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Energetic and Environmental Certification of Building Materials

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***Abstract* — International standards steer towards certification and Life Cycle Assessment (LCA) of many different products, demanding to estimate how much energy is needed and which impacts environment undergoes in order to have materials on market. The same method could be applied to buildings.**

The present paper compares traditional building materials, representative of typical building panorama, to well-known or innovative sustainable products, coming mainly from natural materials and biomass.

Comparison is carried out as an anticipation of energetic and environmental certification of building materials, concerning the analysis of energy demand and CO_2 emissions during material whole life, from production right to disposal.

General disposition consists in addressing choices towards low consumption, high energy saving and sustainable buildings: therefore energetic and environmental balance is useful to optimize the selection of building materials, but also to carry out building total certification from its components, according to requirements of human health, structural resistance and durability.

***Key Words*—Building materials, certification, energy saving, sustainable buildings.**

I. Introduction

Traditional and sustainable building materials must be subjected to energetic-environmental certification, regarding in particular consumption and emission analysis. Integrated energetic and environmental balance is a useful instrument to select building materials but also to carry out total building certification from single components.

European and international standards are supporting Life Cycle Assessment (LCA) of many different products: the same approach could be applied to buildings and building materials. General trend is to prefer low consumption, high energy saving and CO_2 emission decreasing as concerns material production: these objectives must be pursued during entire life of products till disposal.

Typical and innovative natural building materials respecting all safety and health standards must be analysed under the energetic and environmental points of view.

II. Certification

A. *Energy Certification*

Energy certification attests energetic performance of constructions and plants. Buildings or flats are assigned an energy class depending on consumptions.

Methods based on European Directive 2002/91/EC [1] were proposed to assess building energetic performance, taking into account different contributions (heating and cooling, hot water, ventilation, lighting systems and renewable resources).

Energetic label shows the class of energy efficiency by arrows having different length and colour. Seven classes were defined, where "A" means low consumption/high efficiency while "G" means high consumption/low efficiency, thus pursuing the aim to direct people towards sustainable buildings.

B. *Building Certification*

Human activities impose a long time stay into buildings, where high comfort must be guaranteed: such a condition comes from a combination of thermal, hygrometric, acoustic, lighting, safety and technological factors.

A certification model similar to the ones concerning energy assessment was extended to building overall quality, based on "Building Global Performance" index (BGP) [2].

Overall quality means an energetic-environmental assessment of building as a complex system. Single contribution indexes were proposed to evaluate energy performance according to energy certification, together with acoustic insulation, artificial lighting and natural light, rational use of water and renewable resources, safety into buildings and technological devices. As a result, BGP index was defined to classify both new and existing buildings (Fig. 1).

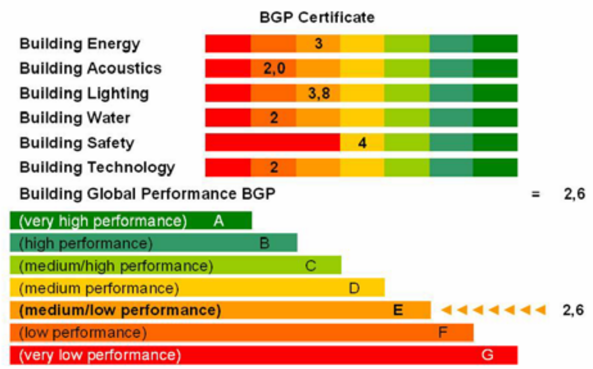

Fig. 1. An example of BGP Certificate, based on Building Global Performance index BGP.

C. *Environmental Certification*

Environmental certification characterizes companies adopting a management system to control and reduce environmental impacts of processes.

Identification, use and updating of best available techniques (BAT) are the main objectives, in harmony with integrated pollution prevention and control (IPPC). In order to encourage development and technological innovation according to economic feasibility, integrated environmental authorization, such as Italian AIA, analyses overall performance of industrial systems (air, water, ground, acoustic, lighting and electromagnetic pollution, waste production, handling and recycling, use of natural resources, energy saving and efficiency, accident prevention).

All different voluntary certifications (international standard ISO 14001, EMAS regulation according to European Directive 761/2001/CE, LCA of products, eco-balance, environmental audit, energy certification, social responsibility of enterprises) guarantee company reliability and product quality. International standard ISO 14020 describes methodologies to assess and communicate environmental sustainability of products; ISO 14000 series deals with audit criteria and environmental management systems of companies and products: standards, such as certification according to ISO 14001, "Environmental Labelling" and "Life Cycle Assessment", by now have a wide practical application in different fields of market.

D. *Material Certification*

In many countries building regulations impose to use quality products for constructions and to apply integrated energetic-environmental criteria. In European Union many building materials need obligatorily CE Brand, such as linear structural elements and alveolar slabs. Besides marks and certifications, also labelling guides consumers to choose products having high energetic yield ("Energy Label" for household-electrics, "Energy Star" for electronic equipments). European Union acknowledged the importance of sustainable buildings, by Directive 89/106/CEE, concerning construction material quality, and by Regulation 880/92, dealing with the European brand "Ecolabel" to certify eco-compatibility of products not only for buildings.

Italian ANAB-IBO-IBN material certification [3] is a complete report concerning physics, engineering, architecture, ecology, electrostatics, biomedicine, toxicology, radioactivity, reference standards and packing systems. Certified products are assigned a quality brand to evidence manufacturer technological engagement and material quality as alternatives to conventional products.

E. *Life Cycle Assessment*

Life Cycle Assessment (LCA), according to international standard ISO 14040 series, is a methodology to carry out a complete study on environmental impacts due to any product, considering all its life long.

Building is a complex system, consisting in a number of different parts and materials: each of them needs its own LCA. Following aspects must be considered:

- origin, extraction and processing of raw materials;
- manufacturing and production of building materials;
- transport, storage and distribution of products;
- running phase, including material permanence, maintenance and substitution in buildings;
- material removal, demolition, recovery and final disposal;
- use and eventual recycling of products.

LCA is a useful instrument:

- to identify opportunities of environmental improvements in production cycle (optimization of resource use);
- to support decisions as regards strategic planning of products or processes;
- to choose environmental indexes;
- to commercialize products provided with environmental declaration or labelling system, having positive consequences on market shares.

Energy consumption as regards buildings consists in:

- production of building materials and components;
- material transport from industries to building places;
- building construction;
- running phase as concerns heating and cooling;
- building demolition;
- material and component recycling.

LCA methodology consists in four main phases:

1. definition of objective and application field of LCA;
2. compilation of a whole inventory of flows in input (material, energy, natural resources) and in output

(emissions, waste) of defined system;

3. assessment of potential environmental impacts and their significance;
4. analysis of results and definition of possible actions.

Sustainability of building products depends on reduction of environmental impact during complete life cycle, therefore it must be assessed through a detailed analysis of material biography.

III. Building Materials

A. Sustainable Building Requirements

Due to ecological emergency and increasing preoccupation with health care, buildings are demanded to be sustainable as concerns environmental impact and energy consumption.

Many people spend about 90% of their time into closed spaces, where unsuitable materials may cause indoor pollution and uneasiness.

Building cost may vary, depending on desired comfort level; however, natural materials having good performances are easily available and not expensive.

The purpose of sustainable buildings is to come as close as possible to an ideal natural model and to create harmony among environment, energy and inhabitants. General objectives are:

- to use renewable, limited, locally available raw materials, needing little manufacturing, cleaning and maintenance (reduced energy waste);
- to aim at efficient energy systems (heat accumulation, thermal insulation, natural lighting, natural devices to regulate temperature, renewable resources such as solar energy, depending on local climate);
- to use materials being not dangerous to human health (both for workers and inhabitants) and components being recyclable and re-usable once the building is demolished.

B. Building Material Requirements

Integrated energetic-environmental certification must consider each building material and component.

Selection of products for constructions must be carried out according to physical, energetic, mechanical, structural and bio-ecological requirements. In order to choose building materials, following characteristics are particularly demanded:

1. *mechanical resistance:* capacity to resist to applied forces depending on structural function of component;
2. *durability:* capacity to last for a long time;
3. *accumulation:* capacity to keep produced heat;
4. *thermal insulation:* capacity not to disperse accumulated heat;
5. *acoustic insulation*: high transmission loss to protect against noise;
6. *density:* mass of volume unit;
7. *temperature:* measurable temperature on material surface;
8. *hygroscopicity:* capacity to absorb water vapour from air and to yield it;
9. *diffusion:* gas and fluid not convective passage;
10. *absorption:* capacity of filtration, accumulation and regeneration of volatile substances;
11. *ventilation:* air movement depending on temperature, pressure and density differences;
12. *fire resistance:* capacity to resist and protect against the fire risk.

Building materials influence life quality, as concerns:

1. *microclimate:* relative humidity, temperature, ventilation;
2. *air quality:* toxicity, smell, bacteria, radioactivity;
3. *electrical climate:* ionization, electromagnetism, electrostatics;
4. *physical climate:* acoustics, lighting, colours.

C. Building Material Characteristics

Following table shows a general classification regarding building materials, with particular attention to natural sustainable products.

TABLE I
Building Materials

Mineral Origin	
Concrete	Perlite
Clay	Vermiculite
Brick	Pumice
Stone	Rock wool
Lime	Glass (fibre)
Gypsum	Iron
Calcium silicate	Metals
Vegetal Origin	
Wood (mineralized, fibre)	Maize (fibre)
Cork	Hemp (fibre)
Cellulose, paper (fibre)	Jute (fibre)
Straw	Cotton (fibre)
Coco (fibre)	Flax (fibre)
Kenaf (fibre)	Rubber (recycled)
Bamboo (fibre)	Textiles (recycled)
Arundo donax, reed (fibre)	Oils, resins
Animal Origin	
Sheep wool	Casein

Main characteristics of materials were analysed [3], according to their use in buildings:

Concrete. Reinforced concrete is the best solution as concerns foundations and structural elements. Material has low transpiration and high conductivity and it keeps humidity over a long time: it needs insulation and chemical treatments against atmospheric agents and it is recommended to use certified pure white concrete. Concrete blocks for masonry are not expensive and blocks obtained by joining concrete to mineralized wood fibres, expanded clay and aluminum powder have good thermo-acoustic performances and also resistance to fire (certified quality concrete blocks).

Iron. Faraday and "antenna" effect due to building metallic elements in reticular form may interfere with living organisms, therefore round steel structural materials, having improved adherence and high resistance, must be preferred in order to limit iron amount in buildings.

Clay. Material is easily available and masonry works guarantee high performances as concerns transpiration and acoustic insulation. Raw clay simply dried has high absorption and thermal inertia, so it contributes to create an ideal indoor climate. Added materials, when needed, must have vegetable or mineral origin, like wooden powder, perlite or agricultural waste. Cooked clay has very good properties as waterproofing and roofing material (tile).

Wood. It is with clay the basic material for bio-ecological buildings and the most renewable resource among building materials. It has very good mechanical resistance, thermal insulation, hygroscopicity and therefore it is perfectly suitable to regulate microclimate and to create balanced rooms. Sustainable wood comes from local production of species having fast growth, such as pine, poplar and robinia (selective cut, productive forestation or recycling). Treatments for wood protection and care can be carried out with natural products like linseed oil, conifer resins, citrus essences, bee wax. Plywood and laminar multi-layers demand always adhesive.

Stone. It is a diffuse natural material but it can be dangerous when it has strong natural radioactivity, as granites or volcanic stones (tuff); besides extraction produces environmental impact.

Lime. It has optimal biological qualities, availability and low energy consumption in production. Slaked lime is basic material used for mortar, plaster and paint, having optimal aesthetic results. Water lime can often replace concrete and guarantee greater transpiration, absorption, insulation, thermo-hygrometric regulation and therefore positive and balanced indoor microclimatic conditions.

Flooring and finishing materials. Wood and clay, although numerous attempts to replace them, are used respectively in form of parquet and floor tile ceramics. A marginal quote is occupied by textile floors in vegetable fibres (coconut, sisal) or animal fibres (wool) but they involve hygienic problems. Ceramic industry has a strong environmental impact due to use of decoration and colouring products (synthetic materials and dangerous heavy metals).

Insulating materials. Thermo-acoustic insulating materials are demanded to assure transpiration, hygroscopicity, resistance to fire, moulds and bugs without environmental impact, toxicity of chemical products, smell, radioactivity, electric fields: they must be obtained by using renewable materials and by reducing energetic cost of production. Environmental certification and quality control of products are therefore fundamental for insulating materials.

Vegetable insulating materials. Cork can be used as an optimal insulating material in masonry interstices, pavements and roofs. Granulated cork can also be agglomerated in panels thanks to combined effect of heat and compression and without bonding agents.

Wood fibre panels. Wood fibres are raw materials coming from sawmill waste: they are combined by means of natural lignin resin to produce insulating panels. Obtained product is completely biodegradable and recyclable and it is used for thermal and acoustic insulation of pavements, walls and roofs.

Mineralized wood panels. Wooden fibres (generally poplar) are used to produce panels having excellent performances. Production process is based on properties of magnesium compounds: wood loses perishable organic parts and in mineralized form it assumes high resistance to fire, besides already known characteristics.

Recycled cellulose fibres. Material comes from recycling of newspapers and, thanks to natural mineral elements, such as boron, it becomes resistant to fire, mildews and bugs. It has good insulating properties into cavities of walls and roofs.

Coconut, jute, cotton, flax fibres. Raw, renewable and recyclable natural materials still have little diffusion, but they have interesting insulating characteristics.

Insulating materials of animal origin. Due to its microstructure, sheep wool is an optimal natural alternative to mineral fibres for thermal and acoustic insulation. Wool has also high hygroscopicity: it yields slowly absorbed water and it guarantees optimal balance for air humidity. It is a raw, renewable and recyclable material with a very low energy balance.

Mineral insulating materials. Calcium silicate is a porous material, used to produce light panels. Vermiculite and perlite can be used as dry fillings into cavities but also as inerts for light insulating plasters. Mineral fibres (glass fibre, rock wool) are dangerous for respiratory apparatus and panels made of these materials may involve adhesive of petrochemical origin.

Paints, adhesives and waterproofing materials. Materials for surface finishing and wood, iron, plaster treatment, together with adhesives and waterproofing materials (waxes, oils), generally come from chemical industry and involve toxicity and environmental impact. Maximum transparency is demanded as concerns row of products, such as vegetable resins (dammar, pine, larch), vegetable oils (linseed, safflower, soy, maize germ), vegetables waxes (carnauba), vegetable rubbers and adhesives (Arabic rubber, rubber latex), vegetable spirits (citrus essential oils, alcohol), products from animal origin (bee wax, cochineal, shellac, casein), elaborated natural minerals (gypsum, talc, ochre, borax).

IV. Methods

Many factors must be considered to evaluate overall energetic-environmental performance of building materials and components.

Specialized literature, associations and producers were consulted and market surveys were carried out regarding energetic efficiency, environmental sustainability and also average cost of construction products, in order to take into account economic feasibility too.

Assessments of impacts on energy and environment during material life cycle were integrated with SimaPRO 7.1 software output. Software implements different approaches to LCA of many building materials and it values cumulative energy demand and CO_2 emissions, according to acknowledged international databases.

Basic references in the analysis of all different processes and contributions, concerning production and disposal of some of the most used building materials, were Ecoinvent databases and IPCC standards (Intergovernmental Panel on Climate Change), having a timeframe of 100 years.

V. Results and Discussion

A synthesis of main results is shown in the following tables, which report technical data, average costs and CO_2 emissions of significant building materials.

TABLE II
TECHNICAL DATA AND COSTS OF MOST USED SUSTAINABLE BUILDING MATERIALS

Material	Density [kg/m^3]	Thickness [m]	Cost [€/m^2]
Concrete	~ 2500	0.30	27.6-47.1
Brick	600-1900	0.30	16.5-67.8
Stone	~ 2800	0.15	13.05-51.6
Expanded clay	330-480	0.10	5.1-8.3
Expanded perlite	80-120	0.10	12.85-16.07
Wood fibre	45-250	0.005-0.200	5.5-10.03
Mineralized wood fibre	320-625	0.015-0.050	7.49-27.65
Cork	108-210	0.002-0.130	3.8-26.4
Cellulose fibre	20-70	0.020-0.060	8.51-39.1
Kenaf	30-180	0.005-0.140	2.2-30
Flax fibre	~ 150	0.002-0.160	2.33-26.14
Sheep wool	10-20	0.003-0.120	3.7-21

TABLE III
EMISSIONS OF MOST USED SUSTAINABLE BUILDING MATERIALS

Material	CO_2 Emissions	
	Production [kg CO_2 eq/kg]	Disposal [kg CO_2 eq/kg]
Concrete	0.111	0.0148
Brick	0.218	0.0141
Stone	0.0231	0.00747
Expanded clay	0.359	0.00747
Expanded perlite	0.989	0.000559
Wood fibre	– 1.59	-
Mineralized wood fibre	– 0.0768	-
Cork	– 0.692	-
Cellulose fibre	0.273	-

Sustainable natural materials must be used in wall, roof and floor cavities or mixed with other products as finishing treatments, generally having good thermal and acoustic insulation; some of them can have structural functions too, thus replacing traditional building materials.

Comparison between traditional building products, such as concrete (Fig. 2), and innovative natural materials, such as cork (Fig. 3), shows a very different behaviour as concerns impacts on environment during life cycle: regarding cork, in fact, CO_2 emissions are avoided, due to origin row and productive process.

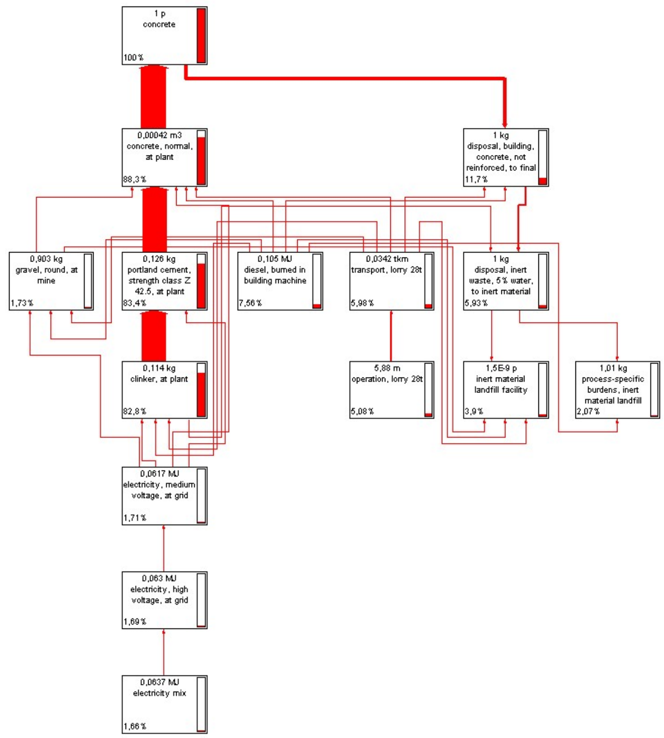

Fig. 2. Concrete LCA network.

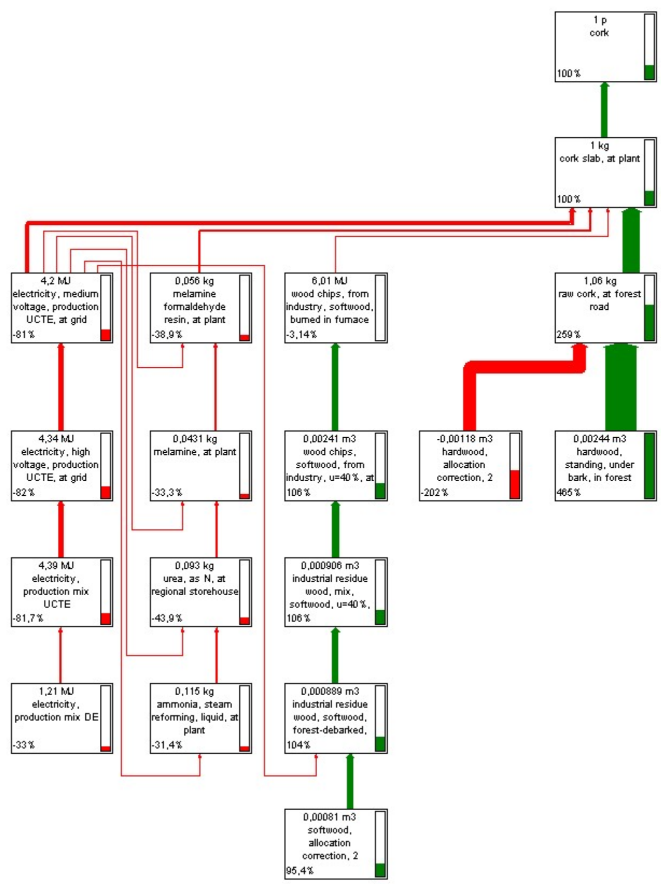

Fig. 3. Cork LCA network.

Together with energetic-environmental benefits, also amortization time, applicability to existing buildings and technological value contribute to positive assessment of sustainable natural materials. Performances and costs of environment compatible materials are encouraging: diffusion of these products on building market will contribute to develop the culture of sustainability.

VI. Conclusion

The main purposes of energetic-environmental certification consist in:

- reducing negative effects coming from building materials during life cycle;
- planning ecological compatible quality of single products and buildings;
- enhancing transparency in building market;
- addressing population and industry in the sense of sustainable use of resources.

Materials must be provided with certification as concerns origin, composition, energy demand and emissions, in order to consider consumption and pollution in the cost of products.

An approach towards building material certification is given by LCA, which allows to select products according to requirements of high efficiency and low pollution: certificate should include technical data, CO_2 emissions and average cost of material.

Sustainable development in buildings can be reached by promoting energetic-environmental certification of products, elaborating common actions on international level, specifying materials and techniques having low consumption, recycling products instead of using new raw materials.

Certification must be applied to any building component and consequently it should be extended to whole building in order to reduce consumption and to improve comfort.

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