Integrated AHP and SAW Methods for Selection Green Building Materials for Insulations

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Abstract. In this paper we propose a selection method for green building materials for insulations, based on an integrated AHP - SAW method. Building materials and thermal insulation materials must have a minimal impact on the environment so as to reduce greenhouse gas emissions but also ensure high energy efficiency to meet the nZEB standard. Starting from the characteristic of the environmentally friendly thermal insulation materials and also from the impact of built environment, we have formulated certain criteria for the selection, like: thermal conductivity, vapor diffusion resistance coefficient, Global Warming Potential (GWP), percentage of reused materials and fire resistance. AHP method is used for weighting criteria according to their importance for the envisaged selection. A total score, obtained by applying SAW method is associated to each product. We have selected and ranked some materials that can be found on the European market of insulation materials according to some scenarios, namely: according to the requirements of the beneficiary, respective the environmental requirements.

Keywords: Green Building Materials · Thermal Insulation · Selection Criteria · Multi Criteria Decision Methods

1 Introduction

The ecological house represents the future in the field of buildings and must be designed taking into account all the stages of the life cycle of a building: starting from the extraction, processing, transport and use of construction materials; until the execution of the building as well as its maintenance and renovation.

Green buildings eliminate the negative impact on the environment by using less water, energy, natural resources and at the same time we can say that they have a positive impact on the environment by generating their own energy.

The economic or financial benefits come from the fact that savings are made on utility bills and in the social field, the benefits refer to the health of people who work or live in green buildings.

In support of sustainable development, there is a concern, both at the level of the European Union and in the country, to support the realization of sustainable buildings. Funding programs such as the Classic Green House Program, the Photovoltaic

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Green House Program, the Energy Efficient House Program, are dedicated to sustainable development.

The use of green building materials and products is an integral part of sustainable building process. From the benefits brought by green building materials to the owner and occupants we mention here: better energy conservation, reduced maintenance costs and improved health. It can also help reduce the environmental impact associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of building materials, so promotes conservation of dwindling nonrenewable resources.

The approach we propose in this paper starts from the complex meaning of a green building material, so from the fact that green building materials are composed of renewable resources and are environmentally responsible, as their environment impact is considered in their evaluation. Because green building materials are used to increase the energy efficiency of a building, we have considered in this paper green building materials for insulations.

2 Thermal Insulations and Green Building Materials

Energy efficiency is a measurable part of sustainability and is one of the priorities of the European Union so from 1 January 2021 the nearly Zero-Energy Building (nZEB) Standard, began to be applied to all new buildings. The nZEB concept means a building with a high energy performance, a building that uses a small amount of fossil fuels and a large amount of renewable energy. For a building to be energy efficient, it must first be well insulated and then produce its own energy.

Heat transfer can be done by conduction, convection or radiation and is caused by the temperature difference between inside and outside and depends on the propagation medium. Heat is lost through ceilings, walls, floors, windows and doors.

Significant energy savings are achieved by limiting this loss and this can be done by insulating surfaces, such as floor, roof or walls that are in direct contact with the outside. The materials used for insulation must ensure a low heat and sound transfer.

Environmentally friendly materials used for thermal insulation are numerous and must be selected on the basis of important characteristics that should be fulfill: thermal conductivity; fire resistant; vapor permeability; sound absorption coefficient; built-in carbon; ease of use; degree of recyclability; percentage of materials reused; cost price, and so on.

The aim of using green building materials is to construct energy-efficient structures and to build those structures one should be aware of different green building materials, their properties and how they contribute into saving energy.

There are two types of insulation materials: conventional insulation materials and natural insulation materials. Conventional insulation materials are made from petrochemicals and include: fiberglass, mineral wool, polystyrene, polyurethane foam, and others. The natural insulation materials represent, from a point of view, the green alternative to synthetic insulation. Among the natural materials used to insulate the buildings we mention: cellulose, wood fibers, vegetable fibers (linen, cotton, hemp, flax, cork, etc.), recycled cotton-denim, vegetable straw, animal fibers (sheep's wool).

In the following paragraphs we will mention some of the most important properties of some of these insulation materials.

Mineral wool (glass mineral wool and rock mineral wool) has the following characteristics: does not burn; it is water resistant; it is durable; insulates very well thermally and acoustically.

Glass mineral wool is mainly used for the thermal insulation of partition walls (or, as they are also known, partition walls), interior insulated facades and attics. Glass mineral wool contains glass fibers, 20% to 30% recycled industrial waste, and a binder. This mixture results in a material with high thermal insulation properties. Thermal conductivity λ varies around 0.035 W/mK.

Rock mineral wool or stone mineral wool is a product that contains molten rock. Basalt mineral wool contains fine particles of molten rock, a mass of fine, woven fibers, a binder and an oil to reduce dust. Thermal conductivity λ varies around value of 0.032–0.044 W/mK.

Wood fiber is a raw material with outstanding insulating properties. This extremely efficient thermal insulation not only offers comfort, but also helps to save energy. Wood for insulating materials, mainly fir and spruce, is a sustainable raw material. Wood improves the carbon footprint twice as it stores carbon and also significantly reduces heat demand. The thermal conductivity, λ of this insulating material is between $0.038 \div 0.043$ W/mK.

Cork is a fast renewable resource produced by sustainable forestry practices that protect cork forests, harvesting the bark of the cork tree has been shown to improve the overall health of the tree.

Cork is biodegradable and recyclable at the end of its life. The cork will not release gas and its surface will not attract dust and pollutants. It is naturally anti-fungal and anti-microbial. Cork insulation does not degrade (degrades) and its structure does not change, it is an ecological solution for the insulation of all constructions. The cork can be used to provide thermal and sound insulation both indoors and outdoors.

It is natural, renewable, recyclable and biodegradable, in addition, it cancels out noise and does not contain toxins.

Costs for cork insulation can be a disadvantage. Compared to other ways of insulation, it is quite expensive. Of course, this depends on the manufacturer and the thickness and density of the material. The thermal conductivity of cork is good and the cork insulation is extremely fireproof [1].

Cellulose is a recycled product of paper waste and it is widely used around the world for insulation purposes in structure, it acts as good sound insulator and available for cheap prices in the market. It is one of the most favored materials of natural builders because it can be blown into cavity walls, floors and roofs.

The paper is crushed to a size of a few millimeters (an important aspect that gives it a seal) and inorganic salts, such as boric acid, are added for fire resistance, mold, insects, parasites and rodents. The insulation is made by blowing or spraying in the wet state.

Cellulose fibers are obtained from recycled renewable resources and require the least amount of energy to produce them. These insulating materials can also be recycled. Cellulose is flammable and therefore treated with flame retardants. The thermal conductivity coefficient of cellulose is between 0.038 $\div$ 0.043 W/mK, for cellulose panels it is 0.039W/mK. Vapor permeability of cellulose is high.

Hemp fibers are made from the straw of the hemp plant. Hemp grows to a height of almost 4 m in a period of 100–120 days, and no chemical protection or toxic additives are needed to grow hemp. Hemp insulation is usually made of 85% hemp fiber.

Flax fiber thermal insulation is made of natural flax fiber and will serve as both a thermal and sound insulation material. Both materials, hemp and flax, have low energy built-in and are often combined in the same product. Their thermal conductivity/λ (lambda) is around 0.039 $\div$ 0.040 W/mK.

Hempcrete is a mixture of hemp and lime used as a building and insulation material. Hempcrete is easier to work with than traditional lime blends and acts as an insulator and moisture regulator. It has net negative carbon emissions, it is a 100% natural material, sustainable and biodegradable, which continuously absorbs CO2. It is a material with a high fire resistance class B1, resistant to moisture and mold; The thermal conductivity λ of hempcrete is around 0.06W/mK.

Cotton is a natural and renewable resource produced from the remnants of crushed and recycled jeans. It must be treated in such a way that the insulation is not flammable. Compared to fiberglass, it is incredibly expensive, costing almost twice as much.

Sheep's wool insulation is a natural alternative to commonly fiberglass insulation or polyurethane spray so, as other natural materials, it can replace processed materials, which use a lot of energy and complementary resources during their production processes. Sheep's wool can also be biodegraded, whereas mineral fiber materials cannot. Compared with other natural insulation materials, as for example straw, it doesn't degrade as quickly. And compared with some natural insulators like cotton, sheep's wool is wider spread and regenerates faster. One of its disadvantages comes from the fact that sheep's wool has to be treated in order to prevent insects and fungi growth, and this treatment lowers sheep's wool eco-friendliness. Other drawback comes from the fact that sheep's wool has higher costs than other types of insulation materials.

Straw is an agricultural product and represents the dried stems of cereal plants, after grains such as barley, oats, rice, rye and wheat have been removed. The volume of straw represents about half of the crops.

Aerogel is an ultra-light and porous synthetic insulating material obtained from a gel. Its thermal conductivity/λ is around 0.014W/mK.

It is well known that aerogel is a synthetic porous ultralight material obtained from a gel, in which the liquid component has been replaced with a gas. It is a solid with extremely low density and low thermal conductivity, because it has very little solid material and approximately 99.8% air, and is a good thermal insulator because in generally gases are very poor heat conductors, see [2] for more details. They have many applications in reducing environment pollution processes, in medicine, and others, not only in the building sector [3]. Silica aerogel is the most common type of aerogel, but there are other types too, like carbon aerogel, bio-based aerogel, and so on. The properties of some materials of aerogels type, which use cellulose as the fiber pillow, (cellulosic aerogels) are studied in papers [4, 5].

3 Criteria Selection

3.1 Motivation

In formulating the five selection criteria we used, we have started from the impact that the construction sector and the built environment have on the environment and sustainable development and from the properties of a good thermal building insulation.

The built environment has a significant impact on many sectors of the economy and requires vast amounts of resources, about 50% of all extracted material. Greenhouse gas emissions from material extraction, manufacturing of construction products, construction and renovation of buildings are estimated at 5–12% of total national GHG emissions and the construction industry is also responsible for more than a third of total waste in Europe, as mentioned in [6]. In March 2020, the Commission committed itself to come forward with a sustainable built environment strategy, in the new circular economy action plan and in the new industrial strategy for Europe, in order to increase material efficiency and to reduce climate impacts of the built environment, particularly promoting circularity principles throughout the life cycle of building.

As mentioned in [7], the resource extraction and processing are responsible for half of total greenhouse gas emissions and more than 90% biodiversity loss and water stress. The European Green Deal launched a concerted strategy for a climate-neutral, resource-efficient and competitive economy, which includes many goals among which: increasing recycled content in products, while ensuring their performance and safety; enabling remanufacturing and high-quality recycling; reducing carbon and environmental footprints. According to [8] 40% of Europe's energy use goes into heating, cooling and powering the buildings in which we live and work. Our buildings produce 36% of the EU's greenhouse gas emissions. So, reducing the energy consumption of our buildings is critical if we want to act for the climate.

The Commission also has adopted in October 2020 the 'Renovation Wave for Europe' initiative, among the objectives of which is to at least double the annual energy renovation rate of residential and non-residential buildings by 2030.

Considering the above, as well as the importance of reducing gasses emissions through technological innovations and efficient processes, and waste through the action of recycling the materials used, we have formulated two criteria: C4 (Global Warming Potential), C5 (Recycled Content).

So, we have used in our approached for green building materials selection, criteria which refer to three of the most important categories worth to use for such a study, so to three classes: resources efficiency, indoor air quality and benefits for residents, environment protection.

From the resource efficiency class- accomplished by using recycled content or a high percentage of natural and renewable materials, we have formulated criterion C5- recycled content. Regarding energy efficiency, one way to achieve its maximization is by using materials with a low thermal conductivity, thus we have considered criterion C1- thermal conductivity. The indoor air quality and benefits for residents are enhanced by using materials that emit few or no carcinogens, have minimal chemical emissions, are moisture resistant, require simple, non-toxic cleaning methods. Based on these considerations we have formulated two criteria: C2 – vapor diffusion resistance coefficient, μ, and

C3 – reaction to fire. We also took into account the environment conservation, a goal which can be obtained by using products and materials that help reduce gases emissions during their processing, by considering criterion C4, which refers to the total GWP related to material's production stage, namely for A1–A3 stages, as mentioned in the Environmental Product Declarations.

There exist other papers regarding green building materials selection but they use other criteria in their approaches [9, 10].

3.2 Criteria and Their Type

In any MCDM it is necessary not only to formulate the criteria used for the selection process, or for making the hierarchy, but also their type, because they can be of max or min type. A max criterion means a criterion for which the higher the value of the response, or attribute, the better the decision variant or product, according to this criterion; a min criterion means a criterion for which the lower the value of the response or attribute the better the decision variant or product. In the following paragraphs the criteria we have used are described and their type is also presented.

C1: Thermal conductivity (min)
Thermal conductivity (W/mK) indicates how well a material transports heat. It measures the amount of heat conducted per hour through a material 1 m thick over an area of 1 m^2, if the difference between the air temperatures on both sides is 1 K.

It is a temperature dependent material constant, but in data sheets of different products is conventionally presented as a constant measured at 10 °C. It is well known that the less the λ value, the better the material insulates, and therefore we consider this criterion as min type.

C2: Water vapor diffusion resistance coefficient (max or min, it depends on the goal).
According to its definition, water vapor diffusion resistance is a measure of the material's reluctance to let water vapor pass through, taking into account the material's thickness. It is a temperature-dependent, dimensionless material property and is commonly referred to as the μ-value.

When analyzing the type of the second criterion, we must start from the importance of the lack of moisture in the insulation materials for a greater durability of the building. Moisture absorption can lead to many negative aspects regarding the resistance and the aspect of the building itself, and also for the health of its habitants: condensation on colder surfaces, damaged materials and fungal growth.

Thermal insulators, especially when they are made of porous materials, trap pockets of gas inside and when these are filled with moisture, a significant loss in insulating efficiency arise, because the thermal conductivity significant increases if air/gas is replaced by water vapor in the insulation.

Absorption of moisture can take place not only when there is a direct contact with water, but also by condensation of water vapors in the walls, and therefore, sometimes it is important to have vapor barriers for protecting the insulation for gaining moisture.

The climate influences a lot the transmission of water vapor through the walls. In most hot climates the transmission of water vapor is from the humid outside to the inside (the external temperature is higher than the internal one and air-conditioned indoors are often met). In the opposite situations, when there are conditions that favor the existence of water vapors inside, so when vapors tend to move from the inside out, as for example in case when the temperature outside is lower than inside, an insulation material that is vapor permeable, so that has a low vapor diffusion resistance coefficient is needed. This movement of water vapors directly influences the type and the placement of the insulation materials within the wall assembly.

So, when asked what type of criterion is C2 the answer is it depends. As mentioned above the type of this criterion for a certain study must be established by taking into account the climate, the moving of vapors, the place where the insulation material is introduced, if a vapor barrier is necessary and where, or if a permeable insulation is needed.

It is important to know that if considering the μ-value as a reference, the higher the μ-value, the better the insulation material is at limiting water vapor passing. So, when needing materials that should act as a vapor barrier it is necessary to use an insulation material with high μ-values, but if a permeable insulation material is needed, an insulation with a lower value of μ is suitable. More details about choosing the best insulation material from this point of view can be found at [11]. [12–14].

C3: Fire-resistance rating

From the point of view of the occupants of a building it is very important that it should be designed in such a way as to be safe from fire, or to provide a reasonable degree of safety from fire. That is why the materials used for its construction should be non - combustible, but this goal is hard to be reached, almost impossible in practice, or at least fire resistances, and do not cause heavy smoke.

According to EN 13501–1, insulation materials' fire resistance is classified in seven fire-resistance classes taking into account three main criteria: flammability, flame propagation, and heat released: A1, A2, B, C, D, E, F. The best class is class A1, which refers to products which do not contribute to the fire load and the spread of the fire at any stage, including a full-scale fire, the worst being F, see [14].

C4: GWP (min)

An important characteristic of all green building materials is represented by their potential environmental impact. This can be evaluated by using Life Cycle Assessment Method (LCA) and it is represented by a set of indicators, which are mandatory indicators according to EN 15804. One of these mandatory indicators is the Global Warming Potential (GWP), which is directly linked to Climate Change, as a measure of greenhouse gas emissions. These emissions increase absorption of radiation emitted by the earth, intensifying the natural greenhouse effect.

The GWP of a gas refers to the total contribution to global warming resulting from the emission of one unit of that gas relative to one unit of the reference gas, carbon dioxide, which is assigned a value of 1. The standard unit for measuring carbon footprints is the carbon dioxide equivalent (CO_2e or CO_2eq or CO_2-e).

CO_2eq for an insulation product is calculated from GWP indicator present in its Environmental Product Declaration (EPD). All products for which such a document exists have the CO_2eq calculated for the production stage (A1-A3), which are mandatory modules according to the Standard EN 15804.

The total GWP for A1-A3 stages is considered as criterion C4 and because all efforts are directed towards reducing carbon emissions, reducing the negative impact of gases on the climate, according to the Global Warming Directive of EU, we have considered C4 as a min type criterion.

C5: Recycled content (max)
Based on the provisions of The Waste Framework Directive (Directive 98/2008/EC article 4) we have formulated criterion C5: Recycled content. Using recycled materials generates less carbon than processing new materials and also means reducing waste, facts that help in better conserving the environment for future generations and for a future better life. Hence criterion C5 is considered to be a max type criterion: the higher the recycled content in a certified product the better the positive environmental impact of that product.

4 Insulation Materials for the Study

We have considered for our comparison study eleven green building insulation materials, existing materials on the European market of thermal insulation materials, chosen from the types mentioned in one of the above paragraphs, materials which we have denoted by M1, M2,…,M9 as follows:

M1- a wool type insulation material, namely Thermafleece UltraWool, made of 75% sheep wool in combination with recycled fibers, [15].
M2 – an insulation material made only of recyclable content, namely SupaSoft Recycled Plastic insulation, made only using recycled PET, [16].
M3 – a glass mineral blowing wool, named SUPAFIL FRAME, which is comprises over 99% inert material content- recycled glass and other mineral raw materials, [17].
M4 – a Rock mineral wool, named Rock Mineral Wool CLT C1 Thermal. In terms of composition, the inorganic part (92–98%) is composed of volcanic rocks, typically basalt, and some dolomite and with an increasing proportion of recycled material in the form of briquettes, a mix of stone wool scrap, other secondary materials and cement, [18].
M5 – a glass mineral wool, named SUPER PROFI Isover, based on natural and abundant raw materials (sand), [19].
M6 – an aerogel insulation, Spaceloft Aerogel (white/gray 10 mm), which is an ultra-high performance, fiber reinforced, silica aerogel blanket thermal insulation, [20].
M7 – an insulation material made mainly of cork, LISOFLEX ASSO Cork (20 mm), a super-compressed ground natural cork panel, [21].
M8 – another insulation material made mainly of cork, Diathonite Thermactive 037 (cork), which has 50% cork, from which about 85% recycled content, [22].
M9 – is a bio-composite material based on natural hemp fibers, EKOLUTION® HEMP FIBRE INSULATION (made of hemp fibers: 85%, bi-component fibers 12% and caustic soda 3%) [23].

5 An Integrated AHP - SAW Method for Ranking the Products

The selection involves using criteria for making the choice and the matrix of the product responses to the envisaged criteria. A total score of evaluation needs to be associated to each product, score given by SAW method. Used criteria need to be weighted according to their importance for the envisage selection as in all MCDM methods [24, 25]. Based on the descending order of the associated scores the products are ranked, and the product situated on the first position in this hierarchy is considered to be the best selection taking into account the envisaged criteria.

The materials we have chosen for the selection represent materials that can be found on the European market of insulation materials. The properties of the mentioned insulation products, M1-M9, regarding the criteria envisaged, have been collected from technical manufacturers' information such as technical data sheets, EPD, certificates, test data, product warranties, information about the recycled content, and other.

Because for criterion C3, the attributes of materials are the reaction to fire classes, so they are qualitative and no quantitative, we have considered in our approach a 0–10 rating scale to convert them. We have associated to each class the number which we considered to reflect its quality, related to fire behavior, intending to make criterion C3, a max one, so considering: 10 marks for A1 class, 9 marks for A2 class, 8 marks to B class, 6 marks for C class, 4 marks for D class, 2 marks for E class and 0 for F class. The properties of materials are presented in Table 1.

The attribute matrix, which contain a supplementary line with criteria type, and classes conversion into numbers on 0–10 scale are presented in Table 2.

Three distinct situations are analyzed in the following paragraphs.

First, we consider a scenario suitable from a beneficiary's point of view so, considering the following hierarchy of involved criteria: C1 > C2 > C3 > C4 > C5. In this case, by applying AHP method, in Saaty's variant, see [26], we have evaluated criteria weights and the results are presented in the penultimate line of Table 3.

Table 1. Materials properties.

Materials	Thermal conductivity [W/mK]	Vapor diffusion resistance coefficient	Reaction to fire	GWP [kgCO_2 eq] A1-A3	Recycled content [%]
M1	0.035	1.8	E	0.11	20%
M2	0.040	1	E	0.99	95%
M3	0.033	1	A1	2.92	80%
M4	0.037	1	A1	7.61	28%
M5	0.032	1	A1	1.5	0%
M6	0.015	5	C	12.3	20%
M7	0.052	10	B	0.076	0%
M8	0.037	3	A1	0.895	41.23%
M9.	0.04	2.3	E	−2.22	12%

Table 2. Attributes matrix.

Materials	C1	C2	C3	C4	C5
M1	0.035	1.8	2	0.11	0.2
M2	0.04	1	2	0.99	0.95
M3	0.033	1	10	2.92	0.8
M4	0.037	1	10	7.61	0.28
M5	0.032	1	10	1.5	0
M6	0.015	5	6	12.3	0.2
M7	0.052	10	8	0.076	0
M8	0.037	3	10	0.895	0.4123
M9	0.04	2.3	2	−2.22	0.12
Criteria type	min	max	max	min	max

Table 3. Normalized attributes matrix.

Materials	C1	C2	C3	C4	C5
M1	0.459459	0.088889	0.000000	0.839532	0.210526
M2	0.324324	0.000000	0.000000	0.778926	1.000000
M3	0.513514	0.000000	1.000000	0.646006	0.842105
M4	0.405405	0.000000	1.000000	0.323003	0.294737
M5	0.540541	0.000000	1.000000	0.743802	0.000000
M6	1.000000	0.444444	0.500000	0.000000	0.210526
M7	0.000000	1.000000	0.750000	0.841873	0.000000
M8	0.405405	0.222222	1.000000	0.785468	0.434000
M9	0.324324	0.144444	0.000000	1.000000	0.126316
Weights I	0.506585	0.261487	0.128899	0.068029	0.035
Weights II	0.128899	0.068029	0.035	0.506585	0.261487

Considering the second scenario, in which the environmental criteria are much more important than the others, so the following hierarchy: C4 > C5 > C1 > C2 > C3, we get the results the last line of Table 3.

The following stage in applying SAW method is to build the normalized attributes matrix. There exist many normalization techniques, but we use in this paper the linear normalization technique, also known as min-max scaling or min-max normalization, because its simplicity and because it standardizes the criteria involved in our approach, see [27]. It consists in rescaling the range of features to [0, 1] range.

Applying this method leads to the result in Table 3.

Table 4. SAW scores, and materials ranking – case of first and second scenario.

Materials	SAW Scores I S	Materials	SAW Scores II S
M6	0.694619	M2	0.697884
M3	0.462458	M3	0.648648
M8	0.461004	M8	0.613766
M5	0.453329	M9	0.591246
M7	0.415433	M1	0.545615
M4	0.366561	M7	0.520759
M1	0.320479	M5	0.481474
M9	0.274518	M4	0.327955
M2	0.252287	M6	0.231684

Using criteria weights and the normalized attributes values we have evaluated the aggregation scores by using SAW method, and we have named them SAW scores, and based on their descending order we obtain materials ranking in case of first and second scenario, presented in Table 4.

For the first scenario, as we can see from the above table, the results have on the first position of the materials ranking M6, namely the aerogel material. It seems to be a realistic result taking into account the fact that M6 has the lowest value for the thermal conductivity, and in this scenario the thermal conductivity, C1, has the highest weight.

In the second case, when the hierarchy of criteria was changed, and the most important criteria are C4 (GWP) and C5, so when environmental criteria are more important than the others, the best material is M2, because it has the highest percentage of recycled material, 95%.

For the third scenario we have considered C2 as a min type criterion (suitable for the situation when a permeable insulation material is needed) and the following hierarchy of criteria:$C1 > C2 > C3 > C4 = C5$. By applying AHP method we get criteria weights presented in the last line of Table 5. In same table, Table 5, there are the normalized value of attributes in this situation.

The results for the third situation are presented in Table 6. M6 keeps his first position in the hierarchy, but M7, the material with the highest values of thermal conductivity and vapor resistance diffusion coefficient gets down to the last position. This fact is in concordance with its properties, because in the third scenario C1 and C2, first and second criterion in criteria hierarchy, so criteria with high weights, are both considered min type criteria.

Table 5. Normalized attributes matrix in case when C2 is a min type criterion.

Materials	C1	C2	C3	C4	C5
M1	0.459459	0.911111	0.000000	0.839532	0.210526
M2	0.324324	1.000000	0.000000	0.778926	1.000000
M3	0.513514	1.000000	1.000000	0.646006	0.842105
M4	0.405405	1.000000	1.000000	0.323003	0.294737
M5	0.540541	1.000000	1.000000	0.743802	0.000000
M6	1.000000	0.555556	0.500000	0.000000	0.210526
M7	0.000000	0.000000	0.750000	0.841873	0.000000
M8	0.405405	0.777778	1.000000	0.785468	0.434000
M9	0.324324	0.855556	0.000000	1.000000	0.126316
Weights III	0.52091	0.222525	0.16017	0.0481977	0.0481977

Table 6. SAW scores for the 3rd scenario.

Materials	SAW Scores III S
M6	0.734767
M3	0.721912
M5	0.700117
M4	0.623648
M8	0.6032
M1	0.492692
M2	0.477209
M9	0.413612
M7	0.160704

6 Conclusions

Today, the impact on the environment is a global concern, which has covered all economic sectors, especially the industrial sector and, implicitly, the construction sector. In particular, the new projects are obliged to meet certain requirements, regulated by rules and specifications, to obtain certifications attesting that they will have few negative effects on the environment. Within the construction industry, the green building materials have evolved and now, more and more builders and architects use these products, especially because they have good properties, but also because those who use them are aware of the necessity to protect the environment.

In this paper we have established some criteria which can be used for the selection of green building materials for insulations and we have applied an integrated AHP-

SAW method for ranking them according to the proposed criteria. We have used in our approached five criteria which refer to: energy and resource efficiency, indoor air quality and benefits for residents and environment protection.

From the point of view of this paper a good thermal insulation material must have the following qualities: a low thermal conductivity coefficient, a suitable vapor diffusion resistance factor, a good resistance to fire. In order to be really friendly to the environment it must have a low value for GWP indicator and a higher percent of recycled content. These qualities are highlighted by criteria used in the approach.

High attention must be given when choosing vapor diffusion resistance coefficient criterion type, namely C2, because it can influence a lot the results. We have mention that for a correct choice it is important to understand what type of insulation is needed. In case of an insulation that has to act like a vapor's barrier, C2 must be considered as a max criterion, but in case when a more vapor permeable insulation is suitable, than it must be considered as a min criterion.

Our studies have also shown that criteria weights influence the result, and if environmental concerns are considered more important than C4 and C5 must have higher weights, but if the building energy efficiency is first envisaged then C1 must be the criteria with the highest weight. In case of the first scenario, so when the thermal conductivity is the most important criterion, material M6, is situated on the first position. M6 is an aerogel material which has the lowest value of the thermal conductivity, so in case of first scenario his first place in the hierarchyis well deserved. On the following positions in the rank, we find M3, a glass mineral wool, and M8 a cork-based material.

In the second scenario, when the criteria regarding the environment protection are considered more important on the first position of the hierarchy M2, a material made mainly by recycled pets (95% recycled content), is situated, followed by M3, and M8 who kept their positions in the hierarchy.

It is obvious that such studies depend on the materials properties, so on data mentioned on the technical data sheets and on the EPD that accompanying the products.

Recently, some prestigious companies have voluntarily chosen, thus showing their responsibility to the environment, to customers and citizens, to make the environmental statements of the products they offer on the market.

The Environmental Product Declaration contains data about product's impact on the environment throughout its life cycle, data collected, analyzed in a standardized manner, making possible comparisons between products and so offering support in establish which of the products of interest is really more environmentally friendly.

Unfortunately selecting the best insulation green building material or studying the environmental impact of these materials is still a time-consuming analyze, because producers often do not provide all necessary data regarding their building materials, or the products do not have EPD, because they are still non mandatory.

For making good comparison between green building materials for insulations a standardization is needed in the presentation of their properties, not only on the technical data, but also on the indicators about their environmental performance. The EPD represent means for promoting transparency about environmental performance of products, so in the future, it will be important to make them mandatory.

The criteria used in this study for ranking green materials for insulations may be completed with other criteria either related to the properties of the insulating materials or related to the environmental indicators present in the EPDs, for more complex studies.

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