ON THE SUSTAINABILITY ASSESSMENT OF BUILDING MATERIALS AND COMPONENTS

ZUR NACHHALTIGKEITSBEWERTUNG VON BAUSTOFFEN UND BAUTEILEN

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SUMMARY

As a basis for any scientifically sound sustainability assessment, the concept of sustainability must first be clarified. This must be considered in a special way with regard to the assessment of individual products. Two essential aspects of the necessary clarification are presented and discussed below. Two examples from the field of building materials are used to illustrate some of the problems that could potentially arise. It is made clear that a sustainability assessment of building materials and components is not possible without explicit reference to the specific purpose of use as well as to the technological and social framework. The limitations outlined should be taken into account when interpreting assessment results that document compliance with sustainability objectives.

ZUSAMMENFASSUNG

Als Grundlage einer jeden wissenschaftlichen fundierten Nachhaltigkeitsbewertung muss zunächst der Begriff der Nachhaltigkeit geklärt sein. Dies muss in Bezug auf die Bewertung einzelner Produkte in besonderer Weise beachtet werden. Zwei wesentliche Aspekte der notwendigen Begriffsklärung werden im Folgenden dargestellt und diskutiert. Anhand zweier Beispiele aus dem Bereich der Baustoffe werden einige hierdurch potentiell entstehende Probleme aufgezeigt. Es wird deutlich gemacht, dass eine Nachhaltigkeitsbewertung von Baustoffen und Bauteilen ohne ausdrücklichen Bezug sowohl zum spezifischen Einsatzzweck als auch zum technologischen und sozialen Rahmen, in dem die Produktverwendung stattfindet, nicht sachgerecht möglich ist. Die aufgezeigten Einschränkungen sollten bei der Interpretation von Bewertungsergebnissen, die die Einhaltung von Nachhaltigkeitszielen dokumentieren, beachtet werden.

1. INTRODUCTION

The final report of the World Commission on Environment and Development (WCED) "Our Common Future" [1] in 1987 established the global political basis for coordinated efforts by the nations of the world with regard to environmental problems that had already been recognized and those that were still to come. In this context, the term "sustainable development" was placed at the center of attention. The fact that this term has since been abbreviated or replaced by the simple word "sustainability" is the cause of much confusion. A necessary consequence of the political demand for "sustainable development" was and is the provision of suitable and scientifically sound evaluation procedures that can be used as instruments for selecting optimal or at least harmless options when making environmentally relevant decisions between different technological solutions.

This article deals specifically with technological decisions that have to be made with regard to building materials and components used in the construction of buildings or that play a central role in the development of new building methods. In the second section, the term "sustainable development" is defined in such a way that it can be appropriately related to the issue under consideration here. In this context, the term "functional unit", which is considered in the third section, plays a central role. Any consideration of sustainability must be embedded in the context of technological development. This necessity is examined in the fourth section. In the fifth section, the theoretical considerations of the previous sections are being applied exemplarily to two cases involving cement as a binder in concrete. The concluding sixth section summarizes what has been said.

2. SUSTAINABLE DEVELOPMENT

If the term "sustainability" is directly assigned to a technical object, this may be an incorrect use of the term. In any case, such a use of the term does not always correspond to the intention of the report cited at the beginning. In principle, it is not things that have the quality of sustainability, but rather "developments", i.e. procedural events that can be honored in this way. In principle, no meaningful statement can be made about the supposed sustainability of technical objects that are not integrated into such an event. As an example, consider the question of whether a motor vehicle of a certain type A is sustainable or not. The statement

a) "Type A vehicles are (particularly) sustainable."

seems meaningless from this point of view, since at first glance a reference to a procedural event is completely lacking. The sentence

b) "The use of type A vehicles to carry out business tasks requiring the covering of distances within Europe of more than 70 000 km per year is the best possible option in the context of sustainable development compared to all other currently available options."

establishes a corresponding context and is thus meaningful. Now it could be assumed that a) is a connotative abbreviation of a statement of type b) and can thus be classified as meaningful. However, this must be clearly contradicted! This becomes clear when we look at a sentence that ranks between a) and b) in terms of its propositional content:

c) "Type A vehicles prove to be more 'sustainable' compared to other options in all usage situations (i.e. in particular regardless of geographical environment and annual mileage)".

In fact, c) is just as pointless as a). If the mileage is only sufficiently low or even zero, the vehicle is a kind of museum or collector's item and a meaningful discussion of sustainable development in which the vehicle plays a role becomes impossible. Sentence b), on the other hand, contains two important concretizations of the claim under consideration:

1) A specific purpose is assigned to the product under consideration.

2) The product under consideration is assigned to a place of use and the respective current point in time and thus to a technological-historical general situation.

Both constraints have to be considered in any sustainability claim, i.e. any claim of the kind considered here is relative in two ways: it has to be formulated in relation to available technological alternatives and relative to development over time. Constraint 1) leads directly to the notion of "functional unit", which will be considered in the next section, and 2) points to the need to consider technological evolution and its potentials, which will be addressed in the third section. Before this, however, the problem under consideration should be made clear once again on the basis of sustainability statements that can be assigned to the building sector. For this purpose, three sentences are considered:

a*) "Wood is a sustainable building material".

b*) "The use of wood is the best possible option in the sustainable development of housing provision, provided it is in the form of (relatively small) single-family houses, compared to all other options currently available in Europe".

c*) "Buildings made of wood are 'sustainable' in all use situations (i.e. in particular regardless of location, size and use) compared to other options".

The assessment of the meaningfulness of the assertions a*) to c*) corresponds exactly to the assessment of the propositions a) to c) given above. Nothing is said here about the truth of the statements under consideration so far.

3. FUNCTIONAL AND DECLARATIVE UNITS

It has already been made clear above that, within the framework of a proper sustainability assessment, a specific application or use of the products under consideration must be assumed to be known and given. Especially in the context of LCA, which is an integral part of any sustainability assessment, this should be ensured by referring to appropriate "functional units". In practice, determining a suitable functional unit can prove extremely difficult, especially in the case of precursors that can be used in a variety of different applications. In such cases, the standard specifications therefore allow the use of a so-called "declarative unit". However, this gives rise to a fundamental problem. Results determined on such a basis represent at best intermediate results or initial data of a sustainability assessment, but cannot be evaluated as independent sustainability data.

In is common practice to generate LCA data sets that do not refer to a specific manufacturing site, but rather by averaging over an entire industry within a geographical area. When determining such "generic data sets", it is implicitly assumed that the entirety of the production processes included in the averaging process exclusively produce functionally or at least declaratively equivalent products. This assumption of equivalence is at least problematic if, in justified individual cases, deviations are made to more specific data sets, for example in order to be able to take into account existing favorable peculiarities. It should be borne in mind here that the generic data sets are related to the entire industry, from which individual production sites cannot be separated without contradiction, insofar as results that are determined with the specific source data are ultimately compared with those that are based on generic data. If this is done, an overall picture emerges that is ultimately systematically too optimistic.

4. TECHNOLOGICAL PROGRESS

The particular difficulties that have to be addressed in the course of the prognostic assessment of the expected impact of innovative products have already been considered elsewhere [2].

One of the main difficulties of international political efforts to achieve sustainable development is that the level of technological development already achieved differs considerably between the various nations. Particularly in the case of intercontinental trade in goods, these differences mean that the conditions set out above for appropriate assessments can hardly be met. The use and the corresponding evaluation of one and the same product within application scenarios, which are located in technologically differently developed economic areas, can under certain circumstances lead to completely different and even contradictory evaluation results. A product changes its ecological profile, so to speak, in the course of trade. The formal side of this problem is usually related to the fact that suitable allocation factors for co-products cannot be determined appropriately without reference to an economic framework situation. Since such allocation factors have a considerable influence on the balance sheet results, the quality of the information they provide may be severely impaired or completely worthless.

5. SUSTAINABILITY ASSESSMENT OF CEMENT AND CONCRETE

Cement is a practically indispensable raw material for concrete production, and large amounts of CO_2 are emitted during its production. The emission of CO_2 per tonne of cement in the different active production sites in Germany varies with a very wide range, as exemplified in Fig. 1. Because of this wide variation, it is common and also quite sensible to take into account the ecological burdens caused by the production of the cement in the form of the generic data described above within the framework of the sustainability assessment of concrete buildings. However, this approach no longer seems suitable if, in the course of a concrete construction project, cement is used that is known to be ecologically more favourable relative to the generic mean value. In this case, there is a well-founded interest in taking the favourable ecological data into account instead of the generic data in the course of the overall balancing of the project. If this is done, however, on the one hand the comparability of project balances is impaired and on the other hand the assessment of an overall situation in which numerous construction projects are taken into account becomes difficult or - as already indicated above - too optimistic (see also [3]).

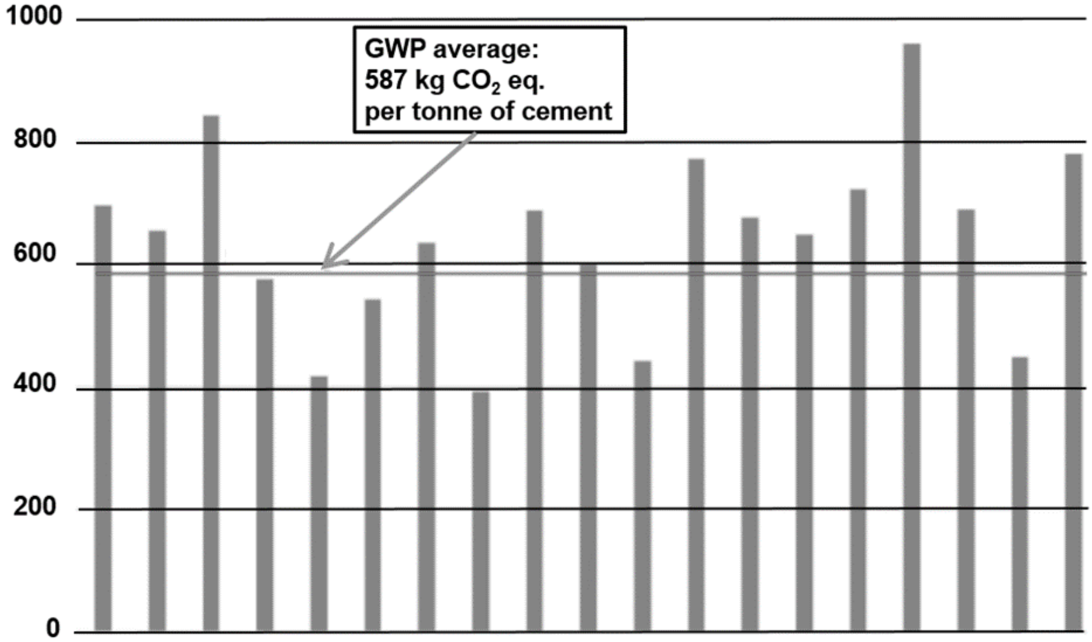

Fig. 1: Exemplary values for the global warming potential (GWP) per tonne of cement for 19 different (anonymized) production sites in Germany compared to a generic mean value. (The figure is an edited excerpt from a corresponding more extensive presentation in [4]).

The mean value shown in Fig. 1 can be taken from the relevant generic EPD [5]. The entirety of the ecological data from this document is shown in Table 1.

Table 1: Life cycle assessment (LCA) results for cement according to [5] per tonne

Parameter	**Unit**	**A1-A3** [1)]
Global warming potential	[kg CO_2-Eq.]	587.0
Depletion potential of the stratospheric ozone layer	[kg CFC11-Eq.]	2.03E-7
Acidification potential of land and water	[kg SO_2-Eq.]	0.75
Eutrophication potential	[kg $(PO_4)^{3-}$-Eq.]	0.19
Formation potential of tropospheric ozone photochemical oxidants	[kg ethene-Eq.]	0.12
Abiotic depletion potential for non-fossil resources	[kg Sb-Eq.]	4.16E-3
Abiotic depletion potential for fossil resources	[MJ]	1830.0

1) acc. to DIN EN 15978

As a building material, concrete as a whole is in comparative contest with other technological solutions, whereby at the same time different functionally equivalent concrete types are in competition with each other. Potentials for improving the position in these competitions exist in the following points, among others:

- Use of alternative heating agents in cement production
- Replacement of CO_2-intensive Portland cement with substitute materials

- Optimization of mixing processes in concrete production
- Reduction of delivery distances

Among the cement substitutes used are by-products from the generation of electricity in coal-fired power plants, namely hard coal fly ash and ground boiler sand (see [6]). The further use of such residues, especially in concrete technology, is rightly regarded as ecologically beneficial. However, this does not mean that these by-products can in themselves be awarded the attribute of sustainability, as is the case in [7]. The LCA data listed in [7], which show a value of zero for all impact categories "since coal-fired power plants primarily produce electricity or heat" and thus "allocate the expenses and emissions of power plant operation to energy production" are also misleading. Such a radical allocation is not justified. This line of reasoning obscures the fact that coal fly ash and boiler sand are by-products of an economic system that is known to be unsustainable overall.

Table 2: LCA results for hard coal fly ash EFA-Füller® S-B/F according to [8] per tonne

Parameter	**Unit**	**A1-A3** [1)]
Global warming potential	[kg CO_2-Eq.]	1.98E-01
Depletion potential of the stratospheric ozone layer	[kg CFC11-Eq.]	1.21E-13
Acidification potential of land and water	[kg SO_2-Eq.]	3.84E-04
Eutrophication potential	[kg $(PO_4)^{3-}$-Eq.]	6.50E-05
Formation potential of tropospheric ozone photochemical oxidants	[kg ethene-Eq.]	-1.36E-05
Abiotic depletion potential for non-fossil resources	[kg Sb-Eq.]	1.72E-09
Abiotic depletion potential for fossil resources	[MJ]	2.08E+00

[1)] acc. to DIN EN 15978

Table 2 compiles the LCA data for a specific hard coal fly ash product. It is particularly important to note that although this is a product that can be substituted for cement to a certain extent, it is by no means functionally equivalent to cement. A sustainability assessment at product level must therefore be rejected from the outset as inappropriate. The fact that the connection between this product and the operation of coal-fired power plants has no influence whatsoever on the life cycle assessment could be remedied to some extent by introducing an additional impact category. It is conceivable to declare the consumption of by-products as a special resource consumption with accumulation of the CO_2 emissions of the respective main product process.

6. CONCLUSION AND OUTLOOK

The sustainability assessment of a specific technical product requires the embedding of the product in an environment in which functionally equivalent products are available and in the overall technical-historical context. Both points lead to considerable difficulties in the evaluation of building materials, for which there is a wide variety of uses and which are subject to rapid changes in circumstances. The particular problem of allocating the environmental impacts of by-products makes the introduction of an additional new impact category, through which the consumption of resources that originate from production processes that are unsustainable overall, could at least be documented.

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