Management of Construction Waste: LCA and Complex System Modeling

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Abstract Construction and demolition waste (CDW) generation, identified as a priority stream by the European Commission, accounts for approximately 25 to 30% of all waste generated in the European Union. According to local specificities (e.g. regulations, waste management organization) best environmental options may differ for transforming waste into new resources. Five oral presentations were given in the session which focused on innovative modelling initiatives combining LCA with complex models in order to improve knowledge for more sustainable urban construction waste management. During the discussions, all participants agreed that re-use or recycling mass performance is a weak and unsufficient indicator for assessing waste management systems. There is an important need for better characterizing stocks and predicting nature and quality of output flows. Geospatialized data combined with Material Flow Analysis was the methodology identified and used by the research community.

1 Introduction

Construction and demolition waste (CDW) generation, identified as a priority stream by the European Commission, accounts for approximately 25–30% of all waste generated in the European Union. Recent political consciousness about circular economy has focused the spotlight on the construction sector, seen as a real

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opportunity to generate new resources and local employment based on urban mining. Behind this will, many challenges arise. Indeed, reaching best environmental performances often relies on many interrelated aspects such as relationships between: territorial waste management, sorting practices and possible reuse or improvements of recycled materials' qualities; existing or innovative treatment technologies, regulations and standards, and possible markets for future recycled products; disturbance of markets' equilibrium by the introduction of recycled materials and possible avoided environmental impacts; environmental effects of scale changing from small innovative experience to large territorial applications, etc. According to local specificities (e.g. regulations, waste management organization) best environmental options may differ. Finding them is finding favorable combinations of solutions all along the waste treatment chain for sustainable urban systems, rather than ready-made preconceived ones. Introducing economic, technological, or social mechanisms into LCA calculations provides knowledge that can be adapted in various contexts.

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2 Prospective and Regional Modelling of Construction Material Flows

The session started with a presentation from Niko Heeren [1] providing an overview of a bottom-up dynamic MFA model he developped and applied for Switzerland, and the relevance of construction material flows for the environmental impact of buildings. Future possible scenarios were compared and potentials for closed loop recycling analysed [1]. The development is based on a GIS-based building stock model to determine material flow of the Swiss building stock. By merging a national building register with a three-dimensional dataset, it is possible to quantify the material volumes for all residential buildings. In order to perform a prospective assessment, element and building service life are determined using a stochastic approach. Therefore, the model accounts for the dynamics due to material dwelling time. Life cycle assessment is used to assess the environmental impacts of future material flow.

3 Guidelines for Effective and Sustainable Recycling of Construction and Demolition Waste

Serena Giorgi presented an analysis of actual re-use and recyling practices in European countries [2]. Starting from a screening of current percentage of reuse and recycling, types of waste and recycling destinations, as well as incentive policies in member states of European Union-28, she explained that the objective of the directive 2008/98/EC on waste that imposes a minimum of 70% re-use or recycling by weight within 2020, can be easily reached or even already achieved by more than half of European countries. Research data of the average material composition of CDW percentage shows that 60–70% (by weight) is composed of concrete and masonry, followed by minor percentages of asphalt, wood, metal, gypsum and plastic. Aggregates are therefore the largest amount of CDW. Based on these facts Serena Giorgi reported that since the Directive 2008/98/CE expresses the objective in percentage of weight, it doesn't value the best material to be recycled in terms of effectiveness and sustainability (e.g. recycling of plastic parts in Italy is only 21%), but heavier ones. Also she argued that there isn't any assessment of the "quality" of recovery, i.e. differentiation between reuse, upcycling/downcycling or energy recovery. In this way, it was found that in many countries, aggregates are mainly recycled for road foundations, earth works and backfilling. A further issue is the assessment of the effectiveness of recycling sustainability, especially for inert waste. A study of the ecological balance of the concrete produced with recycled aggregates shows that there is a sharp increase of environmental impact, first due to the increase of cement content used with recycled aggregates and second due to the transport from supply points to the production facilities. Finally the speaker defined ways to improve legislation and proposed some guidelines, aimed at making the recycling of CDW management more effective and sustainable through Life Cycle Management.

4 Adaptive Reuse of Buildings and Its Life Cycle Sustainability Benefits

Harn Wei Kua then presented a case study of primary school refurbishment strategies in Singapore, based on a life cycle based approach [3]. The environmental and economic assessment was performed for alternate designs for school buildings, aiming at reducing the need or extent of future renovations and demolitions. This analysis lead to design guidelines, in which alternate designs are compared in terms of potential net amount of C&D wastes that could be saved as well as net decrease in life cycle impacts and resources requirements. Also, for each alternate design, the potential of each kind of generated C&D wastes for recycling or reuse, and the life cycle costs of the buildings were estimated, as well as the social and cultural effects of building preservation based on similar projects elsewhere in Singapore.

Based on the life cycle sustainability values of adaptive reuse, policy strategies were recommended to promote and incentivize this alternate design approach in Singapore.

5 Evaluating the Construction and Demolition Waste Management System Implemented in Lombardy Region (Italy) Through Life Cycle Assessment

Among Italian regions, Lombardy was the largest producer of CDW in 2014, with a rough equivalent of 1 ton of CDW per inhabitant during the year 2014. Hence, the establishment of an effective and sustainable CDW management is essential to ensure environmental protection and enhance waste valorisation towards a resource-efficient system. Lucia Rigamonti presented the results of the overall environmental performances of the CDW management system currently implemented in the region, based on LCA [4]. The quality of secondary products obtained from CDW and their actual use has been considered. A focus has been made on the technical characteristics and the actual market of the recycled aggregates, allowing to estimate the type and amount of "avoided natural materials" that can be replaced by recycled products. The environmental benefits due to the "avoided impacts" have been calculated. Based on LCA results and a literature state-of-the-art of treatment technologies, alternative scenarios for CDW management strategies, innovative processes and/or alternative recovery solutions (i.e. "alternative scenarios"), have been defined. LCA results for the alternative scenarios were compared to the results of the current situation to quantify the benefits arising from the suggested improving actions. Results have been used to provide recommendations to the regional authorities to enhance the CDW recycling chain.

6 Alternatives for Materials from an End-of-Life Building, Evaluated with Life Cycle Costing and Life Cycle Assessment

Valentina Prado-Lopez presented a study derived from the EU Horizon 2020 HISER research and innovation program [5]. Two scenarios of demolition waste management were compared, a 'best practice' (BP) and a 'business as usual' (BAU) scenario, from an environmental and financial perspective. An integrated Life Cycle Costing and Life Cycle Assessment was performed to quantify and compare the environmental implications and cost-effectiveness of the scenarios. The scenarios are based on field data collected in the BP demolition of a building located in Almere, the Netherlands. The BP alternatives favor the reuse of retrieved building components and the upcycling of concrete rubble, over general recycling and final disposal. In the BP scenario, the reuse of ceiling tiles, wooden doors and stairs, gypsum walls, and metal beams are win-win situations, compared to the treatments in the BAU scenario, which are more expensive and more pollutant. In both scenarios, the metal beams are the largest contributors to the environmental burden. If metal beams are reused, the cost of onsite construction of a new building drops dramatically. The overall BP scenario is cheaper than the BAU scenario. As further recommendations, the impact of waste management of each material flow can considerably decrease by shortening the transport distances. Selective dismantling and demolition, and the reuse of components should be promoted by including a phase prior to dismantling, in which reusable components and materials are inventoried and potential buyers are contacted.

7 Conclusions

The whole session showed that the construction and demolition waste (C&D waste) management is a complex system to be modelled because several types of information must be considered and collected at different scales: at material, building and processes levels, defining the possibilities in terms of technical valorisation, and at regional level in order to consider regulations and urban planning policies. The temporal aspects are also crucial because today's decisions on construction engage consequences for the next 100 years, therefore with some potential important repercussion for the waste management system despite its strong inertia to changes. All participants agreed that re-use or recycling mass performance is a weak and unsufficient indicator for assessing waste management systems. There is an important need for better characterizing stocks, to predict nature and quality of output flows. Geospatialized data combined with Material Flow Analysis was the methodology identified and used by the research community. Predictions are based on scenarios comparison, mainly comparing recycling technologies and possible substituted materials. However, the link between sorting processes and quality of output material is not enough investigated, and possible changes in building design methods that are expected to avoid waste by favoring better adaptability of buildings should also be investigated. It should support the assessment of waste prevention strategies efficiency. Finally, including economic market mechanisms, making the link with availability of material flows responding to the future materials demand would also be relevant in the framework of the sustainable assessment of C&D waste management.

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