Certification of building eco-compatibility and durability: application to new and existing buildings

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Abstract

The construction sector has a key part in EU sustainable development policies, also owing to the economic incidence and the reduction potential of CO₂ emissions. Certification schemes on energy consumptions due to the operational heating demand of buildings are spreading nowadays. On the contrary, the analysis and study of other life stages and environmental aspects appear to be more complicated and slower. The most recent international assessment and eco-design tools of building sustainability use a Life Cycle Approach (LCA): from raw materials acquirement, to product manufacture, delivery, construction, installation and assembly into work, use, disassembly, disposal, recycling or reuse. Starting from the analysis of environmental effects (air, soil and water emissions, waste production, energy consumptions, etc) impacts and damages caused by the adoption of particular materials, techniques and typologies – but also by building production and management processes- can be calculated. The work focuses on the environmental analysis of some building techniques which are commonly used in residential buildings. The paper will show the developed methodology of sustainable assessment, which includes a LCA of building elements by taking into account likely functional quality through time (durability). Environmental damage categories are distinguished by: damages to human health, ecosystem quality and resources depletion.

Such a methodology can be used for: eco-design, rehabilitation and renewal of building heritage, environmental integration of urban building codes.

Keywords: construction elements, materials and components, architecture technology, building durability, LCA.
1 Introduction

Nowadays local initiatives dealing with urban planning tools and technical and administrative building regulations mainly try to integrate sustainability criteria and indicators into Building Codes, into systems for economic awarding incentives and tax deduction or, also, to select projects and building companies during architectural competition or call for tenders for public or important works. They are mainly focused in promoting energy saving and indoor environmental quality thus concerning operational stage and disregarding impacts due to transport, materials and components production, maintenance, reuse and functional quality and durability in the whole building process. Aspects related to building equipments and technical installations are more often analysed, with a marginal attention to building architectural aspects and, finally, to actual building lifecycle. Yet all aspects connected with exploitation of buildings are closely tied with lifetime and quality prevision of building components in the design phase – the latter strongly influencing management and maintenance costs as well as environmental impacts. Studying such effects, depending on particular building techniques (which are often chosen at the very beginning of the process), and comparing results over the whole building lifecycle is also a way to orientate building industry and market towards solutions that can significantly affect urban sustainability.

2 Sustainability certification of buildings

Certification is the document that proves the quality of products and processes. Reference standards and thresholds values are still to be determined in building sustainability sector, so being premature speaking of “compliance certification” of building, although this target has already being pursued within some international initiatives and projects [1].

The most recent assessment and eco-design tools of building sustainability use a Life Cycle approach (LCA): from raw materials acquirement, to product manufacture, delivery, construction, installation and assembly into work, use, disassembly, disposal, recycling or reuse. Starting from the analysis of environmental effects (air, soil and water emissions, waste production, energy consumptions, etc) impacts and damages caused by adoption of particular materials, techniques and typologies – but also by building production and management processes. LCA analyses the potential impacts to environment that derive from the history of a product (and all associated processes stages), “from cradle to grave”. Its steps and procedures are standardised in ISO series 14040.

Certification and eco-labelling have being studied and standardised to be applied to new and existing buildings [2].

As far as refurbishment of building heritage, the target to achieve is “maintenance global service” by analysing (from environmental, economic, managing points of view) possible maintenance scenarios. Certification methods could signify a guarantee for such an approach. Some softwares have already...
been developed in order to supply cost assessment, energy performance contracting and housing saving financing [3].

The methodology described below might contribute to integrate existing instruments by taking into account more architectural issues concerning functional quality and maintenance cycle statistics.

2.1 LCA methodology of building eco-compatibility and durability assessment

A well-known LCA code has been adopted as a basis to assess sustainability of building elements. The Eco-indicator 99 method [4], as well as an available database, enriched by adding new processes [5] according to project specifications and details supplied by ATER Rovigo - an Italian territorial social housing company, have been used.

Different potential damages on environment, generated by inputs and outputs due to various stages and processes, have been calculated and given as percentages and, finally, as a normalised score. Environmental damages categories are: Human Health, measured in DALY (Disability adjusted life years), Ecosystem Quality, measured in PDF*m2yr (Potentially Disappeared Fraction of plant species), and Resources, measured in MJ surplus (additional energy requirement to compensate lower future ore grade). Some variations have been introduced and added to the method: elements “durability” and primary energy consumptions have also been taken into account as new impacts associated to two new damages categories. Typical use, cleaning and maintenance cycles of building elements, as well as refurbishment (replacement and repair rates) over their lifetime have been included.

The functional unit assumed for the LCA analysis is a square meter of finished construction component (in operational phase).

In spite of single industrial products or entire building, the scale of construction components has been taken into account, with its functional layers sequence that determines, when operating, quality and maintenance cycles needs.

2.2 Description of a case study

Common envelope components have been chosen for their several functions: protecting internal space, supplying indoor environmental quality as well as mechanical and thermal performances and resistance to external agents, etc.

For the analysed components a correct construction phase and installation, a normal use and external agent conditions have been hypothesised: Durability scenarios, constructional details and alternative solutions are all described within section 3 (Table 1).

2.2.1 The building components analysed

According to the components analysed (figure 1 shows two wall types), particular solution and different possible construction materials have been associated to the various functional layers.
The LCA analysis leads to impacts calculation. In the characterization phase, inputs and outputs of different processes defined in the inventory phase, are given as percentage influence on different impact categories: carcinogens diseases, respiratory diseases from organics and inorganic substances (i.e. PM$_{10}$, PM$_{2.5}$, SO$_3$, O$_3$, CO, NO$_x$), climate change (from greenhouse gases), radiation, reduction of ozone layer, as regards damages to human health; eco-toxic substances, acidification and eutrophication (from sulphates, nitrates, phosphates), land use as regards damage to eco-system quality; mineral and fossil fuels consumption, as well as water consumption, as regards resources depletion: also energy and the building component durability have been considered as damage categories, as the following picture (figure 2) shows.

In the case study of the Wall B (external wall made of full bricks, EPS insulating Board, internal wall in holed Bricks, internal plaster of limestone and cement, indoor acrylic painting) respiratory organics impacts are due, in the percentage of nearly 27%, to recycle of building materials for emission of dust; which is influenced by previous brushing operation before painting.

Figure 1: Building components analysed – functional layers.
Acidification/eutrophication (nearly 46% for emission of NO₂), fossil fuels impacts (72%, from consumption of natural gas) and energy consumption are particularly affected by bricks production.

Figure 2: Characterization diagram of Wall B.

Normalization and evaluation phases in the method, applied to different maintenance scenarios, allowed us to calculate scores for each building process but also, for the whole component.

A comparison within different building materials and products options, for each type of component, is also given as result.

3 Results

Different refurbishment scenarios, owing to durability defined during the design stage, may considerably affect the total impact of construction lifecycle. As table below shows, a usual maintenance (medium durability) may affect damage, and therefore, eco-compatibility score, by almost 39%, a 31% rate being due to external insulating board substitution that occurs twice.

Frequency and kind of indoor painting may reduce respiratory organics impact. For example inner natural painting lime and line-seed based and wood-fibre insulating board use, a variation to original project products, may reduce damage on human health.

Mechanical solution in assembling different products and layers, rather than wet and gluing systems, have a lower impact, not only owing to reduction of materials use, but also owing to the possibility to easily disassembling, reusing, recycling single products and to a more flexible conception of the building itself.
Table 1: Wall (Parete) A. Durability hypothesised and LCA eco-compatibility results for medium durability scenario during 50 years lifetime of 1 m².

<table>
<thead>
<tr>
<th>External Coated Wall A</th>
<th>Parete A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Unit: 1 m²</td>
<td>MAINTENANCE SCENARIOS</td>
</tr>
<tr>
<td>1 - Medium durability</td>
<td>2 - Long durability</td>
</tr>
<tr>
<td>3 - No maintenance</td>
<td></td>
</tr>
<tr>
<td>External insulating coat (board) substitution</td>
<td></td>
</tr>
<tr>
<td>No. of times in 50 years (building lifetime):</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Internal painting</td>
<td>No. of times in 50 years</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>External plaster finish repair</td>
<td></td>
</tr>
<tr>
<td>No. of times in 50 years</td>
<td></td>
</tr>
<tr>
<td>5 (10% of surface)</td>
<td>5 (10% of surface)</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
<tr>
<td>End of life</td>
<td>Eco-compatibility Pt. Score *</td>
</tr>
<tr>
<td>- Waste recycling and avoided discharge of all inert materials (bricks, mortar, plaster, etc.)</td>
<td></td>
</tr>
<tr>
<td>- Waste treatment in incinerator for EPS board insulating external coat</td>
<td></td>
</tr>
<tr>
<td>19.8</td>
<td>16.5</td>
</tr>
<tr>
<td></td>
<td>12.1</td>
</tr>
<tr>
<td>* The higher the score, the lower eco-compatibility</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1 Potential damage to Human Heath</th>
<th>1 Potential damage to Ecosystem Quality</th>
<th>1 Potential damage to Resources Depletion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000281 DALY</td>
<td>7.18 PDF m³/year</td>
<td>237 MJ-plus</td>
</tr>
<tr>
<td>31 %</td>
<td>2 %</td>
<td>67%</td>
</tr>
</tbody>
</table>

FUNCTIONAL LAYERS

Layer a 1: Plastic finish rendering (with quartz powder and acrylic resin) Possible defects: lines, fissures, bubbles, and condensation. Plastic plaster, if proper devices are taken to avoid water infiltration, is the best choice. The highest damage is produced within fossil fuels depletion and possible respiratory organs diseases. Dust and resin particles can be dangerous to workers during construction, removing, and repair. Repair processes have 37% impacts rate compared to the production of plaster required for the first original construction of component.

Layer a 2: Mortar finishing, Cement R325, resin based in water dispersion, with glass-fibre net support. Possible defects: incorrect insertion of glass-fibre net support The highest damage is produced within fossil fuels depletion, possible carcinogens and respiratory inorganic diseases. Dust emitted to air can be dangerous to workers during construction, removing, and repair.

Layer a 3: Insulating EPS board, extruded and expanded with resins, glued to wall with cement mortar and polymeric adhesive. Possible variations: wood-fibre boards and/or dry mechanical fixation. The latter allowing to reduce the impact of adhesive, provoking possible carcinogens and respiratory inorganic diseases. The highest damage is produced by possible respiratory inorganic diseases (NOx emission). At their first assembly, during the first 60 days, new panels may release higher VOC quantities (after reducing by 10 times) Two repair-substitution processes have 23% impacts rate compared to the original construction. Repair-substitution of the board also influence by 33% acidification/eutrophication. Wood-fibre boards, with mechanical fixation, would reduce total damage score of 3.3 pt, providing particular attention to fibre dust emission during removal.

Layer b 1: Light brick wall (porosity obtained by burning EPS) Possible variations: concrete lighted by expanded clay (should require more energy) Impact on fossil fuel consumption due to oven baking at temperature of almost 1000 degree C. Nevertheless presence of combustible material (EPS) contributes to calorific power and to reducing energy demand, thus considering energy required to EPS production.

Layer c 1: inner mixed plaster (lime and cement) Mortar is obtained with siliceous sand and calcite. Depletion of material resources is one of the highest impacts.

Layer c 2: inner acrylic painting Possible variation: natural painting lime and lime-seed based Each inner painting process supplies 0.1 Pt total damage potential of the whole wall, affecting mainly damage to respiratory inorganic diseases (60%), to climate change and fossil fuels depletion (28%). Hypothesised interventions cause 2.5% of total damage of component lifecycle.
The use of dry assembly technique, in fact, may reduce of almost 16% the final damage score, being its influence higher than the one obtained by adopting different insulating materials.

Moreover, by comparing the two types of external walls (A and B), the solution A that entails a higher rate of maintenance interventions, - owing to the need to substitute external insulating layer “sacrificed” to external agents stresses (thermal mechanical solicitations, water infiltrations, UV-Rays, etc.) has the lower “eco-compatibility”. In a medium durability scenario, total score of unitary surface of wall A (19.8 Pt) is in fact the double of type B (9.58 Pt) where maintenance cycles are limited to cleaning and repairing of external joints. At the end such examples show as impacts strongly depend on processes and products of original construction but also on different feasible maintenance techniques.

4 Conclusions

As demonstrated through a very simple application, architectural quality issues and - first of all, aiming to urban building regeneration - extent of maintenance, replacement and cleaning characteristics, entail key effects and impacts. By integrating B&C environmental detailed assessing tools, with data on real component behaviour, new systems of sustainable construction and refurbishment may be conceived. Design for long service life (and durability) of components, in fact, can even overcome reusability and recycling of building products or, anyway, can highly contribute to sustainability.

In order to follow such a vision, starting from several data collected in site and from literature, lists of “attributes of building components”, to be implemented in LCA and LCC analyses, are being standardised, structuring data on: quality of labour, capital costs and features of functional aspects, relations between adjacent products and materials, pollutant classification, service life, refurbishment characteristics, use, cleaning maintenance requirements etc, characteristics associated with demolition/disassembly, and disposal. Cleaning (technique, materials, access, safety precautions) in fact, seems to account for a big deal of building’s total environmental impact, being multiplied by a large factor owing to frequency and surface area and to the polluting potential of detergents [7].

We believe that, a final outcome, such analyses are extremely useful for integration of guidelines and recommendation in urban planning instruments (action plans, master plans, building codes) and administrative tools (for selections of projects during architecture competitions, calls for tender, green accounting), as well as to orientate the market.

References