EnviroInfo 2002 (Wien)
Environmental Communication in the Information Society - Proceedings of the 16th Conference
 ISBN: 3-9500036-7-3

Computer Aided Resource Efficiency Accounting: Assessing and Communicating Environmental Impacts and Costs along the Supply Chain

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1 New Business Strategies and its Environmental Impacts

In recent years traditional economics and business were radically changed and accelerated. New methods of conducting business such as 'e-commerce' and 'e-procurement' are leading to a change in structures from traditional commerce towards new business strategies using Information and Communication Technology (ICT), especially in the field of business-to-business (B2B) and business-to-consumer (B2C) relations.

In economical terms the acceleration and globalisation of sale and procurement have manifold positive effects such as competing markets and prices. Cheap and fast transportation allow rapid changes in supplying structures and cut backs in storage capacities at the expense of just-in-time delivery.

Seen from the environmental perspective, the effects of these new business strategies are difficult to assess. First results from case studies show that potential effects lead back to traditional environmental issues such as packaging and transport (see e.g. Matthews/ Hendrickson 2001) but with stronger and worldwide impacts.

Especially transportation contributes to various environmental impacts such as emissions, energy use and consumption of land surface. Only a few of the effects such as higher traffic rates cause immediate and direct local impacts, whereas other effects are indirect and difficult to quantify.

To combine financial with environmental reliability requires solid environmental data and information on a company's production and its supply chains. While the financial assessment of a production and its suppliers can be achieved via various methods of price calculation, the assessment of the environmental performance is

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more difficult because of the sensibility of the data itself. Often data on environmental impacts of a product or a production contains information on product or process specific knowledge and is therefore considered as trade secret.

2 The Project CARE: Objectives and Approach

The research project 'CARE- Computer Aided Resource Efficiency Accounting for Medium-Sized Enterprises'[3] consists of a scientific core-project and three case studies performed with the companies TOSHIBA Europe GmbH (computer assembly), Nolte Möbel (furniture) and Muckenhaupt & Nusselt GmbH & Co. KG (cable).

Objective of the project CARE is to develop an economical and environmental information system for managing and decision-making in companies. The approach uses the method 'Resource Efficiency Accounting' (REA) that combines cost accounting with environmental impact data on production processes and the product life cycle.

2.1 Methodological Background

The approach 'Resource Efficiency Accounting (REA)' was developed by the Wuppertal Institute for Climate, Environment, Energy (see Orbach et al. 1998). Its aim is to give a company and its management new insights and aggregated information on economical and environmental effects for the assessment of a company and its supply chain. The REA can be applied on different levels (company, process and product level) within a company and along a products life cycle.

For environmental impact assessment, the REA uses MI (Material Intensity)-Values[4]. They were developed by the Wuppertal Institute and are available for many resources, materials and standardised transportation and production processes.

Figure 2.1 shows the use and combination of different data on costs, masses and environmental impacts combined in REA. The REA decision-making system bases on economical and environmental data covering different levels of the life cycle.

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3 The project CARE is publicly funded by the German Ministry for Education and Research. Scientific partners in the project are the IAT of the University of Stuttgart, the Wuppertal Institute for Climate, Environment, Energy and synergitec Freiburg. For further information also see the project's website http://www.care.oekoeffizienz.de

4 MI-values count the material intensity of a product, a material or a service measured in metric tonnes. Material intensity is counted as mass-equivalents caused by its production in the following media: water, air, abiotic material, biotic material and soil. MI-Values do not assess the toxicity of a material. They can be seen as indicator that gives consolidated and aggregated information on environmental impacts. For further information on the method and its use see publications by Schmidt-Bleek, F. at http://www.factor10-institute.org

One of the main objectives of the project CARE is to advance and test the REA and to support the implementation with software using existing data from the company. The authors of this paper are developing concepts and solutions to support the different levels of REA with data on costs, mass and energy flows and environmental impact data as named above.

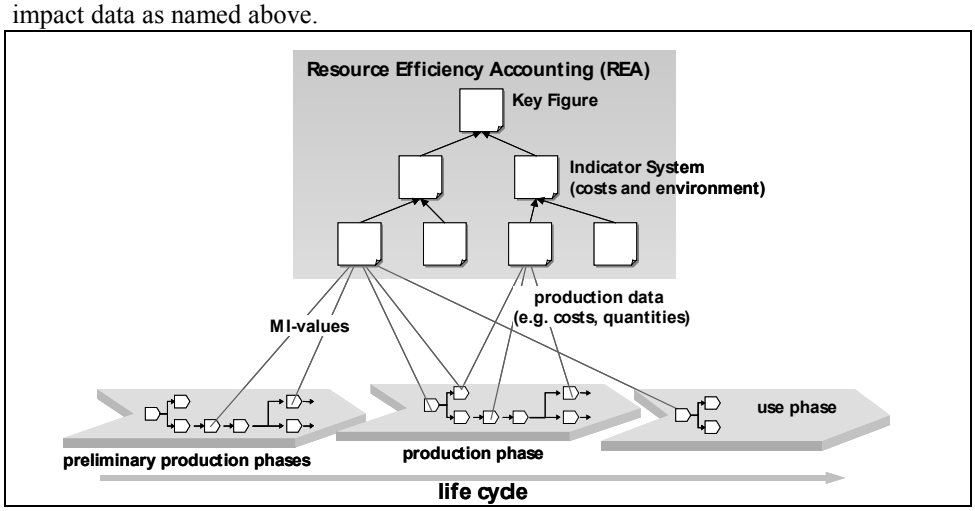

Fig. 2.1 The combination of material and environmental impact data in Resource Efficiency Accounting (REA)

2.2 Material Flow Analysis as the Basis for the REA

Material flows describe the conversion and dislocation of raw materials, operating supplies, semi finished goods or products and form the basis of corporate activity in most producing companies.

A material flow analysis focuses on the modelling, analysis, assessment and controlling of material and energy flows in a company and aims at identifying potentials for optimisation. It requires activity based and contemporary data on material input and output and can be applied on single processes, whole companies or production networks (see Bullinger/ Beucker 2000).

In addition to material and energy flows costs for materials, activities, etc. can be evaluated. Different cost accounting approaches such as Activity Based Costing (see Schaltegger/ Burrit 2000) or Flow Cost Accounting (see Strobel, 2001) can be supported by this method.

A material flow analysis is a sophisticated method to analyse a company's processes and its environmental and economical effects and therefore is uses as a basis

for the REA. At the most detailed level of REA, a company's processes are analysed with a material flow analysis. Costs and material consumption are determined for the processes and are allocated to specific products. This information is supplemented by MI-Values that include the environmental impacts from preliminary and downstream processes from the supply chain and the product life cycle.

2.3 Data Requirements of REA

Data needed for the application of REA are:

- *Structure of production processes:* The structure of the production processes including the connections among the individual processes can often be identified from work plans. Work plans often also contain information on personnel and machinery expenses and allocations to the work places.
- *Data on consumed material, substances and energy per process:* Such data can be found in bills of material, work plans/routings or in production orders.
- *Material consumption per process:* Product related material inputs and outputs of processes are often available in the bill of material. Other outputs such as waste often have to be recorded by measuring. Output of energy from a process is usually not measured but can be estimated if necessary.
- *Mass and cost allocation per process:* Precise mass and cost allocations per process and the outputs of each process have to be made. Especially mass allocations for outputs are often not available and then have to be assessed.
- *MI-Values:* MI-Values for all used materials and energy in the production and the life cycle have to be available for the environmental impact assessment. In the project CARE they were provided by the Wuppertal Institute.

Many of the mentioned data specified above can be found in a company's ERP System[5]. Hence, ERP Systems and its data a valuable information source for the support of REA application. Possibilities for the use ERP Systems and their data for REA will be discussed in the next chapter.

3 The Source for Required Data and the Role of Software to Measure and Assess the Environmental Performance of Companies and Products

A combined assessment of a producing company's financial and environmental performance starts with reliable data and information on the production. Data on material consumption on various levels of detail and material prices are needed for a

5 An ERP (Enterprise Resource Planning) System can be considered as a company's backbone information system containing data on materials, production planning, purchasing and sales, cost accounting, etc. A widely used ERP System is e.g. SAP/R3.

transparent classification of processes consuming material and producing waste. Within the classification and specification of such data, ERP- Systems play a significant role.

A survey conducted by Fraunhofer IAO in 2001 with ERP software companies from Germany, Switzerland and Austria evaluated the environmental functionalities of ERP Systems (see Rey et al. 2002). The conclusion of the survey was that ERP Systems can already be used for monitoring and controlling of waste, dangerous goods and material characteristics. Only a few of the systems can be used for the monitoring and controlling of material, energy and water consumption and can therefore be used for the identification of optimisation potentials.

Nevertheless, ERP Systems can serve as a valuable data source for applying the REA method inside of a company (see section 2.3). Data from there can be used to assemble a material flow analysis. They can be used to evaluate material losses, resource consumption in general and how waste was created and disposed of.

To conduct the REA method, data from ERP Systems can be used by Environmental Management Information Systems (EMIS) [6] for assessment via calculation and evaluation. For the purpose of performing the REA method, EMIS with a focus on material flow management or life cycle assessment can be used, since they have functionalities to conduct a material flow analysis (see Beucker et al. 2002).

Results calculated in a material flow analysis in an EMIS (e. g. performance indicators or graphical evaluations such as charts or Sankey diagrams) could then be displayed in the ERP System..

Data exchange between ERP Systems and EMIS is still a tedious process that often requires manual data transfer and/or costly adaptation of the software being used. A common data format standard for data exchange between ERP Systems and EMIS data format would simplify automatic data exchange between ERP Systems and EMIS. This would enhance the ability of ERP Systems and EMIS to interact.

Up to this day, such data format standard has not been defined yet. The IAT, University of Stuttgart and Fraunhofer IAO are currently working together with software developers to define a data format that could serve as a pre-standard for data exchange. This data format is to be published as a so-called Publicly Available Specification (PAS)[7].

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6 While the term Environmental Management Information System (EMIS) generally refers to organisational-technical systems for systematically obtaining, processing and making environmentally relevant information available in companies (Page, Rautenstrauch 2001), the project CARE defines EMIS as software systems that supports tasks of an Environmental Management System.

7 A publicly available specification (PAS) can be considered as a first step in a standardisation process. A PAS is a normative document representing the consensus within a working group but is not the result of an international agreement as ISO-standards are. For further information see http://www.iso.ch.

Automatic data transfer would have several advantages:

- Data access would not depend on communication or complicated workflows inside the company
- It would decrease data redundancy: the data already collected and stored in the ERP System could be used by the EMIS without additional expenses to regather the data in the EMIS. Results calculated in the EMIS could be displayed in the ERP System.
- Consistency checks between double storage of the same data in two different systems would not be necessary.

The PAS has to be seen in the broader context of the developments of standards for business data and environmental data. Recent developments in e-business show the attractiveness of XML (eXtensible Mark-up Language[8]) for software companies to standardise data when exchanging data such as product catalogues or sales transacation (see Schmitz et al. 2001, Kelkar et al. 2001 and Kelkar et al. 2002). Concerning the standardisation of environmental data, the current development can mostly be found in the research area. Researchers with the Ecoinvent project[9] are developing a common data format for life-cycle analysis data based on XML. The Environmental Mark-up Language (EML) initiative has started a discussion of the standardisation process for environmental data using XML, but so far focuses on corporate environmental reports and spatial environmental data[10].

As mentioned above a Publicly Available Specification (PAS) can be considered as a first step in a standardisation process. It is developed in a three-step process:

1. Business scenarios are collected that require inter-communication between ERP Systems and EMIS. Examples are:
   - The environmental responsible needing environmental data for an internal environment and safety report or to conduct an input-output analysis.
   - The controlling department wanting to know where costly material and energy losses were caused in order to improve the material use efficiency.
   - The cost centre responsible demanding the exact costs of materials used and disposed of in order to control his costs accordingly.
   - The public requesting yearly reports on how the company treats the environment, as put down in the external environmental report to be published once a year.
2. The business scenarios are then generalized. They will describe different applications for the data exchange between ERP Systems and EMIS.
3. Data to be transmitted will be described and a generic data format will be described using XML. Interface specifications will be described.

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8 Extensible Markup Language (XML) is a universal format for structured documents and data. For further information see e.g. http://www.w3.org/XML.

9 see Frischknecht 2001 or http://www.esu-services.ch/ecoinvent2000/

10 See http://www.xml-eml.de, hosted by the Humboldt University at Berlin among others.

Examples for data to be transmitted are:
- product mass, energy, costs,
- production structure, material flow diagrams, bills of material, routings, work plans, involved work centres,
- results calculated in the EMIS such as performance indicators, graphical evaluations (charts, Sankey diagrams, etc.)

The data structure can consist of the data structure (order of elements, tree hierarchy, etc.), allowed data types (like integer, string, float, etc.), the definition of units (kg, m, Euro, etc.), the description of system boundaries or reference bases or reference time periods. The interface specification can consist of a prescribed structure for connection protocols and a set of rules for exception handling.

The different issues and specifications are currently addressed in the PAS consortium and will be published.

4 Summary and Conclusions

The changes and the acceleration of economics and business driven by technological developments in e-business create financial benefits for many companies as well as environmental effects.

The project CARE is developing an information system for companies integrating financial accounting and environmental impact assessment. The methodological background is provided by the approach 'Resource Efficiency Accounting (REA) and MI (Material Intensity)-Values developed by the Wuppertal Institute for Climate, Environment, Energy. Concepts and solutions to support the different levels of REA with data on costs, mass and energy flows and environmental impact data are currently being developed.

The different levels of REA can be facilitated by the use of production data available in the ERP (Enterprise Resource Planning)- System of a company. Such data can be available in bills of material, work plans or in production orders. While ERP Systems can provide most of the data needed to perform the REA method, another group of software systems, so-called EMIS (Environmental Management Information Systems) can be used for the assessment of financial and environmental impacts using a material flow analysis.

The exchange of data between ERP-Systems and EMIS and their interpretation will be eased by the development of a PAS (Publicly Available Specification) that is currently under way. The PAS will define data types, a data format and interface specifications for the exchange between the named systems and will therefore enhance the combined assessment of a company's economical and environmental assessment. The integration and combination of financial and environmental data in companies and along their supply could be made possible by consistent data formats on the different levels of the production and the supply chain.

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