Resources, Conservation and Recycling 123 (2017) 143–152

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

Full length article

# Quantification of future availabilities of recovered wood from Austrian residential buildings

Jasmin Kalcher, Gabriel Praxmarer, Alfred Teischinger*

*Institute of Wood Technology and Renewable Materials, University of Natural Resources and Life Sciences, Vienna (BOKU), Austria*

ARTICLE INFO

*Article history:*
Received 3 March 2016
Received in revised form 1 September 2016
Accepted 1 September 2016
Available online 20 September 2016

*Keywords:*
Recovered wood
Secondary resources
Demolition waste
Material flow analysis
Building stock
Timber construction

ABSTRACT

In recent years, recovered wood that arises from the demolition of buildings has become a demanded raw material for the production of particleboards and energy. Similarly, several statistics and studies have demonstrated that timber was an important building material during the so-called "Wilhelminian time" and that its use has been increasing since the 1980s. We therefore assume that a considerable volume of timber is contained in the Austrian building stock that serves as a potential raw material. A central question that needs to be addressed in this context is what volumes of timber can be expected to arise from the demolition of residential buildings in the coming years. To answer this question, a generic dynamic material flow analysis model presented by Müller, (2005) is adapted to data available on the Austrian building stock and the timber contained. With the help of this model, different scenarios on the development of the timber contained in the Austrian building stock and its input and output flows are developed and presented for the years 2012–2100. The standard scenario shows that (1) the volume of timber stored in the building stock will increase steadily from approx. 32 M $m^3$ to approx. 50 M $m^3$, and (2) the input of timber follows a wavelike behaviour within the frame of approx. 550,000 to approx. 750,000 $m^3$/a. Furthermore, (3) the output of timber will increase slightly during the first two thirds of the period considered and indicates a steeper increase for the remaining period, subsequently rising from approx. 350,000 $m^3$ to approx. 650,000 $m^3$ in 2100.



## 1. Introduction

The material requirements of the building construction industry are of great importance. In the city of Vienna, over 10 t/capita of construction material are used in the building construction annually (Merl, 2005) and the total material stock in building construction and infrastructure amounts to about 400t/capita (Kleemann et al., 2015). Among the building materials, timber is one of the most important construction materials. Historical data on the use of timber in the construction industry show high regional disparities on the one hand, and on the other hand differences over the time. The reason for those differences might be architectural preferences, technological developments of building materials, and the economic availability of the respective building material. As can be seen from Fig. 1, timber was by far the most important construction material until brick/stone and iron/steel gained in importance from the beginning of the 19th century. In the following century, the share of timber in building construction declined gradually, but remained constant during the first half of the 20th century. Afterwards timber again lost in importance until its use as a building material finally started to increase again in the 1980s. The most important construction material of the 20th century was reinforced concrete that could substitute brick/stone, as well as iron/steel and timber.

Recent studies on the development of the timber construction in Austria (Stingl et al., 2011) show that the demand for timber and for timber-based products in the construction sector increased steadily over the past years. In combination with technological developments such as glue laminated timber and building regulations that permit the construction of multi-storey timber constructions, a further increase of timber constructions can be expected in the future.

As the building stock, with both its mineral and organic components, is one of the most important human-made reservoirs for secondary resources (Höglmeier, 2015), there has also been a great deal of interest in the reuse and/or the recycling of construction materials and components. Based on different laws and regulations, rules for the handling of construction waste have been established. In the case of timber, major factors that influenced its recycling rate were the ban of the landfilling of organic materials (§7 Deponieverordnung 2008), a separate collection at the construction

* Corresponding author.
*E-mail address:* alfred.teischinger@boku.ac.at (A. Teischinger).

http://dx.doi.org/10.1016/j.resconrec.2016.09.001
0921-3449/

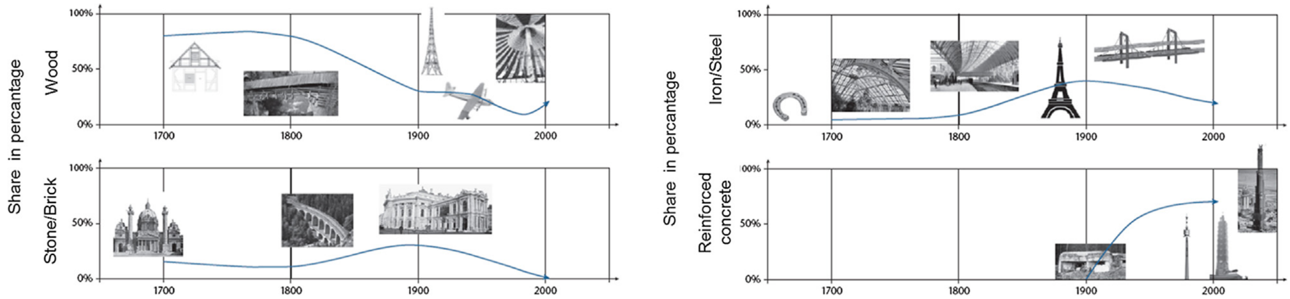


**Fig. 1.** Comparison between the market shares of different building materials for load-bearing applications in building construction since 1700 (Winter, 1994, slightly changed and edited).

site once a defined volume of timber is reached (§1 Baurestmassen-trennV 1991) and quality requirements for the use of recovered wood in the particleboard industry (RecyclingholzV 2012). Timber that arises from the demolition of Austrian buildings is particularly in demand for the production of particleboards and for energy generation (Merl et al., 2007). However, it would also be possible to reuse recovered wood of appropriate condition in the construction sector.

Due to the assumption that a considerable volume of timber is embodied in the Austrian building stock, in combination with the increasing demand for the resource "recovered wood", it is interesting to evaluate the current availability of recovered wood from the demolition of buildings as well as the volume of timber that can be expected in the future.

Therefore, it is the aim of this project to quantify the current and future volume of the timber stock in residential buildings and its input and output flows for the period from 2011 until 2100. In order to achieve this aim, a model is developed that aims to provide information concerning the following questions:

(1) What quantities of timber are embodied in the current and future Austrian building stock?
(2) What volumes of timber can be expected to arise from the demolition of buildings in the period considered?
(3) What are the main factors that influence the volume of timber arising from the demolition of buildings?

In the following section, we will define the types and sources of timber that are considered in the model presented. The paper then moves on to give a precise description what methods, raw data, calculations, and assumptions were used to generate the required initial data and to model different future scenarios. Detailed results for a standard scenario as well as input and output flows for a variety of further scenarios are presented and interpreted in Section 4. Finally, the conclusion provides a critical assessment of the used data and methods, offers some recommendations for future research.

## 2. System boundary definition

It is important at the outset to be explicit about what types and sources of timber are considered in the model presented. Due to the data availability and for reasons of simplicity and transparency, the timber stock and its flows that are illustrated in our model consider only timber of the shell construction of Austrian residential buildings. The output part of the model considers only timber that arises from the demolition of such structures (demolition of whole buildings or parts of the building), whereas the input part considers only timber that is used during the construction of a building for which a building permit is needed. Consequently, the following assortments are excluded:

(1) Timber that is used in non-residential buildings and in underground engineering
(2) Timber that is used for renovation, reconstruction and modernization measures
(3) Timber that is used for finishes (windows, doors, stairs, floors, etc.)
(4) Formwork, packaging, and waste from wood processing on the construction site

However, the model is designed in a way that allows the addition of the assortments listed above. All data presented refer to Austria, but the general approach of the model can be adapted to the data available in other regions. Fig. 2 graphically illustrates the timber stocks in the Austrian construction sector and its input and output flows.

## 3. Material and methods

Müller, (2005) presents a generic dynamic material flow analysis model that can be applied for the forecast of resource demand and waste generation of anthropogenic material stocks. They assume correlations between population growth, new construction and demolition, and use population, service stock per capita (lifestyle), lifetime distribution and material intensity per service unit as external functions.

When their approach is adapted to the data available on the Austrian building stock, the stock dynamics model shown in Fig. 3 is obtained. The figure shows that the volume of stocks (rectangles) depends on different variables (hexagons). The volume of the future building stock, represented by the gross cubic content (GCC),[1] depends on the future population and on the assumed average living space that is available for every inhabitant (GCC/capita). The volume of the future timber stock depends on the past and future timber intensity in addition. To consider differences between the stocks of different years, input and output flows are illustrated (circle). The output flows (demolition) are obtained by considering the average lifetime of the buildings. As for the timber in use, the input flow of timber considers timber intensity of the new buildings.

In the following, a more precise description is given which raw data, calculations, and assumptions were used to generate the required initial data and to model different future scenarios. Table 1 summarizes the data sources and their derivations described below.

[1] See OENORM B 1800 for precise definition.
[2] Calculated by dividing GFA of new buildings (Statistic Austria 2015) by NFA of new buildings (Statistic Austria 2013).