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Life cycle assessment of the end-of-life phase of a residential building

Pierluca Vitale [a], Noemi Arena [b], Fabrizio Di Gregorio [c], Umberto Arena [a,c,*]

[a] Department of Environmental, Biological, Pharmaceutical Sciences and Technologies – Second University of Naples, Via Vivaldi, 43, 81100 Caserta, Italy
[b] Centre for Environment and Sustainability – University of Surrey, GU2 7XH Guildford, United Kingdom
[c] AMRA s.c.a r.l. – Analysis and Monitoring of Environmental Risk, Via Nuova Agnano, 11, 80125 Napoli, Italy

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ABSTRACT

The study investigates the potential environmental impacts related to the end-of-life phase of a residential building, identified in a multifamily dwelling of three levels, constructed in the South of Italy by utilizing conventional materials and up-to-date procedures. An attributional life cycle assessment has been utilised to quantify the contributions of each stage of the end-of-life phase, with a particular attention to the management of the demolition waste. The investigation takes into account the selective demolition, preliminary sorting and collection of main components of the building, together with the processes of sorting, recycling and/or disposal of main fractions of the demolition waste. It quantifies the connections between these on-site and off-site processes as well as the main streams of materials sent to recycling, energy recovery, and final disposal. A sensitivity analysis has been eventually carried out by comparing the overall environmental performances of some alternative scenarios, characterised by different criteria for the demolition of the reference building, management of demolition waste and assessment of avoided burdens of the main recycled materials. The results quantify the advantage of an appropriate technique of selective demolition, which could increase the quality and quantity of residues sent to the treatment of resource recovery and safe disposal. They also highlight the contributions to the positive or negative environmental impact of each stage of the investigated waste management system. The recycling of reinforcing steel appears to play a paramount role, accounting for 65% of the total avoided impacts related to respiratory inorganics, 89% of those for global warming and 73% of those for mineral extraction.

1. Introduction

The construction sector plays an important role all over the world for economic, social and environmental aspects (Bribián et al., 2009) and directly involves about 18 million of workers, constituting the Europe's largest industrial employer (EC, 2016a; Dahlbo et al., 2015; Ortiz et al., 2009). It provides 9% of the EU's gross domestic product (GDP) by including a wide spectrum of economic activities (such as those related to extraction, manufacturing and distribution of construction products; design and management of construction works; construction demolition and management of demolition waste). Then it is a crucial sector "in the delivery of the European Union's "Europe 2020 goals" for smart, sustainable and inclusive growth" (EC, 2016a). On the other hand, the construction sector is responsible for huge environmental burdens, in terms of natural resource and energy consumption as well as pollutant emissions into the atmosphere and waste generation. The sector consumes about 60% of the minerals extracted from the lithosphere, i.e. 24% of the global extractions (Bribián et al., 2011), and requires up to 40% of the total energy demand of an industrialized country, which corresponds to a comparable percentage of greenhouse gases (GHG) emissions (Asdrubali et al., 2013). Recently, the European Commission highlighted that "the construction and use of buildings in the EU account for about half of all our extracted materials and energy consumption and about a third of our water consumption" (EC, 2014). These figures clearly indicate the necessity to improve the sustainability of the construction industry by adopting design solutions and operating procedures, aimed at resource optimisation and waste

Abbreviations: C&DW, construction and demolition waste; EU, European Union; GHG, greenhouse gases; LCI, life cycle inventory; $PM_{2.5}$, particulate matter below 2.5 μm; EC, European Commission; GDP, gross domestic product; LCA, life cycle assessment; MFA, material flow analysis; PM_{10}, particulate matter below 10 μm.

* Corresponding author at: Department of Environmental, Biological, Pharmaceutical Sciences and Technologies – Second University of Naples, Via Vivaldi, 43, 81100 Caserta, Italy.

E-mail address: umberto.arena@unina2.it (U. Arena).

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minimization, as restated in the European Union action plan for the circular economy (EC, 2015).

A crucial problem of the building sector, which requires a prompt and appropriate management, is the huge amount of construction and demolition waste (C&DW): 821 Mtonne/y only in Europe in 2012, i.e. 32.7% of the total amount of European waste (Rodrigues et al., 2013; Eurostat, 2015a,b). It is a "priority" waste stream in the waste strategy of European Union (EC, 2014), for a series of important reasons. The potential environmental concerns relate to a not appropriate treatment (such as the contamination of soil and water resources by illegal dumping or uncontrolled landfilling), an illegal utilization of their large volumes to hide hazardous wastes, and the loss of resources related to disposal without material and energy recovery (EC, 2011; Banias et al., 2011; Nasrullah et al., 2014; Butera et al., 2015; Dahlbo et al., 2015). The importance of these concerns is also highlighted by the approach of urban metabolism, which suggests to investigate the dynamics in building and infrastructure deposits, with the aim of developing technologies to reutilize large amounts of minerals stocked in the society, and reducing the mineral extraction from caves (JRC-EC, 2011).

The study is part of a 3-years project, aimed to assessing the environmental impacts of a residential building, located in the South of Italy, along the three phases of its overall life cycle, defined as in previous studies (Cabeza et al., 2014; Cuéllar-Franca and Azapagic, 2012; Asdrubali et al., 2013; Blengini, 2009). Fig. 1 schematically shows these phases: pre-use (production of construction materials, their transportation to the construction site and final assembling), use (i.e. lighting, appliances, cooling, heating, etc.; but also building maintenance), and end-of-life (deconstruction/demolition, waste collection, pre-sorting, transport, recycle and disposal). The study started from the information and observations contained in recent papers focused on the last of these phases (Butera et al., 2015; Dahlbo et al., 2015; Coelho and de Brito, 2012), and includes all the on-site and off-site activities related to building demolition and C&DW management.

2. The goal and scope definition

The study developed an attributional life cycle assessment (LCA), carried out in agreement with the international standards (ISO, 2006a,b). Goal of the study was to assess the environmental performance of the overall end-of-life phase of a specific residential building, with a particular focus on the management of the generated demolition waste. The reference building is a multifamily dwelling of three levels, typical of the South of Italy, constructed by utilizing Italian conventional materials and up-to-date construction procedures. Its main features are reported in Table 1, together with the functional unit, which coincides with the overall net usable area of the building (1550 m^2).

Fig. 2 schematically shows the system boundaries, in terms of foreground and background systems (Clift et al., 2000), which include all the activities of selective demolition, collection, sorting, transportation, material and energy recovery, and landfilling. The quality of data utilised for the foreground system and large part of the background system is rather high. Most of the environmental burdens (direct, indirect, and avoided) listed in the life cycle inventory (LCI) have been obtained processing data deriving from

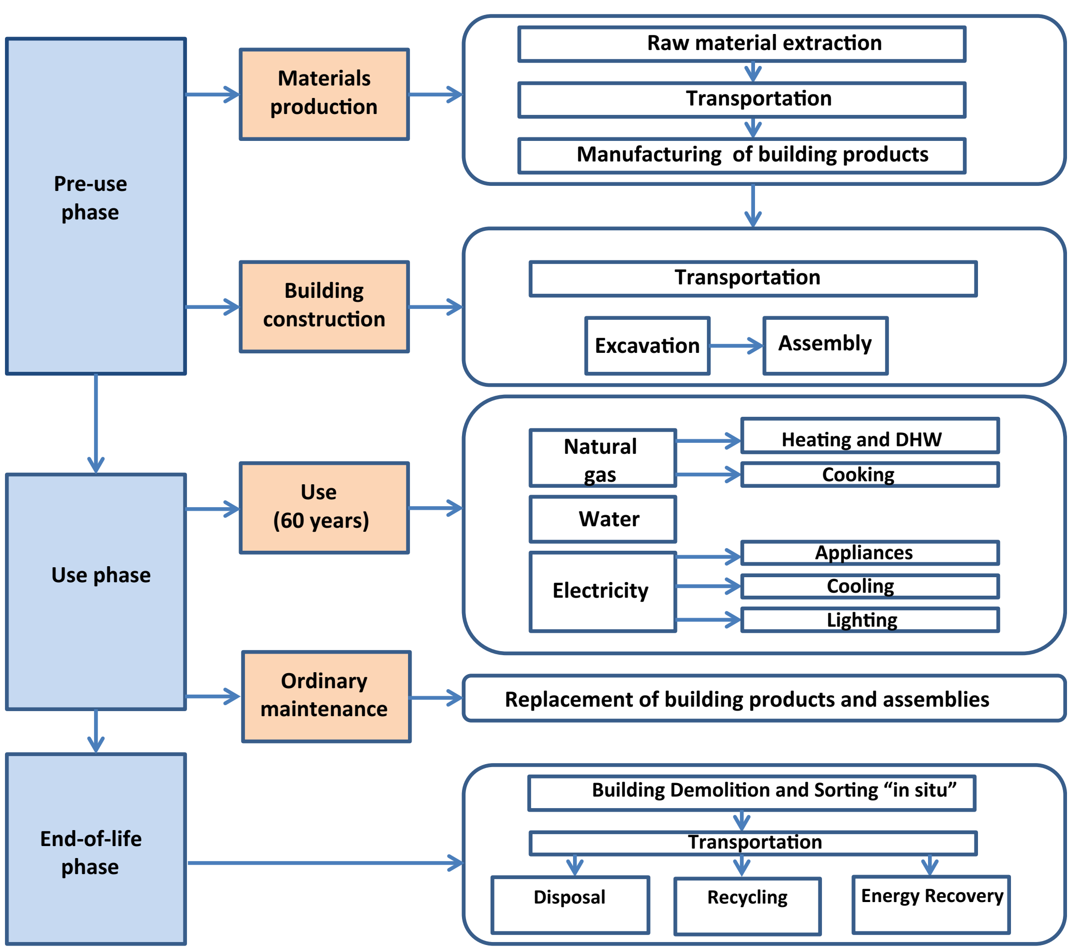

Fig. 1. The pre-use, use and end-of-life phases of the residential building under analysis.

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