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Extending the scope of Material Flow Cost Accounting – methodical refinements and use case

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ABSTRACT

Material Flow Cost Accounting (MFCA) is an instrument with a considerable potential for gaining transparency of material (and energy) flows and corresponding costs and, thereby, supporting the systematic striving for a higher degree of resource efficiency. However, a use case from the aluminum industry reveals some restrictions of MFCA due to its focus on material, the input-orientation, and the short-term orientation. Thus, this paper suggests extending the scope of Material Flow Cost Accounting by methodical refinements concerning the modeling of energy flows, divergent flow system outputs, especially revenues, and long-term monetary effects caused by investments. For demonstrating these methodical refinements of Material Flow Cost Accounting, the aforementioned use case is taken up.

1. Introduction

Since material and energy costs as a whole often represent the largest share of total production cost, industrial companies strive for an increased material and energy efficiency. To support this, Material Flow Cost Accounting (MFCA) has been developed. According to ISO 14051 – which summarizes the state-of-the-art of the MFCA methodology –, the approach is intended to improve transparency of material flows and energy consumption for supporting decisions and enhancing material- and energy-related coordination and communication within organizations (ISO, 2011). Published case studies of the Japanese Ministry of Economy, Trade, and Industry (METI, 2010) demonstrate the empirical application of MFCA and a considerable potential for accomplishing the aforementioned aims. However, some issues for the further development of the methodology of MFCA were indicated by a use case in a company which anodizes aluminum parts: (i) MFCA should be enhanced regarding the modeling and evaluation of energy flows – in the anodizing process energy is a very important resource. (ii) The scope of MFCA should be extended by including revenues and (other) monetary effects of differing outputs – in the use case alternative configurations of the process chain result in differing amounts and types of output. (iii) A further extension refers to the evaluation horizon and the coupling of MFCA with approaches of dynamic investment appraisal – some of the alternative process chain configurations imply investments in new equipment for manufacturing and/or energy conversion. The paper takes a brief exposure of the underlying methodology of MFCA (Section 2), a short presentation of the use case, and an outline of the methodical challenges (Section 3) as initial points. Subsequently, suggestions for the methodical enhancement of MFCA with respect to the three mentioned issues are presented; each, firstly, in a generic way and, afterward, referring to the use case (Sections 4–6). Conclusions are drawn in Section 7.

2. Underlying methodology of MFCA

MFCA is a specialized accounting method aiming at the identification and monetary valuation of inefficiencies in material and energy use. The main idea of the approach is to treat undesired outputs (all types of losses, e.g., clippings, used lubricants, and waste heat) like desired outputs (semi-finished and finished products) regarding cost assignment. Particularly, the quantification of the economic effects of the ‘production of losses’ shall motivate managers and engineers to rethink production processes and to reduce the overall material and energy input by increasing productions' efficiency. Here, the underlying motivation is an

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economic for the most part, but the reduction of resource use and of unintended emissions serves environmental objectives, too. In this regard, it has to be noted that MFCA is commonly recognized as an approach of environmental management accounting (for other approaches of environmental management accounting and their application see, e.g., Burritt and Saka, 2006; Passarini et al., 2013; Schaltegger et al., 2013). In particular by identifying potential fields for improving the economic *and* the environmental performance of the flow system, it can be a powerful tool for the implementation of cleaner production (ISO, 2011; Nakajima, 2011; Schaltegger et al., 2008).

The original concept of MFCA bases on the work of the German 'Institut für Management und Umwelt' (institute for management and environment) in the late 1990's which initialized few pilot projects in the German industry (imu and ZWW, 2003). However, MFCA's breakthrough had been reached in Japan. Due to the great success of first implementations in the year 2000, MFCA was strongly promoted thereafter and more than 300 Japanese companies adopted the method by now (METI, 2010; Nakajima, 2010; Schmidt, 2012; for the original concept see, e.g., imu and ZWW, 2003; Jasch, 2009; Strobel and Redmann, 2002). In parallel, MFCA's methodology was refined (METI, 2007); the final version of the corresponding ISO standard 14051 documents the current status. The following brief description of MFCA largely refers to this standard.

MFCA consists of three main steps of flow modeling: flow structure modeling, quantification of flows, and evaluation (cost appraisals of the quantified flows) (Sygulla et al., 2011).[1] *Flow structure modeling* includes the specification of system boundaries and a time period and the determination of quantity centers and flows. Quantity centers play a major role in flow modeling. They can either be interpreted as spatial or functional units which store, process, or otherwise transform materials or, simplifying, as processes like receiving, machining, assembling, packing, and storing (ISO, 2011; Strobel and Redmann, 2002). The flows are defined as the regular movements of materials[2] between the quantity centers within the defined period. In the step of flow structure modeling, material flows are (only) determined regarding the material(s) they include, the quantity centers that are their source and sink, and their basic character, desired or undesired. The result of the initial step of MFCA is a so called flow structure model describing the analyzed system by quantity centers, the desired and undesired flows, and the system boundaries.

In the second step, the *quantification of flows*, for every quantity center all material in- and outputs (flows) as well as possible (changes in) stocks are quantified for the underlying time period. To ensure consistency, for every quantity center an input–output balance – considering also changes in stock – is created. This, in turn, calls for the use of appropriate physical units. Here, MFCA literature suggests the use of mass units or at least of units transferable in those of mass, like length or number of pieces (ISO, 2011; Strobel and Redmann, 2002).[3] The results of the second step are added to the flow structure model which, therewith, is enhanced to a flow quantity model.[4]

Within the third step of MFCA, the *cost appraisal*, the flow system is valued in monetary units. Here, ISO 14051 differentiates the following cost categories:

- *Material costs* are costs of each "substance that enters and/or leaves a quantity centre" (ISO, 2011, p. 15). They are determined by multiplying a fix material price with the flow and stock quantities and represent the only direct costs of MFCA. Due to their character of direct costs, they can be traced (directly assigned) to the flows and stocks.
- *Energy costs* are "costs of electricity, fuels, steam, heat, compressed air and other like media" (ISO, 2011, p. 13). Energy costs should be calculated for each quantity center on the basis of the measured or estimated energy use. For allocation (indirect assignment) to the outgoing desired and undesired material flows, the use of their mass ratio is proposed. Alternatively, for the case that the physical amount of energy loss is known, ISO (2011, annex B) suggests assigning the energy loss-related costs (which are calculated on base of the share of energy loss) to the outgoing undesired material flows and the rest of the energy costs to the desired material flows.
- *Waste management costs* are costs "of handling material losses generated in a quantity centre" (ISO, 2011, p. 17) and refer to activities like reworking of rejected products and recycling, tracking, storing, treating, or disposing air emissions, waste water, and solid wastes. They are allocated to material losses only. If several undesired material flows leave a quantity center, their mass ratio is used as allocation base.
- Finally, *system costs* represent all costs of handling in-house material flows except for material, energy, and waste management costs. For example, this includes depreciation and costs of labor and maintenance. System costs are accounted at the level of quantity centers and, again, allocated to the outgoing material flows on basis of their mass ratio.

By adding all cost information to the flow quantity model, a flow cost model is created which can be complemented by a more compact representation, the so called flow cost matrix (for examples see, e.g., ISO, 2011; Sygulla et al., 2014).

The results of MFCA enhance transparency regarding the efficiency of material (and partly also of energy) use and form a basis for the improvement of single processes as well as of entire process chains, including the comparison of alternative process (chain) configurations. However, the results' significance is restricted due to some so far unsettled or not conclusively answered methodical questions. Firstly, this includes the question whether MFCA should be designed as full or as marginal costing (with marginal costs as costs varying with flow quantities) – raising further questions of cost determination.[5] Secondly, MFCA's methodology of cost assignment refers to aggregated cost categories. Especially system and waste management costs may include a lot of single cost items which depend on the outgoing material and/or energy flows in different ways. So, a more detailed analysis on the level of single cost items would improve the cost assignment (Sygulla et al., 2011). Thirdly, MFCA is conceptualized as an actual cost accounting system. For enhancing the decision-support, the extension towards a standard cost accounting system seems to be useful (Sygulla et al.,

[1] These steps represent the core methodology of MFCA. Beyond that, ISO (2011) includes these steps in a Plan-Do-Check-Act-Cycle for managing implementation and continuous use.

[2] The naming *Material* Flow Cost Accounting already indicates the straight focus on material. Energy flows are usually neglected and energy use is only regarded as costs on the quantity center level (see, e. g., the numerical examples of ISO, 2011; METI, 2010, 2007; Viere et al., 2011). For a criticism of this treatment of energy see Section 4.

[3] MFCA is designed for the assessment of common industrial processes. So, the mass of materials can be perceived as constant. Physical effects like pair annihilation or the mass defect are either not relevant or the effects are negligible.

[4] Flow quantity models are also a result of the approaches of 'physical environmental management accounting' (see Burritt and Saka, 2006).

[5] For a distinction between direct/marginal costs as well as indirect/full costs see Drury (2012).