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Europäischer Fonds für  
regionale Entwicklung



# IT-for-Green



**Next Generation Corporate Environmental  
Management Information System (CEMIS)  
for Environmental, Energy and Resource  
Management**

**Final Report**



# Content

|   |    |
|---|----|
| Preface .....   | 2  |
| IT-for-Green in Numbers .....                         | 3  |
| Motivation and Aim of the IT-for-Green Project .....  | 4  |
| Four Research Groups .....                            | 6  |
| University of Oldenburg .....                         | 6  |
| Very Large Business Applications.....                 | 6  |
| Embedded Hardware/Software Systems .....              | 11 |
| Osnabrück University.....                             | 14 |
| Göttingen University .....                            | 19 |
| Partners.....   | 21 |
| CEWE Stiftung & Co. KGaA .....                        | 21 |
| erecon AG .....                                       | 21 |
| Gemeinde Spiekeroog.....                              | 22 |
| Hellmann Worldwide Logistics GmbH & Co. KG .....      | 23 |
| NOWIS Nordwest-Informationssysteme GmbH & Co. KG..... | 24 |
| ertemis.....  | 25 |
| SAP University Competence Center.....                 | 25 |
| Core .....  | 26 |
| IT-for-Green Runtime Environment .....                | 26 |
| Module 1: Green IT.....                               | 28 |
| Module 2: Green Production & Logistics.....           | 30 |
| Module 3: Sustainability Reporting & Dialogue.....    | 32 |
| Selected Artifacts .....                              | 34 |
| Quarterly Meetings .....                              | 36 |
| IT-for-Green on Tour .....                            | 37 |
| Roundup of reached IT-for-Green Objectives.....       | 44 |
| Publications .....                                    | 47 |
| Acknowledgment .....                                  | 51 |
| Imprint .....   | 52 |

## Preface

Efforts towards environmental conservation, sustainability and energy efficiency are supported by using corporate environmental management information systems (CEMIS) that require a large number of heterogeneous data for planning, management and control of environmental responsibilities.

Recent developments in the sustainability debate require suitable and state-of-the-art CEMIS since IT plays a crucial role in the sustainable development of companies. A goal-oriented treatment of environmental data and information using state of the art ICT is absolutely necessary to bring environmentally integrated production as well as the strategic nature of decision support to daily business.

The final report of the IT-for-Green project shows impressively the potential of a CEMIS adopted to current needs of companies, by giving examples. The examples cover life-cycle of products from input (measuring energy efficiency of the ICT used) to transformation (logistics and product development) as well as to output (corporate communication via sustainability reports and stakeholder dialogue) by a service-oriented prototypical implementation.

The reader of the report gets at hand an orientation how CEMIS could influence business processes and why they are a key factor for success. An IT-for-Green CEMIS overcomes the goal orientation of only supporting legal compliance and is now influencing also on a strategic and administrative level. Further, the report gives an example how research institutes and companies collaborate in a network and how the IT-for-Green CEMIS can be integrated into the companies' system landscape.

Oldenburg, in October 2014

Prof. Dr.-Ing. Jorge Marx Gómez

Prof. Dr.-Ing. Wolfgang Nebel








Osnabrück

Prof. Dr. Frank Teuteberg

Göttingen


Prof. Dr. Jutta Geldermann

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|---|-------------------------------------|
|    | <b>2.1 M €</b><br>Third-Party Funds |
|    | <b>43 mo.</b><br>Duration           |
|    | <b>4</b><br>Research Groups         |
|    | <b>7</b><br>Partners                |
|   | <b>73</b><br>Publications           |
|  | <b>82</b><br>Artifacts              |
|  | <b>31</b><br>Project Members        |

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## Motivation and Aim of the IT-for-Green Project



The overall political claim of efforts for environmental conservation, sustainability and energy efficiency are supported by the use of environmental management systems. An efficient environmental management system requires a large number of divergent, heterogeneous data to cope with the set task – planning, management and monitoring of environmental challenges. These data need to be stored in Corporate Environmental Management Information Systems

(CEMIS) and processed in a focused manner. However, a look at real-world applications shows that the performance of currently implemented CEMIS does not fulfil the requirements discussed in the debate on sustainability.

We are convinced that the management efficiency of IT plays a decisive role for the sustainable enterprise development, not downstream as an end-of-pipe solution for the mere documentation of environmental indicators or for legal compliance, but directly at the beginning of the development of hybrid products, as part of an environmentally integrated production as well as in strategic decision-making. Through the use of intelligent networked systems and processes, the IT, e.g., supports the strategic enterprise level. Here also strategically relevant environmental information and decision algorithms have to be provided (Active Environmental Data Warehouse), leading to better estimations of sustainable development paths, resource prices critical to success and volatile energy markets. Thereby, associated risks and strategically relevant, system-dynamic cause-and-effect relationships between economic, environmental and social indicators can be identified.

Consequently, the aim of next generation corporate environmental management information system for environmental, energy and resource management has to be to use a company's entire IT as a resource-directing, integrative nervous system for the intelligent and strategic management as a platform (service-oriented architecture, SOA) and in this way to realize a chance and risk efficient, strategic environmental management system, thus enabling sustainable business value. Furthermore, it must be the target of next generation CEMIS to transparently document cause-and-effect relationships between economic, environmental and social indicators in order to compare them in different development scenarios.

This manifold task can't be mastered by science alone. Therefore, for the implementation of new IT concepts that support sustainability, an extensive network of key personnel from all areas will be established to tackle this task in an innovation network

together with partners from academia and industry alike. The research and transfer network ertemis (european research and transfer network for environmental management information systems) was already initiated as part of a feasibility study carried out in advance (November 2009 until April 2010).

The innovation network ertemis primarily pursues two objectives:

1. **Expansion of the research and transfer network ertemis** in order to create a highly innovative community.
2. **Development of next generation CEMIS** and demonstration of the performance based on reference implementations

The project also deals with the central issues of applied computer science, environmental management, ecology as well as economics, develops knowledge in the area of new generation CEMIS and makes it available for companies – especially SMEs – in the form of useful products (e.g., maturity models, reference models, software products, company start-ups, main training priorities and continuing education programs).

Commonly, industrial representatives only indirectly get aware of scientific findings. Likewise, knowledge of the corporate practice often remains hidden for scientists. Therefore, there is a need for an active bilateral technology transfer. Such a transfer can only be successful by forming a network of specific partners and by providing a network manager. Here the network management is given the task as a clearing house between academia and practice, which on the one hand provides academia with industrial partners' knowledge and problems and on the other hand spreads scientific findings within the network – e.g., via presentations, workshops, documentations. To confirm the efficiency of the clearing house, it is necessary to restrict the tasks – in this case to solve environmental problems by using information processing techniques and methods.

In order to cover the entire product life cycle from the input side (energy efficiency measurement of ICT used), the transformation (production/logistics and sustainable product development) to the output side (corporate communications and sustainability reporting), we consider the following three interlocking modules to be essential as reference implementations for an innovative new generation CEMIS.

**Module 1: Green-IT: (Semi-)Automatic energy efficiency measurement of ICT on the example of data centers**

**Module 2: Green Production & Logistics: Automatic determination of CO<sub>2</sub> emissions along the supply chain**

**Module 3: Sustainability Reporting & Dialogue**

## Four Research Groups

### University of Oldenburg

#### *Very Large Business Applications*

The department Business Information Systems / VLBA, University Oldenburg, aims in research and teaching in enterprise-wide operational and inter-organizational information systems. Very large business applications support execution of business processes along value chains and are not restricted to individual organizational boundaries. They can be characterized by their strategic importance, both for individual companies and for corporate networks. Within the department another focus are the fields of production and material flow management or environmental data obtained from life cycle assessment to be integrated into other information systems. Furthermore, aspects of sustainability reporting have been analyzed in the department on different levels - bachelor and master thesis, dissertations or students group (working one year on a specific topic). Further research activities concerning Business Intelligence are in focus of the department Business Information Systems / VLBA.

The department VLBA focuses in the project IT-for-Green on the development and deployment of a service-oriented infrastructure as a runtime environment for the individual modules in the project and module "Sustainability reporting and dialogue". Furthermore, the project lead and management are main task of our department in the project. For more information visit <http://vlba.wi-ol.de/>.



#### **Prof. Dr.-Ing. habil. Jorge Marx Gómez** *Project Coordinator*

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## Academic Staff

### Dipl.-Inform. Swetlana Lipnitskaya

#### Activities

- Module Sustainability Reporting & Dialogue



#### Selected Publications

- Solsbach, A.; van Vliet, S.; Lipnitskaya, S.; Rapp, B.: Nachhaltigkeitsberichterstattung als Service eines BUIS - Anforderungen an ein Schema zur Nachhaltigkeitsberichterstattung im Projekt IT-for-Green, In: Proceedings der Multikonferenz Wirtschaftsinformatik 2014, Paderborn, 2014, pp. 1367-1374.
- Solsbach, A.; Lipnitskaya, S. & van Vliet, S. (2013), Internetbasierte Nachhaltigkeitsberichterstattung im Kontext des Umwelt-, Energie- und Ressourcenmanagements mit BUIS der nächsten Generation, in Jorge Marx Gómez; Corinna Lang & Volker Wohlgemuth, ed., 'IT-gestütztes Ressourcen- und Energiemanagement. Konferenzband zu den 5. BUIS-Tagen', pp. 421-431.



### Dipl.-Inform. Barbara Rapp

#### Activities

- Project Management and Runtime Environment

#### Selected Publications

- Solsbach, A.; Rapp, B.; Teuteberg, F.; Gräuler, M.; Stiel, F.; Renatus, F. & Vornberger, J. (2013), Environmental Foot-

printing in the IT-for-Green Project – A CEMIS Use Case, in Bernd Page; Volker Wohlgemuth; Angela Schwabl; Andreas Fleischer & Heidi Oskarsson, ed., 'Proceedings of the Environmental Informatics and Industrial Environmental Protection: Concepts, Methods and Tools', Springer Verlag, Berlin.

- Rapp, B. & Bremer, J. (2012), Design of an Event Engine for Next Generation CEMIS: A Use Case, in Hans-Knud Arndt; Gerlinde Knetsch & Werner Pillmann, ed., 'Man, Environment, Bau-haus: Light up the Ideas of Environmental Informatics - 26th International Conference on Informatics for Environmental Protection', Shaker Verlag, pp. 759-766.
- Rapp, B.; Vornberger, J.; Renatus, F. & Gössling, H. (2012), An Integration Platform for IT-for-Green: Integrating Energy Awareness in Daily Business Decisions and Business Systems, in Brian Donnellan; João Peças Lopes; João Martins & Joaquim Filipe, ed., 'Proceedings of the 1st International Conference on Smart Grids and Green IT Systems (SmartGreens 2012)', SciTePress - Science and Technology Publications, pp. 226-231.

## Dipl.-Inform. Olaf Roeder

### Activities

- Runtime Environment

### Selected Publications

- Medel-González, F.; van Vliet, S.; Roeder, O.; Marx Gómez, J.: Upgrading Reporting, Communication and Benchmarking Tools of IT-for-Green Project, In: Proceedings der EnvirolInfo 2014, Oldenburg, 2014, in publication.



## Dipl.-Wirt.Inform. Andreas Solsbach

### Activities

- Module Sustainability Reporting & Dialogue

### Selected Publications

- Solsbach, A.; Isenmann, R.; Marx Gómez, J.; Teuteberg, F.: Inter-organizational Sustainability Reporting – A harmonized XRBL approach based on

GRI G4 XBRL and further Guidelines, In: Proceedings der EnvirolInfo 2014, Oldenburg, 2014, in publication.

- Solsbach, A.; van Vliet, S.; Lipnitskaya, S.; Rapp, B.: Nachhaltigkeitsberichterstattung als Service eines BUIS - Anforderungen an ein Schema zur Nachhaltigkeitsberichterstattung im Projekt IT-for-Green, In: Proceedings der Multikonferenz Wirtschaftsinformatik 2014, Paderborn, 2014, pp. 1367-1374.
- Solsbach, A.; Lipnitskaya, S. & van Vliet, S. (2013), Internetbasierte Nachhaltigkeitsberichterstattung im Kontext des Umwelt-, Energie- und Ressourcenmanagements mit BUIS der nächsten Generation, in Jorge Marx Gómez; Corinna Lang & Volker Wohlgemuth, ed., 'IT-gestütztes Ressourcen- und Energiemanagement. Konferenzband zu den 5. BUIS-Tagen', pp. 421-431.

**Dipl.-Inform. Sebastian van Vliet**  
Activities

- Technical Project Management and Runtime Environment



Selected Publications

- Medel-González, F.; van Vliet, S.; Roeder, O.; Marx Gómez, J.: Upgrading Reporting, Communication and Benchmarking Tools of IT-for-Green Project, In: Proceedings der EnviroInfo 2014, Oldenburg, 2014, in publication.
- Solsbach, A.; van Vliet, S.; Lipnitskaya, S.; Rapp, B.: Nachhaltigkeitsberichterstattung als Service eines BUIS - Anforderungen an ein Schema zur Nachhaltigkeitsberichterstattung im Projekt IT-for-Green, In: Proceedings der Multikonferenz Wirtschaftsinformatik 2014, Paderborn, 2014, pp. 1367-1374.
- Solsbach, A.; Lipnitskaya, S.; van Vliet, S. (2013), Internetbasierte Nachhaltigkeitsberichterstattung im Kontext des Umwelt-, Energie- und Ressourcenmanagements mit BUIS der nächsten Generation, in Jorge Marx Gómez; Corinna Lang & Volker Wohlgemuth, ed., 'IT-gestütztes Ressourcen- und Energiemanagement. Konferenzband zu den 5. BUIS-Tagen', pp. 421-431.

**Former Academic Staff**

**Dipl.-Inform. Jörg Bremer**  
Activities

- Runtime Environment



Selected Publications

- Rapp, B. & Bremer, J. (2012), Design of an Event Engine for Next Generation CEMIS: A Use Case, in Hans-Knud Arndt; Gerlinde Knetsch & Werner Pillmann, ed., 'Man, Environment, Bauhaus: Light up the Ideas of Environmental Informatics - 26th International Conference on Informatics for Environmental Protection', Shaker Verlag, pp. 759-766.
- Bremer, J.; Mahmoud, T. & Rapp, B. (2012), Implementing CEMIS Workflows with State Chart XML, in H.K. Arndt; G. Knetsch & W. Pillmann, ed., 'EnviroInfo 2012 - Part 2: Open Data and Industrial Ecological Management', Shaker Verlag, Dessau, Germany, pp. 749-757.
- Rapp, B.; Solsbach, A.; Mahmoud, T.; Memari, A. & Bremer, J. (2011), IT-for-Green: Next Generation CEMIS for Environmental, Energy and Resource Management, in Werner Pillmann; Sven Schade & Paul Smits, ed., 'EnviroInfo 2011 - Innovations in Sharing Environmental Observation and Information, Proceedings of the 25th EnviroInfo Conference 'Environmental Informatics'', Shaker Verlag, pp. 573-581.

## Dr.-Ing. Tariq Mahmoud

### Activities

- Runtime Environment

### Selected Publications

- Bremer, J.; Mahmoud, T. & Rapp, B. (2012), Implementing CEMIS Workflows with State Chart XML, in H.K. Arndt; G. Knetsch & W. Pillmann, ed., 'EnviroInfo 2012 - Part 2: Open Data and Industrial Ecological Management', Shaker Verlag, Dessau, Germany, pp. 749-757.
- Gräuler, M.; Teuteberg, F.; Mahmoud, T. & Marx Gómez, J. (2012), Anforderungspriorisierung und Designempfehlungen für Betriebliche Umweltinformationssysteme der nächsten Generation – Ergebnisse einer explorativen Studie, in 'Multikonferenz Wirtschaftsinformatik', pp. 1531-1543.
- Allam, N.; Mahmoud, T. & Gómez, J. M. (2011), Web Service-enabled Collaborative Corporate Environmental Management Information Systems, in 'Information Technologies in Environmental Engineering: New Trends and Challenges', Springer (Heidelberg), Poznan, Poland, pp. 179-188.



## Embedded Hardware/Software Systems

The division Embedded Hardware/Software Systems (EHS) of the department of computer science at the Carl von Ossietzky University of Oldenburg constitutes – in teaching and research – the bridge between computer science and electrical engineering as a scientific disciplines, which have their particular application mainly in development of software and hardware. The teaching activities of the division focus on embedded systems as well as their design methods and tools. The aim of the research activities is development of modern design methods and tools for the specification, conceptualization, and design of embedded systems, which are also termed today as Cyber Physical Systems. The targeted methods should first of all enable description of the system on an abstract level (e.g. C/C++, MATLAB/Simulink or SystemC), and secondly allow estimation of relevant parameters of the chip (time behavior, chip area, energy demand, reliability, and robustness) already in the early design phases. Finally, the methods should support an efficient transformation into a realizable circuitry. Another field of research of the division focuses on improving energy efficiency of IT systems, especially of server, data communication components, and data centers.



### Prof. Dr.-Ing. Wolfgang Nebel

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## Academic Staff

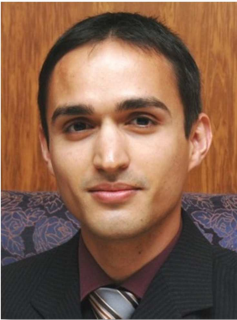
### Ammar Memari Activities

- Subproject manager of Module Green IT
- Design of the main workflow
- DC metamodel, editor, and data transformations development
- Measurement infrastructure
- Analysis of the measured data



### Selected Publications

- Memari, A., & Marx Gómez, J. (2014). Adaptive Applications: Definition and Usability in IT-based Service Systems Management. In M. Mora, J. Marx Gómez, L. Garrido, & F. Cervantes Pérez (Eds.), Engineering and Management of IT-based Service Systems: An Intelligent Decision-making Support Systems Approach (Vol. 55, pp. 131–154). Springer.
- Memari, A., Vornberger, J., Marx Gómez, J., & Nebel, W. (2014). A Data Center Simulation Framework Based on an Ontological Foundation. In Proceedings of EnviroInfo 2014: ICT for Energy Efficiency. Oldenburg, Germany: BIS Verlag.
- Memari, A. (2013). Angewandtes Semantisches Metamodell von Rechenzentren für Green IT. In J. Marx Gómez, C. Lang, & V. Wohlgemuth (Eds.), 5. Buis Tage: IT-gestütztes Ressourcen- und Energiemanagement (pp. 93–102). Springer Berlin Heidelberg.



### Kiril Schröder Activities

- Documentation

## Former Academic Staff

### Jan Vornberger Activities

- Measurement infrastructure
- Profiling of DC components
- Analysis of the measured data



### Selected Publications

- Rapp, B., Vornberger, J., Renatus, F., & Gössling, H. (2012). An Integration Platform for IT-for-Green-Integrating Energy Awareness in Daily Business Decisions and Business Systems. In SMART-GREENS (pp. 226–231).
- Vornberger, J., Tröschel, M., Nieße, A., & Appelrath, H.-J. (2011). Optimized charging management for electric vehicles. In 1st International 100% Renewable Energy Conference and Exhibition (Vol. 100).

## Osnabrück University

Today, more than ever, IT needs to prove its economic efficiency and value orientation. Moreover, IT finds itself in a field of tension between increasing regulatory requirements (e.g., Sarbanes Oxley Act, KontraG, Basel II), cost pressure, security risks and increasing demands on its performance.

The Research Group in Accounting and Information Systems takes this into account and endeavors to bridge the gap between Accounting and Information Systems with regard to an efficient and value-oriented use of IT for corporate management.

The Research Group in Accounting and Information Systems aims at developing concepts, (reference) models, processes and information systems on a solid theoretical basis for practical use in the field of value-oriented corporate management. We do not regard theoretical and practical orientations as opposites, but understand them as complementary elements of academic work. Our courses are designed to convey concepts of thought, theoretical approaches and applicable methods as well as to impart knowledge of relevant business management software for analysis, planning and reporting.

The Research Group has published more than 190 scientific papers which have appeared in leading German and international Conferences (e.g., ICIS, ECIS, WI) and scientific journals (e.g., Business & Information Systems Engineering (BISE), Electronic Markets: The International Journal of Electronic Commerce & Business Media, International Journal of Project Management, International Journal of Computer Systems Science & Engineering, International Journal of Logistics Systems and Management, Information Systems Frontiers).

The main research interests are Green IT/IS, Sustainable Supply Chain Management, Cloud Computing, Green Logistics, Semantic Business Process Management and IT Risk Management.



### Prof. Dr. Frank Teuteberg

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## Academic Staff

### Dipl.-Wirt.-Inf. Volker Frehe Activities

- Publication and presentation of the research findings in international renowned journals and conferences in English and German
- Development of a platform and a maturity model for the qualitative evaluation and benchmarking of the environmental managing in companies
- Representation of the project at various conferences and symposia domestically and internationally



### Selected Publications

- Frehe, V.; Stiel, F.; Teuteberg, F.: A Maturity Model and Web Application for Environmental Management Benchmarking, In: Proceedings of the 20th Americas Conference on Information Systems (AMCIS 2014), Savannah, USA, 2014
- Frehe, V., Teuteberg, F.: The Role of ICT in Green Logistics – A Systematic Literature Review, In: Proceedings of the 6th International Conference on Information Technologies in Environmental Engineering (ITEE 2013); Lüneburg (Germany)
- Frehe, V.; Stiel, F.; Teuteberg, F.: Web-Portal und Reifegradmodell für ein Benchmarking des betrieblichen Umweltmanagements; In: Proceedings zur INFORMATIK 2013: Informatik angepasst an Mensch, Organisation und Umwelt; 43. Jahrestagung der Gesellschaft für Informatik e.V. (GI); Lecture Notes in Informatics (LNI), 2013



### Matthias Gräuler, M.Sc. Activities

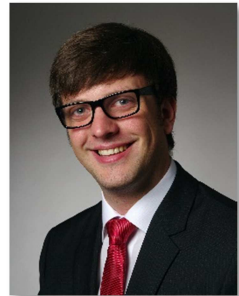
- Publication and presentation of the research findings in international renowned journals and conferences in English and German
- Head of the work package "Completion of the Visualization Possibilities"
- Execution of a practical project with five students over a year: prototypical implementation of an enterprise-wide acquisition system for environmental data and an online sustainability report for Hellmann Worldwide Logistics
- Planning, preparation and execution of industrial workshops and project meetings with external partners

## Selected Publications

- Gräuler, M.; Freundlieb, M.; Ortwerth, K.; Teuteberg, F.: Understanding the Beliefs, Actions and Outcomes of Sustainability Reporting: An Experimental Approach; In: Information Systems Frontiers, Vol., 15 Iss. 5, 2013.
- Gräuler, M.; Teuteberg, F.; Mahmoud, T.; Marx Gómez, J.: Requirements Prioritization and Design Considerations for the Next Generation of Corporate Environmental Management Information Systems - A Foundation for Innovation, In: International Journal of Information Technology and the Systems Approach, Vol. 6, Iss. 1, 2013.
- Freundlieb, M.; Gräuler, M.; Teuteberg, F.: A Conceptual Framework for the Quality Evaluation of Sustainability Reports; In: Management Research Review, Vol. 36, Iss. 11, 2013.

## Dipl.-Wirt.-Ing. Florian Stiel Activities

- Generalization of the project results by the derivation of universal implications
- Development of application contexts for the use of the developed artifacts (especially module 1 and module 2)
- Publication and presentation of the research findings in international renowned journals and conferences in English and German
- Conducting market and competition studies in the field of corporate environmental information systems in the context of the work package "Generalization and Follow-Up Utilization"
- Deriving "lessons learned" of the cooperation between all participating members from academia and industry



## Selected Publications

- Stiel, F., Teuteberg, F.: Measuring the Environmental Impact of IT/IS Solutions - A Life Cycle Impact Modelling Approach, Environmental Modelling & Software, Vol. 56 No. 11, pp. 94-104, 2012.
- Stiel, F., Teuteberg, F.: Towards a Conceptual Framework for Life Cycle Assessment in Sustainable Information Systems Management, In: Proceedings of the 21st European Conference on Information Systems (ECIS 2013), Utrecht, 2013.
- Stiel, F., Teuteberg, F.: Entwicklung praxisrelevanter IKT-Artefakte für ein betriebliches Umwelt- und Nachhaltigkeitsmanagement mittels Konsortialforschung - Implikationen des Verbundprojekts IT-for-Green, In: Proceedings zur Multikonferenz Wirtschaftsinformatik MKWI 2014, Paderborn, 2014.



### Marc Walterbusch, M.Sc.

#### Activities

- Publication and presentation of the research findings in international renowned journals and conferences in English and German
- Planning, preparation and execution of industrial workshops and project meetings with external partners
- Support of the work packages "Completion of the Visualization Possibilities" and "Generalization and Follow-Up Utilization"
- Representation of the project at various conferences and symposia domestically and internationally

#### Selected Publications

- Walterbusch, M.; Handzlik, J.; Teuteberg, F.: Status Quo der Wirtschaftsprüfung von Nachhaltigkeitsberichten; In: Proceedings der 15. Tagung der Fachgruppe Betriebliche Umweltinformationssysteme der Gesellschaft für Informatik e.V. (5. BUIS-Tage), Oldenburg, 2013. Best Paper Nomination.
- Walterbusch, M.; Grove, S.; Breitschwerdt, R.; Stolze, C.; Teuteberg, F.; Thomas, O.: Case-based Selection of Business Process Modeling Tools: An Evaluation Criteria Framework; In: Proceedings of the 19th Americas Conference on Information Systems (AMCIS 2013), Chicago, Illinois, USA, 2013.
- Walterbusch, M.; Gräuler, M.; Teuteberg, F.: How Trust is Defined: A Qualitative and Quantitative Analysis of Scientific Literature, In: Proceedings of the 20th Americas Conference on Information Systems (AMCIS 2014), Savannah, 2014.

### Former Academic Staff

#### Dr. rer. pol. Michael Freundlieb

##### Activities

- Design and implementation of a balanced scorecard for the compliance management of a corporate environmental management information system
- Publication and presentation of the research findings in international renowned journals and conferences in English and German
- Development of a management cockpit for server rooms and data centers
- Prototypical implementation of an augmented sustainability report





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## Selected Publications

- Freundlieb, M. und Teuteberg, F.: Corporate Social Responsibility Reporting – A Transnational Analysis of Online Corporate Social Responsibility Reports by Market-Listed Companies: Contents and their Evolution; in: International Journal of Innovation and Sustainable Development, Volume 7, Issue 1, 2013, pp. 1–26.
- Freundlieb, M.; Teuteberg, F.: Augmentierte Nachhaltigkeitsberichterstattung; in: HMD – Praxis der Wirtschaftsinformatik, Heft 286, 2012.
- Boehm, M.; Freundlieb, M.; Stolze, C.; Thomas, O.; Teuteberg, F.: Towards an Integrated Approach for Resource-Efficiency in Server Rooms and Data Centers; in: Tuunainen, V.; Nandhakumar, J.; Rossi, M.; Soliman, W. (Eds.): Proceedings of the 19th European Conference on Information Systems (ECIS) – ICT and Sustainable Services Development, Helsinki, 2011.

## Göttingen University

Planning and designing competitive and environmentally friendly products and production processes presents a challenge for industrial production. Besides the usual business objectives, the scarcity of raw materials also makes increasing demands on resource efficiency.

In the context of modelling and optimizing production and logistics systems we develop material and energy flow models to depict production systems along selected value creation chains. They can contribute to improving resource efficiency on the business level and analyze the effects of the emission reduction options during the preparation of investment decisions.

To make specific predictions regarding the establishment of bio energy villages and other bio energy projects, meaningful and quantifiable valuation criteria are formulated in a joint project for the Ministry of Science and Culture of Lower Saxony for a sustainable usage of energy and biomass. With the help of multi-criteria decision support approaches and by means of perception psychology methods, these valuation criteria are intensified in a decision-oriented manner.

Industrial emergencies can suddenly occur and require coherent and effective contingency management. Complex decision-making situations arise in situations of the industrial risk management that require consideration of technical, economic, ecological, socio-psychological and political aspects. Reliable model predictions are an essential prerequisite for effective emergency planning measures. Strategy combinations are modelled on this basis and can be subsequently evaluated according to their respective advantages and disadvantages.



### Prof. Dr. Jutta Geldermann

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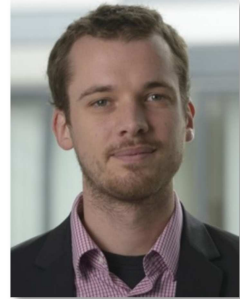


GEORG-AUGUST-UNIVERSITÄT  
 GÖTTINGEN

## Dipl.-Wirt.-Ing. Henning Gösling

### Activities

Henning Gösling became part of the “IT-for-Green”-Team in May 2011. In the project, he develops a tool for SME to quantify their environmental impacts (Module Green Production & Logistics).



### Selected Publications

- Gösling, H., Hausmann, M., Renatus, F., Uphoff, K., Geldermann, J.: Praxisorientierte Entwicklung einer Ökobilanzierungssoftware für KMU, in: Marx Gómez, J., Lang, C., Wohlgemuth, V. (Hrsg.): IT-gestütztes Ressourcen- und Energiemanagement. Konferenzband zu den 5. BUIS-Tagen Teil II, Springer-Verlag, Berlin, 2013, pp. 131-144.
- Renatus, F., Gösling, H., Geldermann, J.: Betriebliche Umweltinformationssysteme der nächsten Generation, in: Renatus, F., Kunze, R., Karschin, I. Geldermann, J., Fichtner, W. (Hrsg.): Entscheidungsunterstützung durch Operations Research im Energie- und Umweltbereich, Shaker Verlag, Aachen, 2012, pp. 76-89.
- Rapp, B.; Vornberger, J.; Renatus, F.; Gösling, H.: An Integration Platform for IT-for-Green: Integrating Energy Awareness in Daily Business Decisions and Business Systems, in: Donnellan, B., Lopes, J.P., Martins, J., Filipe, J. (Eds.): Proceedings of the 1st International Conference on Smart Grids and Green IT Systems (SmartGreens 2012), SciTePress - Science and Technology Publications, 2012, pp. 226-231.



## Fabian Renatus, M.Sc.

### Activities

Fabian Renatus (M.Sc. in Business Information Systems) is part of the IT-for-Green project since May 2011. He is working on the development of a multi-criteria decision support method for small and medium sized enterprises which supports the sustainable alignment of business process in a fast and cost efficient manner.

### Selected Publications

- Renatus, F., Geldermann, J.: Multi-Criteria Decision Support within Corporate Environmental Management Information Systems, in: Geldermann, J., Schumann, M. (Hrsg.): Resource Efficiency in Interorganizational Networks, Universitätsdrucke Göttingen, Göttingen, 2013, pp. 338-349.
- Gösling, H., Hausmann, M., Renatus, F., Uphoff, K., Geldermann, J.: Praxisorientierte Entwicklung einer Ökobilanzierungssoftware für KMU, in: Marx Gómez, J., Lang, C., Wohlgemuth, V. (Hrsg.): IT-gestütztes Ressourcen- und Energiemanagement. Konferenzband zu den 5. BUIS-Tagen Teil II, Springer-Verlag, Berlin, 2013, pp. 131-144.
- Renatus, F., Gösling, H., Geldermann, J.: Betriebliche Umweltinformationssysteme der nächsten Generation, in: Renatus, F., Kunze, R., Karschin, I. Geldermann, J., Fichtner, W. (Hrsg.): Entscheidungsunterstützung durch Operations Research im Energie- und Umweltbereich, Shaker Verlag, Aachen, 2012, pp. 76-89.

## Partners



### CEWE Stiftung & Co. KGaA

The photo and online print service company CEWE, with 11 highly-technical production operations and a staff of around 3,200 employees in 24 European countries, is both market and technological leader. In 2013 CEWE delivered

around 2.37 billion prints, 5.8 million copies of the CEWE PHOTO BOOK and photo gift articles to more than 30,000 retail partners to generate consolidated turnover of 528.6 million euros. CEWE is a "first mover" in the introduction of new digital technologies and products. In the new business segment of online printing, printed material for advertising is marketed through the sales platforms [CEWE-PRINT.de](http://cewe-print.de), saxoprint and viaprinto. In 1961 CEWE was founded by Senator h. c. Heinz Neumüller. The company went public under the leadership of Hubert Rothärmel in 1993. CEWE Stiftung & Co. KGaA is listed on the SDAX.

**Sustainability:** CEWE was one of the first companies listed on the SDAX (Germany's stock market index for SMEs) to produce a transparent sustainability report: for the last five years, CEWE has been reporting on and documenting sustainability activities in an annual sustainability report based on the current guidelines recommended by the Global Reporting Initiative (GRI).

More information at <http://company.cewe.de/de/unternehmen/nachhaltigkeit.html>

During the project various studies were conducted in cooperation, e.g. to make the use of information and communication technology (ICT) eco-and resource-efficient (Module 1: Green IT) and concrete development work for a practical Life Cycle Assessment (LCA) Software for SMEs (Module 2: Green Production & Logistics).

### erecon AG

In 2003, Harald Rossol, founder of erecon AG, set himself a dedicated goal. As managing director of the technology and management company b.r.m. business resource management he wants to transform his server room into a "one-percent computer centre" within the next years. Today, the company has already reduced its energy consumption by almost 2/3 (65%) since 2003 – with increasing tendency. Since 2008, erecon AG has put its skills in the area of Green IT to good use in the form of consulting services nationwide.



Guided by the concept of Green IT erecon AG is uniting server architecture, building management and air conditioning into an innovative, integrated system that brings double profit: on the environment and for the balance of the company. With our consulting expertise we approach companies, public services and other institutions, which

operate data centers and server rooms. In essence, it's about optimizing all information and communication processes with the help of a contemporary eco-friendly, energy-efficient and climate-friendly green IT - while at the same time that Green IT relieves all users significantly on the cost side. Green IT requires a holistic approach to act sustainable and cost-efficient.

In January 2010 the optimization and upgrading of four data centers in Bremen (by erecon AG) was awarded, with the label of "Good Practice in Energy Efficiency" by the German Energy Agency (dena) in the category of object-related projects. With its commitment to sustainable climate protection erecon AG is a member of the "Green IT-Alliance" between the German Government, industry and science.

Since 2011 erecon AG is partner of the "business partnership for environment" network. Together with seven other members the climate fund "environment businesses human nature" was launched. As Germany's first company in the field of information and communication technologies erecon AG is now officially bearing the "Blue Angel for energy efficient data centers" in the company's appearance. erecon AG awarded the 2<sup>nd</sup> prize of the "Energy Efficiency Award 2013". The company implemented a variety of energy efficiency activities systematically and reached a high reduction in power consumption (in spite of higher work load).



### Gemeinde Spiekeroog

Spiekeroog is absolutely independent municipality. In addition to the mayor eight women and men are representatives for about 750 citizens of the municipality in the council. All of the important departments are represented in the town hall of Spiekeroog. The municipality is responsible for the kindergarten and primary school. They have a volunteer fire brigade. Sport clubs, sailing club, museum association and a club for special German type of sport named "Klootschießen" ensure a living together in solidarity and sociability and contribute significantly to feeling of togetherness and belonging of the islanders. Two active church municipalities give Spiekeroog the

expression "island of church" and are also responsible for a good living on Spiekeroog. New citizens are always welcome. Everyone would be integrated specially for employers who works there for a fixed period.

Sustainability is important for Spiekeroog. Spiekeroog is a partner of the biosphere reserve at the administration of the National Park Wadden Sea of Lower Saxony and coshareholder of the "Umweltzentrums Wittbülten" (centrum for environmental in Wittbülten). Spiekeroog is also member of Trustees environmental Foundation of Spiekeroog. The municipality participate also in research projects like in this case "IT-for-Green".

Spiekeroog knows their responsibility for environmental, for tourists and guests and for the citizens which lives on this island and tries to harmonize the different reconstruction



efforts. Since 2011 is Spiekeroog one of the industrial partners of the project It for Green and their main focus is on the module sustainability reporting and dialogue.

More information: <http://www.spiekeroog.de/inselinfo/gemeinde-spiekeroog.html>

### Hellmann Worldwide Logistics GmbH & Co. KG



Founded in 1871, the company started with one man, Carl Heinrich Hellmann, using a horse-drawn cart to deliver parcels in and around the town of Osnabrueck, northern Germany. Four generations later, Carl's great-grandchildren, Jost and Klaus, own and run the company with an active network in 157 countries. Today Hellmann operates a truly global organization while remembering our humble beginnings: they continue to value every customer and understand that each project requires a unique solution. This powerful combination of an individual approach within an international framework ensures that Hellmann delivers top-quality customized logistics solutions, every time.

Different international Logistic Solutions are offered including different modes of transport, such as Air and Sea transports as well as Rail and Road transports.

Further activities as an extensive range of CEP services, contract logistics and specific solutions for industry branches and IT as well as recycling solutions, training and insurance services, are part of the company's portfolio.

For a globally active company such as Hellmann Worldwide Logistics, the development of economic interests is inherently connected to their responsibility for the environment, and the idea of sustainable development has long been our focus. At Hellmann, they are committed to working within a structured system of environmental management using task-oriented methods, continuous self-monitoring, and regular external auditing.

Hellmann Worldwide Logistics supports the UN Global Compact.

“Optimizing our logistic processes regarding Efficiency and Sustainability is a core objective of our company and firmly established in our mission statement, the corporate D.N.A. Our IT systems are an important and indispensable part of logistic processes. Because of that IT-for-green supports our efforts in measuring, controlling and minimizing the carbon footprint of our IT systems.“

More information: [http://www.hellmann.de/de/ueber\\_hellmann/ueber\\_hellmann](http://www.hellmann.de/de/ueber_hellmann/ueber_hellmann)



EUROPÄISCHE UNION  
Europäischer Fonds für  
regionale Entwicklung



## NOWIS Nordwest-Informationssysteme GmbH & Co. KG

NOWIS is a specialist for IT-based process optimization. As a member of the VRG group NOWIS is consistently

focused on consulting and serving midmarket organizations for over 49 years. On these capabilities organizations from very different industries and sectors rely on – manufacturing and process industry, service companies and public institutions.

The NOWIS business model is holistic. With the portfolio of consulting and solution for medium sized enterprises NOWIS offered one of the most comprehensive service and product ranges. NOWIS analyzes existing processes and is implementing quickly and inexpensively customized IT solutions.

As a company and employer NOWIS bears great responsibility for people and the environment: With investments in new air-conditioning solution and optimization of cooling NOWIS ensures a resource-saving operation of modern server centers.

Flexible working hours and a comprehensive range of sporting activities in cooperation with Hanse Fit are results for a good work life balance of their employees. The supply chain management attaches great importance to the reduction in CO2 emission. Sustainable success – this is the main goal of NOWIS!

NOWIS is participating as a practical partner in the research project:

- For NOWIS as a data center operator is the overview about management, IT, energy and air-conditioning systems and continuous improvements in energy management important.
- NOWIS still has the focus on the sustainability reporting and on pragmatic support to the distribution of important information for the report.

More information at <http://www.vrg-gruppe.de/> and [www.nowis.de](http://www.nowis.de)

## ertemis

An additional supportive partner of the research project IT-for-Green is the innovation network **ertemis** (European Research and Transfer Network for Environmental Management Information Systems). The network bundles expertise in the field of corporate environmental management and provides knowledge about: Information Systems, Business Administration, Ecology, Economics and Computing Science. The network's objective is to support partners from industry in tackling new challenges of Environmental Management.



Ertemis is transdisciplinary partner of the research project and supports a bi-directional knowledge transfer between practitioners and scientists. Various joint activities were done:

- Research papers were created and developed together – with topics such as: "Methods of Carbon Footprinting - An analysis of the solutions to an internationally operating manufacturer or cable"; "Sustainable measurement at the local level – development of a list of measurement-indicators" etc.
- In addition the network participants were invited to numerous events of the collaborative project (CeBIT 2012 and 2013, Oldenburg CEMIS days in April 2013, EnvirolInfo 2014 etc.). Different project-related aspects were discussed during these events.
- In different research and development contexts (e.g. "Sustainable Water Management") joint research proposals were attempted.

For more information visit <http://www.ertemis.eu/ertemis/>



## SAP University Competence Center

The SAP University Competence Center (SAP UCC) Magdeburg was established by its project partners SAP AG, Hewlett Packard (HP), T-Systems CDS GmbH and Otto von Guericke University Magdeburg in June 2001. Today, approximately 450 German and international educational institutions – mainly universities, universities of applied sciences and vocational schools – are provided with hosted SAP solutions for teaching and research. During the last 13 years and based on their SAP licenses for teaching and research, almost 4,000 lecturers have incorporated innovative teaching material developed at SAP UCC Magdeburg

into their courses. In April 2014, SAP UCC Magdeburg was announced the first SAP Big Data Innovation Center and is providing international educational institutions with SAP solutions based on the in-memory technology SAP HANA.

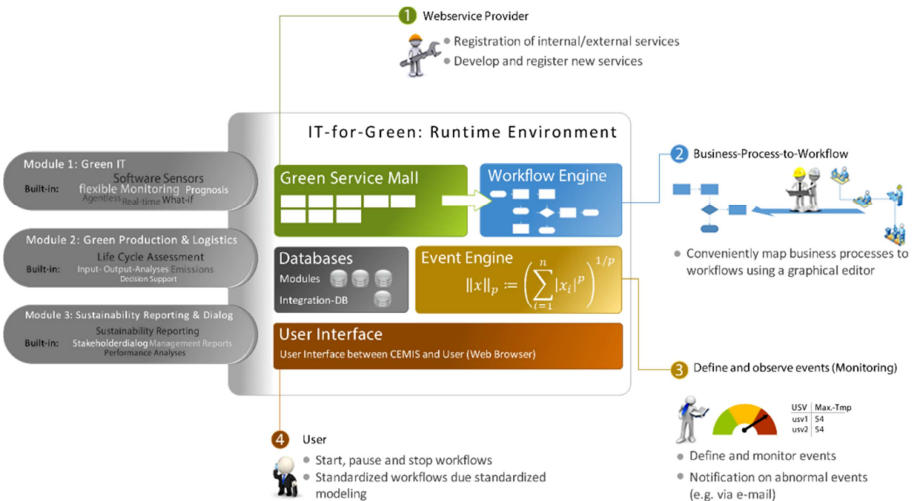
Weitere Informationen unter: <http://www.sap-ucc.com>

# Core

## IT-for-Green Runtime Environment

The IT-for-Green CEMIS, as next generation of current solutions, is built in a modular manner whereby service orientation is a major conceptual design. Service oriented means that the smallest units of the CEMIS modules are realized as services (called Green Web Services). These services are published in the so called Green Service Mall (service registry). Following the service orientation will improve functionality via integration of new or modified services. Missing functionality can be developed by companies themselves and integrated in the IT-for-Green CEMIS.

The runtime environment is the central element of the next generation CEMIS and is made available on a web server. The following figure shows the architecture of the CEMIS with a focus on the runtime environment.



Primarily, the runtime environment provides possibilities to integrate new services through a Web Service Provider (1) besides modelling (2) and execution (4) of workflows. The execution of the workflows is managed by a Workflow Engine. Monitoring activities and further actions for specific events within the runtime environment can be defined using the Event Engine (3) such as temperature excess of a threshold value in a data center.

Using such a composition (via a graphical user interface) enables a better discovery of internal business processes of organizations and the selection and invocation of Green Web Services that are published in the Green Service Mall. The workflow editor makes use of Web Services registered in the Green Service Mall regardless of their origin (whether they have been created internally in the company or externally). Web Service providers can be either external entities or internal providers who develop customized services and make it available by publishing it in the Green Service Mall.

The Green Service Mall is the central part of the service oriented platform. This component provides a set of “yellow pages” and makes them available on the web. All the services developed in the CEMIS modules are advertised as services in these yellow pages. The workflow editor can then orchestrate different workflows by discovering, selecting, and invoking these services. In summary, the Green Service Mall supports all the service phases from discovery to invocation.

The user interface is operated using any kind of web browser. In particular, the execution of workflows is done using the user interface. Workflows can directly be started, paused and stopped from a web browser. Another advanced part of the user interface is a dashboard that is responsible of monitoring the defined events and the Green Service Mall (presented as a catalog of services and groups of services classified based on specific criteria).

Rights and Roles System Authorizations for specific functions and areas can be granted using the rights and roles system that is responsible of issuing rights and roles for services. The rights and role system does not only restrict the access to individual services, rather it hides the information from the unauthorized users (or groups).

## Module 1: Green IT

Module 1 of the project is concerned with energy efficiency of Information and Communication Technology (ICT) equipment. It aims at providing the tools and the procedure enabling a (semi-)automatic measurement of ICT energy efficiency exemplified in data centers. Such measurement allows detecting various energy saving potentials that result from different factors such as suboptimal load management or underutilization of servers and other components.

The module examines two example scenarios: a data center of a Small and Medium Enterprise (SME), and another of a large enterprise. Two scenarios were used in order for the results to be relevant for a wider range of company sizes.

In order to estimate the energy demand of IT components, we need to build a suitable measurement infrastructure. The highest energy demand lies in the IT components, the cooling system, and the Uninterruptible Power Supply (UPS) units. In both Data Centers (DCs), the UPS is connected to the IT components whereas the cooling system is within a parallel power network. Measurement points are set therefore before and after the UPS and before the cooling system. The aggregated energy demand after the UPS serves as a control value for the measurement points on the servers and racks.

A measurement infrastructure was built in the data center of the VLBA department, which resembles a data center of a Small and Medium Enterprise (SME). Using smart Power Distribution Units (PDUs), energy demand of single servers. On the other hand, a measurement infrastructure is already available in the DC of CeWe Stiftung. Measurement of energy demand of single servers is not possible in this scenario, instead measurements are made on the Racks granularity level. For the cooling system, measurement points are installed on the ventilation cabinets as well as on the chillers. Moreover, temperature sensors are installed which measure temperature of the outside environment, the cold aisle, and the warm area inside the DC.

For both DCs utilization of single servers is collected and related to the other measurements. A static virtualization is applied in the VLBA DC which means that several services that are encapsulated in Virtual Machines (VMs) operate on the same hardware server. However, a higher density of VMs could be achieved through a dynamic virtualization approach. To achieve that a detailed measurement and analysis of the resource utilization of single VMs and services is required.

Servers of CeWe Stiftung function as clusters which are used to operate single services each composed of several processes. Each process is replicated on several servers so that the load generated from requests can be balanced on them. Since the servers are oversized, their average utilization stays on a very low level. A higher density of services per physical server could have been achieved without loss of performance and more than 40% of the energy could have been saved as a result. However, such savings on the IT energy demand could lead to a worse Power Usage Effectiveness (PUE) when not accompanied with corresponding savings on the infrastructure's energy demand. Most prominent infrastructure energy demand is the cooling system, and it is also oversized in this scenario in terms of keeping one chiller always on regardless of the outside temperature and the IT components' energy demand repre-

sented by the produced heat. This lack of adaptivity of the cooling system would make any effort to reduce IT energy demand negatively influence the PUE. Moreover, it has been determined that optimizing the installation of the sensors for the outside temperature and the warm area inside the DC results in higher significance of the measurements. Large room for improvement was found in the extraction and preparation of measurement data. These improvements, when implemented, will decrease redundancy in data, improve its quality, and facilitate access and analysis.

Based on the collected measurement data, different components in both data centers (except the cooling system) were represented in a way that allows an energy demand simulation of the data center. A matter of a major importance for deploying load and power management systems, and examining what-if scenarios.

A data center simulation framework was elaborated within this module to be part of a larger Corporate Environmental Management Information System (CEMIS) solution. This framework was developed in three iterations that resulted in three prototypes. The main design requirements were flexibility and high interoperability; therefore we have taken great care in choosing appropriate open standards where applicable, and a flexible architecture for the framework.

This also led to the decision of utilizing an ontology of the data center as the foundation of the simulation framework. The main goal here is to have as few hardcoded components in the framework as possible, and instead derive them from a central external source (the ontology). Evolving the framework is then a simple matter of updating this source and having the updates propagate throughout the rest of the system. Among other things, a toolbox is derived from such an ontology for a graphical editor. This editor can then be used to model an existing data center to prepare for a simulation.

The editor was based on the graphical editor “Visual Understanding Environment (VUE)” in the first two iterations and on “Dia” in the third. It features the dynamic generation of the toolbox, and allows the designer to place instances of the components onto a canvas and to specify relations among them (e.g. heat exchange, electric energy exchange). The user does not necessarily have to start from scratch for this task, as it is also possible to import Comma Separated Values (CSV) files of data center inventory, which can be used as a starting point to quickly model an existing data center. After finishing the design, the user can run consistency checks on it. These are both syntactic checks (e.g. every server needs to have a label) as well as more complicated semantic checks. An example for the latter would be assessing the requirement, specified in the ontology, that every server needs to be at the receiving end of at least one power relation. After ending up with an error-free data center design, the workflow goes further into generating an operational model out of the design in the form of Modelica code. The third iteration of the prototype allows running this model directly from the editor by connecting to an OpenModelica server. The operational model can be run with live load measurements as input stream, outputting energy consumption and exhaust heat production at each component without the need to measure them. It can be run on historical or presumed load data as well with the aim of examining different what-if scenarios.

## Module 2: Green Production & Logistics

Module 2 is divided into three sub-modules, which can be used according to the requirements of the user. The first sub-module “Green Production” offers the possibility to analyze production processes, whereas the sub-module “Green Logistics” is helping to analyze logistics processes. The third sub-module “Decision Support” provides a way to solve multi-criteria decision problems with the help of the PROMETHEE method.

### *Green Production*

Production processes can comprise several inputs and outputs with an impact on the environment. Inputs are often separated into energy and material while outputs are distinguished into waste, air, water and soil emissions. In this part of module 2, the goal was to develop a software tool for life-cycle analysis. This tool should help SME to quantify the relevant inputs and outputs of their products, especially the inputs and outputs of the production processes within their sphere of influence (gate-to-gate analysis). In order to specify the requirements for such a tool, an exemplary gate-to-gate analysis was conducted together with one of the project partners, the CEWE Stiftung & Co. KGaA. The results of the study can be found in one of the publications.

The user of the tool is able to record the inputs and outputs of relevant production processes and associated machines as completely and systematically as possible. The generation of power, the manufacturing of materials or the processing of waste can be broken down into certain inputs and outputs as well. In order to incorporate these into the calculation, the corresponding suppliers and waste management companies must have the data and also the willingness to provide the data. If the data is not available, publicly available LCI-databases can be accessed. For this purpose, the user of the tool can access the LCI-databases of the German Federal Environmental Agency (Probas) and of the EU Commission (ELCD). To determine the environmental impacts of the recorded production processes, the user can use established impact assessment methods.

### *Green Logistics*

The climate change has a crucial impact on haulers and companies that are dependent on logistic processes. A rising number of customers include environmental aspects into their buying decisions. The transportation of goods from manufacturers to customers plays an important role in this regard. Additionally, legislators aggravate legal requirements. In this context, the German Institute for Standardization (DIN) has published the DIN EN 16258:2013, which can be used as a general guideline to quantify the greenhouse gas emissions and energy consumptions of transport services.

The Green Logistics sub-module offers companies a user friendly implementation of that particular DIN guideline. On the one hand, the software will help to record all logistics processes and determine their environmental impacts. Additionally, certain allocations allow the calculation of environmental impacts of goods. On the other hand, the software will support companies to decide which mode of transport (truck, train, ship, or



airplane.) is the most environmental friendly on the basis of energy consumption and greenhouse gas emissions.

### *Decision Support*

The previously described sub-modules are able to identify weaknesses in the companies' operations, for instance excessive pollution due to old production technologies. The company then faces strategic decisions that are characterized by high investments and a certain specificity, which make it hard to include experiences from the past. Therefore, a well-structured decision process is required. The decision support sub-module offers this service.

Decisions in a business context are usually characterized by a variety of goals, which may contradict each other. Multi-criteria decision aiding methods such as PROMETHEE, which is used within the software, are able to address this issue and lead to satisfactory solutions. The software supports the user in defining the criteria that the decision will be based on, allows a clear input of the data that describes the possible alternatives, offers a graphical evaluation of the results and an examination of their stability with the help of a sensitivity analysis. Furthermore the software offers the possibility to integrate other decision support methods.

### Module 3: Sustainability Reporting & Dialogue

The third module of the IT-for-Green Project “Sustainability Reporting & Dialogue” implements the functionality to support the process of sustainability reporting of a company by a service-oriented CEMIS solution.

The module Sustainability Reporting & Dialogue is implemented as a composition of web services that can be integrated and combined through the IT-for-Green runtime environment and its functionality with the other modules and web services. In this form the individual workflows form corporate business processes. The composed workflows allow two types of use:

- Direct interaction with users via a web browser (HTML)
- Exchange of information of web services with each other via the runtime environment

Moreover, the web services are invoked either by other services or directly via a user interface. For the direct interaction of a user with a web service a web browser is required to use the implemented user interface. Direct communication of web services is carried out via a workflow context, which acts as a common data storage and allows storing and removing of data values.

The primary objective in the module is to generate a pre-press sustainability report, which can be processed into a printed sustainability report with reasonable efforts. Environment-related information can be gathered supported by the software as central acquisition point and be used in the sustainability reporting process. Theoretical studies and expert interviews during the project were conducted to fulfil the project. As results, business requirements, e.g. process requirements concerning review phases and further concepts, were collected focusing communication processes.

The third module of the IT-for-Green solution particularly supports the following processes of reporting:

- Reduction of existing complexity of the data collection (through a centralized information collection and management)
- Reduction of organizational efforts of the overall process by developing a procedure for schema-based sustainability reporting

The core areas of the IT-for-Green solution in the third module are company management, data management, integration of standards, schema-based structure, reporting and review concept.

Locations have to deliver information for the process of sustainability reporting, due to that they are included in the company's internal reporting which is the database of sustainability reporting. Therefore, necessary information, such as indicators or statements, have to be gathered for filling out the so-called “standard”, combination of indica-

tors and statements depending on company's requirements and of guidelines to be supported such as GRI G4 chosen by the company. Lists of indicators can be redefined for each location to be filled with content and updated via data management. Also, comparison of indicators across different reporting periods is possible.

The main element in the IT-for-Green module "Sustainability Reporting & Dialogue" is the so-called standard element. A standard includes all required and optional statements and indicators. In the IT-for-Green project we chose the Global Reporting Initiative G4 guideline as a base for the exemplary implementation of the process of sustainability reporting. As part of the standards, a catalog of performance indicators has been defined by the GRI, which was taken as examples in the prototypical implementation. The data model of the third module allows mapping and integration of all common standards. A standard consists of a list of guidelines. Taking GRI G4 as example requires general and specific disclosures such as statements and indicators. On the other hand United Nations Global Compact requires only principals. One or more indicators can support the meaning of a statement. Textual statements are statements about a specific policy, which are made by the rapporteurs. Indicators demonstrate a specific quantity (quantitative) and factual based (qualitative) measure of entrepreneurial performance. Once a company has identified all relevant content for coverage, substantive aspects contained in the defined structure can be converted into the schema of the report by the IT-for-Green solution. The scheme is based on a selected standard and serves the rapporteurs as a kind of template or a guideline and reflects requirements that were defined in advance (table of content, or quantitative and qualitative information).

Within a schema reporting levels can be defined to reflect chapters, which are written in the later report. Each reporting level can have an unlimited number of further sub-report levels, thereby allowing any document structure as required from the reporting company. In addition, a blank report is generated by the system based on the predefined and selected scheme. In the next step the blank report will be filled up with information and the report structure can be changed if necessary. The report structure is a 1:1 copy of the schema into a blank report including insertion of reporting guidelines (statements, such as preface of CEO, and indicators, such as standard disclosures of GRI G4 with "EN1") created by the IT-for-Green solution. In this process for each indicator or statement in the schema an article in the 1:1 copy is created to be filled out in the next step. Each article can be edited and changed as necessary by editors to insert content.

As a final step in the sustainability reporting process a multi-level review phase has to be supported by the IT-for-Green solution. Therefore, a review concept for the schema and the report is supported to check (1) the schema before locations and editors are informed inserting content and (2) the report. The report is checked on its correctness and completeness by responsible persons, the report has three different status: in progress, in review and final. Further status and review-levels can be added if necessary at any time by the reporting companies.

## Selected Artifacts

### Market Study BUIS Software

This portal provides a comprehensive view of corporate environmental management information systems (CEMIS). Software vendors are able to use the portal as a "platform" in order to present their products and to enable interested parties to inform themselves in a structured way. Link

to the portal: <http://www.buis-software.com>

### Maturity Model for the Sustainable Supply Chain Management

Model for the maturity assessment of the sustainable supply chain management within companies. Here, the focus not only lies on the recycling (reverse logistics / closed-loop), but processes along the entire supply chain are considered. Link to the model: <http://sscm.ertemis.eu>

### Environmental Management Assessment and Benchmarking (EMAB) Portal

The EMAB Portal from the research group in Accounting and Information Systems from the Osnabrück University shows how environmental management can be measured and benchmarked without having to get an inside view on this wide field. Link to the portal: <http://emab.ertemis.eu>



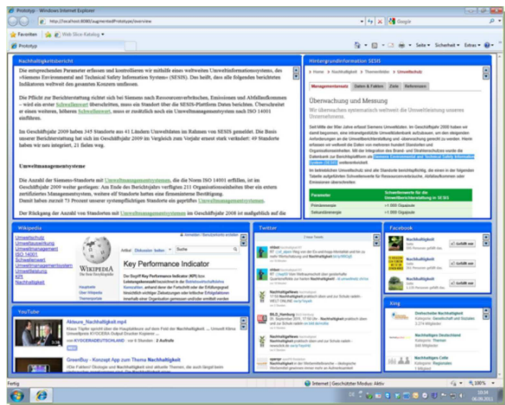
## Online Sustainability Report for Hellmann Worldwide Logistics

The existing sustainability report from Hellmann Worldwide Logistics, which was available only as a static PDF document, has been transformed into an online sustainability report with many additional features (e.g., an interactive key performance indicator comparison, a glossary function with additional information on specific keywords and the possibility to create a personalized sustainability report based on the

wide range of information). In addition, a systems was developed and implemented that facilitates and considerably accelerates the collection of relevant data from the numerous branches of Hellmann Worldwide Logistics for the preparation of a consolidated sustainability report.

## Augmented Sustainability Reports

Design, prototypical implementation and evaluation of augmented sustainability reports, in which automatically additional multimedia information to the content of the report is presented according to the user's reading position. In contrast to the existing practice of sustainability reporting also external sources of information are integrated.



## Management and Consulting Cockpit for Server Rooms and Data Centers

A hybrid package of products and services which ensures the energy efficient planning, realization and operation of IT infrastructure. It is based on two industry workshops with more than 60 participants from science and practice and on semi-structured interviews with 8 experts.

## Quarterly Meetings



## IT-for-Green on Tour

### WI 2013

Matthias Gräuler presented results of his research at the largest and most prestigious conference on information systems in the in German-speaking area, the International Conference on Wirtschaftsinformatik:

- *Matthias Gräuler, Frank Teuteberg*  
**Experimental Evaluation of a Process Benchmarking Tool in a Green Business Process Management Context**

Mr. Gräuler presented the results of his evaluation and demonstrated that the concepts used for process benchmarking on the example of the environmental impact of the production of a photo book usefully supplement conventional approaches.

Once again, the conference was characterized by its academic claim and throughout interesting program. Prof. Dr. Frank Teuteberg is proud to continue this tradition in 2015, as the conference will take place in Osnabrück under his direction.

### CeBIT 2013

A higher proportion of qualified visitors, more than 120 nations and as many IT decision makers as not seen for a long time have made the CeBIT 2013 to the highest quality event of the last years. We were also on site and presented the highlights of our research during four days, e.g., to Andrea Hoops (State Secretary at the Lower Saxony Ministry for Science and Culture).



Although the main topics of this year's CeBIT were in the areas of Big Data, Shareconomy, Cloud Computing and the Internet of Things, we enjoyed interesting conversations with representatives from science and practice.

Our exhibit consisted of an interactive presentation and highlighted the interaction of the modules 1 to 3 within the runtime environment as well as the potentials for next generation corporate environmental management information systems arising from the service-oriented infrastructure. For the first time we were able to demonstrate the practical use of the components and to illustrate it in a concrete, practical scenario. The scenario followed the life cycle assessment of CEWE photo books by CEWE Color.

### BUIS-Tage 2013

From April 24<sup>th</sup> until April 26<sup>th</sup> 2013 the 5<sup>th</sup> so called BUIS-Tage (translates to CEMIS conference) took place in Oldenburg, Lower Saxony. The conference was held under the theme "IT-supported resource and energy management". A total of 55 submissions were presented in the following tracks:

- Green IT & Energy Efficiency
- Green Production & Logistics
- Material Efficiency & Recycling
- Material Flow Management
- Sustainability Management & Communication
- Sustainable Mobility
- Green Software

More than 100 participants attended the presentations by the keynote speakers Andreas F. L. Heydemann (CEWE Stiftung & Co. KGaA), Prof. Dr. Ralf Isenmann (University of Applied Sciences Munich) and Dr. Frank Köster (DLR). The CEMIS conference sees itself primarily as a forum to inform about the status quo of CEMIS and to present new ideas and solutions as well as to intensively discuss them with a panel of experts from science and practice.



## ECIS 2013

The IT-for-Green project was represented on the 21<sup>st</sup> Conference on Information Systems in Utrecht, Netherlands, with the two following contributions:

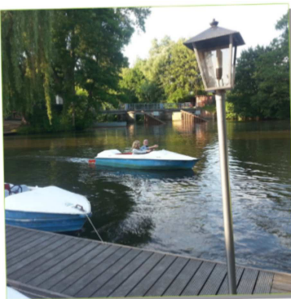
- *Florian Stiel, Frank Teuteberg*  
**Towards a Conceptual Framework for Life Cycle Assessment in Sustainable Information Systems Management**
- *Marc Walterbusch, Benedikt Martens, Frank Teuteberg*  
**Exploring Trust in Cloud Computing: A Multi-Method Approach**



Both papers ran through a rigorous review process (3 reviews per paper). In total, more than 800 papers were submitted to ECIS 2013, whereas approximately 30% were accepted (acceptance rate). The ECIS ranks among the top conference in information systems (A-ranked according to WKWI).

## ITEE 2013

From July 10<sup>th</sup> until July 12<sup>th</sup> 2013 the 6<sup>th</sup> International Conference on Information Technologies in Environmental Engineering took place in Lüneburg, Germany. During the presentations and afterwards environmental computer science, interdisciplinary and the role of information and communication technology have been discussed.



The conference dinner with a rich buffet and natural scenery set the perfect environment for further discussions on sustainable development and IT support. A prior paddle boat ride allowed for taking a deep breath and to discuss in a nice atmosphere. Contribution from the IT-for-Green project:

- *Andreas Solsbach, Barbara Rapp*  
**Municipalities and Sustainable Tourism - Challenges, Requirements and Added Value**
- *Volker Frehe, Frank Teuteberg*  
**The Role of ICT in Green Logistics – A Systematic Literature Review**

## EnviroInfo 2013

In the time between September 2<sup>nd</sup> and 4<sup>th</sup>, 2013, the EnviroInfo 2013 took place in Hamburg, Germany. At this international conference the project was represented with the following paper:

- *Andreas Solsbach, Barbara Rapp, Frank Teuteberg, Matthias Gräuler, Florian Stiel, Fabian Renatus, Jan Vornberger*  
**Environmental Footprinting in the IT-for-Green Project – A CEMIS Use Case**

## OR 2013

The International Conference on Operations Research 2013 took place in Rotterdam. Like every year there were plenty possibilities for exchange between scientists and company representatives. The conference theme was "Impact on People, Business and Society" and offered several points of contact for the IT-for-Green project. As part of the presentations the IT-for-Green decision support system was presented:

- *Fabian Renatus, Jutta Geldermann*  
**Interactive Multi-Criteria Decision Support for Corporate Environmental Management Information Systems International Conference on Operations Research**

## Informatik 2013

In the period from September 16<sup>th</sup> until September 20<sup>th</sup>, 2013, the 43<sup>rd</sup> Annual Meeting of the Gesellschaft für Informatik, short Informatik 2013, was held in Koblenz, Germany. The research group in Accounting and Information Systems (Prof. Teuteberg), Osnabrück University, was represented with four papers. No other department successfully placed so many papers at the Informatik 2013.

- *Volker Frehe, Florian Stiel, Frank Teuteberg*  
**Web-Portal und Reifegradmodell für ein Benchmarking des betrieblichen Umweltmanagements**
- *Matthias Gräuler, Frank Teuteberg*  
**Zum Beitrag von NeuroIS in der Nachhaltigkeitsberichterstattung**
- *Frank Teuteberg, Iwona Hamerski*  
**Status Quo der Risikokommunikation im Kontext von ERP-System-Einführungsprojekten**
- *Marc Walterbusch, Alexander Bosse, Frank Teuteberg*  
**Social Network Trend Indicator: Konzeption, prototypische Implementierung und Evaluation eines Stimmungsbarometers auf Basis sozialer Netzwerke**



## MKWI 2014

Between February 26<sup>th</sup> and 28<sup>th</sup>, 2014, the Multikonferenz Wirtschaftsinformatik, short MKWI 2014, was held in Paderborn, Germany. The following (partial) results of the IT-for-Green project were presented:

- *Matthias Gräuler, Frank Teuteberg*  
**Greenwashing in Online Marketing – Investigating Trust-Building Factors Influencing Greenwashing Detection**
- *Andreas Solsbach, Sebastian van Vliet, Swetlana Lipnitskaya, Barbara Rapp*  
**Nachhaltigkeitsberichterstattung als Service eines BUIS – Anforderungen an ein Schema zur Nachhaltigkeitsberichterstattung im Projekt IT-for-Green**
- *Florian Stiel, Frank Teuteberg*  
**Entwicklung praxisrelevanter IKT-Artefakte für ein betriebliches Umwelt- und Nachhaltigkeitsmanagement mittels Konsortialforschung – Implikationen des Verbundprojekts IT-for-Green**
- *Marc Walterbusch, Frank Teuteberg*  
**Datenverluste und Störfälle im Cloud Computing: Eine quantitative Analyse von Service Level Agreements, Störeignissen und Reaktionen der Nutzer**



## EMAN 2014

During the 17<sup>th</sup> EMAN conference from March 26<sup>th</sup> until 27<sup>th</sup>, 2014 Matthias Gräuler represented the IT-for-Green project in Rotterdam in front of an international audience. He presented the following paper in the session "Effects of Sustainability reporting" (Chair: Nathalie Crutzen):

- *Matthias Gräuler, Frank Teuteberg*  
**Greenwashing in Sustainability Communication – A Quantitative Investigation of Trust-Building Factors**



In addition to interesting keynotes and discussions with well-known experts in the area of sustainability many opportunities arose to make contacts outside of science.

## BUIS Tage 2014

From April 24<sup>th</sup> until April 25<sup>th</sup> 2014 in Berlin the sixth 6<sup>th</sup> BUIS-Tage conference was held. This time it was about: concepts, applications, implementations and trends in CEMIS. IT-for-Green brought in current results of a study to existing requirements for data exchange (interface problems).

- *Karsten Uphoff, Andreas Solsbach, Sebastian van Vliet, Barbara Rapp, Ralf Isenmann*  
**Nachhaltigkeitsberichterstattung – Anforderungen zum Datenaustausch aus Sicht der Praxis**

## ECIS 2014

Again, the project IT-for-Green was successful and was represented with the following completed research paper on the European Conference on Information Systems 2014 in Tel Aviv, Israel:

- *Stiel, Florian*  
**On the Use of Discrete Event Simulation in Green IS Research - Developing a Conceptual Framework**

## AMCIS 2014

At the 20th Americas Conference on Information Systems (AMCIS2014), which was held in Savannah, Georgia, between August 7<sup>th</sup> and 9<sup>th</sup>, 2014, members of the IT-for-Green project presented two papers after passing a double-blind review process:

- *Volker Frehe, Florian Stiel, Frank Teuteberg*  
**A Maturity Model and Web Application for Environmental Management Benchmarking**
- *Marc Walterbusch, Matthias Gräuler, Frank Teuteberg*  
**How Trust is Defined: A Qualitative and Quantitative Analysis of Scientific Literature**



## Roundup of reached IT-for-Green Objectives

Throughout its lifetime, the project has fulfilled concrete objectives, which were set as goals right from the beginning. Not only through its three modules and platform, but additionally through the supporting work packages which ran alongside.

The first work package is concerned with a lively transfer network. This task was accomplished along the project lifetime through own network and transfer management:

- Four times a year, an invitation to a dialogue between science and practice was sent. Among the qualitative objectives of this dialogue were suggestions and ideas for the next steps of software development, as well as informing the project partner companies and institutions directly about the status of software development.
- Additionally, in the frame of the so-called “workshops for requirements definition” intensively-present requirements were individually explored and discussed in the participating companies and institutions.
- Further dialogues with relevant (software) users were held in the frame of exhibitions and events (the project was represented in 2011 and 2013 with a stand in CeBIT). Intensive user training and briefing are planned for the end of the project.
- The transfer network will continue after the end of the project, in order to discuss current aspects of the subject, and provision further (joint) R&D activities.

With the efforts of the 2<sup>nd</sup> work package, the design of the planned software system should be developed. To this, a feasibility and requirements study was accomplished already before the beginning of the project. As a result of the study, the first requirements were documented. These (ergonomic, functional, data and information technical) requirements were discussed, developed, and supplemented along different dialogues with the project partners and finally brought together into a requirements and criteria catalog, which formed the basis for the coarse design and system development of CEMIS.

In the third work package, The IT-for-Green runtime environment, which provides a service-oriented platform for basic services of the later application scenarios of the modules, was implemented. Essential functionalities like access rights and user management system are provided by this environment, in order for the basic services to be used and extended. For this purpose, a script was supplied through which the creation of services was supported and the implementation efforts were minimized. Binding external services is supported, since their description can be retrieved and a corresponding SCXML code for using the service can be automatically generated, which stays at the disposal of the developer while binding the external service into a prototypical implementation.

The contents of work package 1 correspond to Module 1, which ended up with an approach to energy-efficient data centers (DCs) along two parallel case studies each

addressing a different size of enterprises. Measurement infrastructures of both DCs were assessed, established, and measurements of loads (utilization), powers, and temperatures were collected. Measurements led to creation of energy models of different components in addition to recognition of energy saving potentials.

Moreover, module 1 resulted in a prototypical implementation of software tools that support various activities for modeling the DC and its composing components. A metamodel defining the DC terms and relations sets the starting point, a DC graphical editor utilizes the metamodel as a toolbox and allows to instantiate, lay out, and connect the components to form both a graphical and an operational model. In order to simulate energy flow in a DC, models of single components are required. These models can be built using tools developed for this purpose which measure resource utilization and combine it with energy consumption to produce energy models usable by the operational model of the DC. Open standards and open-source software were used while developing the software tools. This choice together with having a central, interoperable, (re-) usable, and comprehensive metamodel proved useful and conferred flexibility, interoperability, tool support, and freedom of usage on the framework as a whole.

Work package 5 had the aim to implement the submodules “Green Production”, “Green Logistics”, and “Decision Support”. The “Green Production” submodule offers, among others, capturing the material and energy demand of production processes and portraying them as key figures. On top of that, access to the open Life Cycle Inventory (LCI) databases Probas and ELCD is made available. The functionalities of the submodule “Green Logistics” include, beside calculating the emission of greenhouse gases and energy demand of transport services, the selection of the most environmentally friendly transport alternative. The selection is accomplished through the multiple-goals decision support method PROMETHEE, which was prepared in the “Decision Support” submodule.

In work package 6, with focus on the module “Sustainability Reporting & Dialogue”, Web Services were prototypically implemented which enable software-supported construction of sustainability reports into a prepress stage. That data model is prepared for the semi-standard of the Global Reporting Initiative G4. As a results of this work package, companies are supported by the devised solution with both the process of selection, arrangement, collection, and preparation of the content to be reported on the one hand, and the process of review and publication on the other; up to the prepress stage.

After realization of the majority of the backend functionalities in work package 3, the client-side frontend is added and upgraded in work package 7 (Completion of the Visualization Possibilities). Herewith the user is presented with standardized access onto the distributed available data, services, and diagram types, which are realized in turn as services in the platform. With the end of this work package important functions for interaction with the system are made available for the user.

In work package 8 (Generalization and Follow-Up Utilization), usefulness of the software for the end user is confirmed through a comprehensive market study. It is shown that the software is the only product capable of binding together environmentally rele-

vant contents from different business application and function domains, and enabling thereby a platform-independent access.

Regarding project management, which was accomplished through work package 9, all supportive and planning tasks in the project as well as documentation tasks (e.g. technical reports) were carried out in consultation with the end beneficiaries.

For the coordination of such a country-wide joint project, a structured organization with fixed roles and continuous communication among all project participants is required. Therefore, the project management is given the responsibility to bring the project partners together, and to direct the common goals of the joint project. For this the various instruments were employed and the paths were followed. To this belong, among others: development of media materials for the information of internal and external stakeholders of the project, conception and maintenance of the homepage ([www.it-for-green.eu](http://www.it-for-green.eu)) in both the internal and the public domains, enabling the communication among the project participants with the aid of different IT-solutions and tools (blogs, teleconferences, etc.), and finally supporting the employees in (formal-legal) correct administration and arrangement of (complex) research joint projects.



In the first and last work package in particular the ecco consulting company (as associated institute of the Carl von Ossietzky University of Oldenburg) supported the research project. ecco has a significant advisory and research focus in the context of sustainability and sustainable management and has many years of experience in management of complex projects. ecco has already advised numerous organizations in the implementation of sustainable, environmental and quality management systems. ecco is partner in numerous university research projects. For example: approaches to sustainable consumption, sustainable development for future markets and sustainable communication strategies were developed.



## Publications

1. Allam, N.; Mahmoud, T. & Gómez, J. M. (2011), Web Service-enabled Collaborative Corporate Environmental Management Information Systems, in 'Information Technologies in Environmental Engineering: New Trends and Challenges', Springer (Heidelberg), Poznan, Poland, pp. 179-188.
2. Allam, N.; Mahmoud, T.; Gómez, J. M. & Junker, H. (2011), A Central Collaborative CEMIS, in 'Energy Saving through User Scheduled Load Balancing within Service Oriented Architectures', Shaker Verlag, Ispra, Italy, pp. 683-691.
3. Bleck, F.; Wittstruck, D. & Teuteberg, F. (2011), Entwicklung und Validierung eines Reifegradmodells für das Sustainable Supply Chain Management, in 'INFORMATIK 2011: Informatik schafft Communities'.
4. Boehm, M.; Freundlieb, M.; Stolze, C.; Thomas, O. & Teuteberg, F. (2011), Towards an Integrated Approach for Resource-Efficiency in Server Rooms and Data Centers, in 'Proceedings of the 19th European Conference on Information Systems, Helsinki'.
5. Bremer, J.; Mahmoud, T. & Rapp, B. (2012), Implementing CEMIS Workflows with State Chart XML, in H.K. Arndt; G. Knetsch & W. Pillmann, ed., 'Envirolno 2012 - Part 2: Open Data and Industrial Ecological Management', Shaker Verlag, Dessau, Germany, pp. 749-757.
6. Frehe, V. & Teuteberg, F. (2013), The Role of ICT in Green Logistics – A Systematic Literature Review, in Burkhardt Funk; Peter Niemeyer & Jorge Marx Gómez, ed., '6th International Conference on Information Technologies in Environmental Engineering (ITEE2013)', Springer, Lüneburg (Germany), pp. 53-65.
7. Frehe, V., Stiel, F., Teuteberg, F.: A Maturity Model and Web Application for Environmental Management Benchmarking, In: Proceedings of the 20th Americas Conference on Information Systems (AMCIS 2014), Savannah, 2014 (accepted for publication)
8. Frehe, V.; Stiel, F. & Teuteberg, F. (2013), Web-Portal und Reifegradmodell für ein Benchmarking des betrieblichen Umweltmanagements, in 'Informatik'.
9. Freundlieb, M. & Teuteberg, F. (2012), 'Augmentierte Nachhaltigkeitsberichterstattung', HMD – Praxis der Wirtschaftsinformatik(286).
10. Freundlieb, M. & Teuteberg, F. (2012), Evaluating the Quality of Web Based Sustainability Reports: A Multi-Method Framework, in 'Proceedings of the 45th Hawaii International Conference on System Sciences', pp. 1177-1186.
11. Freundlieb, M. & Teuteberg, F. (2013), 'Corporate Social Responsibility Reporting - A Transnational Analysis of Online Corporate Social Responsibility Reports by Market-Listed Companies: Contents and their Evolution', International Journal on Innovation and Sustainable Development.
12. Freundlieb, M.; Gräuler, M. & Teuteberg, F. (2013), 'A Conceptual Framework for the Quality Evaluation of Sustainability Reports', Management Research Review 36(11).
13. Gössling, H.; Hausmann, M.; Renatus, F.; Uphoff, K. & Geldermann, J. (2013), Praxisorientierte Entwicklung einer Ökobilanzierungssoftware für KMU, in Jorge Marx Gómez; Corinna Lang & Volker Wohlgemuth, ed., 'IT-gestütztes Ressourcen- und Energiemanagement', Springer Berlin Heidelberg, Berlin and Heidelberg, pp. 131-144.
14. Gräuler, M. & Teuteberg, F. (2013), Ergebnisse einer qualitativen Befragung zur Gestaltung von Nachhaltigkeitsberichten, in 'Proceedings der 15. Tagung der Fachgruppe Betriebliche Umweltinformationssysteme der Gesellschaft für Informatik e.V. (5. BUIS-Tage)'.
15. Gräuler, M. & Teuteberg, F. (2013), Experimental Evaluation of a Process Benchmarking Tool in a Green Business Process Management Context, in 'Proceedings der Wirtschaftsinformatik'.
16. Gräuler, M. & Teuteberg, F. (2013), Zum Beitrag von NeuroIS in der Nachhaltigkeitsberichterstattung, in 'INFORMATIK 2013: Informatik angepasst an Mensch, Organisation und Umwelt; 43. Jahrestagung der Gesellschaft für Informatik e.V. (GI)'.
17. Gräuler, M.; Freundlieb, M.; Ortwerth, K. & Teuteberg, F. (2013), 'Understanding the Beliefs, Actions and Outcomes of Sustainability Report-

- ing: An Experimental Approach', *Information Systems Frontiers* 15(5).
18. Gräuler, M.; Martens, B. & Teuteberg, F. (2011), IT-Sicherheitsmanagement im Cloud Computing – Entwicklung und Implementierung einer Ontologie, in 'Proceedings zur INFORMATIK 2011: Informatik schafft Communities'.
19. Gräuler, M.; Teuteberg, F.: Greenwashing in Online Marketing – Investigating Trust-Building Factors Influencing Greenwashing Detection, In: Proceedings der Multikonferenz Wirtschaftsinformatik 2014, Paderborn, 2014.
20. Gräuler, M.; Teuteberg, F.: Greenwashing in Sustainability Communication – A Quantitative Investigation of Trust-Building Factors, In: Environmental and Sustainability Management Accounting Network (EMAN) Conference, Rotterdam, 2014.
21. Gräuler, M.; Teuteberg, F.; Mahmoud, T. & Marx Gómez, J. (2012), Anforderungspriorisierung und Designempfehlungen für Betriebliche Umweltinformationssysteme der nächsten Generation – Ergebnisse einer explorativen Studie, in 'Multikonferenz Wirtschaftsinformatik', pp. 1531-1543.
22. Gräuler, M.; Teuteberg, F.; Mahmoud, T. & Marx Gómez, J. (2013), Requirements Prioritization and Design Considerations for the Next Generation of Corporate Environmental Management Information Systems - A Foundation for Innovation', *International Journal of Information Technology and the Systems Approach* 6(1).
23. Mahmoud, T.; Marx Gómez, J.; Rezgui, A.; Peters, D. & Solsbach, A. (2012), Enhanced BI Systems with On-Demand Data Based on Semantic-Enabled Enterprise SOA, in 'Proceedings of the 20th European Conference on Information Systems, Paper 184'.
24. Martens, B. & Teuteberg, F. (2011), 'IT-Outsourcing in Unternehmen der Recyclingbranche – Eine Studie zum Status Quo', *Information Management & Consulting* 26(2), 79-86.
25. Martens, B. & Teuteberg, F. (2011), Risk and Compliance Management for Cloud Computing Services: Designing a Reference Model, in 'Proceedings of the Seventeenth Americas Conference on Information Systems, Detroit, Michigan'.
26. Martens, B. & Teuteberg, F. (2011), 'Vom IT-Outsourcing zum Cloud Computing – Eine Fallstudie zur Anwendung der Szenariotechnik, Teil 1: Motivation und Fallstudienbeschreibung', *WiSt – Wirtschaftswissenschaftliches Studium* 40(5), 272-274.
27. Martens, B. & Teuteberg, F. (2012), 'Decision-Making in Cloud Computing Environments - A Cost and Risk Based Approach', *Information Systems Frontiers*, 1-23.
28. Martens, B.; Pöppelbuß, J. & Teuteberg, F. (2011), Understanding the Cloud Computing Ecosystem: Results from a Quantitative Content Analysis, in Schwabe G. Bernstein, A., ed., 'Proceedings of the 10th International Conference on Wirtschaftsinformatik WI 2.011', pp. 466-476.
29. Martens, B.; Teuteberg, F. & Gräuler, M. (2011), Design and Implementation of a Community Platform for the Evaluation and Selection of Cloud Computing Services: A Market Analysis, in 'Proceedings of the 19th European Conference on Information Systems'.
30. Martens, B.; Walterbusch, M. & Teuteberg, F. (2012), Costing of Cloud Computing Services: A Total Cost of Ownership Approach, in 'Proceedings of the 45th Hawaii International Conference on System Sciences', pp. 1563-1572.
31. Martens, B.; Zarvic, N.; Teuteberg, F. & Thomas, O. (2011), Designing a Risk-based Partner Selection Process for Collaborative Cloud Computing Environments, in 'Proceedings of the 4th International Workshop on Enterprise Modelling and Information Systems Architectures (EMISA)'.
32. Medel-González, F.; van Vliet, S.; Roeder, O.; Marx Gómez, J.: Upgrading Reporting, Communication and Benchmarking Tools of IT-for-Green Project, In: Proceedings der EnviroInfo 2014, Oldenburg, 2014, in publication.
33. Memari, A. & Marx Gómez, J. (2013), Adaptive Applications: Definition and Usability in IT-based Service Systems Management, in Manuel Mora; Jorge Marx Gómez; Leonardo Garrido & Francisco Cervantes Pérez, ed., 'Engineering and Management of IT-based Service Systems: An Intelligent Decision-making Support Systems Approach', Springer, pp. 131-154.
34. Memari, A. (2013), Angewandtes Semantisches Metamodell von Rechenzentren für Green IT, in Jorge Marx Gómez; Corinna Lang & Volker Wohlgemuth, ed., 'IT-gestütztes Ressourcen-

und Energiemanagement', Springer Berlin Heidelberg, pp. 93-102.

35. Memari, A., Vornberger, J., Marx Gómez, J., & Nebel, W. (2014). A Data Center Simulation Framework Based on an Ontological Foundation. In Proceedings of EnviroInfo 2014: ICT for Energy Efficiency. Oldenburg, Germany: BIS Verlag.

36. Memari, A.; vom Berg, B. W. & Gómez, J. M. (2011), An Agent-based Framework for Adaptive Sustainable Transportation, in 'WETICE 2011: 20th IEEE International Conference on Collaboration Technologies and Infrastructures'.

37. Meyer, J. & Teuteberg, F. (2012), Nachhaltiges Geschäftsprozessmanagement – Status Quo und Forschungsagenda, in 'Proceedings der Multikonferenz der Wirtschaftsinformatik - MKWI 2012'.

38. Meyerholt, D.; Mahmoud, T. & Gómez, J. M. (2011), Administrating Environmental Performance Indicators Utilizing Lightweight Semantic Web Services, in Paulina Golinska; Marek Fertsch & Jorge Marx Gómez, ed., 'Proceedings of the 5th International Symposium on Information Technologies in Environmental Engineering'.

39. Ortwerth, K. & Teuteberg, F. (2012), Green IT/IS Forschung - Ein systematischer Literaturreview und Elemente einer Forschungsagenda, in 'Proceedings der Multikonferenz Wirtschaftsinformatik - MKWI 2012'.

40. Ortwerth, K.; Zarvic, N.; Thomas, O. & Teuteberg, F. (2012), Datenseitige Anforderungen bei der Preisfindung hybrider Leistungsbündel, in 'Proceedings der Multikonferenz Wirtschaftsinformatik - MKWI 2012'.

41. Rapp, B. & Bremer, J. (2012), Design of an Event Engine for Next Generation CEMIS: A Use Case, in Hans-Knud Arndt; Gerlinde Knetsch & Werner Pillmann, ed., 'Man, Environment, Bauhaus: Light up the Ideas of Environmental Informatics - 26th International Conference on Informatics for Environmental Protection', Shaker Verlag, pp. 759-766.

42. Rapp, B.; Solsbach, A.; Mahmoud, T.; Memari, A. & Bremer, J. (2011), IT-for-Green: Next Generation CEMIS for Environmental, Energy and Resource Management, in Werner Pillmann; Sven Schade & Paul Smits, ed., 'EnviroInfo 2011 - Innovations in Sharing Environmental Observation and Information, Proceedings of the 25th

EnviroInfo Conference 'Environmental Informatics', Shaker Verlag, pp. 573-581.

43. Rapp, B.; Vornberger, J.; Renatus, F. & Gösling, H. (2012), An Integration Platform for IT-for-Green: Integrating Energy Awareness in Daily Business Decisions and Business Systems, in Brian Donnellan; João Peças Lopes; João Martins & Joaquim Filipe, ed., 'Proceedings of the 1st International Conference on Smart Grids and Green IT Systems (SmartGreens 2012)', SciTePress - Science and Technology Publications, pp. 226-231.

44. Renatus, F.; Gösling, H. & Geldermann, J. (2012), Betriebliche Umweltinformationssysteme der nächsten Generation, in F. Renatus; R. Kunze; I. Karschin; J. Geldermann & W. Fichtner, ed., 'Entscheidungsunterstützung durch Operations Research im Energie- und Umweltbereich, Tagungsband des Workshops der GOR-Arbeitsgruppen "OR im Umweltschutz" und "Entscheidungstheorie und -praxis"', Shaker Verlag, Aachen, pp. 76-89.

45. Sinamo Boltena, A.; Rapp, B.; Solsbach, A.; Marx Gómez, J.: Towards Green ERP Systems: The selection driven perspective, In: Proceedings der EnviroInfo 2014, Oldenburg, 2014, in publication.

46. Solsbach, A. & Rapp, B. (2013), Municipalities and Sustainable Tourism - Challenges, Requirements and Added Value, in Burkhardt Funk; Peter Niemeyer & Jorge Marx Gómez, ed., 'Information Technologies in Environmental Engineering', Springer Verlag, Berlin, Deutschland, pp. 155-165.

47. Solsbach, A.; Isenmann, R.; Marx Gómez, J.; Teuteberg, F.: Inter-organizational Sustainability Reporting – A harmonized XBRL approach based on GRI G4 XBRL and further Guidelines, In: Proceedings der EnviroInfo 2014, Oldenburg, 2014, in publication.

48. Solsbach, A.; Lipnitskaya, S. & van Vliet, S. (2013), Internetbasierte Nachhaltigkeitsberichterstattung im Kontext des Umwelt-, Energie- und Ressourcenmanagements mit BUIS der nächsten Generation, in Jorge Marx Gómez; Corinna Lang & Volker Wohlgemuth, ed., 'IT-gestütztes Ressourcen- und Energiemanagement. Konferenzband zu den 5. BUIS-Tagen', pp. 421-431.

49. Solsbach, A.; Marx Gómez, J. & Isenmann, R. (2011), iSTORM – Idea and Reference Archi-

ture approach to Inter-Organisational sustainability Reporting, in Werner Pillmann; Sven Schade & Paul Smits, ed., 'Environmental Informatics - Informatics for Environmental Protection, Sustainable Development and Risk Management. Innovations in sharing environmental observations and information', Shaker Verlag; Shaker, Aachen, pp. 639-646.

**50.** Solsbach, A.; Rapp, B.; Teuteberg, F.; Gräuler, M.; Stiel, F.; Renuat, F. & Vornberger, J. (2013), Environmental Footprinting in the IT-for-Green Project - A CEMIS Use Case, in Bernd Page; Volker Wohlgemuth; Angela Schwab; Andreas Fleischer & Heidi Oskarsson, ed., 'Proceedings of the Environmental Informatics and Industrial Environmental Protection: Concepts, Methods and Tools', Springer Verlag, Berlin.

**51.** Solsbach, A.; Süpke, D.; vom Berg, B. W. & Gómez, J. M. (2011), Sustainable Online Reporting Model – a Web Based Sustainability Reporting Software, in Paulina Golinska; M. Fertsch & Jorge Marx Gómez, ed., 'Information Technologies in Environmental Engineering - ITEE 2011', Springer-Verlag, Berlin.

**52.** Solsbach, A.; van Vliet, S.; Lipnitskaya, S.; Rapp, B.: Nachhaltigkeitsberichterstattung als Service eines BUIS - Anforderungen an ein Schema zur Nachhaltigkeitsberichterstattung im Projekt IT-for-Green, In: Proceedings der Multikonferenz Wirtschaftsinformatik 2014, Paderborn, 2014, 1367-1374.

**53.** Stiel, F. & Teuteberg, F. (2013), 'Towards a Conceptual Framework for Life Cycle Assessment in Sustainable Information Systems Management', ECIS 2013.

**54.** Stiel, F., Teuteberg, F.: Entwicklung praxisrelevanter IKT-Artefakte für ein betriebliches Umwelt- und Nachhaltigkeitsmanagement mittels Konsortialforschung - Implikationen des Verbundprojekts IT-for-Green, In: Proceedings zur Multikonferenz Wirtschaftsinformatik MKWI 2014, Paderborn, 2014.

**55.** Stiel, F., Teuteberg, F.: Measuring the Environmental Impact of IT/IS Solutions - A Life Cycle Impact Modelling Approach, Environmental Modelling & Software, Thomson Reuters Impact Factor (2012): 3.476 (available online)

**56.** Stiel, F.: On the Use of Discrete Event Simulation in Green IS Research - Developing a

Conceptual Framework, In: Proceedings of the 22st European Conference on Information Systems (ECIS 2014), Tel Aviv, 2014 (accepted for publication)

**57.** Stolze, C.; Freundlieb, M.; Thomas, O. & Teuteberg, F. (2011), Hybride Leistungsbündel für energieeffiziente Planung, Steuerung und Betrieb von IT-Infrastruktur, in G. Bernstein, A.; Schwabe, ed., 'Proceedings of the 10th International Conference on Wirtschaftsinformatik', pp. 312-321.

**58.** Teuteberg, F. (2011), 'Kommentar zum Beitrag 'Sustainable Supply Chain Management im globalen Kontext – Praxisstand des Lieferantenmanagements in DAX- und MDAX-Unternehmen' von Erik G. Hansen, Dorli Harms und Stefan Schaltegg', Die Unternehmung: Swiss Journal of Business Research and Practice 2(65), 110-113.

**59.** Teuteberg, F. (2011), 'Nachhaltiges Informationsmanagement bei Supply Chains', WISU – Das Wirtschaftsstudium 5(40), 690-700.

**60.** Uphoff, K.; Solsbach, A.; van Vliet, S.; Rapp, B.; Isenmann, R.: Nachhaltigkeitsberichterstattung – Anforderungen zum Datenaustausch aus Sicht der Praxis. In: Volker Wohlgemuth, Corinna V. Lang, Jorge Marx Gomez, Konzepte, Anwendungen und Entwicklungstendenzen von betrieblichen Umweltinformationssystemen (BUIS), S. 205 - 216, Shaker Verlag, Aachen 2014

**61.** Walterbusch, M. & Teuteberg, F. (2012), 'Vertrauen im Cloud Computing', HMD – Praxis der Wirtschaftsinformatik(288).

**62.** Walterbusch, M. & Teuteberg, F. (2013), Status Quo der Wirtschaftsprüfung von Nachhaltigkeitsberichten, in 'Proceedings der 15. Tagung der Fachgruppe Betriebliche Umweltinformationssysteme der Gesellschaft für Informatik e.V. (5. BUIS-Tag)'.  
**63.** Walterbusch, M.; Bosse, A. & Teuteberg, F. (2013), Social Network Trend Indicator: Konzeption, prototypische Implementierung und Evaluation eines Stimmungsbarometers auf Basis sozialer Netzwerke, in 'INFORMATIK 2013: Informatik angepasst an Mensch, Organisation und Umwelt; 43. Jahrestagung der Gesellschaft für Informatik e.V. (GI)'.  
**64.** Walterbusch, M.; Gräuler, M.; Teuteberg, F.: How Trust is Defined: A Qualitative and Quantitative Analysis of Scientific Literature, In: Prod-

ceedings of the 20th Americas Conference on Information Systems (AMCIS 2014), Savannah, 2014.

65. Walterbusch, M.; Grove, S.; Breitschwerdt, R.; Stolze, C.; Teuteberg, F. & Thomas, O. (2013), Case-based Selection of Business Process Modeling Tools: An Evaluation Criteria Framework, in 'Proceedings of the 19th Americas Conference on Information Systems (AMCIS 2013)'.

66. Walterbusch, M.; Martens, B. & Teuteberg, F. (2013), 'Evaluating Cloud Computing Services from a Total Cost of Ownership Perspective', Management Research Review 36(7).

67. Walterbusch, M.; Martens, B. & Teuteberg, F. (2013), Exploring Trust in Cloud Computing: A Multi-Method Approach, in 'Proceedings of the 21st European Conference on Information Systems (ECIS 2013)'.

68. Walterbusch, M.; Teuteberg, F.: Datenverluste und Störfälle im Cloud Computing: Eine quantitative Analyse von Service Level Agreements, Störereignissen und Reaktionen der Nutzer, In: Proceedings der Multikonferenz Wirtschaftsinformatik 2014, Paderborn, 2014, S. 2227-2240. Proceedings

69. Walterbusch, M.; Truh, S.; Teuteberg, F.: Hybride Wertschöpfung durch Cloud Computing, In: Modellierung 2014 (Workshop "Dienstleistungsmodellierung"), Wien, 2014. accepted for publication.

70. Wittstruck, D. & Teuteberg, F. (2011), Development and Simulation of a Balanced Scorecard for Sustainable Supply Chain Management - A System Dynamics Approach, in 'Proceedings of the 10th International Conference on Wirtschaftsinformatik, Zürich', pp. 332-341.

71. Wittstruck, D. & Teuteberg, F. (2011), Towards a holistic Approach for Sustainable Partner Selection in the Electrics and Electronics Industry, in 'Proceedings of the IFIP 8.6 Working Conference'.

72. Wittstruck, D. & Teuteberg, F. (2011), 'Understanding the Success Factors of Sustainable Supply Chain Management: Empirical Evidence from the Electrics and Electronics Industry', Corporate Social Responsibility and Environmental Management (formerly Journal of Eco-Management and Auditing).

73. Wittstruck, D. & Teuteberg, F. (2012), 'Integrating the Concept of Sustainability into the Partner Selection Process: A Fuzzy-AHP-TOPSIS Approach', International Journal of Logistics Systems and Management 12(2), 195-226.

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