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Construction and demolition waste management – a holistic evaluation of environmental performance

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ABSTRACT

A growing amount of construction and demolition waste (C&DW) is produced in Europe each year. Increased recycling of C&DW is required by the EU Waste Framework Directive, targeting at 70% recycling of non-hazardous C&DW by 2020. The aim of the study was to assess the performance of the common Finnish C&DW management system against this target, thus identifying the environmental and economic impacts of the system and the effects brought about by changes in the waste composition. In this study, a combination of different methodologies was applied to evaluate holistically the performance of the C&DW management system: material flow analysis (MFA) was employed to assess material and energy recovery rates, life cycle assessment (LCA) was utilised to evaluate climate change impacts, and environmental life cycle costing (ELCC) was used for measuring the costs. In addition, the applicability of the best available technology (BAT) approach for developing the efficiency of the waste management system was scrutinised. Thus, aligned with the empirical aim of assessing the performance of Finnish C&DW in reference to the EU Waste Framework Directive, the theoretical aim of the study was to test how the employment of different assessment methodologies affects the performance results of the C&DW management system.

According to the results, the overall system produced environmental benefits and was economically profitable, but was far behind the target of recycling 70%. Based on the assessments, the EU Waste Framework Directive target will not be achieved, even with the likely changes in waste composition. Thus, major changes will be needed to source separation and recovery within the system, e.g. by finding recycling concepts for waste wood without decreasing the environmental and economic benefits of the system. The employment of different methodologies gave a diversified view of the possibilities to develop the system. The metal treatment performed well in all assessments; hence improvements to it would not benefit the system notably. For wood the results were controversial, since the energy recovery generated environmental and economic benefits, but did not increase the recycling rate. Material recovery concepts should be developed, but simultaneously the environmental and economic benefits should be retained. Miscellaneous waste had the potential for increasing recycling and avoiding costs and emissions. Mixed waste was identified as the worst fraction in relation to climate change impacts, costs and material recycling. Applying the BAT approach showed that BAT for waste management needs to be based on system-level rather than installation-level assessments.

This multi-methodological assessment of C&DW management showed the need for analysing the environmental performance of a system from different perspectives before decision-making. In general, the recycling of waste generates greater environmental benefits than energy recovery, but this may not always be the case. Regional differences in operations and waste composition may support arguments for differing recycling targets in different regions.

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1. Introduction

A considerable and growing amount of construction and demolition waste (C&DW) is produced in Europe each year; in 2006 around 970 million tonnes (Monier et al., 2011). As a result, special attention is being paid to C&DW management at the European level, which is having implications for national-level policies. C&DW management is steered in particular by the EU Waste Framework Directive (2008/98/EC), which sets a target for the recycling of non-hazardous C&DW at a minimum of 70% of its weight by 2020. Increased recycling is demanded in several national and EU strategies and most recently in the proposals from the European Commission to move towards a circular economy (European Commission, 2012a; European Commission, 2014). Additionally, in the future, waste (including C&DW) management will be more controlled by the waste treatment BAT reference document (WT BREF) currently under preparation. The BREF document will contain a chapter with BAT conclusions, including BAT-associated emission levels (BAT AEL). These BAT AELs are binding in environmental permitting for installations covered by the Industrial Emissions Directive (IED) and can also be used as benchmarks for other installations. C&DW is also prioritised in waste policy in other parts of the world, such as Hong Kong, where new construction waste policies have been adopted efficiently during the past decade to reduce construction waste and divert it from being landfilled (Lu and Tam, 2013).

Generally, the main barriers for recycling C&DW are the high availability and low cost of virgin raw materials, which decrease the demand for recyclates and the interest in developing business from recycling. The competitiveness of recycling could be increased by raising the price of primary raw materials through taxation. In addition, setting End-of-Waste criteria for certain C&DW fractions could contribute to increasing the market for secondary raw materials obtained from C&DW (Monier et al., 2011). Currently, Finland is far away from the recycling targets for C&DW and below the average European level of 47% (Kojo and Lilja, 2011). To make landfilling unattractive to operators, the landfilling of organic waste will be restricted in Finland from 2016 by the landfill decree. This is expected to boost the recovery of waste wood and plastics in particular (Meinander et al., 2012). The composition of C&DW will most probably change in the future due to ageing buildings needing renovation and low-quality houses from especially 1960s and 70s coming to the end of their lifetimes and needing demolishing (Kojo and Lilja, 2011). At the moment it is not known whether this will help to reach recycling targets or if there is a need for a major reform of the system.

The need for broad-scope empirical measurement of the environmental and economic performance of C&DW management system has been emphasised in scientific studies and common political discussion (e.g. Lu and Yan, 2011; Monier et al., 2011; Singh et al., 2011). Increased recycling should be achieved by environmentally feasible and economically viable measures in order to improve the overall sustainability of waste management. In general, the recycling of wastes has been shown to produce environmental benefits more than it produces environmental impacts (e.g. Michaud et al., 2010). Ortiz et al. (2010) studied Spanish C&DW and concluded that environmentally, recycling was the best performing option and landfilling the worst, while energy recovery came in somewhere in between. Even with long transport distances, recycling was beneficial for everything other than heavy stony materials for which recycling close to the point of generation was preferable. According to Lu and Yan (2011), enhancing the use of recycled materials requires them to be competitive with virgin materials in terms of costs and quality. Improving the quality of recycled materials requires enhanced sorting, separation and processing, which may increase costs. On the other hand, using developed technologies and implementing appropriate management of processes to improve resource efficiency provide opportunities for decreasing costs. Developing C&DW management is thus a combination of legal, administrative, financial, engineering and planning functions.

The theoretical objective of the study was to test whether the employment of different assessment methodologies generates similar results related to the performance of the C&DW management system and how the methodologies complement each other. The empirical objective of the research was to evaluate the current environmental and economic performance of the C&DW management system and the key waste fractions or processes influencing the performance. In line with this, it was also analysed whether the target of 70% recycling of C&DW by 2020 can be achieved with the current management practices but taking into consideration changes in the composition of waste. The implications of the composition change on environmental and economic performance were also assessed. Finally, it was asked whether the environmental performance of the current processes can be improved in order to improve the overall performance of C&DW management. The understanding hereby gained leads to the proposal of measures for improvements needed in the C&DW management system.

2. Methods and materials

2.1. Research methods

The methodologies of the study comprise a combination of tools appropriate for a holistic assessment of the performance of the C&DW management system. Material flow analysis (MFA) was applied in order to produce a description of the waste flows within the treatment lines (Fig. 1) and quantifying the inputs and outputs of processes in the C&DW system. MFA is a descriptive approach that provides snapshots of parts of the physical economy (Reuter et al., 2005). MFA refers to the analysis of the throughput of a process chain comprising the extraction or harvest, chemical transformation, manufacturing, consumption, recycling and disposal of materials (Bringezu and Moriguchi, 2002). Material and energy recovery rates were calculated from the outputs of the sorting and separation, i.e. the inputs to recovery processes. This approach differs from the current common practice of assessing recycling rates, but was considered to give a realistic picture of the systems efficiency in recovering wastes, hence its use in this study. The generation of C&DW has been studied with dynamic material flow analysis by Hu et al. (2010) and Müller (2008). However, MFA has not been applied at the unit process level to the treatment of C&DW. In this study, MFA was performed using STAN 2.0 software (Cencic, 2008).

Life cycle assessment (LCA) was used to assess the environmental impacts of the system described with MFA (Fig. 1). LCA is a method for integrating the environmental impacts of a studied product or service over the whole value chain. The focus of the LCA in this study was to provide an estimate of the potential climate change (CC) impacts of C&DW management and to identify the waste fractions and activities contributing most to these impacts. In order to enable the comparison of the same C&DW system with differing waste composition, the functional unit (FU) of the LCA was defined as one tonne of C&DW generated. For the inclusion of the benefits that can be obtained from waste recovery, the system described with MFA (Fig. 1) was expanded with processes that could be avoided by recovering the material or energy of the

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