SOLCONCER, A HELPFUL TOOL FOR CHARACTERISING CONSTRUCTION SOLUTIONS

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1. ABSTRACT

This paper presents the methodology and IT program used to accurately characterise numerous construction products or building solutions in terms of their environmental, economic and social benefits, so that specifications writers, cladding manufacturers, and the public at large may be able to evaluate different surface cladding materials. To make that assessment, a number of indicators related to the three aspects at issue are specified. Furthermore, a series of scenarios (usage, traffic intensity, type of premises, etc.) are defined, which allow for closer fine tuning of the initial assumptions that affect how these construction solutions are calculated.

Characterisation of Performance stems from a methodology based on the requirements of the EOTA[1]'s Technical Guidelines (ETAGs) for construction solutions, in turn based on six of the seven essential requirements contained in the EU Construction Products Directive, but includes an eighth requirement that considers **durability** and its finish (i.e. technical obsolescence and/or aesthetic obsolescence with regard to 'impaired appearance'). Based on this set of requirements, a series of indicators are considered that determine the quality of construction solution performance.

Characterisation of environmental impact and associated costs for the construction solutions under consideration has been organised into different life cycle stages, in accordance with the system of modules set out in the UNE-EN 15804 and

15978 standards on Sustainability in construction. The construction solution is thus assessed in its entirety, including the costs and impacts associated with extracting its raw materials and with its installation, usage and end of life process.

The indicators for each of the three aspects under assessment can be viewed or modified by the user, which adds great flexibility to the program. This feature allows manufacturers to foresee how a change in material characteristics (price, environmental impacts or performance) affects the way a construction system is perceived.

2. INTRODUCTION

This paper presents the Solconcer software tool, the main objective of which is to assess the performance of construction elements that use ceramic tiles and other alternative materials, in order to select, on the basis of certain criteria of choice, which solution is the most suitable of the various options under analysis.

To carry out that assessment, various construction elements are examined from different viewpoints, namely their environmental impact, cost in economic terms, and their technical performance, hereinafter referred to as 'sets of indicators'. Each of these three sets comprises a series of **indicators**, which, in the case of environmental impact and economic cost, are always the same, regardless of the type of construction solution being assessed (horizontal partitions, vertical partitions, etc.), for example, potential contribution to climate change or cost in Euros, whereas in the case of performance, the indicators vary according to the technical requirements to be met by each type of construction solution, for example Slipperiness or Continuity of flooring.

At the end of the assessment of the various construction systems, the user of the computer tool, hereinafter referred to as **program**, is given a triad of scores on a scale of between 1 and 10 that correspond to each set of indicators. However, the user can see the value assigned to each indicator in order to evaluate the influence it has had on the final assessment score.

The user first has to define the conditions and features of the construction solution under assessment in order to assign the indicators. Thus, for instance, environmental impact or economic cost will vary depending on the distance from the point of supply, maintenance, or other conditions. The particular circumstances of each construction solution are hereinafter called '**scenarios**' and are defined by the different assumptions that apply to each. Figure 1 shows an overview of the program:

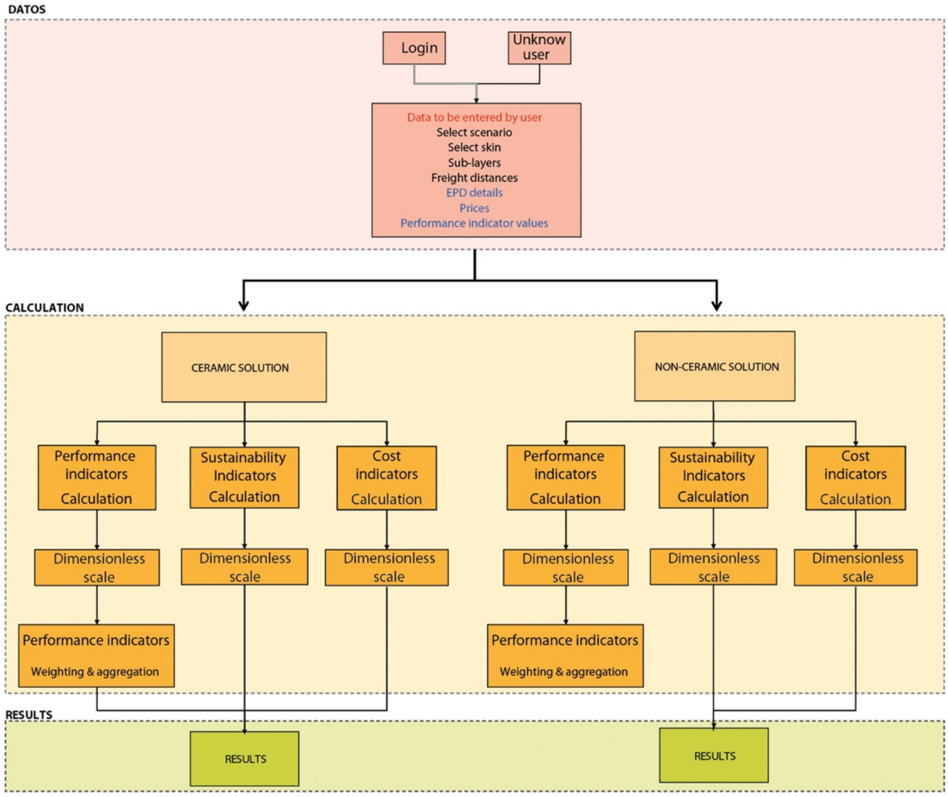


Figure 1. *Overview of the Solconcer program*

The sources of information used are opinions from construction sector professionals, different technical standards and the EOTA Technical Guidelines (ETAGs) and reference documents [2, 3, 4 y 5] in order to cover both the most common construction techniques and the recommendations proposed by different guides and manuals.

Let us now explain the assumptions used, the relevant scenarios, the construction solutions assessed, materials, groups of indicators, calculation procedures used and the characteristics of the software.

3. CONSIDERATIONS AFFECTING ALL CONSTRUCTION SOLUTIONS

A number of assumptions have been established for all construction solutions that primarily affect the environmental and economic sets of indicators, since the third set of indicators – performance – is directly related to the specific nature of each construction solution.

A construction solution includes all the various layers that comprise it (Figure 2).

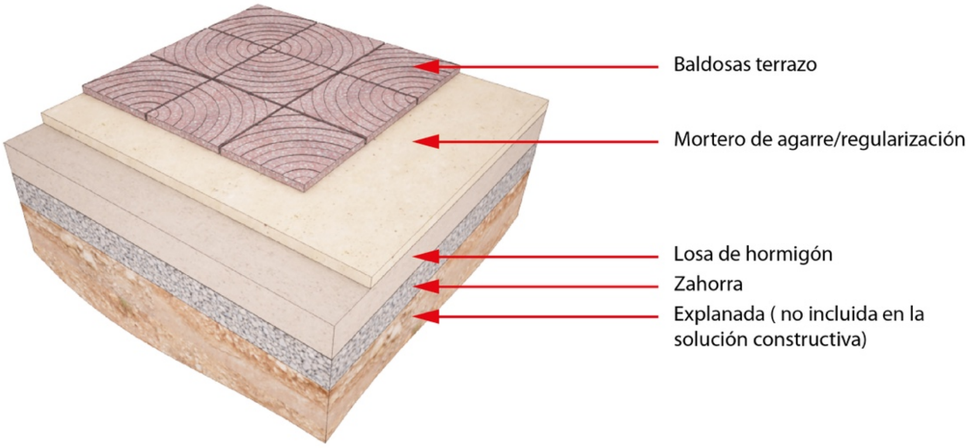


Figure 2. *Example of a construction solution. Street paving*

3.1. LIFE CYCLE

In all cases, the Functional Unit represents the function of the construction solution with a surface area of 1 m^2 over a time span of 50[6] years, in the case of indoor vertical and horizontal partition walls, and 40[7] years, in the case of urban street paving within the geographical and technological context of Spain. The various life cycle stages have been taken from the model proposed in the Sustainability in Construction standards[8] (Figure 2)

[redacted]

Figure 2*. Life cycle stages*

The software in this tool takes modules A1-A3 together. Furthermore, module B5-Refurbishment, which comprises the scheduled replacement of the item, would be practically tantamount to Replacement B4. Similarly, modules B6 and B7 on Operating Energy and Water are not applicable.

3.2. TRANSPORT OF CONSTRUCTION PRODUCTS (A4)

This variable has a bearing on environmental and economic impacts. In order to track its significant variability, two options have been proposed that allow for flexibility and reasonable accuracy. In the case of the cladding material, if the user knows the exact place where it was manufactured, the user has the option of entering the distance in kilometres. In this case, the program assigns road haulage for short distances and sea freight when that distance is exceeded, with an amount of road haulage to cover transfer to/from port.

The alternative is that the user does not know where the cladding was manufactured and so simply chooses its origin between national, European (overland haulage along default routes), or rest of the world (sea freight plus pre-set road haulage).

For the remaining layers, regional road haulage is allocated, as all components are supposed to have been delivered by a local supplier.

With regard to costing out road haulage (€/kg/km), the costs are calculated using data from the Ministry of Public Works' Observatory of Goods Freight Costs[9], whereas sea freighting costs (€/kg/km) are calculated on the basis of data contained in the Observatory for Intermodal Land and Sea Freight[10].

3.3. REPLACEMENT FREQUENCIES

The operations involved in any replacement are:

- Deconstrucción de la dermis
- Transporte de los residuos generados en la deconstrucción
- Tratamiento y/o eliminación de dichos residuos
- Fabricación del nuevo material a reponer
- Transporte del nuevo material a reponer
- Colocación del nuevo material a reponer

The assumptions and environmental and economic impacts associated with each of these operations are:

- Demolition or dismantling of the cladding and transport of the waste generated during dismantling, the same waste as is defined in the End of Life stage discussed below.
- For all operations involving the new materials to be fitted: manufacture, transportation and installation, where the values obtained the first time it was built shall be used.

A reference number or frequency of operations during the estimated service life of the construction solution is taken into consideration. Figure 4 shows the number and type of operations required on the assumption that the cladding has a service life of 20 years.

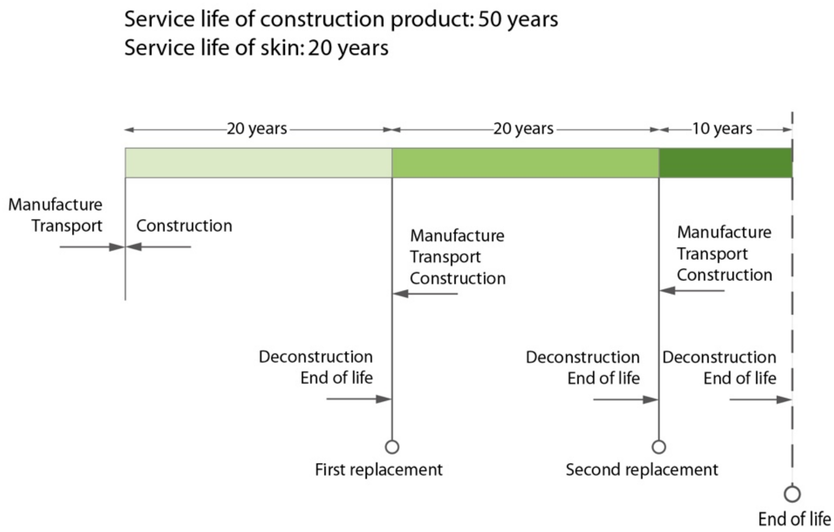


Figure 4. *Example of operations required throughout a life cycle*

3.4. IMPACTS ON END OF LIFE OPERATIONS

In order to assess the environmental and economic impacts likely to arise in each construction solution, each component's end of life stage is evaluated:

- Dismantling and demolition (C1): This includes disassembling and tearing down the construction product and its components. At the end of its service life, the product will be removed either to be replaced or finally dismantled. This aspect takes into consideration the use of suitable ancillary equipment for demolition of the cladding and other components that make up the construction solution.
- Transport of Waste (C2): This includes removing and transporting waste from dismantling and demolition within a waste management programme, whether to landfill or for subsequent re-use.
- Reuse, recovery and recycling (C3): This includes the treatment of waste materials up to the end of their waste status, through reuse, recycling and energy recovery processes. The assumption is that 70% of construction and demolition waste is destined for re-use, recovery and recycling.
- Disposal: this includes the physical pre-treatment and disposal management on-site at the landfill. 30% of the product is estimated to be landfilled.

SOLCONCER does not calculate module D, which states the loads and potential benefits of secondary materials, secondary fuel or energy recovered when the construction product exits the system.

3.5. ENVIRONMENTAL IMPACTS

The environmental impacts relating to the cladding materials and part of the materials that form the other layers, are taken from Environmental Product Declarations (EPDs) registered in European programmes complying with UNE*EN standard 15804. Data for all other materials have been taken from commercial Life Cycle Assessment databases, namely the GaBi (PE International) and ELCD databases.

For each construction product, the program provides the values corresponding to the environmental impact recognised in the Sustainability in Construction standards[11] as shown in Table 1.

The concept of Abiotic Resource Depletion has been removed from the set of indicators recommended by these standards, due to the range of different methods used to assess this impact in EPDs, so that they are no longer comparable. Furthermore, according to standard UNE-EN 15804: 2012, this indicator is subject to further scientific development and it is foreseen that the use of that indicator will be reviewed when the standard is revised.

Parameters in the environmental impact category	Unit(*)
Global warming potential	kg CO_2 equivalent
Acidification potential of land and water	kg SO_2 equivalent,
Eutrophication potential	kg PO_4^{3-} equivalent
Stratospheric ozone depletion potential	kg CFC 11 equivalent
Tropospheric ozone formation potential	kg C_2H_4 equivalent
Abiotic resource depletion potential of fossil fuels	MJ, net calorific value
* *Expressed per functional unit, which in this case is 1 m^2*	

Table 1. *Environmental impact categories.*

3.6. STANDARDISATION OF ENVIROMENTAL

The standardisation process is an optional element in life-cycle assessment. The main objective of standardising the results of impact category indicators is to convey the relative significance and magnitude of these values for the system being studied and to reveal the most environmentally friendly building systems more easily.

Our standardisation method is the one proposed by CML2001 - 2001-2013, EU25+3[12], which provides data about the environmental situation over the period 2001–2013 from the 25 countries of the European Union in 2006, plus Iceland, Norway and Switzerland (EU 25+3).

Table 2 shows the standardisation values used:

Standardisation factors: CML2001 - 2001-2013, EU25+3	
Global warming potential (kg CO_2 equivalent)	5,21E+12
Acidification potential (kg SO_2 equivalent)	1,68E+10
Eutrophication potential (kg PO_4^{3-} equivalent)	1,85E+10
Ozone depletion potential (kg R11 equivalent)	1,02E+07
Photochemical ozone creation potential (kg C_2H_4 equivalent)	1,73E+09
Abiotic depletion potential of fossil energy (MJ)	3,51E+13

***Table 2**. Standardisation factors used*

3.7. ECONOMIC COST ASSESMENT

Total cost is given for each construction product, sorted into 7 life cycle stages, made up of the various costs applicable to each item comprising the overall construction product or solution (Table 3).

Cost indicators	Unit
Manufacturing costs (A1-A3)	€ / m^2
Freight costs (A4)	€ / m^2
Construction and Installation costs (A5)	€ / m^2
Maintenance costs (B2)	€ / m^2
Repair costs (B3)	€ / m^2
Replacement costs (B4)	€ / m^2
End of Life costs (dismantling and waste removal) (C1-C4)	€ / m^2

Table 3. *Economic indicators*

The costs of all components comprising the construction product or solution are considered, including any material likely to form part of the installation of 1m^2 of the construction solution. Many of the prices were taken from the "Construction Price Generator" database developed by CYPE, except for ceramic materials, for which average market price is used; freight costs, for which the method has already been explained above; Maintenance, for which the reference are the most common conditions stated in EPDs and manufacturers' recommendations; and the costs of disposing of the waste generated during construction and installation.

3.8. PERFORMANCE INDICATORS

Performance characterisation using the Solconcer tool is based on the requirements made in the EOTA Technical Guide to construction products, based in turn on six of the seven essential requirements of the Construction Product Regulations (CPR), plus an eighth requirement that concerns **durability** and finish (technical and/or aesthetic obsolescence, so-called 'impaired appearance'). This set of requirements leads to a number of indicators that characterise performance on the basis of:

- The set of standards (harmonised standards, product standards and trials) and regulations (Technical Building Code (TBC), *et alia*) applicable to construction products or to their components
- EU Regulation No 305/2011[13], which replaces the former Construction Products Directive.
- The set of EOTA ETAG 2 guidelines, adapted to meet the Regulations.

Having obtained the baseline data, **scenarios** (use, traffic intensity, type of premises, etc.) have to be defined in order to continue with the assessment and evaluation of the indicators.

The indicators are individually converted to a dimensionless scale one by one, in some cases by linear distribution but in most cases by direct allocation. Another particular decision that arises with this method also needs to be considered: the way it penalises those parameters that have no associated magnitude. In this case, the intention is to reward manufacturers' efforts to benchmark their products through their characteristics (especially standardised characteristics).

Some indicators are expressed by more than one magnitude. In such cases, the **arithmetic mean** of the values of the different magnitudes is taken once conversion to the dimensionless scale has taken place.

Apart from these series of magnitudes that represent one indicator, there is one other group of basic or essential indicators (the first six in EU Regulation No. 305/2011 plus the eighth indicator on durability). According to the project, the User of the Solconcer method can assess indicators some more than others.

This differing assessment of indicator sets is known as Weighting in the project. The Solconcer weighting methodology adopts a default weighting rate for all aggregations. This weighting was agreed by a workshop team of Architects, Surveyors and Managers from the ceramic tile industrial sector, who by survey provided their particular appreciation of each set of indicators. With that as the basis, the User can modify the weighting in the program. Having defined the weighting, an end dimensionless value is obtained that defines the construction product under assessment from the performance point of view. Table 4 shows the essential requirements and the weighting used, a detailed description of which is summarised further below.

Essential requirement	**Weighting**
ER1 Mechanical strength and stability	14%
ER2 Safety in the event of fire	20%
ER3 Hygiene, health and environment	13%
ER4 Security and user accessibility	19%
ER5 Noise protection	10%
ER6 Energy saving and heat insulation	12%
ER7 Energy saving and heat insulation	N/A
ER8 Durability and service	12%

Tabla 4. *Basic requirements*

3.9. FINAL SCALING

In order to provide a quick overview of the assessment, Solconcer runs a scaling exercise on each set of indicators to adapt the results to a 0–10 scale, where 0 is the worst situation (highest cost/environmental impacts or worst performance) and 10 the best.

4. FACTORS AFFECTING HORIZONTAL PARTITIONS

At present, Solconcer assesses three types of construction solutions: horizontal partitions, wet vertical partitions and urban flooring. Given its limited scope, this paper will only discuss horizontal partitions, and refer the reader to the actual software (http://solconcer.es/) and help files for further information about this and other solutions.

4.1. STRUCTURE AND MATERIALS

The top layer materials chosen for assessment are: ceramic tiles, PVC, laminate flooring, carpeting, natural stone, terrazzo and plywood parquet flooring. Each material uses different materials for its installation, such as Glue and Adhesive, Mortar, Sheeting, etc. and this assembly is known in Solconcer as the **Skin**.

Under the skin come the intermediate layers, composed of the sound insulation layer and levelling mortar, which in the case of ceramic tiles and stone have two options: Low Compressibility and High/Medium Compressibility; a single option: Self-levelling, in the case of laminate flooring, plywood parquet, carpeting and PVC; and High Compressibility in the case of terrazzo.

All the above components are laid on a deck, which may comprise beams and arches (residential background) or prefabricated slabs (background in public thoroughfares). This deck will then have two possible finishes on its underside: pre-fab suspended ceiling or a roughcast.

Figure 5 shows a variant of this type of construction solution.

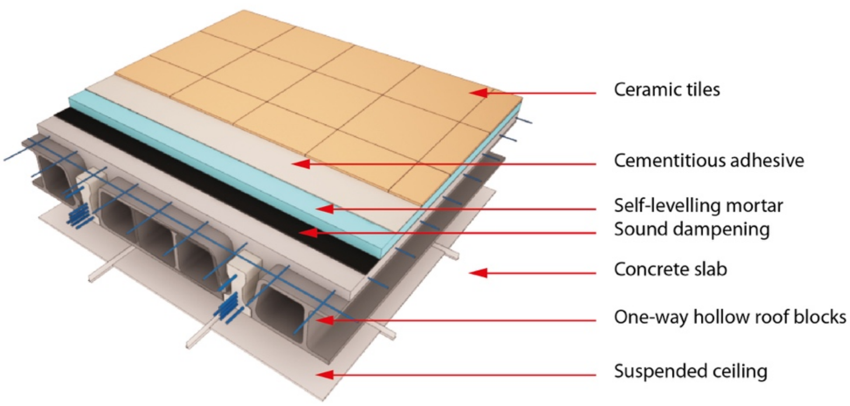


Figure 5. *Example of a construction solution in a horizontal partition*

4.2. SCENARIOS

Figure 6 shows the different scenarios that have been considered for this type of construction solution. Most of these scenarios have already been discussed or are sufficiently clear; nevertheless, some of them need further explanation.

Three levels of **traffic intensity** have been established: Low, corresponding to traffic in a residential dwelling; Medium, which refers to traffic in a retail outlet or places with average public presence; and High, which corresponds to publicly-trafficked premises and shopping centres. This scenario impacts on the ER8-Durability performance indicator and on the selection between the different quality grades of the materials.

As far as **Type of Premises** is concerned, two options have been defined – damp and dry – which have a bearing on indicators ER3 - Hygiene, Health and Environment and ER4 – Security and User Accessibility.

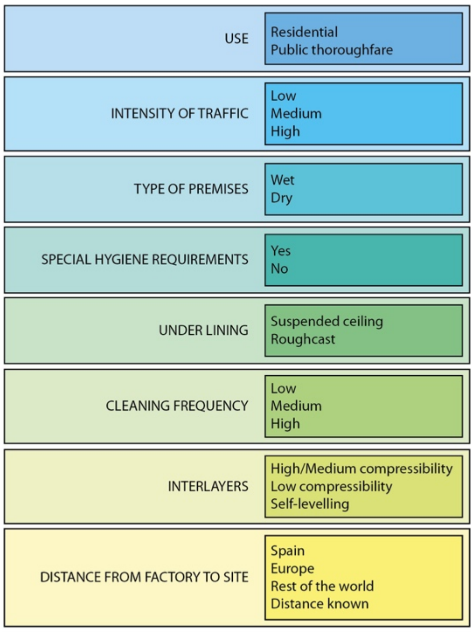


Figure 6. *Scenarios in a horizontal partition*

The scenario **Special Hygiene Requirements** affects performance indicators ER8.4 (stain resistance) and ER8.5 (chemical resistance).

Table 5 shows the different scenarios in terms of **Cleaning Frequency** with its parameters taken from EPDs and manufacturers' recommendations, which influence environmental and economic impacts.

Skin	Low maintenance	Medium maintenance	High maintenance
Laminate and PVC flooring	Washed with soap and water once a week. Vacuum cleaned twice a month.	Washed with soap and water once a day. Vacuum cleaned once a week.	Washed with soap and water. Vacuum cleaned twice a day with heavy-duty equipment.
Ceramic tiling, natural stone and Terrazzo	Washed with soap and water once a week.	Washed with soap and water once a day.	Washed with soap and water and vacuum cleaned twice a day with heavy-duty equipment.
Carpets	Vacuum cleaned 3 times a week.	Vacuum cleaned 5 times a week.	Vacuum cleaned 7 times a week with

	Wet cleaned once a year.	Wet cleaned once a year.	heavy-duty equipment. Wet cleaned 4 times a year with heavy-duty equipment.
Parquet	N/A	N/A	N/A

Table 5. *Skin maintenance scenarios*

5. IT TOOL

The result of the whole methodology outlined above is the online program http://solconcer.es/, fully available for free use and where the User can register in order to save the data calculated with the software.

The program displays the results in clearly depicted groups (Figure 7), although it also provides a detailed breakdown of each indicator to see what influence it has (Figure 8).

Figure 7. *Grouped results*

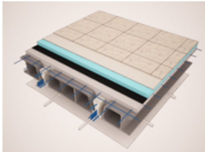
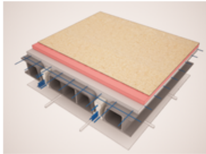
Escenario **Uso:** Residencial **Intensidad de tránsito:** baja **Tipo de local:** seco **Necesidades especiales de higiene:** no **Frecuencia de mantenimiento:** baja **Revestimiento Inferior:** falso_techo Indicador	Cerámica 	Moqueta 	
Ambientales	**5.9**	**2.7**	-
Indicadores de solución completa	5.9	2.7	-
Potencial de calentamiento global (GWP)	1.07 E2 kg CO2-Equiv.	1.56 E2 kg CO2-Equiv.	
Potencial de agotamiento de la capa de ozono estratosférico (ODP)	1.53 E-4 kg R11-Equiv.	1.92 E-3 kg R11-Equiv.	
Potencial de acidificación del suelo (AP)	3.16 E-1 kg SO2-Equiv.	4.62 E-1 kg SO2-Equiv.	
Potencial de eutrofización (EP)	5.76 E-2 kg Phosphate-Equiv.	8.31 E-2 kg Phosphate-Equiv.	
Potencial de formación de ozono troposférico (POCP)	3.12 E-2 kg Ethene-Equiv.	5.61 E-2 kg Ethene-Equiv.	
Potencial de agotamiento de recursos abióticos para recursos fósiles (ADP-combustibles fósiles)	9.31 E2 MJ	1.76 E3 MJ	
Indicadores de dermis	6.0	2.5	+
Económicos	**6.0**	**5.4**	-
Indicadores de solución completa	193.6 €/m²	284.4 €/m²	+
Indicadores de dermis	41.1 €/m²	134.9 €/m²	+
Prestacionales	**6.4**	**4.0**	-
Resistencia mecánica y estabilidad	5.0	5.0	+
Seguridad en caso de incendio	7.5	5.5	+
Higiene, salud y medio ambiente	10.0	2.2	+
Seguridad y accesibilidad de utilización	5.0	5.8	+
Protección contra el ruido	5.3	6.5	+
Ahorro energético y aislamiento térmico	5.0	1.0	+
Durabilidad y servicio	6.5	0.6	+

Figure 8. *Results with detail of environmental indicators*

CONCLUSIONS

This paper presents the methodology behind the Solconcer software program that enables:

- Different construction products and solutions to be objectively assessed through contrasting indicators that evaluate their environmental, economic and performance levels.
- Enhancement of environmental protection in the context of a strategy of sustainable development based on redirecting the construction sector towards sustainable building.
- The use of ceramic systems to be disseminated and their inherent features to be publicised;
- Manufacturers to foresee how a modification in the characteristics of a material (cost, environmental impacts or performance) will affect the assessment of the construction system as a whole.

FUNDING

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