

IT Solutions for EPI Management

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Abstract Measuring an organization's impact on the environment with appropriate EPIs demands specific ICT solutions that support this task. At the same time, the realm of the upcoming, so called IT-for-Green approach, is to increase the environmental friendliness of companies and their processes by means of ICT. In this context, corporate environmental management information systems (CEMIS) have already become an indispensable tool in support of the environmental policies described in chapter "Environmental Performance". However, conventional CEMIS alone are not sufficient for achieving this objective, as they serve mainly for ensuring legal compliance with relevant environmental laws and regulations in order to avoid financial sanctions from authorities. In this sense, these systems are not compliant with the results from the sustainability debate and with the required strong operational focus. Traditional systems fulfill the requirements entailed by the concept of sustainable development only to a very limited degree. For this reason, existing ICT tools will be reviewed and the benefit OEPI can append.

1 Terms and Definitions

In order to provide a common understanding of IT solutions for EPI management, we will start with definitions of the used terms. On an abstract level, the task of environmental management is often addressed by the implementation of an environmental management system, which is in turn rather an organizational

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model. If software comes into play for supporting the task of environmental management, these tools are usually referred to as (corporate) environmental management information systems. Here, a distinction will be made between traditional tools and strategically oriented tools that are currently developed or rather scrutinized by research.

According to Rautenstrauch (1999), the term *environmental management* refers to the interaction of human societies and the environment, as well as to the environmental impact of human activities. As has been explained in more detail in chapter “[Environmental Performance](#)”, there are three main issues that affect environmental protection officers: politics (networking, legal restraints, public confidence, etc.), programs (projects, activities), and resources (money, facilities, raw materials, etc.). Environmental management can refer to the management of all environmental components. Anyway, an organization has to manage and organize its environmental programs in a comprehensive, systematic, planned and documented manner. This is usually done with the help of so called *environmental management systems* (EMS) as it has been explained in the previous Chapter. Such systems include: the organizational structure; the planning process and needed resources for developing the plan; the implementation, and finally the maintaining policy for sustainability and environmental protection. This process is not necessarily supported by the help of information systems, but usually follows certain implementation models.

According to older definitions (Rautenstrauch 1999; Page and Hilty 1995), a *corporate environmental management information system* (CEMIS) is regarded as an organizational and technical system that offers the possibility of systematically covering, analyzing, processing, appraising and archiving all environmentally relevant organizational information. These systems support a strategic as well as operative management by planning, control and transaction of an organization’s environment-related measures. CEMIS are often also simply referred to as EMIS, without qualifying them as corporately used software tools. Henceforth, the term CEMIS will be used for clarity, and for putting an emphasis on the corporate character.

2 Classification

Today’s CEMIS mainly fulfill the task of establishing legal compliance for companies or of implementing standards like ISO 14001. Such systems do not incorporate the sustainability concept, and therefore do not support any related strategic aims. Actually, they often support isolated operational aims. Currently, two groups of software systems for companies are available to handle these issues: compliance driven CEMIS that enable companies to comply with environmental regulations, and eco-efficiency driven CEMIS that enable companies to analyze their business activities, material flows and logistics activities with respect to environmental impact. Teuteberg and Straßenburg (2009) conducted a thorough literature

review on the topic of CEMIS. This report gives an overview of the current state of the art in CEMIS, ongoing and missing research activities in this field.

New concepts for CEMIS envision a strategic orientation for an integrative and holistic approach. Traditional CEMIS tend to be isolated, operation-oriented information systems (for example, they merely serve to ensure legal compliance based on key performance indicators (KPIs), disregarding the concept of sustainability). In contrast, *next generation CEMIS* should follow an integrated approach in line with the concept of strategic management. For example, by facilitating the company-wide assessment of KPIs, new CEMIS will contribute to an efficient sustainability management. In this spirit, future CEMIS are information systems that take a comprehensive approach involving material and energy efficiency, minimization of waste and emissions, disposal of waste, stakeholder support, compliance with legal requirements, and strategic environmental management.

As it has been seen above, the design and implementation of CEMIS may have a very polymorphic character. Hence, before reviewing some existing systems, they will be grouped into a classification. Some classifications of CEMIS are readily available in literature. The following one (Teuteberg and Straßenburg 2009) also takes into account new trends in research as well as missing features (see Fig. 1). Therefore, it will be taken as a starting point for the further discussion of CEMIS.

Criterion		Value							
Environment & Organisation	strategy	precautionary				maintenance			
	business objective	EMAS/ISO certification	environmental optimization/eco-efficiency			compliance with environmental legislation		presentation of environmental performance	
	time frame	long-term strategy			medium-term policy		short-term operation		
	function level	strategic function	controlling function			information function	communication function		commercial function
	addressees	company management	ecology department	production / material mangement	other departments	public authorities	insurances	investors	suppliers and customers
EMIS Specific Criteria	type	key performance indicator based systems	environmental accounting systems	sustainability reporting systems	input-oriented systems	process-oriented systems		output-oriented systems	
	database	material master data	structural data			process data	data on energy flows		organizational data
	environmental medium	soil	air			water	waste		
	object	material flows	waste	emission	energy	hazardous material	facilities		
	methods/ tools	active data warehouses	model development and simulation	environmental databases	knowledge-based systems	document management	artificial intelligence (e.g. neuro-fuzzy techniques)	meta-information	
	application area	procurement	environmentally friendly production	distribution/eco-logistics	recycling planning	waste management	life cycle assessment	reporting	
	integration level	stand-alone			add-on		integrated		
	system boundary	product			process		department	company	inter-corporate level

Fig. 1 Classification of CEMIS (Teuteberg and Straßenburg 2009)

CEMIS is an active topic within several ongoing and newly established research activities, because of the missing features in current systems, and the approaches to new architectures that will be explored at the end of this chapter. Hence, several surveys and overviews on CEMIS tools as well as current market analyses are available (Fig. 2).

A simplified categorization of corporate environmental management information systems (given in Teuteberg and Straßenburg 2009) is the following: *Reporting and information systems for external reporting* are systems for the fulfillment of different stakeholder's information needs. *Eco-controlling systems for internal operations* provide ecologically relevant information for decision makers and—by making effects of daily business operations transparent—they provide an ecological information stock for decision making. *Life cycle assessment systems* provide support for life cycle analyses. *Key performance indicator based systems* provide key ratios that enable companies to control and monitor business operations. Using EPIs, a monitoring with respect to ecological aspects becomes possible. Such CEMIS would not only be seen as monitoring tools for environmental damage, but also as a planning and controlling means with regard to environmental measures. The usage of *sustainability reporting systems* for an automated generation of sustainability reports should also be incorporated. Systems focusing merely on the input-side of a production process are called *input-oriented systems*. *Output-oriented systems* are focusing merely on the output-side of a production process (end-of-pipe). *Process-oriented systems* focus merely on the production process itself. *Production related CEMIS* are systems that help to realize eco-friendly production and disposal methods. Such systems may optimize the material and energy efficiency of processes. Minimization or (better) avoidance of unwanted and ecologically questionable output is a further goal of these systems that might, for example, be achieved by means of material and/or energy flow analyses, or waste management. Recycling or disassembly planning systems, production planning and control systems (PPS), or systems for ecological and disassembly-compatible construction are further examples of such systems.

The broad realm of environmental impacts and their possible causes, as well as the wide range of actions for counter-steering undesired developments, allow a classification along multiple dimensions. In order to break down the quite fine grained classification mentioned above to fit the OEPI scope, it has been mapped to six tool categories for further scrutinizing: sustainability reporting tools; tools related to distribution and (green) logistics; tools for waste management and recycling planning; tools supporting compliance and environmental management; tools for life cycle assessment, and material flow analysis tools.

		value									
organizational viewpoint	criterion	precautionary				environmental performance, ecobalance				maintenance	
	strategy	eco-efficiency		EMAS/ISO DIN certification		environmental performance, ecobalance		(environmental) compliance management			
	business objective	strategic/long-term				tactic/medium-term		operational/short-term			
	time frame	external				in-house					
system related viewpoint	addressee	the public	suppliers and customers	insurance	investors	public authority/ certifier	other departments	production/ material management department	environmental protection department	company management	
	system boundary	company-wide		affiliated group		company		product	process		
	environmental medium	energy	air		water		soil	waste			
	scope	ecobalance	life cycle assessment	distribution/ eco- logistics	procurement/ production	disassembling/ recycling		materials flow analysis	environmental reporting	Compliance Management	
	application	reporting and information system (external reporting)				eco-controlling system (in-house decision preparation)				production-related system	
	methods/tools	(active) data warehouses		soft computing		modeling and simulation		knowledge-based systems	environmental databases	document management	
	integration level	integrated				add-on		stand-alone			
maturity of realization											

Fig. 2 Maturity of CEMIS realization (Teuteberg and Freundlieb 2009)

3 Sustainability Reporting Tools

Several standards for creating sustainability reports have been evolved. The most prominent is the Global Reporting Initiative (GRI) Sustainability Reporting Framework. The EMAS includes much more than just a sustainability report. To follow the GRI Guidelines for creating reports is sufficient for what is demanded by EMAS. In this way, the GRI emerged as de facto standard, and provides a structure for creating a sustainability report. The content of such reports consists of several indicators, which are composed of common core indicators provided by the reporting organizations. Additionally, each report contains so-called sector supplements, which complement the report by sector-specific indicators (for example, overcoming the digital divide in the telecommunications sector).

Specialized tools are: SAP Sustainability Performance Management (SuPM), Enablon SD-CSR, SoFi and credit360, and STORM. All presented tools offer similar possibilities regarding their reporting capabilities. Data needs to be imported into the system by using different approaches like extended mark-up language (XML), CSV or Excel data. Most of the solutions provide specialized input methods using customized approaches like connecting to enterprise resource planning (ERP) systems. That integration is mostly assisted by the vendors' experts. Furthermore, they allow the creation of indicators and further pre- and post-processing. The gathered and processed data can then be grouped and organized as to have some kind of structure in them. The structures may be created by using one of the common reporting standards like GRI. The structured information is then used to create the final reports. The tools offer the possibility to create traditional printable reports, as well as web interfaces to access the data in real time. A standard for the exchange of indicators or reports does not exist. Some tools expect that all report data is mainly used inside the tool itself, and sometimes even do provide internal import, export or conversion functionality.

The tools mostly ship with interfaces for data input. Data input is mostly done by hand or by CSV and Excel files. These processes can be automated in some ways by common extract, transform and load processes. Further input interfaces can be added by extending the software which is in most cases possible by contacting the vendors. Most tools can be installed to the local IT-infrastructure, and then be integrated using customized interfaces. Especially the SAP solutions provide seamless integration to other SAP products in use. Credit360 uses a software-as-a-service approach for integration. The centralized approach ensures an always up-to-date and ubiquitous working environment, although the centralized storage of company-related data at a centralized place may be a disadvantage, with regard to system isolation, extensibility and data security.

The concept of real time reporting using a web interface is supported in all reviewed tools. That provides the different stakeholders with much more tailored information, and allows them to browse through the desired information in an easy way. Multiple user levels allow for fine-grained presentation and data levels. The

lack of standardized and publicly available interfaces for data input and output is a disadvantage that most tools have. The concept of a centralized system only works if the organizations using it have the possibility to integrate their own systems for data exchange. Innovative approaches, like the feedback of stakeholders and other Web 2.0 paradigms used in STORM, provide new possibilities for the creation and reception of sustainability reports.

Notwithstanding, listed drawbacks and sustainability reporting tools already provide added value to reporting by supporting the creation, as well as post- and pre-processing of indicators, as soon as data is imported into the system by experts. Data may be grouped, analyzed and structured for an easier integration into reports. In this way, the workflow of generating a report from raw data to type-setting the report may be much easier spread among several experts.

4 Tools Related to Distribution and (Green) Logistics

This category comprises all software for the support of operating warehouses, customs clearings, forwarding and backwarding logistics (as long as they do not belong to the class of waste management), dispatching of goods and other activities within the framework of product distribution. Logistics shows a high potential for optimization. In this context, eco-logistics used to be a frequent term (Macher 1991). Green logistics refers to the optimization effort within the logistics sector with a focus on sustainability. Examples of CEMIS application in the realm of the above mentioned activities are for example, an ICT based comparison of alternatives for travel avoidance and travel distance reduction, emission optimized route planning, higher vehicle capacity utilization rates, optimal packaging, reusable packaging and recycling through logistic measures or optimized intermodal freight transport (Teuteberg and Straßenburg 2009). Disposal logistics, which encompasses the collection, transport, reloading, storing and handling of waste and secondary raw materials, is treated separately in the waste management section.

Due to the large number of available tools within this software class, we restrict ourselves to selected examples with outstanding features or general descriptions of tool classes for warehouse management systems, sales information systems, in-house solutions and perishable logistics. Probably, the most promising opportunity for applying EPIs within the logistics sector is within the class of transport management systems, as transport causes the biggest impact within logistics. Software, in these classes, usually interacts directly with data from mobile devices like barcode scanners, printers or RFID-systems. Currently, it is hardly possible—but obviously wanted by freight forwarders—to include EPIs, e.g., carbon footprint of a specific, ordered transport into offers, and provide potential customers with transportation alternatives with different environmental impact. Though such software tools are designed to integrate with other transactional systems, the complexity of actually achieving this integration highly depends on the scenario at hand.

The benefit of today's logistics related ICT systems lies in the ability of easing the comparison of alternatives, for example, for optimizing transport via load consolidation. Hereby, the reduced shipments lead to a significant decrease in fuel consumption, and therefore in reduced costs.

Yet, the carbon footprint of e.g., a shipment can be answered within 0.5–1 business days, and a certain environmental commitment of the freight forwarder is necessary in order to achieve such times—if a certain level of accuracy for the result is desired. Nevertheless, this response time is already diminishing continuously, but the whole process is still not as automated as it could be when it comes to integrating the results in reporting.

5 Tools for Waste Management and Recycling Planning

Software for waste management is not a clearly-defined term, or rather class for software tools. Often, software that claims to be waste management software turns out to be merely specialized software for the waste disposal industry. As long as such specialization reduces to the integration of scales or similar, the respective software is not separately treated here. Today, recycling planning, as the second realm within this category, is usually done by means of adapted production planning and –control (or –scheduling) systems. Accordingly, these systems are sometimes referred to as disassembly planning and –control (or -scheduling). Due to many uncertainties that complicate the planning process in the case of recycling (or remanufacturing), recycling planning is still rather a research issue.

Tools are for example david.net, Silvanus 360, Envis recycle and Envis waste, Wizard and Waste Manager, or SAP Recycling Administration (REA). In Germany, support for electronic certification of waste disposal (German: elektronisches Abfallnachweisverfahren) is a commonly-found feature, which—in fact—belongs to the category of compliance management. Further, features related to waste or recycling activities concentrate on support for (national as well as EU) waste legislation requirements. In general, all these software tools offer support for standard business processes. Added value, qualifying them as waste management software, usually reduces to the extra functionality mentioned above. Seen in the light of environmental management, almost all these software tools are end-of-pipe solutions lacking support for waste avoidance. Assessment of environmental impact is mostly done with hindsight, and for statutory reporting. As far as dashboards are available, these are merely used for business performance, and not for environmental performance. All of these software tools are stand-alone solutions that come with all functions bundled or, as the case may be, split-up into different modules from which one may be chosen. Data exchange is mostly limited to data export to Excel data format.

Recycling planning is an important issue of the OEPI scope and for more sustainable products by integrating EPIs into the product design phase. The evaluation of a design alternative's impact on the environment will clearly have to

incorporate the recycling ability of the product. At present, there seems to be at least one product (Waste-Integrated Systems for Assessment of Recovery and Disposal, wizard) that allows the identification of opportunities to increase the eco-efficiency of a product's end-of-life management.

6 Tools for Compliance and Environmental Management

Due to the growing number of voluntary or mandatory environmental information that an organization has to manage, it is often necessary to implement specialized software that supports them in these tasks. Specifically, organizations need to keep track of indicators and information to fulfill national or international laws and regulations, or they need to manage them in order to keep environmental norms and certifications like the European EMAS or the several ISO 14000 standards. In the last year, many providers improved their environmental management systems in order to support users in compliance management.

The three example tools from this software category are: Intelix EMS, SAP EHS Management and SoFi. The presented tools are all part of larger software solutions as the data used in EMS has to be derived from various sources. The thing that they have in common is that they support the user in fulfilling several different statutory provisions. On one side, there are standards set by the European EMAS or by the ISO 14001 that concentrate on the level of a whole company. On the other hand, the tools can give support in reaching compliance on a production level (like REACH or RoHS). It is also notable that some of the solutions are focused more on the European market, and others on the American market, as the popularity of the standards in different regions are to be distinguished. Not only for European companies, it may, for example be desirable to have some kind of footprint accounting to support the regulations like REACH, RoHS, and Clean water/air acts, and other compliance issues that this software is dealing with.

As mentioned above, the tools are often integrated into a larger software architecture, which has to be used at the company level. Achieving certain compliance may be a challenging task—for example, if the used ERP system does not allow accessing information on the desired level. The exchange of indicators between different systems is in no way standardized, and always needs to be customized by the organizations. The holistic and integrated functionalities of EMS tools demonstrate how tight environmental information is coupled to the corresponding business processes and the software in use. The interfaces for importing environmental data into the management system need to be open, well documented and versatile.

7 Life Cycle Assessment and Design for Environment Tools

The ISO standards 14040 and 14044 on Life Cycle Assessment are the basis to assess the environmental impacts of the whole life cycle of a product. The environmental impacts are calculated by representing quantitatively all the inputs e.g., energy consumption, raw materials, hazardous and nonhazardous waste and assessing the environmental impacts of these flows. Life cycle assessment includes the whole life cycle of a product or service, from extraction of raw materials, manufacturing, transporting, assembling, use, maintenance and recycling.

Common LCA tools are SimaPro, Gabi, Umberto and KCL-Eco. All the tools have basically similar functionalities and entities: life cycle assessment as an overall process (with the basic functionalities Scope definition, data gathering, creating process map, generating LCI, LC impact analysis, simulations, etc.), life cycle costing, life cycle impact assessment, life cycle inventory, life cycle management, life cycle sustainability assessment, life cycle work environment, life cycle engineering, product stewardship, supply chain management and substance/material flow analysis. The tools have their own databases, libraries, and the possibility to use additional databases. Ecoinvent database from a competence group (ETH Zurich, EMPA, EPFL, PSI and ART) can be used with most of the tools described. Additionally, the tools use some other databases, especially databases with inventory data like the United Nations Greenhouse Gas Inventory Data. All tools have import and export format possibilities, like EcoSpold and Excel. These enable data transfer from one tool or database to another on a process level. Usability issues differ with the tools. Some tools enable direct reporting of results and visualization varies with different tools—but it is possible with all the tools described.

Different LCA databases offer useful data for EPI calculation, and would therefore be valuable to incorporate into OEPI. At the same time, classic engineering design tools, like for instance AutoCAD, in the meantime offer new functions to integrate EPIs into the design process via their Eco Materials Adviser in Autodesk Inventor. In this way, considerations regarding the environmental performance of new designs may be taken into account at a very early stage of design. The identification of so called environmental hotspots that will determine the overall impact of new products is an advantage.

8 Challenges for Future CEMIS

This section focusses on the missing features of IT solutions for EPI management from different perspectives. Teuteberg and Wittstruck (2010) give an overview of the state of the art in sustainable supply chain management (sSCM) research, and

an outlook on the research on missing features. They identified 32 still unsolved problems, among which, some of the most important are:

- What are the impacts of transport uncertainty on supply chain environmental performance?
- Real-time vehicle management: How could decision support methods be constructed?
- How can knowledge be used and presented in environmental management information systems?
- How can product design be integrated into sSCM?
- What are the effects of sSCM on organizational performance and vice versa?
- How do we measure sustainability and sustainable value added?

Teuteberg and Straßenburg (2009) developed the classification catalogue for CEMIS tools (see Fig. 1), and did an exhaustive survey on currently used CEMIS and their features. Junker et al. (2010) abet the discussion for a change in the CEMIS paradigm. They show as well that established CEMIS are indeed no longer state of the art in support for environmental management, and do not contribute to the integration of sustainability into business operations. Brunotte (2009) developed a criteria catalogue for a comparison of different CEMIS, and additionally provides a list of currently available CEMIS.

Figure 1 shows a classification given by Teuteberg and Straßenburg (2009) that distinguishes environmental management tools according to multiple discriminative criteria. Here, the complete morphological box in order to give an impression on the variety of possible classifications has been shown.

8.1 Situation from the Organizations' Point of View

From a business' point of view, a combination of software, the underlying infrastructure, and an appropriate integration into the business organization is necessary in order to provide proper decision support in sustainability questions and strategic environmental management. A business needs support for making an appropriate decision as to on which level of abstraction to work with, as well as for choosing the right standards and indicator sets. Tools for CEMIS must not focus merely on operative business: strategic questions (simulation, scenario analysis, potential analysis, sustainable product design, multi-criteria optimization, etc.) are to be supported. In future, CEMIS are supposed to enable mapping of an organization's internal structure and processes for a seamless integration of related environmental information. Integration into an organization's IT infrastructure is the key success factor for an integration of sustainability issues into the daily business operations. Non integrative single solutions currently prevent the omniscient availability of environmental information. Without a better integration, a means of management for calculated environmental indicators is also a missing feature in today's tools for environmental management. Many

business people and environmental protection officers complain that the process of aggregating data for EPIs is currently not a transparent process. Neither any information about the exact scope and the system boundaries, nor information about data quality or similar is usually available. In this way, the calculation of environmental performance indicators with means of today's CEMIS is not traceable, and therefore often irreproducible.

8.2 Data Management Status

Although environment and sustainability as topics within the enterprise are gaining importance, and besides political and cultural environment, business practice still shows up with isolated applications instead of integrated CEMIS solutions. The integration is often constrained by a lack of standardized interfaces, and appropriate data interchange formats. This fact additionally makes it more complicate to import environmental data with an Active Environmental Data Warehouse, which would be an appropriate means for further processing and analysis.

8.3 Information Technology and Sustainable Business

Information technology is the key factor for controlling sustainable business development. It has to be brought into action at the beginning of the life cycle of (hybrid) products and to become operative within the framework of environmentally integrated as well as sustainability enabled production, and also for strategic decision processes. Ex-post documentation of environmental impacts will not be sufficient and will not be accepted in future. In future, strategically relevant environmental information and decision algorithms will be required for a better assessment of (alternative) sustainable development paths, material's process as a critical success factor or volatile energy markets. In this way, it would become possible to reveal risks and system relevant cause-and-effect-chains among economical, ecological and social indicators. The ubiquitous IT together with the coalescence of digital and physical systems, allow for an alteration of business process towards sustainable business development, increasing transparency as well as for a decremented energy- and materials usage, if the missing features of today's CEMIS are implemented within the next generation of supporting tools.

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