Bottom-up policy support: Using a construction materials model to identify and quick scan circular opportunities

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Abstract

Although the need for a more circular economy is supported by diverse people in both politics as well as in the scientific community, implementation of circular principles in reality is rarely occurring. This study shows how quantitative models can help to develop new policies for enhancing circularity in the construction sector.
By means of a bottom-up construction materials model, an analysis of the circular opportunities for the Netherlands was developed. First of all, the national material stock in the built environment and their embodied environmental impacts were assessed. Next, the most important flows (being reinforced concrete, bricks, timber, aluminium and glass and copper) were subjected to an environmental quick scan. With this quick scan, potential alternatives for more circular end-of-life treatment routes could be compared and ranked by their effectiveness. The study was finalized by interviewing stakeholders about the political practicability of the outcomes and by defining recommendations for new policy development.
In comparison to a business-as-usual scenario, the circular treatments of the selected materials show a reduction potential up to around 30% of the environmental impact over their full life cycles. When compared to the total national construction material demand in the coming years, considering all materials, these circular treatments could help to achieve a reduction of around 10%. The outcomes and the feasibility for implementation were discussed with stakeholders.
The construction material model was based on generic and average construction practises, but even though this bottom-up approach is sensitive for assumptions, it proved to be a useful tool to start policy discussions thanks to its informative visualizations. The model can be further refined in case study projects, but it is yet ready to identify environmental hotspots and provide input for discussions about circular strategies.

Keywords: Construction and demolition waste, Circular economy, Built environment, Urban metabolism, Policy development.

Introduction

The demand for more circular thinking is a rising topic in diverse sectors. Several goals for increased material recycling are set, like the European Waste Framework Directive which requires that 70% of the non-hazardous Construction and Demolition Waste (CDW) should be recycled or recovered by 2020. Nevertheless, circular scenarios including high-quality waste treatment ("upcycling"), nihilation of primary resource use and real circular thinking and are barely analysed by scientific studies, nor translated to real projects.

Although many studies exist on the environmental impacts of the construction sector (e.g. Bijleveld *et al.*, 2015), none of them help to prioritize material flows which require more circular thinking and treatment. For example, Miatto *et al.* (2016) note that bulk materials in the construction sector cause a substantial environmental impact, but the estimations of the magnitude of these material flows contain large uncertainties because more attention is paid to other, costlier, streams.
More insight in the diversity of material streams, their origin and their impacts, could support the development of new policies for enhancing circularity in the construction sector. In this study, a quantitative model is developed to serve the development of new policies which aim to increase circularity and decrease environmental impacts. The model is applied for the prioritization of circularity policies in the Dutch construction sector for dwellings and utility buildings.

Methodology

This research followed a four-step approach, combining national datasets, expert judgement and stakeholder interviews. First of all, a model was developed to inventory the national material stock in the built environment and their embodied environmental impacts. The model connects national surface occupation data with dwellings and utility building profiles and environmental data. The building profiles were developed by construction experts in an early phase of this study. The environmental data were based on general material records from the international database ecoinvent 3.0. The environmental impact assessment guidelines of the Dutch construction sector were used to calculate a single-score outcome for each material, called MKI (Stichting Bouwkwaliteit, 2014).
In the second step, the material flows with the highest environmental impacts were subjected to a circularity assessment: for each material, several potential circular scenarios were developed during a workshop and evaluated by means of environmental quick scans. The quick scan results were compared and combined to determine the maximum achievable environmental impact reduction. In the third step, stakeholders were interviewed about the political practicability of the outcomes. Fourth, all modelling results and interview insights were combined to define recommendations for new policy development.

Results

The inventory of the environmental impacts of all construction materials in the Dutch construction sector are shown in Figure 1. Steel (mostly in a reinforcing function), copper, bricks, concrete, aluminium and glass are the materials with the largest environmental impacts, causing together 80% of the impacts. In addition to this set of materials, circular scenarios were developed for timber, because this is an important construction material from the perspective of renewable resources.

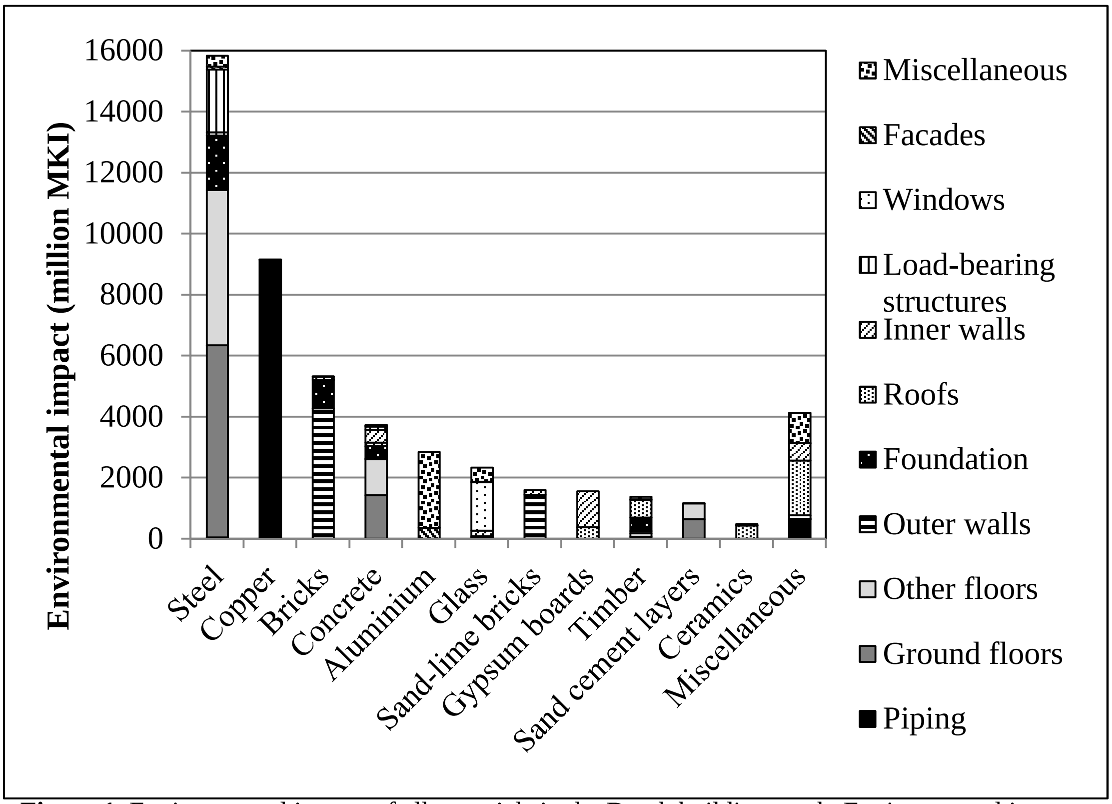

Figure 1. Environmental impact of all materials in the Dutch building stock. Environmental impacts reflect only the production of building materials.

The following reference (R) and circular (C) scenarios were developed:

- *Reinforced concrete:* recycling as foundation material (R); 50% of Portland cement is substituted by blast furnace slag cement (C1); 20% of concrete waste substitutes gravel or sand in new concrete (C2); "legolisation": 50% of reinforced concrete structures gets a second life (C3).
- *Bricks:* recycling as foundation material (R); use crushed bricks instead of crushed gravel (C1); 25% of brick waste crumbles used in new bricks, with lower production temperature (C2); "legolisation": 50% of bricks gets a second life (C3).
- *Copper:* recycling (R); reuse electrical wires from utility buildings (C1).
- *Glass & aluminium:* recycling of separate materials, with environmental bonus (R); reuse of 10% of curtain walls, for example in greenhouses (C1).
- *Timber:* incineration with energy recovery (R); lifetime prolongation (C1); constructions of timber instead of concrete (C2).

The optimal combination of circular scenarios is shown in Figure 2, achieving an environmental impact reduction of around 30% (60 million MKI/year) compared to the reference scenarios for these materials (200 million MKI/year). In comparison to the total national construction material demand, this means a reduction of 10% in environmental impacts.

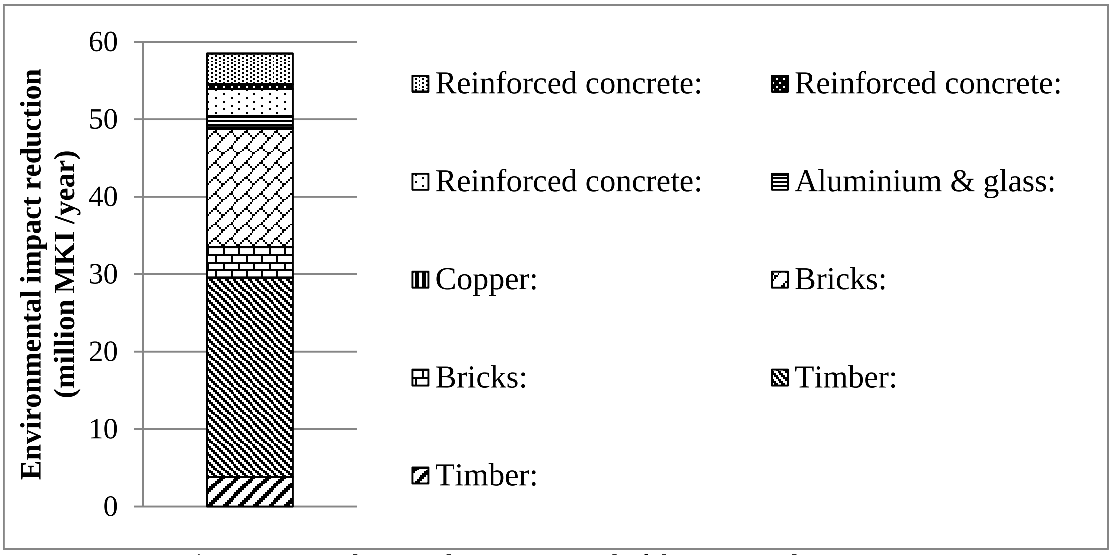

Figure 2. Cumulative reduction potential of diverse circular scenarios.

The outcomes and the feasibility for implementation were discussed with experts in project development, demolition and waste treatment, a social housing corporation, an economic institute and a higher education institution. The stakeholders mentioned three main barriers for implementation: 1) the long life time of buildings; 2) conflicts of interest due to complex relations in the construction sector; 3) innovations experience many difficulties in competition with mainstream materials and processes.

Conclusions and Discussion

The study's aim to serve the development of new policies in the construction sector was achieved by developing and applying a bottom-up construction material model. Although the model is based on generic and average construction practises and many common-sense assumptions, it proved to be a useful tool to start policy discussions thanks to its informative visualizations. Explicitly, the models does not aim to cover all possible strategies, material chains or stakeholders, since it is meant as a discussion support tool and not as detailed study of the construction sector.
Summarizing, the model is ready to identify environmental hotspots and provide input for discussions about circular strategies. The model can be further refined in case study projects, either on material, city or national level.

Acknowledgement

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References

- Bijleveld, M., Bergsma, G., Krutwagen, B., & Afman, M. (2015). Meten is weten in de Nederlandse bouw. Milieu-impacts van Nederlandse bouw- en sloopactiviteiten in 2010. Delft: CE Delft.
- Miatto, A., Schandl, H., Fishman, T., & Tanikawa, H. (2016). Global patterns and trends for non-metallic minerals used for construction. Journal of Industrial Ecology, DOI: 10.1111/jiec.12471.

- Stichting Bouwkwaliteit (2014). Bepalingsmethode Milieuprestatie Gebouwen en GWW-werken, versie 2.0. Rijswijk: Stichting Bouwkwaliteit.