relating to the life cycle assessment.

3.5. Energy performance analysis

In order to ensure comfort for cluster users and reduce the energy required for building heating and cooling system, it is necessary to check the energy performance of the building. In the state of affairs (SDF), clusters do not have isolated stratigraphies as they have been designed as temporary buildings. It will be necessary to intervene on the various stratigraphies of the buildings in order to increase their performance in terms of insulation. The stratigraphies considered present in many cases the outer layers degraded, for this reason it is more economical and effective to intervene with the addition of an insulation layer in the outermost part of the building which must already be modified by necessity.

3.5.1. Comfort limits

The comfort limits have been calculated considering the "ASHRAE Handbook of Fundamentals Comfort Model"; to obtain the maximum temperature, the level of activity within the space and the typical clothing of the function was considered. The data used for the analysis:

Activity level daytime (1.1 Met = sitting, reading, office activity) [Met]	1.10
Winter Clothing indoors (1.0 Clo = long pants, sweater) [Clo]	1.10
Summer Clothing indoors (0.5 Clo = short pants, t-shirt) [Clo]	0.40
Maximum wet bulb temperature [°C]	17.80
Minimum dew point temperature [°C]	2.20
Summer Comfort Zone shifted by this temperature [ΔT]	2.80

Result:

Comfort Low - Minimum Comfort effective Temperature (50%RH) [°C]	**20.00**
Comfort High - Maximum Comfort effective Temperature (50%RH) [°C]	**25.00**

These limits will be used in energy simulations in order to determine the energy required to maintain this range within the rooms.

3.5.2. Intervention methods

Analyzing the building packages, it is evident the lack of insulation in the external walls and in the slabs of the ground floor; the roof unlike the other stratigraphies has an insulating layer which is consistent even in the actual state.

In order to increase the efficiency of the building, it is necessary to intervene through two different practices:

- External slabs:

it is necessary to add an insulating layer on the internal side of the stratigraphy; the addition of an internal insulation layer is easy to apply but the increase in the thickness of the floor will cause a difference in height between the external and internal flooring. In order to solve the problem caused by the addition of a layer, is necessary to realize stairs outside the entrance and at least one ramp for each building in order to ensure compliance with the national law “legge 13” (overcoming of architectural barriers).

- Walls:

considering that is necessary to replace the external layers of the stratigraphies with more durable materials, the addition of an insulating layer on the external part of the wall is more effective and economical. Thanks to the presence of the air gap used for the joint and the substructure of the ventilated wall, is not necessary an increase in the thickness of the stratigraphy. The cavity part dedicated to the transoms will not be modified while the part used for point anchors will be occupied by the insulation. Considering the hooks used in the project, a correct positioning of the insulation will make the thermal bridges created by the hooks negligible. The gutters in the cavities have been moved outside.

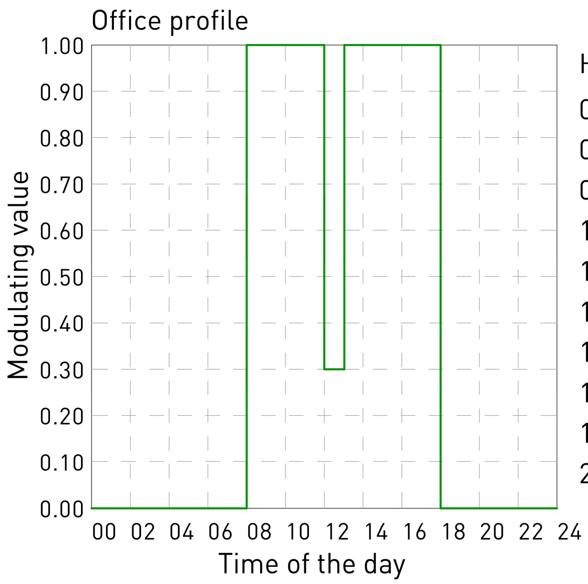
3.5.3. Stratigraphies improvement

The layers added in order to increase the building's performance will be made of wood fiber material. This material guarantees a thermal resistance similar to that of commonly used products (XPS, EPS, etc.) and at the same time drastically reduces the environmental impact values in favor of the life cycle assessment analysis. The technical data for this material:

Density [kg/m^3]	110
Nominal value of thermal conductivity [W/(m·K)]	0,037
Reaction to fire according to DIN EN 13501	E
Building material class according to DIN4102	B2
Production method	dry process
Water vapor/diffusion resistance	3
Significant thermal capacity [J/(kg·K)]	2100

3.5.4. Daily profile

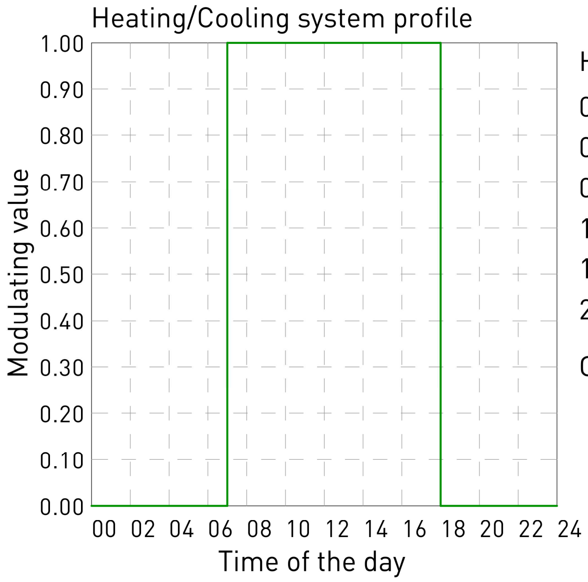
In the building energy balance, people heat gain constitute an important positive or negative load. It is therefore necessary to consider the occupational profiles of people as well as of the various devices in order to create a model that is as close as possible to reality.



Hour	Modultaing value
00:00	0,00
08:00	0,00
08:00	1,00
12:00	1,00
12:00	0.30
13:00	0.30
13:00	1,00
18:00	1,00
18:00	0,00
24:00	0,00

Fig. 21 – Daily profile, people occupation

The first profile is referred to the people occupation; during the lunch time the profile consider a reduction in the number of people inside the office. The people density considered inside the simulation is 10 m^2/person. The same profile is used also for the computers and the other appliances that generate heat; the arbitrary nominal value considered for this category is 1 watt for each square meter.

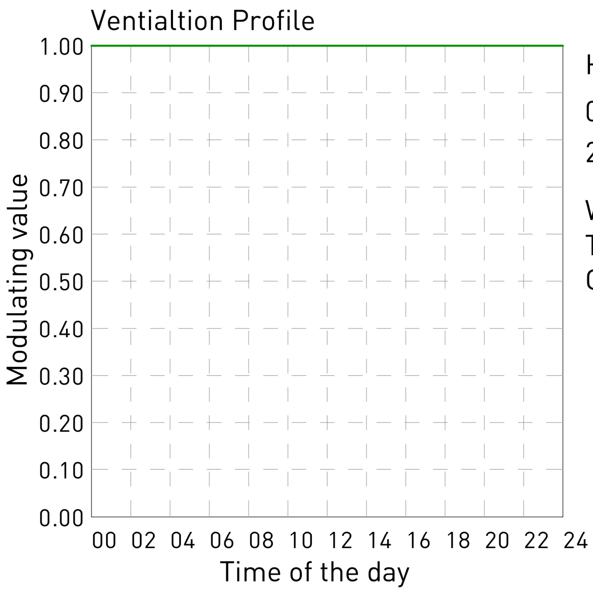


Hour	Modultaing value
00:00	0,00
07:00	0,00
07:00	1,00
18:00	1,00
18:00	0,00
24:00	0,00

ON/OFF system strategy

Fig. 22 – Daily profile, Heating and cooling

The second profile consider the heating and cooling system operation. The strategy choose for this system is the on/off one since is the most convenient in term of inexpensiveness and performance. The starting hour is switch of thirty minutes considering the people profile in order to prepare the room before the entrance of the user.



Hour	Modultaing value
00:00	1 if (Ti > 24°C) and (CO_2 > 900ppm)
24:00	1 if (Ti > 24°C) and (CO_2 > 900ppm)

With:
Ti = Internal temperature
CO_2 = Room carbon dioxide

Fig. 23 – Daily profile, ventilation profile

The last profile used is for the natural ventilation process; in this case the profile is always active and will open the windows if two condition are satisfied. The first condition is the temperature, if the temperature is higher than 24°C the windows will be opened until the heating and cooling system will turn on. The second condition consider the quality of the air, if the air surpasses the value of 900 ppm the windows will open. These two strategies are necessary but not sufficient to open the windows, it is required that the satisfaction of both of the conditions at the same time. The ventilation inside the room is managed by a hybrid system, the windows works in order to maintain the level of pollutant in a low concentration but if the limit is reach and the windows can't be opened the HVAC system considered in the project will start to change the air.

3.5.5. Results

The results of the simulations are compared between those of the actual state (left side) with those of the project state (right side) in order to analyze the benefits of the proposed applications in terms of efficiency.

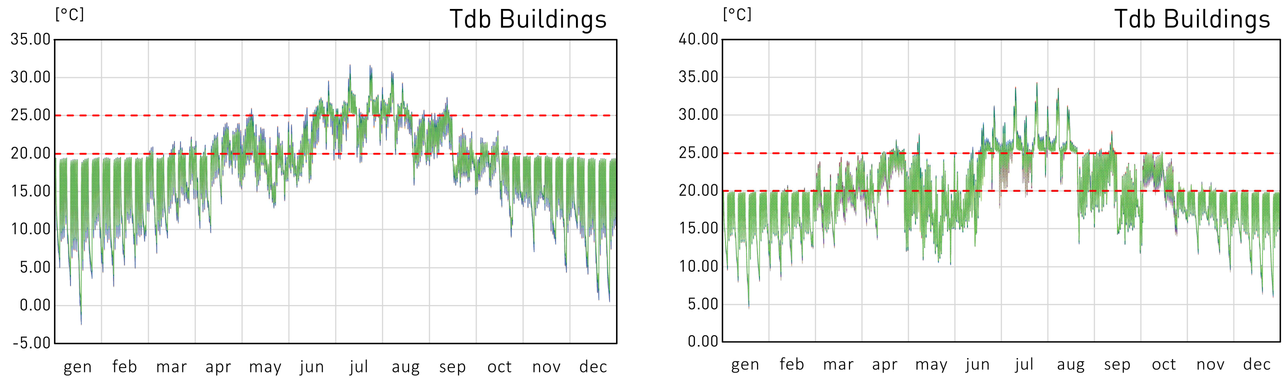


Fig. 24 – Dry bulb temperature results

Legend

For Tdb and CO_2

- Typology 1 - Building A
- Typology 1 - Building B
- Typology 1 - Building C
- Typology 1 - Building D
- Typology 1 - Building E
- Typology 1 - Building F
- Typology 1 - Building G
- Typology 1 - Building H
- Typology 1 - Building I
- Typology 2 - Building A
- Typology 2 - Building B
- Typology 2 - Building C
- Typology 2 - Building D

The first comparison proposed is between temperatures during the whole year. The scheme considers all the buildings inside the project area; the presence for the most part of a single color denotes very similar behavior among the various cases considered. The red lines inside the graph indicate the comfort limits calculated before. The most obvious aspect is the temperature behavior due to the on/off strategy which causes most of the time a temperature inside the buildings below the comfort limit during the winter. During the summer, the behavior, even in a reduced way, is the same: outside the activity times the temperature does not respect the limits set. The periods in which there is a greater allowable temperature response without the functioning of the heating and cooling system are the half seasons.

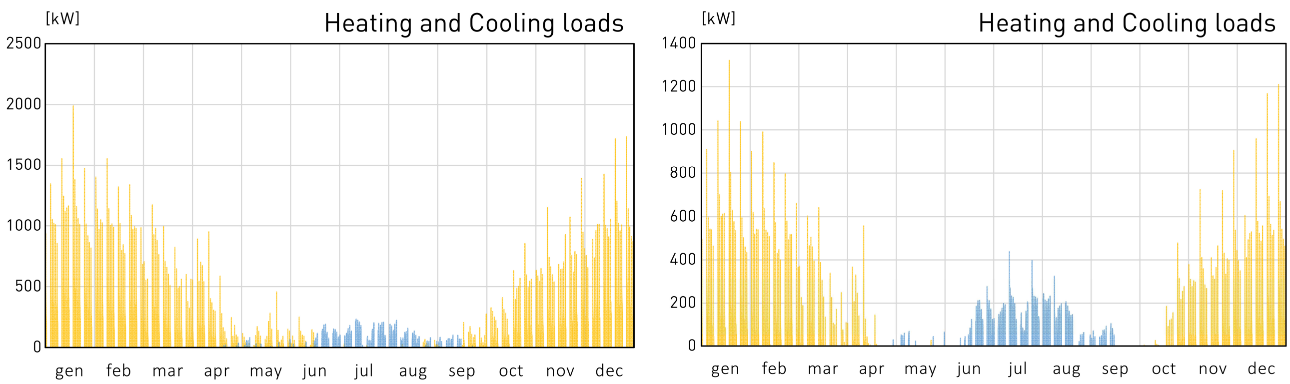


Fig. 25 – Energy demand results

For heating and cooling

- Project heating load
- Project cooling load

Considering the heating and cooling loads, the improvements made to the building drastically reduce the consumption relating to heating while they do not improve those relating to building cooling. The improvement relating to heating is mainly due to the presence of the insulation which increases the thermal resistance of the walls and slabs. Cooling is not improved since the building, despite being more isolated, does not have a greater thermal inertia and therefore, does not take advantage of the night cooling strategy. The current building, on the other hand, manages to cool more effectively during the day thanks to the presence of an air gap partially sacrificed in the project for the insertion of the insulation. Considering the annual consumption, it is possible to observe an improvement due to the applied strategies in the heating load and considering the total energy balance.

SDF [state of affairs]	
Heating	69.74 kW
Cooling	7.35 kW
SDP [project state]	
Heating	22.44 kW
Cooling	11.45 kW

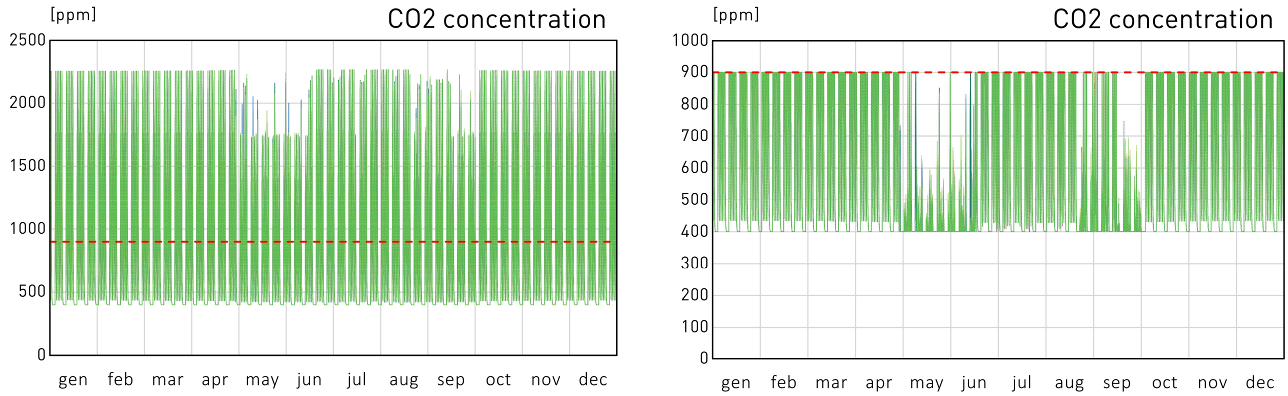


Fig. 26 – CO_2 concentration results

Legend
For Tdb and CO_2
Typology 1 - Building A
Typology 1 - Building B
Typology 1 - Building C
Typology 1 - Building D
Typology 1 - Building E
Typology 1 - Building F
Typology 1 - Building G
Typology 1 - Building H
Typology 1 - Building I
Typology 2 - Building A
Typology 2 - Building B
Typology 2 - Building C
Typology 2 - Building D

The last comparison concerns the concentration of CO2 in the air. The scheme considers all the buildings inside the project area; as in the first case the presence for the most part of a single color denotes very similar behavior among the various cases considered. The red lines inside the graph indicate the maximum limits considered in the ActiveHouse Protocol in the best case. In the state of affairs (SDF) are considered the same CO_2 load as in the project case. In this case, the building can regulate the level of pollutants only throughout the use of windows while the project case is equipped with a hybrid system that can use windows and the HVAC system.

In conclusion, analyzing all the elements that characterize the assessment of the building's energy performance, it is possible to say that the improvement carried out in the design phase give positive values in all the sector considered.

3.5.6. Lighting demand

In order to estimate the energy consumption due to lighting, the number of office rooms (41 in total) that require the use of artificial light for each hour of the year were considered. The result of the analysis:

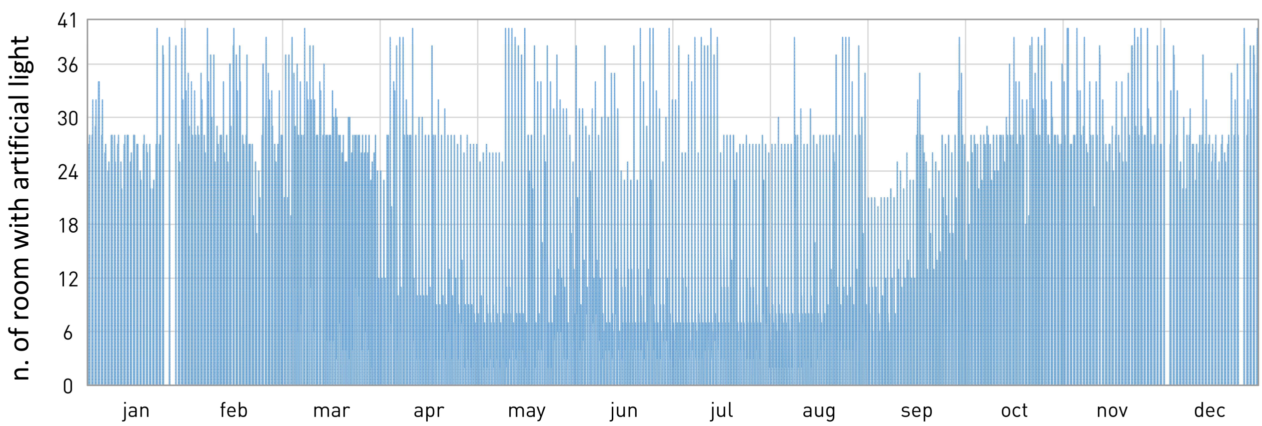


Fig. 27 – Room with artificial light chart

The threshold in lux required to switch on the artificial lighting is equal to 300 lux (as required by UNI-EN-12464-1). The graph shows a considerable reduction in the need for artificial light during the summer period. Despite the improvements made, the use of light points is necessary, in particular in the first two floors of the building, the use of artificial light is necessary throughout the year. Considering the use of LEDs for all devices inside the building, consumption is 2.15 kWh/m^2·year.

4. SDP (stato di progetto - project state)

4.1. BIM approach

The use of a BIM (Building Information Modeling) software provides an opportunity to improve the proposal since, once the model has been created, the export of information relating to all the project elements into other software, for the calculation of the LCA, energy performance and lighting and comfort, it is manageable and more complete.

In order to use a BIM approach, it is necessary to develop both the state of affair and the state of the project. Through the process of drafting the relief, databases relating to the elements and materials that compose it are created within the software, as well as the design geometry that allow future analyzes to be carried out without incurring in new modeling phases. The model used for the representation of the current state and for the various analyzes has a level of detail (LOD) LOD 300.

In addition to the information requested, the model relating to the state of affairs (SDF) contain information related to the future use of each element considering the state of deterioration found. Each element can therefore be "kept" or "removed" from the project area; the fate of the removed materials will then be decided in the life cycle assessment phase.

The data relating to the principal elements making up the actual project are presented below:

FOUNDATIONS

Foundation - slabs					
type	*thickness [m]*	*surface [m²]*	*volume [m³]*	*density [kg/m³]*	*mass [kg]*
Slab - lower	0.100	2551.40	255.14	2100	535794.00
Slab - higher	0.150	1405.53	210.83	2100	442743.00

Foundation - beams					
type	*tot. lenght [m]*	*surface [m²]*	*volume [m³]*	*density [kg/m³]*	*mass [kg]*
beams - 50x50h cm	989.000	0.25	247.25	2100	519225.00
beams - 80x50h cm	637.175	0.40	254.87	2100	535227.00

Foundation - igloo					
type	*n. volume [m³]*	*n. of igloo*	*tot. volume [m3]*	*density [kg/m³]*	*mass [kg]*
HDPE igloo	0.0032	7200.00	22.68	940	21319.20

STRUCTURE

Wood - columns					
type	*tot. lenght [m]*	*surface [m²]*	*volume [m³]*	*density [kg/m³]*	*mass [kg]*
column - 20x30h cm	1290.240	0.06	77.41	450	34836.48

Wood - beams					
type	*tot. lenght [m]*	*surface [m²]*	*volume [m³]*	*density [kg/m³]*	*mass [kg]*
beam - 16x20h cm	1700.000	0.032	54.40	450	24480.00
beam - 20x60h cm	694.400	0.120	83.33	450	37497.60
beam - 08x20h cm	2174.900	0.016	34.80	450	15659.28
diagonals - 16x16h cm	865.920	0.026	22.17	450	9975.40

Wood - portals					
type	*n. of element*	*n. volume [m³]*	*volume [m³]*	*density [kg/m³]*	*mass [kg]*
portals - main structure	73	3.68	268.64	450	120888.00

Wood - mullions					
type	*tot lenght [m]*	*surface [m²]*	*volume [m³]*	*density [kg/m³]*	*mass [kg]*
mullion - 6x6h cm	9854.100	0.0036	35.47	450	15963.64

Steel - columns					
type	*tot lenght [m]*	*surface [m²]*	*volume [m³]*	*density [kg/m³]*	*mass [kg]*
HEA 180	362.000	0.0045	1.64	7700	12612.99
UPN 180	83.020	0.0028	0.23	7700	1789.91
external - d20	29.160	0.012	0.357	7700.000	2749.619

Steel - beams					
type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
IPE 240	529.260	0.00391	2.07	7700	15942.58

Steel - transoms					
type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
transom - 6x6h cm	5334.010	0.0020	10.67	7700	82143.75

Steel - joints					
type	n. of element	n. volume [m^3]	volume [m^3]	density [kg/m^3]	mass [kg]

WALL

wall 01					
type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	2261.65	33.92	450	15266.15
air space	0.262	2261.65	592.55	1	592.55
OSB panels	0.012	2261.65	27.14	660	17912.28
XPS	0.026	2261.65	58.80	25	1470.07
OSB panels	0.012	2261.65	27.14	660	17912.28

wall 02					
type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	648.21	9.72	450	4375.40
air space	0.262	648.21	169.83	1	169.83
OSB panels	0.012	648.21	7.78	660	5133.80
XPS	0.026	648.21	16.85	25	421.33
OSB panels	0.012	648.21	7.78	660	5133.80
air space	0.160	648.21	103.71	1	103.71
fir boards	0.015	648.21	9.72	450	4375.40

wall 03					
type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	347.59	5.21	450	2346.21
air space	0.262	347.59	91.07	1	91.07
OSB panels	0.012	347.59	4.17	660	2752.88
XPS	0.026	347.59	9.04	25	225.93
OSB panels	0.012	347.59	4.17	660	2752.88
air space	0.180	347.59	62.57	1	62.57
fir boards	0.015	347.59	5.21	450	2346.21

wall 04					
type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	997.82	14.97	450	6735.30
air space	0.262	997.82	261.43	1	261.43
OSB panels	0.012	997.82	11.97	660	7902.76
XPS	0.026	997.82	25.94	25	648.58
OSB panels	0.012	997.82	11.97	660	7902.76
air space	0.200	997.82	199.56	1	199.56
fir boards	0.015	997.82	14.97	450	6735.30

wall 05					
type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
air space	0.262	1524.56	399.43	1	399.43
OSB panels	0.012	1524.56	18.29	660	12074.50
XPS	0.026	1524.56	39.64	25	990.96
OSB panels	0.012	1524.56	18.29	660	12074.50
air space	0.160	1524.56	243.93	1	243.93
fir boards	0.015	1524.56	22.87	450	10290.77

wall 06					
type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
air space	0.262	531.57	139.27	1	139.27
OSB panels	0.012	531.57	6.38	660	4210.07
XPS	0.026	531.57	13.82	25	345.52
OSB panels	0.012	531.57	6.38	660	4210.07
air space	0.200	531.57	106.31	1	106.31
fir boards	0.015	531.57	7.97	450	3588.13

wall 07					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
fir boards	0.015	698.40	10.48	450	4714.17
fir boards	0.040	698.40	27.94	450	12571.13
fir boards	0.015	698.40	10.48	450	4714.17
air space	0.262	698.40	182.98	1	182.98
OSB panels	0.012	698.40	8.38	660	5531.30
XPS	0.026	698.40	18.16	25	453.96
OSB panels	0.012	698.40	8.38	660	5531.30
air space	0.180	698.40	125.71	1	125.71
gypsium panels	0.012	698.40	8.38	680	5698.91
gypsium panels	0.012	698.40	8.38	680	5698.91

wall 08					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
fir boards	0.020	115.11	2.30	450	1036.01
fir boards	0.040	115.11	4.60	450	2072.01
fir boards	0.020	115.11	2.30	450	1036.01
air space	0.262	115.11	30.16	1	30.16
OSB panels	0.012	115.11	1.38	660	911.69
XPS	0.026	115.11	2.99	25	74.82
OSB panels	0.012	115.11	1.38	660	911.69
air space	0.210	115.11	24.17	1	24.17
gypsium panels	0.012	115.11	1.38	680	939.31
gypsium panels	0.012	115.11	1.38	680	939.31

wall 09					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
fir boards	0.015	610.67	9.16	450	4122.00

wall 10					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
fir boards	0.015	178.67	2.68	450	1206.00
fir boards	0.030	178.67	5.36	450	2412.00
fir boards	0.015	178.67	2.68	450	1206.00

wall 11					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
gypsium panel	0.012	7.29	0.09	680	59.49

wall 12					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
gypsium panels	0.012	485.83	5.83	680	3964.40
gypsium panels	0.012	485.83	5.83	680	3964.40

wall 13					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
gypsium panels	0.012	8384.99	100.62	680	68421.52
gypsium panels	0.012	8384.99	100.62	680	68421.52
air space	0.075	8384.99	628.87	1	628.87
gypsium panels	0.012	8384.99	100.62	680	68421.52
gypsium panels	0.012	8384.99	100.62	680	68421.52

wall 14					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81
air space	0.075	452.55	33.94	1	33.94
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81
air space	0.075	452.55	33.94	1	33.94
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81

SLABS

slab 01					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
epoxy resin	0.005	5853.77	29.27	561	16419.82
sand-cement	0.060	5853.77	351.23	1200	421471.26
concrete	0.150	5853.77	878.07	2100	1843936.74

slab 02					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
epoxy resin	0.005	2510.55	12.55	561	7042.09
sand-cement	0.060	2510.55	150.63	1200	180759.45
XPS	0.080	2510.55	200.84	25	5021.10
vapour barrier	0.001	2510.55	2.51	650	1631.86

slab 03					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
fir flooring	0.020	421.95	8.44	450	3797.58
sand-cement	0.060	421.95	25.32	1200	30380.65
EPE insulation	0.010	421.95	4.22	120	506.34
concrete	0.120	421.95	50.63	2100	106332.28
steel sheets	0.005	421.95	2.11	7700	16245.21

slab 04					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
fir flooring	0.020	1791.12	35.82	450	16120.08
EPE insulation	0.010	1791.12	17.91	120	2149.34
OSB boards	0.012	1791.12	21.49	660	14185.67
Cork insulation	0.060	1791.12	107.47	240	25792.13
CLT	0.120	1791.12	214.93	500	107467.20

ROOF

roof 1					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
waterproof membrane	0.004	1824.83	7.30	1000	7299.32
waterproof membrane	0.004	1824.83	7.30	1000	7299.32
OSB panels	0.012	1824.83	21.90	660	14452.66
cork insulation	0.200	1824.83	364.97	240	87591.86
vapour barrier	0.001	1824.83	1.82	650	1186.14
fir boards	0.015	1824.83	27.37	450	12317.61

roof 2					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
waterproof membrane	0.004	250.62	1.00	1000	1002.48
waterproof membrane	0.004	250.62	1.00	1000	1002.48
concrete	0.100	250.62	25.06	2100	52630.09
steel sheets	0.005	250.62	1.25	7700	9648.85

SHELL

Wood - columns					
type	*tot. lenght [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
columns - 20x20h cm	497.930	0.04	19.92	450	8962.74

Wood - beams					
type	*tot. lenght [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
beams - 20x20h cm	1458.500	0.04	58.34	450	26253.00
beams - 8x30h cm	1083.750	0.02	26.01	450	11704.50

Steel - bracings					
type	*tot. lenght [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
steel bracing	698.353	0.0028	1.97	7700	15196.30

ELEMENTS

Openings			
type	*n. of elements*	*width [m]*	*height [m]*
skylights	141	1.200	1.200
doors	244	0.900	2.100
doors	15	1.200	2.100
doors	6	1.500	2.100
doors	10	1.600	2.100
doors	32	1.800	2.100

LEGEND

- Mantained in the SDP phase
- Removed in the SDP phase
- Expanded in the SDP phase
- Reduced in the SDP phase

Wood panels					
type	*thickness [m]*	*surface [m^2]*	*volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
Fir panels	0.012	3427.370	41.13	450.000	18507.798
PMMA panel	0.012	1713.685	20.56	1190.000	24471.422
PVC panel	0.012	1713.685	20.56	1380.000	28378.624
Fir internal structure	0.012	7197.477	86.37	450.000	38866.376

Internal stairs					
type	*n. volume [m^3]*	*n. of stairs*	*tot. volume [m^3]*	*density [kg/m^3]*	*mass [kg]*
beam 10x16h cm	0.511	36.00	18.39	450.000	8273.664
fir boards	0.185	36.000	6.66	450.000	2999.106

Internal railing					
type	*area [m^2]*	*stairs lenght [m]*	*additional lenght [m]*	*density [kg/m^3]*	*mass [kg]*
steel profile	0.0001	258.84	1294.20	7700.000	1195.841
steel tube	0.0028	258.84	-	7700.00	5632.41

Fig. 28 – Building component index (shred)

These tables are proposed for illustrative purposes and represent a part of the data possibilities obtainable following the representation of the current situation. The required data is provided for life cycle assessment and for the various performance analysis required. The various elements within the project have been divided by type of artefacts (foundations, stratigraphies, shells, etc.) and considering the different construction types of the project.

4.2. Architecture and internal configuration

The architecture of the building takes inspiration from food boxes; this influence was used during Expo to define its primary function through the aesthetics of the building: to be a container of a food theme for different countries that share similar raw materials. The architecture of the building is today, thanks to the exhibition that took place, reminiscent of a particular moment for the city that has favored greater internationalization opportunities for Milan. The Mind project itself was born from the ashes of Expo as a new opportunity for this area.

Considering these aspects, it is important to maintain the architecture of these clusters and for this reason the different technical choices applied to the building in order to meet the various criteria considered will always try to maintain the architecture of the clusters.

The partitions present today inside the buildings are not useful for the different needs that the office function will require and do not coincide with the concept of elasticity that the document wants to apply to them, as the possible needs of future owners are not known to date; for this reason, the project will provide for its removal in favor of an open space that can be organized through the preparation of movable walls or partitions. The existing stairwells and partitions inherent the vertical connections and bathroom service will be in part maintained.

The wooden shells made outside the pavilions are currently in a serious state of deterioration and will be removed during the design phase.

4.3. Building function

The clusters considered within the project area will take on different functions depending on the building typology and the project needs. The secondary building used for the different systems serving the primary building will maintain the same function and configuration. The main clusters, on the other hand, will have to host offices except for the ground floor which, depending on the MIND project, will be able to host the retail or office function. Considering the functional part, the primary buildings can be divided considering those with standard module and those with double module. The following are the functions for the clusters:

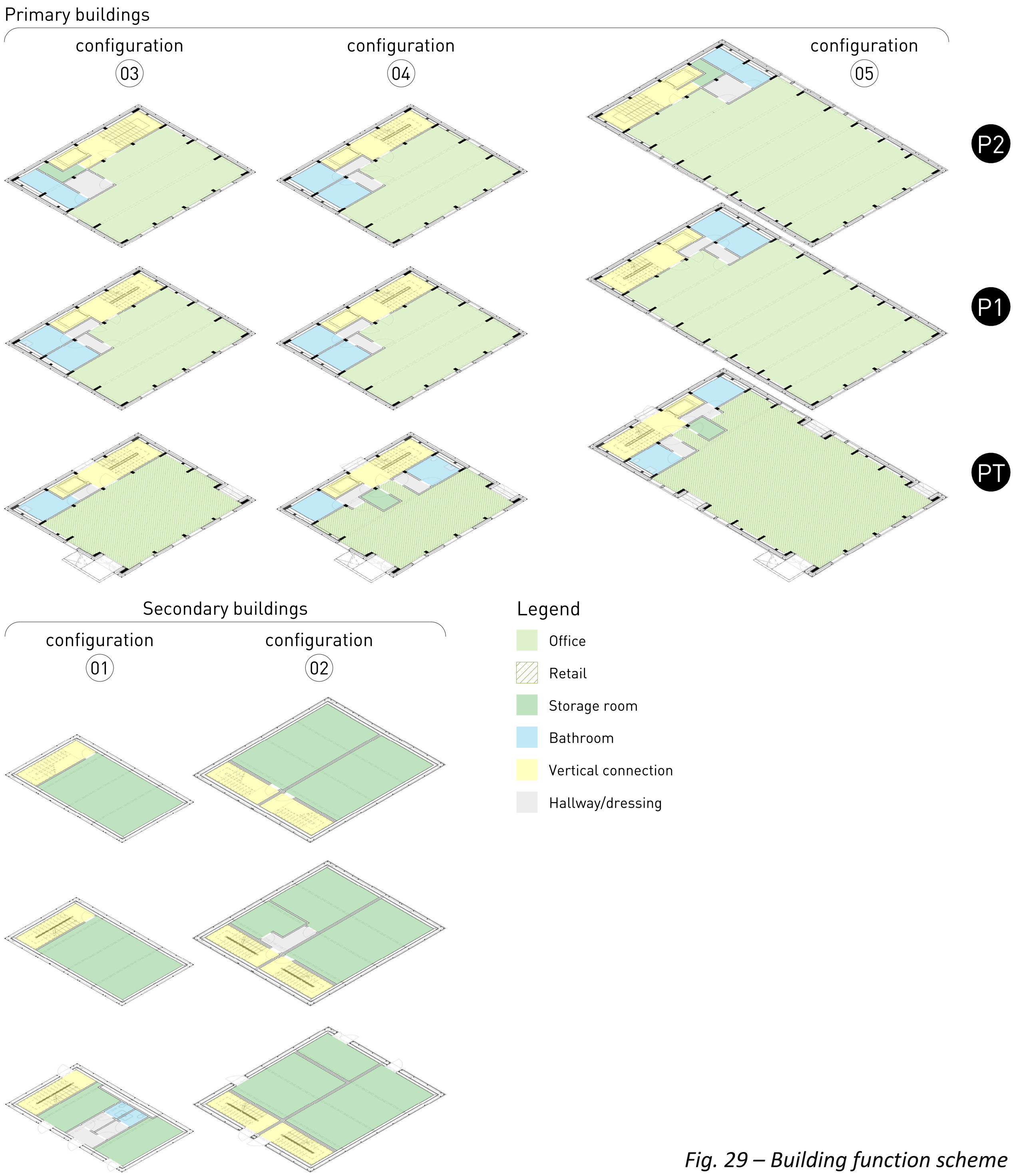


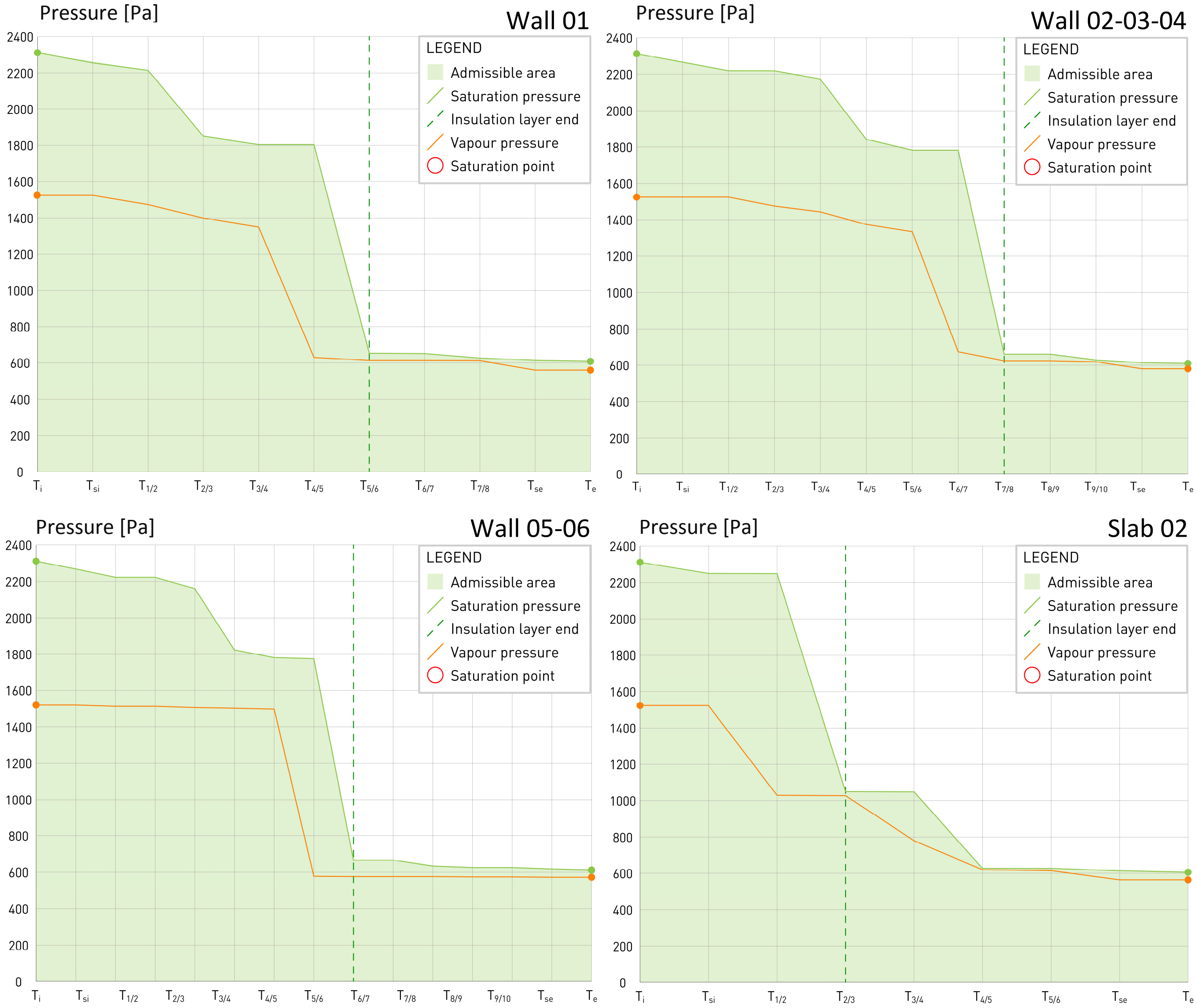
Fig. 29 – Building function scheme

4.4. Stratigraphies

The new stratigraphies present in the project buildings, as seen in chapter “3.5.3 Stratigraphies improvement", have been subject to the insertion of an insulating layer in order to make the building more efficient in terms of energy. The condensation has been considered in the design of the new stratigraphies. The stratigraphies present in the state of affairs in fact presented a condensation problem, as found in the inspection carried out in the project area. In order to solve the problems related to the presence of condensation, membranes have been added to the various stratigraphies considered. The stratigraphies taken into consideration in the glazer verification are those belonging to primary buildings which, due to the addition of the insulating layer, require careful study of this aspect. The stratigraphies belonging to secondary buildings, on the other hand, presented problems in the external layers which will be replaced during the design phase with elements made up with more durable materials in addition to the addition of a waterproofing membrane placed in the inner part of the external air gap.

The result obtained by the Glazer verification:

Fig. 30 – Glazer verifications



The checks were carried out considering a critical situation; the external temperature was assumed equal to 0 ° C (RH = 65%) while the internal one 20 ° C (RH = 95%). The results following the simulations are positive and show that there is no condensation in any stratigraphy. To each stratigraphy, two membranes have been added respectively for waterproofing in the external position of the insulation and for block vapor in the internal position. The internal stratigraphies, have been kept the same also for the design phase. Following the changes to the layout, the internal partitions are used only for the service area.

4.5. Solar panel

In order to increase energy savings and reduce emissions during the project use phase, photovoltaic panels are installed. The state of affairs allows the installation of the panels on the roof of the clusters, this strategy will avoid occupying space on the ground in the project area and will not affect the aesthetics of the building since the external wall panels are one meter and a half higher than on the roof level.

Considering the different types of solar panels, mono crystalline silicon was chosen for the project which constitute a good compromise between efficiency and conversion efficiency. From EN-15316-4-3: 2017:

Type of photovoltaic module	K_{pk} [kW/m²]
Mono crystalline silicon*	0.15 to 0.20
Multi crystalline silicon*	0.12 to 0.18
Thin film amorphous silicon	0.04 to 0.10
Other thin film layers	0.035
Thin film Cooper-Indium-Gallium diselenide	0.105
Thin film Cadmium-Telloride	0.095
*With a minimum package density of 80%	

Type of ventilation of the modules	f_{perf}
Unventilated modules	0.76
Moderately ventilated modules	0.80
Strongly ventilated modules	0.82

For the calculation of the required area needed to cover the entire electrical energy demand, the amount of annual global radiation reaching the PV system must be assessed. According to the layout of the roof, reference is made to a surface facing south and tilted by 30°.

The global solar radiation reaching the PV system is equal to 1073,74 kWh/m²·year.

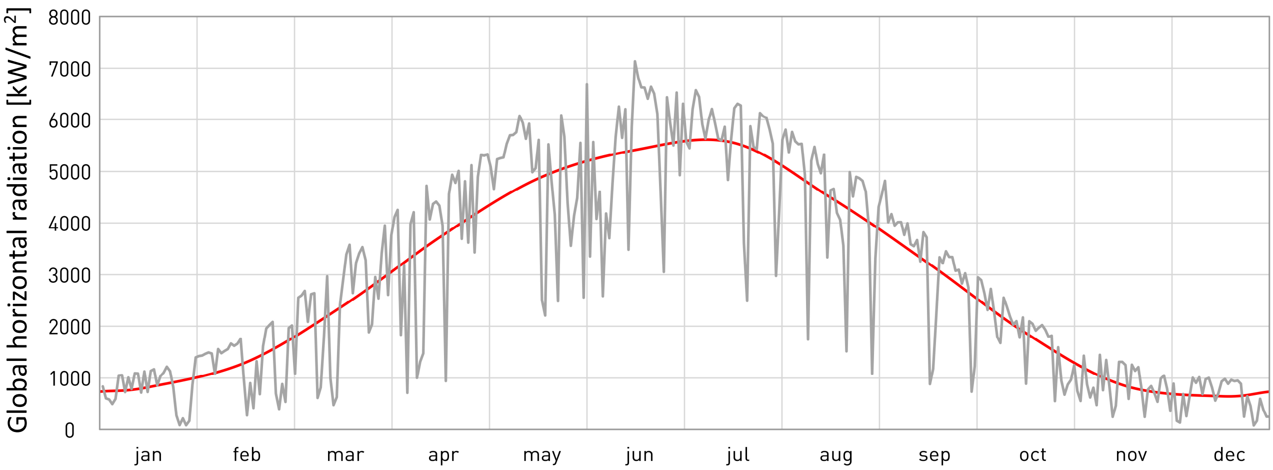


Fig. 31 – Hourly global horizontal radiation

$$\dot{W_{pk}} = \frac{\left[\left(36.04\frac{kWh}{m^2 \cdot year}\right) \cdot\ 6738.81m^2\right] \cdot 1\frac{kW}{m^2}}{1073.74\frac{kWh}{m^2 \cdot year} \cdot 0.8} = 282.73kW$$

$$A_{pv} = \frac{282.73\ kW}{0.18\ \frac{kW}{m^2}} = \mathbf{1570,74m^2}$$

The required area of PV panels is suitable for installation on the roof, thus the 100% of the yearly energy demand can be covered by means of a renewable energy source.

4.6. Project results

In order to evaluate the effectiveness of the proposed project choices, the ActiveHouse Protocol is taken into consideration, which analyzes the various performance outputs of the project. The protocol considers the environmental impact performance of the building; at this stage of the project only the performance part will be considered in order to evaluate the results achieved so far.

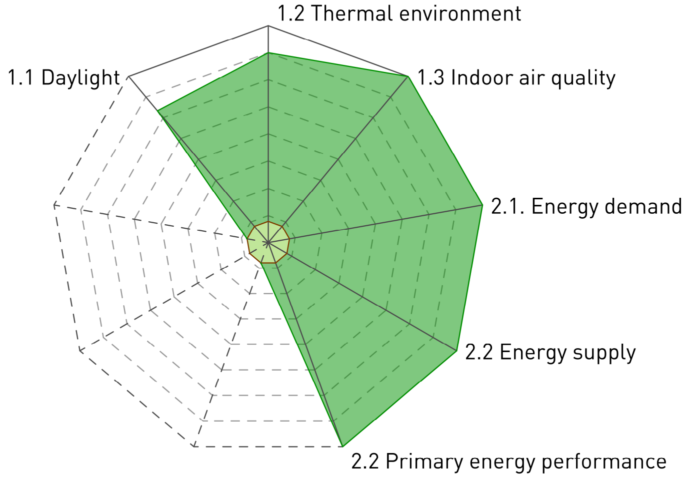


Fig. 32 – Radar from ActiveHouse Protocol

The daylight as well as the thermal environment do not reach the maximum possible values. The intervention on an already built project reduce the possibility to achieve the maximum points related to daylight, partly because of the project structure partly for the positioning of the various buildings in the area. The thermal environment does not reach the maximum levels due to the lower set point of 20°C (in order to reach the maximum level is required 21°C); the set point allows energy savings during the winter season but slightly reduces the comfort level of the users.

The ActiveHouse Protocol results:

Comfort		
Verification	Value	Category
Daylight	4.3%	1.80
Thermal environment	Better level	1.50
Indoor air quality	≤500 ppm	1.00
Energy		
Energy demand	36.00 kWh/m^2	1.00
Energy supply	58.60 kWh/m^2	1.00
Primary energy	0.00 kWh/m^2	1.00

In general, the structure obtains a high score in this section through the use of the proposed strategies.

5. Life cycle assessment

5.1 Building data collection

The development of the BIM project has made it possible to easily obtain the quantitative and technical data of the building divided according to the material used and the elements that compose it. The use of this type of software also made it possible to analyze the effect of each material on the environmental impact.

This module will be developed by dividing the analysis by the materials added and removed following the project. The division based on materials subjected to demolition and construction is visible within the developed BIM models. Project actions on materials are summarized in this table:

Actions on materials in SDP							
Name	**Quantity**	**Unit of measure**	Removed	Builted	Mainained	Expanded	Reduced
Wall - Fir panels/boards	191.33	m3	X	X			
Wall - Sandwich panels	813.51	m2		X			
Wall - PMMA panels	1713.69	m2	X	X			
Wall - PVC panels	1713.69	m2	X	X			
Wall - Waterproof membrane	5963.81	m2		X			
Wall/Slab - Vapour barrier	8474.36	m2		X			
Wall - Gypsium board	8497.52	m2	X		X		X
Wall/Slab - Wood fiber insulation	1186.41	m3		X			
Slab - Fir flooring	104.04	m3		X			
Structure - Structural laminated timber	104.27	m3	X				
Slab - CLT	209.33	m3		X	X	X	
Slab - OSB boards	20.93	m3		X	X	X	
Slab - Cork insulation	104.66	m3		X	X	X	
Slab - EPE insulation	1744.41	m2		X	X	X	
Elements - Steel sheet	21483.00	kg		X			
Elements - Steel profile	44162.33	kg	X	X			
Elements - Alluminum profile	61.074	kg		X			
Elements - Concrete	19.67	m3		X			
Elements - Fir windows [1.20x1.50h m]	455	n.		X			
Elements - Fir doors [0.90x2.10h m]	29	n.		X	X	X	
Elements - PV panels	1571.20	m2		X			
Elements - w.c.	100	n.		X	X	X	
Elements - Sink	87	n.		X	X	X	
Elements - AHU (water-air)	14	n.		X			

Fig. 33 – "Action on materials" table

It is important to note that some materials are subject to both demolition and construction; in these cases, the removed materials are replaced by similar or equal materials, being in a state of degradation that requires replacement. The materials belonging to the "expanded" or "reduced" category are already present in the project and depending on the need they are expanded or partially removed for the SDP.

5.2 LCA Goal and Scope

In order to perform the LCA analysis, it is important to establish some essential parameters. The required parameters will be different depending on the case under consideration, since the project buildings are subject to the analysis of three different solutions:

- Case 1: retrofit of buildings to accommodate new on-site functions
- Case 2: retrofit of buildings and move in a new area
- Case 3: demolition and disposal of clusters

The different parameters are analyzed for each case separately.

Case 1

The aim of the work is to perform the life cycle assessment for existing structures subject to retrofit in order to be used as offices and eventually retails. The building is considered permanent (50 years of service life) and it is located in the Milan Expo area.

The functions considered in the project are offices and retail; the offices represent the main function projected while the retail can be considered in order to satisfy the MIND macro-project. The functions may be subjected to changes according to the provisions of the MIND macro-project.

The functional unit is to guarantee spaces in the office for 9 hours/day, 6 days/week in an environment that guarantees comfort to users; in compliance with National Codes regarding indoor comfort and hygienic conditions, for a service life of 50 years.

Using these definitions is possible to establish that the reference flow will be measured in square meters.

Case 2

The aim of the work is to perform the life cycle assessment for existing structures moved in another area (assumed in a radius of 50 Km) and subject to retrofit in order to be used as offices. The building is considered permanent (50 years of service life).

The functions considered in the project are offices; the use of this function is encouraged, in the case of the project buildings, by the surface made available to the buildings and by the technology used for the construction of the building that lends itself more to work-related rather than residential functions.

The functional unit and the reference flow will be the same as in the previous case.

Case 3

The aim of the work is to perform the life cycle assessment for an existing structure subjected to selective demolition. The project area will be used for the construction of new buildings envisaged in the macro-project MIND.

In this case, no function is considered, since the SDF buildings are destined for demolition. For the same reason, a functional unit cannot be established.

The reference flow will be the same as in the previous cases.

The LCA will be considered all the stages envisaged (cradle to grave); not all the modules are considered since some are negligible or not present in the project.

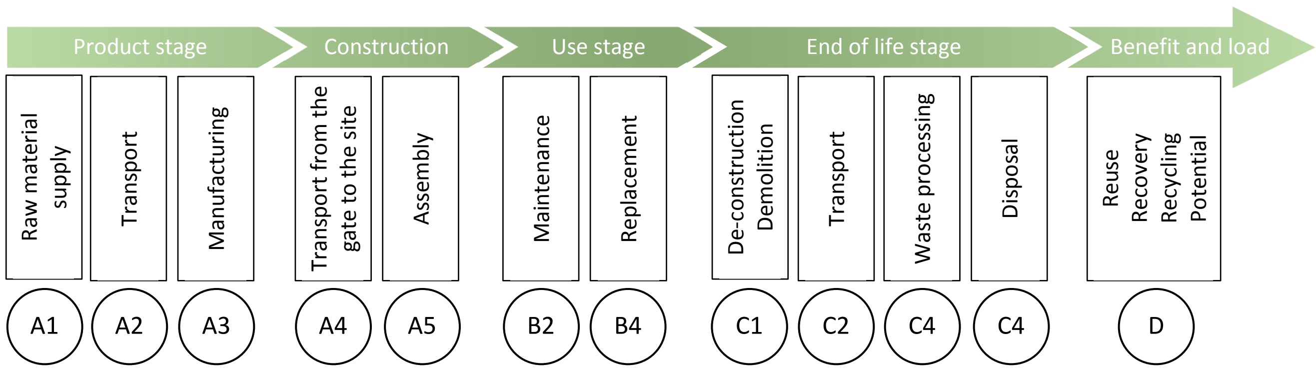


Fig. 34 – "LCA stages and modules considered" illustration

5.3 LCA and EPD data

In order to obtain an LCA analysis, it was necessary to identify each project material through the use of an EPD (Environmental Product Declaration). For some of the materials present in the project it was not possible to find the relative EPD, in this case it was used documentation and values of similar materials depending on the phase considered. The following table shows the resources used by material:

Materials' EPD		
Name	**EPD number**	Description
Wall - Fir panels/boards	EPD-RUB-20180061-IBB2-EN	The EPD is refered to the material used in the project
Wall - Sandwich panels	S-P-01550	The EPD is refered to the material used in the project
Wall - PMMA panels	SCS-EPD-04814	The EPD is refered to the material used in the project
Wall - PVC panels	S-P-00737	The EPD is refered to the material used in the project
Wall - Waterproof membrane	EPD-DUP-20150236-IBE1-EN	The EPD is refered to the material used in the project
Wall/Slab - Vapour barrier	S-P-00762	The EPD is refered to the material used in the project
Wall - Gypsium board	S-P-00796	The EPD is refered to the material used in the project
Wall/Slab - Wood fiber insulation	EPD-GTX-20140222-IBC2-EN	The EPD is refered to the material used in the project
Slab - Fir flooring	EPD-RUB-20180061-IBB2-EN	The EPD is refered to a fir product used in for internal installation
Structure - Structural laminated timber	S-P-01314	The EPD is refered to generic laminated wood product used for structure
Slab - CLT	S-P-01314	The EPD is refered to generic laminated wood product used for structure
Slab - OSB boards	EPD-EGG-20180107-IBD1-EN	The EPD is refered to the material used in the project
Slab - Cork insulation	000464	The EPD is refered to the material used in the project
Slab - EPE insulation	S-P-00840	The EPD is refered to EPS material that have similar manufacture process
Elements - Steel sheet	EPD-ARM-20180069-IBD1-EN	The EPD is refered to the material used in the project
Elements - Steel profile	S-P-00697	The EPD is refered to generic steel profile used in the building sector
Elements - Alluminum profile	S-P-01205	The EPD is refered to the material used in the project
Elements - Concrete	EPD-RMC-20180095-CBG1-EN	The EPD is refered to the material used in the project
Elements - Fir windows [1.20x1.50h m]	NEPD00245E	The EPD is refered to the material used in the project
Elements - Fir doors [0.90x2.10h m]	S-P-01392	The EPD is refered to the material used in the project
Elements - PV panels	TERR-00001-V01.01-FR	The EPD is refered to the material used in the project
Elements - w.c.	GEB_EPD_D71192	The EPD is refered to the material used in the project
Elements - Sink	4788268911.119.1	The EPD is refered to the material used in the project
Elements - AHU (water-air)	UNIC-00020-V01.01-FR	The EPD is refered to generic AHU unit used in the office function

Fig. 35 – "Materials' EPD" table

It is possible to note that some EPDs have been used for more than one material, in these cases the EPDs refer to a generic material that has processes and properties similar to more than one design element.

In order to quantitatively define the materials in each module, a unique table is displayed for all the cases considered; depending on the module and the operations envisaged, only certain sections of the quantitative table are then used for each step. The table used is shown below:

Overall quantity of materials									
Material type	**Removed**			**Added**			**Transported**		
	Surface [m^2]	Volume [m^3]	Mass [kg]	Surface [m^2]	Volume [m^3]	Mass [kg]	Surface [m^2]	Volume [m^3]	Mass [kg]
Fir boards	17320.64	249.42	112240.73	14880.11	191.33	86097.23	-	114.66	51598.52
Fir flooring	-	-	-	52020.00	104.04	46818.00	2213.07	44.26	19917.66
Wood panels - PMMA	1713.69	20.56	24471.42	1713.69	20.56	24471.42	-	-	-
Wood panels - PVC	1713.69	20.56	28378.62	1713.69	20.56	28378.62	-	-	-
CLT	-	-	-	1744.41	209.33	104664.60	1791.12	214.93	107467.20
Structural timber	-	104.27	46920.24	-	-	-	-	594.61	267574.06
OSB boards	-	-	-	1744.41	20.93	13815.73	15604.12	214.39	141496.88
Wood fiber inulation	-	-	-	8474.36	1186.41	59320.54	-	-	-
Cork insulation	-	-	-	1744.41	104.66	25119.50	1791.12	107.47	25792.13
EPE insulation	-	-	-	1744.41	17.44	2093.29	1791.12	17.91	2149.34
XPS insulation	-	-	-	-	-	-	9635.46	386.09	9652.29
Gypsium panel	8497.52	108.51	73786.96	-	-	-	5866.27	70.40	47868.78
Waterproof membrane	-	-	-	5963.81	23.86	23855.26	4150.90	16.60	16603.60
Vapour barrier	-	-	-	8474.36	5.96	3876.48	4335.38	4.34	2818.00
Sandwich panel	-	-	-	813.51	48.81	4881.05	-	-	-
Concrete	-	-	-	-	19.67	41307.00	15312.61	1480.94	2635510.47
Epoxy resin	-	-	-	-	-	-	2510.55	12.55	7042.09
Steel sheet	-	-	-	-	2.79	21483.00	421.95	2.11	16245.21
Steel profile	-	2.33	17945.92	-	5.74	44162.33	-	15.94	122708.21
Alluminum sheet	-	-	-	-	0.02	61.07	-	-	-

Element type	Removed			Added			Transported		
	N. elements	Lenght [m]	Height [m]	N. elements	Lenght [m]	Height [m]	N. elements	Lenght [m]	Height [m]
Door	27	0.90	2.10	-	-	-	217	0.90	2.10
Door	2	1.20	2.10	-	-	-	13	1.20	2.10
Door	-	-	-	-	-	-	6	1.50	2.10
Door	-	-	-	-	-	-	10	1.60	2.10
Door	-	-	-	-	-	-	32	1.80	2.10
Skylight	-	-	-	-	-	-	141	1.20	1.20
Window	-	-	-	455	1.20	1.50	-	-	-
PV panel	-	-	-	982	1.00	1.60	-	-	-
W.c.	-	-	-	100	-	-	12	-	-
Sink	-	-	-	87	-	-	25	-	-

Legend - Added material due to transport

Fig. 36 – Quantitative table

5.4 *Case 1 - LCA phases*

In this chapter the different phases useful for the calculation of the life cycle assessment of the Case 1 are analyzed; in some cases, the values for the phase were taken from the EPD, while in others, calculated using the project data. In Case 1, the intervention foresees the retrofitting of the building, for this reason the sections used in the quantitative table are: "Removed" and "Added".

5.4.1 A1-A2-A3 (EPD)

“Raw material supply” (A1), “transport to the production site” (A2) and “manufacturing” (A3) are the modules that compose the “product stage”. The whole analysis will consider these three parts linked since the union of the three guarantees the availability of the final product on the production site. All the data used for this section have been taken from EPD.

5.4.2 A4 (Calculated)

The transport (A4) module is part of the “construction process stage”, it considers the transport from the production site to the project site that is influenced by the type of transport used. This module is, within the analysis, considered separately from the entire stage since in the case of a project it is important to determine the influence that this action has on the global impact.

The transport type is established considering the overall volume or weight, the type of transport is established for each material. Once the type of transport chosen has been identified, it is possible to calculate the number of trips to be made to complete the supply of a material. The possibilities considered for transportation are:

- Heavy duty track (45ton): with a maximum volume of 130m^3
- Heavy duty truck (12 ton): with a maximum volume of 35m^3
- Light vehicles (2.5 ton): with a maximum volume of 20m^3

Transport evaluation						
Product	Manufacturer	Production site	Distance from site [km]	Transport type	overall quantity	n. of trips
Wall - Fir panels/boards	Rubner Holzbau	Bressanone (BZ)	348.00	Heavy duty truck (45ton)	191.33 m^3	2
Wall - Sandwich panels	Isopan	Verona (VR)	160.00	Light vehicles (2.5ton)	17.44 m^3	1
Wall - PMMA panels	I.L.M.A. plastica	Gavirate (VA)	65.00	Heavy duty truck (12ton)	20.56 m^3	1
Wall - PVC panels	I.L.M.A. plastica	Gavirate (VA)	65.00	-	20.56 m^3	-

Fig. 37 – “Transport evaluation” table; LCA-A4 (shred)

Following the evaluation of the types of transport and the number of trips, it is necessary to calculate the different emissions generated. In order to calculate the latter, the different emissions per kilometer for each type of transport considered, the emissions will be grouped by material allowing the assessment of the impact of each move. The kilometers obtained from the previous table are multiplied for all the type of emission considered, the result express the grams of the different emission for each material.

Emission by transport type								
vehicle type	*CO_2 (g/km)*	*SO_2 (g/km)*	*CH_4 (g/km)*	*NH_3 (g/km)*	*NO_2 (g/km)*	*N_2O (g/km)*	*CO (g/km)*	*NO_x (g/km)*
Heavy duty trucks 45 ton/130m^3 [diesel euro 5]	878.98	0.00405	0.004725	0.0110	0.2940	0.05836	1.527200	2.94060
Heavy duty trucks 12 ton/35m^3 [diesel euro 5]	321.38	0.00148	0.001587	0.0110	0.1102	0.01804	0.496200	1.10265
Light vehicles 2.5 ton/20m^3 [diesel euro 5]	240.96	0.00111	0.000002	0.0019	0.5601	0.00694	0.000309	1.40030

Fig. 38 – "Emission by transport" table; LCA-A4 (shred)

The last procedure in this section requires an impact assessment considering the classes provided by the life cycle assessment; the emissions are transformed into equivalent emissions by using the factors present in BS EN 15804: 2012 - Annex C "Characterization factors for GWP, OPD, AP, EP, POCP, ADP":

Equivalent emission by transport type					
vehicle type	$kgCO_{2eq}$/km	kgR_{11eq}/km	$kgSO_{2eq}$/km	$kgPO_{4eq}$/km	kgC_2H_{4eq}/km
Heavy duty trucks 45 ton/130m^3 [diesel euro 5]	8.97E-01	0.00E+00	1.64E-03	4.40E-04	1.32E-04
Heavy duty trucks 12 ton/35m^3 [diesel euro 5]	3.27E-01	0.00E+00	6.26E-04	1.66E-04	4.74E-05
Light vehicles 2.5 ton/20m^3 [diesel euro 5]	2.43E-01	0.00E+00	9.85E-04	2.57E-04	5.50E-05

Fig. 39 – "Equivalent emission by transport" table; LCA-A4

The equivalent emissions are calculated and then divided by material in order to obtain a unit value.

In order to calculate the primary energy, it is necessary to establish the consumption of fuel; to calculate it the grams of CO_2 emissions were divided by the diesel emission of CO_2 per kilometer. The consumption of fuel per kilometer is then multiplied by the non-renewable energy per kilometer value in order to obtain the non-renewable primary energy. Building transport in Italy takes place mainly by truck (wheeled transport), for this reason primary renewable energy is not considered.

Diesel		
Properties	0.83	kg/l
	2640.00	gCO2/liter
	40.90	MJ/kg
	49.16	MJ/l
Heavy duty trucks (45 ton)	0.333	l/km
Heavy duty trucks (12 ton)	0.122	l/km
Light vehicles (2.5 ton)	0.091	l/km
Heavy duty trucks (45 ton)	**16.37**	**MJ/km**
Heavy duty trucks (12 ton)	**5.98**	**MJ/km**
Light vehicles (2.5 ton)	**4.49**	**MJ/km**

Fig. 40 – "Diesel properties" table; LCA-A4 (shred)

5.4.3 A5 (Calculated)

The module A5 considers the "assembly" of the product on site, it is part of the "construction process stage". In the project, the technologies used and the position of the project, allow the construction of the elements through the use of electrical equipment only. In order to obtain the impact of each material related to the assembly, the hours of use of each electric machinery is initially calculated using the aid of the Trento price-list (provided by the municipality) which allows the calculation of the labor time for each material and consequently the time of use of the electric machinery:

Required time for electric machinery										
Name	electric crane		electric device		electric crane			electric device		
	set up	set down	get on	get off	quantity [$m/m^2/m^3/n$]	n. lifting	required time [h]	quantity [$m/m^2/m^3/n$]	specific time [h/quantity]	required time [h]
Wall - Fir panels/boards	X	X	X	X	191.33 m^3	21	1.42	14880.11 m^2	0.10	1488.01
Wall - Sandwich panels		X		X	48.81 m^3	5	0.36	813.51 m^2	0.10	81.35
Wall - PMMA panels	X	X	X	X	20.56 m^3	2	0.15	1713.69 m^2	0.07	114.25
Wall - PVC panels	X	X	X	X	20.56 m^3	2	0.15	1713.69 m^2	0.07	114.25

Fig. 41 – "Required time for electric machinery" table; LCA-A5 (shred)

After calculating the hours in which electric machinery is used, it is necessary to establish the average power for each category in order to calculate the electrical consumption. In the analysis the value chosen for the average device power are the medium between the common machinery used in a building site. The different consumptions are divided considering materials:

Electric consumption for assembly				
Name	electric crane		electric device	
	Average crane power [W]	Crane electric consumption [kWh]	Average device power [W]	device electric consumption [kWh]
Wall - Fir panels/boards	20000	28.486	575	855.607
Wall - Sandwich panels	20000	7.267	575	46.777
Wall - PMMA panels	20000	3.062	575	65.691
Wall - PVC panels	20000	3.062	575	65.691

Fig. 42 – "Electric consumption for assembly" table; LCA-A5 (shred)

The total electric consumption obtained is used to calculate the equivalent emissions considered in the LCA. The values related to primary energy are obtained through the conversion coefficients presented below:

Equivalent emission conversion coefficients for electricity							
Electricty	GWP [kg CO2eq]	ODP [kg CFC11eq]	AP [kg SO2eq]	EP [kg (PO4)3eq]	POCP [kg C2H4eq]	PE (non Re) [MJ]	PE (Re) [MJ]
1kW	0.41577	5.35343E-08	0.00186	0.00052	0.000081971	1kWx1.95x3.6	1kWx0.47x3.6

Fig. 43 – "Equivalent emission conversion coefficients for electricity" table;

Within this phase, all the materials added in the design phase are considered, as well as the values relating to the disassembly of the materials for replacement or assembly needs.

5.4.4 B2-B4 (EPD + Calculated)

"Maintenance" (B2) and "replacement" (B4) are part of the "use stage". The values related to the maintenance operation derive only from the EPD, while for the replacement the values are calculated. Considering maintenance only two materials/elements are considered over the life of the building (50 years service life), the windows and the PV system. The replacement, on the other hand, will be carried out for the elements made up of fir boards and panels as already envisaged in the actual design phase; despite the fact that the wooden elements are replaced with products treated in order to withstand weather conditions, they will develop deterioration states similar to those observed in the SDF and will therefore require replacement. The formula used for the calculation of replacement values are:

$$B4\ (GWP) = [A1 - A2 - A3(GWP) + A4(GWP) + A5(GWP) + C1 - C2 - C3 - C4(GWP) + D(GWP)] \cdot n.times$$

The "n.times" value consider the number of times the replacement operation is required. The use stage (B) doesn't consider the operational energy used (B6) of the buildings since the building are electrically independent, as previously analyzed in chapter "4.5 Solar panel".

5.4.5 C1-C2-C3-C4 (EPD+Calculated)

"De-construction/demolition" (C1), "transport" (C2), "waste processing" (C3) and "disposal" (C4) modules are part of the "end of life stage". The C1 and C2 values are obtained using the same methodology already used in the construction process stage, while the C3 and C4 values are taken from the EPD.

The values calculated in the first two phases consider different volumes than those considered in phase A4, the specific time values are different only for some materials, since generally dry material require deconstruction times similar to those previously considered. Module C1 considers the activity necessary for the deconstruction of the elements at the end of the project's life, the disassembly activities at the start of the construction site necessary for the replacement of materials or the assembly of additional elements are contained in module A5. Module C2 instead considers all the products that are part of the project regardless of the timing in which they are dismantled.

The transport phase is in some cases the same as that proposed in form A4, the equality is present if the material manufacturer is also involved in the recycling of the material, usually for the production of the same product or products belonging to the same production chain. If the materials are not recycled by the manufacturer, they must be taken to another center for recycling, waste-to-energy or disposal process; there are no recycled materials in the project other than the one that return to the center they belong to. For waste-to-energy or disposal, the centers closest to the whole project area were chosen and the transport operation was analyzed to deliver the materials to these sites.

C2 - Transport evaluation considering end of life				
Name	End of life operation	End of life action	Waste dump or waste to energy	
			name of the center	km
Wall - Fir panels/boards	recycling	returned	-	-
Wall - Sandwich panels	recycling	returned	-	-
Wall - PMMA panels	disposal	waste to energy	AMSA - Termovalorizzatore Silla 2	5
Wall - PVC panels	disposal	waste to energy	AMSA - Termovalorizzatore Silla 2	5
Wall - Gypsium board	disposal	waste dump	Ecometal	3

Fig. 44 – "Transport evaluation considering end of life" table; LCA-C2 (shred)

Waste processing (C3) and disposal (C4) values are taken from the EPD. The final values reported for the entire end of life stage are the sum of the values obtained from the operations; the values as in the other cases are assigned to each project material.

5.4.6 D (EPD)

The last section considers benefits and loads beyond the system boundaries; the possibility of reuse or recycling are counted within the LCA. The values assigned to the materials in this phase derive from the EPD. The project mainly presents recyclable materials, the table relating to recycling or reuse operations on materials is shown below:

EPD actions and related centers			
Name	Recycling	Waste dump	return centre
Wall - Fir panels/boards	recycling	returned	Bressanone (BZ)
Wall - Sandwich panels	recycling	returned	Verona (VR)
Wall - PMMA panels	disposal	waste to energy	Milano (MI)
Wall - PVC panels	disposal	waste to energy	Milano (MI)
Wall - Waterproof membrane	disposal	waste to energy	Milano (MI)
Wall/Slab - Vapour barrier	disposal	waste to energy	Milano (MI)
Wall - Gypsium board	disposal	waste dump	Milano (MI)
Wall/Slab - Wood fiber insulation	recycling	returned	Bressanone (BZ)
Slab - Fir flooring	recycling	returned	Racconigi (CN)
Structure - Structural laminated timber	recycling	returned	Bressanone (BZ)

Structure - Structural laminated timber	recycling	returned	Bressanone (BZ)
Slab - CLT	recycling	returned	Bressanone (BZ)
Slab - OSB boards	recycling	returned	Bressanone (BZ)
Slab - Cork insulation	reuse	returned	Bressanone (BZ)
Slab - EPE insulation	reuse	returned	Bressanone (BZ)
Elements - Steel sheet	recycling	returned	Legnano (MI)
Elements - Steel profile	recycling	returned	Racconigi (CN)
Elements - Alluminum profile	recycling	returned	Legnano (MI)
Elements - Concrete	disposal	waste dump	Milano (MI)
Elements - Fir windows [1.20x1.50h m]	recycling	returned	Lannach (Austria)
Elements - Fir doors [0.90x2.10h m]	recycling	returned	Lannach (Austria)
Elements - PV panels	-	-	-
Elements - w.c.	disposal	waste dump	Milano (MI)
Elements - Sink	disposal	waste dump	Milano (MI)
Elements - AHU (water-air)	recycling	returned	Ariccia (RM)

Fig. 45 – "EPD actions and related centers" table; LCA-D (shred)

5.5 Case 2 - LCA phases

Considering Case 2, the values calculated for Case 1 can be used, in part, to calculate the retrofit present also in this case. The move considered for the project material have a small radius in order to partially reduce the environmental impact of the move and consider an easily implementable scenario; in addition, the actual project area is near Milan which presents settlement opportunities for this type of project. In order to complete the life cycle assessment for this option, it is necessary to consider the additional move of all the materials kept in the SDP. The sections considered in the quantitative table are "Removed", "Added" and Transported".

The move of the structure to another place causes the need to produce additional materials to those considered in Case 1, not all the materials that are removed can in fact be reused in the next building site. In the case of cement, for example, due to the move operation, the material present in the SDF must be disposed and another quantity of product for SDP must be produced. The additional materials, highlighted in the quantitative table, are:

- Concrete
  Material already present in the "Added" of Case 1, is used for external stairs and for the floor of metal structures. The part used for the floors is added at this stage, in the "Transported" section (but counted as "Added")

- Waterproof membrane
  Material already present in the "Added" of Case 1, is used for the walls, the roof and part of the floors. The part used for the roof and floors is added at this stage, in the "Transported" section (but counted as "Added")

- Epoxy resin
  Material not present in Case 1, is used for floors (internal flooring). The material is present only in the "Transported" section (but counted as "Added")

The "product stage", as well as module A4, is calculated using the same methodology used for Case 1. The module considers, differently from the previous one, the materials to be added or removed from the project and the materials transported from the current project area.

The "assembly" (A5) module, in the calculation phase, is more complex having to consider the operations of two different construction sites. For this reason, the calculation phases have been further divided considering both the type of machinery and the construction or deconstruction operation of the product.

The "end of life stage" is calculated with the same methodology used previously.

5.6 Case 3 - LCA phases

Unlike the previous solutions, Case 3 provides for the dismantling of the entire project now present in order to allow the construction of new buildings envisaged by the MIND macro-project. The analysis only considers "end of life stage" and "benefit and loads beyond the system boundaries". The results will therefore allow to consider only one of the phases necessary for the new use of the area.

The steps are performed in the manner already explained above.

5.7 Results

Following the analysis, the results obtained are presented in this chapter; the results are divided by module with the aim of observing each phase. Case 3 foresees only the demolition of the current project, for this reason it will be present only from the end of life phase.

5.7.1 A1-A2-A3 - Product stage

This chapter lists the values related to the product stage.

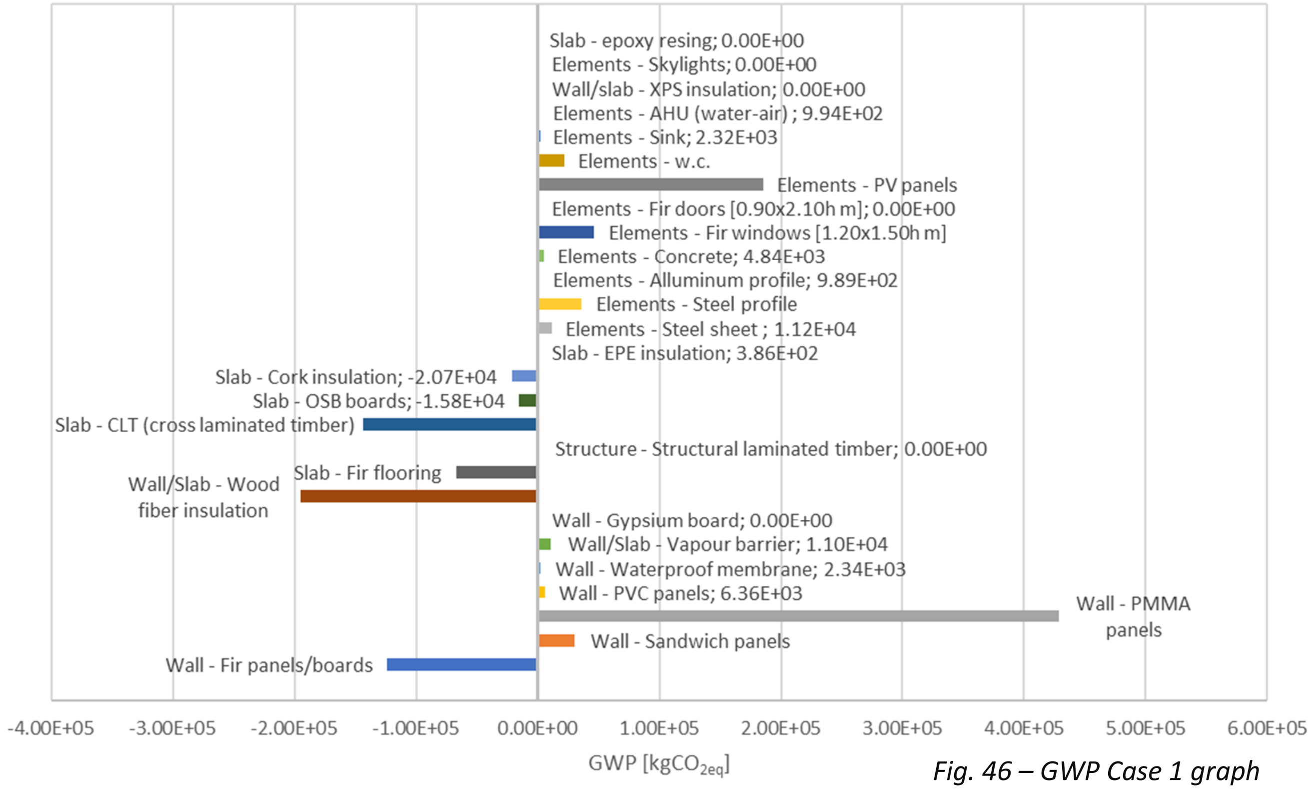


Fig. 46 – GWP Case 1 graph

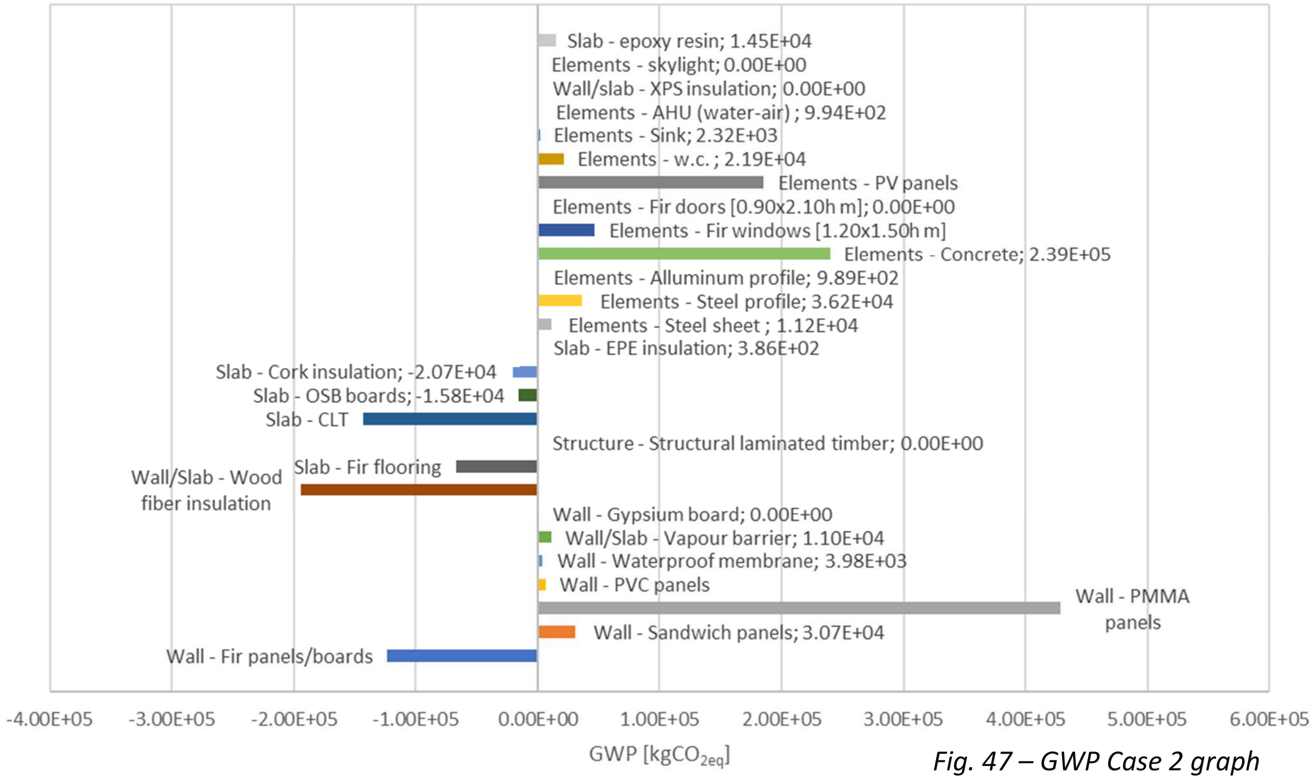


Fig. 47 – GWP Case 2 graph

In the graph it is possible to see that the materials with the greatest impact are photovoltaic panels and PMMA panels. Photovoltaic panels, despite the high value in this phase, permit to have an electric autonomous building and therefore to set to zero the "operational use of energy" phase; PMMA panels have been chosen for aesthetic needs in order to preserve the current appearance of the building. The two diagrams are for the most part very similar but differ in the value of the concrete and in the impact of epoxy resin in Case 2. Concrete has a much higher value in the second case, in fact it is necessary to use a greater quantity of material due to the move operation. Epoxy resin is present only in Case 2, since in the case 1 is possible to use the already present material in the SDF.

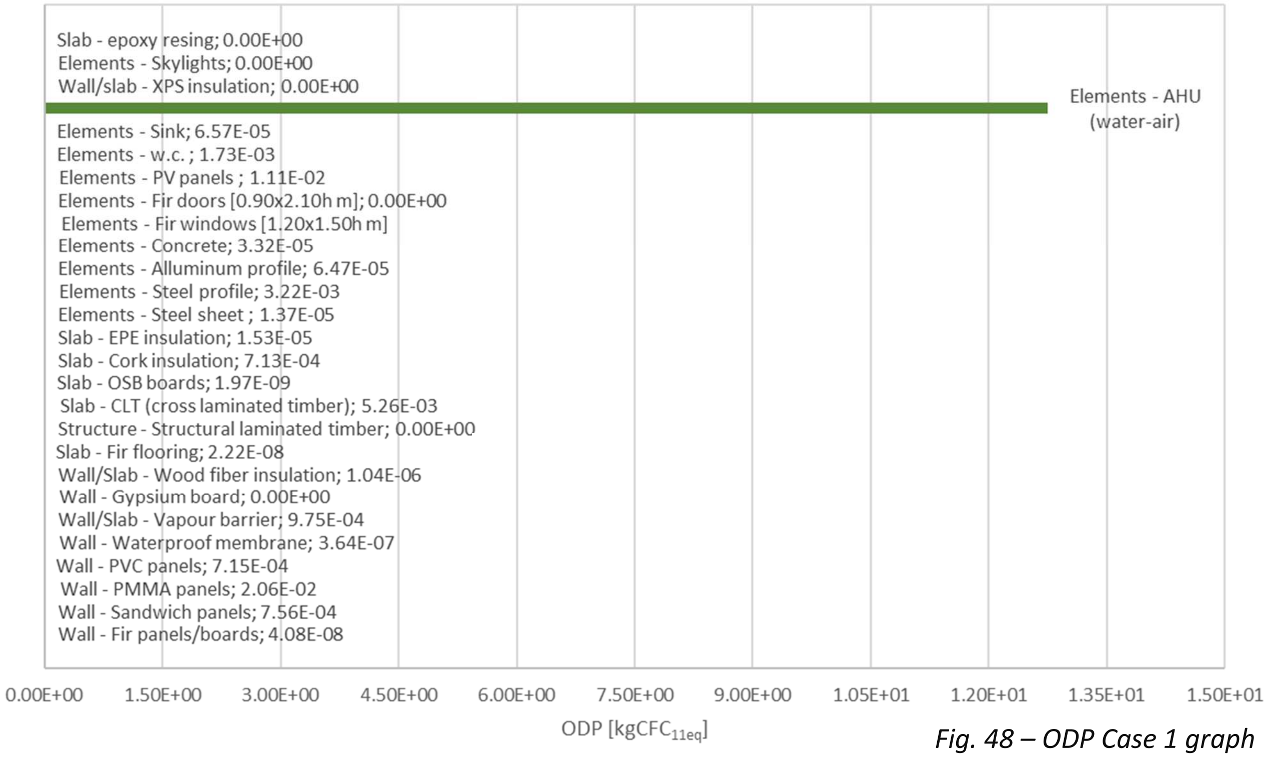


Fig. 48 – ODP Case 1 graph

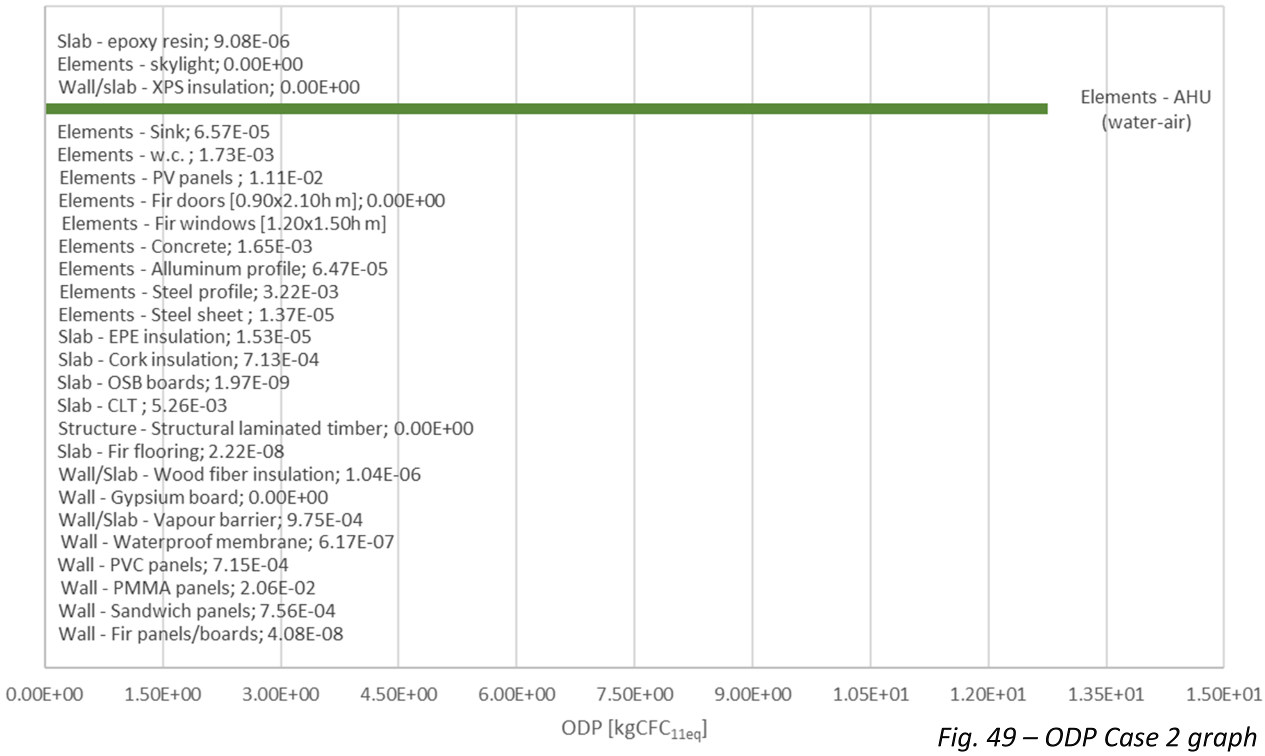


Fig. 49 – ODP Case 2 graph

Considering the impacts present in the ODP graphs, it is possible to see, as in the previous case the value, the difference given by the value of the epoxy resin. In this case, however, the values of the various materials lose importance since a higher value of different measurement orders is present. The AHU (air handling unit) constitutes the prevalence of the overall value of ODP and is present in both cases characterizing the results.

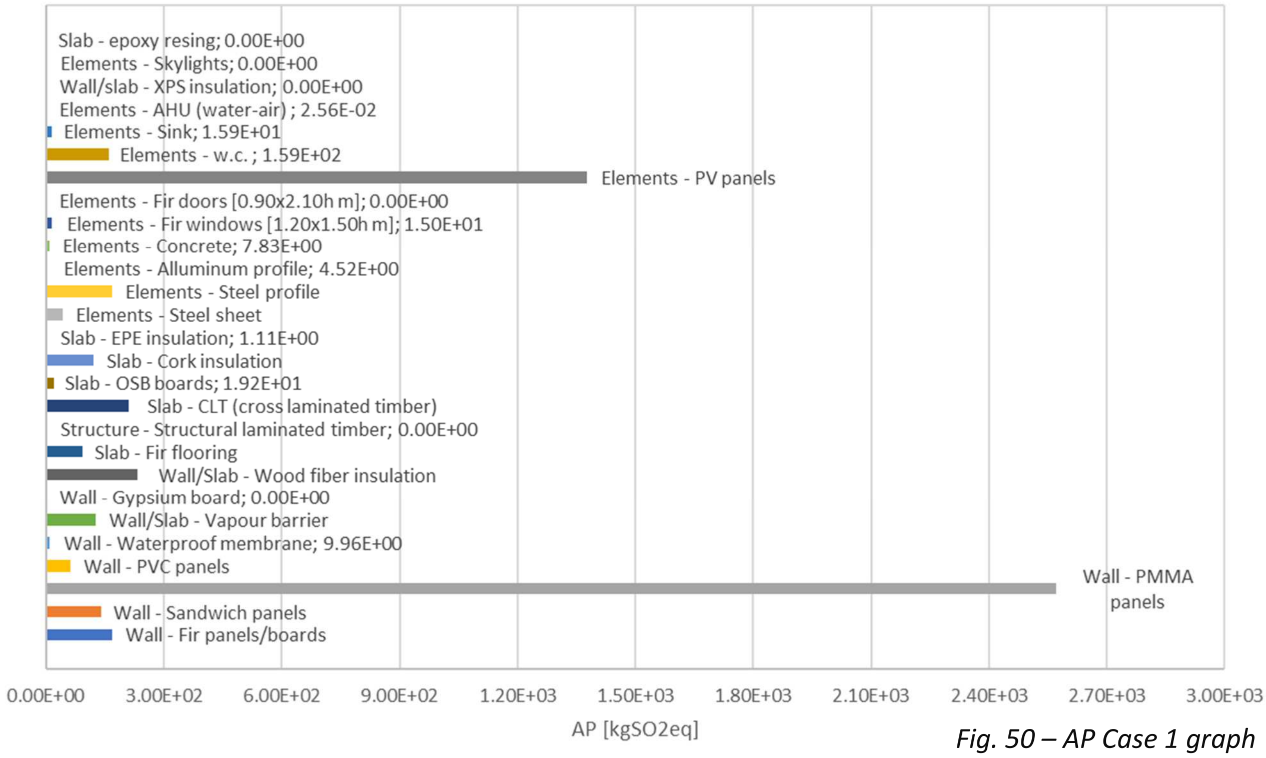


Fig. 50 – AP Case 1 graph

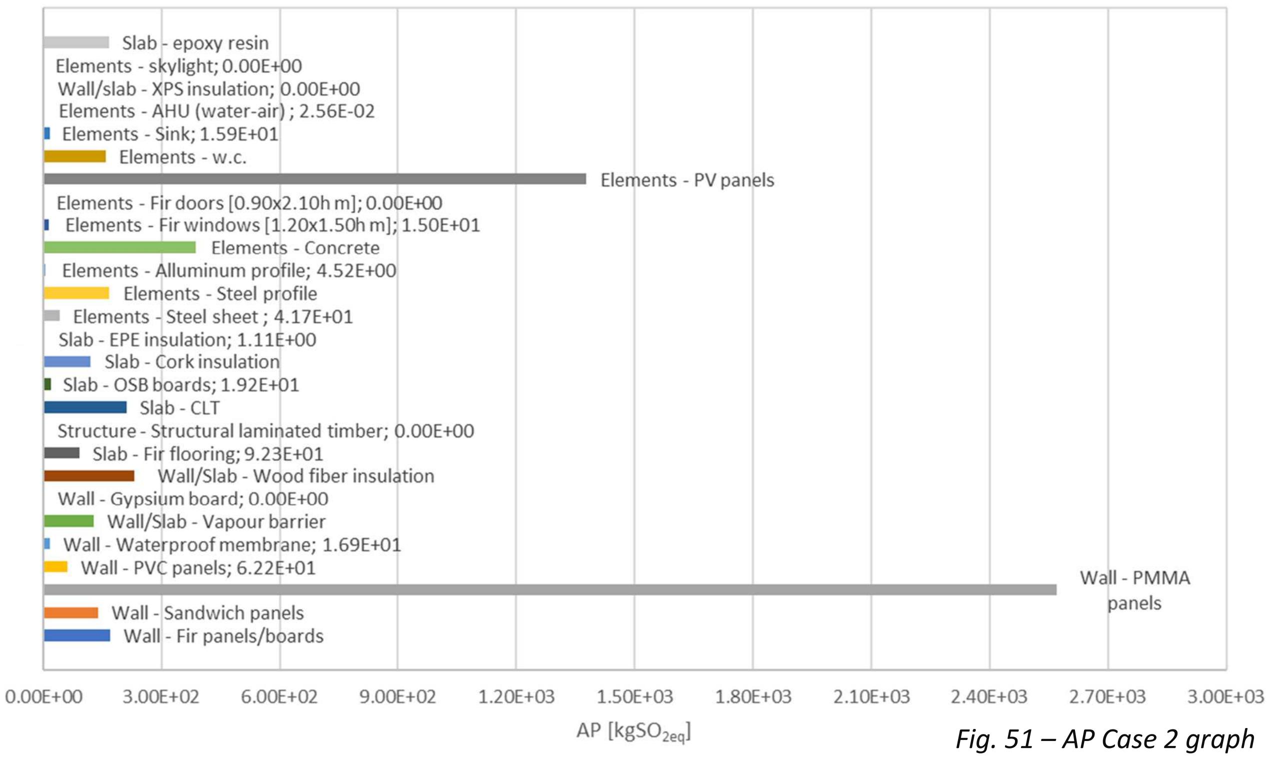


Fig. 51 – AP Case 2 graph

In the graph relating to acidification potential, it is possible to find similar behavior for the two cases. The difference values continue to be that of concrete and epoxy resin. The values relating to the PV system and PMMA panels are the maximum values within the graph. Most of the values are comparable in terms of order of magnitude.

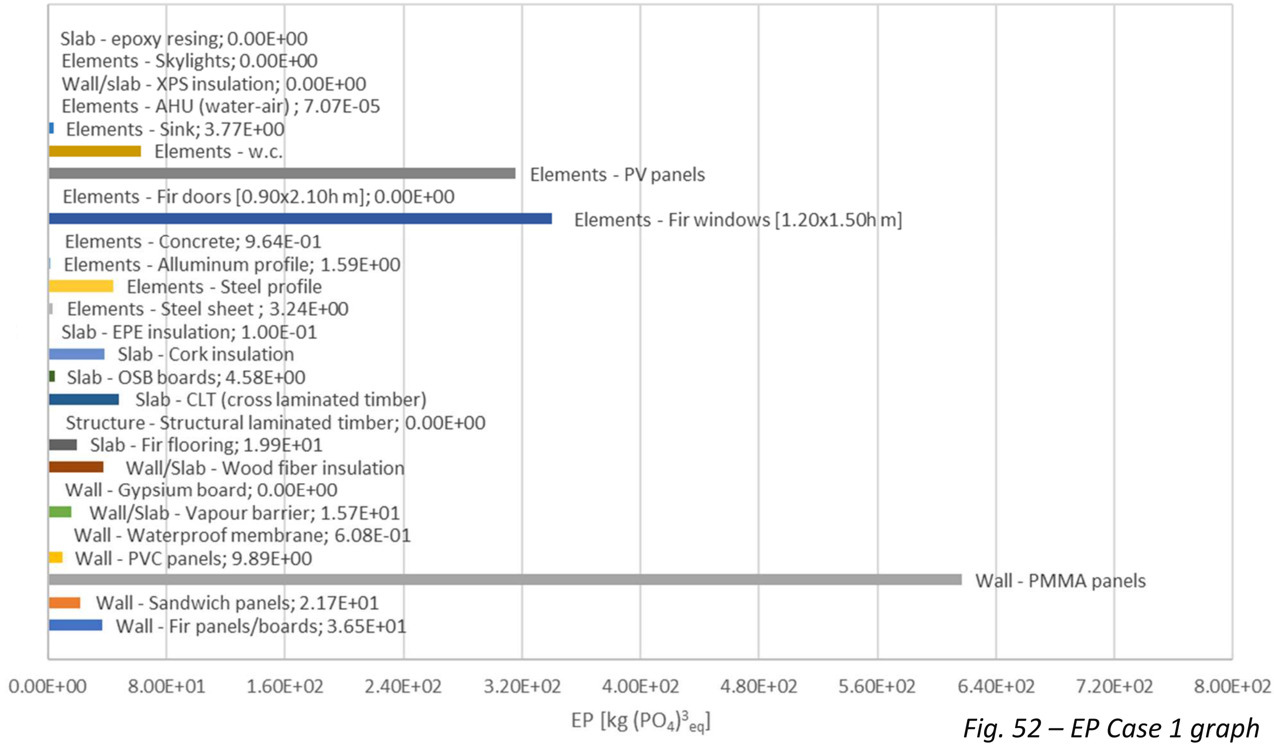


Fig. 52 – EP Case 1 graph

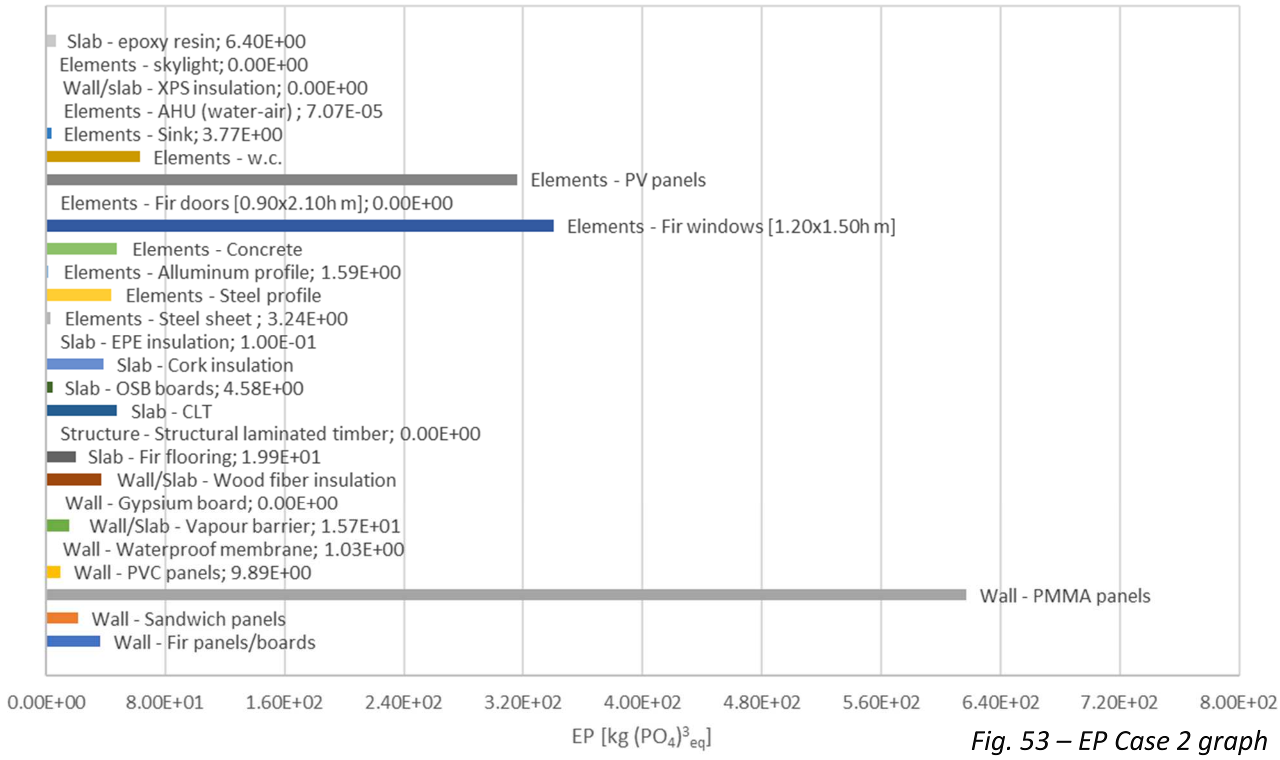


Fig. 53 – EP Case 2 graph

Considering the eutrophication potential graph, it is possible to affirm that the behavior in the two cases remains almost unchanged with the exception of the materials already considered previously. The windows are in this case one of the maximum impact values. The values for the most part have the same order of magnitude.

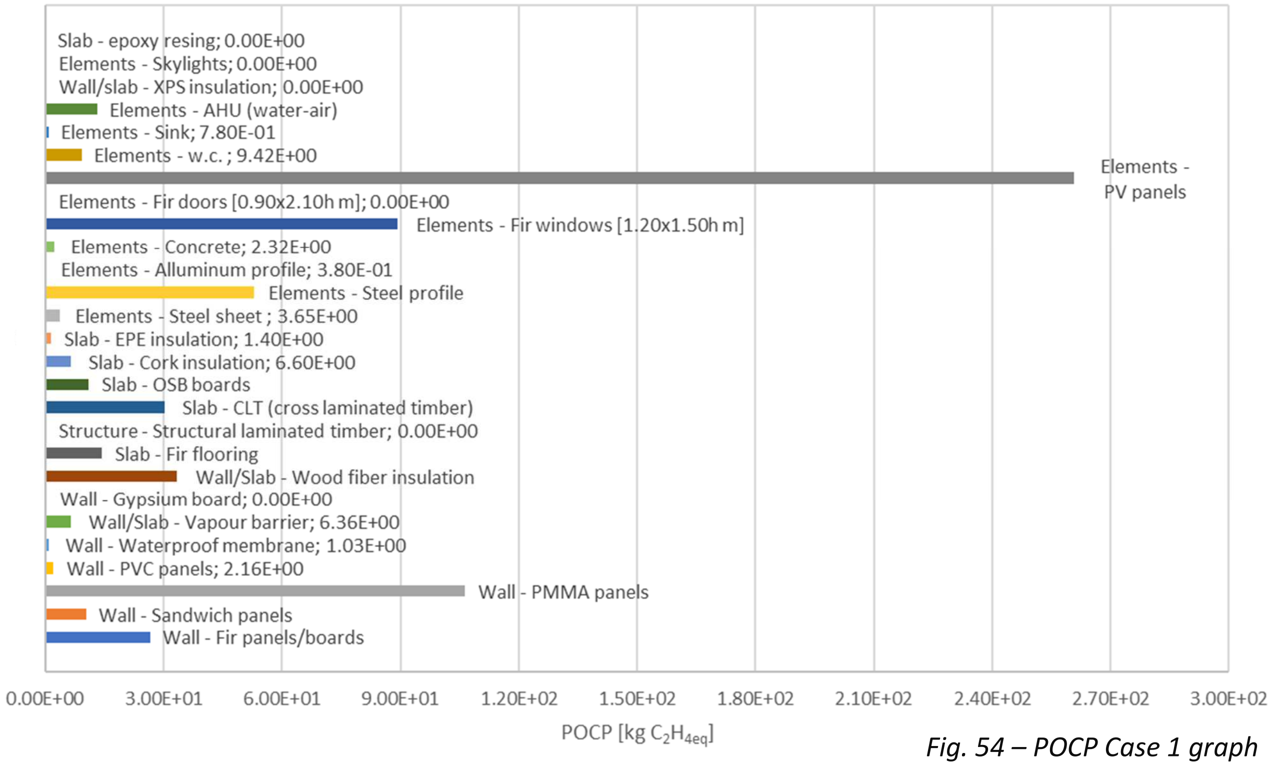


Fig. 54 – POCP Case 1 graph

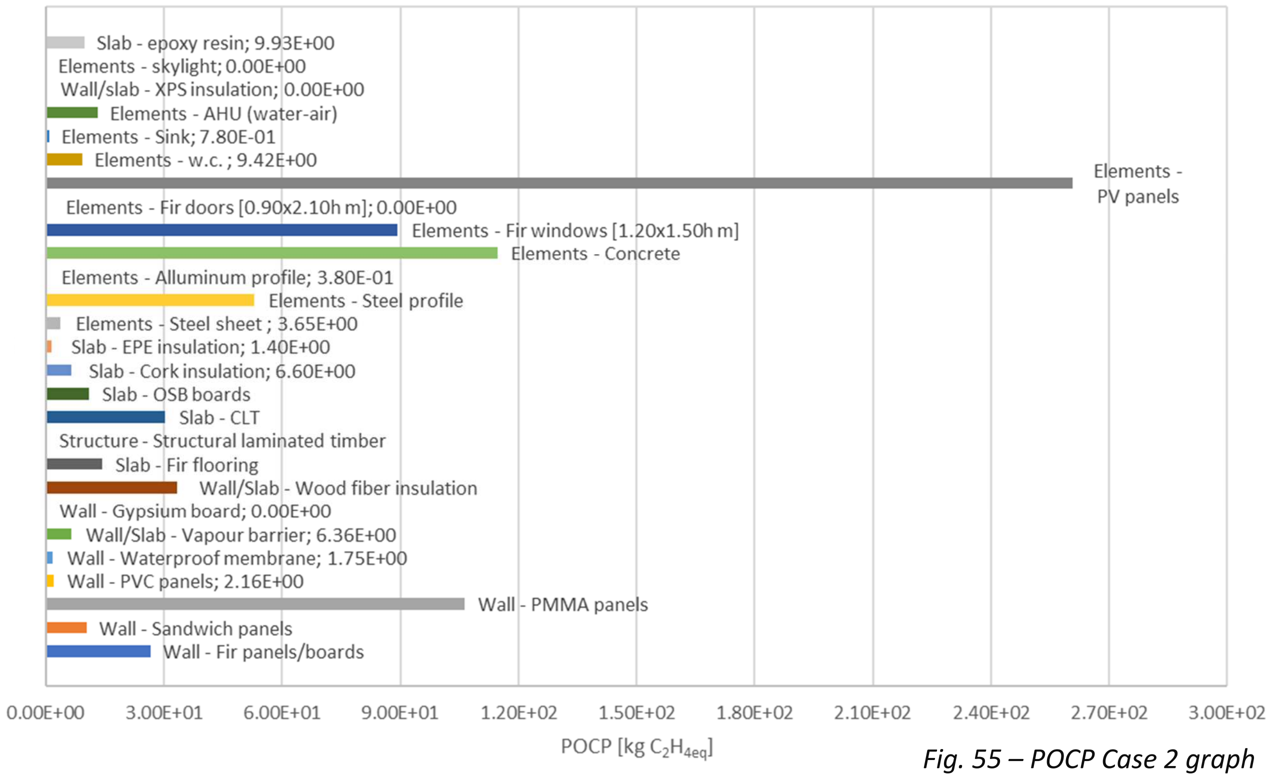


Fig. 55 – POCP Case 2 graph

Considering the photochemical ozone creation potentials, it is possible to notice how the PV panels constitute the maximum value within the graph. Windows as well as cement and PMMA panels together with solar panels constitute the maximum impact values for this category. The values for this category tend to be uniform except for the maximum values.

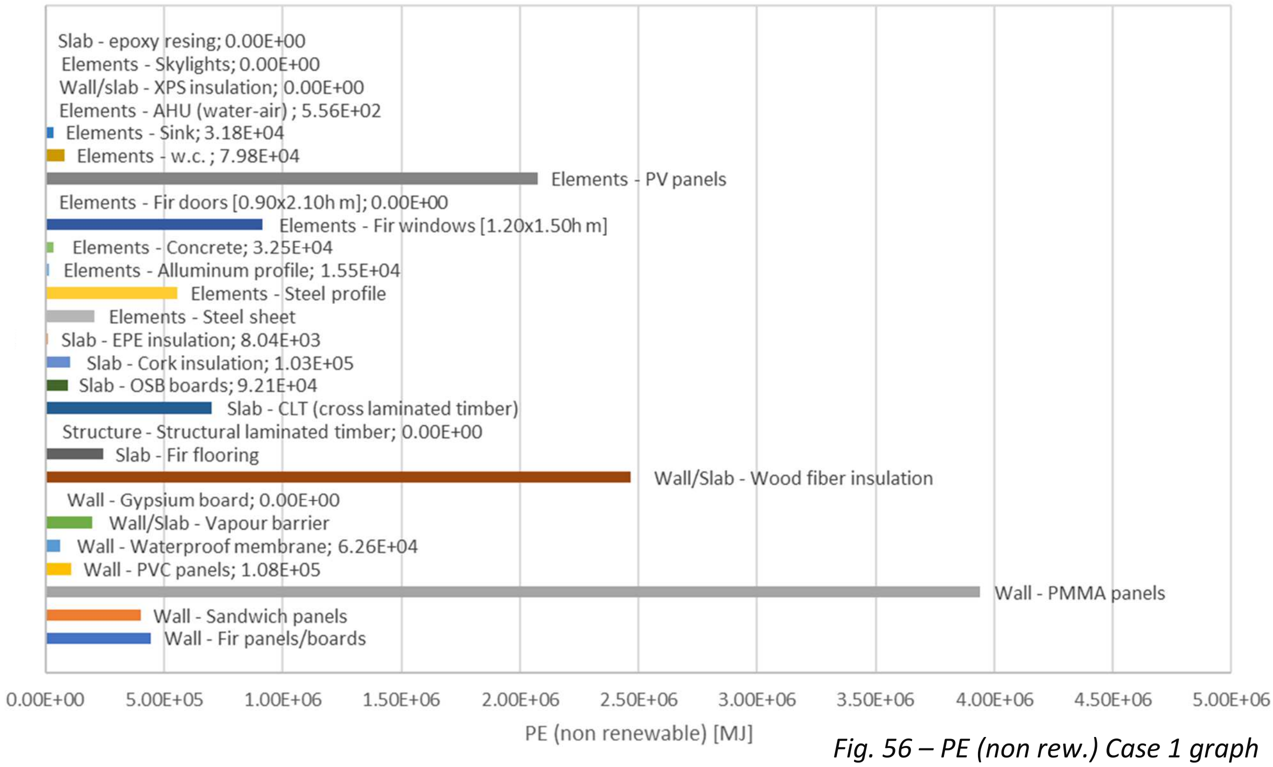


Fig. 56 – PE (non rew.) Case 1 graph

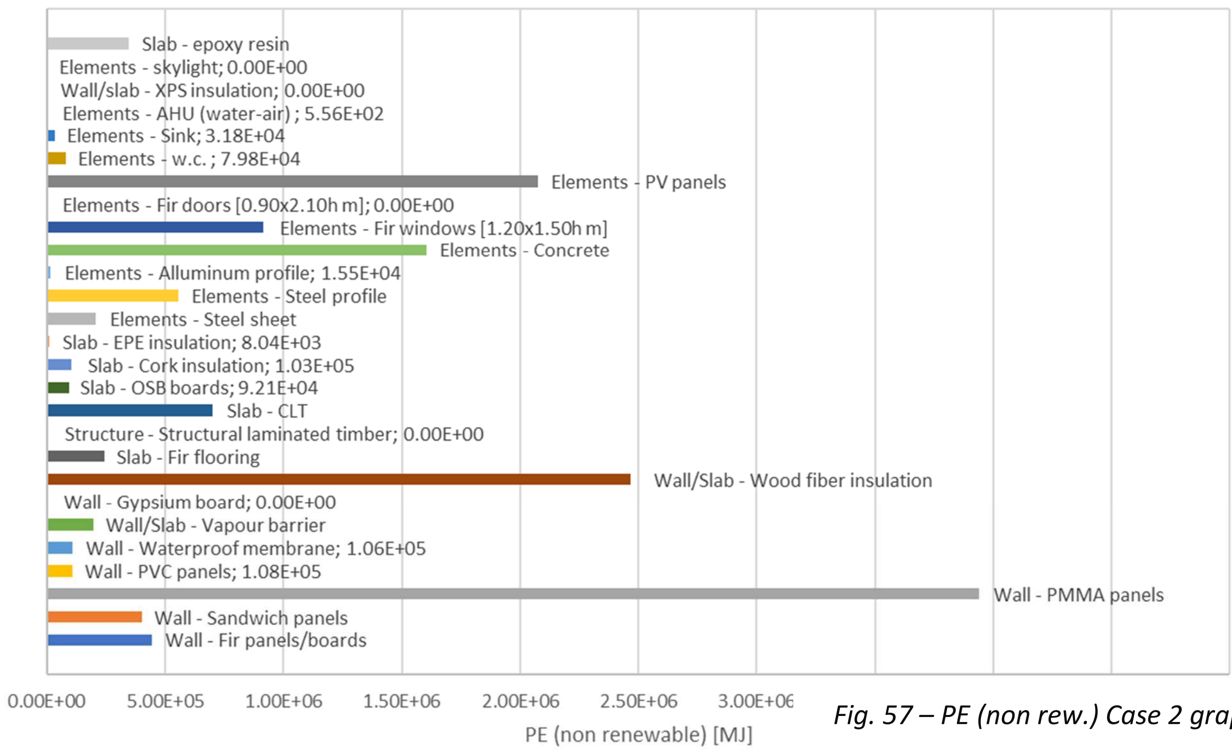


Fig. 57 – PE (non rew.) Case 2 graph

The non-renewable primary energy used in the project for the production of material maintain the same behavior, considering the graph, of the cases already described above. The renewable primary energy finds the highest values with wood products as in the case of structural wood and external cladding panels.

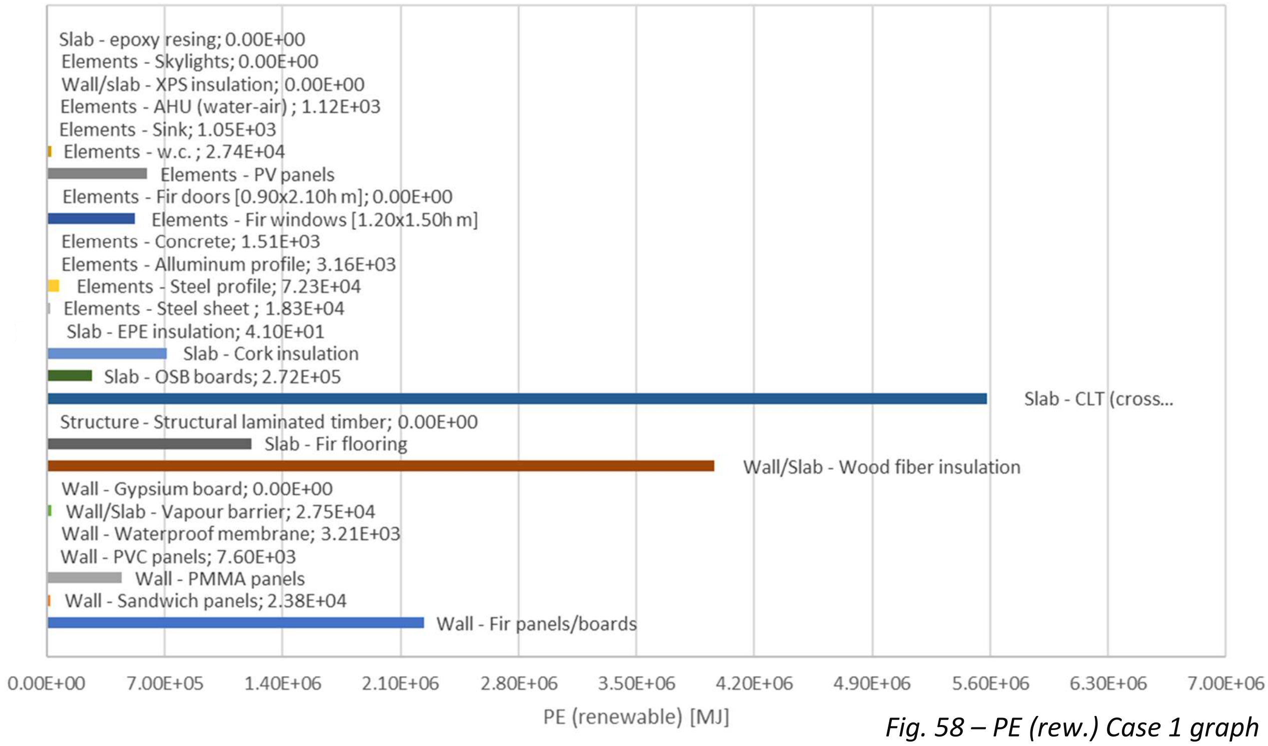


Fig. 58 – PE (rew.) Case 1 graph

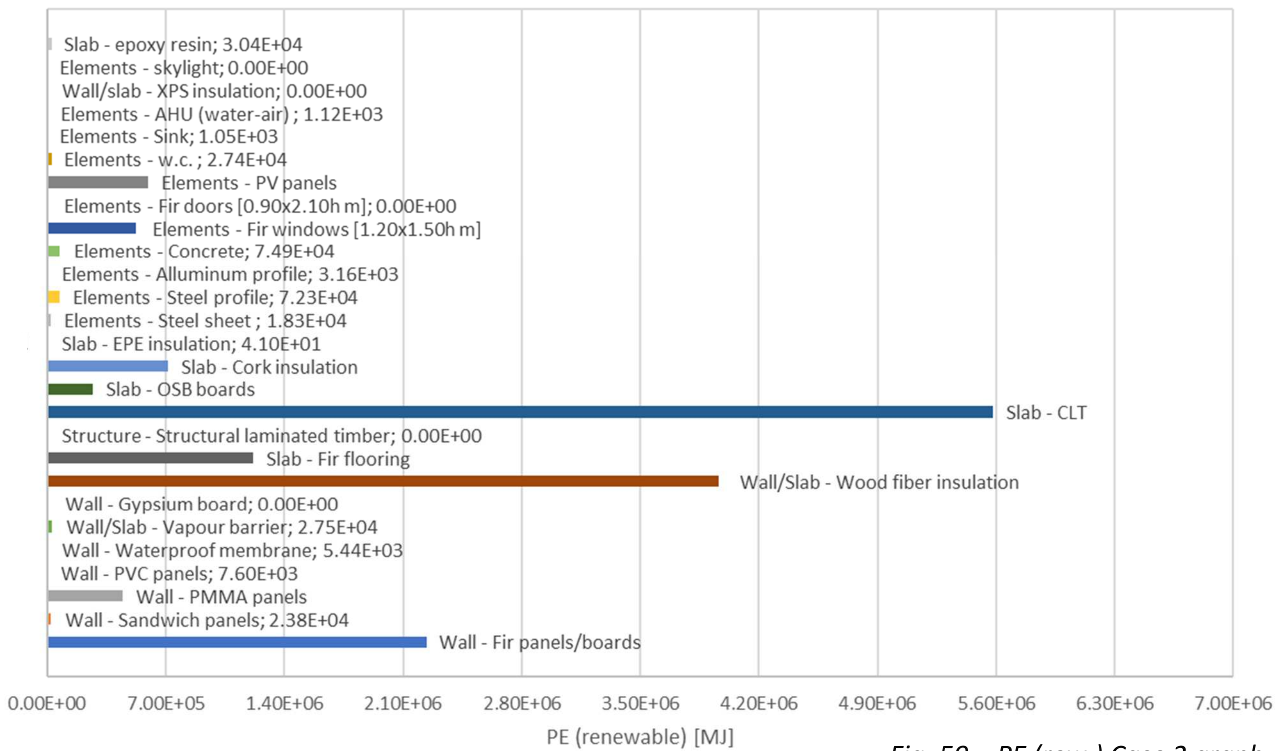


Fig. 59 – PE (rew.) Case 2 graph

5.7.2 A4 – Transfer from the gate to the site

The following chapter presents the data relating to the transport from production site to project site.

Case 1 considers for some transports more than one material carried, in these specific cases, the materials are in small quantities and coming from the same production site.

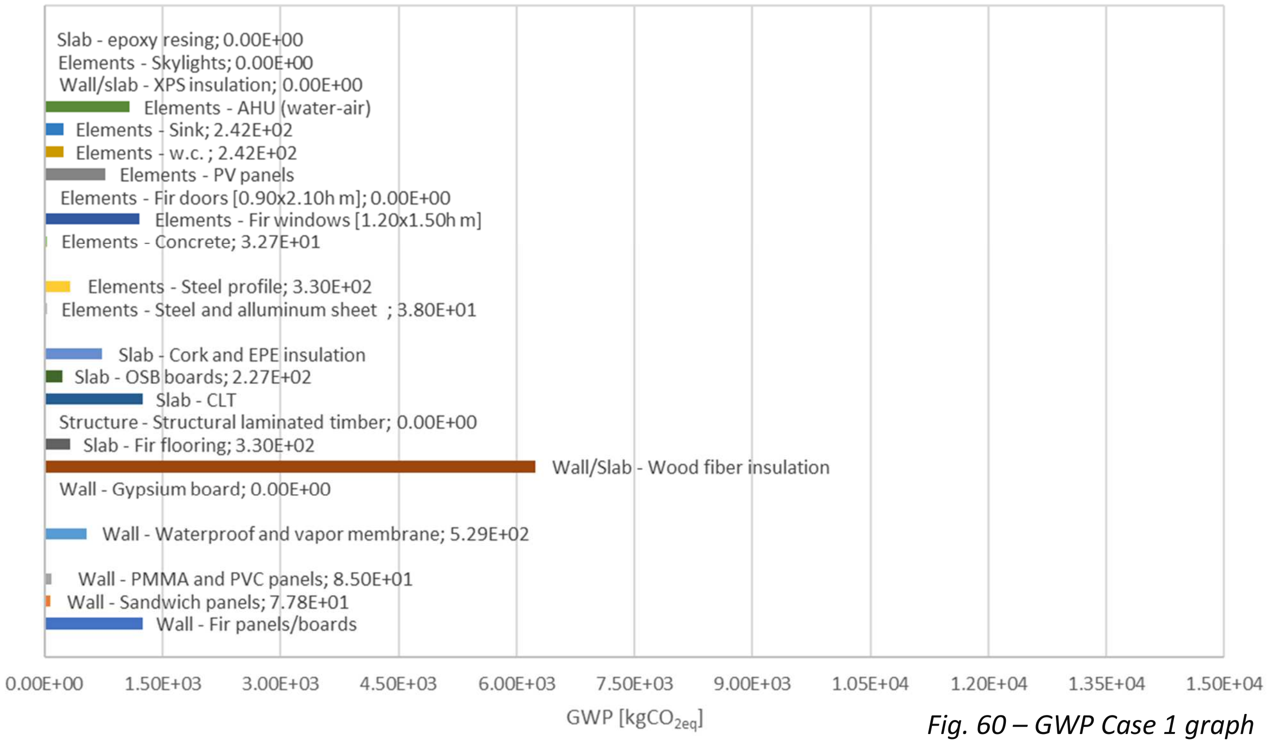


Fig. 60 – GWP Case 1 graph

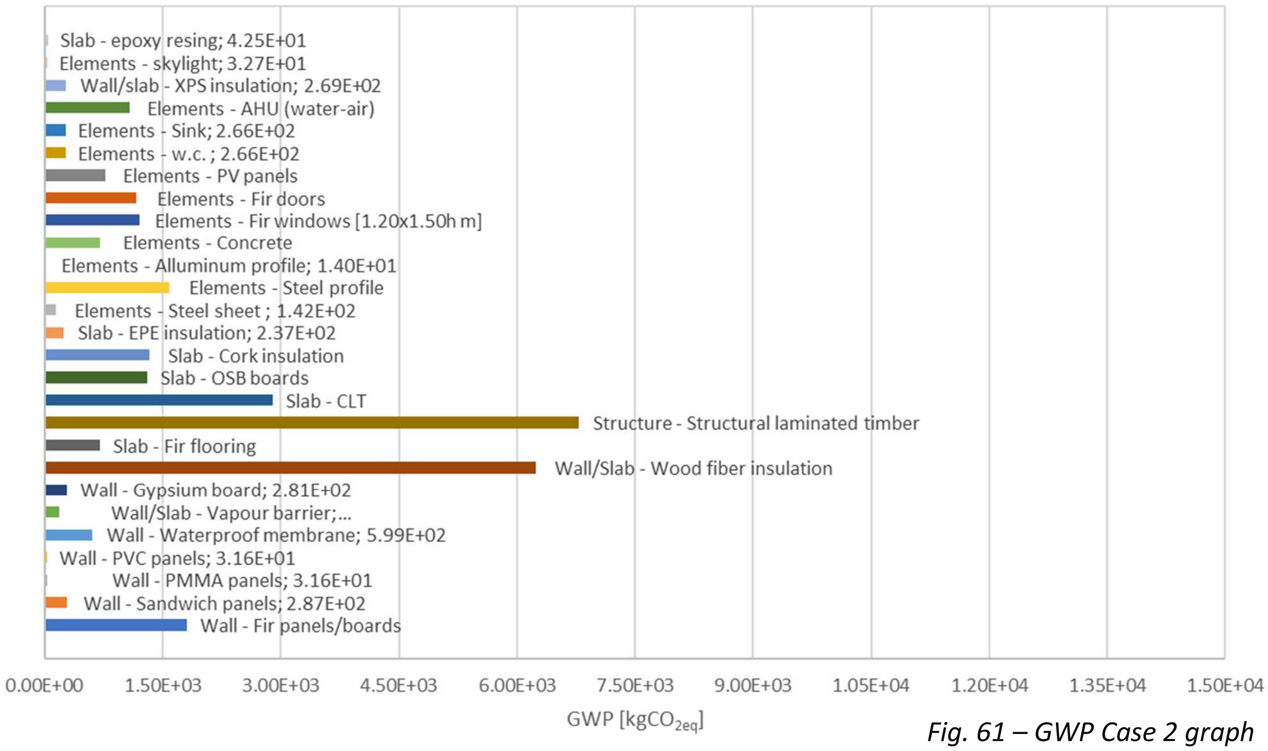


Fig. 61 – GWP Case 2 graph

Significant differences between the two cases can be seen from the graph. The first case, with the exception of the value relating to wood fiber insulation, has very low values proportionally to the second case. The second case has several peaks, the main ones refer to the transport of the insulation and the existing structure to the new site. The transport of all materials belonging to the SDF causes a significant increase in impact.

The ODP for all the cases is equal to zero since the transport emission doesn't fall in this equivalent emission section. For this reason, the tables are not shown in this document for this module.

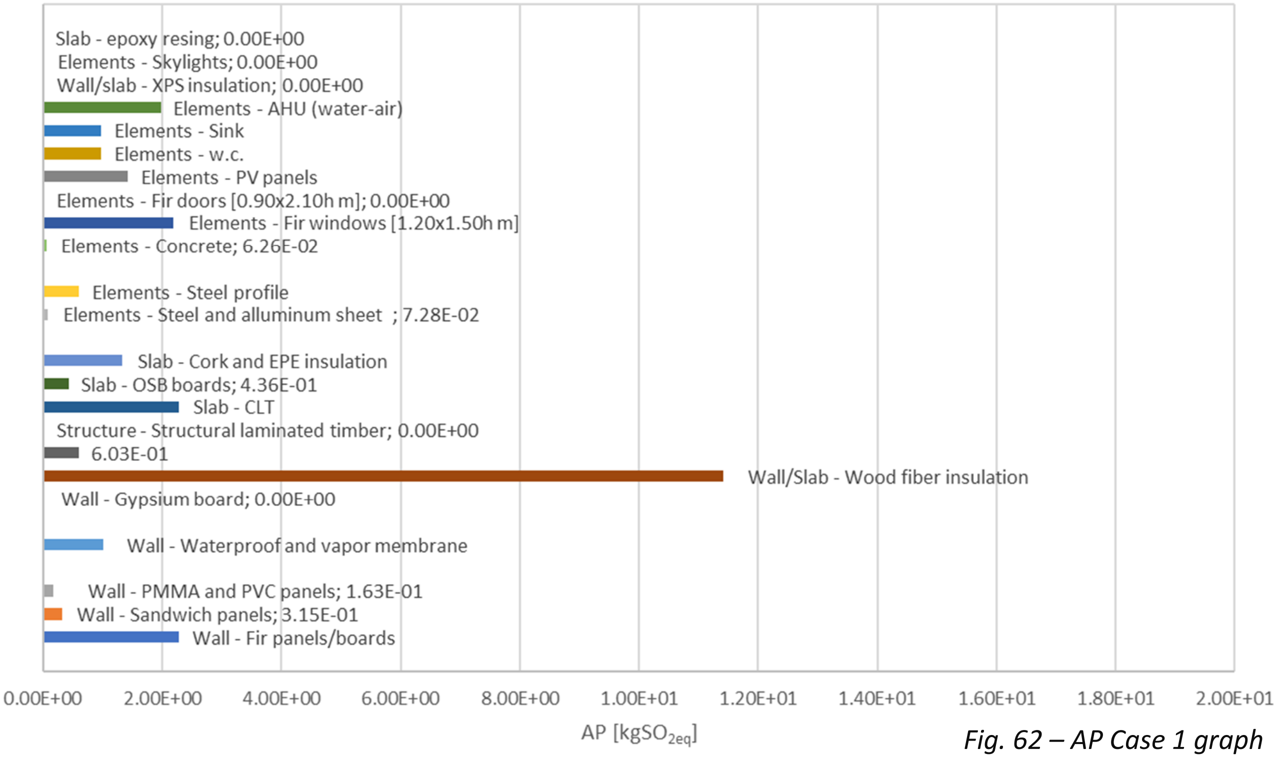


Fig. 62 – AP Case 1 graph

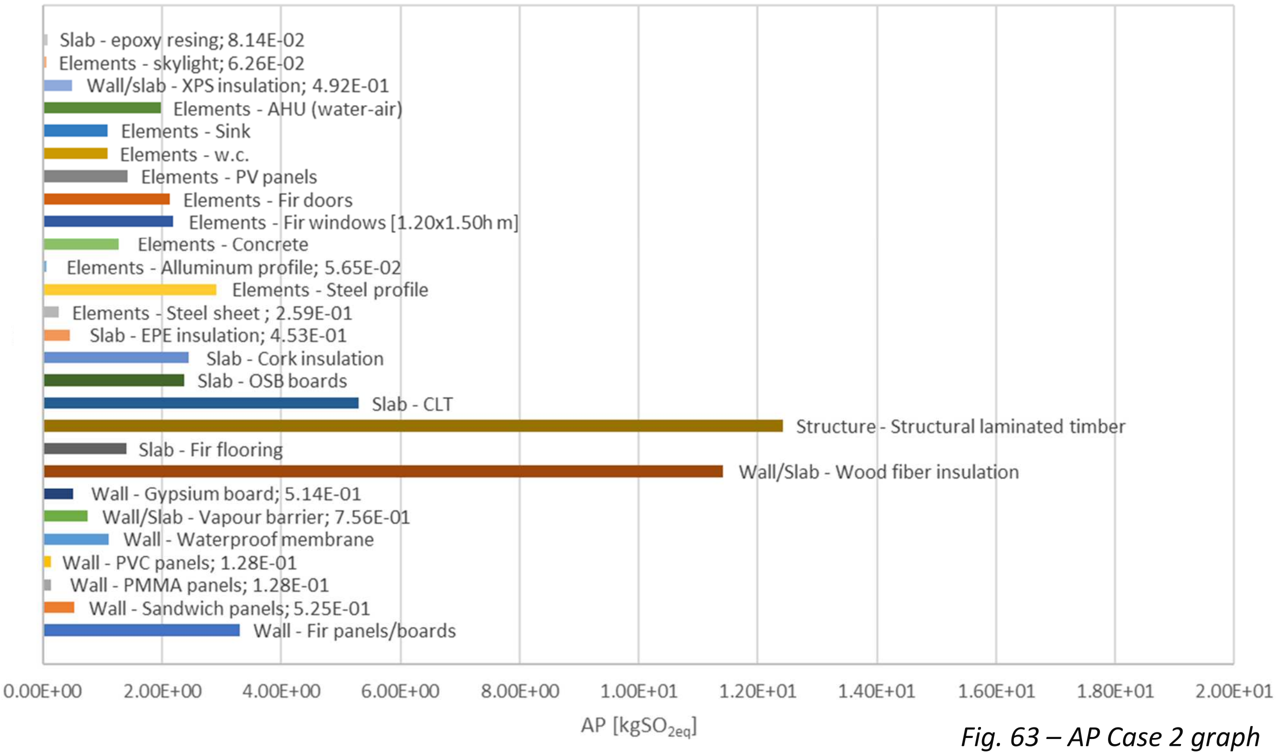


Fig. 63 – AP Case 2 graph

As already observed for the GWP, the materials that cause the maximum impact of this category remain the same. With the exception of some common values, as in the case of wood fiber insulation, which being a new design material therefore has the same value in both cases, the other values are always higher in Case 2. In the second case, there are no values lower than Case 1 values.

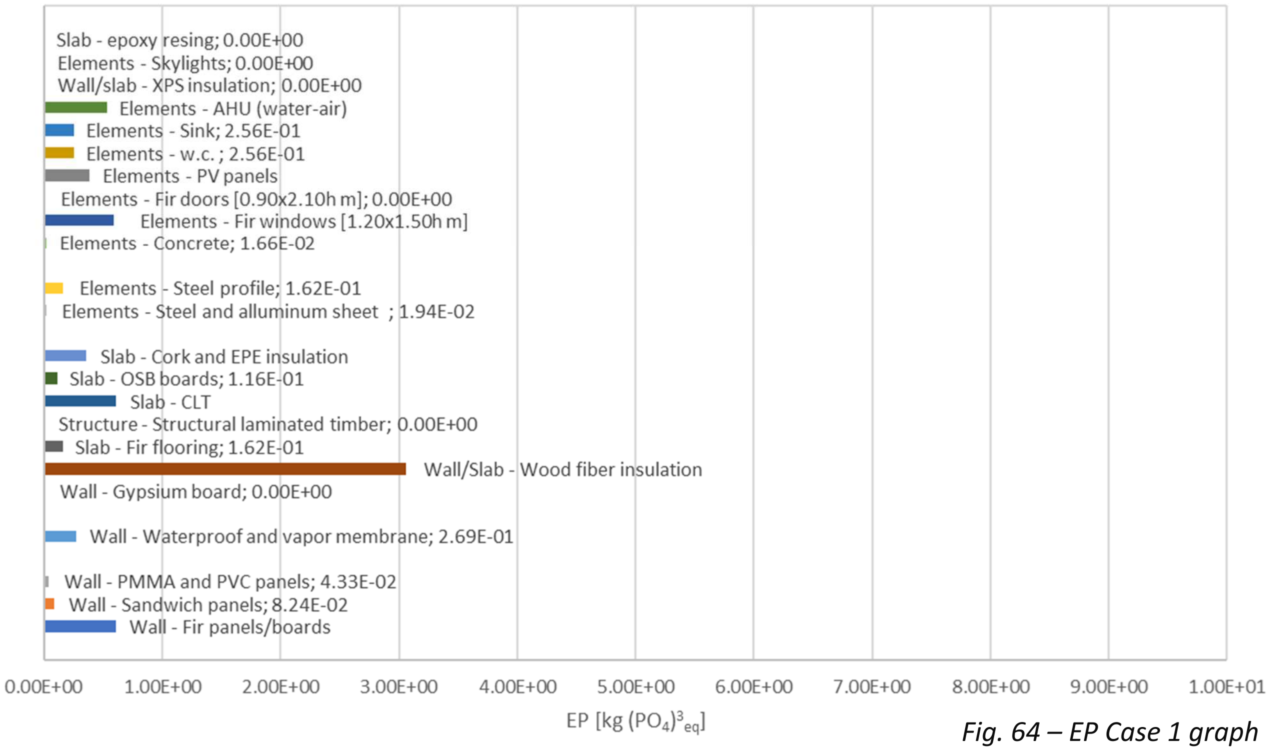


Fig. 64 – EP Case 1 graph

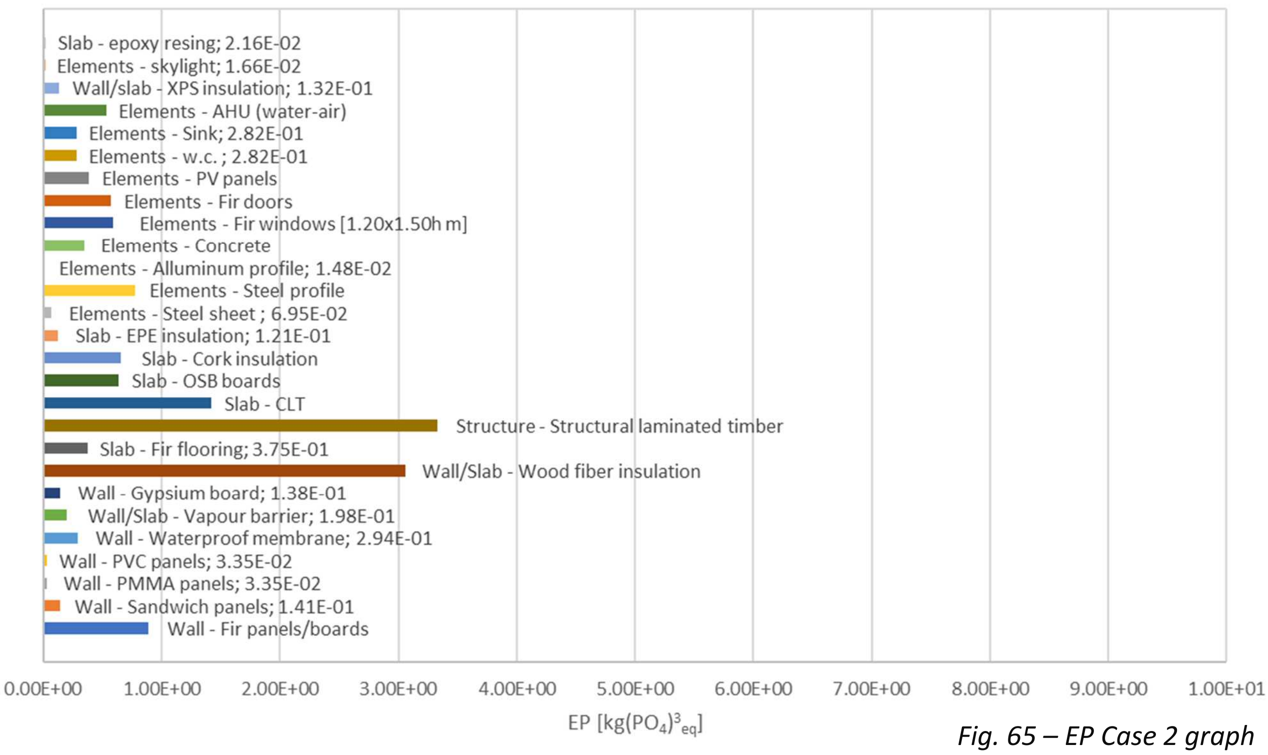


Fig. 65 – EP Case 2 graph

The trend in the graph remains similar to that analyzed in the previous graphs. The greatest impacts are, as in the other cases, constituted by isolation, in both cases, and by the displacement of the structure in only Case 2. The values are for the most part of the same order of magnitude. Also, in this case there is an increase in the values in Case 2.

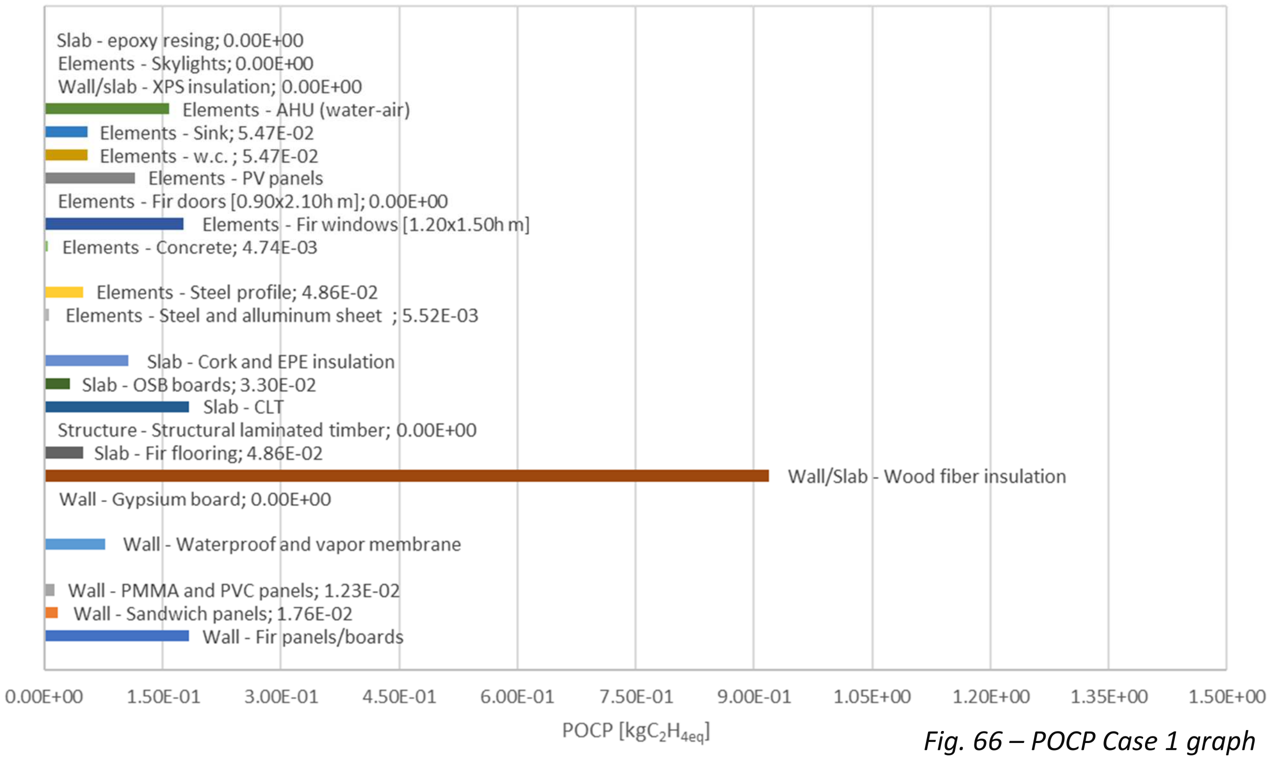


Fig. 66 – POCP Case 1 graph

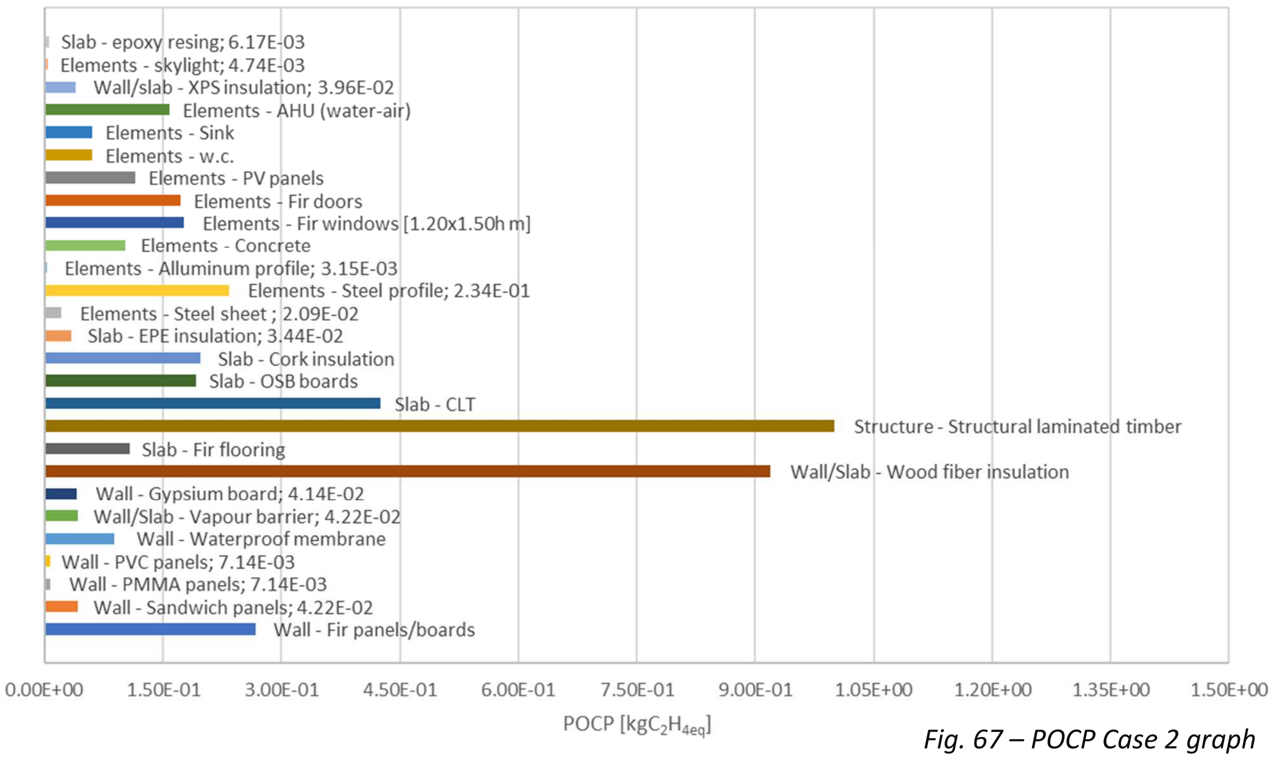


Fig. 67 – POCP Case 2 graph

The wooden materials relating to the structure and all the insulation remain the maximum values also in the graph relating to all the photochemical ozone creation potentials. Some materials present in Case 2, as in the other graphs, are not present in Case 1. In the graph also the metal profile relating mainly to the structure has a central role in determining the overall impact.

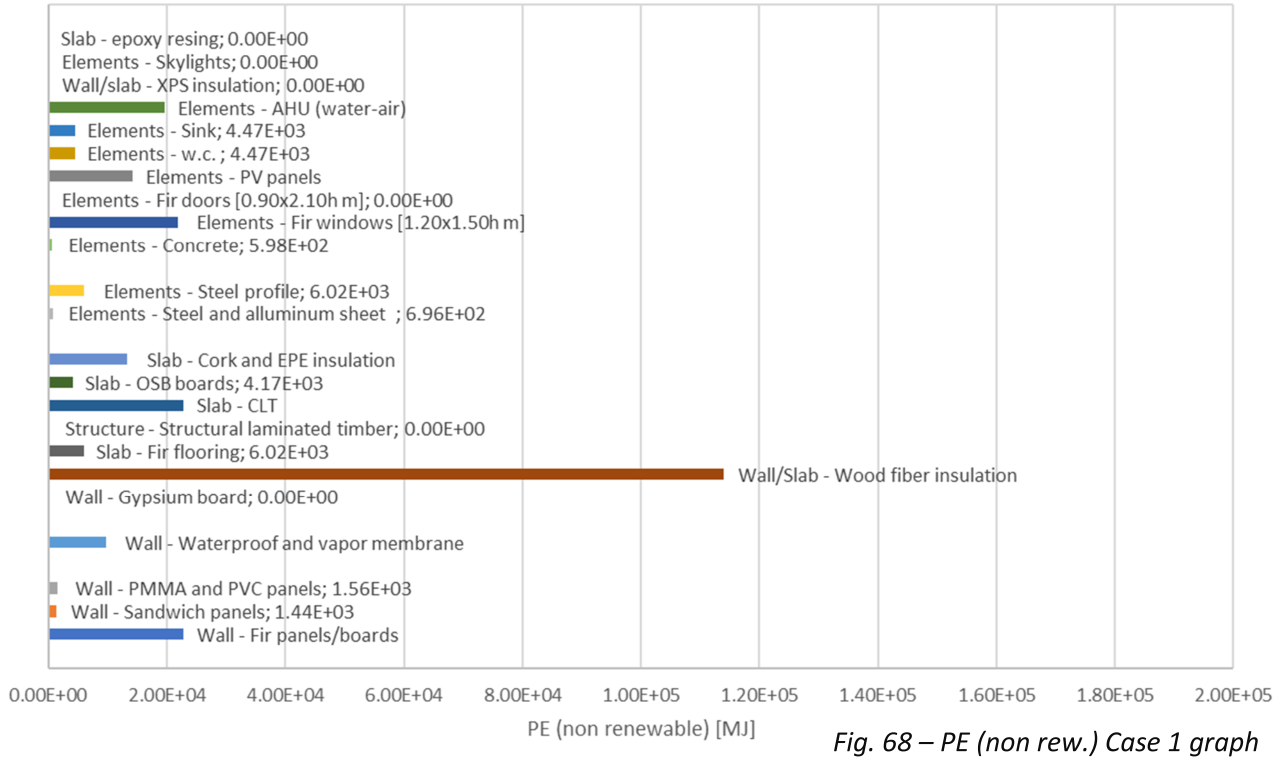


Fig. 68 – PE (non rew.) Case 1 graph

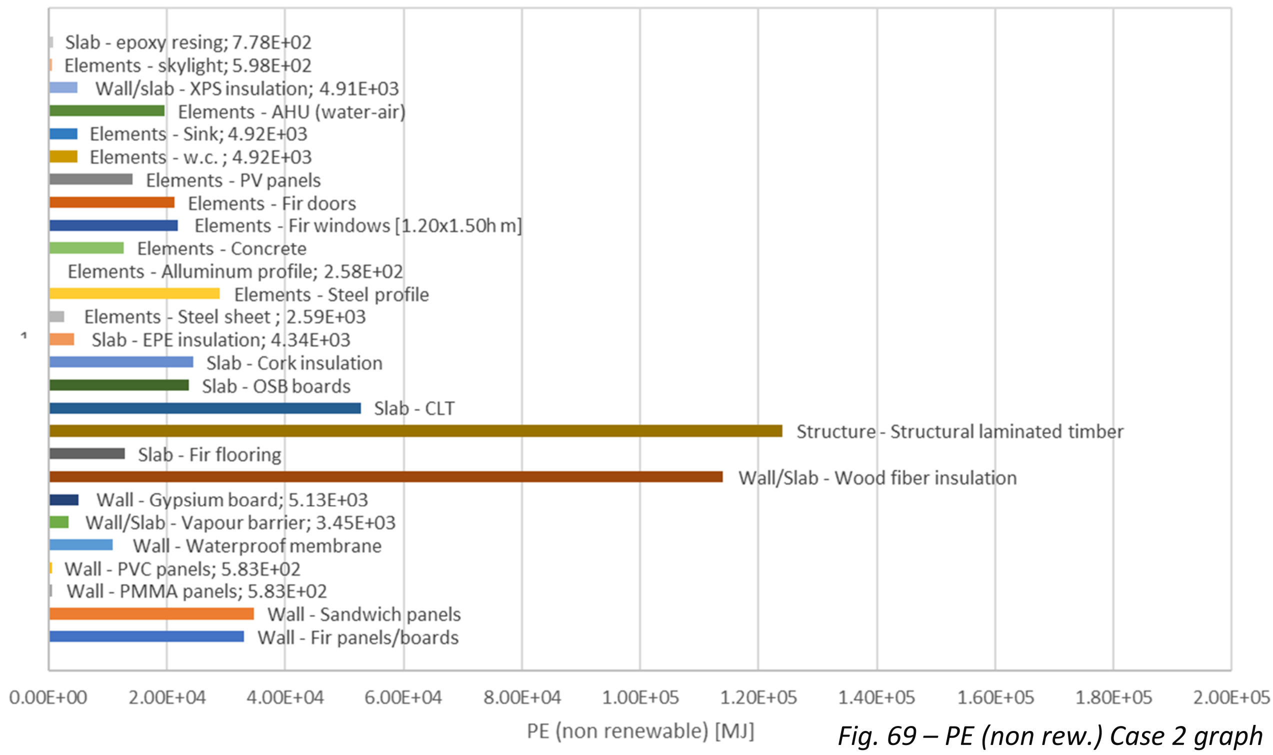


Fig. 69 – PE (non rew.) Case 2 graph

Non-renewable primary energy is the last graph of phase A4, this is because transport is done in all cases analyzed on average trucks and therefore without the use of renewable energy. The values depend, in this case, almost only on the quantity. The values of the various materials tend to conform more in this case.

5.7.3 A5 – Assembly

This chapter lists the values related to the assembly module.

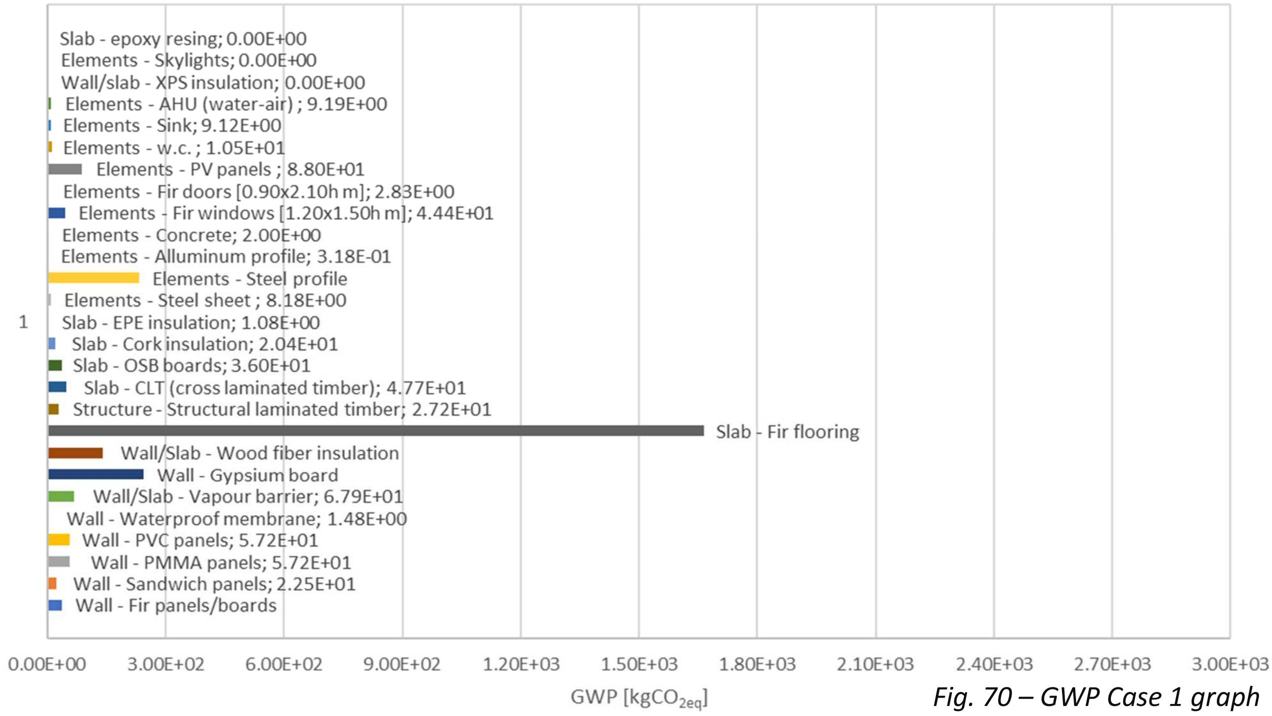


Fig. 70 – GWP Case 1 graph

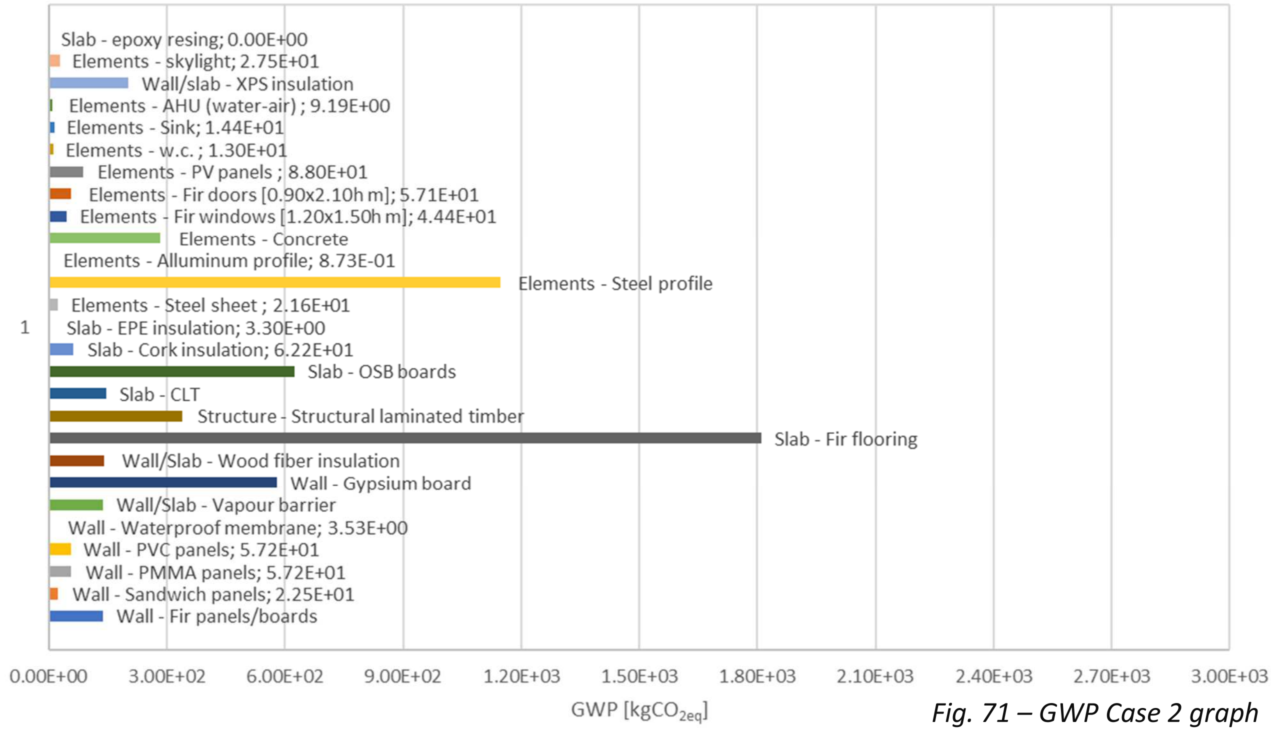


Fig. 71 – GWP Case 2 graph

The graphs relating to the global warming potential show an increase in most of the values of the materials. The different quantities of increase are due to the assembly and disassembly operation which in Case 2 sometimes requires only a partial operation while other times applied to all the material.

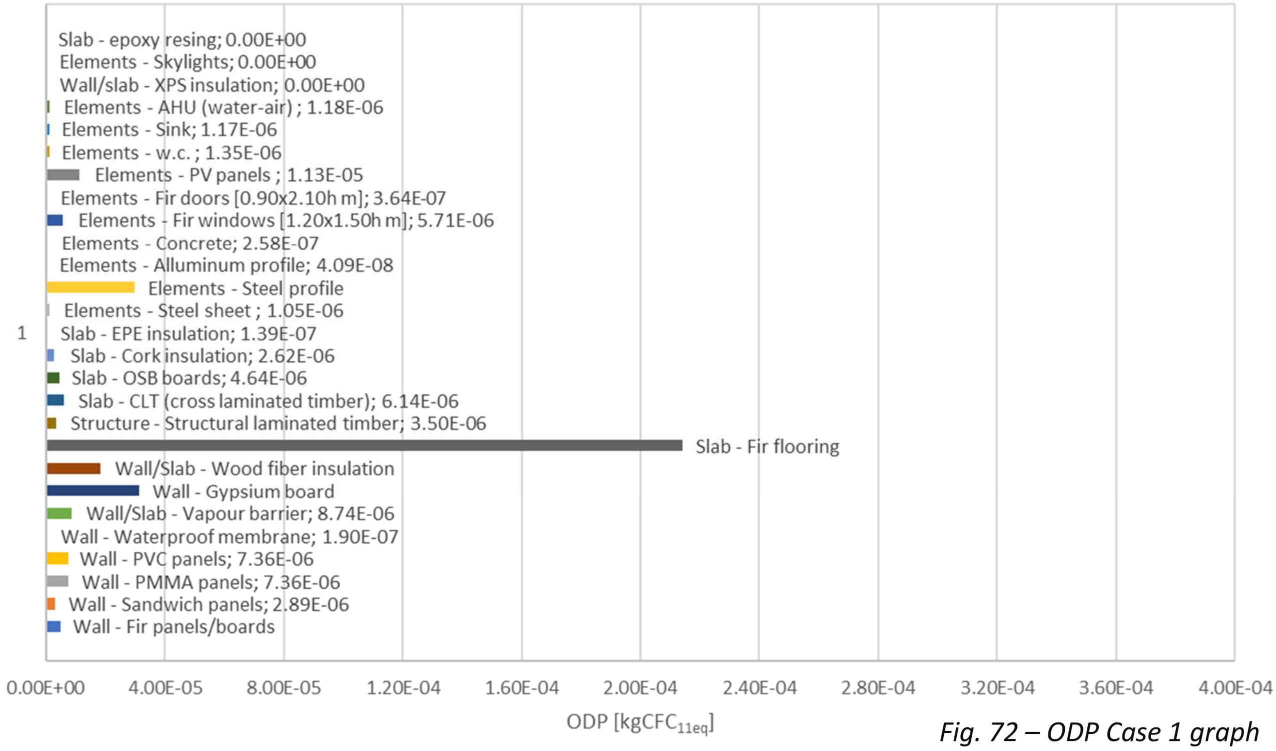


Fig. 72 – ODP Case 1 graph

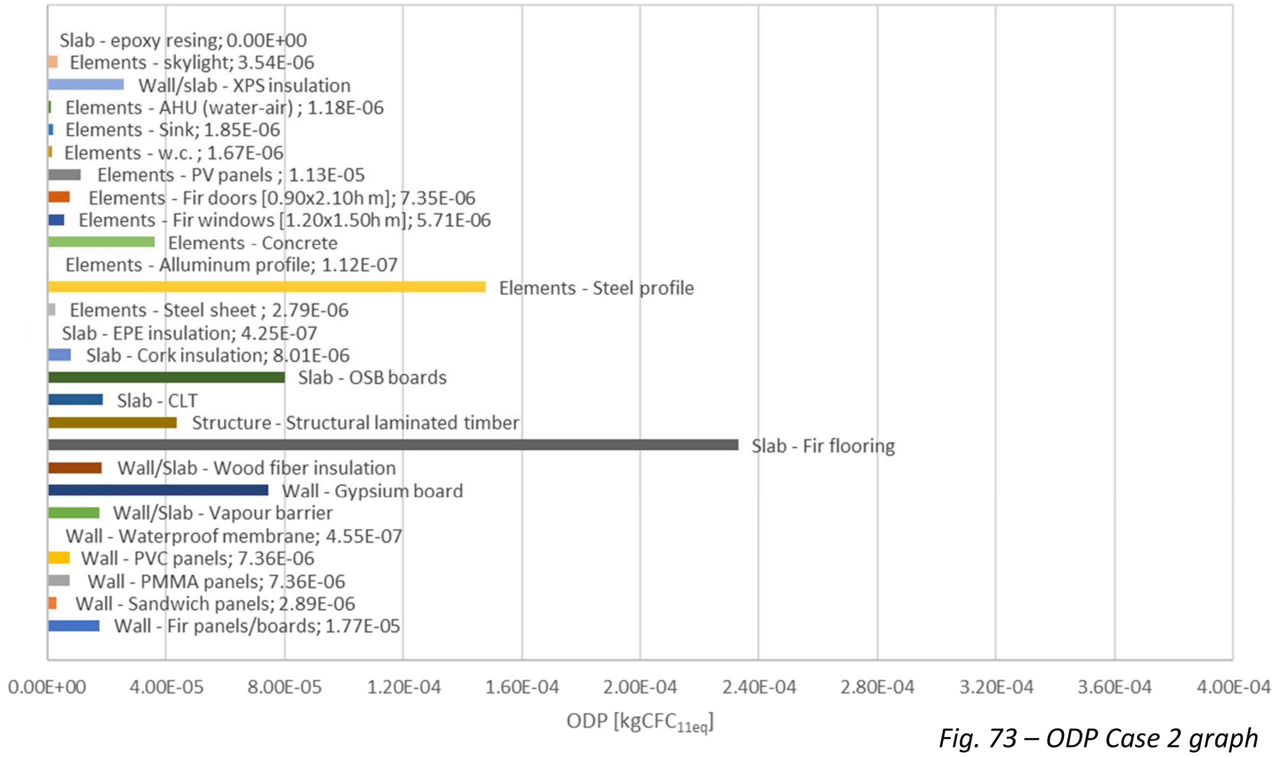


Fig. 73 – ODP Case 2 graph

In the case of the ODP it is possible to notice an increase in the values in Case 2; in particular, the greatest increase belongs to the steel profiles which are also one of the maximum values of Case 2, together with fir flooring. The other values are uniform and have, for the most part, the same order of magnitude.

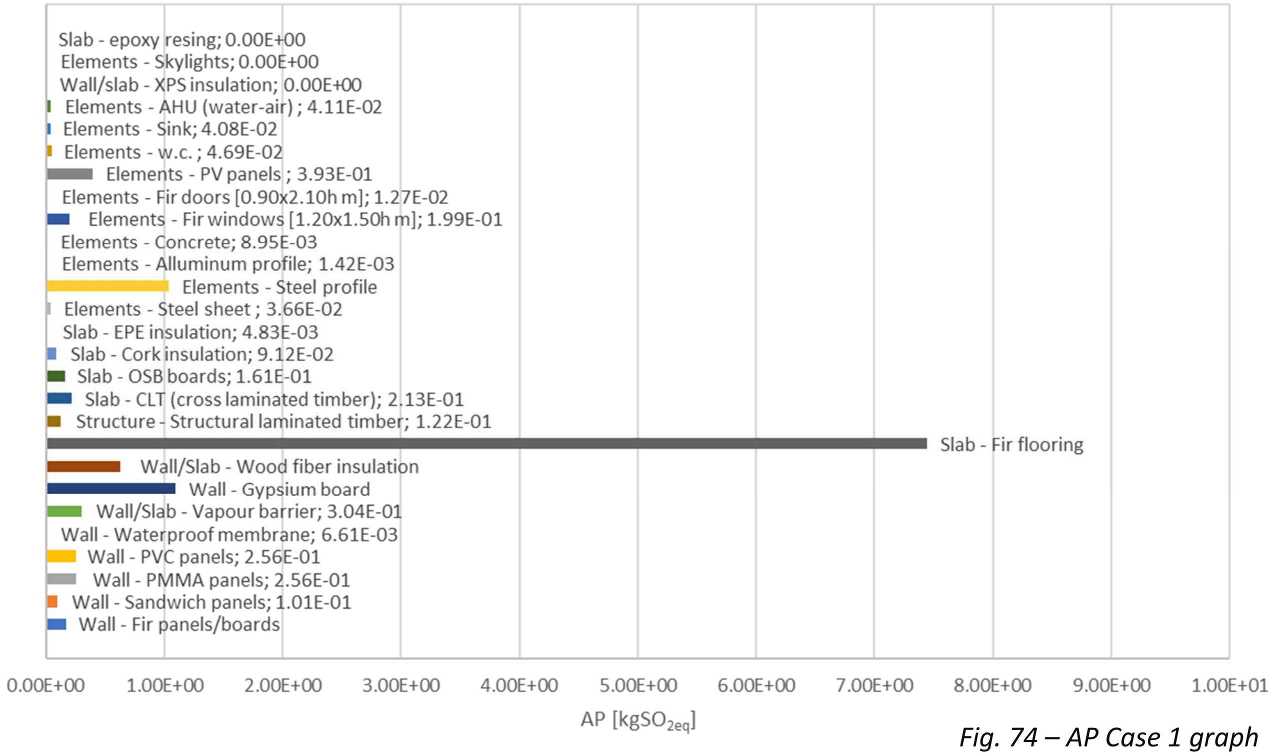


Fig. 74 – AP Case 1 graph

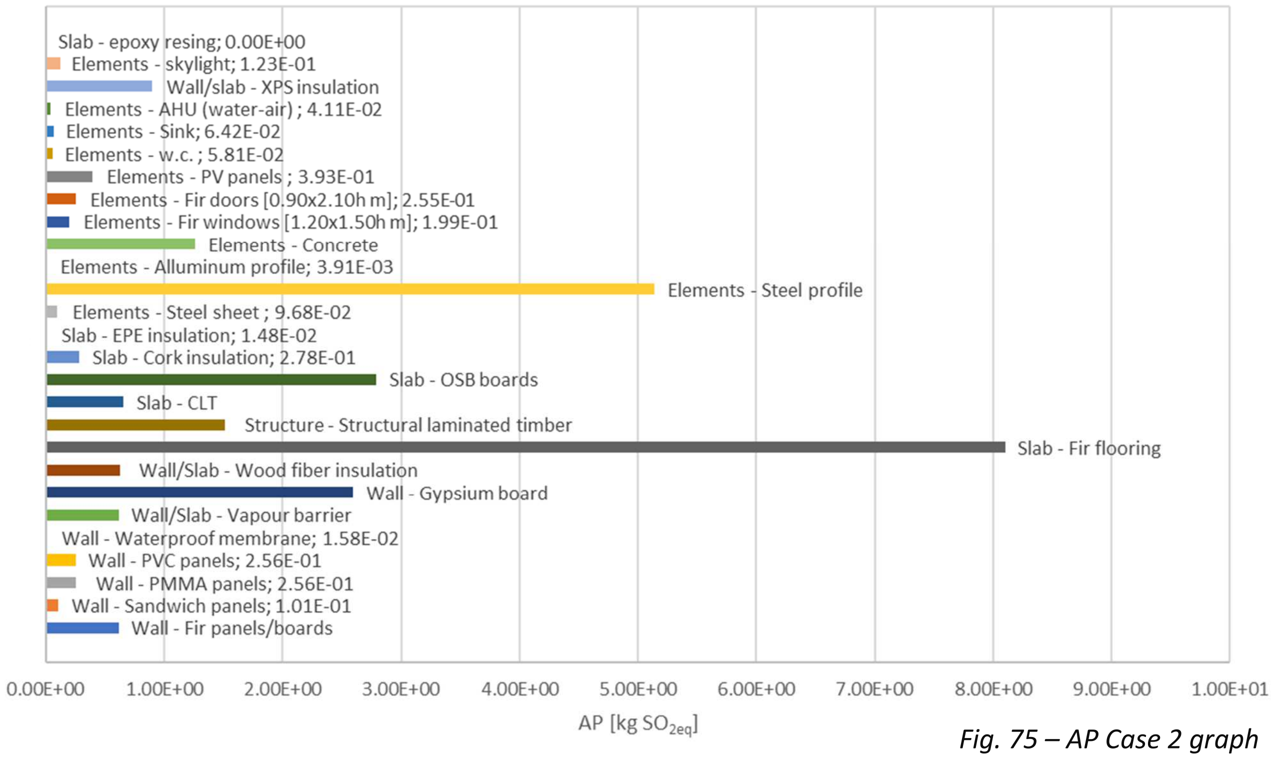


Fig. 75 – AP Case 2 graph

As observed in the previous graphs, the second case analyzed shows an increase in all the values considered in the graph. The maximum values continue to be those relating to steel profiles and fir flooring. It is also important to observe the increase in cement, which despite having a lower value, proportionally more increase.

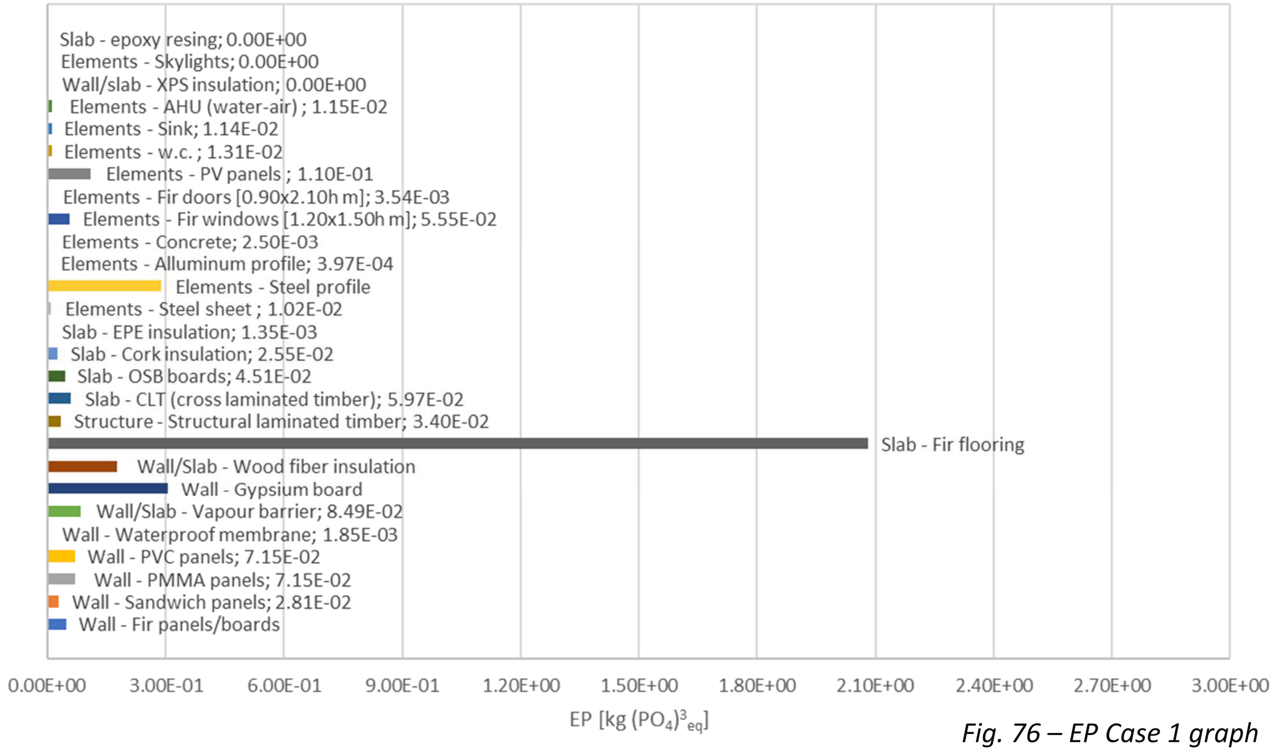


Fig. 76 – EP Case 1 graph

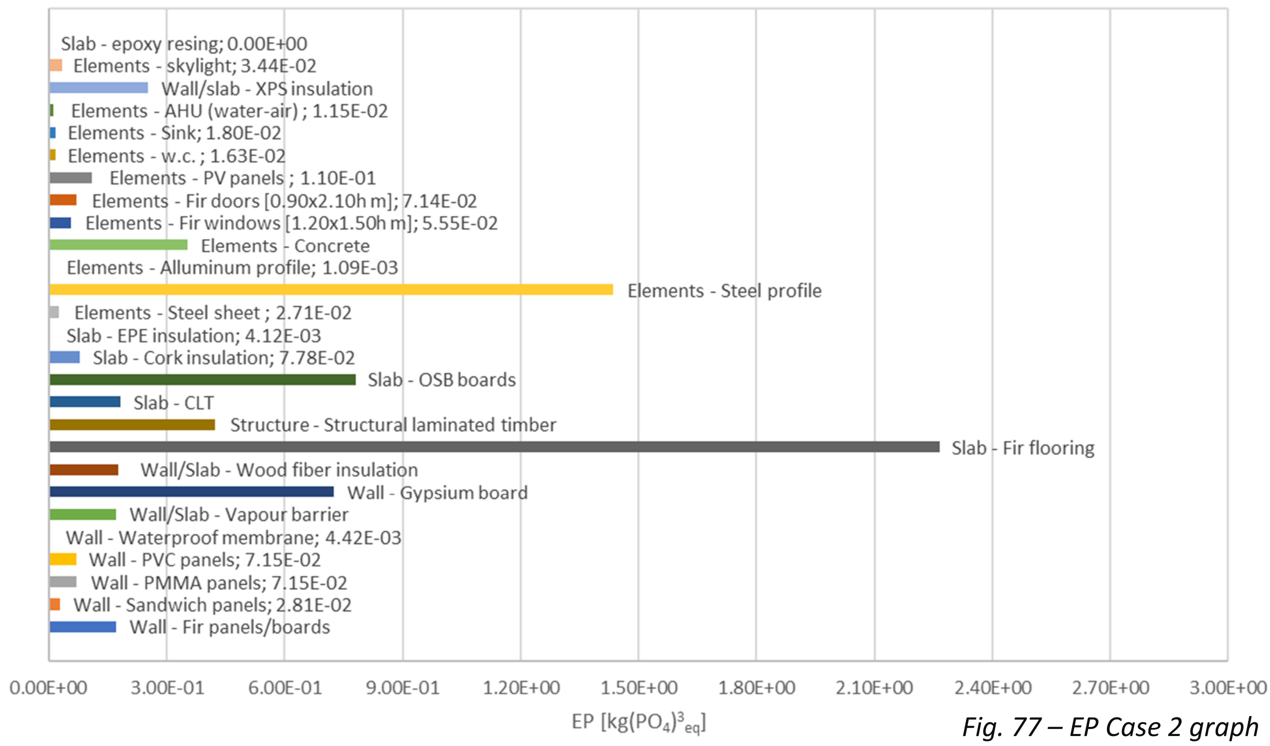


Fig. 77 – EP Case 2 graph

The graphs relating to the eutrophication potential have a behavior very similar to that relating to the acidification potential; the maximum materials represent the same as well as in this case it is also possible to see an increase in the values relating to Case 2. Some materials not considered in the first graph are instead analyzed in the second, an example are the skylights.

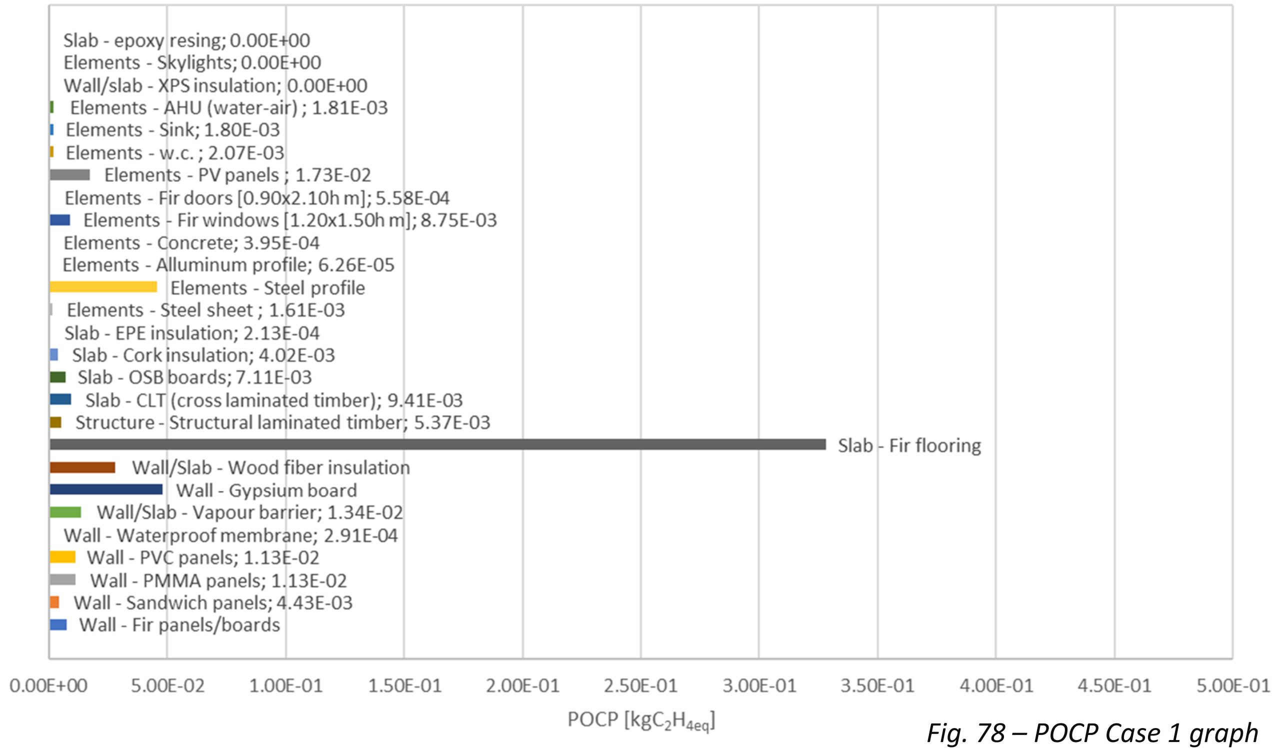


Fig. 78 – POCP Case 1 graph

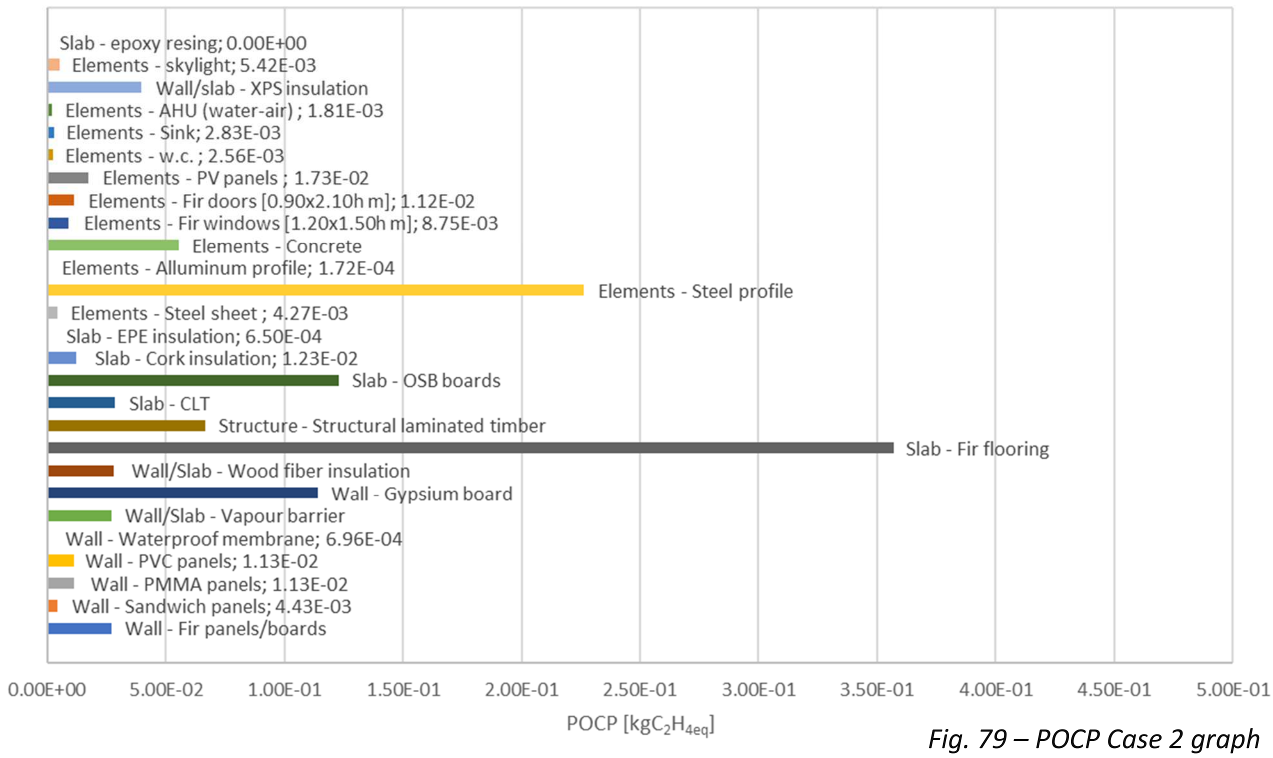


Fig. 79 – POCP Case 2 graph

The graphs relating to the POCP maintain the same trend as those previously analyzed. In general, the operations of moving the materials to a new project area require additional assembly and disassembly which add to those originally foreseen by Case 1, increasing the values of all the graphs.

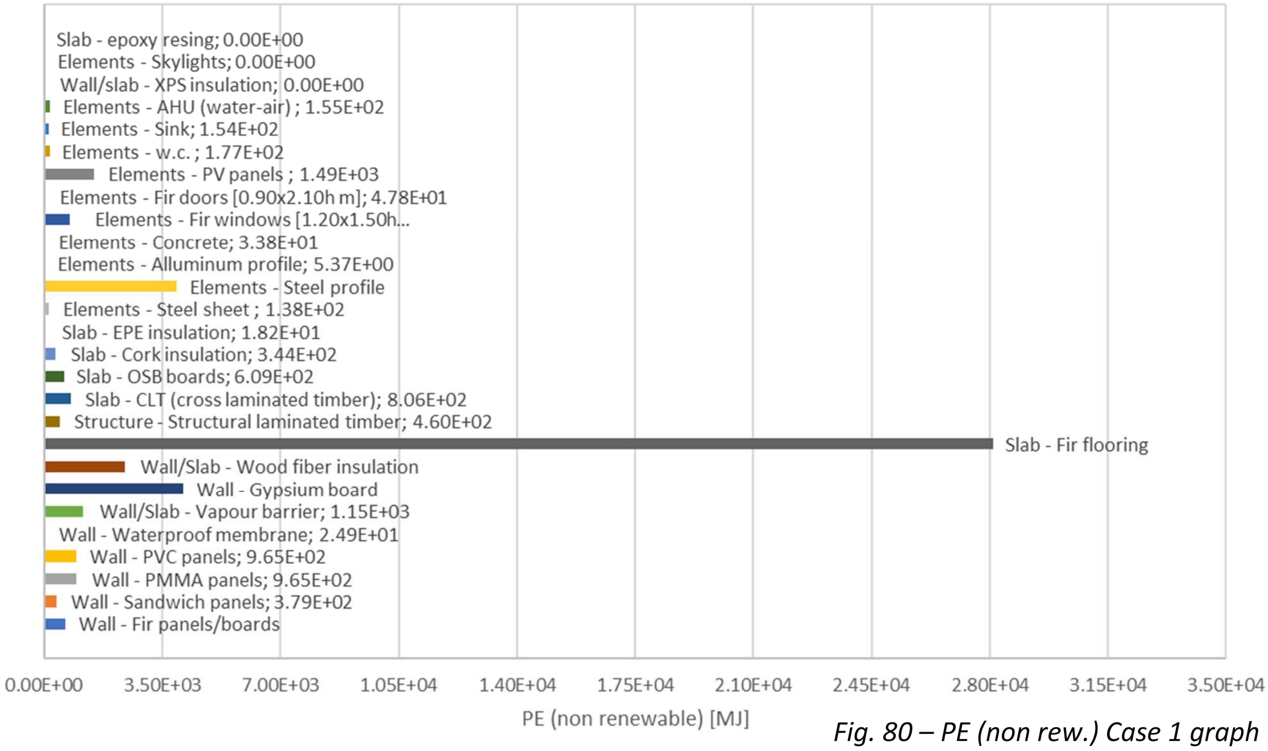


Fig. 80 – PE (non rew.) Case 1 graph

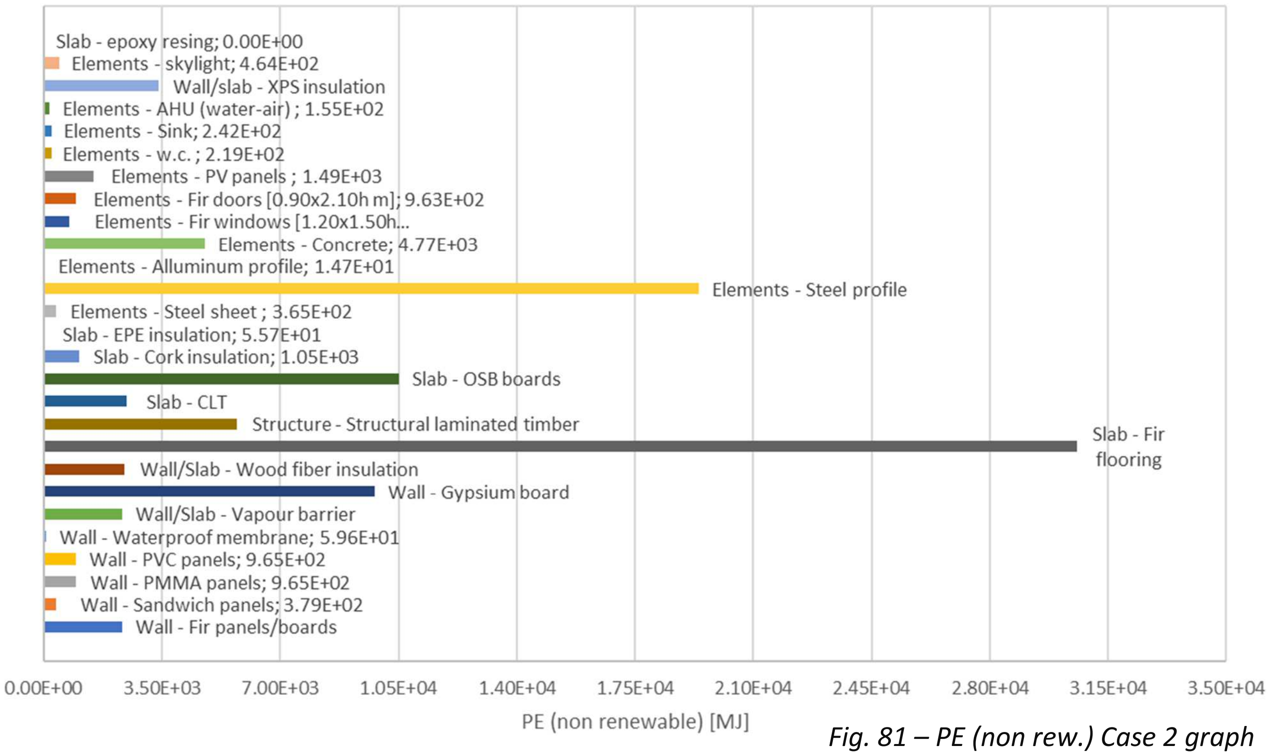


Fig. 81 – PE (non rew.) Case 2 graph

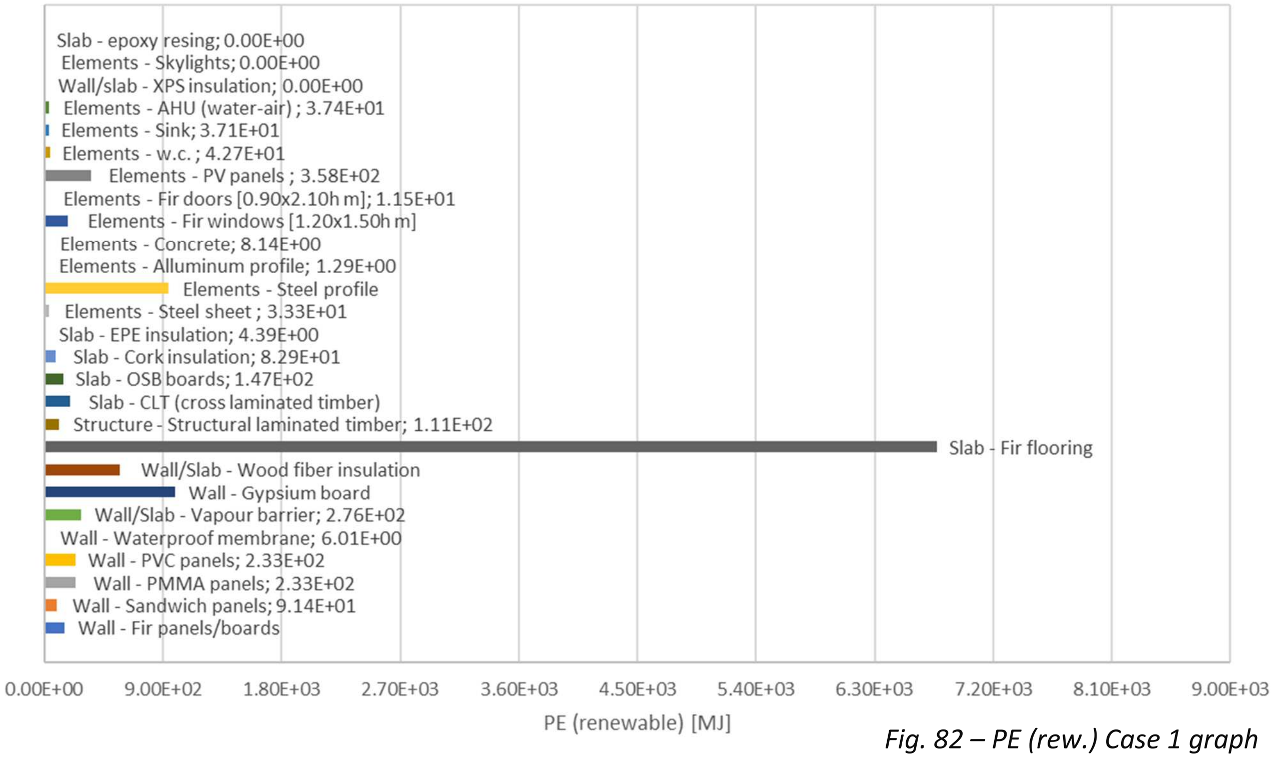


Fig. 82 – PE (rew.) Case 1 graph

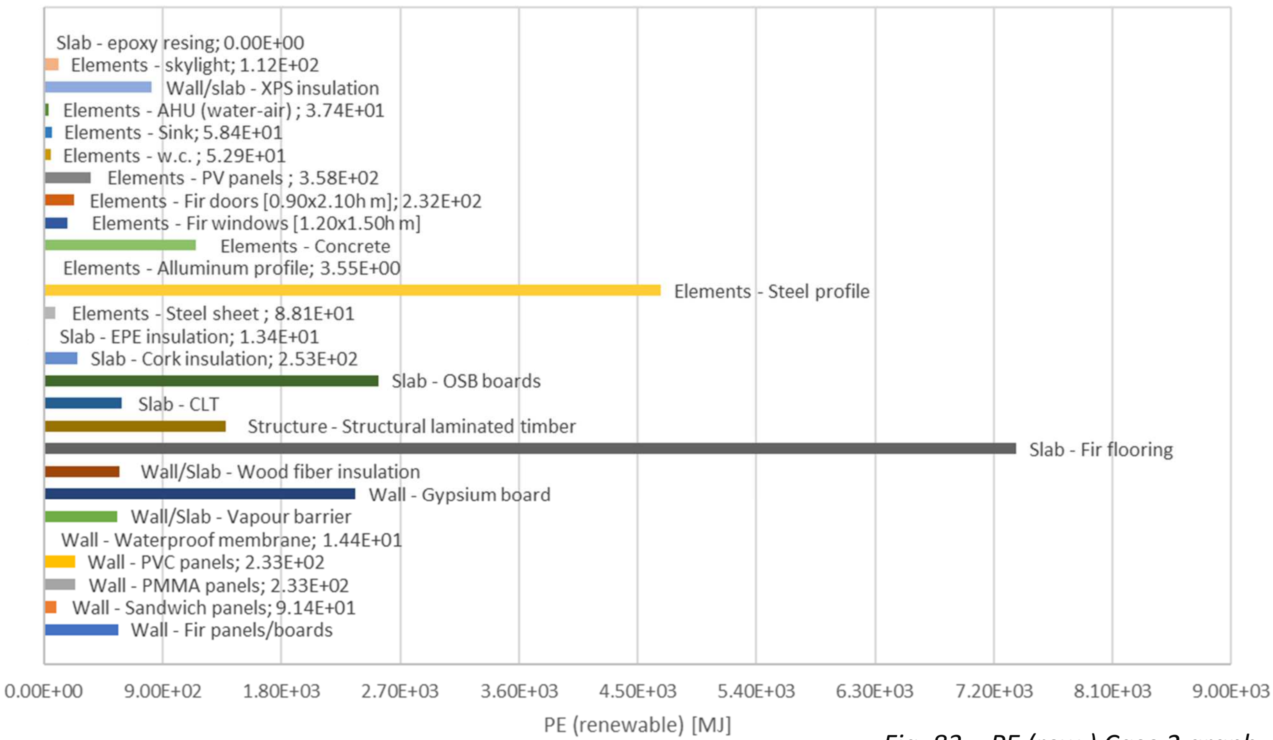


Fig. 83 – PE (rew.) Case 2 graph

The trends of both types of graph respect what was said for the previous graphs. It is important to highlight how the proportionality of all the graphics in this case is due to the use of electrical devices only, their electrical consumption derives from the time of use of the electrical devices which will in turn be proportional to the quantity of material. The values of non-renewable primary energy are generally higher than those of renewable but have the same proportions.

5.7.4 B2-B4 – Use stage

The module considers the maintenance and replacement phase. In this chapter, only the graph relating to Case 1 is shown, presenting Case 2 with the same values as Case 1. The values for all stages are equal in both cases since the SDP is the same despite the fact that they are made with different procedure.

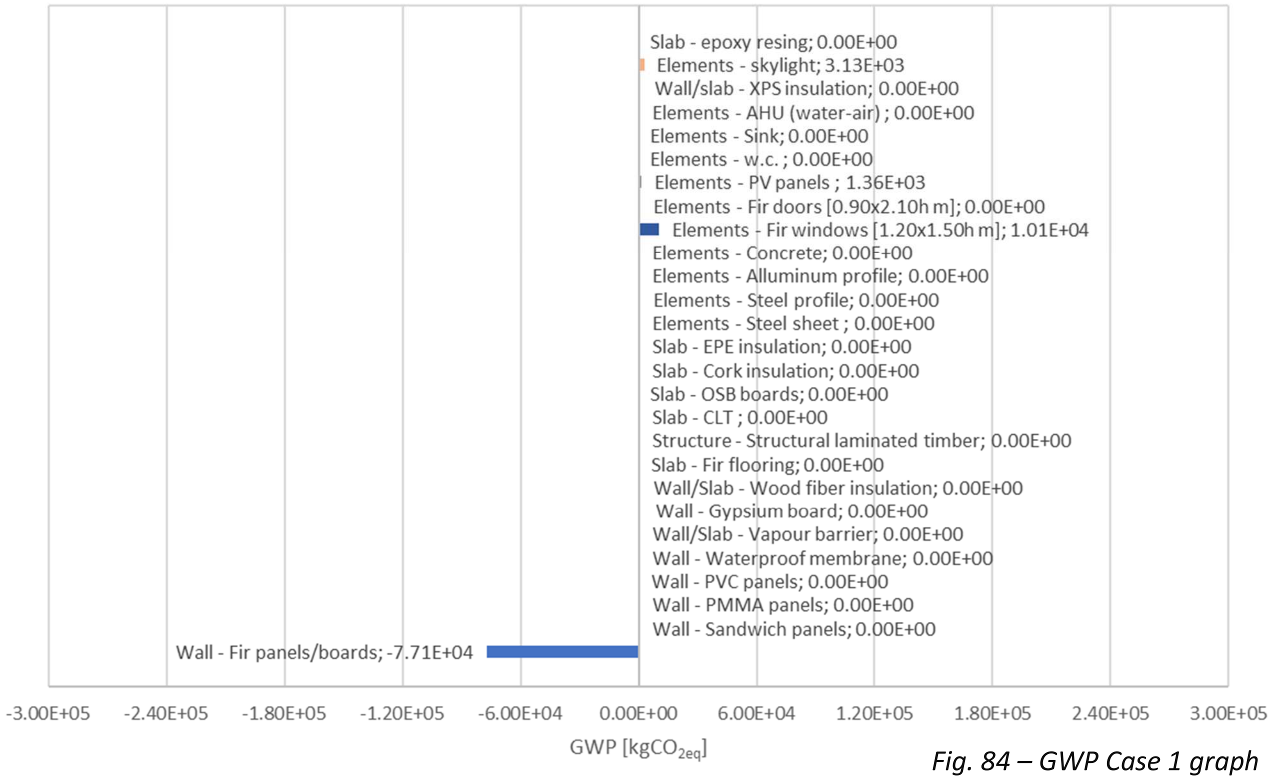


Fig. 84 – GWP Case 1 graph

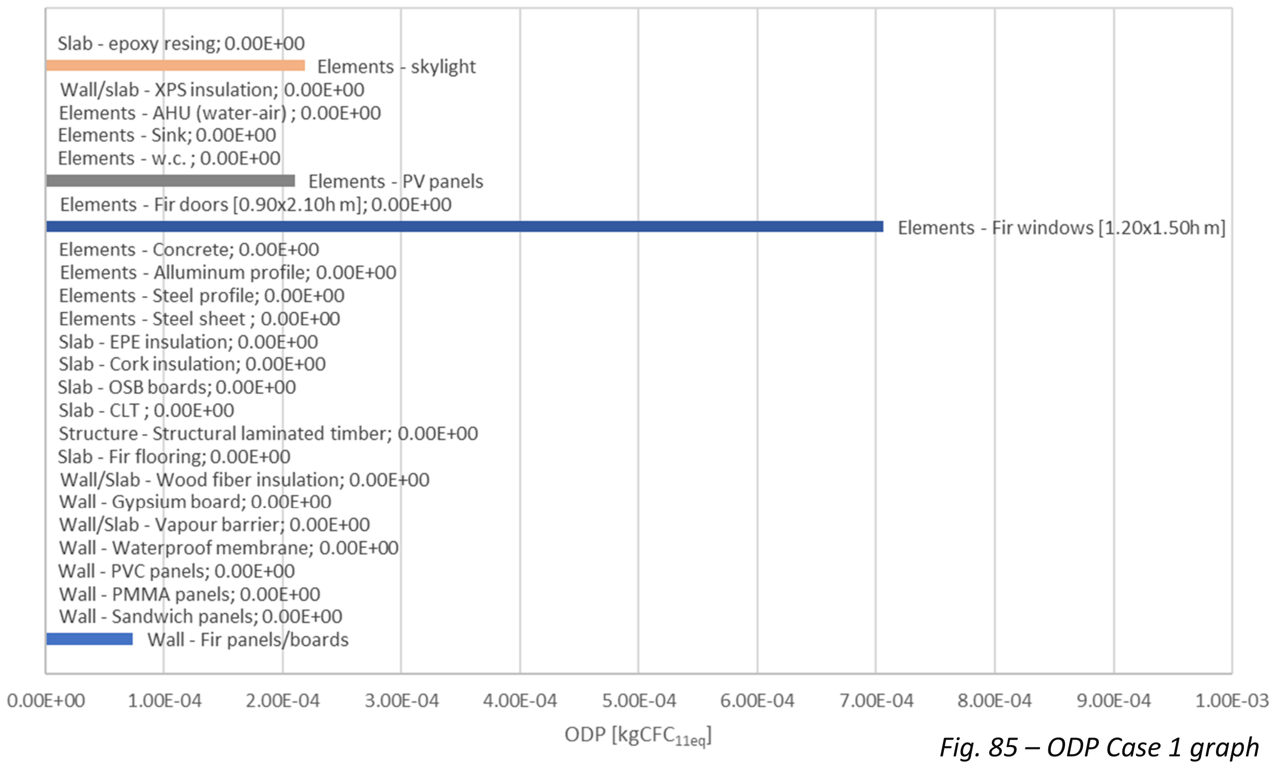


Fig. 85 – ODP Case 1 graph

The values relating to GWP are mainly negative thanks to the wood used for the external coating. The values for the ozone depletion potential are for the most part caused by the maintenance of the windows; in general, the values for this graph are of the same order of magnitude.

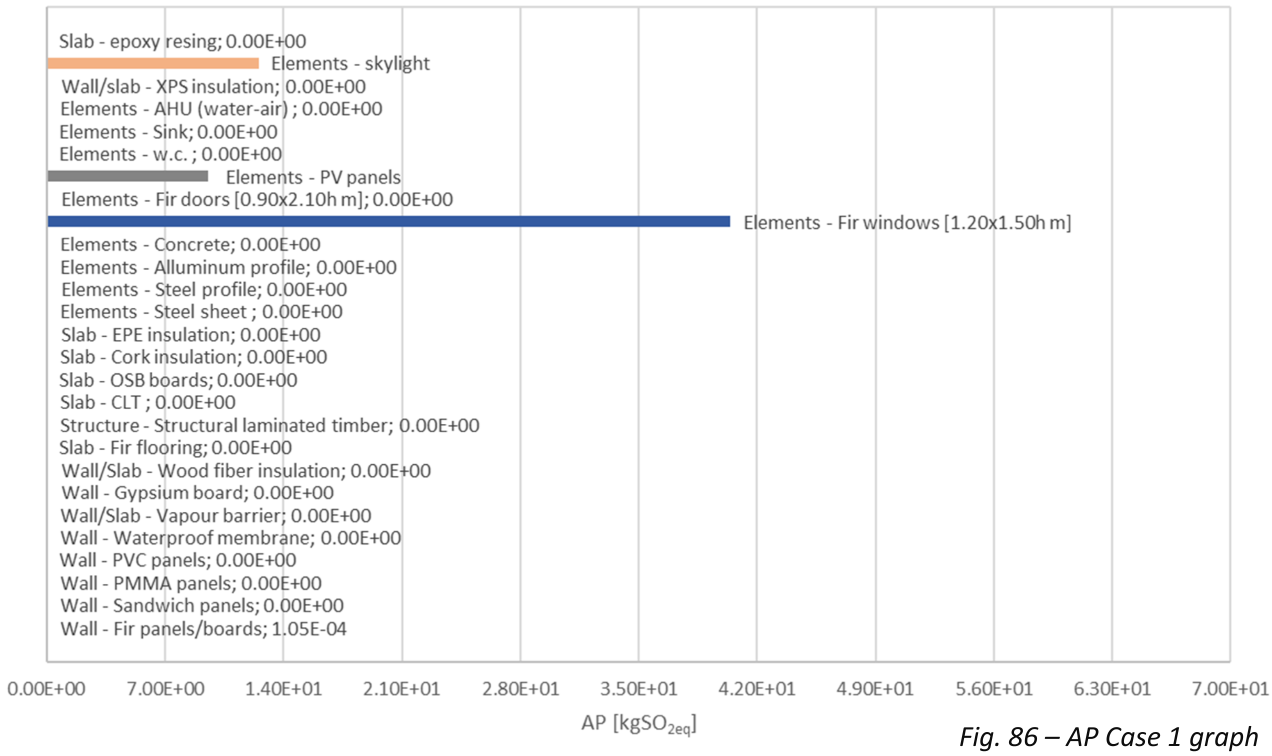


Fig. 86 – AP Case 1 graph

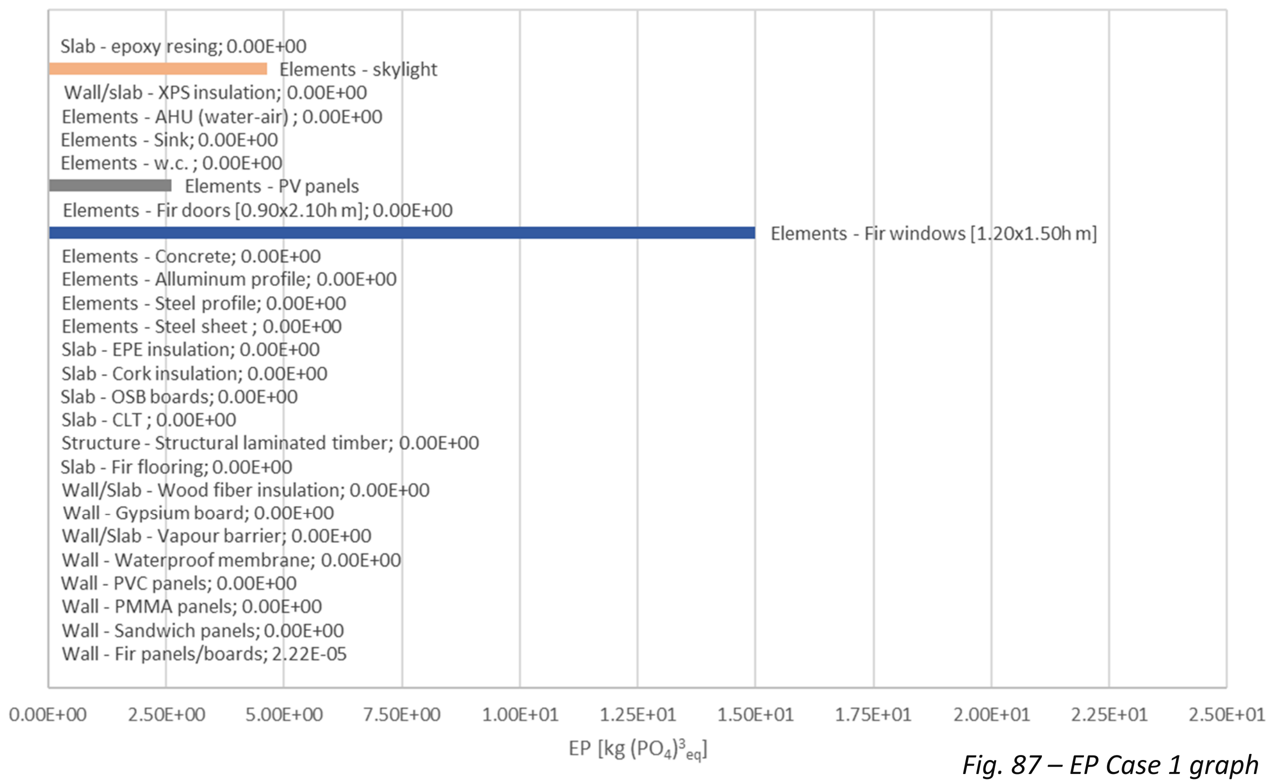


Fig. 87 – EP Case 1 graph

The graphs show a similar trend; as previously the windows represent the greatest impact for both of the equivalent emissions analyzed. The values relating to this stage are, however, are minimal compared to those of other analyzed chapters.

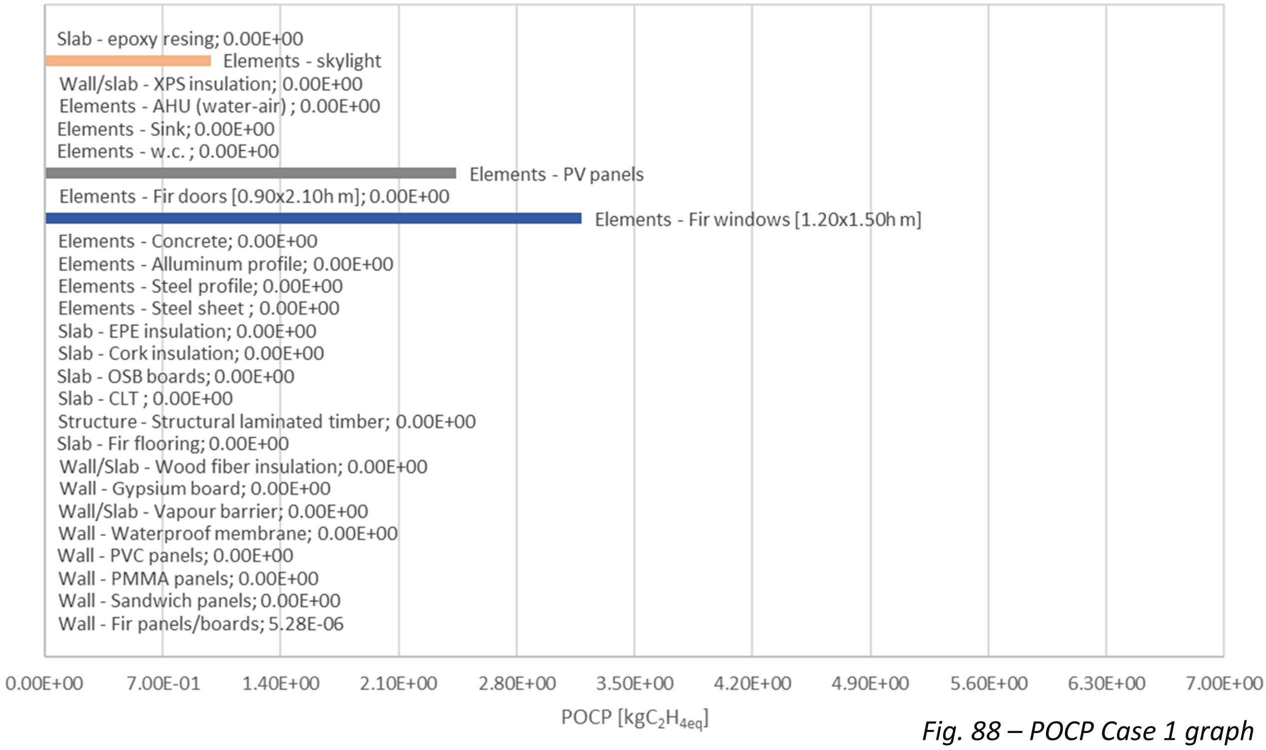


Fig. 88 – POCP Case 1 graph

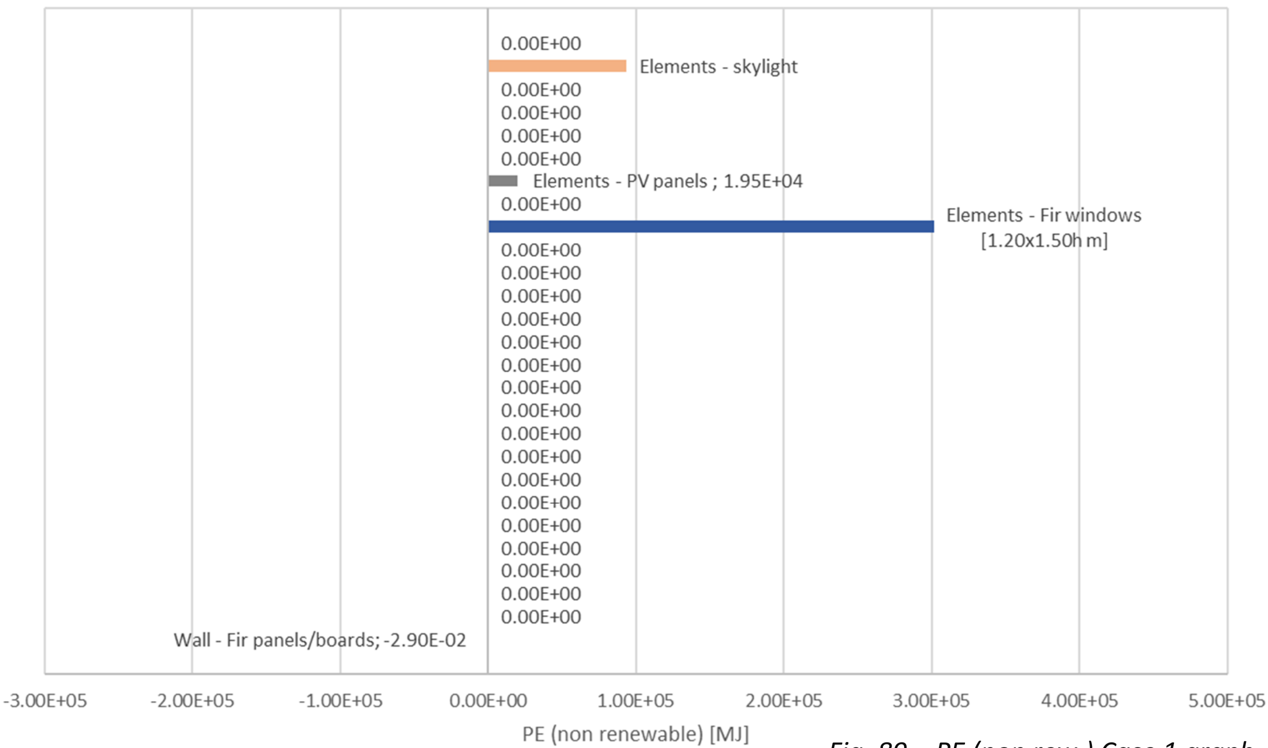


Fig. 89 – PE (non rew.) Case 1 graph

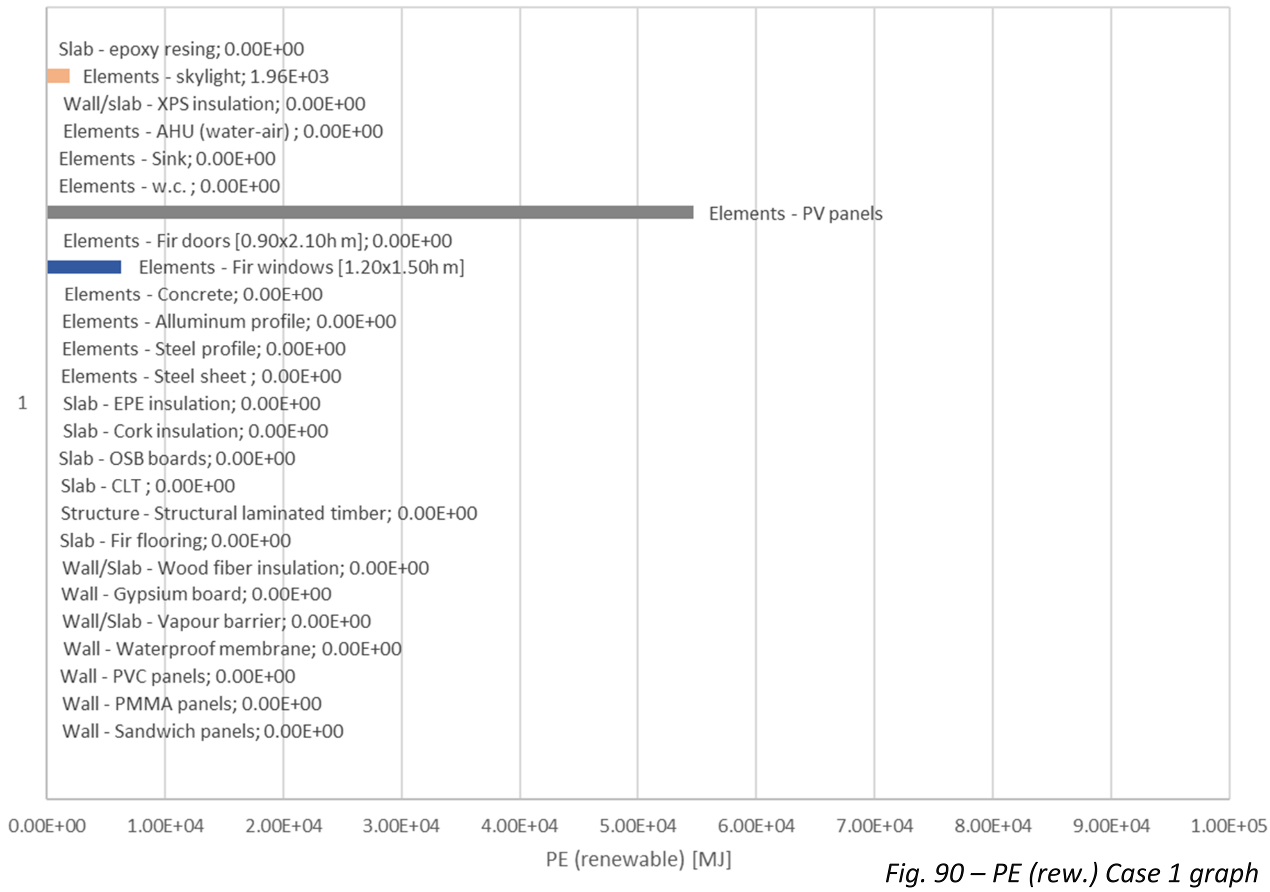


Fig. 90 – PE (rew.) Case 1 graph

The values relating to the POCP show an increase, proportionally to the graphs previously analyzed, of the PV system compared to the skylights; the value of the external wooden elements remains very low. Considering the primary energy, there is a decrease in solar panels compared to the other materials that characterize the graph of non-renewable energy, while for renewable energy the behavior is reversed with an increase in the PV system compared to other materials.

5.7.5 C1-C2-C3-C4 – End of life stage

This chapter lists the values related to the end of life stage; from this chapter onwards the Case 3 in considered.

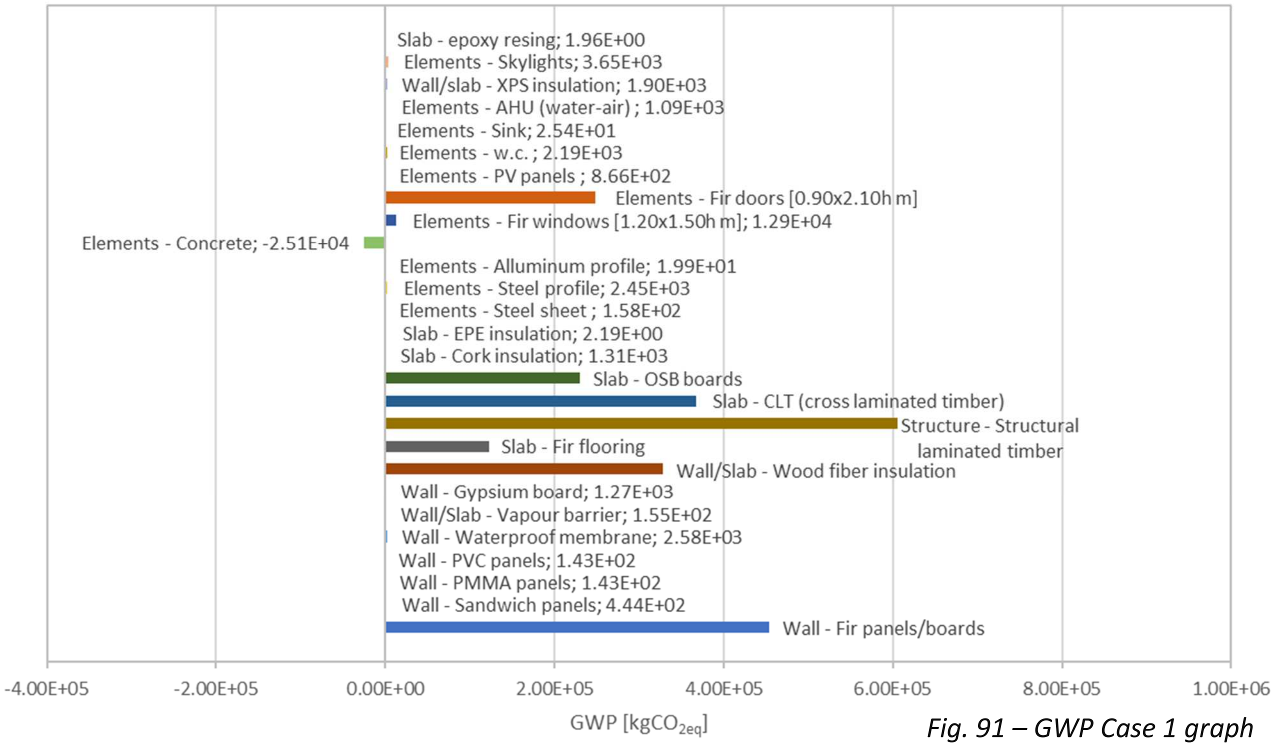


Fig. 91 – GWP Case 1 graph

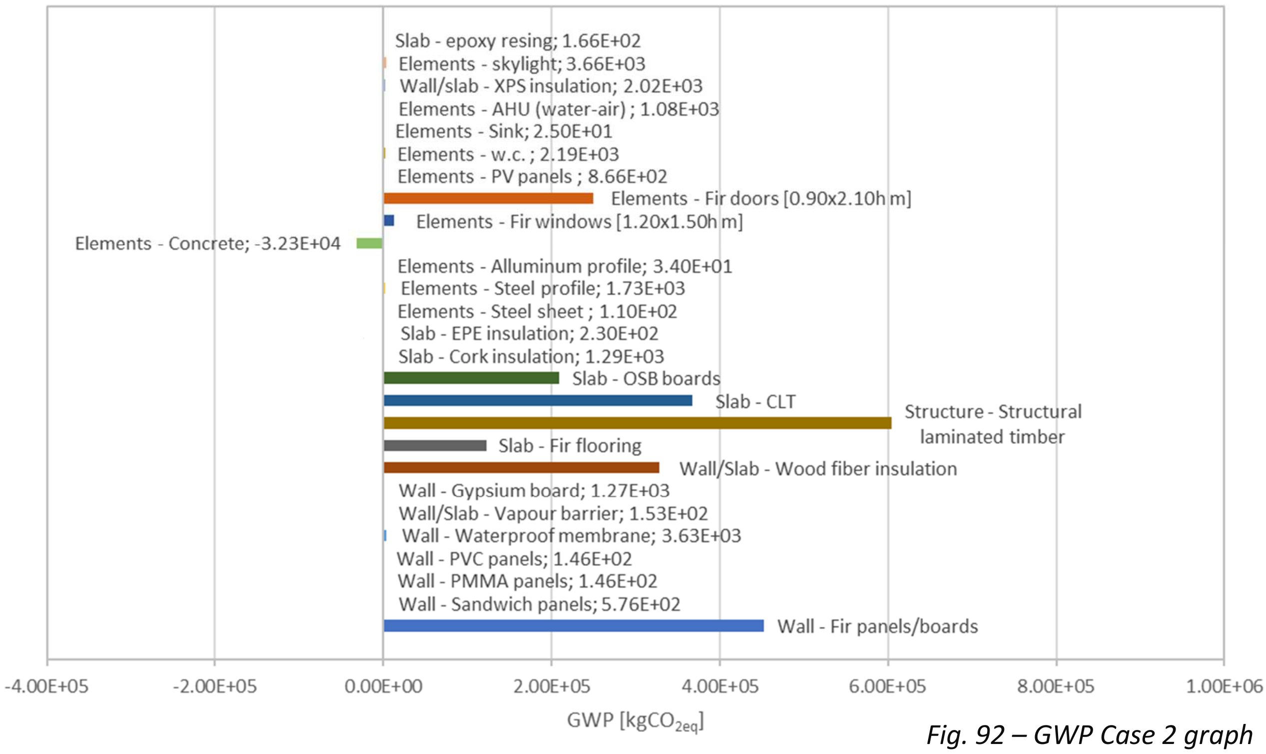


Fig. 92 – GWP Case 2 graph

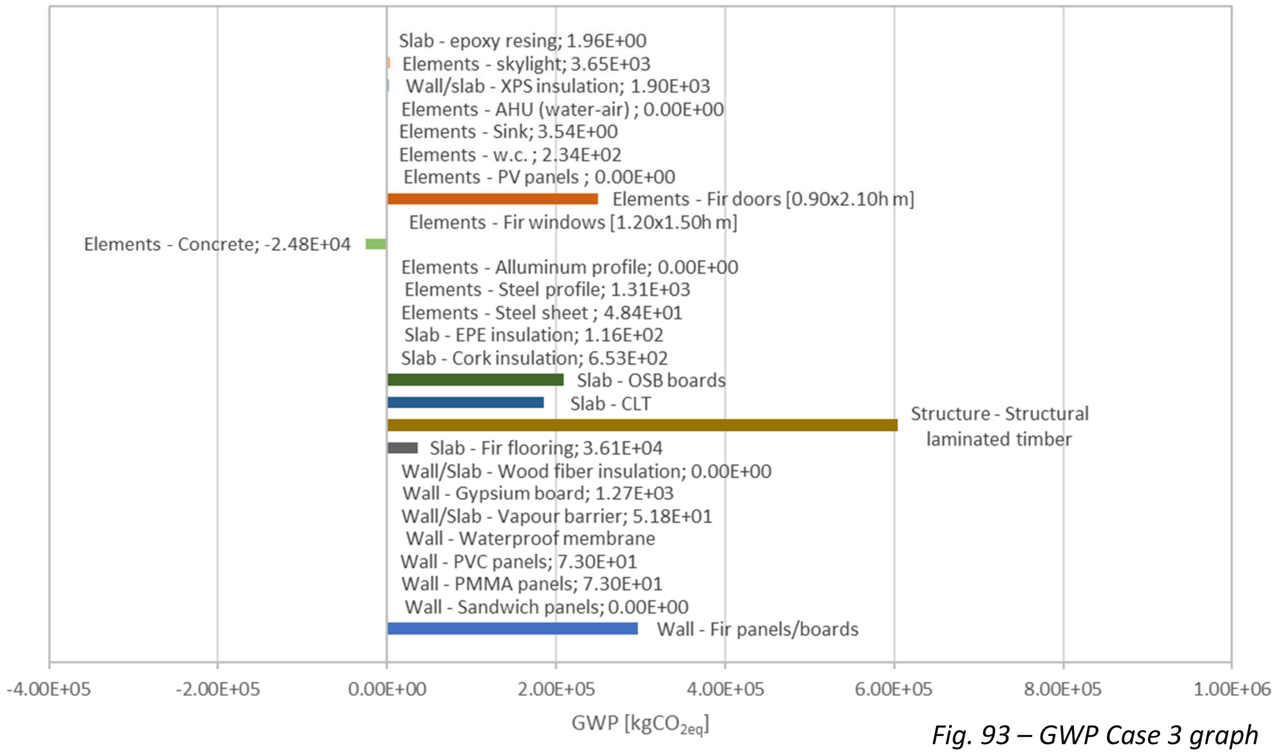


Fig. 93 – GWP Case 3 graph

Analyzing the graphs relating to the GWP it is possible to observe the equality between Case 1 and Case 2; in fact, the only difference between the two cases in this form is due to the materials added to Case 2 due to the non-portability. Case 3 has lower values due to the non-addition of design materials. The maximum value found in all cases is that of structural laminated timber which is used for the structure of the clusters already present.

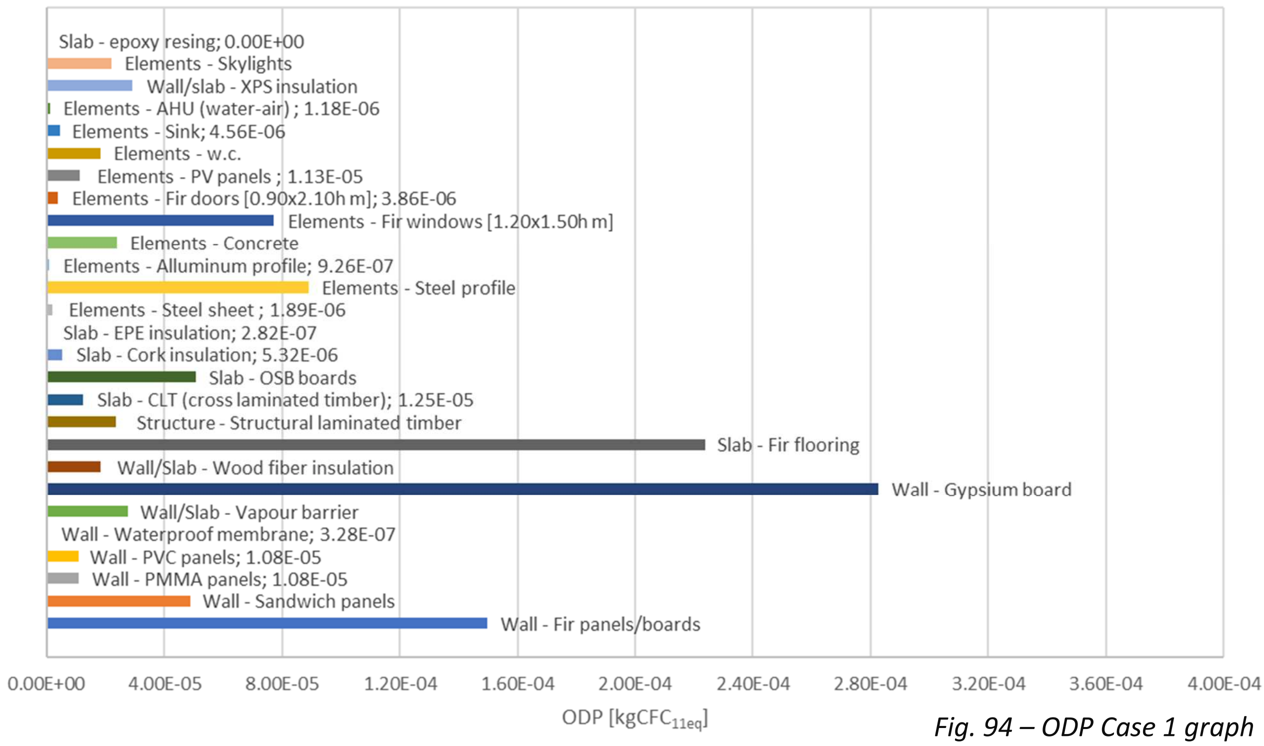


Fig. 94 – ODP Case 1 graph

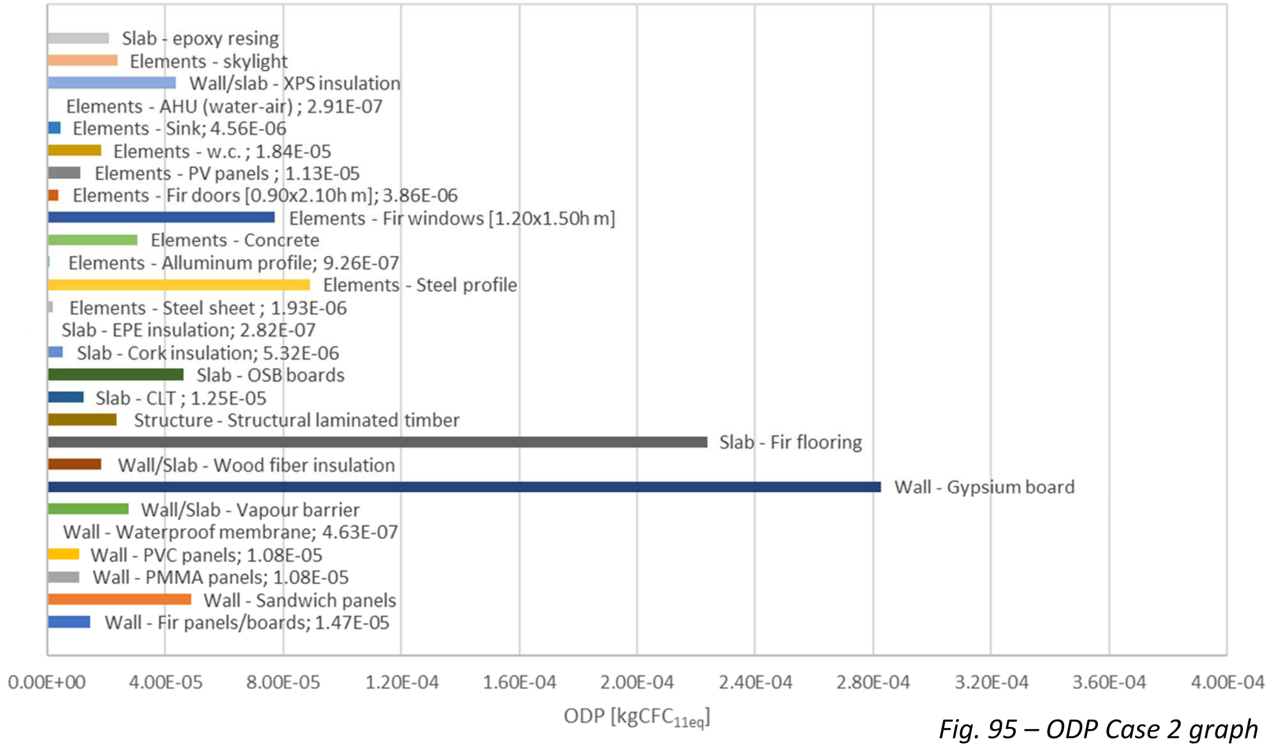


Fig. 95 – ODP Case 2 graph

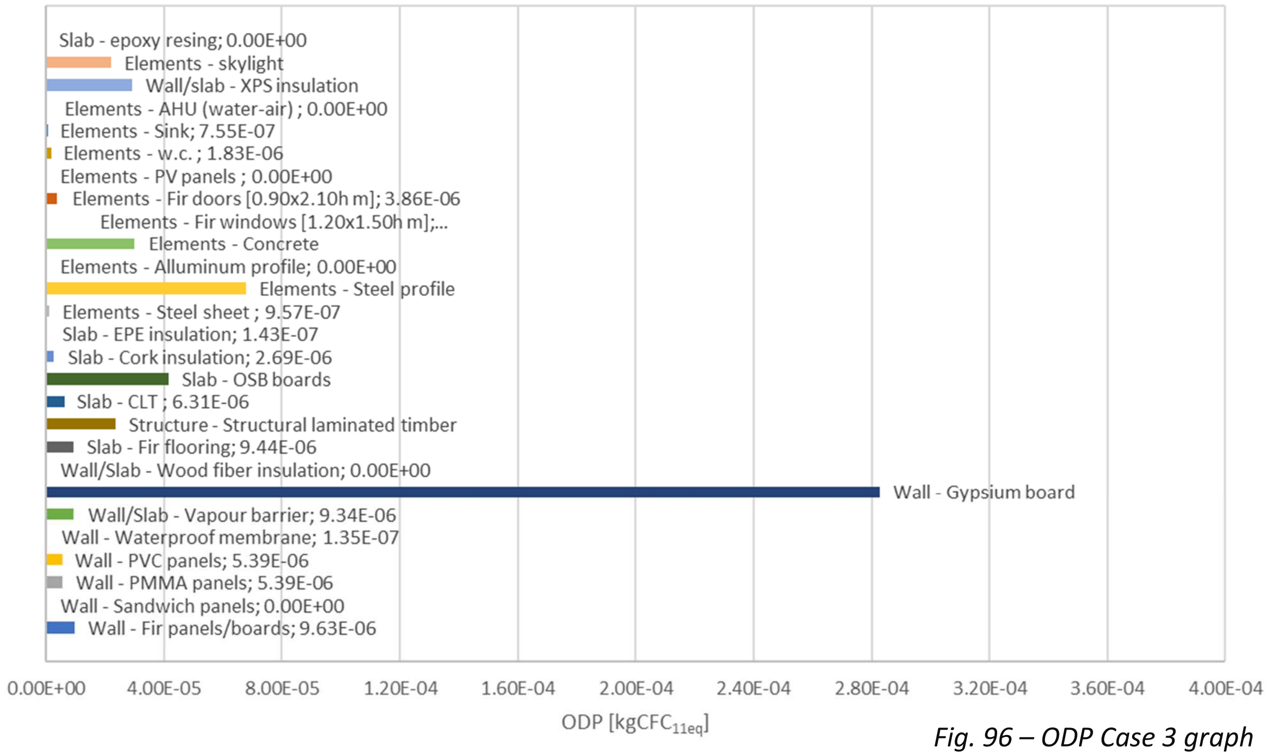


Fig. 96 – ODP Case 3 graph

The graphs relating to the ozone depletion potential confirm the behavior analyzed in the previous case. The maximum values are caused by the gypsum board in all cases and by the addition of fir flooring in Cases 1 and 2 (provided for in the SDP). In general, the steel profiles and the wood used for the external cladding, the latter only in the design cases, contribute significantly to the impact of this category.

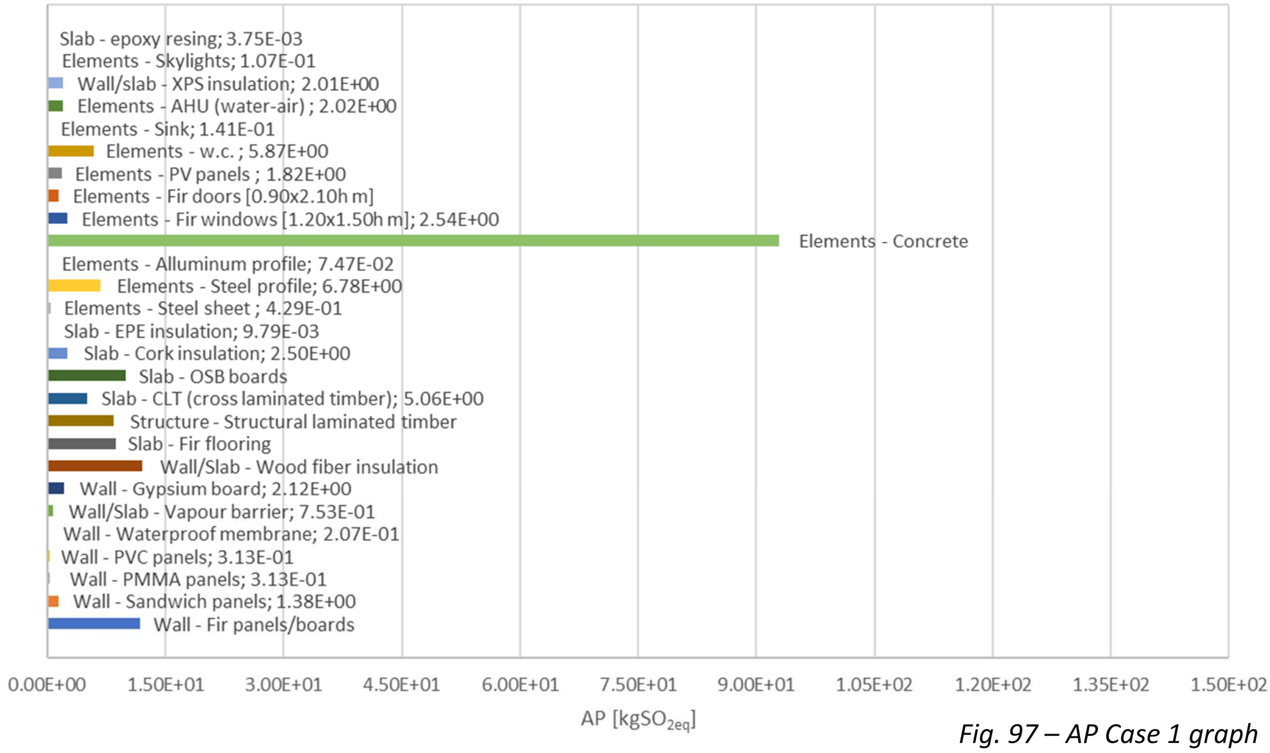


Fig. 97 – AP Case 1 graph

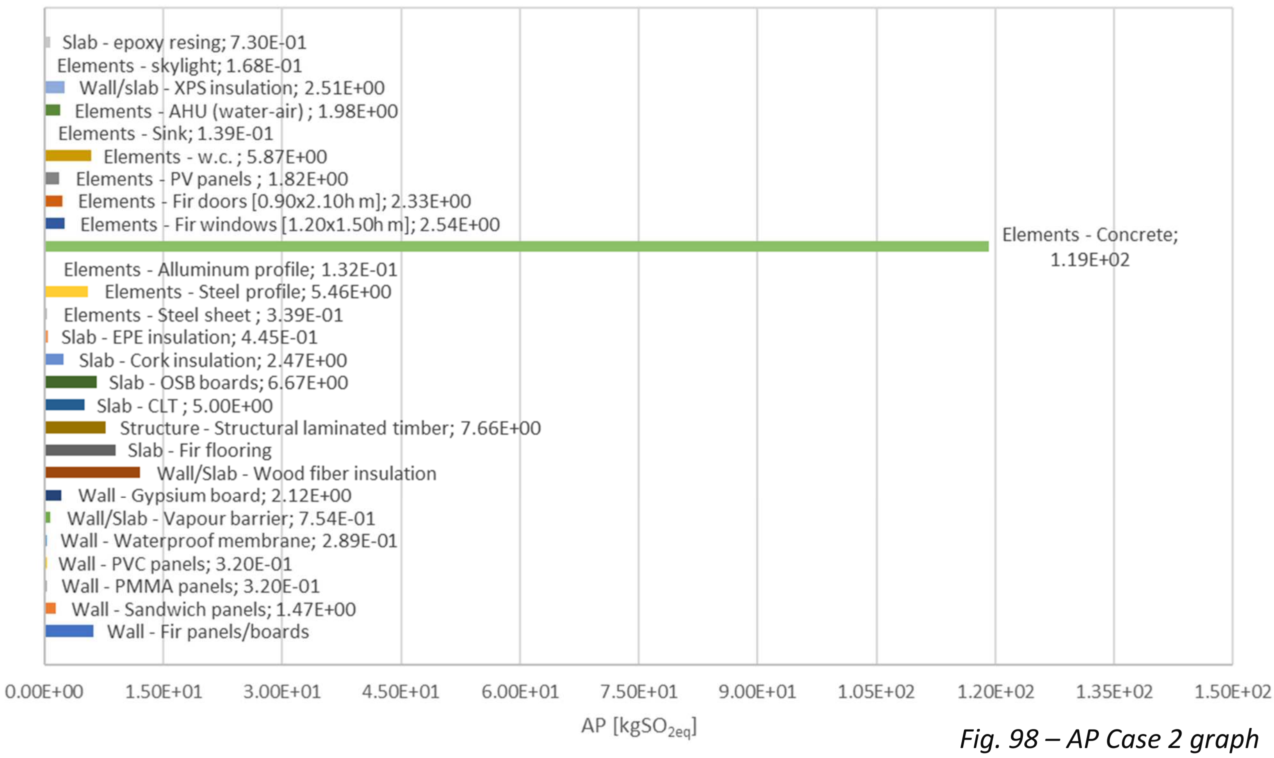


Fig. 98 – AP Case 2 graph

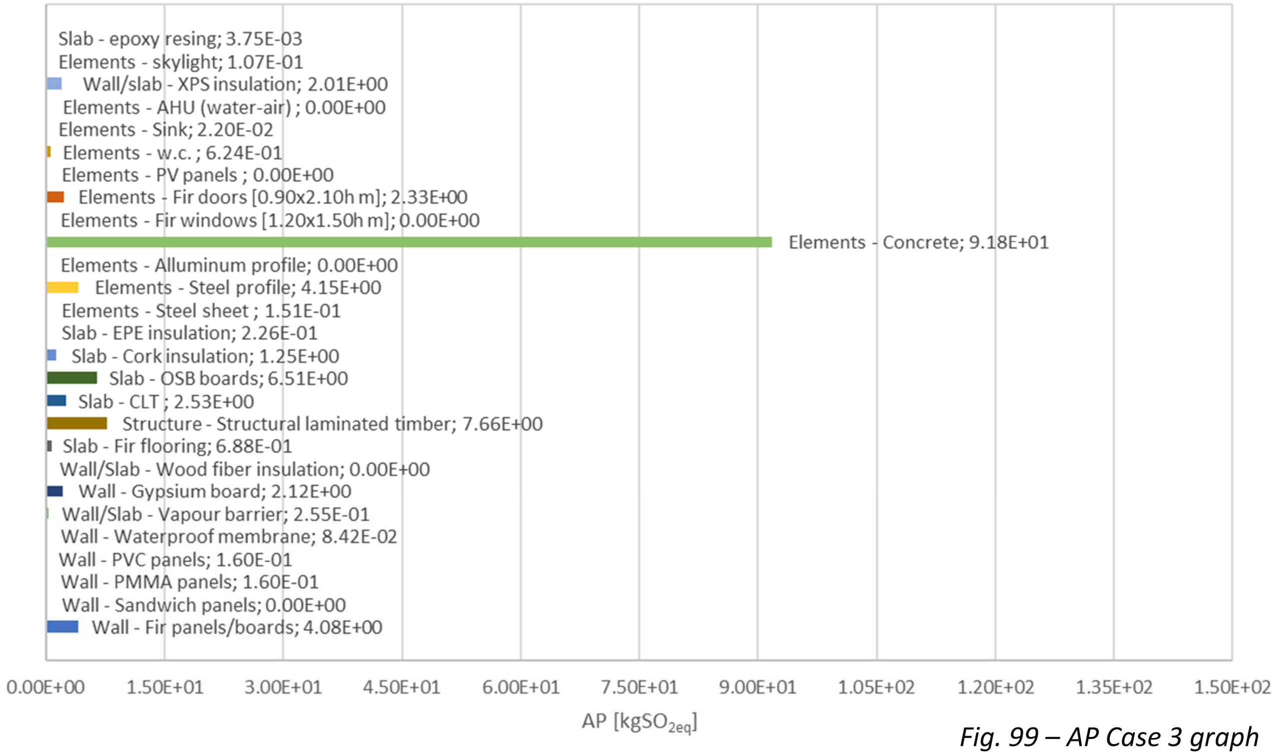


Fig. 99 – AP Case 3 graph

From the graphs relating to acidification potential, it is clear that the greatest contribution to the final impact of this category is given by the concrete. The maximum values are reached, as already noted, in Case 2. The other values present are for the most part of the same order of magnitude. Case 3 has significantly lower values.

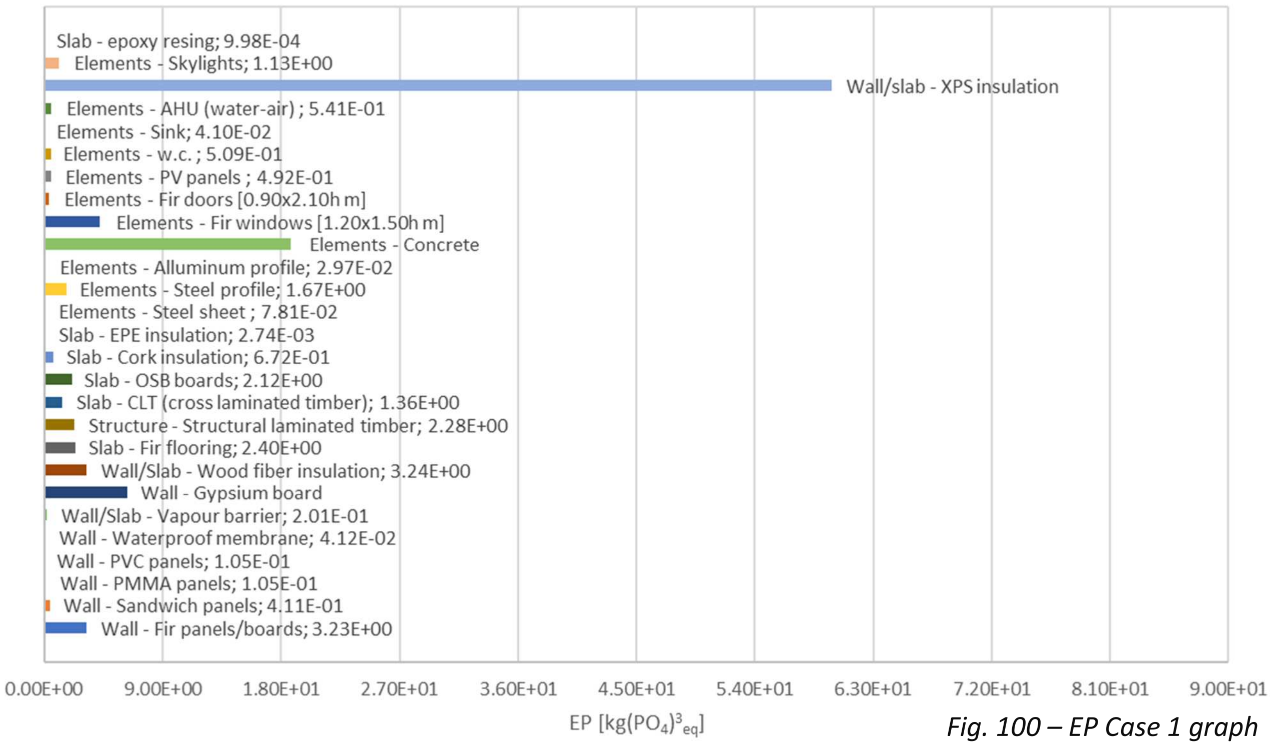


Fig. 100 – EP Case 1 graph

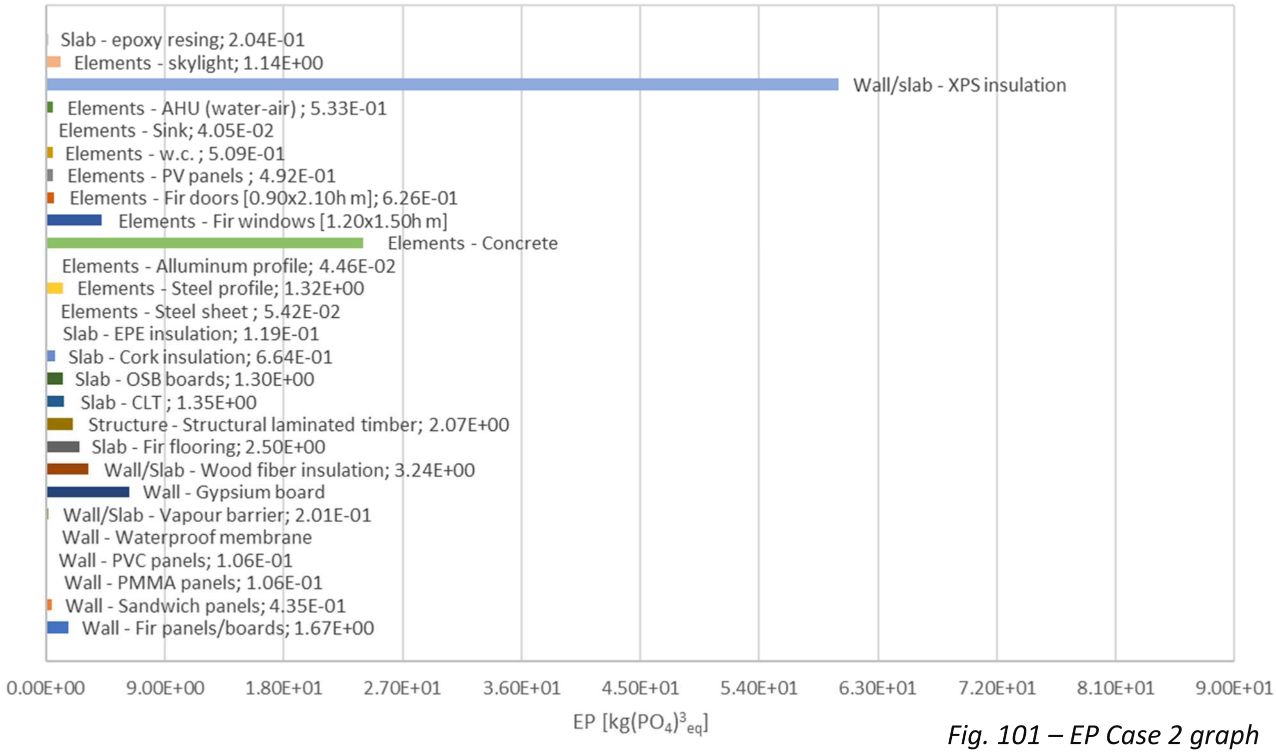


Fig. 101 – EP Case 2 graph

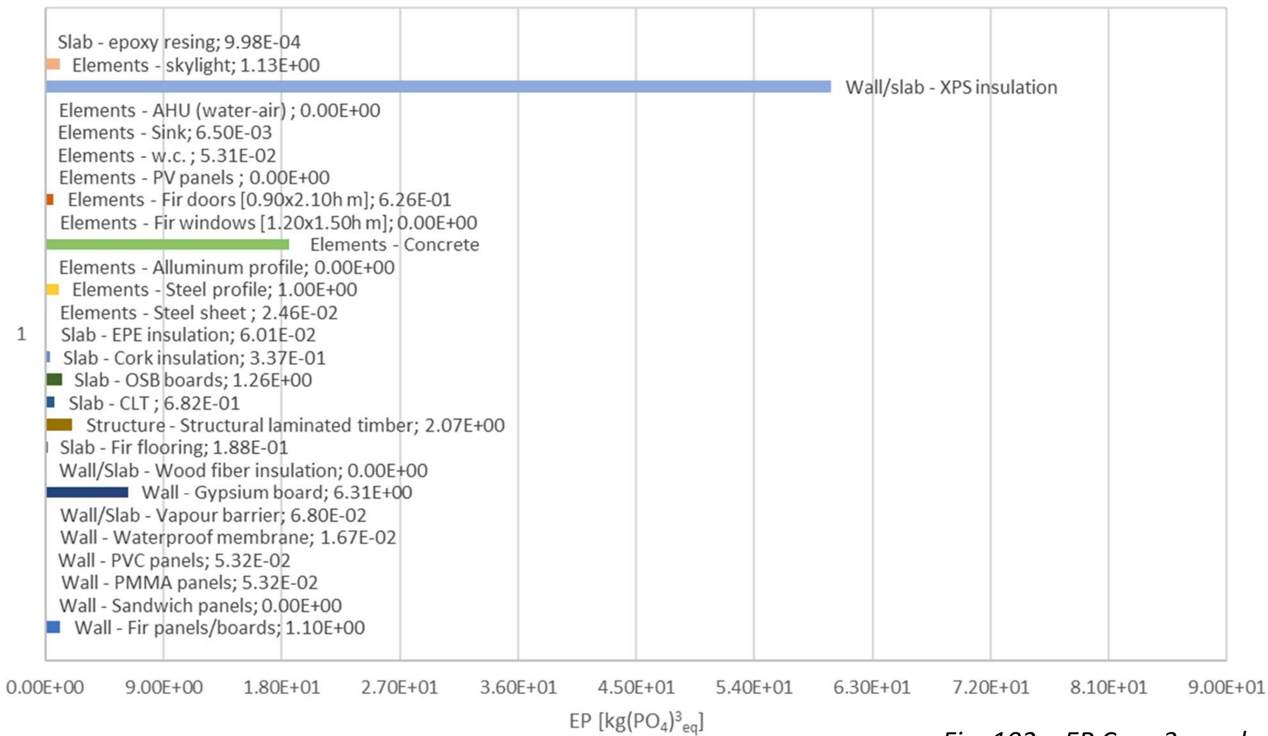


Fig. 102 – EP Case 3 graph

Considering eutrophication potential, it is possible to see that the maximum value, given by the insulation in XPS, is the same in all cases; this result is due to the presence of the XPS in the SDF and not added during the design phase, the material considered is therefore the same in all three cases. It is important to underline the contribution of the concrete which varies instead for each case. The behavior detectable in the graphs remains that observed in the previous cases.

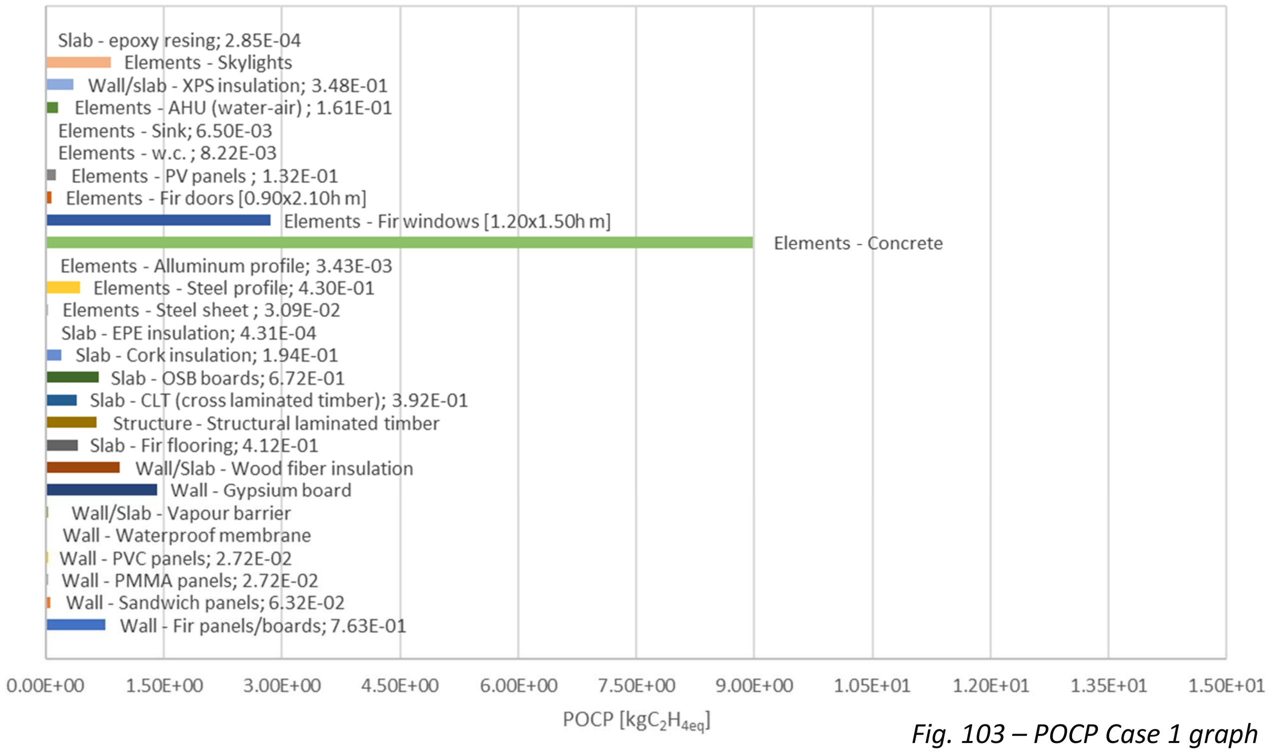


Fig. 103 – POCP Case 1 graph

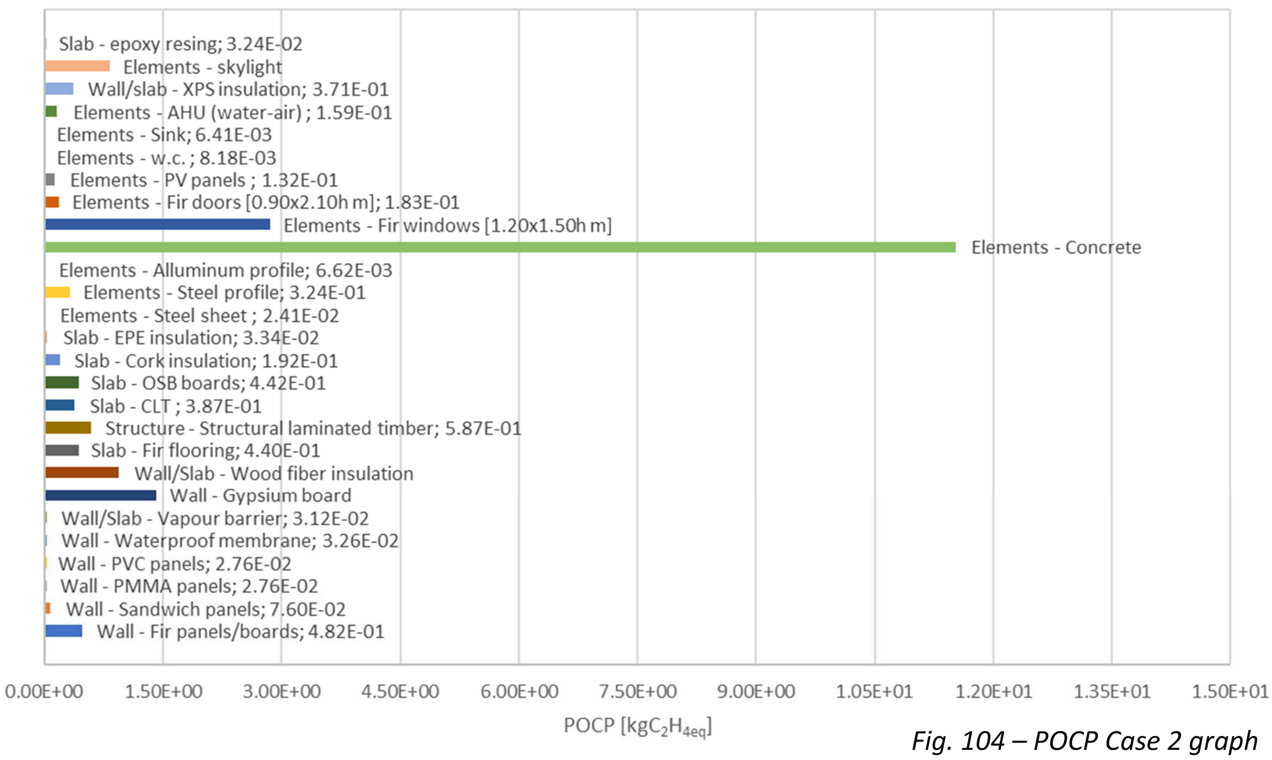


Fig. 104 – POCP Case 2 graph

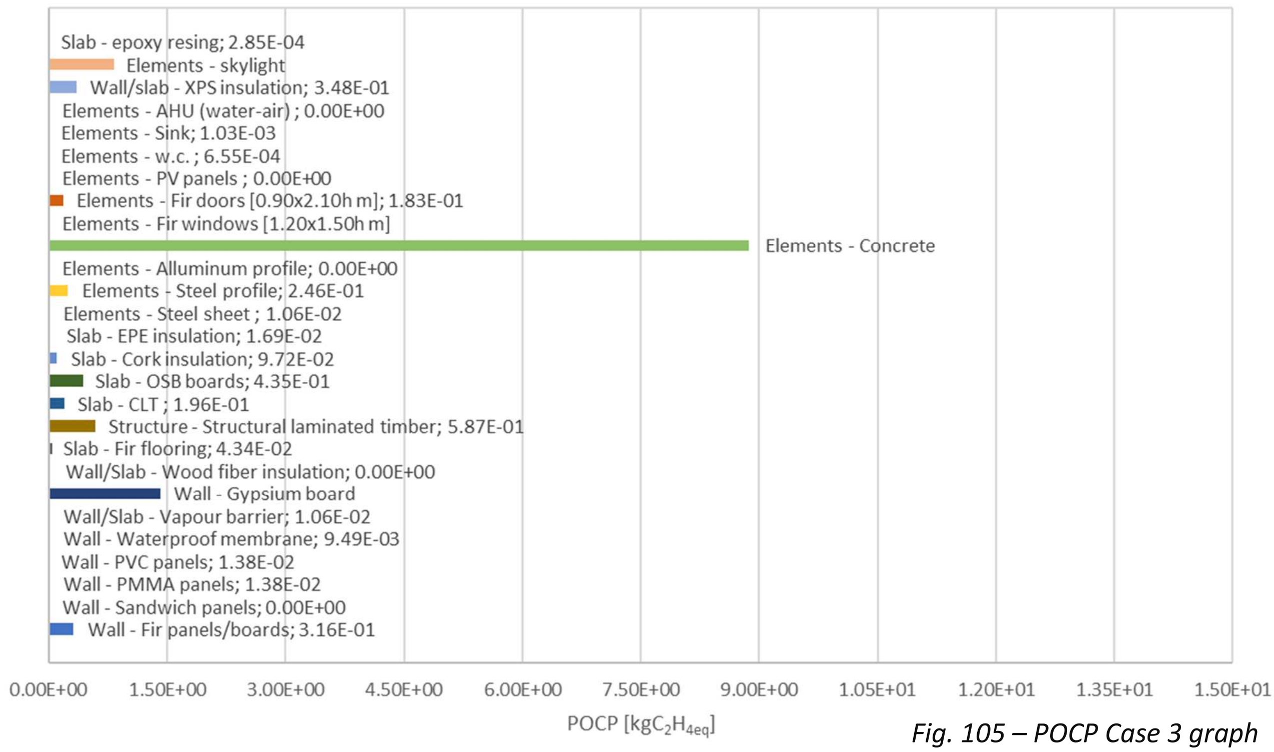


Fig. 105 – POCP Case 3 graph

The graphs relating to the photochemical ozone creation potential have at most the concrete variation, according to the logic described above, for each case. Gypsum panels and windows also contribute in part to the final result, the latter only in cases where the SDP is expected to be built.

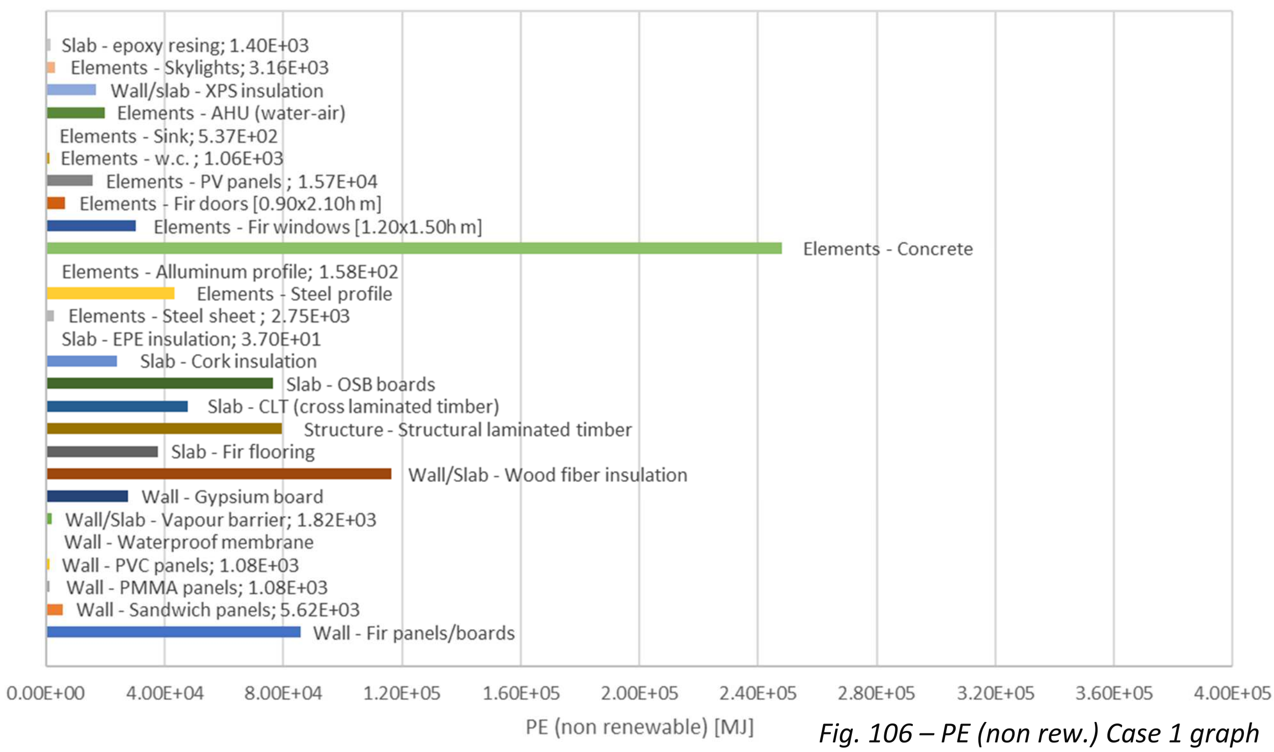


Fig. 106 – PE (non rew.) Case 1 graph

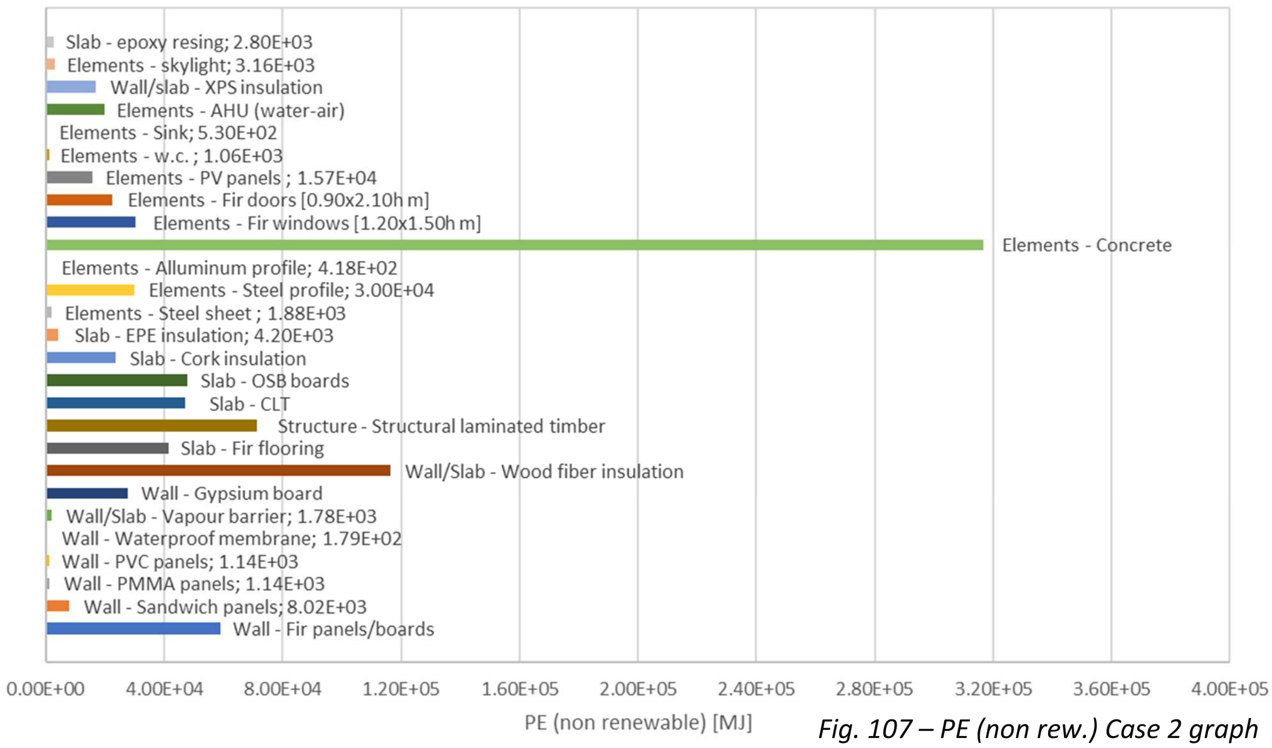


Fig. 107 – PE (non rew.) Case 2 graph

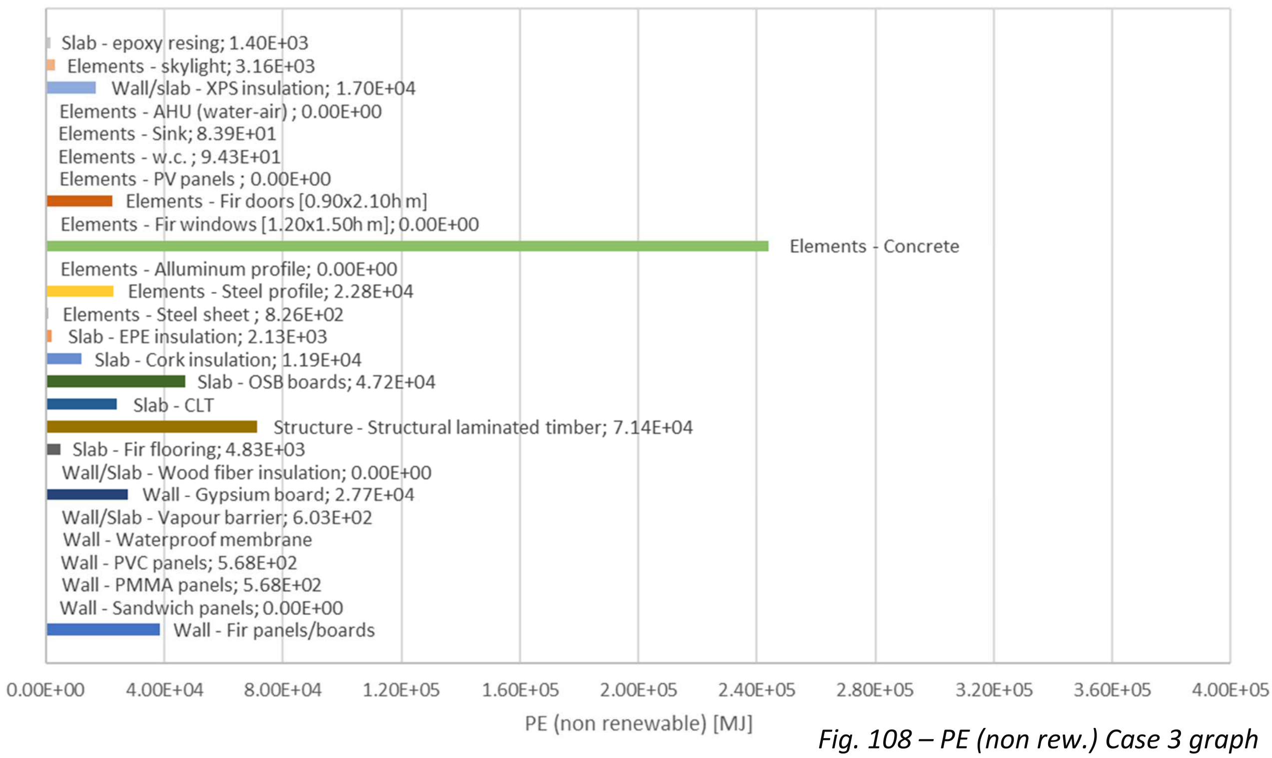


Fig. 108 – PE (non rew.) Case 3 graph

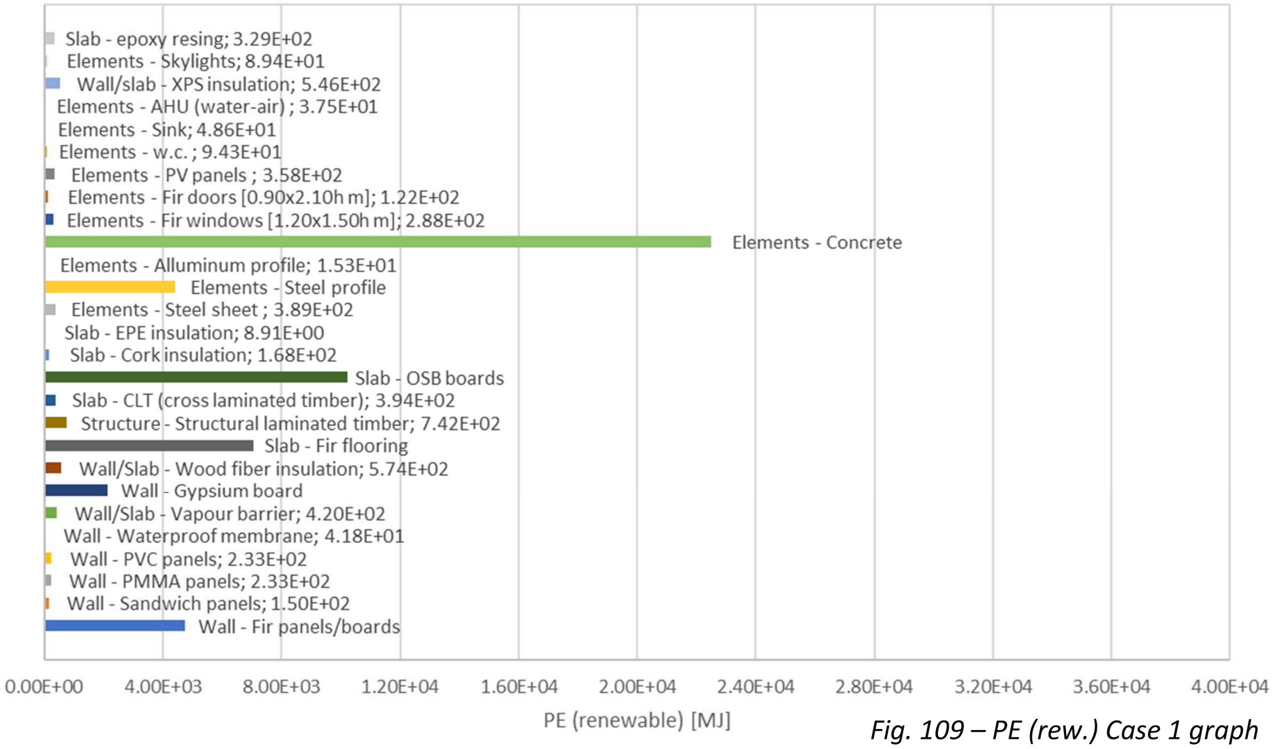


Fig. 109 – PE (rew.) Case 1 graph

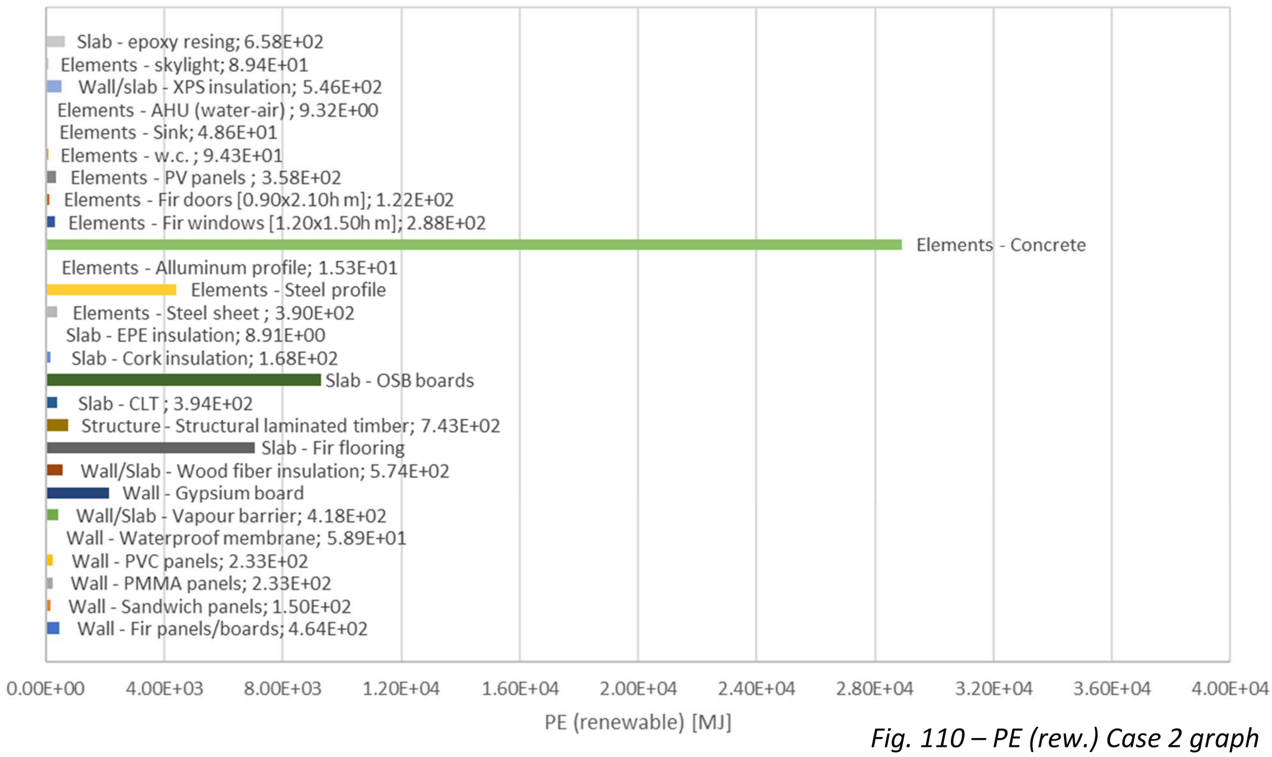


Fig. 110 – PE (rew.) Case 2 graph

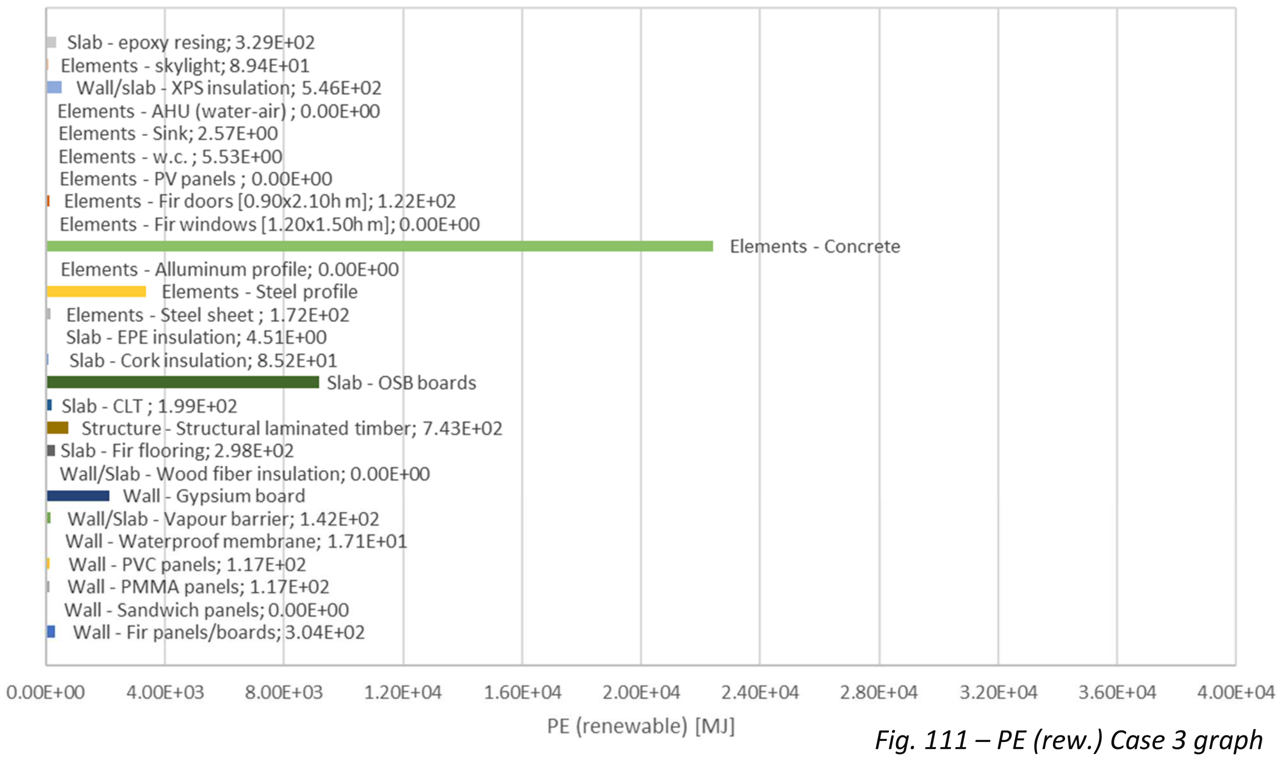


Fig. 111 – PE (rew.) Case 3 graph

In all the cases presented relating to primary energy the maximum value is constituted by cement. The behavior of the graphs remains that already observed in the previous cases, Case 2 has the highest values and is similar to Case 1 while Case 3 has the lowest values being the intervention relating only to demolition.

The graphs relating to the non-renewable primary energy show higher values than the renewable; most of the values, excluding those relating to the concrete, are of the same order of magnitude and are therefore uniform. The wood used for the existing structure, as well as the insulation for the design cases only, contributes significantly to the final impact of this category.

The graphs relating to renewable primary energy show fewer uniform values with different orders of magnitude. The OSB panels and steel profiles are, together with cement, the maximum values shown in the graph.

5.7.6 D – Benefit and loads beyond the system boundaries

This chapter lists the values related to benefit and loads beyond the system boundaries stage.

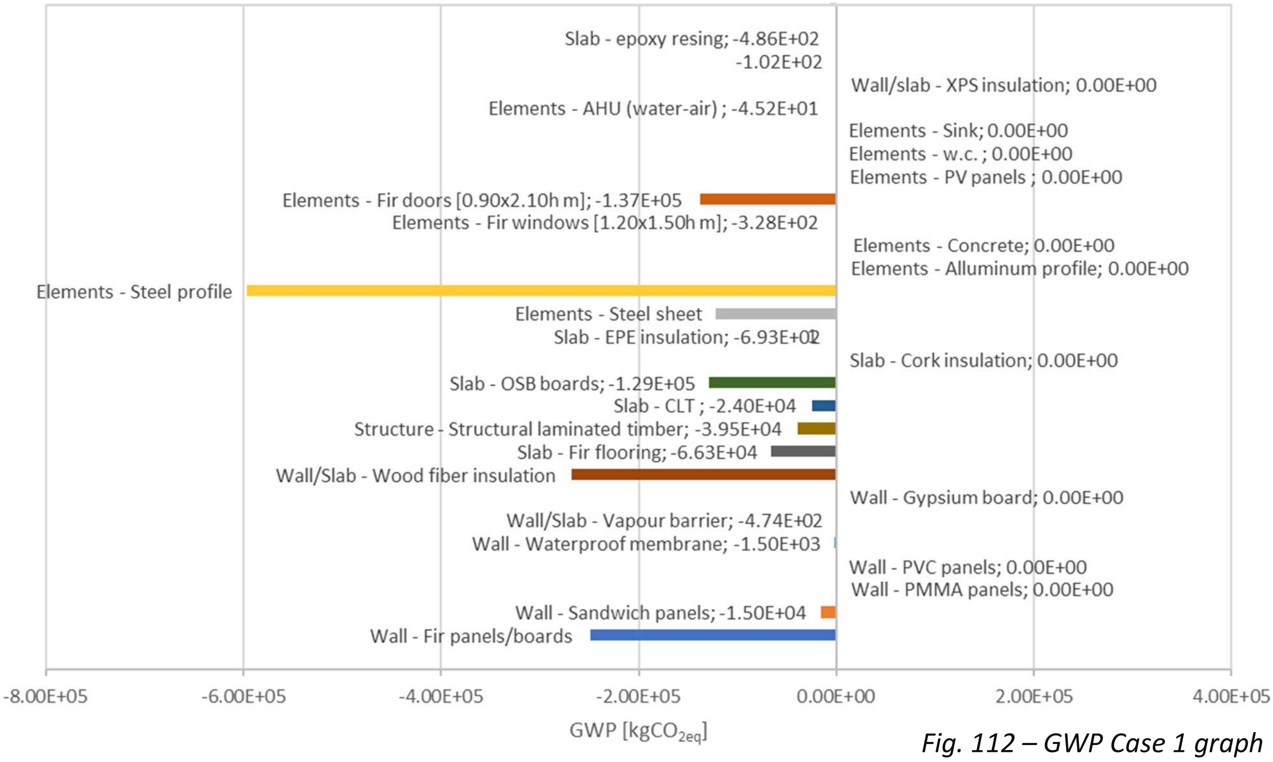


Fig. 112 – GWP Case 1 graph

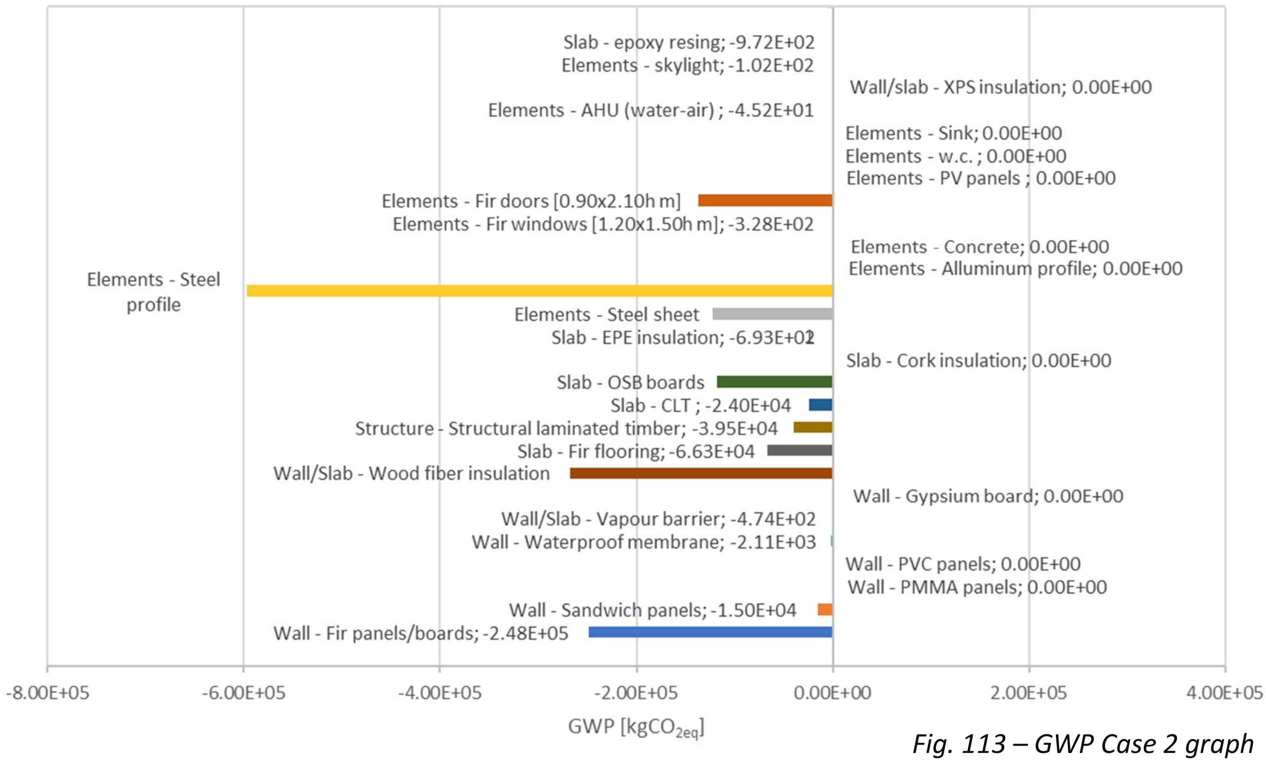


Fig. 113 – GWP Case 2 graph

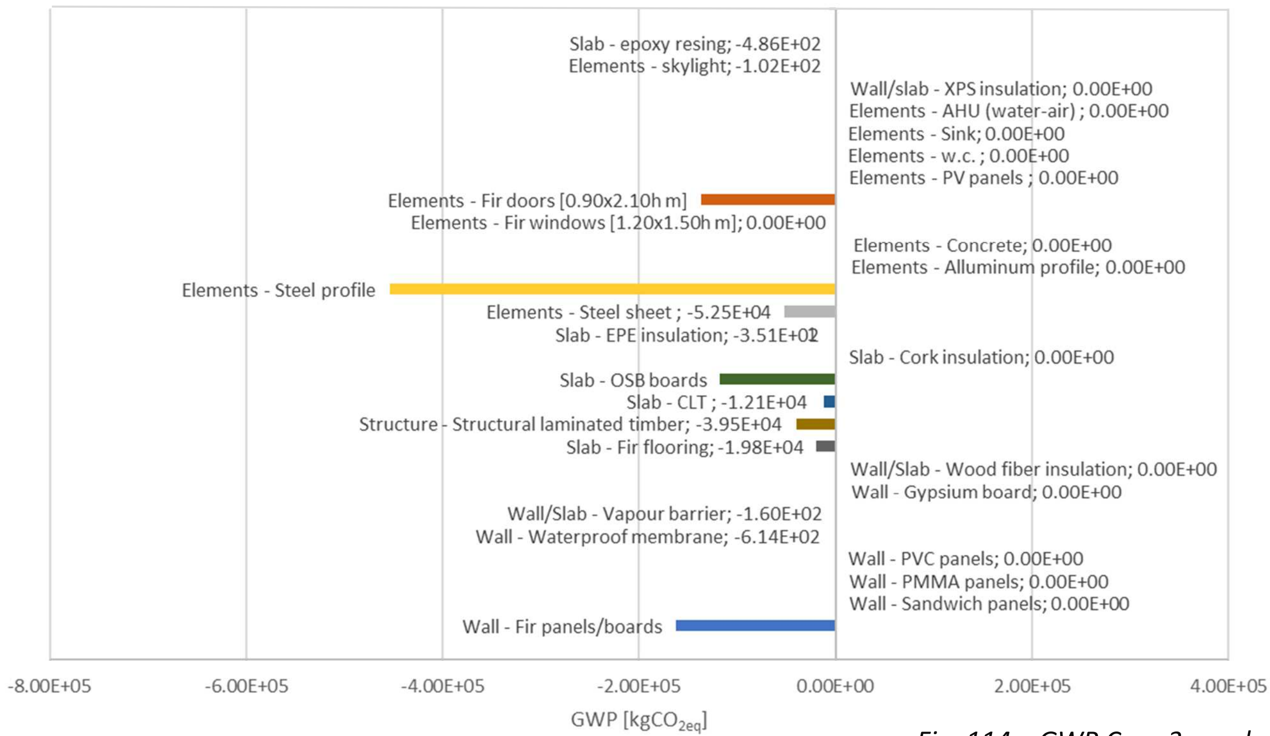


Fig. 114 – GWP Case 3 graph

The global warming potential analysis returns similar values for Case 1 and 2. This result is due to the equality in quantity of most of the material in the two project proposals; some values are however dissimilar since it is necessary, in Case 2, to add some materials that are not transportable from the SDF. Case 3 has reduced values compared to the first two cases since no material was added.

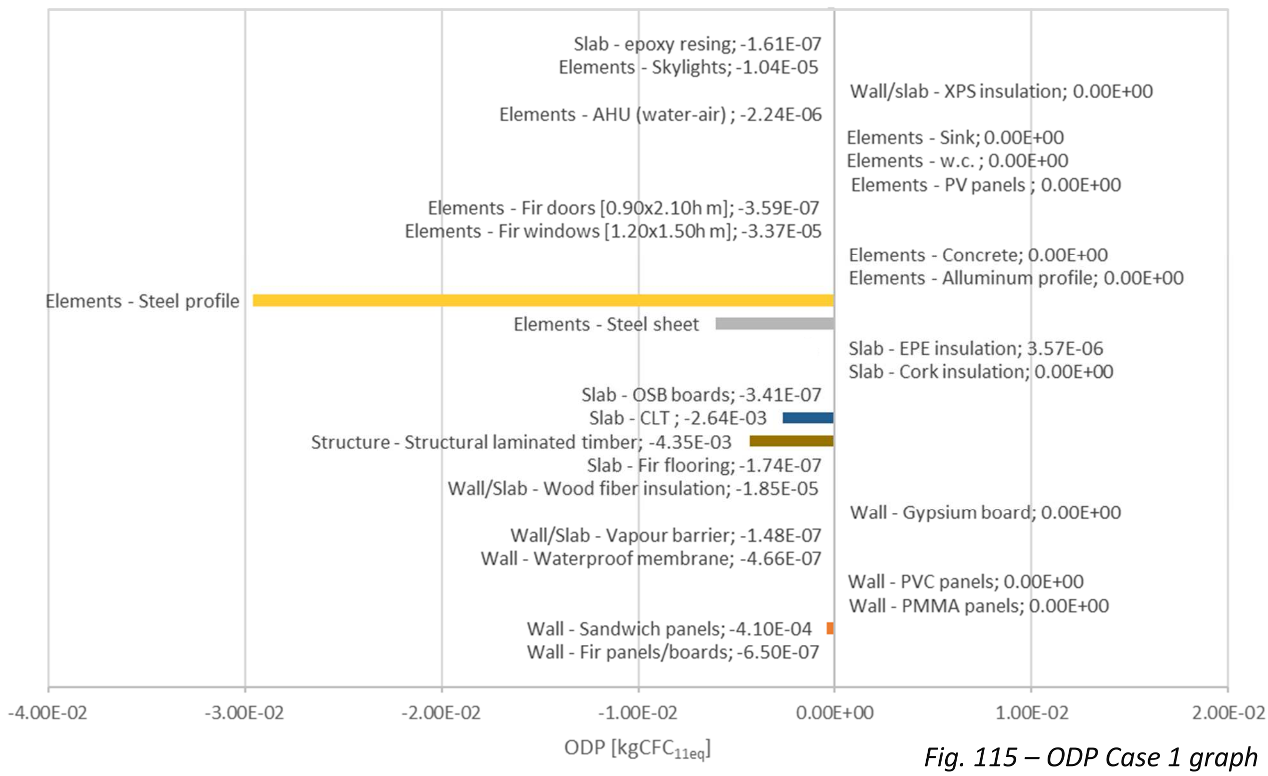


Fig. 115 – ODP Case 1 graph

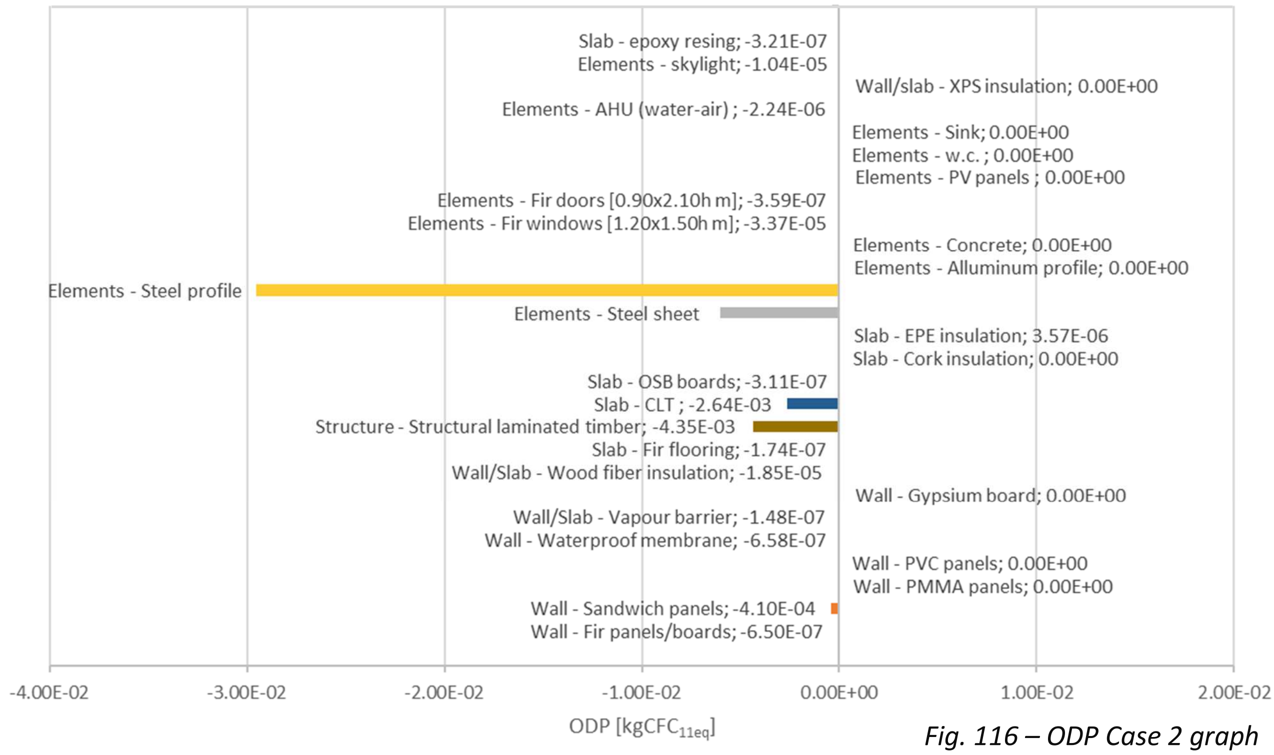


Fig. 116 – ODP Case 2 graph

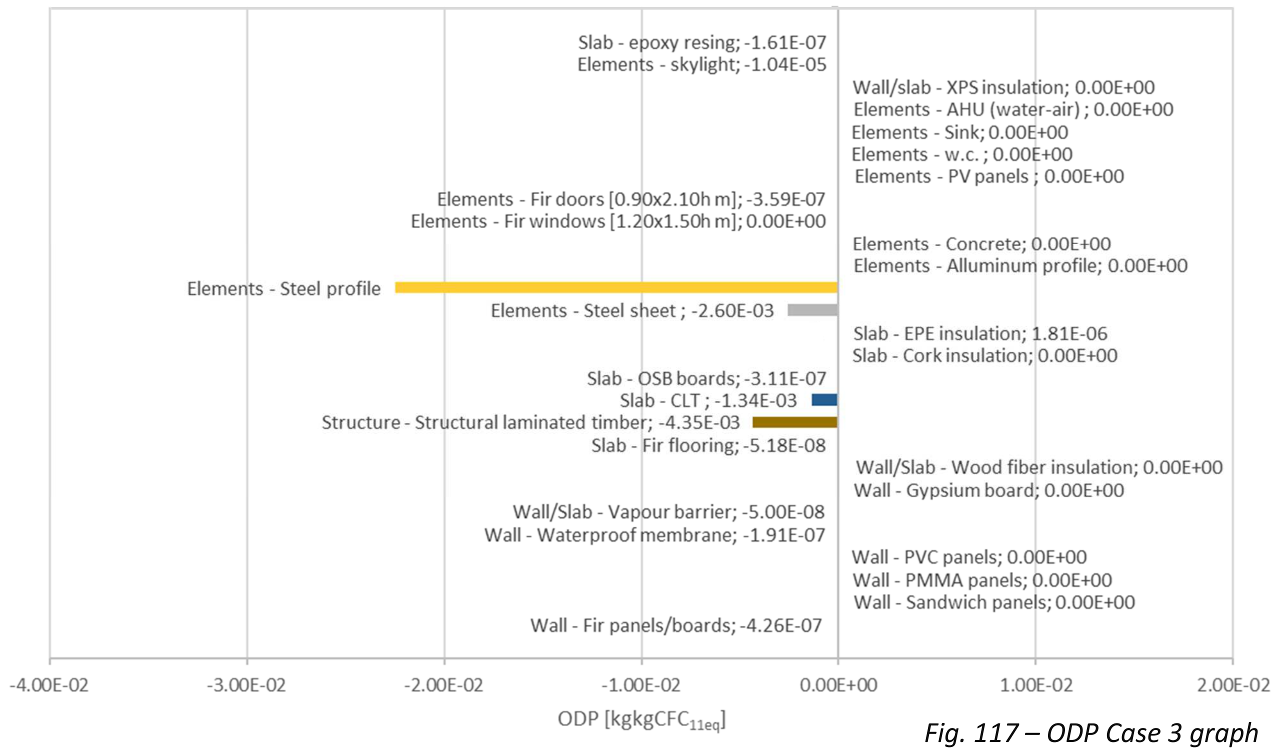


Fig. 117 – ODP Case 3 graph

In the case of the graphs relating to the ODP, it is possible to observe a behavior, among the various cases, similar to that already observed previously. In this case the iron profiles constitute the greatest load for this equivalent emission, followed by some wooden elements of the structure and the steel sheets. Many materials have values equal to zero.

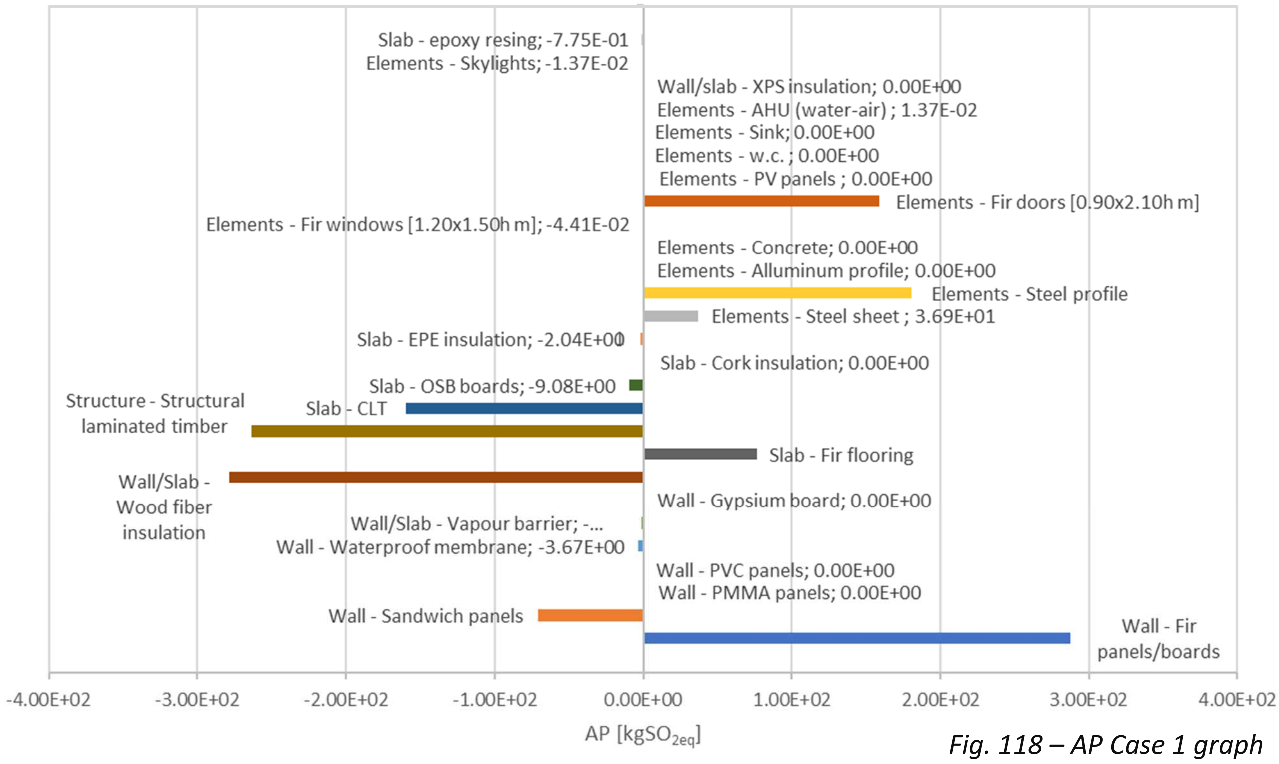


Fig. 118 – AP Case 1 graph

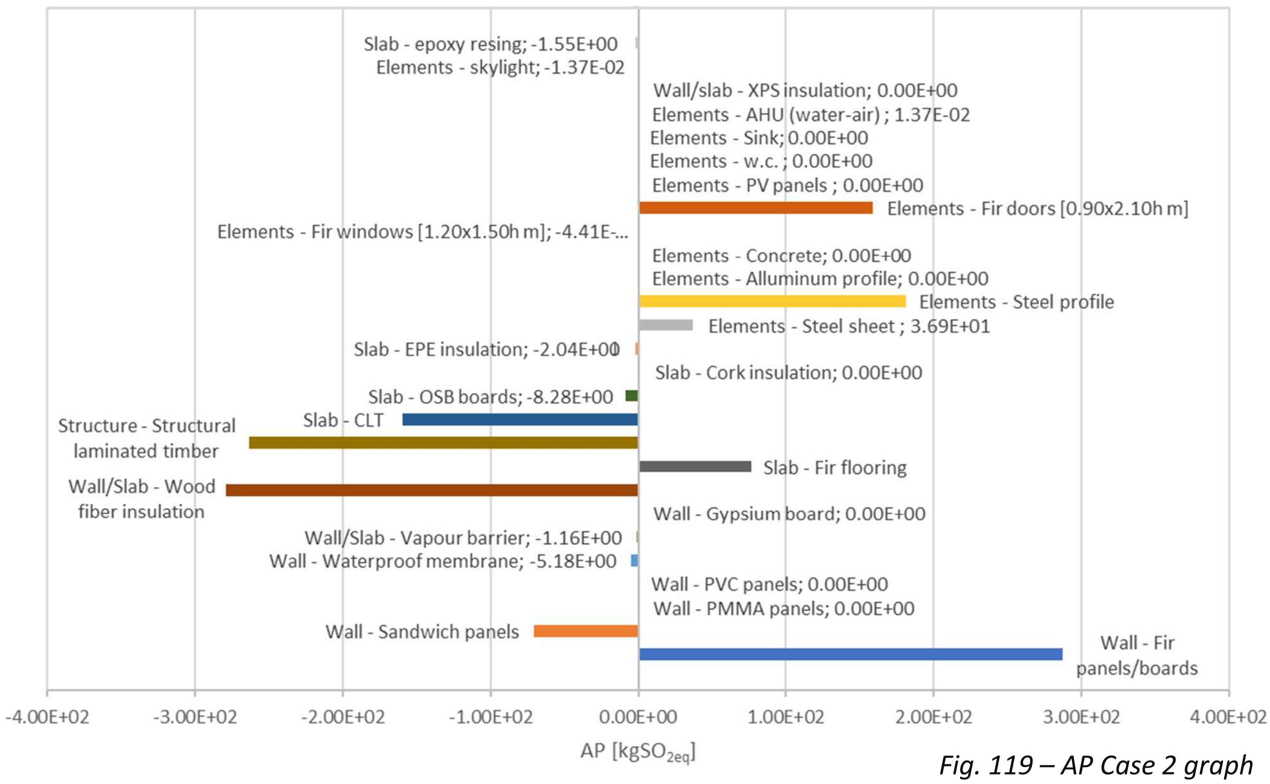


Fig. 119 – AP Case 2 graph

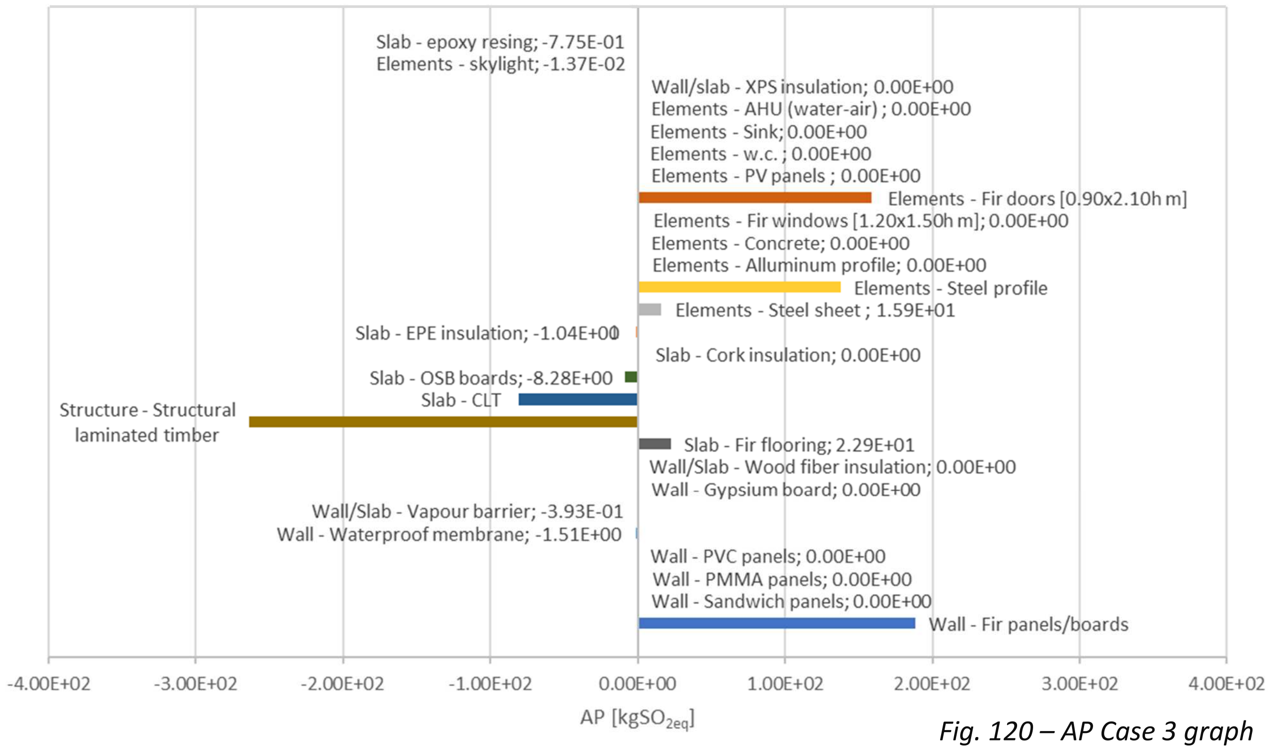


Fig. 120 – AP Case 3 graph

In the AP graphs there are several materials that determine the total impact; the wooden finishing products as well as the materials used for the structure and for the insulation determine the maximum values found in the graph. The values also depend on the difference in the quantity of materials used in the project (all the materials that make up the maxima are present in large quantities). The overall values are not homogeneous and have different orders of magnitude.

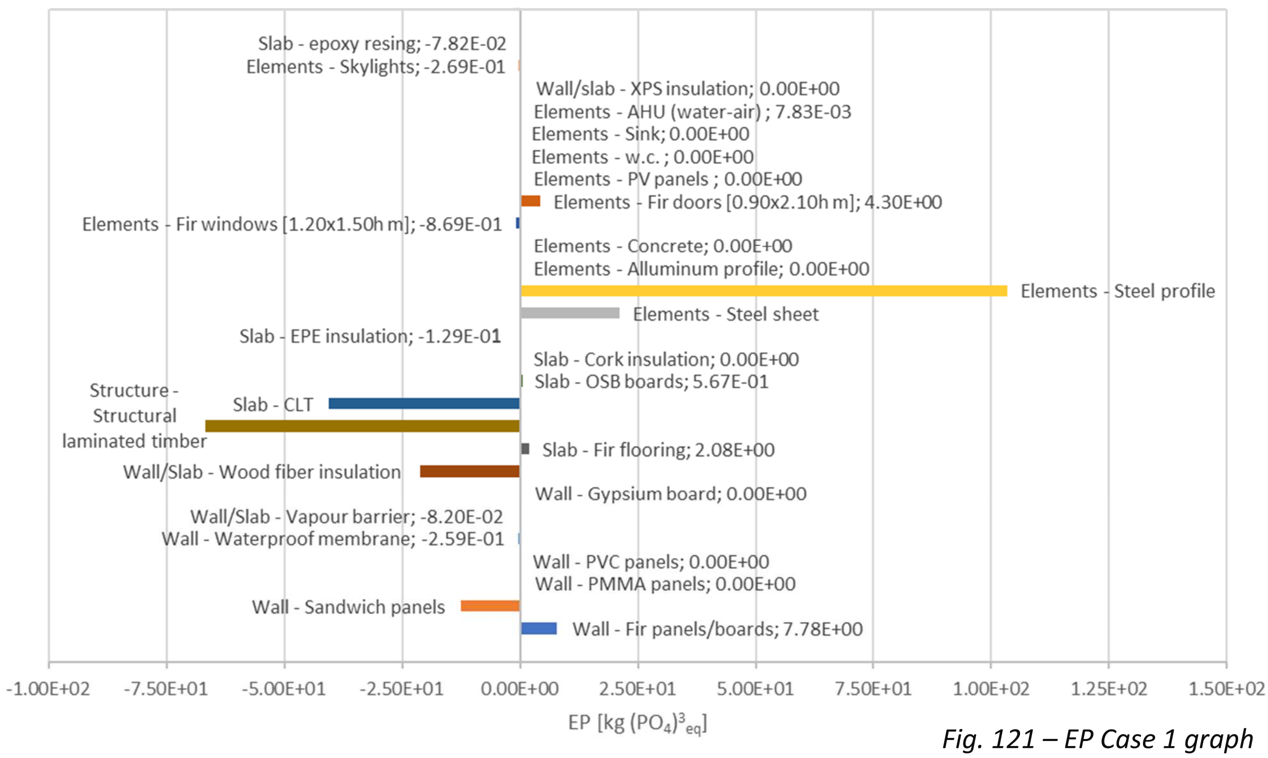


Fig. 121 – EP Case 1 graph

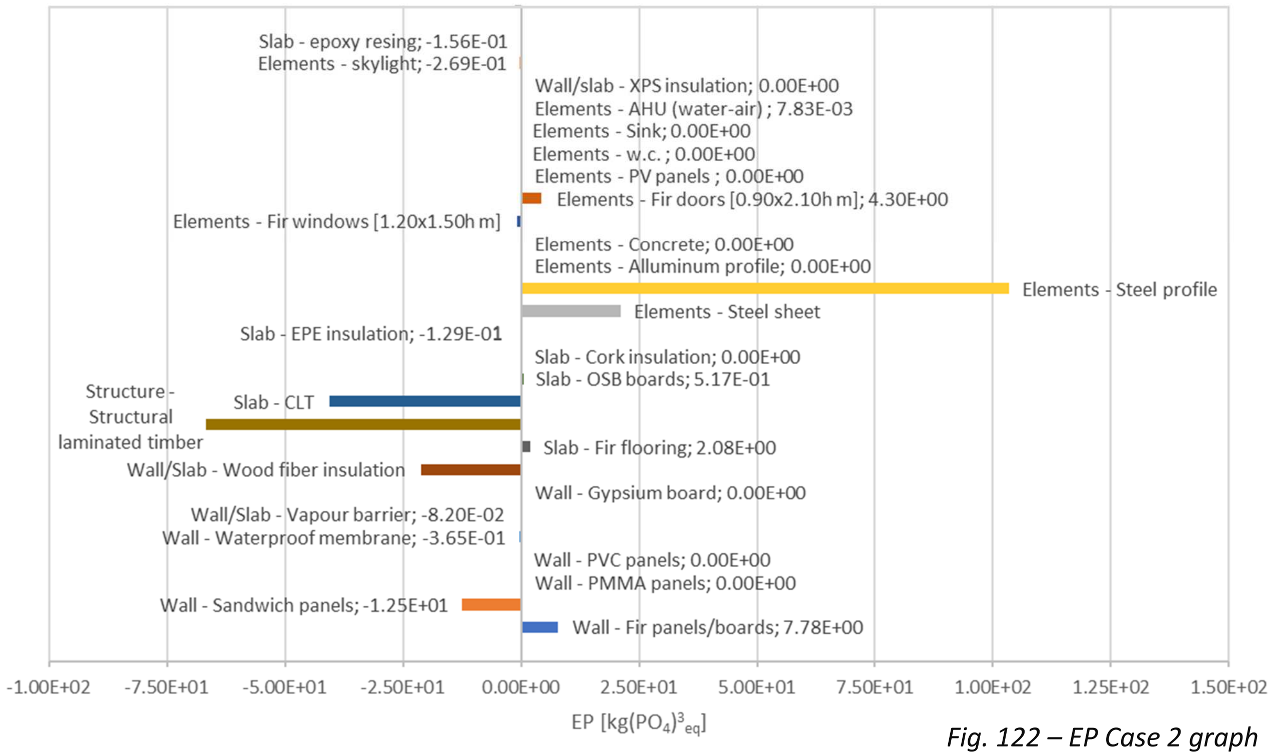


Fig. 122 – EP Case 2 graph

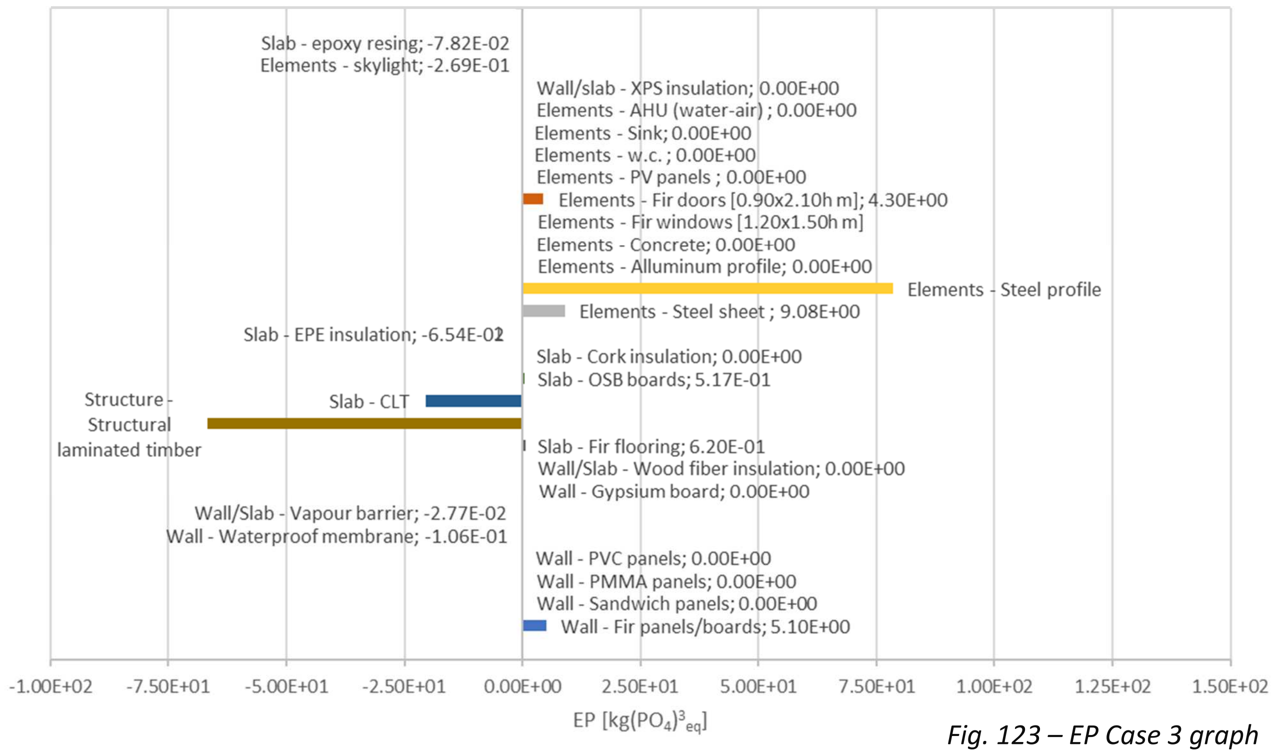


Fig. 123 – EP Case 3 graph

Considering the eutrophication potential graph, the values of the first two graphs continue to be similar to each other while Case 3 has reduced values. In this case, the material that constitutes the maximum impact is the metal profiles while the wooden products continue to represent an element of characterization even if with reduced values.

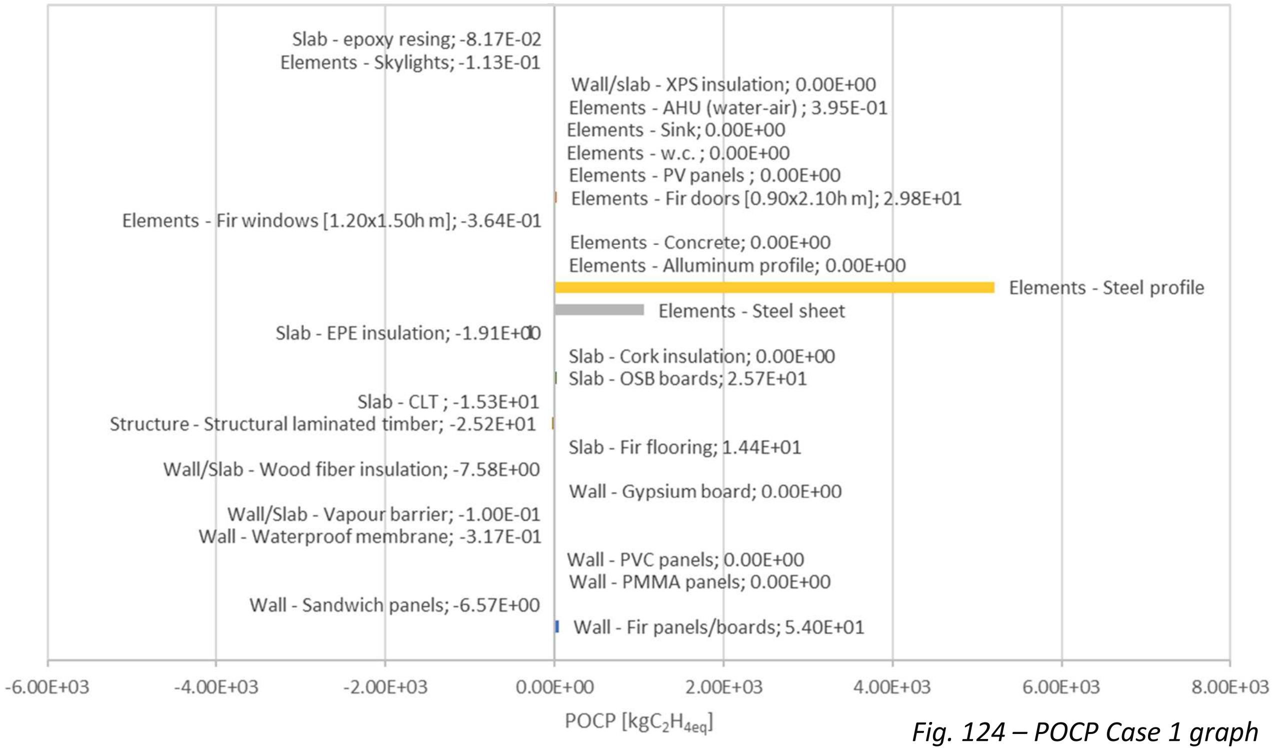


Fig. 124 – POCP Case 1 graph

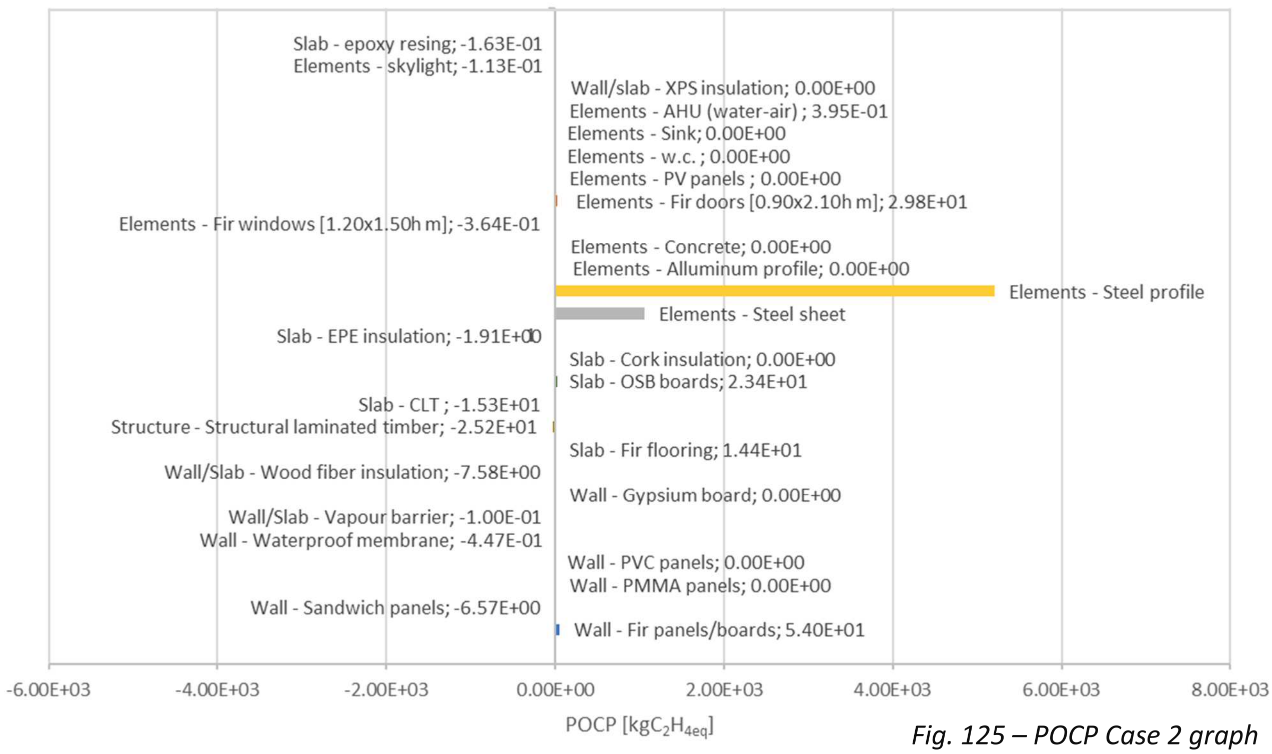


Fig. 125 – POCP Case 2 graph

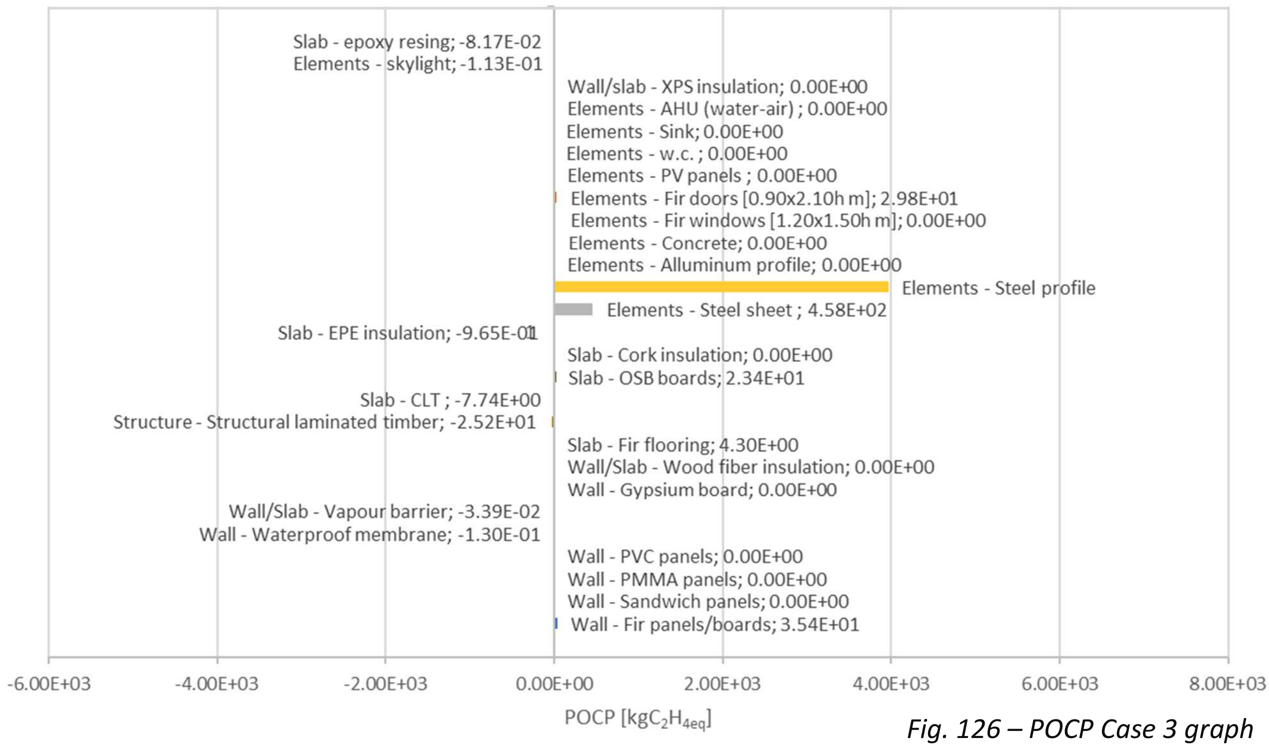


Fig. 126 – POCP Case 3 graph

In the graphs it is possible to note that only two values have an order of magnitude such as to influence the final value of the equivalent emission; The steel profiles as well as the steel sheets represent the maximums present in the graph. The other values in the graph are small compared to the two values relating to steel and therefore do not affect the graph.

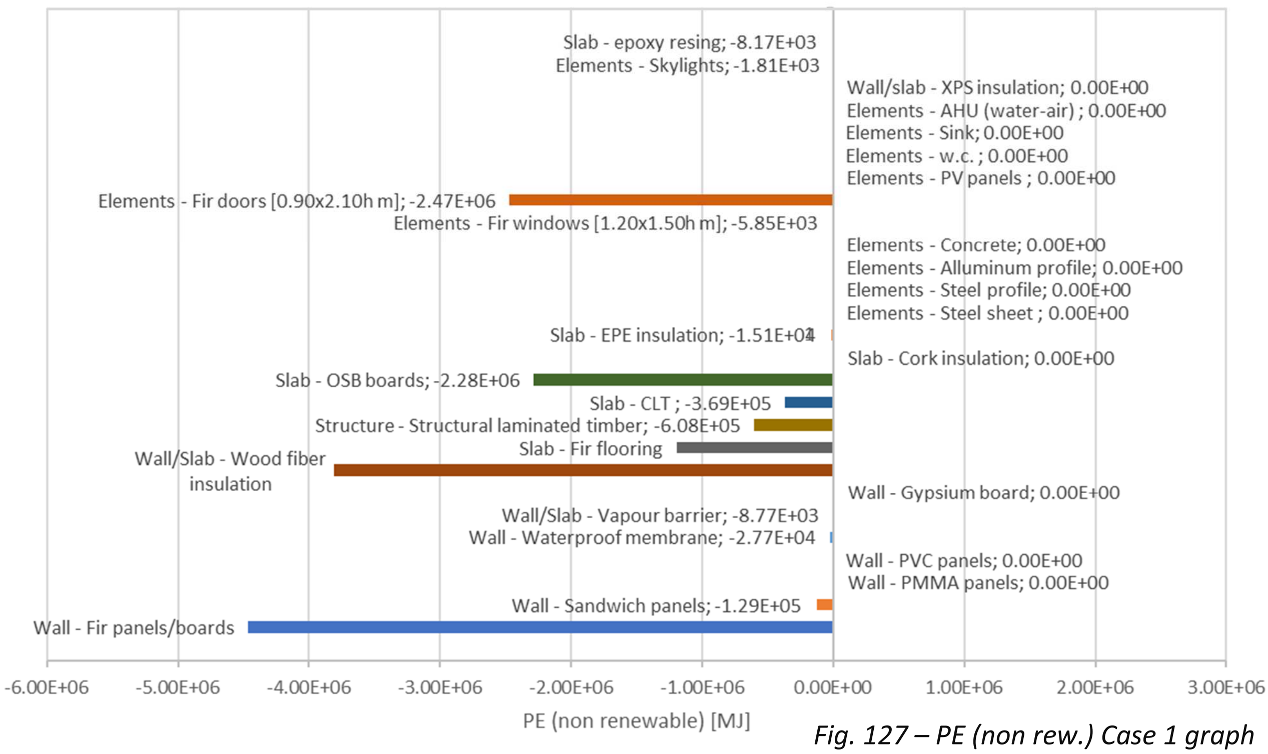


Fig. 127 – PE (non rew.) Case 1 graph

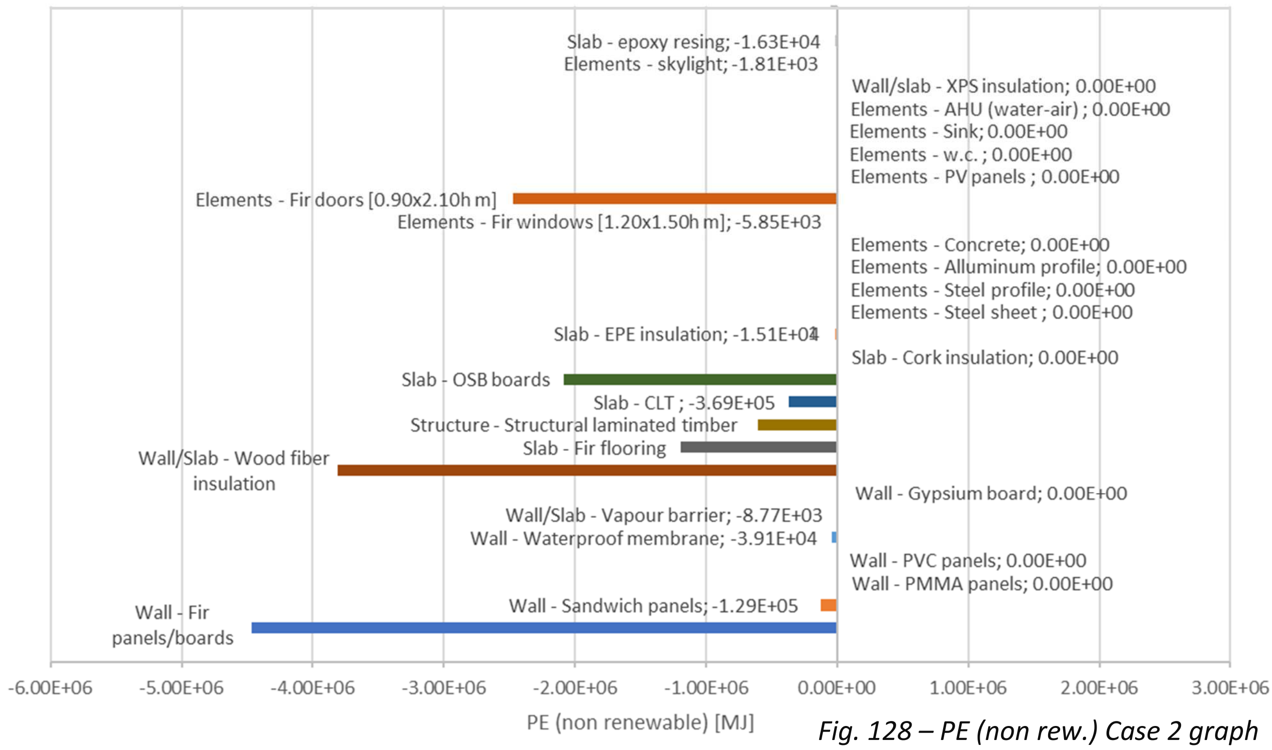


Fig. 128 – PE (non rew.) Case 2 graph

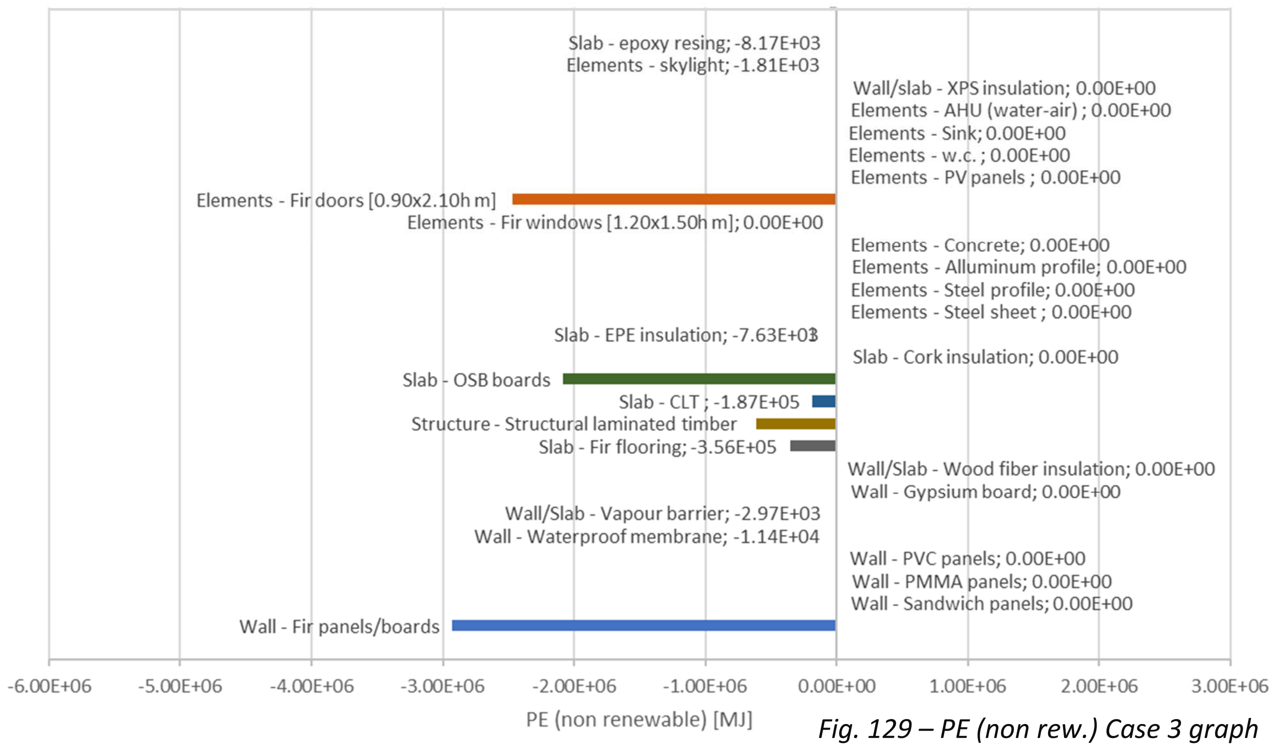


Fig. 129 – PE (non rew.) Case 3 graph

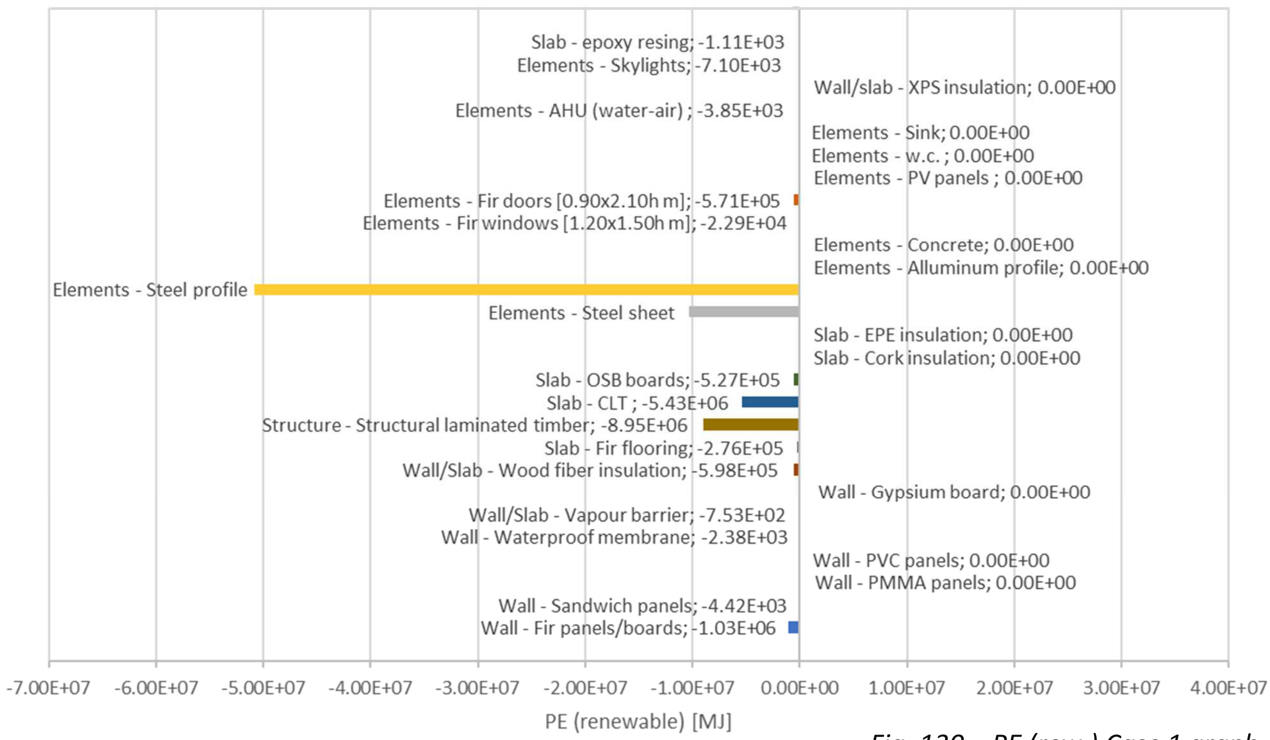


Fig. 130 – PE (rew.) Case 1 graph

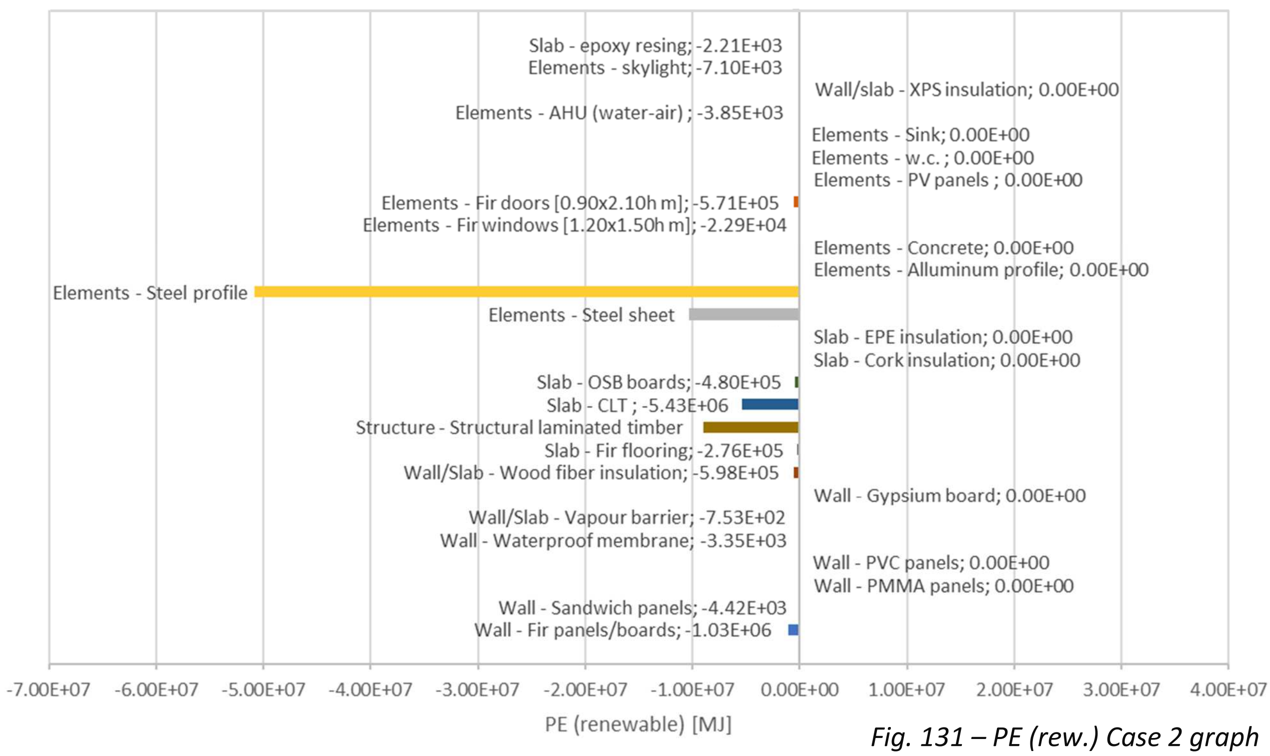


Fig. 131 – PE (rew.) Case 2 graph

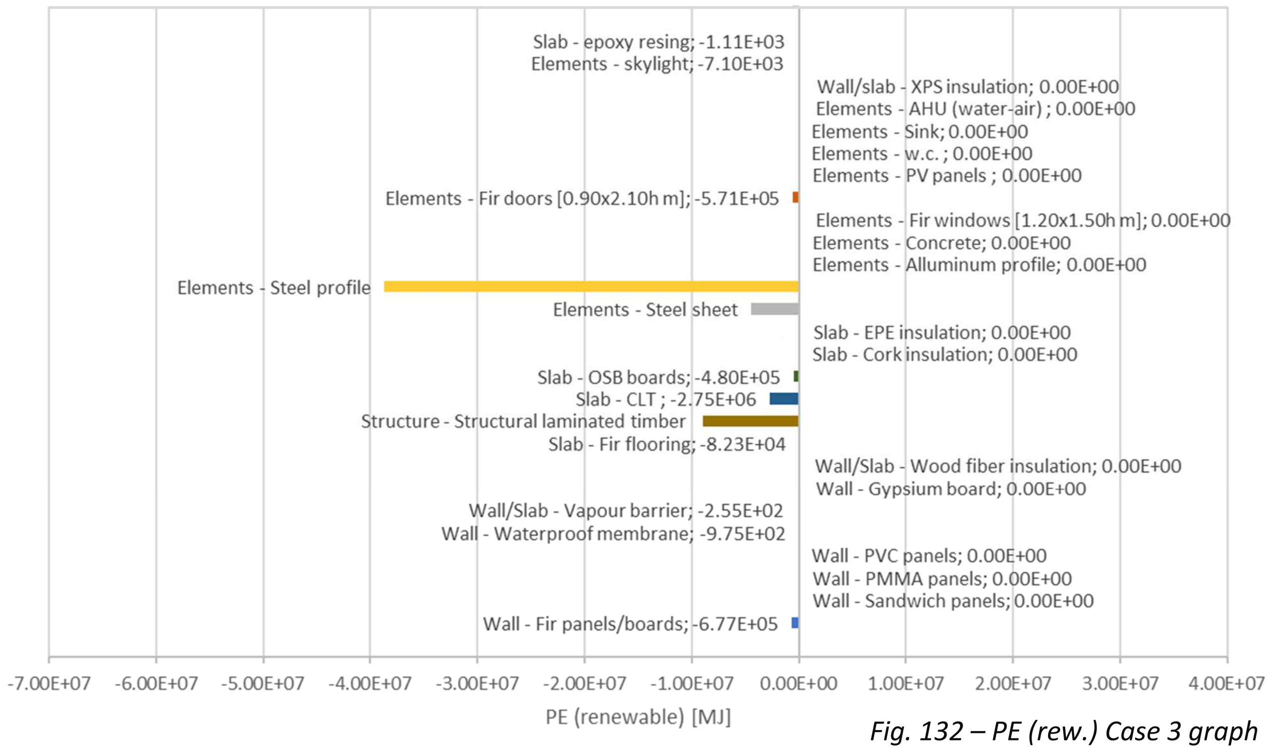


Fig. 132 – PE (rew.) Case 3 graph

Considering all the graphs relating to primary energy, the values shown in the graph are all negative or equal to zero; this is because the stage considered, in the case of the materials analyzed, considers the benefits given by the materials following the disposal phase. All graphs have higher values for Cases 1 and 2 (similar to each other) and lower values for Case 3.

The maximum values present in the graphs relating to non-renewable primary energy are given by wooden materials, the external coating of the clusters and the doors in the project constitute the maximum negatives for these graphs. It is important to emphasize that the positive values for the environmental impact (negative in the graph) are proportional to the values seen previously in the other stages.

The renewable primary energy graphs generally show lower values than those relating to the non-renewable PE; steel profiles are the exception to this rule, constituting the negative mass value among all the graphs relating to PE. The other values in the renewable graph have orders of magnitude smaller and are not characteristic for the graphs.

5.8 *Rendering of the results*

In this chapter, the results obtained from the LCA analysis are analyzed and commented with reference to the various project cases proposed. The values analyzed are summed for the purpose of assessing the overall environmental impact.

The values relating to the equipment for the site and the cabinets necessary for the construction and deconstruction phase in the project are considered within this chapter; the values obtained for these elements are in any case negligible and do not affect any of the equivalent emissions considered. The low value of these elements can be explained by analyzing their quantity; four cabins, 250 meters of parapets to fence the area and 4 drains added by electric crane for other equipment are counted. The equipment for the construction site is also not produced but only transported and installed and is therefore counted only in categories A4 and A5.

From a general point of view, considering the proposed cases, it is possible to see that Case 2 requires a greater quantity of materials than the other two cases. The greater quantity of material is due to the need to replace some materials present in the SDF which are not transportable in the new project area. Case 2 is the solution with the most environmental impact; the reason appears to be, in addition to the addition of materials already considered, the transport and construction and deconstruction operations which are significantly higher due to the need to move all possible materials from the current project area to a new area (considered within 50 kilometers). Case 3, on the other hand, turns out to be the one with the least environmental impact and the least amount of materials used, this can be explained considering that this solution only involves the demolition of the SDF buildings and their disposal. It is important to underline that Case 3 is analyzed only in a first phase, being necessary subsequently, considering the needs of the MIND macro-project, the construction of new buildings. Adding the environmental impact of the new project built in Case 3 it would be possible to see that the overall environmental impact would far outweigh the other cases considered. The new project would include: the production, transport, construction and disposal of new materials which would significantly increase the overall values, since the new project would have to provide new materials also for the parts already present and in excellent condition. Case 1, envisaged in the design phase, is the best solution from an environmental point of view, offering a structure ready for use after the phases considered, and respecting all the major comfort parameters for the office function.

The tables containing the total equivalent emissions values for each project are shown below:

Case 1								
Name	Units	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
		kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	m3	3.17E+04	-1.43E-02	4.71E+02	4.82E+01	8.15E+01	-3.91E+06	1.27E+06
Wall - Sandwich panels	m2	1.62E+04	3.97E-04	7.03E+01	9.71E+00	3.93E+00	2.81E+05	1.96E+04
Wall - PMMA panels	m2	4.29E+05	2.06E-02	2.57E+03	6.17E+02	1.06E+02	3.95E+06	4.46E+05
Wall - PVC panels	m2	6.56E+03	7.33E-04	6.28E+01	1.01E+01	2.20E+00	1.11E+05	8.06E+03
Wall - Waterproof membrane	m2	3.95E+03	4.16E-07	7.51E+00	6.61E-01	8.15E-01	4.48E+04	8.79E+02
Wall/Slab - Vapour barrier	m2	1.08E+04	1.01E-03	1.27E+02	1.59E+01	6.30E+00	1.89E+05	2.75E+04
Wall - Gypsium board	m2	1.51E+03	3.14E-04	3.21E+00	6.61E+00	1.47E+00	3.18E+04	3.12E+03
Wall/Slab - Wood fiber insulation	m3	-1.28E+05	1.88E-05	-2.22E+01	2.27E+01	2.77E+01	-1.11E+06	3.37E+06
Slab - Fir flooring	m3	-9.43E+03	4.38E-04	1.86E+02	2.66E+01	2.97E+01	-8.79E+05	9.55E+05
Structure - Structural laminated timber	m3	5.65E+05	-4.32E-03	-2.55E+02	-6.44E+01	-2.45E+01	-5.28E+05	-8.95E+06
Slab - CLT	m3	2.01E+05	2.64E-03	5.84E+01	9.39E+00	1.56E+01	4.04E+05	1.50E+05
Slab - OSB boards	m3	8.58E+04	5.50E-05	2.07E+01	7.43E+00	3.73E+01	-2.11E+06	-2.45E+05
Slab - Cork insulation	m3	-1.87E+04	7.21E-04	1.24E+02	3.95E+01	6.91E+00	1.40E+05	7.11E+05
Slab - EPE insulation	m2	-3.04E+02	1.93E-05	-9.21E-01	-2.48E-02	-5.04E-01	-6.96E+03	5.43E+01
Elements - Steel sheet	kg	-1.10E+05	-6.02E-03	7.92E+01	2.44E+01	1.07E+03	2.12E+05	-1.04E+07
Elements - Steel profile	kg	-5.58E+05	-2.62E-02	3.57E+02	1.50E+02	5.27E+03	6.09E+05	-5.07E+07
Elements - Alluminum profile	kg	1.01E+03	6.57E-05	4.60E+00	1.62E+00	3.83E-01	1.57E+04	3.18E+03
Elements - Concrete	m3	-2.02E+04	5.73E-05	1.01E+02	1.97E+01	1.13E+01	2.81E+05	2.40E+04
Elements - Fir windows [1.20x1.50h m]	n.	7.03E+04	5.85E-03	6.03E+01	3.59E+02	9.50E+01	1.26E+06	5.04E+05
Elements - Fir doors [0.90x2.10h m]	n.	1.11E+05	3.86E-06	1.60E+02	4.68E+00	2.99E+01	-2.46E+06	-5.71E+05
Elements - PV panels	m2	1.88E+05	1.13E-02	1.39E+03	3.19E+02	2.64E+02	2.12E+06	6.49E+05
Elements - w.c.	n.	2.43E+04	1.75E-03	1.66E+02	6.38E+01	9.49E+00	8.55E+04	2.75E+04

Elements - Sink	n.	2.60E+03	7.14E-05	1.71E+01	4.08E+00	8.43E-01	3.70E+04	1.14E+03
Elements - AHU (water-air)	n.	3.13E+03	1.28E+01	4.07E+00	1.09E+00	1.39E+01	4.03E+04	-2.65E+03
Wall/slab - XPS insulation	m2	1.90E+03	2.91E-05	2.01E+00	5.99E+01	3.48E-01	1.70E+04	5.46E+02
Elements - skylight	n.	6.68E+03	2.31E-04	1.26E+01	5.51E+00	1.71E+00	9.48E+04	-5.05E+03
Slab - epoxy resin	kg	-4.84E+02	-1.61E-07	-7.71E-01	-7.72E-02	-8.14E-02	-6.77E+03	-7.77E+02
Other - cabin/site equipment	-	1.79E+02	0.00E+00	3.28E-01	8.80E-02	2.64E-02	3.27E+03	0.00E+00

Fig. 133 – "Case 1, overall results" table

Case 2								
Name	Units	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
		kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	m3	5.46E+03	-4.39E-03	4.67E+02	4.71E+01	8.14E+01	-3.93E+06	1.22E+06
Wall - Sandwich panels	m2	1.65E+04	3.97E-04	7.06E+01	9.80E+00	3.97E+00	3.17E+05	1.96E+04
Wall - PMMA panels	m2	4.29E+05	2.06E-02	2.57E+03	6.17E+02	1.06E+02	3.94E+06	4.46E+05
Wall - PVC panels	m2	6.59E+03	7.33E-04	6.29E+01	1.01E+01	2.21E+00	1.11E+05	8.06E+03
Wall - Waterproof membrane	m2	6.10E+03	8.77E-07	1.31E+01	1.02E+00	1.42E+00	7.83E+04	2.16E+03
Wall/Slab - Vapour barrier	m2	1.10E+04	1.02E-03	1.28E+02	1.62E+01	6.36E+00	1.94E+05	2.78E+04
Wall - Gypsium board	m2	2.13E+03	3.57E-04	5.23E+00	7.17E+00	1.57E+00	4.26E+04	4.49E+03
Wall/Slab - Wood fiber insulation	m3	-1.28E+05	1.88E-05	-2.22E+01	2.27E+01	2.77E+01	-1.11E+06	3.37E+06
Slab - Fir flooring	m3	-8.71E+03	4.57E-04	1.87E+02	2.71E+01	2.98E+01	-8.66E+05	9.56E+05
Structure - Structural laminated timber	m3	5.72E+05	-4.28E-03	-2.42E+02	-6.09E+01	-2.35E+01	-4.07E+05	-8.95E+06
Slab - CLT	m3	2.03E+05	2.65E-03	6.18E+01	1.03E+01	1.59E+01	4.36E+05	1.51E+05
Slab - OSB boards	m3	7.73E+04	1.26E-04	2.28E+01	7.82E+00	3.51E+01	-1.91E+06	-1.96E+05
Slab - Cork insulation	m3	-1.80E+04	7.26E-04	1.26E+02	3.98E+01	7.01E+00	1.52E+05	7.11E+05
Slab - EPE insulation	m2	1.62E+02	1.96E-05	-2.23E-02	2.14E-01	-4.36E-01	1.57E+03	6.33E+01
Elements - Steel sheet	kg	-1.10E+05	-6.02E-03	7.93E+01	2.45E+01	1.07E+03	2.13E+05	-1.04E+07
Elements - Steel profile	kg	-5.56E+05	-2.61E-02	3.62E+02	1.51E+02	5.27E+03	6.35E+05	-5.07E+07
Elements - Alluminum profile	kg	1.04E+03	6.58E-05	4.71E+00	1.65E+00	3.90E-01	1.62E+04	3.18E+03
Elements - Concrete	m3	2.08E+05	1.71E-03	5.09E+02	7.24E+01	1.27E+02	1.94E+06	1.05E+05
Elements - Fir windows [1.20x1.50h m]	n.	7.03E+04	5.85E-03	6.03E+01	3.59E+02	9.50E+01	1.26E+06	5.04E+05
Elements - Fir doors [0.90x2.10h m]	n.	1.14E+05	1.08E-05	1.63E+02	5.57E+00	3.02E+01	-2.42E+06	-5.71E+05
Elements - PV panels	m2	1.88E+05	1.13E-02	1.39E+03	3.19E+02	2.64E+02	2.12E+06	6.49E+05
Elements - w.c.	n.	2.43E+04	1.75E-03	1.66E+02	6.38E+01	9.49E+00	8.60E+04	2.75E+04
Elements - Sink	n.	2.63E+03	7.21E-05	1.72E+01	4.11E+00	8.49E-01	3.75E+04	1.16E+03
Elements - AHU (water-air)	n.	3.12E+03	1.28E+01	4.04E+00	1.08E+00	1.39E+01	4.02E+04	-2.68E+03
Wall/slab - XPS insulation	m2	2.49E+03	6.95E-05	3.91E+00	6.04E+01	4.50E-01	2.53E+04	1.37E+03
Elements - skylight	n.	6.75E+03	2.36E-04	1.29E+01	5.57E+00	1.72E+00	9.58E+04	-4.94E+03
Slab - epoxy resin	kg	1.37E+04	2.96E-05	1.65E+02	6.47E+00	9.80E+00	3.34E+05	2.88E+04
Other - cabin and site equipment	-	1.79E+02	0.00E+00	3.28E-01	8.80E-02	2.64E-02	3.27E+03	0.00E+00

Fig. 134 – "Case 2, overall results" table

Case 3								
Name	Units	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
		kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	m3	1.34E+05	1.88E-05	1.93E+02	6.29E+00	3.57E+01	-2.89E+06	-6.77E+05
Wall - Sandwich panels	m2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - PMMA panels	m2	1.02E+02	9.07E-06	2.88E-01	8.89E-02	1.95E-02	1.05E+03	2.33E+02
Wall - PVC panels	m2	1.02E+02	9.07E-06	2.88E-01	8.89E-02	1.95E-02	1.05E+03	2.33E+02
Wall - Waterproof membrane	m2	4.44E+02	7.57E-08	-1.42E+00	-8.83E-02	-1.20E-01	-1.13E+04	-9.54E+02
Wall/Slab - Vapour barrier	m2	-7.38E+01	1.38E-05	1.77E-02	8.38E-02	-1.65E-02	-1.78E+03	2.87E+01
Wall - Gypsium board	m2	1.68E+03	3.36E-04	3.96E+00	6.82E+00	1.50E+00	3.46E+04	3.81E+03
Wall/Slab - Wood fiber insulation	m3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - Fir flooring	m3	1.64E+04	1.88E-05	2.39E+01	9.00E-01	4.36E+00	-3.50E+05	-8.17E+04
Structure - Structural laminated timber	m3	5.65E+05	-4.30E-03	-2.55E+02	-6.44E+01	-2.45E+01	-5.33E+05	-8.95E+06
Slab - CLT	m3	1.74E+05	-1.32E-03	-7.83E+01	-1.98E+01	-7.53E+00	-1.62E+05	-2.75E+06
Slab - OSB boards	m3	9.14E+04	8.32E-05	-3.16E-01	2.18E+00	2.39E+01	-2.03E+06	-4.70E+05
Slab - Cork insulation	m3	6.74E+02	5.39E-06	1.34E+00	3.63E-01	1.01E-01	1.22E+04	1.70E+02
Slab - EPE insulation	m2	-2.34E+02	2.09E-06	-8.05E-01	-3.93E-03	-9.48E-01	-5.48E+03	9.02E+00
Elements - Steel sheet	kg	-5.24E+04	-2.60E-03	1.61E+01	9.11E+00	4.58E+02	9.49E+02	-4.47E+06
Elements - Steel profile	kg	-4.52E+05	-2.24E-02	1.44E+02	8.03E+01	3.97E+03	3.17E+04	-3.87E+07
Elements - Alluminum profile	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Concrete	m3	-2.45E+04	6.03E-05	9.28E+01	1.88E+01	8.91E+00	2.48E+05	2.34E+04
Elements - Fir windows [1.20x1.50h m]	n.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Fir doors [0.90x2.10h m]	n.	1.12E+05	7.35E-06	1.61E+02	4.96E+00	3.00E+01	-2.45E+06	-5.71E+05
Elements - PV panels	m2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - w.c.	n.	2.34E+02	1.85E-06	6.25E-01	5.33E-02	6.81E-04	9.66E+01	6.08E+00
Elements - Sink	n.	4.12E+00	8.31E-07	2.46E-02	7.23E-03	1.14E-03	9.38E+01	4.95E+00
Elements - AHU (water-air)	n.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/slab - XPS insulation	m2	2.01E+03	4.21E-05	2.46E+00	6.00E+01	3.68E-01	1.87E+04	9.55E+02
Elements - skylight	n.	3.56E+03	1.35E-05	1.55E-01	8.76E-01	7.21E-01	1.58E+03	-6.96E+03
Slab - epoxy resin	kg	-4.84E+02	-1.61E-07	-7.71E-01	-7.72E-02	-8.14E-02	-6.77E+03	-7.77E+02
Other - cabin and site equipment	-	1.79E+02	0.00E+00	3.28E-01	8.80E-02	2.64E-02	3.27E+03	0.00E+00

Fig. 135 – "Case 3, overall results" table

GWP (global warming potential)

The maximum values found within this category are those of steel profiles, structural laminated timber and PMMA panels. The value of the steel profiles is negative within the graph, therefore it constitutes a positive contribution to the overall impact of this category. The negative values are determined by phase D which allows the recycling or reuse of materials with a gain from an environmental point of view; most of the quantity of steel profiles is not counted in the production and transport phase as it is already present on the site. PMMA panels as well as structural laminated timber, on the other hand, constitute a negative contribution in terms of overall impact; in the case of structural laminated timber the reason for a high value is to be found in the quantity rather than the unit value (which is very low being wood).

ODP (ozone depletion potential)

In this category the maximum value as well as the total value is made up of the air handling units installed during the project phase; the other values are of different units of lower magnitude and can be considered negligible. The air handling units, despite constituting the greatest source of impact for this category, are a choice enough on the environmental impact, they allow to make the building autonomous from a thermal point of view through the use of the current produced by the PV system. Case 3, not being subject to the installation of these devices, appears to have much lower ODP values than the other two cases.

AP (acidification potential)

In this category the maximum values belong to the PV system and the PMMA panels. The PV systems, despite being one of the highest values of different categories, including acidification potential, allow buildings to have electrical autonomy which in turn allows the cancellation, in terms of environmental impact, of the module relating to current consumption during the use phase of the building. PMMA panels are an obligatory design choice, they are used to preserve the architecture and the significance of the building.

EP (eutrophication potential)

As noted in the previous category, the highest values relating to this equivalent emission remain those of the PV system and PMMA panels, to which are added the values of the windows for this category. The equivalent emissions relating to acidification potential and eutrophication potential are in the case of three drastically reduced since the windows and the PV system are not present and the PMMA panels, as well as other materials, are present in reduced quantities.

POCP (photochemical ozone creation potential)

In this category the elements made of steel almost completely characterize the graph. Steel sheets and steel profiles are the maximum values present; the other materials have lower values of several orders of magnitude. As previously noted in the case of eutrophication potential, Case 3 has the same maximums, but the values are significantly lower as the quantities of materials are lower and the supply of new material for the project is not necessary.

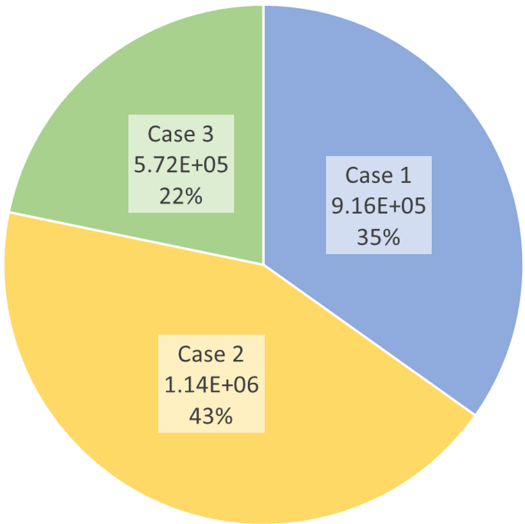
PE [non rew.] (Primary energy non-renewable)

The materials in this category alternate, in the graphs, between negative and positive values. The maximum positive values (therefore negative in terms of environmental impact) are due to the PV system, the PMMA panels, the concrete and the windows. The maximum negative values, in the graphs, are made up of wooden materials; the wood used for the external finishing, for the insulation, for the OSB panels and for the doors are the maximum negatives of this category. Adding the present values, it is possible to affirm that Case 1 has a result close to zero, Case 2 has a negative impact from an environmental point of view while Case 3 is positive. Case 2 is negative due to the value of the cement, and in general, due to the increase in all values due to transportation and processing in the new area.

PE [rew.] (Primary energy renewable)

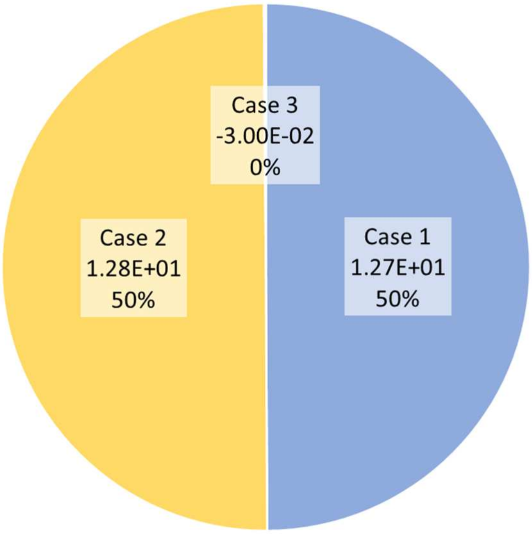
The graphs relating to this category show a positive overall environmental impact. There are no high positive values in the graphs, while there are high negative values that determine a positive effect. The values relating to steel, both in the case of the profiles and in the case of the sheets, are significantly higher than all the other values in all the cases considered.

The graphs relating to the comparison between the overall balance of the equivalent emissions considered are proposed below:



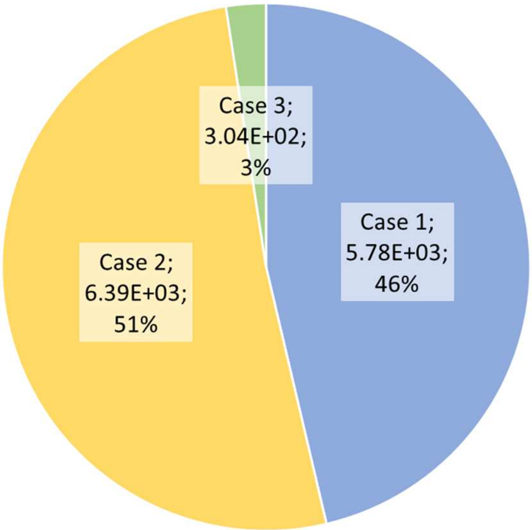
GWP	kg CO_{2eq}	Case 1	9.16E+05
		Case 2	1.14E+06
		Case 3	5.72E+05

Fig. 136 – GWP comparison chart and table



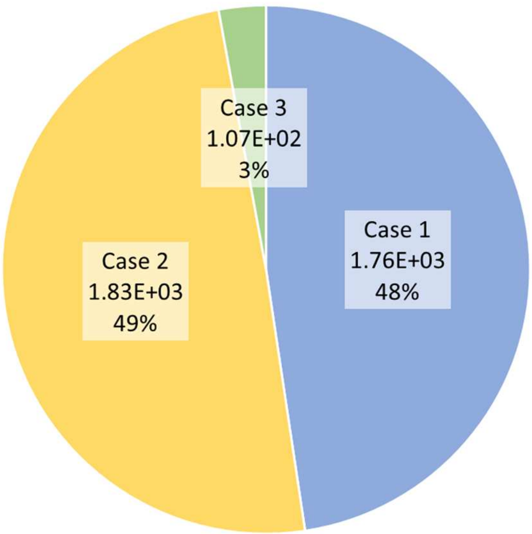
ODP	kg CFC_{11eq}	Case 1	1.27E+01
		Case 2	1.28E+01
		Case 3	-3.00E-02

Fig. 137 – ODP comparison chart and table



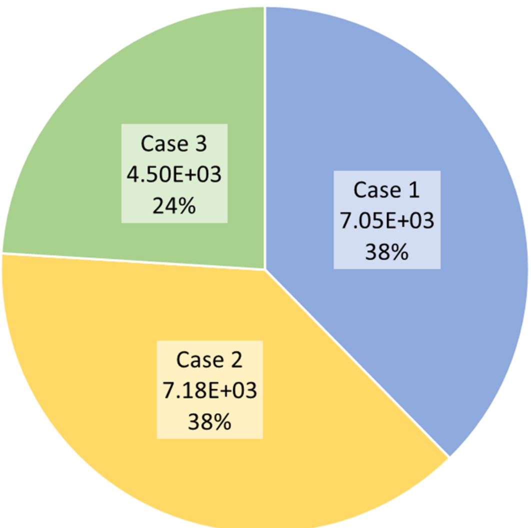
AP	kg SO_{2eq}	Case 1	5.78E+03
		Case 2	6.39E+03
		Case 3	3.04E+02

Fig. 138 – AP comparison chart and table



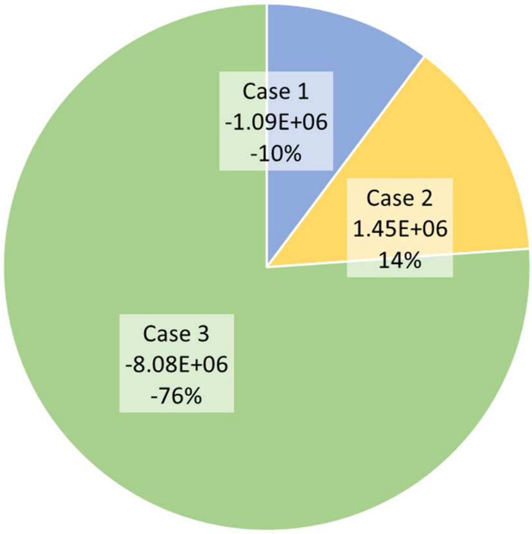
EP	kg $(PO_4)^{3}{}_{eq}$	Case 1	1.76E+03
		Case 2	1.83E+03
		Case 3	1.07E+02

Fig. 139 – EP comparison chart and table



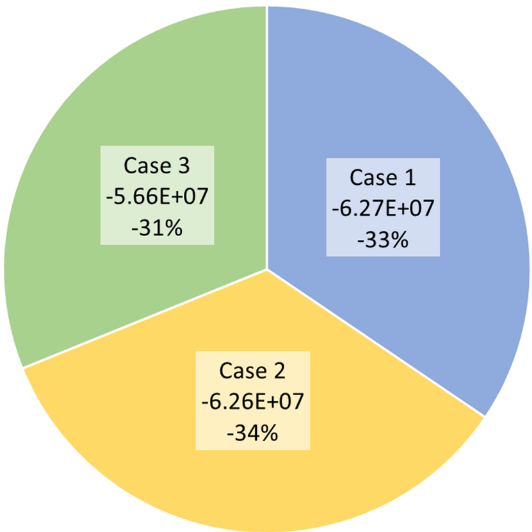
POCP	kg C_2H_{4eq}	Case 1	7.05E+03
		Case 2	7.18E+03
		Case 3	4.50E+03

Fig. 140 – POCP comparison chart and table



PE (non rew.)	MJ	Case 1	-1.09E+06
		Case 2	1.45E+06
		Case 3	-8.08E+06

Fig. 141 – PE (non rew.) comparison chart and table



PE (rew.)	MJ	Case 1	-6.27E+07
		Case 2	-6.26E+07
		Case 3	-5.66E+07

Fig. 142 – PE (rew.) comparison chart and table

6. Final results

6.1 Final remarks

In order to evaluate the results obtained in the LCA analysis part, the ActiveHouse protocol is again considered.

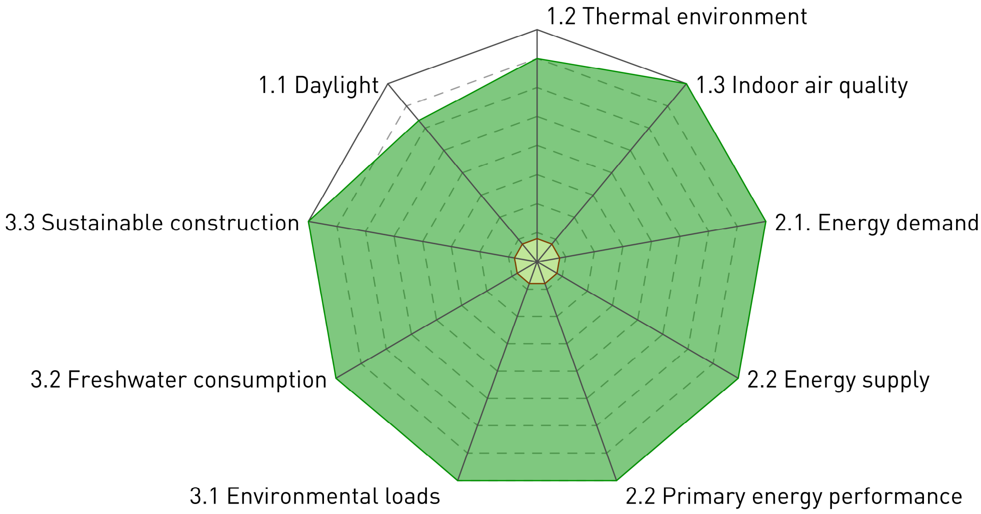


Fig. 143 – Radar from ActiveHouse protocol

The values used in the protocol are compared to those found by means of the very different EPDs; for the evaluation carried out via protocol, the values relevant to its library were used. Freshwater consumption was calculated using the national average of water consumption and assuming an average consumption per person inside the offices of twenty liters of water per day.

The ActiveHouse Protocol results:

Environment		
Verification	Value	Category
Environmental loads	Best level	1.00
Freshwater consumption	85%	1.00
Sustainable construction	Best level	1.00

The projected buildings obtain a high score in all the section through the use of the proposed strategies.

Considering what has been calculated for this project, it is possible to affirm that the best strategy to be applied in this case is that of on-site retrofit which allows the development of a high energy performance building with high levels of comfort and with a minimal environmental impact compared to the construction of new buildings.

SDF

STRUCTURE

LEGEND

- Mantained in the SDP p
- Removed in the SDP pl
- Expanded in the SDP p
- Reduced in the SDP ph

Wood - columns

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
column - 20x30h cm	1290.240	0.06	77.41	450	34836.48

Wood - beams

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
beam - 16x20h cm	1700.000	0.032	54.40	450	24480.00
beam - 20x60h cm	694.400	0.120	83.33	450	37497.60
beam - 08x20h cm	2174.900	0.016	34.80	450	15659.28
diagonals - 16x16h cm	865.920	0.026	22.17	450	9975.40

Wood - portals

type	n. of element	n. volume [m^3]	volume [m^3]	density [kg/m^3]	mass [kg]
portals - main structure	73	3.68	268.64	450	120888.00

Wood - mullions

type	tot lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
mullion - 6x6h cm	9854.100	0.0036	35.47	450	15963.64

Steel - columns

type	tot lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
HEA 180	362.000	0.0045	1.64	7700	12612.99
UPN 180	83.020	0.0028	0.23	7700	1789.91
external - d20	29.160	0.012	0.357	7700.000	2749.619

Steel - beams

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
IPE 240	529.260	0.00391	2.07	7700	15942.58

Steel - transoms

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
transom - 6x6h cm	5334.010	0.0020	10.67	7700	82143.75

Steel - joints

type	n. of element	n. volume [m^3]	volume [m^3]	density [kg/m^3]	mass [kg]
joints transom/mullion	1460.000	0.0009	1.33	7700	10218.98

WALL

wall 01

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	2261.65	33.92	450	15266.15
air space	0.262	2261.65	592.55	1	592.55
OSB panels	0.012	2261.65	27.14	660	17912.28
XPS	0.026	2261.65	58.80	25	1470.07
OSB panels	0.012	2261.65	27.14	660	17912.28

wall 02

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	648.21	9.72	450	4375.40
air space	0.262	648.21	169.83	1	169.83
OSB panels	0.012	648.21	7.78	660	5133.80
XPS	0.026	648.21	16.85	25	421.33
OSB panels	0.012	648.21	7.78	660	5133.80
air space	0.160	648.21	103.71	1	103.71
fir boards	0.015	648.21	9.72	450	4375.40

wall 03

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	347.59	5.21	450	2346.21
air space	0.262	347.59	91.07	1	91.07
OSB panels	0.012	347.59	4.17	660	2752.88
XPS	0.026	347.59	9.04	25	225.93
OSB panels	0.012	347.59	4.17	660	2752.88
air space	0.180	347.59	62.57	1	62.57
fir boards	0.015	347.59	5.21	450	2346.21

wall 04

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	997.82	14.97	450	6735.30
air space	0.262	997.82	261.43	1	261.43
OSB panels	0.012	997.82	11.97	660	7902.76
XPS	0.026	997.82	25.94	25	648.58
OSB panels	0.012	997.82	11.97	660	7902.76
air space	0.200	997.82	199.56	1	199.56
fir boards	0.015	997.82	14.97	450	6735.30

wall 05

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
air space	0.262	1524.56	399.43	1	399.43
OSB panels	0.012	1524.56	18.29	660	12074.50
XPS	0.026	1524.56	39.64	25	990.96
OSB panels	0.012	1524.56	18.29	660	12074.50
air space	0.160	1524.56	243.93	1	243.93
fir boards	0.015	1524.56	22.87	450	10290.77

wall 06

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
air space	0.262	531.57	139.27	1	139.27
OSB panels	0.012	531.57	6.38	660	4210.07
XPS	0.026	531.57	13.82	25	345.52
OSB panels	0.012	531.57	6.38	660	4210.07
air space	0.200	531.57	106.31	1	106.31
fir boards	0.015	531.57	7.97	450	3588.13

wall 07

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	698.40	10.48	450	4714.17
fir boards	0.040	698.40	27.94	450	12571.13
fir boards	0.015	698.40	10.48	450	4714.17
air space	0.262	698.40	182.98	1	182.98
OSB panels	0.012	698.40	8.38	660	5531.30
XPS	0.026	698.40	18.16	25	453.96
OSB panels	0.012	698.40	8.38	660	5531.30
air space	0.180	698.40	125.71	1	125.71
gypsium panels	0.012	698.40	8.38	680	5698.91
gypsium panels	0.012	698.40	8.38	680	5698.91

wall 08

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.020	115.11	2.30	450	1036.01
fir boards	0.040	115.11	4.60	450	2072.01
fir boards	0.020	115.11	2.30	450	1036.01
air space	0.262	115.11	30.16	1	30.16
OSB panels	0.012	115.11	1.38	660	911.69
XPS	0.026	115.11	2.99	25	74.82
OSB panels	0.012	115.11	1.38	660	911.69
air space	0.210	115.11	24.17	1	24.17
gypsium panels	0.012	115.11	1.38	680	939.31
gypsium panels	0.012	115.11	1.38	680	939.31

wall 09

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	610.67	9.16	450	4122.00

wall 10

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	178.67	2.68	450	1206.00
fir boards	0.030	178.67	5.36	450	2412.00
fir boards	0.015	178.67	2.68	450	1206.00

wall 11

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
gypsium panel	0.012	7.29	0.09	680	59.49

wall 12

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
gypsium panels	0.012	485.83	5.83	680	3964.40
gypsium panels	0.012	485.83	5.83	680	3964.40

wall 13

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
gypsium panels	0.012	8384.99	100.62	680	68421.52
gypsium panels	0.012	8384.99	100.62	680	68421.52
air space	0.075	8384.99	628.87	1	628.87
gypsium panels	0.012	8384.99	100.62	680	68421.52
gypsium panels	0.012	8384.99	100.62	680	68421.52

wall 14

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81
air space	0.075	452.55	33.94	1	33.94
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81
air space	0.075	452.55	33.94	1	33.94
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81

SLABS

slab 01

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
epoxy resin	0.005	5853.77	29.27	561	16419.82
sand-cement	0.060	5853.77	351.23	1200	421471.26
concrete	0.150	5853.77	878.07	2100	1843936.74

slab 02

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
epoxy resin	0.005	2510.55	12.55	561	7042.09
sand-cement	0.060	2510.55	150.63	1200	180759.45
XPS	0.080	2510.55	200.84	25	5021.10
vapour barrier	0.001	2510.55	2.51	650	1631.86

slab 03

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir flooring	0.020	421.95	8.44	450	3797.58
sand-cement	0.060	421.95	25.32	1200	30380.65
EPE insulation	0.010	421.95	4.22	120	506.34
concrete	0.120	421.95	50.63	2100	106332.28
steel sheets	0.005	421.95	2.11	7700	16245.21

slab 04

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir flooring	0.020	1791.12	35.82	450	16120.08
EPE insulation	0.010	1791.12	17.91	120	2149.34
OSB boards	0.012	1791.12	21.49	660	14185.67
Cork insulation	0.060	1791.12	107.47	240	25792.13
CLT	0.120	1791.12	214.93	500	107467.20

ROOF

roof 1

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
waterproof membrane	0.004	1824.83	7.30	1000	7299.32
waterproof membrane	0.004	1824.83	7.30	1000	7299.32
OSB panels	0.012	1824.83	21.90	660	14452.66
cork insulation	0.200	1824.83	364.97	240	87591.86
vapour barrier	0.001	1824.83	1.82	650	1186.14
fir boards	0.015	1824.83	27.37	450	12317.61

roof 2

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
waterproof membrane	0.004	250.62	1.00	1000	1002.48
waterproof membrane	0.004	250.62	1.00	1000	1002.48
concrete	0.100	250.62	25.06	2100	52630.09
steel sheets	0.005	250.62	1.25	7700	9648.85

FOUNDATIONS

Foundation - slabs

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
Slab - lower	0.100	2551.40	255.14	2100	535794.00
Slab - higher	0.150	1405.53	210.83	2100	442743.00

Foundation - beams

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
beams - 50x50h cm	989.000	0.25	247.25	2100	519225.00
beams - 80x50h cm	637.175	0.40	254.87	2100	535227.00

Foundation - igloo

type	n. volume [m^3]	n. of igloo	tot. volume [m3]	density [kg/m^3]	mass [kg]
HDPE igloo	0.0032	7200.00	22.68	940	21319.20

SHELL

Wood - columns

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
columns - 20x20h cm	497.930	0.04	19.92	450	8962.74

Wood - beams

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
beams - 20x20h cm	1458.500	0.04	58.34	450	26253.00
beams - 8x30h cm	1083.750	0.02	26.01	450	11704.50

Steel - bracings

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
steel bracing	698.353	0.0028	1.97	7700	15196.30

ELEMENTS

Openings

type	n. of elements	width [m]	height [m]
skylights	141	1.200	1.200
doors	244	0.900	2.100
doors	15	1.200	2.100
doors	6	1.500	2.100
doors	10	1.600	2.100
doors	32	1.800	2.100

Wood panels

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
Fir panels	0.012	3427.370	41.13	450.000	18507.798
PMMA panel	0.012	1713.685	20.56	1190.000	24471.422
PVC panel	0.012	1713.685	20.56	1380.000	28378.624
Fir internal structure	0.012	7197.477	86.37	450.000	38866.376

Internal stairs

type	n. volume [m^3]	n. of stairs	tot. volume [m^3]	density [kg/m^3]	mass [kg]
beam 10x16h cm	0.511	36.00	18.39	450.000	8273.664
fir boards	0.185	36.000	6.66	450.000	2999.106

Internal railing

type	area [m^2]	stairs lenght [m]	additional lenght [m]	density [kg/m^3]	mass [kg]
steel profile	0.0001	258.84	1294.20	7700.000	1195.841
steel tube	0.0028	258.84	-	7700.00	5632.41

Gutter and tubes

type	tot. lenght [m]	area [mm^2]	volume [m^3]
gutters	801.460	680.00	0.54
tubes	604.510	872.92	0.53

Furniture

type	n. of elements
w.c.	12
sink	25

SDP

STRUCTURE

LEGEND

- Mantained in the SDP p
- Builted in the SDP phas
- Expanded in the SDP p
- Reduced in the SDP ph

Wood - columns

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
column - 20x30h cm	1290.240	0.06	77.41	450	34836.48

Wood - beams

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
beam - 16x20h cm	1700.000	0.032	54.40	450	24480.00
beam - 20x60h cm	694.400	0.120	83.33	450	37497.60
beam - 08x20h cm	2174.900	0.016	34.80	450	15659.28
diagonals - 16x16h cm	865.920	0.026	22.17	450	9975.40

Wood - portals

type	n. of element	n. volume [m^3]	volume [m^3]	density [kg/m^3]	mass [kg]
portals - main structure	73	3.68	268.64	450	120888.00

Wood - mullions

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
mullion - 6x6h cm	9854.100	0.0036	35.47	450	15963.64

Steel - columns

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
HEA 180	362.000	0.0045	1.64	7700	12612.99
UPN 180	83.020	0.0028	0.23	7700	1789.91

Steel - beams

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
IPE 240	529.260	0.00391	2.07	7700	15942.58

Steel - transoms

type	tot. lenght [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
transom - 6x6h cm	5334.010	0.0020	10.67	7700	82143.75

Steel - joints

type	n. of element	n. volume [m^3]	volume [m^3]	density [kg/m^3]	mass [kg]
joints transom/mullion	1460.000	0.0009	1.33	7700	10218.98

WALLS

wall 01

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	2261.65	33.92	450	15266.15
air space	0.117	2261.65	264.61	1	264.61
waterproof membrane	0.004	2261.65	9.05	1000	9046.61
wood fiber inulation	0.140	2261.65	316.63	50	15831.56
vapour barrier	0.001	2261.65	2.26	650	1470.07
OSB panels	0.012	2261.65	27.14	660	17912.28
XPS	0.026	2261.65	58.80	25	1470.07
OSB panels	0.012	2261.65	27.14	660	17912.28

wall 02

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	648.21	9.72	450	4375.40
air space	0.117	648.21	75.84	1	75.84
waterproof membrane	0.004	648.21	2.59	1000	2592.83
wood fiber inulation	0.140	648.21	90.75	50	4537.45
vapour barrier	0.001	648.21	0.65	650	421.33
OSB panels	0.012	648.21	7.78	660	5133.80
XPS	0.026	648.21	16.85	25	421.33
OSB panels	0.012	648.21	7.78	660	5133.80
air space	0.160	648.21	103.71	1	103.71
fir boards	0.015	648.21	9.72	450	4375.40

wall 03

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	347.59	5.21	450	2346.21
air space	0.262	347.59	91.07	1	91.07
OSB panels	0.012	347.59	4.17	660	2752.88
XPS	0.026	347.59	9.04	25	225.93
OSB panels	0.012	347.59	4.17	660	2752.88
air space	0.180	347.59	62.57	1	62.57
fir boards	0.015	347.59	5.21	450	2346.21

wall 04

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	997.82	14.97	450	6735.30
air space	0.117	997.82	116.75	1	116.75
waterproof membrane	0.004	997.82	3.99	1000	3991.29
wood fiber insulation	0.140	997.82	139.70	50	6984.76
vapour barrier	0.001	997.82	1.00	650	648.58
OSB panels	0.012	997.82	11.97	660	7902.76
XPS	0.026	997.82	25.94	25	648.58
OSB panels	0.012	997.82	11.97	660	7902.76
air space	0.200	997.82	199.56	1	199.56
fir boards	0.015	997.82	14.97	450	6735.30

wall 05

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
air space	0.117	1524.56	178.37	1	178.37
waterproof membrane	0.004	1524.56	6.10	1000	6098.23
wood fiber inulation	0.140	1524.56	213.44	50	10671.91
vapour barrier	0.001	1524.56	1.52	650	990.96
OSB panels	0.012	1524.56	18.29	660	12074.50
XPS	0.026	1524.56	39.64	25	990.96
OSB panels	0.012	1524.56	18.29	660	12074.50
air space	0.160	1524.56	243.93	1	243.93
fir boards	0.015	1524.56	22.87	450	10290.77

wall 06

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
air space	0.117	531.57	62.19	1	62.19
waterproof membrane	0.004	531.57	2.13	1000	2126.30
wood fiber inulation	0.140	531.57	74.42	50	3721.02
vapour barrier	0.001	531.57	0.53	650	345.52
OSB panels	0.012	531.57	6.38	660	4210.07
XPS	0.026	531.57	13.82	25	345.52
OSB panels	0.012	531.57	6.38	660	4210.07
air space	0.200	531.57	106.31	1	106.31
fir boards	0.015	531.57	7.97	450	3588.13

wall 07

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
sandwich panel	0.060	698.40	41.90	100	4190.38
air space	0.262	698.40	182.98	1	182.98
OSB panels	0.012	698.40	8.38	660	5531.30
XPS	0.026	698.40	18.16	25	453.96
OSB panels	0.012	698.40	8.38	660	5531.30
air space	0.180	698.40	125.71	1	125.71
gypsium panels	0.012	698.40	8.38	680	5698.91
gypsium panels	0.012	698.40	8.38	680	5698.91

wall 08

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
sandwich panel	0.060	115.11	6.91	100	690.67
air space	0.262	115.11	30.16	1	30.16
OSB panels	0.012	115.11	1.38	660	911.69
XPS	0.026	115.11	2.99	25	74.82
OSB panels	0.012	115.11	1.38	660	911.69
air space	0.210	115.11	24.17	1	24.17
gypsium panels	0.012	115.11	1.38	680	939.31
gypsium panels	0.012	115.11	1.38	680	939.31

wall 09

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	610.67	9.16	450	4122.00

wall 10

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir boards	0.015	178.67	2.68	450	1206.00
fir boards	0.030	178.67	5.36	450	2412.00
fir boards	0.015	178.67	2.68	450	1206.00

wall 11

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
gypsium panels	0.012	7.29	0.09	680	59.49

wall 12

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
gypsium panels	0.012	758.33	9.10	680	6188.00
gypsium panels	0.012	758.33	9.10	680	6188.00

wall 13

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
gypsium panels	0.012	6124.36	73.49	680	49974.78
gypsium panels	0.012	6124.36	73.49	680	49974.78
air space	0.075	6124.36	459.33	1	459.33
gypsium panels	0.012	6124.36	73.49	680	49974.78
gypsium panels	0.012	6124.36	73.49	680	49974.78

wall 14

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81
air space	0.075	452.55	33.94	1	33.94
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81
air space	0.075	452.55	33.94	1	33.94
gypsium panels	0.012	452.55	5.43	680	3692.81
gypsium panels	0.012	452.55	5.43	680	3692.81

SLABS

slab 01

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
epoxy resin	0.005	5853.77	29.27	561	16419.82
sand-cement	0.060	5853.77	351.23	1200	421471.26
concrete	0.150	5853.77	878.07	2100	1843936.74

slab 02

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
vapour barrier	0.001	2510.55	2.51	650	1631.86
wood fiber insulation	0.140	2510.55	351.48	50	17573.84
epoxy resin	0.005	2510.55	12.55	561	7042.09
sand-cement	0.060	2510.55	150.63	1200	180759.45
XPS	0.080	2510.55	200.84	25	5021.10
waterproof membrane	0.004	2510.55	10.04	1000	10042.19

slab 03

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir flooring	0.020	421.95	8.44	450	3797.58
sand-cement	0.060	421.95	25.32	1200	30380.65
EPE insulation	0.010	421.95	4.22	120	506.34
concrete	0.120	421.95	50.63	2100	106332.28
steel sheets	0.005	421.95	2.11	7700	16245.21

slab 04

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir flooring	0.020	3535.53	70.71	450	31819.77
EPE insulation	0.010	3535.53	35.36	120	4242.64
OSB boards	0.012	3535.53	42.43	660	28001.40
Cork insulation	0.060	3535.53	212.13	240	50911.63
CLT	0.120	3535.53	424.26	500	212131.80

ROOF

roof 1

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
waterproof membrane	0.004	1824.83	7.30	1000	7299.32
waterproof membrane	0.004	1824.83	7.30	1000	7299.32
OSB panels	0.012	1824.83	21.90	660	14452.66
cork insulation	0.200	1824.83	364.97	240	87591.86
vapour barrier	0.001	1824.83	1.82	650	1186.14
fir boards	0.015	1824.83	27.37	450	12317.61

roof 2

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
waterproof membrane	0.004	250.62	1.00	1000	1002.48
waterproof membrane	0.004	250.62	1.00	1000	1002.48
concrete	0.100	250.62	25.06	2100	52630.09
steel sheet	0.005	250.62	1.25	7700	9648.85

ELEMENTS

Openings

type	n. of elements	width [m]	height [m]
windows	455	1.20	1.50
skylights	141	1.200	1.200
doors	217	0.900	2.100
doors	13	1.200	2.100
doors	6	1.500	2.100
doors	10	1.600	2.100
doors	32	1.800	2.100

Wood panels

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
Fir panels	0.012	3427.370	41.13	450.000	18507.798
PMMA panel	0.012	1713.685	20.56	1190.000	24471.422
PVC panel	0.012	1713.685	20.56	1380.000	28378.624
Fir internal structure	0.012	7197.477	86.37	450.000	38866.376

Internal stairs

type	n. volume [m^3]	n. of stairs	tot. volume [m^3]	density [kg/m^3]	mass [kg]
beam 10x16h cm	0.511	36.00	18.39	450.000	8273.664
fir boards	0.185	36.000	6.66	450.000	2999.106

Internal railing

type	area [m^2]	stairs lenght [m]	additional lenght [m]	density [kg/m^3]	mass [kg]
steel profile	0.0001	258.84	1294.20	7700.000	1195.841
steel tube	0.0028	258.84	-	7700.00	5632.41

External stairs and ramps

type	n. volume [m]	n. of elements [m^2]	tot. volume [m^3]	density [kg/m^3]	mass [kg]
concrete	0.323	31.00	10.02	2100.000	21042.000
steel sheet	0.199	14.000	2.79	7700.000	21483.000

External railing

type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
concrete	0.150	64.33	9.65	2100.000	20265.000
alluminum handrail	0.002	11.310	0.02	2700.000	61.074

Additional floor layers element

type	n. volume [m^3]	n. of hooks	tot. volume [m^3]	density [kg/m^3]	mass [kg]
steel hooks	0.00042	13530.00	5.74	7700.000	44162.326
type	thickness [m]	surface [m^2]	volume [m^3]	density [kg/m^3]	mass [kg]
fir flooring	0.002	52020.000	104.04	450.000	46818.000

PV system

type	n. of elements	lenght [m]	height [m]
Pv panels	982	1.00	1.60

Gutter and tubes

type	tot. lenght [m]	area [mm^2]	volume [m^3]
gutters	801.460	680.00	0.54
tubes	604.510	872.92	0.53

Furniture

type	n. of elements
w.c.	112
sink	112

Quantitative table

Removed

type	surface [m^2]	volume [m^3]	mass [kg]
columns - 20x20h cm	-	19.92	8962.74
beams - 20x20h cm	-	58.34	26253.00
beams - 8x30h cm	-	26.01	11704.50
fir boards	6695.79	121.93	54866.55
wood panels - fir	10624.85	127.50	57374.17
wood panels - PMMA	1713.69	20.56	24471.42
wood panels - PVC	1713.69	20.56	28378.62
external d20	-	0.36	2749.62
steel bracing	-	1.97	15196.30
gypsium panels	0.00	108.51	73786.96
type	n. of elements	lenght [m]	height [m]
doors	27	0.90	2.10
doors	2	1.20	2.10

Added

type	surface [m^2]	volume [m^3]	mass [kg]
fir boards	4255.27	63.83	28723.06
fir flooring	52020.00	104.04	46818.00
wood panels - fir	10624.85	127.50	57374.17
wood panels - PMMA	1713.69	20.56	24471.42
wood panels - PVC	1713.69	20.56	28378.62
CLT	1744.41	209.33	104664.60
OSB boards	1744.41	20.93	13815.73
wood fiber inulation	8474.36	1186.41	59320.54
Cork insulation	1744.41	104.66	25119.50
EPE insulation	1744.41	17.44	2093.29
waterproof membrane	5963.81	23.86	23855.26
vapour barrier	8474.36	5.96	3876.48
sandwich panel	813.51	48.81	4881.05
concrete	-	19.67	41307.00
steel sheet	-	2.79	21483.00
steel hooks	-	5.74	44162.33
alluminum handrail	-	0.02	61.07
type	n. of elements	lenght [m]	height [m]
windows	455	1.20	1.50
PV panels	982	1.00	1.60
w.c.	100	-	-
sink	87	-	-

Added due to movment

type	surface [m^2]	volume [m^3]	mass [kg]
waterproof membrane	0.00	0.00	0.00
concrete	0.00	0.00	0.00
sand-cement	0.00	0.00	0.00
epoxy resin	0.00	0.00	0.00

Transported

type	surface [m^2]	volume [m^3]	mass [kg]
fir boards	-	0.00	0.00
fir flooring	0.00	0.00	0.00
Structural laminated timbe	-	0.00	0.00
CLT	0.00	0.00	0.00
OSB boards	0.00	0.00	0.00
Cork insulation	0.00	0.00	0.00
EPE insulation	0.00	0.00	0.00
XPS insulation	0.00	0.00	0.00
vapour barrier	0.00	0.00	0.00
gypsium panels	0.00	0.00	0.00
steel sheet	0.00	0.00	0.00
steel profile	-	0.00	0.00
type	n. of elements	lenght [m]	height [m]
skylight	0	0.00	0.00
doors	217	0.90	2.10
doors	13	1.20	2.10
doors	6	1.50	2.10
doors	10	1.60	2.10
doors	32	1.80	2.10
w.c.	0	-	-
sink	0	-	-

CASE 1

Name	Density[kg]	Unit		Amount[unit]	Source	A1-A2-A3 (EPD)							A4 (Calculated)						
						GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
						kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	450	volume	m3	1	EPD-RUB-20180061-IBB2-EN	-6.47E+02	2.13E-10	8.87E-01	1.91E-01	1.39E-01	2.32E+03	1.17E+04	6.52E+00	0.00E+00	1.19E-02	3.20E-03	9.61E-04	1.19E+02	0.00E+00
Wall - Sandwich panels	100	area	m2	1	S-P-01550	3.77E+01	9.29E-07	1.71E-01	2.67E-02	1.28E-02	4.94E+02	2.92E+01	9.56E-02	0.00E+00	3.87E-04	1.01E-04	2.16E-05	1.76E+00	0.00E+00
Wall - PMMA panels	1190	area	m2	1	SCS-EPD-04814	2.50E+02	1.20E-05	1.50E+00	3.60E-01	6.20E-02	2.30E+03	2.60E+02	2.48E-02	0.00E+00	4.75E-05	1.26E-05	3.60E-06	4.54E-01	0.00E+00
Wall - PVC panels	1380	area	m2	1	S-P-00737	3.71E+00	4.17E-07	3.63E-02	5.77E-03	1.26E-03	6.33E+01	4.43E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - Waterproof membrane	1000	area	m2	1	EPD-DUP-20150236-IBE1-EN	3.93E-01	6.10E-11	1.67E-03	1.02E-04	1.73E-04	1.05E+01	5.38E-01	3.66E-02	0.00E+00	7.01E-05	1.86E-05	5.31E-06	6.70E-01	0.00E+00
Wall/Slab - Vapour barrier	650	area	m2	1	S-P-00762	1.30E+00	1.15E-07	1.50E-02	1.85E-03	7.50E-04	2.30E+01	3.25E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - Gypsium board	680	area	m2	1	S-P-00796	1.78E+00	1.59E-07	2.82E-04	5.29E-03	1.57E-03	2.89E+01	7.53E-01	7.05E-02	0.00E+00	1.29E-04	3.46E-05	1.04E-05	1.29E+00	0.00E+00
Wall/Slab - Wood fiber insulation	50	volume	m3	1	EPD-GTX-20140222-IBC2-EN	-1.64E+02	8.75E-10	1.96E-01	3.16E-02	2.81E-02	2.08E+03	3.34E+03	5.26E+00	0.00E+00	9.62E-03	2.58E-03	7.75E-04	9.60E+01	0.00E+00
Slab - Fir flooring	450	volume	m3	1	EPD-RUB-20180061-IBB2-EN	-6.47E+02	2.13E-10	8.87E-01	1.91E-01	1.39E-01	2.32E+03	1.17E+04	3.17E+00	0.00E+00	5.80E-03	1.56E-03	4.67E-04	5.79E+01	0.00E+00
Structure - Structural laminated timber	500	volume	m3	1	S-P-01314	-6.86E+02	2.51E-05	1.01E+00	2.29E-01	1.45E-01	3.35E+03	2.67E+04	5.98E+00	0.00E+00	1.09E-02	2.94E-03	8.81E-04	1.09E+02	0.00E+00
Slab - CLT (cross laminated timber)	500	volume	m3	1	S-P-01314	-6.86E+02	2.51E-05	1.01E+00	2.29E-01	1.45E-01	3.35E+03	2.67E+04	5.96E+00	0.00E+00	1.09E-02	2.93E-03	8.78E-04	1.09E+02	0.00E+00
Slab - OSB boards	660	volume	m3	1	EPD-EGG-20180107-IBD1-EN	-7.53E+02	9.43E-11	9.19E-01	2.19E-01	5.22E-01	4.40E+03	1.30E+04	1.09E+01	0.00E+00	2.08E-02	5.53E-03	1.58E-03	1.99E+02	0.00E+00
Slab - Cork insulation	240	volume	m3	1	000464	-1.98E+02	6.81E-06	1.15E+00	3.67E-01	6.31E-02	9.80E+02	6.79E+03	5.96E+00	0.00E+00	1.09E-02	2.93E-03	8.78E-04	1.09E+02	0.00E+00
Slab - EPE insulation	120	area	m2	1	S-P-00840	2.21E-01	8.79E-09	6.35E-04	5.74E-05	8.03E-04	4.61E+00	2.35E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Steel sheet	7700	weight	kg	1	EPD-ARM-20180069-IBD1-EN	5.20E-01	6.37E-10	1.94E-03	1.51E-04	1.70E-04	9.69E+00	8.54E-01	1.76E-03	0.00E+00	3.38E-06	8.98E-07	2.56E-07	3.23E-02	0.00E+00
Elements - Steel profile	7700	weight	kg	1	S-P-00697	8.20E-01	7.30E-08	3.80E-03	1.00E-03	1.20E-03	1.26E+01	1.64E+00	7.47E-03	0.00E+00	1.37E-05	3.67E-06	1.10E-06	1.36E-01	0.00E+00
Elements - Aluminum profile	2700	weight	kg	1	S-P-01205	1.62E+01	1.06E-06	7.40E-02	2.60E-02	6.22E-03	2.54E+02	5.17E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Concrete	2100	volume	m3	1	EPD-RMC-20180095-CBG1-EN	2.46E+02	1.69E-06	3.98E-01	4.90E-02	1.18E-01	1.65E+03	7.69E+01	1.66E+00	0.00E+00	3.18E-03	8.46E-04	2.41E-04	3.04E+01	0.00E+00
Elements - Fir windows [1.20x1.50h m]	-	element	n.	1	NEPD00245E	1.02E+02	1.12E-05	3.30E-02	7.48E-01	1.96E-01	2.01E+03	1.14E+03	2.64E+00	0.00E+00	4.82E-03	1.29E-03	3.88E-04	4.81E+01	0.00E+00
Elements - Fir doors [0.90x2.10h m]	-	element	n.	1	S-P-01392	4.90E+01	4.40E-07	1.50E-01	8.00E-02	4.00E-02	7.82E+02	1.35E+03	1.06E+00	0.00E+00	4.29E-03	1.12E-03	2.40E-04	1.96E+01	0.00E+00
Elements - PV panels	-	area	m2	1	TERR-00001-V01.01-FR	1.18E+02	7.06E-06	8.77E-01	2.01E-01	1.66E-01	1.32E+03	3.78E+02	4.95E-01	0.00E+00	9.06E-04	2.43E-04	7.29E-05	9.04E+00	0.00E+00
Elements - w.c.	-	element	n.	1	GEB_EPD_D71192	2.19E+02	1.73E-05	1.59E+00	6.30E-01	9.42E-02	7.98E+02	2.74E+02	2.42E+00	0.00E+00	9.81E-03	2.56E-03	5.47E-04	4.47E+01	0.00E+00
Elements - Sink	-	element	n.	1	4788268911.119.1	2.67E+01	7.55E-07	1.83E-01	4.33E-02	8.96E-03	3.66E+02	1.21E+01	2.78E+00	0.00E+00	1.13E-02	2.95E-03	6.29E-04	5.14E+01	0.00E+00
Elements - AHU (water-air)	-	element	n.	1	UNIC-00020-V01.01-FR	7.10E+01	9.11E-01	1.83E-03	5.05E-06	9.45E-01	3.97E+01	8.02E+01	7.71E+01	0.00E+00	1.41E-01	3.78E-02	1.14E-02	1.41E+03	0.00E+00
Wall/slab - XPS insulation	25	area	m2	1	S-P-00501	2.57E+00	8.52E-08	1.04E-02	1.35E-03	6.30E-04	5.59E+01	2.34E+00	2.79E-02	0.00E+00	5.11E-05	1.37E-05	4.11E-06	5.10E-01	0.00E+00
Elements - Skylights	-	element	n.	1	NEPD00245E	1.02E+02	1.12E-05	3.30E-02	7.48E-01	1.96E-01	2.01E+03	1.14E+03	2.32E-01	0.00E+00	4.44E-04	1.18E-04	3.36E-05	4.24E+00	0.00E+00
Slab - Epoxy resin	561	weight	kg	1	S-P-00219	2.06E+00	1.29E-09	2.36E-02	9.09E-04	1.41E-03	4.93E+01	4.31E+00	6.03E-03	0.00E+00	1.16E-05	3.07E-06	8.76E-07	1.10E-01	0.00E+00

Name	A5 (Calculated)							B2-B4 (EPD) + (Calculated)						
	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	8.58E-02	1.10E-08	3.84E-04	1.07E-04	1.69E-05	1.45E+00	3.49E-01	-2.70E+02	-7.55E-05	-1.08E-04	-2.32E-05	-5.54E-06	3.02E-02	2.97E+02
Wall - Sandwich panels	2.76E-02	3.56E-09	1.24E-04	3.45E-05	5.45E-06	4.66E-01	1.12E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - PMMA panels	1.67E-02	2.15E-09	7.46E-05	2.09E-05	3.29E-06	2.82E-01	6.79E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - PVC panels	1.67E-02	2.15E-09	7.46E-05	2.09E-05	3.29E-06	2.82E-01	6.79E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - Waterproof membrane	2.48E-04	3.19E-11	1.11E-06	3.10E-07	4.88E-08	4.18E-03	1.01E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/Slab - Vapour barrier	8.01E-03	1.03E-09	3.58E-05	1.00E-05	1.58E-06	1.35E-01	3.26E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - Gypsium board	2.87E-02	3.69E-09	1.28E-04	3.59E-05	5.65E-06	4.84E-01	1.17E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/Slab - Wood fiber insulation	1.19E-01	1.53E-08	5.32E-04	1.49E-04	2.34E-05	2.01E+00	4.84E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - Fir flooring	1.60E+01	2.06E-06	7.16E-02	2.00E-02	3.15E-03	2.70E+02	6.51E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Structure - Structural laminated timber	2.61E-01	3.36E-08	1.17E-03	3.26E-04	5.15E-05	4.41E+00	1.06E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - CLT (cross laminated timber)	2.28E-01	2.93E-08	1.02E-03	2.85E-04	4.49E-05	3.85E+00	9.28E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - OSB boards	1.72E+00	2.22E-07	7.70E-03	2.15E-03	3.40E-04	2.91E+01	7.01E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - Cork insulation	1.95E-01	2.51E-08	8.71E-04	2.44E-04	3.84E-05	3.29E+00	7.92E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - EPE insulation	6.19E-04	7.97E-11	2.77E-06	7.74E-07	1.22E-07	1.05E-02	2.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Steel sheet	3.81E-04	4.90E-11	1.70E-06	4.76E-07	7.50E-08	6.43E-03	1.55E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Steel profile	3.73E-03	4.81E-10	1.67E-05	4.67E-06	7.36E-07	6.30E-02	1.52E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Aluminum profile	5.20E-03	6.70E-10	2.33E-05	6.51E-06	1.03E-06	8.78E-02	2.12E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Concrete	1.02E-01	1.31E-08	4.55E-04	1.27E-04	2.01E-05	1.72E+00	4.14E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Fir windows [1.20x1.50h m]	9.75E-02	1.26E-08	4.36E-04	1.22E-04	1.92E-05	1.65E+00	3.97E-01	2.22E+01	1.55E-06	8.88E-02	3.30E-02	7.00E-03	6.63E+02	1.39E+01
Elements - Fir doors [0.90x2.10h m]	9.75E-02	1.26E-08	4.36E-04	1.22E-04	1.92E-05	1.65E+00	3.97E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - PV panels	5.60E-02	7.21E-09	2.50E-04	7.00E-05	1.10E-05	9.45E-01	2.28E-01	8.64E-01	1.34E-07	6.09E-03	1.66E-03	1.55E-03	1.24E+01	3.48E+01
Elements - w.c.	1.05E-01	1.35E-08	4.69E-04	1.31E-04	2.07E-05	1.77E+00	4.27E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Sink	1.05E-01	1.35E-08	4.69E-04	1.31E-04	2.07E-05	1.77E+00	4.27E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - AHU (water-air)	6.57E-01	8.46E-08	2.94E-03	8.21E-04	1.29E-04	1.11E+01	2.67E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/slab - XPS insulation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.53E-01	8.50E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Skylights	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.29E+00	7.94E-01	2.22E+01	1.55E-06	8.88E-02	3.30E-02	7.00E-03	6.63E+02	1.39E+01
Slab - Epoxy resin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Name	C1-C2-C3-C4 (EPD) + (Calculated)							D (EPD)							Reuse / Recycling / Disposal	Returned / Waste dump / Waste to energy
	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)		
	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ		
Wall - Fir panels/boards	8.18E+02	2.70E-07	2.13E-02	5.82E-03	1.37E-03	1.54E+02	8.52E+00	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Wall - Sandwich panels	5.46E-01	6.00E-08	1.70E-03	5.05E-04	7.77E-05	6.91E+00	1.84E-01	-1.85E+01	-5.04E-07	-8.68E-02	-1.54E-02	-8.07E-03	-1.58E+02	-5.43E+00	recycling	returned
Wall - PMMA panels	4.16E-02	3.15E-09	9.14E-05	3.05E-05	7.93E-06	3.14E-01	6.80E-02								disposal	waste to energy
Wall - PVC panels	4.16E-02	3.15E-09	9.14E-05	3.05E-05	7.93E-06	3.14E-01	6.80E-02								disposal	waste to energy
Wall - Waterproof membrane	2.55E-01	3.24E-11	2.05E-05	4.07E-06	2.30E-06	1.42E-02	4.13E-03	-1.48E-01	-4.61E-11	-3.63E-04	-2.56E-05	-3.13E-05	-2.74E+00	-2.35E-01	disposal	waste to energy
Wall/Slab - Vapour barrier	1.21E-02	2.15E-09	5.88E-05	1.57E-05	2.45E-06	1.42E-01	3.28E-02	-3.70E-02	-1.15E-11	-9.08E-05	-6.40E-06	-7.83E-06	-6.85E-01	-5.88E-02	disposal	waste to energy
Wall - Gypsium board	8.83E-02	1.97E-08	1.47E-04	4.39E-04	9.87E-05	1.93E+00	1.48E-01								disposal	waste dump
Wall/Slab - Wood fiber insulation	2.76E+02	1.53E-08	1.02E-02	2.73E-03	7.98E-04	9.80E+01	4.84E-01	-2.26E+02	-1.56E-08	-2.35E-01	-1.79E-02	-6.39E-03	-3.21E+03	-5.04E+02	recycling	returned
Slab - Fir flooring	8.24E+02	1.51E-06	5.82E-02	1.62E-02	2.78E-03	2.56E+02	4.77E+01	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Structure - Structural laminated timber	8.66E+02	3.36E-08	1.21E-02	3.26E-03	9.33E-04	1.14E+02	1.06E+00	-5.65E+01	-6.22E-06	-3.77E-01	-9.55E-02	-3.60E-02	-8.69E+02	-1.28E+04	recycling	returned
Slab - CLT (cross laminated timber)	8.66E+02	2.93E-08	1.19E-02	3.21E-03	9.23E-04	1.13E+02	9.28E-01	-5.65E+01	-6.22E-06	-3.77E-01	-9.55E-02	-3.60E-02	-8.69E+02	-1.28E+04	recycling	returned
Slab - OSB boards	9.80E+02	2.16E-07	4.22E-02	9.01E-03	2.86E-03	3.25E+02	4.34E+01	-5.49E+02	-1.45E-09	-3.86E-02	2.41E-03	1.09E-01	-9.71E+03	-2.24E+03	recycling	returned
Slab - Cork insulation	6.16E+00	2.51E-08	1.18E-02	3.17E-03	9.16E-04	1.12E+02	7.92E-01								reuse	returned
Slab - EPE insulation	6.19E-04	7.97E-11	2.77E-06	7.74E-07	1.22E-07	1.05E-02	2.52E-03	-1.96E-01	1.01E-09	-5.78E-04	-3.65E-05	-5.39E-04	-4.26E+00	0.00E+00	reuse	returned
Elements - Steel sheet	4.18E-03	5.02E-11	1.14E-05	2.07E-06	8.20E-07	7.28E-02	1.03E-02	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Elements - Steel profile	1.32E-02	4.82E-10	3.67E-05	9.03E-06	2.33E-06	2.34E-01	2.40E-02	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Elements - Aluminum profile	3.25E-01	1.52E-08	1.22E-03	4.87E-04	5.61E-05	2.59E+00	2.51E-01								recycling	returned
Elements - Concrete	-1.67E+01	1.59E-08	6.19E-02	1.25E-02	5.99E-03	1.65E+02	1.50E+01								disposal	waste dump
Elements - Fir windows [1.20x1.50h m]	2.84E+01	1.70E-07	5.57E-03	9.30E-03	6.27E-03	6.63E+01	6.34E-01	-7.20E-01	-7.41E-08	-9.69E-05	-1.91E-03	-8.00E-04	-1.29E+01	-5.04E+01	recycling	returned
Elements - Fir doors [0.90x2.10h m]	8.10E+02	1.26E-08	4.73E-03	1.24E-03	2.59E-04	2.12E+01	3.97E-01	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Elements - PV panels	5.51E-01	7.21E-09	1.16E-03	3.13E-04	8.40E-05	9.99E+00	2.28E-01								-	-
Elements - w.c.	1.96E+01	1.64E-07	5.24E-02	4.55E-03	7.34E-05	9.47E+00	8.42E-01								disposal	waste dump
Elements - Sink	2.27E-01	4.07E-08	1.26E-03	3.66E-04	5.81E-05	4.80E+00	4.34E-01								disposal	waste dump
Elements - AHU (water-air)	7.78E+01	8.46E-08	1.44E-01	3.87E-02	1.15E-02	1.42E+03	2.68E+00	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Wall/slab - XPS insulation	1.98E-01	3.02E-09	2.09E-04	6.21E-03	3.62E-05	1.76E+00	5.66E-02								disposal	waste to energy
Elements - Skylights	2.59E+01	1.57E-07	7.58E-04	8.00E-03	5.89E-03	2.24E+01	6.34E-01	-7.20E-01	-7.41E-08	-9.69E-05	-1.91E-03	-8.00E-04	-1.29E+01	-5.04E+01	recycling	returned
Slab - Epoxy resin	2.78E-04	0.00E+00	5.33E-07	1.42E-07	4.04E-08	1.99E-01	4.67E-02	-6.90E-02	-2.28E-11	-1.10E-04	-1.11E-05	-1.16E-05	-1.16E+00	-1.57E-01	disposal	waste dump

CASE 2

Name	Density[kg]	Unit		Amount[unit]	Source	A1-A2-A3 (EPD)							A4 (Calculated)						
						GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
						kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	450	volume	m3	1	EPD-RUB-20180061-IBB2-EN	-6.47E+02	2.13E-10	8.87E-01	1.91E-01	1.39E-01	2.32E+03	1.17E+04	6.41E+00	0.00E+00	1.17E-02	3.15E-03	9.44E-04	1.17E+02	0.00E+00
Wall - Sandwich panels	100	area	m2	1	S-P-01550	3.77E+01	9.29E-07	1.71E-01	2.67E-02	1.28E-02	4.94E+02	2.92E+01	3.53E-01	0.00E+00	6.45E-04	1.73E-04	5.19E-05	4.28E+01	0.00E+00
Wall - PMMA panels	1190	area	m2	1	SCS-EPD-04814	2.50E+02	1.20E-05	1.50E+00	3.60E-01	6.20E-02	2.30E+03	2.60E+02	1.84E-02	0.00E+00	7.47E-05	1.95E-05	4.17E-06	3.40E-01	0.00E+00
Wall - PVC panels	1380	area	m2	1	S-P-00737	3.71E+00	4.17E-07	3.63E-02	5.77E-03	1.26E-03	6.33E+01	4.43E+00	1.84E-02	0.00E+00	7.47E-05	1.95E-05	4.17E-06	3.40E-01	0.00E+00
Wall - Waterproof membrane	1000	area	m2	1	EPD-DUP-20150236-IBE1-EN	3.93E-01	6.10E-11	1.67E-03	1.02E-04	1.73E-04	1.05E+01	5.38E-01	5.92E-02	0.00E+00	1.08E-04	2.91E-05	8.72E-06	1.08E+00	0.00E+00
Wall/Slab - Vapour barrier	650	area	m2	1	S-P-00762	1.30E+00	1.15E-07	1.50E-02	1.85E-03	7.50E-04	2.30E+01	3.25E+00	1.46E-02	0.00E+00	5.90E-05	1.54E-05	3.29E-06	2.69E-01	0.00E+00
Wall - Gypsium board	680	area	m2	1	S-P-00796	1.78E+00	1.59E-07	2.82E-04	5.29E-03	1.57E-03	2.89E+01	7.53E-01	4.79E-02	0.00E+00	8.77E-05	2.35E-05	7.06E-06	8.75E-01	0.00E+00
Wall/Slab - Wood fiber insulation	50	volume	m3	1	EPD-GTX-20140222-IBC2-EN	-1.64E+02	8.75E-10	1.96E-01	3.16E-02	2.81E-02	2.08E+03	3.34E+03	5.26E+00	0.00E+00	9.62E-03	2.58E-03	7.75E-04	9.60E+01	0.00E+00
Slab - Fir flooring	450	volume	m3	1	EPD-RUB-20180061-IBB2-EN	-6.47E+02	2.13E-10	8.87E-01	1.91E-01	1.39E-01	2.32E+03	1.17E+04	4.78E+00	0.00E+00	9.47E-03	2.53E-03	7.29E-04	8.73E+01	0.00E+00
Structure - Structural laminated timber	500	volume	m3	1	S-P-01314	-6.86E+02	2.51E-05	1.01E+00	2.29E-01	1.45E-01	3.35E+03	2.67E+04	1.14E+01	0.00E+00	2.09E-02	5.61E-03	1.68E-03	2.08E+02	0.00E+00
Slab - CLT (cross laminated timber)	500	volume	m3	1	S-P-01314	-6.86E+02	2.51E-05	1.01E+00	2.29E-01	1.45E-01	3.35E+03	2.67E+04	6.82E+00	0.00E+00	1.25E-02	3.35E-03	1.00E-03	1.24E+02	0.00E+00
Slab - OSB boards	660	volume	m3	1	EPD-EGG-20180107-IBD1-EN	-7.53E+02	9.43E-11	9.19E-01	2.19E-01	5.22E-01	4.40E+03	1.30E+04	6.07E+00	0.00E+00	1.11E-02	2.98E-03	8.93E-04	1.11E+02	0.00E+00
Slab - Cork insulation	240	volume	m3	1	000464	-1.98E+02	6.81E-06	1.15E+00	3.67E-01	6.31E-02	9.80E+02	6.79E+03	6.31E+00	0.00E+00	1.15E-02	3.10E-03	9.29E-04	1.15E+02	0.00E+00
Slab - EPE insulation	120	area	m2	1	S-P-00840	2.21E-01	8.79E-09	6.35E-04	5.74E-05	8.03E-04	4.61E+00	2.35E-02	6.70E-02	0.00E+00	1.28E-04	3.41E-05	9.72E-06	1.23E+00	0.00E+00
Elements - Steel sheet	7700	weight	kg	1	EPD-ARM-20180069-IBD1-EN	5.20E-01	6.37E-10	1.94E-03	1.51E-04	1.70E-04	9.69E+00	8.54E-01	3.75E-03	0.00E+00	6.87E-06	1.84E-06	5.53E-07	6.85E-02	0.00E+00
Elements - Steel profile	7700	weight	kg	1	S-P-00697	8.20E-01	7.30E-08	3.80E-03	1.00E-03	1.20E-03	1.26E+01	1.64E+00	9.52E-03	0.00E+00	1.74E-05	4.67E-06	1.40E-06	1.74E-01	0.00E+00
Elements - Alluminum profile	2700	weight	kg	1	S-P-01205	1.62E+01	1.06E-06	7.40E-02	2.60E-02	6.22E-03	2.54E+02	5.17E+01	2.28E-01	0.00E+00	9.26E-04	2.42E-04	5.17E-05	4.22E+00	0.00E+00
Elements - Concrete	2100	volume	m3	1	EPD-RMC-20180095-CBG1-EN	2.46E+02	1.69E-06	3.98E-01	4.90E-02	1.18E-01	1.65E+03	7.69E+01	7.17E-01	0.00E+00	1.31E-03	3.52E-04	1.06E-04	1.31E+01	0.00E+00
Elements - Fir windows [1.20x1.50h m]	-	element	n.	1	NEPD00245E	1.02E+02	1.12E-05	3.30E-02	7.48E-01	1.96E-01	2.01E+03	1.14E+03	2.64E+00	0.00E+00	4.82E-03	1.29E-03	3.88E-04	4.81E+01	0.00E+00
Elements - Fir doors [0.90x2.10h m]	-	element	n.	1	S-P-01392	4.90E+01	4.40E-07	1.50E-01	8.00E-02	4.00E-02	7.82E+02	1.35E+03	4.20E+00	0.00E+00	7.68E-03	2.06E-03	6.18E-04	7.67E+01	0.00E+00
Elements - PV panels	-	area	m2	1	TERR-00001-V01.01-FR	1.18E+02	7.06E-06	8.77E-01	2.01E-01	1.66E-01	1.32E+03	3.78E+02	4.95E-01	0.00E+00	9.06E-04	2.43E-04	7.29E-05	9.04E+00	0.00E+00
Elements - w.c.	-	element	n.	1	GEB_EPD_D71192	2.19E+02	1.73E-05	1.59E+00	6.30E-01	9.42E-02	7.98E+02	2.74E+02	2.38E+00	0.00E+00	9.63E-03	2.52E-03	5.38E-04	4.39E+01	0.00E+00
Elements - Sink	-	element	n.	1	4788268911.119.1	2.67E+01	7.55E-07	1.83E-01	4.33E-02	8.96E-03	3.66E+02	1.21E+01	2.38E+00	0.00E+00	9.63E-03	2.52E-03	5.38E-04	4.39E+01	0.00E+00
Elements - AHU (water-air)	-	element	n.	1	UNIC-00020-V01.01-FR	7.10E+01	9.11E-01	1.83E-03	5.05E-06	9.45E-01	3.97E+01	8.02E+01	7.71E+01	0.00E+00	1.41E-01	3.78E-02	1.14E-02	1.41E+03	0.00E+00
Wall/slab - XPS insulation	25	area	m2	1	S-P-00501	2.57E+00	8.52E-08	1.04E-02	1.35E-03	6.30E-04	5.59E+01	2.34E+00	2.79E-02	0.00E+00	5.11E-05	1.37E-05	4.11E-06	5.10E-01	0.00E+00
Elements - Skylights	-	element	n.	1	NEPD00245E	1.02E+02	1.12E-05	3.30E-02	7.48E-01	1.96E-01	2.01E+03	1.14E+03	2.32E-01	0.00E+00	4.44E-04	1.18E-04	3.36E-05	4.24E+00	0.00E+00
Slab - Epoxy resin	561	weight	kg	1	S-P-00219	2.06E+00	1.29E-09	2.36E-02	9.09E-04	1.41E-03	4.93E+01	4.31E+00	6.03E-03	0.00E+00	1.16E-05	3.07E-06	8.76E-07	1.10E-01	0.00E+00

Name	A5 (Calculated)							B2-B4 (EPD) + (Calculated)						
	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	2.48E-01	3.19E-08	1.11E-03	3.10E-04	4.88E-05	4.18E+00	1.01E+00	-2.73E+02	-1.56E-05	-2.23E-05	-4.72E-06	-1.12E-06	6.17E-03	6.08E+01
Wall - Sandwich panels	2.76E-02	3.56E-09	1.24E-04	3.45E-05	5.45E-06	4.66E-01	1.12E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - PMMA panels	1.67E-02	2.15E-09	7.46E-05	2.09E-05	3.29E-06	2.82E-01	6.79E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - PVC panels	1.67E-02	2.15E-09	7.46E-05	2.09E-05	3.29E-06	2.82E-01	6.79E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - Waterproof membrane	2.48E-04	3.19E-11	1.11E-06	3.10E-07	4.88E-08	4.18E-03	1.01E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/Slab - Vapour barrier	1.07E-02	1.38E-09	4.80E-05	1.34E-05	2.12E-06	1.81E-01	4.37E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - Gypsium board	4.04E-02	5.20E-09	1.81E-04	5.05E-05	7.96E-06	6.81E-01	1.64E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/Slab - Wood fiber insulation	1.19E-01	1.53E-08	5.32E-04	1.49E-04	2.34E-05	2.01E+00	4.84E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - Fir flooring	1.22E+01	1.57E-06	5.46E-02	1.53E-02	2.41E-03	2.06E+02	4.97E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Structure - Structural laminated timber	4.83E-01	6.22E-08	2.16E-03	6.04E-04	9.53E-05	8.16E+00	1.97E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - CLT (cross laminated timber)	3.43E-01	4.42E-08	1.54E-03	4.29E-04	6.77E-05	5.80E+00	1.40E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - OSB boards	2.91E+00	3.74E-07	1.30E-02	3.64E-03	5.73E-04	4.91E+01	1.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - Cork insulation	2.93E-01	3.78E-08	1.31E-03	3.67E-04	5.78E-05	4.95E+00	1.19E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - EPE insulation	9.33E-04	1.20E-10	4.17E-06	1.17E-06	1.84E-07	1.57E-02	3.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Steel sheet	5.74E-04	7.39E-11	2.57E-06	7.17E-07	1.13E-07	9.69E-03	2.33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Steel profile	6.21E-03	8.00E-10	2.78E-05	7.77E-06	1.22E-06	1.05E-01	2.53E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Alluminum profile	1.43E-02	1.84E-09	6.40E-05	1.79E-05	2.82E-06	2.41E-01	5.82E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Concrete	1.47E-01	1.89E-08	6.55E-04	1.83E-04	2.89E-05	2.47E+00	5.96E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Fir windows [1.20x1.50h m]	9.75E-02	1.26E-08	4.36E-04	1.22E-04	1.92E-05	1.65E+00	3.97E-01	2.22E+01	1.55E-06	8.88E-02	3.30E-02	7.00E-03	6.63E+02	1.39E+01
Elements - Fir doors [0.90x2.10h m]	1.86E-01	2.39E-08	8.31E-04	2.32E-04	3.66E-05	3.14E+00	7.56E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - PV panels	5.60E-02	7.21E-09	2.50E-04	7.00E-05	1.10E-05	9.45E-01	2.28E-01	8.64E-01	1.34E-07	6.09E-03	1.66E-03	1.55E-03	1.24E+01	3.48E+01
Elements - w.c.	1.16E-01	1.49E-08	5.19E-04	1.45E-04	2.29E-05	1.96E+00	4.72E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Sink	1.28E-01	1.65E-08	5.74E-04	1.60E-04	2.53E-05	2.16E+00	5.22E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - AHU (water-air)	6.57E-01	8.46E-08	2.94E-03	8.21E-04	1.29E-04	1.11E+01	2.67E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/slab - XPS insulation	2.09E-02	2.69E-09	9.35E-05	2.61E-05	4.12E-06	3.53E-01	8.50E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Skylights	1.95E-01	2.51E-08	8.73E-04	2.44E-04	3.85E-05	3.29E+00	7.94E-01	2.22E+01	1.55E-06	8.88E-02	3.30E-02	7.00E-03	6.63E+02	1.39E+01
Slab - Epoxy resin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Name	C1-C2-C3-C4 (EPD) + (Calculated)							D (EPD)							Reuse / Recycling / Disposal	Returned / Waste dump / Waste to energy
	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)		
	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ		
Wall - Fir panels/boards	8.15E+02	2.64E-08	1.12E-02	3.01E-03	8.68E-04	1.06E+02	8.36E-01	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Wall - Sandwich panels	7.08E-01	6.00E-08	1.81E-03	5.34E-04	9.34E-05	9.85E+00	1.84E-01	-1.85E+01	-5.04E-07	-8.68E-02	-1.54E-02	-8.07E-03	-1.58E+02	-5.43E+00	recycling	returned
Wall - PMMA panels	4.26E-02	3.15E-09	9.33E-05	3.10E-05	8.07E-06	3.32E-01	6.80E-02								disposal	waste to energy
Wall - PVC panels	4.26E-02	3.15E-09	9.33E-05	3.10E-05	8.07E-06	3.32E-01	6.80E-02								disposal	waste to energy
Wall - Waterproof membrane	2.55E-01	3.24E-11	2.03E-05	4.02E-06	2.29E-06	1.26E-02	4.13E-03	-1.48E-01	-4.61E-11	-3.63E-04	-2.56E-05	-3.13E-05	-2.74E+00	-2.35E-01	disposal	waste to energy
Wall/Slab - Vapour barrier	1.19E-02	2.15E-09	5.88E-05	1.57E-05	2.44E-06	1.39E-01	3.26E-02	-3.70E-02	-1.15E-11	-9.08E-05	-6.40E-06	-7.83E-06	-6.85E-01	-5.88E-02	disposal	waste to energy
Wall - Gypsium board	8.84E-02	1.97E-08	1.48E-04	4.39E-04	9.88E-05	1.93E+00	1.48E-01								disposal	waste dump
Wall/Slab - Wood fiber insulation	2.76E+02	1.53E-08	1.02E-02	2.73E-03	7.98E-04	9.80E+01	4.84E-01	-2.26E+02	-1.56E-08	-2.35E-01	-1.79E-02	-6.39E-03	-3.21E+03	-5.04E+02	recycling	returned
Slab - Fir flooring	8.25E+02	1.51E-06	6.06E-02	1.68E-02	2.97E-03	2.79E+02	4.77E+01	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Structure - Structural laminated timber	8.65E+02	3.36E-08	1.10E-02	2.96E-03	8.40E-04	1.02E+02	1.06E+00	-5.65E+01	-6.22E-06	-3.77E-01	-9.55E-02	-3.60E-02	-8.69E+02	-1.28E+04	recycling	returned
Slab - CLT (cross laminated timber)	8.65E+02	2.93E-08	1.18E-02	3.17E-03	9.11E-04	1.11E+02	9.28E-01	-5.65E+01	-6.22E-06	-3.77E-01	-9.55E-02	-3.60E-02	-8.69E+02	-1.28E+04	recycling	returned
Slab - OSB boards	9.74E+02	2.16E-07	3.11E-02	6.08E-03	2.06E-03	2.23E+02	4.34E+01	-5.49E+02	-1.45E-09	-3.86E-02	2.41E-03	1.09E-01	-9.71E+03	-2.24E+03	recycling	returned
Slab - Cork insulation	6.08E+00	2.51E-08	1.16E-02	3.13E-03	9.05E-04	1.11E+02	7.92E-01								reuse	returned
Slab - EPE insulation	6.50E-02	7.97E-11	1.26E-04	3.35E-05	9.46E-06	1.19E+00	2.52E-03	-1.96E-01	1.01E-09	-5.78E-04	-3.65E-05	-5.39E-04	-4.26E+00	0.00E+00	reuse	returned
Elements - Steel sheet	2.92E-03	5.11E-11	8.99E-06	1.44E-06	6.38E-07	4.98E-02	1.03E-02	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Elements - Steel profile	9.33E-03	4.82E-10	2.95E-05	7.12E-06	1.75E-06	1.62E-01	2.40E-02	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Elements - Alluminum profile	5.56E-01	1.52E-08	2.16E-03	7.31E-04	1.08E-04	6.85E+00	2.51E-01								recycling	returned
Elements - Concrete	-1.68E+01	1.59E-08	6.18E-02	1.25E-02	5.98E-03	1.64E+02	1.50E+01								disposal	waste dump
Elements - Fir windows [1.20x1.50h m]	2.84E+01	1.70E-07	5.57E-03	9.30E-03	6.27E-03	6.63E+01	6.34E-01	-7.20E-01	-7.41E-08	-9.69E-05	-1.91E-03	-8.00E-04	-1.29E+01	-5.04E+01	recycling	returned
Elements - Fir doors [0.90x2.10h m]	8.13E+02	1.26E-08	7.58E-03	2.04E-03	5.95E-04	7.30E+01	3.97E-01	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Elements - PV panels	5.51E-01	7.21E-09	1.16E-03	3.13E-04	8.40E-05	9.99E+00	2.28E-01								-	-
Elements - w.c.	1.96E+01	1.64E-07	5.24E-02	4.54E-03	7.30E-05	9.44E+00	8.42E-01								disposal	waste dump
Elements - Sink	2.23E-01	4.07E-08	1.24E-03	3.62E-04	5.72E-05	4.73E+00	4.34E-01								disposal	waste dump
Elements - AHU (water-air)	7.73E+01	2.08E-08	1.42E-01	3.81E-02	1.14E-02	1.41E+03	6.66E-01	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Wall/slab - XPS insulation	2.09E-01	4.52E-09	2.61E-04	6.23E-03	3.85E-05	1.76E+00	5.66E-02								disposal	waste to energy
Elements - Skylights	2.60E+01	1.70E-07	1.19E-03	8.12E-03	5.91E-03	2.24E+01	6.34E-01	-7.20E-01	-7.41E-08	-9.69E-05	-1.91E-03	-8.00E-04	-1.29E+01	-5.04E+01	recycling	returned
Slab - Epoxy resin	1.18E-02	1.48E-09	5.19E-05	1.45E-05	2.30E-06	1.99E-01	4.67E-02	-6.90E-02	-2.28E-11	-1.10E-04	-1.11E-05	-1.16E-05	-1.16E+00	-1.57E-01	disposal	waste dump

CASE 3

Name	Density[kg]	Unit		Amount[unit]	Source	A1-A2-A3 (EPD)							A4 (Calculated)						
						GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
						kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	450	volume	m3	1	EPD-RUB-20180061-IBB2-EN	-6.47E+02	2.13E-10	8.87E-01	1.91E-01	1.39E-01	2.32E+03	1.17E+04	4.37E+00	0.00E+00	8.00E-03	2.15E-03	6.44E-04	7.98E+01	0.00E+00
Wall - Sandwich panels	100	area	m2	1	S-P-01550	3.77E+01	9.29E-07	1.71E-01	2.67E-02	1.28E-02	4.94E+02	2.92E+01	9.56E-02	0.00E+00	3.87E-04	1.01E-04	2.16E-05	1.76E+00	0.00E+00
Wall - PMMA panels	1190	area	m2	1	SCS-EPD-04814	2.50E+02	1.20E-05	1.50E+00	3.60E-01	6.20E-02	2.30E+03	2.60E+02	1.84E-02	0.00E+00	7.47E-05	1.95E-05	4.17E-06	3.40E-01	0.00E+00
Wall - PVC panels	1380	area	m2	1	S-P-00737	3.71E+00	4.17E-07	3.63E-02	5.77E-03	1.26E-03	6.33E+01	4.43E+00	1.84E-02	0.00E+00	7.47E-05	1.95E-05	4.17E-06	3.40E-01	0.00E+00
Wall - Waterproof membrane	1000	area	m2	1	EPD-DUP-20150236-IBE1-EN	3.93E-01	6.10E-11	1.67E-03	1.02E-04	1.73E-04	1.05E+01	5.38E-01	2.16E-02	0.00E+00	4.13E-05	1.10E-05	3.13E-06	3.95E-01	0.00E+00
Wall/Slab - Vapour barrier	650	area	m2	1	S-P-00762	1.30E+00	1.15E-07	1.50E-02	1.85E-03	7.50E-04	2.30E+01	3.25E+00	1.46E-02	0.00E+00	5.90E-05	1.54E-05	3.29E-06	2.69E-01	0.00E+00
Wall - Gypsium board	680	area	m2	1	S-P-00796	1.78E+00	1.59E-07	2.82E-04	5.29E-03	1.57E-03	2.89E+01	7.53E-01	4.79E-02	0.00E+00	8.77E-05	2.35E-05	7.06E-06	8.75E-01	0.00E+00
Wall/Slab - Wood fiber insulation	50	volume	m3	1	EPD-GTX-20140222-IBC2-EN	-1.64E+02	8.75E-10	1.96E-01	3.16E-02	2.81E-02	2.08E+03	3.34E+03	5.26E+00	0.00E+00	9.62E-03	2.58E-03	7.75E-04	9.60E+01	0.00E+00
Slab - Fir flooring	450	volume	m3	1	EPD-RUB-20180061-IBB2-EN	-6.47E+02	2.13E-10	8.87E-01	1.91E-01	1.39E-01	2.32E+03	1.17E+04	2.55E+00	0.00E+00	5.40E-03	1.44E-03	4.02E-04	4.67E+01	0.00E+00
Structure - Structural laminated timber	500	volume	m3	1	S-P-01314	-6.86E+02	2.51E-05	1.01E+00	2.29E-01	1.45E-01	3.35E+03	2.67E+04	7.22E+00	0.00E+00	1.32E-02	3.54E-03	1.06E-03	1.32E+02	0.00E+00
Slab - CLT (cross laminated timber)	500	volume	m3	1	S-P-01314	-6.86E+02	2.51E-05	1.01E+00	2.29E-01	1.45E-01	3.35E+03	2.67E+04	6.82E+00	0.00E+00	1.25E-02	3.35E-03	1.00E-03	1.24E+02	0.00E+00
Slab - OSB boards	660	volume	m3	1	EPD-EGG-20180107-IBD1-EN	-7.53E+02	9.43E-11	9.19E-01	2.19E-01	5.22E-01	4.40E+03	1.30E+04	1.73E+00	0.00E+00	3.24E-03	8.66E-04	2.53E-04	3.16E+01	0.00E+00
Slab - Cork insulation	240	volume	m3	1	000464	-1.98E+02	6.81E-06	1.15E+00	3.67E-01	6.31E-02	9.80E+02	6.79E+03	3.36E+00	0.00E+00	6.15E-03	1.65E-03	4.95E-04	6.14E+01	0.00E+00
Slab - EPE insulation	120	area	m2	1	S-P-00840	2.21E-01	8.79E-09	6.35E-04	5.74E-05	8.03E-04	4.61E+00	2.35E-02	5.20E-02	0.00E+00	1.93E-04	5.04E-05	1.11E-05	9.58E-01	0.00E+00
Elements - Steel sheet	7700	weight	kg	1	EPD-ARM-20180069-IBD1-EN	5.20E-01	6.37E-10	1.94E-03	1.51E-04	1.70E-04	9.69E+00	8.54E-01	3.38E-03	0.00E+00	6.27E-06	1.68E-06	4.96E-07	6.18E-02	0.00E+00
Elements - Steel profile	7700	weight	kg	1	S-P-00697	8.20E-01	7.30E-08	3.80E-03	1.00E-03	1.20E-03	1.26E+01	1.64E+00	3.59E-03	0.00E+00	6.56E-06	1.76E-06	5.29E-07	6.55E-02	0.00E+00
Elements - Alluminum profile	2700	weight	kg	1	S-P-01205	1.62E+01	1.06E-06	7.40E-02	2.60E-02	6.22E-03	2.54E+02	5.17E+01	2.28E-01	0.00E+00	9.26E-04	2.42E-04	5.17E-05	4.22E+00	0.00E+00
Elements - Concrete	2100	volume	m3	1	EPD-RMC-20180095-CBG1-EN	2.46E+02	1.69E-06	3.98E-01	4.90E-02	1.18E-01	1.65E+03	7.69E+01	2.18E-02	0.00E+00	4.17E-05	1.11E-05	3.16E-06	3.99E-01	0.00E+00
Elements - Fir windows [1.20x1.50h m]	-	element	n.	1	NEPD00245E	1.02E+02	1.12E-05	3.30E-02	7.48E-01	1.96E-01	2.01E+03	1.14E+03	2.64E+00	0.00E+00	4.82E-03	1.29E-03	3.88E-04	4.81E+01	0.00E+00
Elements - Fir doors [0.90x2.10h m]	-	element	n.	1	S-P-01392	4.90E+01	4.40E-07	1.50E-01	8.00E-02	4.00E-02	7.82E+02	1.35E+03	1.35E+00	0.00E+00	7.68E-03	2.06E-03	6.18E-04	2.49E+01	0.00E+00
Elements - PV panels	-	area	m2	1	TERR-00001-V01.01-FR	1.18E+02	7.06E-06	8.77E-01	2.01E-01	1.66E-01	1.32E+03	3.78E+02	4.95E-01	0.00E+00	9.06E-04	2.43E-04	7.29E-05	9.04E+00	0.00E+00
Elements - w.c.	-	element	n.	1	GEB_EPD_D71192	2.19E+02	1.73E-05	1.59E+00	6.30E-01	9.42E-02	7.98E+02	2.74E+02	2.38E+00	0.00E+00	9.63E-03	2.52E-03	5.38E-04	4.39E+01	0.00E+00
Elements - Sink	-	element	n.	1	4788268911.119.1	2.67E+01	7.55E-07	1.83E-01	4.33E-02	8.96E-03	3.66E+02	1.21E+01	2.38E+00	0.00E+00	9.63E-03	2.52E-03	5.38E-04	4.39E+01	0.00E+00
Elements - AHU (water-air)	-	element	n.	1	UNIC-00020-V01.01-FR	7.10E+01	9.11E-01	1.83E-03	5.05E-06	9.45E-01	3.97E+01	8.02E+01	7.71E+01	0.00E+00	1.41E-01	3.78E-02	1.14E-02	1.41E+03	0.00E+00
Wall/slab - XPS insulation	25	area	m2	1	S-P-00501	2.57E+00	8.52E-08	1.04E-02	1.35E-03	6.30E-04	5.59E+01	2.34E+00	2.79E-02	0.00E+00	5.11E-05	1.37E-05	4.11E-06	5.10E-01	0.00E+00
Elements - Skylights	-	element	n.	1	NEPD00245E	1.02E+02	1.12E-05	3.30E-02	7.48E-01	1.96E-01	2.01E+03	1.14E+03	2.32E-01	0.00E+00	4.44E-04	1.18E-04	3.36E-05	4.24E+00	0.00E+00
Slab - Epoxy resin	561	weight	kg	1	S-P-00219	2.06E+00	1.29E-09	2.36E-02	9.09E-04	1.41E-03	4.93E+01	4.31E+00	6.03E-03	0.00E+00	1.16E-05	3.07E-06	8.76E-07	1.10E-01	0.00E+00

Name	A5 (Calculated)							B2-B4 (EPD) + (Calculated)						
	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)
	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ
Wall - Fir panels/boards	2.05E-01	2.64E-08	9.19E-04	2.57E-04	4.05E-05	3.47E+00	8.36E-01	-2.75E+02	-1.43E-05	-2.03E-05	-4.27E-06	-1.02E-06	5.62E-03	5.53E+01
Wall - Sandwich panels	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - PMMA panels	1.67E-02	2.15E-09	7.46E-05	2.09E-05	3.29E-06	2.82E-01	6.79E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - PVC panels	1.67E-02	2.15E-09	7.46E-05	2.09E-05	3.29E-06	2.82E-01	6.79E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - Waterproof membrane	2.48E-04	3.19E-11	1.11E-06	3.10E-07	4.88E-08	4.18E-03	1.01E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/Slab - Vapour barrier	8.03E-03	1.03E-09	3.59E-05	1.00E-05	1.58E-06	1.36E-01	3.27E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall - Gypsium board	2.87E-02	3.69E-09	1.28E-04	3.58E-05	5.65E-06	4.84E-01	1.17E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/Slab - Wood fiber insulation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - Fir flooring	1.66E+00	2.13E-07	7.41E-03	2.07E-03	3.26E-04	2.80E+01	6.74E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Structure - Structural laminated timber	2.61E-01	3.36E-08	1.17E-03	3.27E-04	5.15E-05	4.41E+00	1.06E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - CLT (cross laminated timber)	2.28E-01	2.93E-08	1.02E-03	2.85E-04	4.49E-05	3.85E+00	9.28E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - OSB boards	1.51E+00	1.95E-07	6.76E-03	1.89E-03	2.98E-04	2.55E+01	6.15E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - Cork insulation	1.95E-01	2.51E-08	8.71E-04	2.44E-04	3.84E-05	3.29E+00	7.92E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slab - EPE insulation	6.19E-04	7.97E-11	2.77E-06	7.74E-07	1.22E-07	1.05E-02	2.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Steel sheet	4.48E-04	5.77E-11	2.01E-06	5.61E-07	8.84E-08	7.57E-03	1.82E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Steel profile	3.73E-03	4.81E-10	1.67E-05	4.67E-06	7.36E-07	6.30E-02	1.52E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Alluminum profile	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Concrete	1.58E-01	2.03E-08	7.07E-04	1.98E-04	3.11E-05	2.67E+00	6.43E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Fir windows [1.20x1.50h m]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.22E+01	1.55E-06	8.88E-02	3.30E-02	7.00E-03	6.63E+02	1.39E+01
Elements - Fir doors [0.90x2.10h m]	9.75E-02	1.26E-08	4.36E-04	1.22E-04	1.92E-05	1.65E+00	3.97E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - PV panels	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.64E-01	1.34E-07	6.09E-03	1.66E-03	1.55E-03	1.24E+01	3.48E+01
Elements - w.c.	1.12E-02	1.45E-09	5.02E-05	1.40E-05	2.21E-06	1.90E-01	4.57E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Sink	2.34E-02	3.01E-09	1.05E-04	2.93E-05	4.61E-06	3.95E-01	9.52E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - AHU (water-air)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Wall/slab - XPS insulation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.53E-01	8.50E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elements - Skylights	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.29E+00	7.94E-01	2.22E+01	1.55E-06	8.88E-02	3.30E-02	7.00E-03	6.63E+02	1.39E+01
Slab - Epoxy resin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Name	C1-C2-C3-C4 (EPD) + (Calculated)							D (EPD)							Reuse / Recycling / Disposal	Returned / Waste dump / Waste to energy
	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)	GWP	ODP	AP	EP	POCP	PE (non Re)	PE (Re)		
	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ	kg CO2eq	kg CFC11eq	kg SO2eq	kg (PO4)3eq	kg C2H4eq	MJ	MJ		
Wall - Fir panels/boards	8.15E+02	2.64E-08	1.12E-02	3.01E-03	8.68E-04	1.06E+02	8.36E-01	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Wall - Sandwich panels	6.80E-01	5.64E-08	1.68E-03	5.00E-04	8.79E-05	9.39E+00	7.16E-02	-1.85E+01	-5.04E-07	-8.68E-02	-1.54E-02	-8.07E-03	-1.58E+02	-5.43E+00	recycling	returned
Wall - PMMA panels	4.26E-02	3.15E-09	9.33E-05	3.10E-05	8.07E-06	3.32E-01	6.80E-02								disposal	waste to energy
Wall - PVC panels	4.26E-02	3.15E-09	9.33E-05	3.10E-05	8.07E-06	3.32E-01	6.80E-02								disposal	waste to energy
Wall - Waterproof membrane	2.55E-01	3.24E-11	2.03E-05	4.02E-06	2.29E-06	1.26E-02	4.13E-03	-1.48E-01	-4.61E-11	-3.63E-04	-2.56E-05	-3.13E-05	-2.74E+00	-2.35E-01	disposal	waste to energy
Wall/Slab - Vapour barrier	1.20E-02	2.15E-09	5.89E-05	1.57E-05	2.44E-06	1.39E-01	3.27E-02	-3.70E-02	-1.15E-11	-9.08E-05	-6.40E-06	-7.83E-06	-6.85E-01	-5.88E-02	disposal	waste to energy
Wall - Gypsium board	8.84E-02	1.97E-08	1.48E-04	4.39E-04	9.88E-05	1.93E+00	1.48E-01								disposal	waste dump
Wall/Slab - Wood fiber insulation	2.76E+02	0.00E+00	9.62E-03	2.58E-03	7.75E-04	9.60E+01	0.00E+00	-2.26E+02	-1.56E-08	-2.35E-01	-1.79E-02	-6.39E-03	-3.21E+03	-5.04E+02	recycling	returned
Slab - Fir flooring	8.15E+02	2.13E-07	1.55E-02	4.25E-03	9.82E-04	1.09E+02	6.74E+00	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Structure - Structural laminated timber	8.65E+02	3.36E-08	1.10E-02	2.96E-03	8.40E-04	1.02E+02	1.06E+00	-5.65E+01	-6.22E-06	-3.77E-01	-9.55E-02	-3.60E-02	-8.69E+02	-1.28E+04	recycling	returned
Slab - CLT (cross laminated timber)	8.65E+02	2.93E-08	1.18E-02	3.17E-03	9.11E-04	1.11E+02	9.28E-01	-5.65E+01	-6.22E-06	-3.77E-01	-9.55E-02	-3.60E-02	-8.69E+02	-1.28E+04	recycling	returned
Slab - OSB boards	9.74E+02	1.95E-07	3.04E-02	5.87E-03	2.03E-03	2.20E+02	4.28E+01	-5.49E+02	-1.45E-09	-3.86E-02	2.41E-03	1.09E-01	-9.71E+03	-2.24E+03	recycling	returned
Slab - Cork insulation	6.08E+00	2.51E-08	1.16E-02	3.13E-03	9.05E-04	1.11E+02	7.92E-01								reuse	returned
Slab - EPE insulation	6.50E-02	7.97E-11	1.26E-04	3.35E-05	9.46E-06	1.19E+00	2.52E-03	-1.96E-01	1.01E-09	-5.78E-04	-3.65E-05	-5.39E-04	-4.26E+00	0.00E+00	reuse	returned
Elements - Steel sheet	2.98E-03	5.89E-11	9.27E-06	1.51E-06	6.50E-07	5.09E-02	1.06E-02	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Elements - Steel profile	9.33E-03	4.82E-10	2.95E-05	7.12E-06	1.75E-06	1.62E-01	2.40E-02	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Elements - Alluminum profile	5.51E-01	1.45E-08	2.14E-03	7.24E-04	1.07E-04	6.76E+00	2.30E-01								recycling	returned
Elements - Concrete	-1.67E+01	2.04E-08	6.20E-02	1.25E-02	5.99E-03	1.65E+02	1.51E+01								disposal	waste dump
Elements - Fir windows [1.20x1.50h m]	2.83E+01	1.57E-07	5.14E-03	9.17E-03	6.25E-03	6.47E+01	2.37E-01	-7.20E-01	-7.41E-08	-9.69E-05	-1.91E-03	-8.00E-04	-1.29E+01	-5.04E+01	recycling	returned
Elements - Fir doors [0.90x2.10h m]	8.13E+02	1.26E-08	7.58E-03	2.04E-03	5.95E-04	7.30E+01	3.97E-01	-4.47E+02	-1.17E-09	5.17E-01	1.40E-02	9.72E-02	-8.04E+03	-1.86E+03	recycling	returned
Elements - PV panels	4.95E-01	0.00E+00	9.06E-04	2.43E-04	7.29E-05	9.04E+00	0.00E+00								-	-
Elements - w.c.	1.95E+01	1.52E-07	5.20E-02	4.43E-03	5.46E-05	7.86E+00	4.61E-01								disposal	waste dump
Elements - Sink	1.41E-01	3.02E-08	8.80E-04	2.60E-04	4.12E-05	3.36E+00	1.03E-01								disposal	waste dump
Elements - AHU (water-air)	7.71E+01	1.22E-12	1.41E-01	3.78E-02	1.14E-02	1.41E+03	8.76E-03	-3.23E+00	-1.60E-07	9.79E-04	5.59E-04	2.82E-02	0.00E+00	-2.75E+02	recycling	returned
Wall/slab - XPS insulation	1.98E-01	3.02E-09	2.09E-04	6.21E-03	3.62E-05	1.76E+00	5.66E-02								disposal	waste to energy
Elements - Skylights	2.59E+01	1.57E-07	7.58E-04	8.00E-03	5.89E-03	2.24E+01	6.34E-01	-7.20E-01	-7.41E-08	-9.69E-05	-1.91E-03	-8.00E-04	-1.29E+01	-5.04E+01	recycling	returned
Slab - Epoxy resin	2.78E-04	0.00E+00	5.33E-07	1.42E-07	4.04E-08	1.99E-01	4.67E-02	-6.90E-02	-2.28E-11	-1.10E-04	-1.11E-05	-1.16E-05	-1.16E+00	-1.57E-01	disposal	waste dump