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An Environmental Management Information System for Eco-Efficiency of Agro-Industries in Thailand Based on Material Flow Networks

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Abstract

This paper introduces a joint Thai-German cooperation project for the development of a Management Information System for Eco-efficiency in the Thai agro-industrial sub-sector of palm oil production. The project aims at the improvement of the information and decision basis for factory management on a short term as well as long term basis, with the objective to foster resource efficiency and strengthen long-term competitiveness. The MIS consists of a database application with short production term data as well as a reference Material Flow Network production model for longer term production process data providing management reports with key performance indicators, material and energy balances and benchmark charts. The application of the rather complex model-based system is facilitated by an Assistant program guiding the user through a self explanatory dialog. The approach can be transferred to other industrial branches with rather standardized production processes allowing the development of standard reference models.

1. Introduction: Review of Material Flow Networks

Material Flow Analysis is an important constituent of Environmental Management Information Systems (EMIS). Material Flow Networks, representing relevant energy and material flows and transformations within a company, have been originally introduced as a powerful Material Flow Analysis (MFA) method at the University of Hamburg as early as 1995 (Möller (1995) and refined in Möller (2000). Material Flow Networks are a graphical modelling notation based on the popular Petri Net methodology from Computer Science and provide detailed information on environmental effects of a company and on ecological optimization of products. They constitute a combined flow and inventory analysis. In Material Flow Networks the *transitions*, represented in diagrams by squares, stand for the location of material and energy transformations. Transitions play a vital role in Material Flow Networks, because material and energy transformations are the source of material and energy flows. Another defining characteristic of Material Flow Networks is their concept of *places*. Places separate different transitions. This allows for a distinct analysis of every transition. Beyond that places can describe inventories for materials. Circles are used in diagrams to represent places. Arrows show the paths of material and energy flows between transitions and places.

Based on this early innovative Environmental Informatics idea a suitable software tool named Umberto[R] has been developed as a prototype at the university institute at first and subsequently as a commercial software product at a Spin-off company founded by university graduates and employees in the nineties. Meanwhile Material Flow Networking and the related modelling software Umberto[R] are well established methods and tools in the context of EMIS for building up accounting systems for relevant material and energy flows and transformations within a production process in a company (including cost data) in order to achieve Eco-Efficiency (Möller, et.al., 2001). Today the software is widely used in many industries on a national as well as international level. One recent international application of Material Flow Networks is

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a joint Thai-German project for establishing an EMIS in Thai palm oil industry which is introduced in this paper.

The Department of Industrial Works (DIW, Ministry of Industry) in Bangkok in cooperation with the German Society for Technical Cooperation (GTZ) has been carrying out the two-year project "Management Information Systems for Industrial Pollution Prevention and Control" from 2005-2007. One of the expected results of this project is the development and implementation of a special Environmental Management Information System for Eco-Efficiency in the agro-industrial sub-sector of Palm Oil Production in Thailand.

This paper is organized as follows: After this short introduction into Material Flow Networks as a modelling approach in Material Flow Analysis and into background of the Thai-German project we summarize the motivation for developing an EMIS for factories in the Thai agro-industrial branch of palm oil production in the next section. In section 3 we introduce the main components of the EMIS for Eco-Efficiency. Section 4 presents the MFA model for palm oil production in its structure and analysis functionality. The requirements for future model adaptations are outlined in section 5 before we discuss the project status and will give an outlook on the potential of introducing this approach into other industrial branches in the final section.

2. Development Goals for the Environmental Management Information System in Thai Agro-Industry

The development of a Management Information System for Eco-Efficiency in the joint Thai-German project aimed at the enlargement of the information basis for the management in palm oil factories and therefore as an improvement of the management decision process under economic as well as environmental criteria. Palm oil industry is a significant agro-industrial sub-sector in Thai economy. Based on the current situation as identified in a comprehensive local consultant study including a number of palm oil production site visits during the initial period of the project, the companies could benefit from the implementation of an EMIS in a number of ways:

- Higher degree of transparency on the entire production process
- Indications for more efficient use and savings of energy and materials
- Performance indicators for resource efficiency
- Performance indicators for production efficiency
- Decision aid for management regarding productivity and environmental issues
- Improved cost information
- Higher competitiveness also on the international scale.

On this background an EMIS has been designed and implemented in the second phase of the project including mainly a database application and a material flow model for palm oil production as outlined in the next sections.

3. Components of the Environmental Management Information System for Eco-Efficiency

The MIS Software for Eco-Efficiency (EMIS) consists of different components (as shown in Figure 1) including the database application, the Material Flow production model as well as the Assistant program.

An essential component of the EMIS for Eco-efficiency is a production database application for the palm oil sector. The main focus of the database application is short term data (daily to monthly) and monitoring the production process on a timely basis. They provide (economic as well as resource efficiency related) Key Performance Indicators (KPIs) on a short term scale as well as short term reports supporting factories in day-to-day business. The database application has been just introduced recently in a number of palm oil factories in different regions of Thailand as a data collection, data storage and reporting facility in a stepwise procedure. The users in the companies are now able to produce daily and monthly reports from the standard relational database management system (i.e. Microsoft Access).

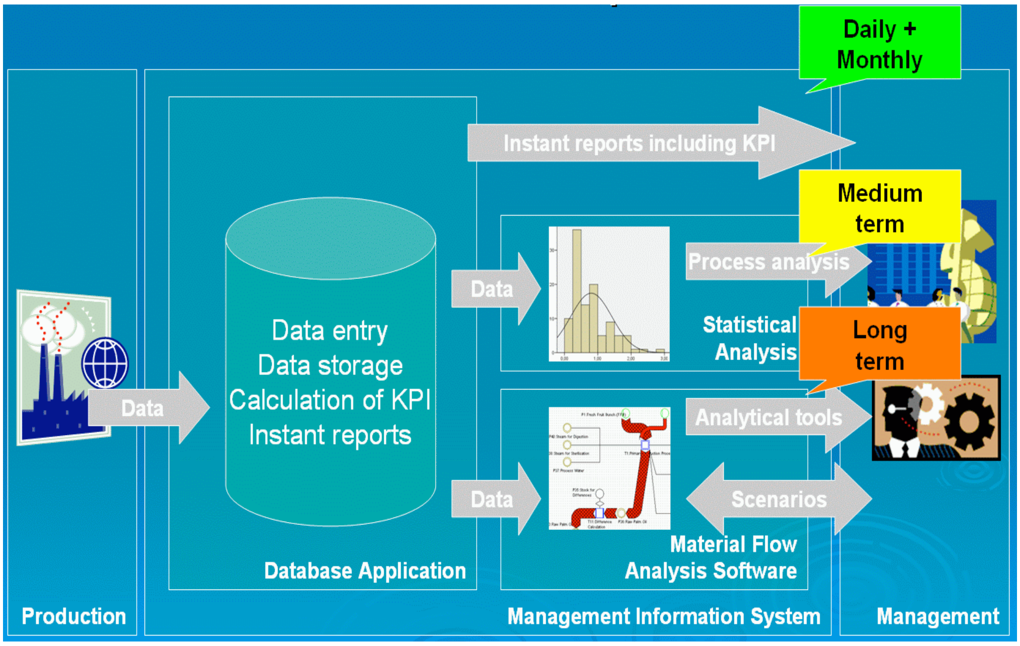

Figure 1: Structure of the MIS for Eco-Efficiency developed in the Thai-German Joint Project

In contrast Material Flow Analysis Models based on Material Flow Networks have a long term focus on flexible time periods such as quarter, six month, or yearly periods and beyond. Thus another central component of the EMIS for Eco-Efficiency is a suitable EMIS software product such as Umberto^{R}- which has been selected for the project during a software market study based on a set of well defined evaluation criteria. This software component reads company measurement data from the database application by defined interfaces and runs MFA models for the selected industrial sub-sector. The model represents the principal processing steps of the production process of palm oil. Since MFA modelling is very much a data-driven approach, the database application of the EMIS plays an important role as the central data source. In addition process knowledge by specialists in the GTZ project team as well as material flow modelling expertise by the short term experts have been incorporated into the modelling process.

Due to the typical similarities in the production processes in most companies of the industrial sub-sector palm oil this model is a branch-specific Reference Model used by all participating companies of this sector. Quantitative differences between the productions in the single company would be covered by varying parameter values derived from the respective company database. Structural differences in the production processes, however, require individual model adaptations (see Sec. 5).

IT-users in the companies such as production managers will be working with a runtime version of the MFA model (“Umberto^{R}-Runtime”) and will be supported by so-called Assistants in order to facilitate the

MFA application. The user is prompted in a guided dialog for certain model data items which can be typed in manually or directly accessed from the database and overwritten where necessary. The users do not have direct access to the rather complex network model, they just trigger the model computation. The left section of the Assistant user interface (see Figure 4) shows the principal MFA-model or production system structure, which is passed through step by step. The Assistants will transfer the input data and parameters to the EMIS model for processing. Beyond data input the selection of available reports and analyses is also supported by the guided dialog. The Assistant program is an essential prerequisite for bringing MFA-models to non-technical users in the factories. The dialogs will be later on translated into Thai by local contractors, i.e. factory personal will work with Thai Assistant programs in the future while the rather abstract network model is hidden.

4. The Palm Oil Material Flow Network

4.1 Model Structure

The Palm Oil Model described in Material Flow Network notations consists of five different production sub-sections, i.e. Primary Production Process, Oil Room, Dry Process, Utility and Waste-Water Biogas System. The notation used in the network model of the palm oil production process is specified in Figure 2.

Each of these subsections of the overall model are again refined into sub-models describing the different process sections in more detail. With increasing model complexity additional hierarchical levels of sub-models could be introduced into the model. The global model structure is shown in Figure 3. This figure also includes a Sankey diagram of material flow as a typical model output which is explained in the next paragraph. In Figure 4 a more detailed view of one of the submodels representing the model section of the Waste Water Biogas System of palm oil production is given.

4.2 Palm Oil Model Analysis

The MFA model is used to derive different forms of production analyses under economic as well as ecological aspects. A network computation based on collected production data stored in the database application delivers model results for a specified production period (e.g. yearly) such as long term Key Performance Indicators (e.g. fresh fruit bunch quality index, oil loss e.g. in waste water and in different production steps, crude palm oil yield, electricity or water consumption, etc.). Besides material and energy balances for the whole production process or of sections of the process, respectively, are generated. The input-output balance lists all input- and output-material groups and an aggregation of respective materials (shown in kg) and energies (shown in kJ) during the model period. Another option in palm oil model analysis is the presentation of a so-called Sankey diagrams. In general Sankey diagrams in MFA can show the mass-proportional flow of significant materials and used energies along the production process chain. In our palm oil case Sankey diagrams are used to visualize the flow of palm oil through the different production steps and highlight in particular where the losses occur. This can be seen in Figure 3 where the palm oil model structure together with the flow of palm oil symbolized by red mass-proportional arrows are mapped. If the flow quantities lie above a certain limit the arrow is marked with a pattern to signal an overflow.

Notation used in Network Model of the palm oil production process:

- The central components of Material Flow Networks are the **Transitions**, which are marked as blue **boxes** in the network. They specify energy and material transformation processes in a production system. There are predefined rules for transformation of input into output materials which can be based on parameters, mathematical functions, standard transitions from libraries, or user defined transformation programs.
- **Circles** are so-called **Places**, i.e. inventory and connections without material transformation. They describe system boundaries (Input-/Output), take care of branching and fusing in the network or denote inventories.
  Green circles marked with a vertical line on the left are **Input Places** for materials and energy; **red circles** are **Output Places** for products and emissions. **Yellow circles** are connection places for material flow branching and storage.
- **Connections** shown as directed **lines** represent material and energy flows from Places to Transitions and from Transitions to Places. Several materials can flow in one arrow.
- Embedded blue boxes within another box denote **Submodels** which include another partial network in order to reduce model complexity.

Figure 2: Graphical Notation used in Material Flow Networks

Pie charts are employed to depict costs by section relative to total expense. In another form of analysis selected benchmarks symbolized with traffic lights are shown to highlight the standing of the company in comparison to benchmark values established in the industry (see Figure 5). Green colours symbolize better performance, red poorer performance and yellow colors close to benchmark value performance. An alternative presentation mode of benchmark comparisons are net charts with different axes which also depict the quantitative deviations from the benchmark values. The complete standard model analysis can be printed in a model report in Word-format, which can be adapted to individual factory requirements.

The user dialog with the palm oil model assistant also allows for the selection of defined scenario input variables in order to run parametric model experiments. In this way alternative scenarios can be analyzed which allow a what/ if-analyses comparing different options for resource efficiency improvements and cost reductions.

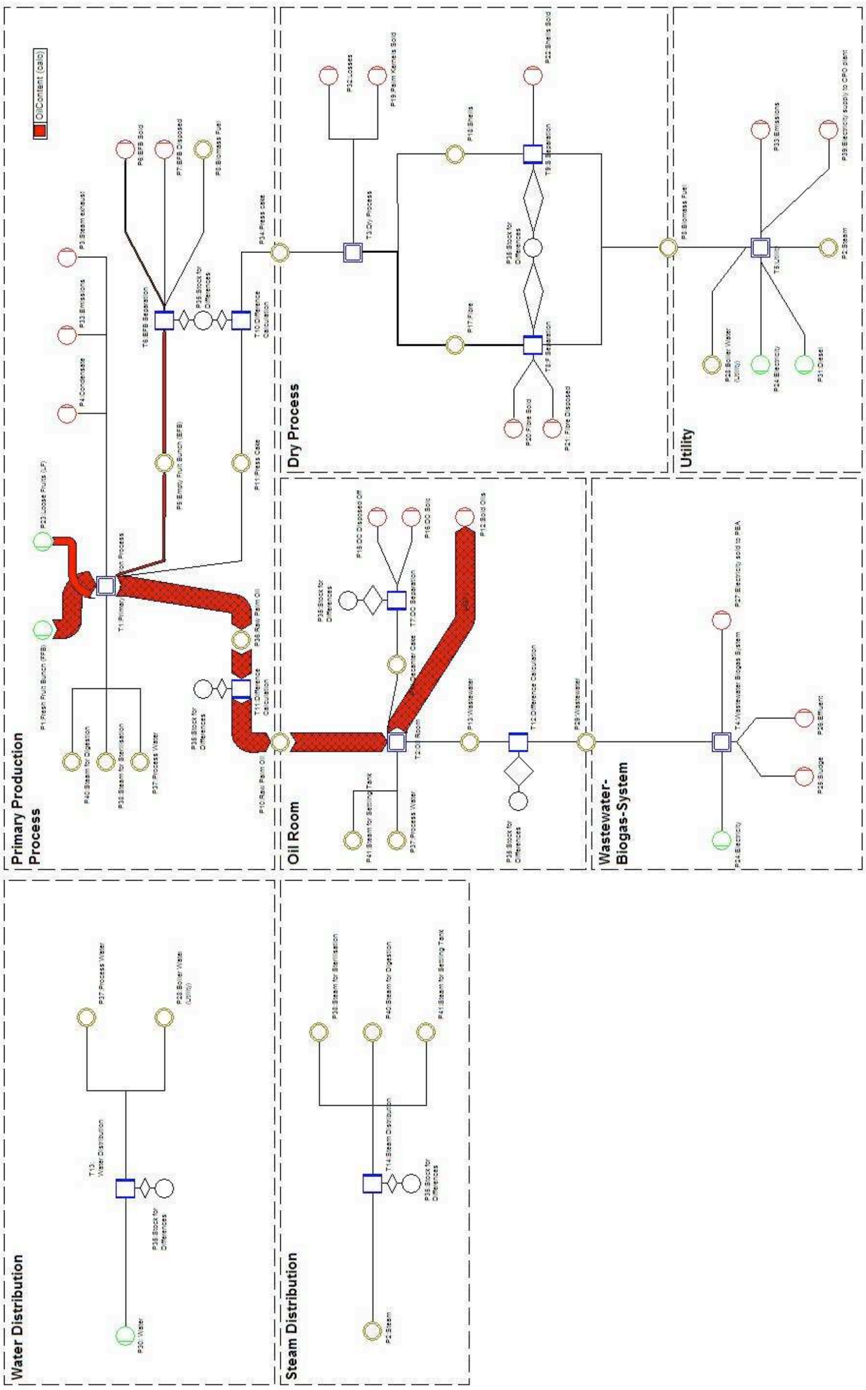

Figure 3: Structure of the Palm Oil Model in Material Flow Analysis Notation showing also the Oil Flow as a Sankey-Diagram

5. Requirements for Model Enhancements

As outlined above a reference model for palm oil production has been designed representing the general process steps of a typical palm oil production which has been introduced in a number of factories and will be applied in the same fashion in most companies. However, there might be some significant differences in production processes with some factories requiring special model enhancements. Beyond that the reference models might require model adaptations for a number of reasons in the future. Firstly some palm oil factories might demand company-specific and more detailed models and analyses. Secondly the data situation could generally improve in the future which will allow a more detailed model. Thirdly new process technologies (e.g. new machines, new processing steps) could be applied which would require a model update. Fourthly a change of production lines or (by-) products could take place which have to be integrated into updated model versions. Finally new performance indicators with additional analyses and reports could be in demand and would have to be introduced into the extended model. However, model modifications will not be required in case of e.g. increased production capacities or other model parameter values, because the models are parameter-driven and e.g. higher parameter values could take care of growing capacities.

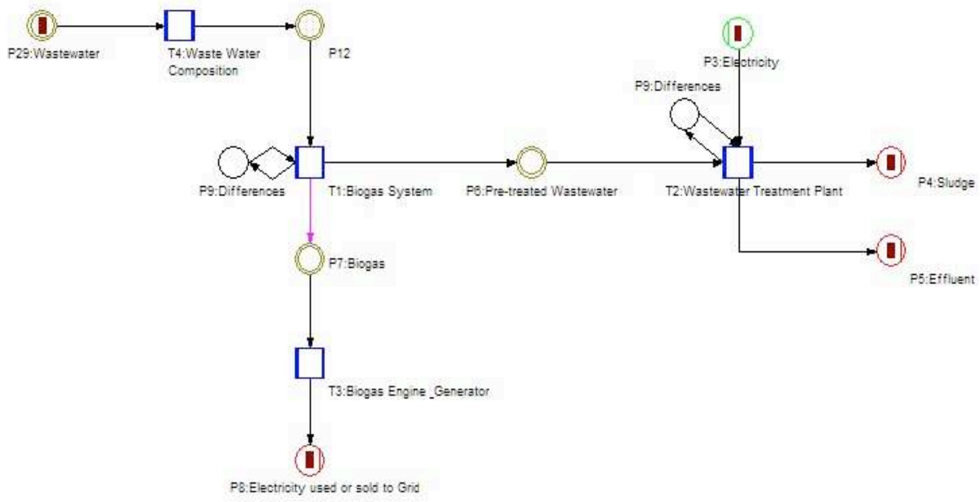

Figure 4: Detailed Submodel of Wastewater-Biogas-System

Model adaptations, which will have to be carried out by local consultants after the end of the project, have to go through a number of typical steps as outlined below:

1. Analysis of new Factory Situation
   - Technology / process changes
   - New data items
2. Data Collection
   - Data Verification
   - Data Adaptation to comparable level of detail
3. Redesign of MFA process model with new processes
   - New places and transitions

- New materials, products
- New sub-models

4. Design of new model analyses
5. Model implementation and test
   - Model programming with MFA-software tool
6. Test run new model programs
7. Development of updated model reports
   - Modification of Word-report documents with graphics following the company requirements
   - Adaptation of model Assistant program
8. Maintenance and support during model application in factories.

It is clear that similar changes are required at the database structures for palm oil production.

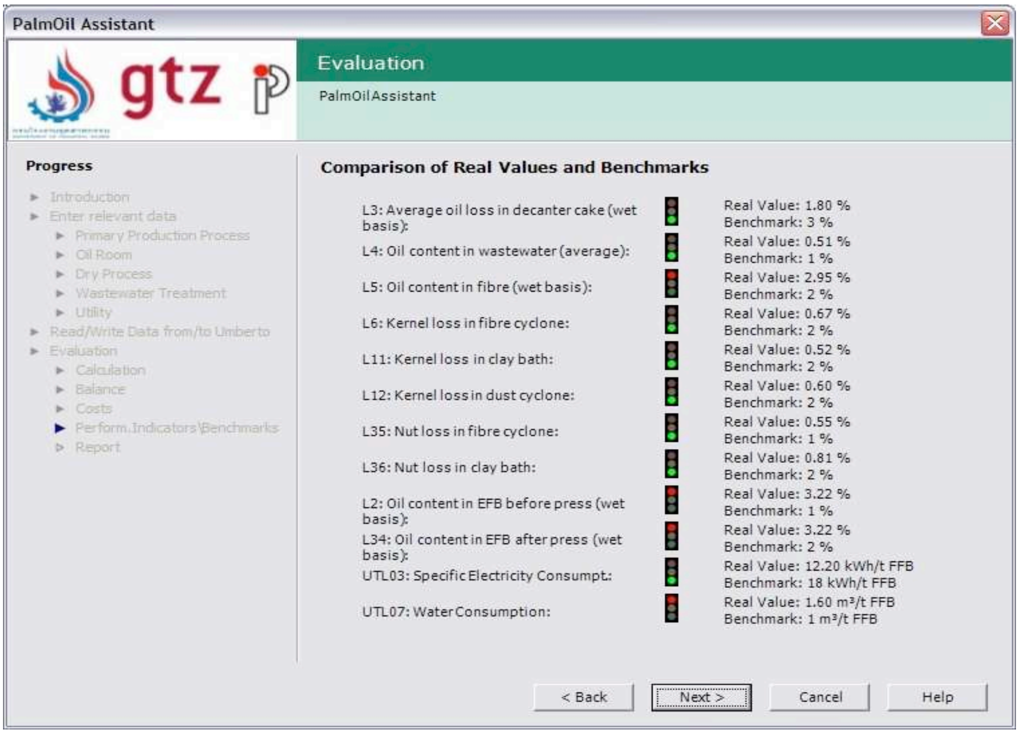

Figure 5: Assistant for Material Flow Network Model Application (user guidance see left column) with Output of Benchmark Performance Comparisons

6. Conclusions

At the time of the conference the cooperation project for the EMIS for Eco-efficiency will have been just completed and first on-site experiences with the system at participating factories in Thai palm oil industry will be already at hand. However, it turns out that an improvement of the information and decision basis for the factory management can be already noticed in particular with the earlier introduction of the database application as a part of the project. Beyond that the EMIS for Eco-efficiency could also be considered as a first step toward a general MIS for the participating companies, because a lot of the data and many performance measures are of general relevance for business of the companies far beyond the environmental domain.

A critical factor for a successful implementation of the EMIS for Eco-efficiency in a wide range of factories of palm oil industry and beyond will be setting up a qualified local consultant infrastructure well trained in EMIS technologies and tools. The local consultants have to advice the palm oil factories in using the EMIS properly and interpret the analysis results. Beyond that they have to be ready to take action when extensions and modifications of the MFA-models will be in demand by the factories. In order to put local consultants into the position of performing the required tasks in EMIS dissemination, advice, maintenance and further development on a high level of quality additional technical training measures would be useful. They would have to deal with reference model application and interpretation and with technical matters such as with enhancements of the reference models, update of the database application interface to the MFA models as well as with the implementation of new Assistant versions for updated model versions.

Eventually there will a local consultant infrastructure for MIS development will evolve in Thailand which will also provide the basis for transferring the model-based approach into other agro-industriesl or different industrial branches. The most important aspect for the suitability of different industrial branches for a model-based EMIS development are rather standardized production processes which qualify for the utilization of production reference models. One candidate from agro-industry in Thailand is native starch production where a similar approach making use of a specialized data base application and a Material Flow Network reference model is under way. Other sectors in agro-industry and beyond will be considered for similar MIS projects on the local level depending on the degree of improvements in Eco-Efficiency and competitiveness in palm oil and starch industry achieved by the current joint MIS for Eco-efficiency project. In the end the model-based approach also seems suitable for comparable industrial sectors in other countries.

Bibliography

Department of Industrial Works (ed.) (2006): Management Information System (MIS) Guidelien for Eco-efficiency – Palm Oil Industry. Report. Bangkok.

Möller, A. (1995): Stoffstromnetze – Konzeption eines rechnergestützten ökologischen Rechnungswesens. Diploma thesis at the Department of Informatics, University of Hamburg.

Möller, A. (2000): Grundlagen stoffstrombasierter Betrieblicher Umweltinformationssysteme. Bochum

Möller, A., et.al. (2001): Foundations and Applications of Computer Based Material Flow Networks for Environmental Management. In: Rautenstrauch, C., Patig, S. (Eds.): Environmental Information Systems in Industry and Public Administration, London, pp. 379-396.

Page, B., Wohlgemuth V. (2005): Linking Economic Optimisation and Simulation Models to Environmental Material Flow Networks for Ecoefficiency. In: L.M. Hilty, (et.al) (eds): Information Systems for Sustainable Development. Hershey, pp. 94-108.

Perini, A., Susi, A.(2004): Developing a decision support system for integrated production in agriculture. Environmental Modelling & Software, 19(9): 821-829.

Wohlgemuth, V. (2005): Komponentenbasierte Unterstützung von Methoden der Modellbildung und Simulation im Einsatzkontext des betrieblichen Umweltschutzes. Aachen.

Wohlgemuth, V., Page, B., Kreutzer, W. (2006): Combining discrete Event Simulation and Material Flow Analysis in a Component-based Approach to industrial environmental Protection. Journal Environmental Modelling & Software, 21: 1607-1617.