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Strategies, Stakeholders, Success factors

7th - 11th March 2016

KIT Karlsruhe Institute of Technology

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Program Overview

	Monday 7.3.2016	Tuesday 8.3.2016	Wednesday 9.3.2016	Thursday 10.3.2016	Friday 11.3.2016
8.00-9.00 a.m.		Registration	Registration	Registration	
9.00-10.30 a.m.		Opening Keynotes	Scientific sessions / Housing Industry Day	Scientific sessions / Day of Architecture, Planning & Engineering	PhD Session / Excursions
10.30-11.00 a.m.		Coffee	Coffee	Coffee	Excursions
11.00 a.m.-12.30 p.m.		Scientific sessions / Day of Municipalities	Keynote Session UN Climate Change Conference	Scientific sessions / Day of Architecture, Planning & Engineering	PhD Session / Excursions
12.30-2.00 p.m.		Lunch	Lunch	Final Session / Lunch	
2.00-3.30 p.m.	Excursions / Pre-Registration	Scientific and special sessions / Day of Municipalities	Scientific and special sessions / Housing Industry Day	Final Session, Excursions / Day of Architecture, Planning & Engineering	PhD Session
3.30-4.00 p.m.	Excursions / Pre-Registration	Coffee	Coffee	Excursions / Coffee	
4.00-5.30 p.m.	Excursions / Pre-Registration	Scientific and special sessions / Day of Municipalities	Scientific and special sessions / Housing Industry Day	Excursions / Day of Architecture, Planning & Engineering	
5.30-7.00 p.m.	Warm-up and exhibition opening	Welcome and Networking-Reception for all participants (Handelskammer)	Get Together and Award Ceremony (Holcim Study Award)		

Scientific Session
Session in German language
PhD Session

SBE16 Hamburg

International Conference on Sustainable Built Environment Strategies – Stakeholders – Success factors

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Resource saving potentials through increase recycling in the building sector – sensitivity studies on current and future construction activity

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Summary

Despite adequate supplies of materials for recycling as well as the introduction of dedicated norms on the use of recycled materials, a poor level of secondary raw material use persists in the building industry. Before political action can be taken to improve this situation, it is first necessary to gain a clear picture of current and future material flows, and in particular, which rates of recycling can be achieved when good framework conditions for the circular flow of materials are implemented. The aim of the described research was therefore to determine the potentials for the high value recycling of construction and demolition waste from buildings by means of sensitivity studies. Estimates were made of material flow masses in the building sector for 2010 as well as projections for the years 2030 and 2050.

Keywords: resource efficiency, recycling potentials, development of building stock, material flows, urban mining

1. Introduction

In the year 2002 the German government adopted a national sustainability strategy [1, 2]. Since this time concrete guidelines and indicators have shaped the path towards sustainable development. These are closely linked to the aim of conserving natural resources through improved efficiency. Specifically, the government decided that resource efficiency should increase by 50 % to the year 2020 (from the base level in 1990).

A nation’s overall resource efficiency is determined by the gross domestic product (here in euros) and the total flow of materials (in tons). Hence the building sector, which consumes huge amounts of primary materials (such as sand, gravel, crushed stone, concrete, etc.), clearly has a major impact on resource efficiency. Lower demand for primary materials, e.g. through new construction techniques or the use of recycled materials, will therefore directly impact resource efficiency at the national level. Despite the importance of recycling, recycled materials still make up a small proportion of total material mass. Although in most cases recycled materials are available in sufficient quantities, and their use in particular applications is already permitted by construction norms, there has been a low uptake of recycled materials in the building sector. Political action is required to remedy this situation. Yet before politicians can get to work, it is necessary to describe as precisely as possible the current and likely future state of the building sector. This was the intention of the investigation described here.

Specifically, the research aim was to examine the potential for increased high-grade recycling of construction and demolition waste. Material flows were examined for 16 construction materials/products (see table 1). The first step was to gather data on construction activity (new buildings, renovation and demolition) for 2010[1], the beginning of the period under consideration. From this data it was possible to forecast material flows for the years 2030 and 2050 [3, 4]. Two research avenues were pursued simultaneously. On the one hand, we investigated the origin, composition, collection, sorting and recycling paths of the 16 building materials/products. This involved the setting of "optimistic" recycling ratios in discussion with experts on the building sector as well as representatives of trade federations. On the other hand, a material flow model was developed in order to provide a quantitative picture of current and future construction activity.

The objects of investigation were the potentials for the circular flow of material within Germany's stocks of residential and non-residential buildings – from buildings to buildings. Thus the question of related infrastructural work (utility connections, access roads, etc.) is here ignored.

2. Methodology

The calculations to derive recycling potentials took the form of four sensitivity studies. These studies determined the extent to which recycling ratios can be increased through different forms of construction as well as new recycling technologies and application conditions. These factors were investigated within a specially developed material flow model, for which input data was required to describe the intensity of activities in the building sector (Fig. 1).

Two different analytical paths were linked in the material flow model: Data on the size of the building stock and the intensity of building activities was captured in a top-down view, while the material constitution was determined in a bottom-up view. The quantitative top-down path made use of all available statistics on the building sector [5]. The bottom-up characterization took the form of a building material matrix, which could be used to translate official data on the stocks of residential and non-residential buildings into material flows and material masses.[2] These calculations made use of a typology of residential and non-residential buildings, employing material indicators for type of construction and for technical installations [6, 7, 8]. By considering the specific material indicator values for building types, the data on the stock of residential and non-residential buildings as well as on estimates of current and future construction activity (new buildings, renovation, demolition), it was possible to calculate the total mass of materials within buildings stocks as well as the total material flows. The results of the sensitivity studies were values in tons of material stocks as well as material input and output flows. Recycling potentials could then be derived by applying the estimated recycling ratios.

[1] 2010 was set as reference year because of availability of data.

[2] The bottom-up characterization calculated all material flows as determined by official statistics. This took account of the main core of construction activities. Statistically irrelevant structures (e.g. free-standing garages), external structures (e.g. supporting walls) and extraordinary buildings (e.g. airports) were not included in data.

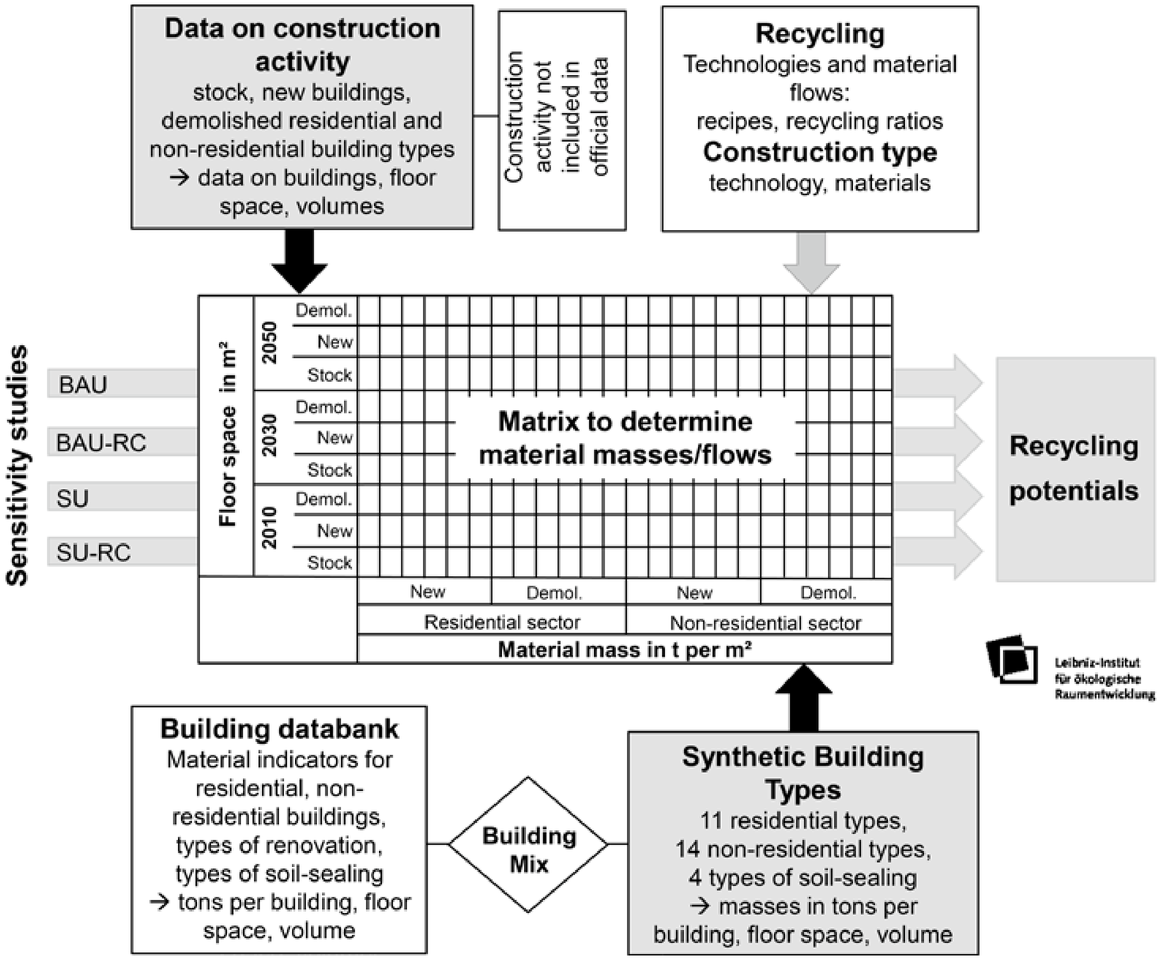

Fig. 1: Overview of material flow model [based on 3, p. 22]

2.1 Synthetic building types

11 such synthetic building types (based on period of construction) were formed to reflect the range of residential buildings. Here a distinction was made between one- and two-family homes as well as multi-family homes. 14 synthetic building types were specified for non-residential buildings. Here the types were distinguished by usage. The synthetic building types were created by abstracting a number of real buildings present in the IOER building databank (unpublished). In order to create a specific type, data on suitable existing buildings was captured and then averaged out to produce a standard (or synthetic) type.

2.2 Construction activity

Construction activity encompasses all activity that increases or decreases the building stock in the form of new buildings, conversions, extensions, renovations, partial or complete demolition and the joining of separate buildings into single structures. Data from national statistics [5] was used to calculate previous and current construction activity. Future construction activity was based on population forecasts for the year 2050. The factors and assumptions for the “translation” of demographic trend into building activities are presented in detail in the publications by Banse & Effenberger 2006 [9], Gruhler & Böhm 2011 [6] and Deilmann et al. 2015 [3].

Statistics were available on the stock of residential buildings [5]. These provided a framework for estimates of material masses of this stock. To overcome the problem of a lack of official statistics or sufficiently verified data on the stock of non-residential buildings, it was possible to turn to previous and current studies [10, 11, 12].

2.3 Recycling ratios

The possibilities of incorporating recycled materials into new building materials and products were discussed with experts in this field [3]. It was agreed that the estimates of likely recycling ratios should only be used within the described sensitivity studies and must not in any way be considered as target values for the setting of national sustainability goals. The recycling ratios specified for the sensitivity studies are indicated in table 1. In the material flow model these ratios were applied to the varying intensities of construction and the derived material flows.

Table 1: Ratios of recycled materials (RC ratios) determined for the sensitivity studies [3, p. 96]

	RC ratios (in %) for products in the building industry		
Material and product	2010	2030	2050
Concrete	0.4	6.0	12.0
Brick	0.0	10.0	15.0
Calcium silicate brick	0.0	5.0	5.0
Porous concrete	0.0	2.0	5.0
Other minerals /fill material	6.0	21.0	21.0
Plasterboard	0.0	30.0	50.0
Other plaster products	0.0	0.0	5.0
Timber	0.0	0.0	0.0
Plywood panels	4.0	10.0	20.0
Plate glass	15.0	25.0	35.0
Mineral-based heat insulating materials, approx 40 % rock wool RC ratios 0, 15, 20	27.0	42.0	56.0
Oil-based heat insulating materials	10.0	19.0	19.0
Plastic doors/windows	13.0	25.0	50.0
Other plastics /PVC flooring/carpets	1.0	5.0	10.0
Metals (only supplementary data, not part of investigation)	50.0	60.0	70.0
Other	0.0	2.0	5.0

2.4 Sensitivity studies

Material masses/flows for the years 2030 and 2050 were examined in four sensitivity studies, entitled BAU, SU, BAU-RC and SU-RC [3]. The same initial data on the building sector formed the basis for all studies. Table 2 describes the differences between the studies.

Table 2: Sensitivity studies – description [based on 3, p.93-94]

Sensitivity study	Description
BAU	Business As Usual: Current RC ratios remain unchanged up to 2050. Building stocks reflect the assumptions on construction activity for 2030/2050.
SU	Sustainability: Current RC ratios remained unchanged up to 2050. Construction activities changes as follows: Ratio of timber construction in residential housing rises from 15 % to 30 % for one- and two-family houses, and from 2 % to 15 % for multi-family houses. A 10 % reduction in material mass is achieved in concrete elements by new concrete mixes and forms of reinforcement. Triple glazing becomes standard in many non-residential buildings. The mass of insulating material increases by 30 % from the current level. Only half as many one- and two-family houses are built as indicated for "BAU", yet this is compensated by more housing units in multi-family houses.
BAU-RC	The RC ratios viewed as optimistic by experts are achieved by 2050 for "BAU".
SU-RC	The RC ratios viewed as optimistic by experts are achieved by 2050 for "SU".

3 Results

3.1 Construction activity and material flows – Germany 2010

3.1.1 Construction activity

In 2010 Germany's stock of residential housing was approx. 18 million buildings with a total floor space of approx. 3.6 billion m² [5]. In the same year around 84,000 new residential buildings were built, providing an extra 16.2 m² floor space, while around 6,313 residential buildings were demolished, reducing the total residential floor space by around 2.1 m² million. Taking account of the age of the various building types as indicated in official statistics, it is possible to assign the material masses from demolished buildings to the various building types.

No official statistics are available for Germany's stock of non-residential buildings. Based on recent research findings, the usable floor space of the non-residential building stock is estimated at 3 billion m^2. This total area can be broken down according to the various types of non-residential building as recognized by official statistics. This distribution of floor space reflects the average ratios between the types of non-residential building by considering the floor space (in m²) of newly constructed buildings. Thus in 2010 a total of 26,990 non-residential buildings were erected, providing a total usable floor space of 25.5 million m² [13, 14]. In the same year around 9,000 non-residential buildings were demolished, reducing usable floor space by 6.5 million m².

3.1.2 Material flows

The total material mass in Germany's building stock in 2010 can be estimated at 15.3 billion tons. Around 85 % of this was in the form of mineral-based materials such as concrete, brick, calcium silicate brick, porous concrete and other materials (screed, grout, sand, gravel, grit and crushed stone). Around 121 m tons of material flowed into the building stock in 2010 (input) while there was an outflow of around 42 m tons (output) (see table 3). These figures, which are largely determined by the general building activities (new construction and demolition), show that the stock takes on 7.9 ‰ (input) and losses 2.8 ‰ (output) related to the total material mass in the stock of buildings. In theory the output represents waste material for recycling.

3.2 Developments in the building sector and material flows – Germany in 2030 and 2050

3.2.1 Future building activity

Future developments in the housing sector are closely linked to the number of households and the demand for housing. In contrast, the development of the non-residential building stock is largely determined by demographic trends. For the current study, assumptions on population and the number of households were derived from 10 to 12 coordinated population forecasts [15].

In regard to the housing sector, we estimated that 7 million new housing units would be built by 2050. Over the same period, it was assumed that approx. 7.3 million units would disappear from the stock by 2050 [16]. Using these figures and taking account of the expected fall in the population, it can be estimated that *per capita* floor space in Germany will increase by around 11 % from 2010 to 2050.

The non-residential sector we draw on the hypothesis that demographic trends influence the stock of non-residential buildings [16]. Population-based parameters were devised by considering data from previous years (*per capita* usable floor space for new and demolished buildings in m²). These parameters, together with forecasts on population for 2030 and 2050, can be used to calculate values for useable floor space for new and demolished buildings for these two years. The estimated trend is for *per capita* usable floor space to rise by a maximum of 30 % from 2010 to 2050.

3.2.2 Material flows and recycling potentials

The input material flow for new buildings, extensions and renovation work will scarcely change in the period up to 2030: the figure is approx. 121 m tons for 2010 and 2030. In contrast, the material output flow due to deconstruction work – in particular partial or complete demolition – will increase from 42 m tons in 2010 to 64 m tons in 2030, a jump of 52 %. A clear break in this trend is expected by the year 2040 at the latest due to the continually falling population. The material mass for new construction in the year 2050 is expected to be 55 m tons lower than in 2010, i.e. a drop of 45 %. At the same time the mass of material issuing from deconstruction work will increase by 62 m tons, i.e. a jump of 150 %. Compared to the figure for 2010, the total mass of material flows (input and output) will be 13 % higher in 2030 and 4 % higher in 2050 (Tab. 3, BAU and /BAU-RC).

Estimates for the mass of recycled materials used for new construction and renovation work is based on the described material flows. The estimate of approx. 8 m tons recycled materials for 2010 (based on the current RC ratio) is only approx. 7 % of the corresponding figure of 121 m tons of primary material. If the framework conditions for the recycling of waste materials improve (cf. assumptions in Tab. 1) then the use of recycled materials could peak in 2030 at a mass of 19 to 20 m tons. Thereafter the mass will decrease to a level of about 12 to 14 m tons by the year 2050 (Tab. 3).

Table 3: Input and output material flows as well as recycling ratios in m tons for the years 2010, 2030 und 2050 – comparison of sensitivity studies [based on 3, p. 100 and 101]

	Material flows and recycling ratios in m tons								
	2010			2030			2050		
Sensitivity study	Input	Output	RC in input	Input	Output	RC in input	Input	Output	RC in input
BAU	121	42	8	120	64	8	66	104	5
BAU-RC	121	42	8	120	64	20	66	104	14
SU	121	42	8	113	64	8	60	104	4
SU-RC	121	42	8	113	64	19	60	104	12

The drop in the absolute mass of recycled materials can be attributed to a falling rate of new constructions, reflecting demographic trends. A contracting population means lower demand for new buildings both in the residential and non-residential sector. This serves to lower material flows for new construction and thus the absolute mass of recycled materials. Hence the mass of recycled materials will drop by some 30 to 35 % in the period 2030 to 2050 even though the proportion of recycled materials (based on the investigated 16 material types or products) will increase from approx. 16 % in 2030 to approx. 21 % in 2050 (Fig. 2).

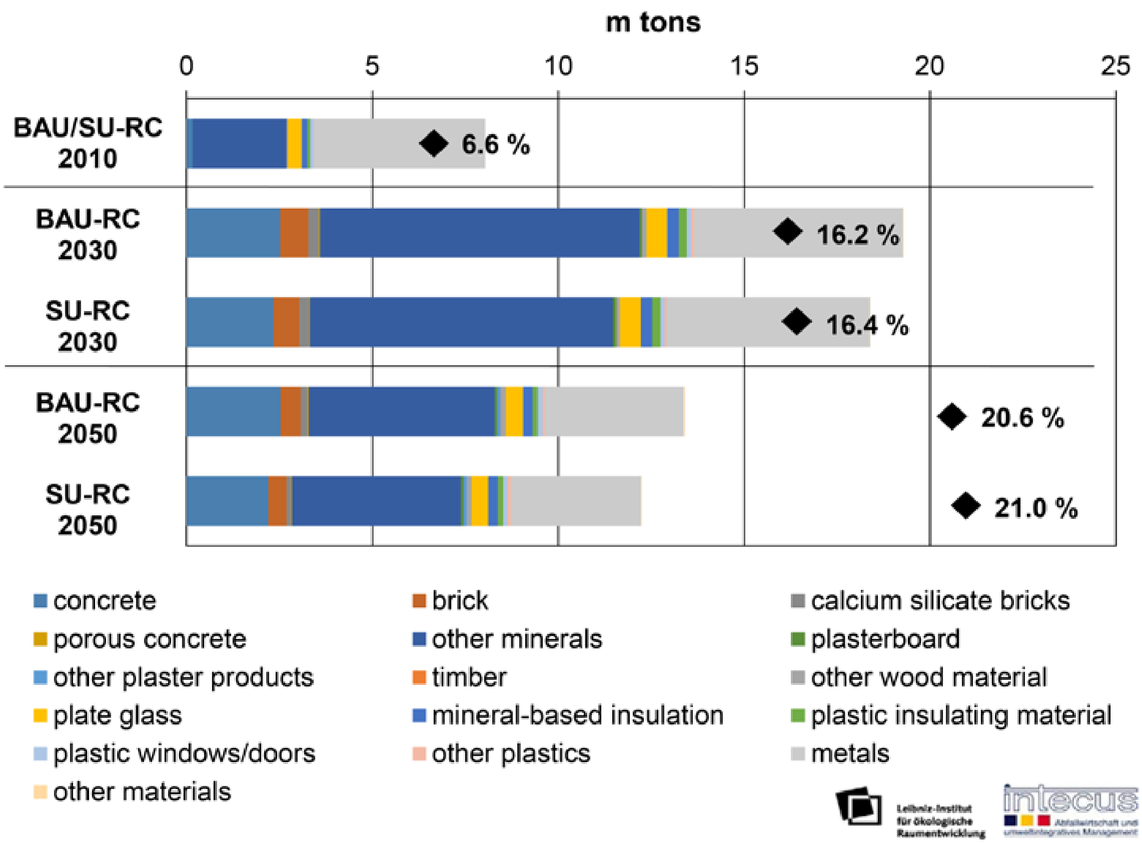

Fig. 2: Mass of recycled materials in m tons and average recycling ratios – comparison of sensitivity studies [3, p. 98]

Alongside metals and concrete, the third major type of recycled material is other mineral-based materials. Here the greatest potential to increase recycling ratios is to use such materials as fill. These can be sand, gravel and crushed stone for the blinding layer and foundation slabs, to construct access roads, car parks and patios on private land, as well as bedding for the laying of utility pipelines and to fill other infrastructural trenches. The simplest and most effective way to increase the proportion of recycled mineral waste material is therefore to use this consistently as fill material for damp-proof courses, levelling sand and pipeline trenches as part of buildings.

4. Discussion

In the described research we have undertaken sensitivity studies to illustrate and describe developments in Germany's building stock and its impact on resource consumption (material flows for the years 2010, 2030 and 2050). It is estimated that the total mass of material flowing into and out of the building sector will rise from 163 m tons in 2010 to 183 m tons in 2030 before falling back to 170 m tons by 2050. But the ratio between input and output flows will also change during these periods: In 2010 input was almost three times output; in 2030 it will be only twice as large; by 2050 input will in fact be lower than output. One likely scenario is that the use of recycled materials will peak in 2030 at between 18 and 20 m tons, falling by 2050 (despite a higher recycling ratio) to around 12 to 14 m tons due to a contracting building sector. At the same time the average recycling ratios can be expected to rise from only 7 % in 2010 to 16 % in 2030 and 21 % in 2050.

Despite sufficient availability of recycled materials for a range of applications (as determined by norms on building material), contractors, project developers and manufacturers of building materials have so far been reluctant to fully exploit mineral-based recycling materials, for example in concrete or brick structures. Thus although construction norms and standards permits a wide variety of materials to be used as aggregate, almost the only form of processed building waste currently employed in Germany as aggregate for concrete structures is high-grade concrete rubble. Furthermore, this recycled material makes up only a small fraction of total aggregate. Hence the potential of using recycled rubble as aggregate remains only partially realized.

Actors in the building sector frequently underestimate the relevance of (private) infrastructural work such as the construction of access roads, patios, supporting walls and household connections to public utility networks, for the recycling of materials. Yet the simplest way to increase the proportion of recycled materials in the building sector would be to consistently replace the fill materials required by builders for damp-proof courses, for levelling sand under floor panels, for infrastructural trenches, for parking spaces and garages as well as for pipeline bedding by recycled materials.

5. Conclusion

One important goal in the field of environmental policy is to conserve our natural resources. Material recycling in the building sector can play an important role in achieving this goal by substituting large volumes of primary raw materials with recycled materials.

Unfortunately, the revealed potentials are still not fully exploited in practice. There are multilayered, complex reasons for this deficit: A lack of practical solutions to increase the circular flow of materials, strict regulations on the range of substitute materials, high quality standards applying to recycled materials, etc. In general, it is vital to promote the recycling of materials within the building sector and to undermine resistance to recycled materials and products. At the same time more high quality data needs to be gathered on building waste. Material recycling can be boosted if the building sector and related infrastructural activities are always seen as forming a single complex system of material flows. Recycled materials should always be preferred when relevant standards permit their use, regardless of whether these materials originate from the building sector or from infrastructural activities.

If more recycled materials are to be used in both the building sector and in related infrastructural work, then a competitive market will arise for these products. The availability of recycled materials depends both on the volume of building waste and the distances between demolition sites and sites undergoing development. Regional cost-benefit models must therefore be drawn up for mineral materials in order to take account of the transport distances between dynamic regions and those undergoing contraction. However, transport distances and related costs are largely irrelevant in the case of metals and other high value recycled materials, so that the use of such materials does not require cost-benefit analysis.

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