# THE ROLE OF CONSTRUCTION MATERIALS IN A SUSTAINABLY BUILT ENVIRONMENT

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## Summary

Sustainable construction is one of the 6 lead markets identified by the European Commission. The new CPR (Construction Products Regulation) expands the requirements for construction works and products by the new basic requirement 7 „sustainable use of natural resources“ significantly. Investors and project developer request progressively for certified green or even blue buildings. CEN/TC 350 has developed a suite of standards for sustainable construction, inter alia a framework for the assessment of the integrated performance of buildings as well as a standard for EPDs (environmental product declarations).

These actual developments and the changing boundary conditions within the construction sector ask the question for the significance of construction materials for sustainability assessment of construction works and their interface to the structural design. It doesn’t make sense to optimize construction materials like concrete or steel without considering the opportunities of the structural design. The paper reports about recent research activities, illustrates strenghtes and weaknesses of different materials and highlights strategies how construction materials can find their (new) position in the context of sustainable construction.

**Keywords:** sustainability assessment, building certification, construction products, construction products regulation

## 1 Introduction

The term sustainable development appeared for the first time in the publication of the United Nation’s Brundtland Report in 1987 and five years later in the Rio Declaration [1, 2]. Since 2006 it has been an immaterial element of the European Union, too. The building sector plays a particularly important role in the context of sustainable development, as confirmed by some figures given below:

- 10% share in the gross domestic product [3]
- 7% share in jobs [4]
- 40% of energy consumption (buildings) [5]
- 50% of all waste produced including excavation material [6].

While the Brundtland Report was limited to the economic and social dimensions, the definition of sustainable development was extended in the aftermath of the Earth Summit in Rio de Janeiro in 1992 to include the environmental dimension as well, which today can be regarded as a consensus and is referred to as the Three-pillar Model (ecologic, economic and social aspects). This holistic approach, in particular considering the entire life cycle of a building, is something that the construction sector cannot abstain from either.

This development has been encouraged by the European Commission for years by creating the appropriate framework conditions in the form of directives, regulations and strategies, which are geared to accelerate the market for sustainable construction and creative competition.

## 2 Framework conditions for sustainable building

Examples for changes in framework conditions related to the building sector are, inter alia:

- the Waste Framework Directives (2008) [7]
- the Energy Performance of Buildings Directives with “Nero Zero Energy Buildings” later than 2021 (2010) [8]
- the Construction Products Regulation with a New Basic Requirement 7 (2011and 2013, respectively) [9]
- the Thematics Strategy for Urban Environment (2006) [10]
- Resource Efficient Europe – Flagship Initiative under the Europe 2020 Strategy (2011) [11]
- the Roadmap to a Resource Efficient Europe (2011) [12]
- the Lead Market Initiative “Sustainable Construction” (2007) [13]
- Action Plan “Sustainable Construction” [13]
- the Strategy for the Sustainable Competiveness of Construction Sector and Enterprises (2012) [14]
- Suite of European Standards for Sustainable Constructions developed by CEN/TC 350 “Sustainability of Construction Works” [15].

Key objectives from today’s vantage point are a considerable reduction of energy consumption in the operation of buildings, a lower consumption of material resources as well as undertaking every effort to maximize the portion of building materials that is being recycled. Accordingly, an annual refurbishment rate of 2 % should be achieved in the existing building stock and a recycling quota of 70 % for non-hazardous construction and demolition waste by 2020 [12]. Based on mandate M 350 of the European Commission to CEN, a number of European standards have been developed by CEN/TC 350, which define, inter alia, a harmonized procedure for the assessment of the three dimensions of sustainability of construction works (EN 15643-1 to 4), as well as a European standard for the disclosure of environmental impacts through Environmental Product Declarations as defined in EN 15804. Furthermore, calculation rules (EN 15978) have been developed, rules on how to deal with generic LCA data (EN 15941) as well as standardized communication formats (currently EN 15942) [15].

While adherence to the rules and regulations set out in CEN/TC 350 is voluntary, several of them nevertheless overlap with the regulated domain of the Construction Products’ Regulations: The (new) Basic Requirement 7 specifies the following [9]:

*The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and ensure the following:*

*a) recyclability of the construction works, their materials and parts after demolition;*
*b) durability of the construction works;*
*c) use of environmentally compatible raw and secondary materials in the construction works.*

Overlap exists in particular as regards recyclability and durability throughout the entire service life as well as regarding the use of eco-friendly resources; the use of secondary building materials falls under the criterion of recyclability.

When reviewing the demands made on building products and construction works, one cannot fail to notice that requirements have increased considerably, and particularly so during the last two decades. Whereas 2000 years ago at the time of the Roman Empire it was sufficient to meet three requirements (beauty, firmness and convenience), we are nowadays confronted with much higher requirement profiles, as shown in Tab. 1.

While policy guidelines in Austria focused on energy conservation and climate protection in recent years, more and more emphasis has been placed lately on how we deal with material resources and on the recyclability of building products and construction works. This is exemplified, for instance, by the National Action Plan – Efficiency of Resources – published at the beginning of 2012 as well as by the growing recycling rate in the construction sector and the increased use of recycled building materials [16].

***Tab. 1*** *Increasing requirements for construction products*

| **Requirements** | |
|---|---|
| structurals safety | Vitruv (30 b. Chr.) |
| beauty | |
| fitness for use | |
| health protection | Construction Products Directive (1987) |
| fire protection | |
| noise protection | |
| thermal insulation | |
| resource saving | Construction Products Regulation (as of 2013) |
| recyclability | |
| durability | |
| environmental soundness | |
| secondary raw materials | |
| reparability | Green Buildings (as of 2000) |
| exchange capacity | |
| emissions | |
| economic soundness | Blue Buildings (since 2010) |

## 3 Sustainable buildings as a target

Sustainable Construction is a concept that defies concrete measurements and thus objective judgment. What cannot be measured cannot be controlled. Therefore there has been no lack of attempts to render the extent to which this concept of sustainability in construction works has been implemented measurable. The consequence is that meanwhile there are so many building certifications systems world-wide that it is hardly possible to keep track of them anymore. Examples of the most widely spread systems in Europe include, e.g., BREEAM, which is the oldest one, LEED, which is the most frequently used, as well as DGNB (in Germany) and ÖGNI (in Austria). All certification systems, particularly those of the second generation, are based on the three-pillar model, take into account the entire life cycle and differ in complexity, depth, weighting and the efforts that need to be invested. Frequently, a distinction is made depending on the usage of the building (e.g. administration buildings, educational facilities, industrial and commercial buildings) and different weightings and priorities are defined. In this context, the assessment of existing buildings intended for general refurbishment plays a crucial role.

A necessary prerequisite for ensuring high energy efficiency in the operation of buildings is to optimize the envelopes of buildings as well as their technical equipment, which requires an integral planning approach and which must be standard when designing sustainable buildings. In many cases, clients and architects place their chief emphasis on the choice of building products thereby focusing on issues such as energy content and production-related emissions ($CED_{nr}$ – cumulated energy demand non renewable, GWP – global warming potential, etc.). The structures associated with these building materials or building products are often neglected. Figure 1 shows the 10 most weighted criteria as specified in the DGNB/ÖGNI certification system for the usage profile “new office and administration buildings” and how these are weighted. As can be seen, it is in particular criteria with a high weighting that are influenced both by the choice of the building material and the structural design, with the latter having a major impact on recyclability, which is determined by the extent to which it can be dismantled, separated and reused. In the future, industry will increasingly be forced to bear this in mind, which will also require thinking in terms of building systems rather than in terms of building products.

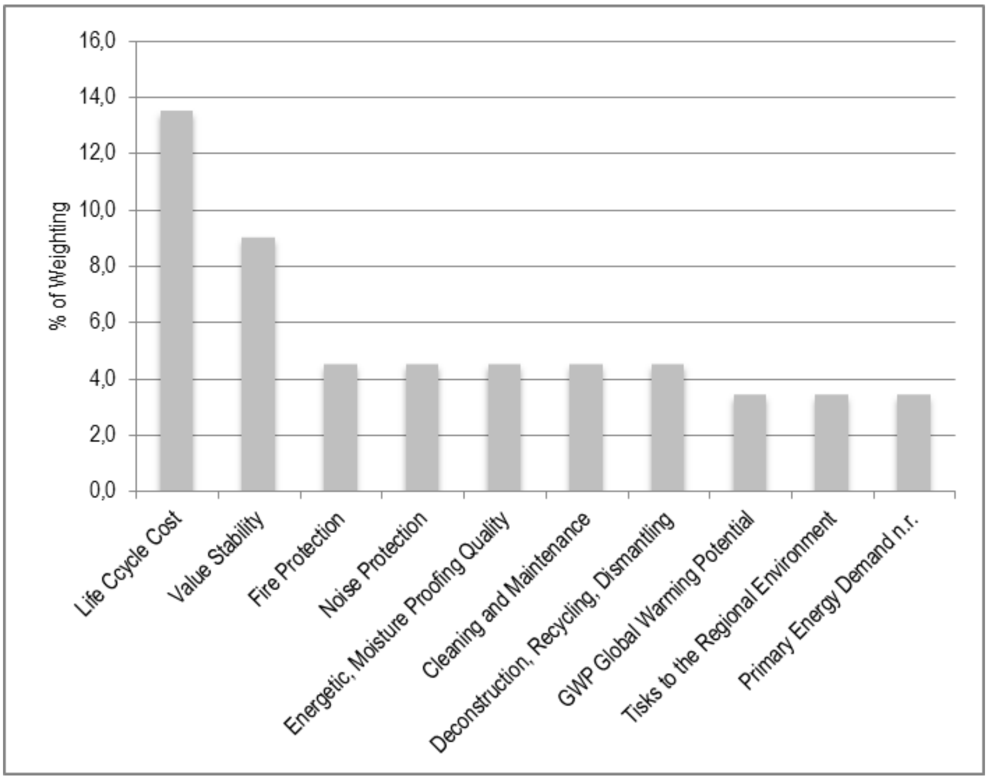


***Fig. 1*** *Assessment criteria and weighting acc. to DGNB/ÖGNI (outline)*

## 4 Current research activities at Graz University of Technology

In the context of “*Multifunctional Plug & Play Façade*”, a research project which was co--funded by the Austrian Research Promotion Agency (FFG), a façade system which contains numerous building service components, has a modular structure and can easily be adapted to future changing technological developments as well as to special wishes as regards surface design was developed. Another requirement was that the system be designed in such a way that the efforts and costs of dismantling and separating the individual building products be kept as low as possible. This should ensure maximum recyclability of the entire façade. In terms of material-related assessment, separation into one-type materials, which is possible in particular if curtain wall facades are mounted metallic load-bearing structures (steel, aluminum), yields high revenues so that, considering life cycle costs, higher production costs are acceptable. To demonstrate the savings potential, the efforts of assembling and dismantling were analyzed in terms of cost and time (final report to be published 2013).

The primary objective of another research project, which was supported by “Building of tomorrow”, was to determine the potential of reducing the consumption of primary energy and of lowering $CO_2$ emissions by refurbishing the existing building stock in Austria to meet the “plus energy standard”. Based on preliminary third-party analyses it was established that neither $CO_2$-neutral buildings nor a “plus energy standard” are achievable, not even in case of extensive refurbishment to meet plus energy standards. This would require further savings in areas such as lighting and electrical equipment as well as a higher efficiency of existing PV installations and the increased use of renewable sources of energy. Nevertheless, there is a considerable savings potential as far as greenhouse gas emissions are concerned, by about 19 % even in the worst case scenario and by 39 % in the best case scenario versus the status quo, as shown in Figure 2 ($CO_2$ equivalents). However, the studies were not limited to the level of energy, but included the service life and the recyclability of building products and structures as well. The resulting recommendations were published in a Refurbishment Guide. Figure 3 illustrates the considerable benefits that can be achieved even when just looking at the volume of waste if the ability to dismantle and separate are taken into consideration when choosing the refurbishment system (façade system for thermal rehabilitation) and the respective structural design [17].

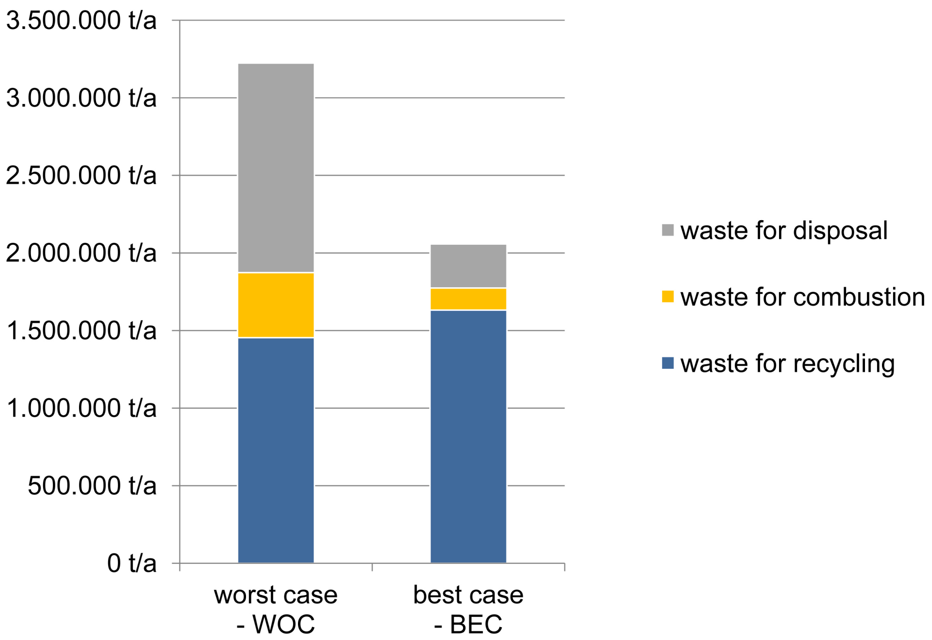


***Fig. 2*** *Annual Waste amount for two scenarios in t/a*

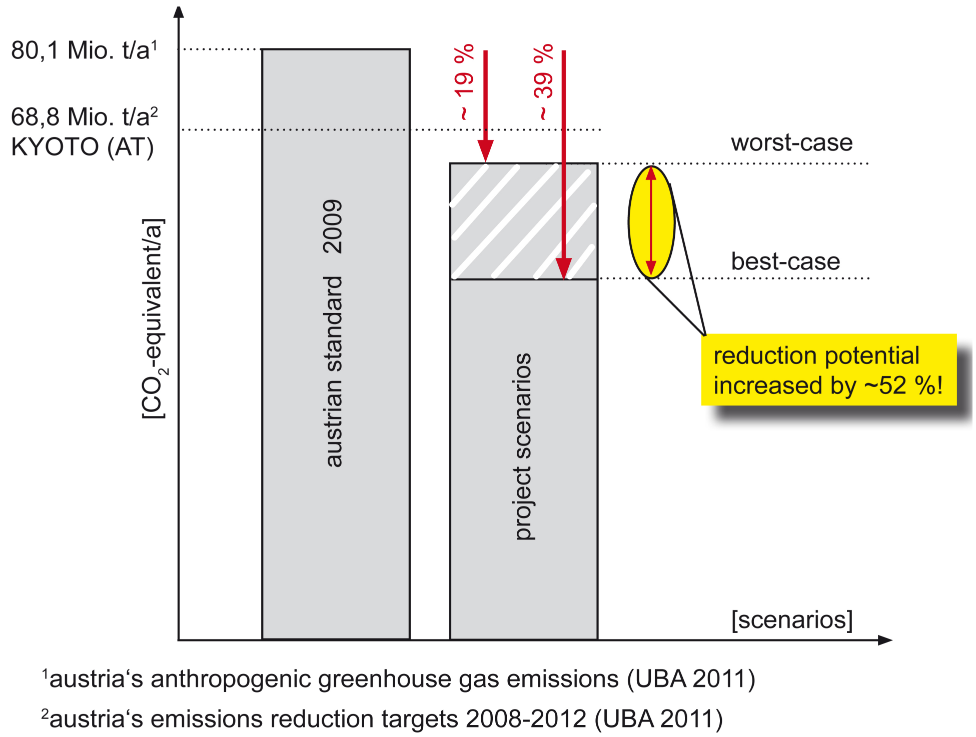


***Fig. 3*** *Potential of carbon dioxide reduction*

In a third project commissioned by the Austrian stone and ceramic industry, the strengths and weaknesses of solid building products (concrete products and bricks) were analyzed in the context of sustainable construction. It is true that solid building materials compare rather unfavorably in a life cycle assessment partly due to their high bulk density, their cumulated energy demand and their greenhouse gas emissions during manufacture (incineration processes) and due to process-related $CO_2$ emissions in the case of cement and limestone. However, assuming a long service life (> 50 years) and given their robustness against unplanned impact and given, in most cases, the relative ease of rehabilitation after the impact of fire and water, this drawback is usually at least compensated for. In future, the building systems which will succeed in the competition among bidders will be those that combine low consumption of resources, low emissions and low production and maintenance costs (life cycle costs) with long-term functionality, durability/robustness and recyclability [18].

# 5 Outlook

Sustainable building will considerably change competition among construction products. A comprehensive and holistic assessment is only possible at the level of individual buildings, especially if intended for comparison. It makes little sense to exhaust construction products by virtue of single properties (ecological or functional ones) as building products are merely one partial aspect in a comprehensive certification of a building. What is crucial, apart from a sound project development with defined targets (type of use, useful life), is that planning be interdisciplinary/integral and optimized for functionality, environmental impacts and life cycle costs throughout the entire planning stage. Regardless of whether the building is being certified upon completion or not, advanced building certification systems are able to point out strategies for optimization if these are incorporated into and accompany planning from an early stage on. At any rate, in the future much more emphasis will have to placed on constructive design, in particular of the building envelope, the joining technique and the recyclability of the chosen structure than in the past. However, if investors and clients expect a fully optimized building, they must also be willing to allow their planners sufficient time.

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