SUSTAINABLE DESIGN OF AN ECO-RESTORATION FOR THE FUNCTIONAL RECUPERATION OF A HISTORIC BUILDING TO BE USED AS A TOWN HALL

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Abstract – The aim of this study is to assess both environmental performance and *cultural, historical and social* aspects of the refurbishment of a historical building. This work has been conducted within of an Italian project named "ARACNE". The main aim of this project was to study and eco-design eco-friendly building materials with higher technological properties extending their application to a historical building restoration process. Within this project, the Fiorano Modenese's Town hall (Modena, Italy) has been selected as case study. Furthermore, the recovery and restoration process considered the installation of innovative building products such as nanomaterials, i.e. nano-TiO_2 functionalized float glass and nano-TiO_2 polyurea resin applied on aluminum panel. Life Cycle Assessment (LCA) methodology has been adopted to model these issues. A preliminary definition of *social, cultural and historical* indicators (e.g. historical evidence, cultural instances, human well-being local traditions, social fabric, identification of the population in the analysed building and so on) in the Life Cycle Impact Assessment (LCIA) stage has been carried out. Moreover, preliminary attempts to evaluate the potential risks that nanomaterials could provoke to human health and environment has been taken into account.

Key Words – historical building restoration, sustainability assessment, nanotechnology.

I. INTRODUCTION

This study aims to assess the environmental performance and the *cultural, historical and social* aspects of the refurbishment of Fiorano Modenese's Town hall (Modena, Italy) by Life Cycle Assessment (LCA) methodology. This approach allows to consider not only the environmental impacts due to the refurbishment but also the social benefits that this process originates. The recovery and restoration process considered the installation of innovative building products such as nanomaterials. Therefore, a preliminary attempt to evaluate the potential risks that nanomaterials could provoke to human health and environment has been analysed. The benefit derived from nanomaterials application (i.e. reduction of airborne pollutants and organic substances deposited on the surface materials) has been considered. Furthermore, an introductory definition of *social, cultural and historical* indicators (i.e. historical evidence, cultural instances, human well-being local traditions, social fabric, identification of the population in the analysed building and so on) in the Life Cycle Impact Assessment (LCIA) stage has been carried out. The system function of Fiorano Modenese's Town hall is the municipal offices location. In particular, the refurbishment begins in 2013 and 100 years has been assumed as building life time. The restoration process contemplates a reorganization of all interior spaces:

- reduction of the electric energy consumption of lighting by adopting open spaces and installing glass walls;
- elimination of all architectural barriers;
- introduction of snack point and disabled toilet;
- definition of a sustainable waste collection system;
- incorporation of novel building nanomaterials such as nano-TiO_2 functionalized float glass and nano-TiO_2 polyurea resin applied on aluminum panel.

Energy building consumptions for heating and air-conditioning have been calculated by Termotecnica-Italsoft software [1]. LCA study has

been performed by Simapro 8 software [2] and taking the Ecoinvent database [3] as reference to configure the inventory of Input/Output inventory data. When available, primary data have been used. If missing, they have been built ad hoc. The system boundaries ranging from supply and resources and raw materials extraction to the disposal of each building materials, including the use phase and the maintenance operations. IMPACT 2002+ method [4] has been modified adding new categories for evaluating these novel issues and adopted to conduct the analysis se reported in Pini, 2015 [5].

II. RESULTS AND DISCUSSION

The analysis of results show that the total damage is 1161.63 Pt. The energy consumption for heating is the contribution which are mainly responsible for the total damage (28.28%), followed by transports (12.42%), electric energy consumption for lighting and cleaning (12.45%), and floors (11.36%), electronic equipment (9.76%). The endpoint analysis highlights that the damage is mainly affected by 29.56% to Human Health, 25.92% to Resources, 20.17% to Climate Change, 17.87% to Radioactive waste. Moreover, it is reduced by the environmental benefits derived from nano-TiO_2 applications: -8.18E-4% to Non-carcinogens indoor, -9.13E-3% to Respiratory inorganics indoor – environmental benefits derived from indoor nanoparticle applications- and by the decrease in concentration of NOx (in Respiratory inorganics) and Toluene (VOCs) emissions (in Respiratory organics). Again, a positive contributes resulted from social, cultural and historical aspects: -9.7E-3% to the Human well-being, -3.18E-2% to Maintenance of cultural assets, -6.02E-2% to Function and 8.61E-2% to Maintenance of the urban fabric.

Table 1 LCIA results at end-point level of 1 p of the refurbishment of Fiorano Modenese's Town hall

Damage category	Unit	Total
Human health	DALY	2,435
Ecosystem quality	PDF*m2*yr	1055196
Climate change	kg CO2 eq	2319647,7
Resources	MJ primary	45762653
Renewable energy	MJ	21872490
Maintenance of cultural assets	p	-1,036
Human well-being	p	-0,8
Function	p	-0,7
Maintenance of the urban fabric	p	-1
Radioactive waste	kg	207,85
Carcinogens inhaled	DALY	1,99E-3
Respiratory inorganics indoor	DALY	-7,52E-4
Non-carcinogens indoor	DALY	-6,743E-5

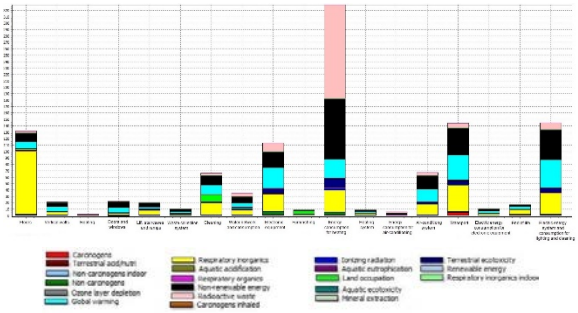

Figure 1. Evaluation by single score of 1 p of the refurbishment of Fiorano Modenese's Town hall

III. CONCLUSION

This study is the first that implements in LCIA phase a framework to assess *social, cultural and historical* aspects of the restoration of an historical building and the potential risk to human and environment associated to the application of building nanomaterials. Nevertheless, a comprehensive and well-structured LCIA framework is mandatory in order to obtain a complete assessment of the restoration of historical building and the use and production of nanomaterials. Regarding the nanomaterials production according to the life cycle thinking, all manufacturing processes have been conceived with the idea to minimize all environmental loads. This has been achieve by adopting the presence of a closed systems and personal protective equipment to prevent the exposure of workers to dust and nanoparticles emissions in the whole life cycle, including the use and the end of life stages. For this reason, the environmental loads associated to nanoparticles toxicity are contained. The *Maintenance of the urban fabric* is the category that mainly contributes positively to social aspects this means that Fiorano Modenese's Town hall really embodies the character of the local tradition and the identity of places, and it constitutes a reference point for the population.

ACKNOWLEDGEMENTS

This study was supported by an Italian project named "ARACNE" Bando Regione Emilia Romagna - Dai distretti produttivi ai distretti tecnologici – 2 DGR n. 1631/2009.

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