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The role of ICT in industrial symbiosis projects – Environmental ICT applications for eco-industrial development

Ralf Isenmann, Konstantin Chernykh
Fraunhofer Institute for Systems and Innovation Research (ISI)
Breslauer Straße 48, D-76139 Karlsruhe
ralf.isenmann@isi.fraunhofer.de
konstantin.chernykh@isi.fraunhofer.de

Abstract

This discussion paper provides an overview of environmental ICT applications (information and communication technologies) for eco-industrial development examples in Europe. This requires – among others – at least two basic elements: (i) a classification scheme on how to group the vast number of environmental ICT applications and software tools currently in use or being developed so far, and – no less important – (ii) an inventory of industrial symbiosis projects identified in European countries.

1. Introduction

Investigating the role of ICT in industrial symbiosis projects is an issue at the intersection between Environmental Informatics and Industrial Ecology. Environmental Informatics and Industrial Ecology are two emerging fields of research striving for sustainability.

The object of Environmental Informatics is to analyze information processing, support information management, and develop information systems related to the environment in its broadest sense, while using methods, techniques, and tools of computer science, thereby – it is hoped – contributing to environmental protection and finally to a more sustainable future (Pillmann et al 2006).

The object of Industrial Ecology is to study industrial systems and their fundamental linkage with natural ecosystems, with the aim to contribute to a more sustainable future. According to White (1994) the focus of Industrial Ecology is „the study of the flows of materials and energy in industrial and consumer activities, of the effects of this flows on the environment, and of the influences of economic, political, regulatory, and social factors on the flow, use and transformation of resources“.

Despite differences in history and early movements in detail, similarities between Environmental Informatics and Industrial Ecology are obvious (Isenmann 2008a, 2008b): Both fields share the same goal, and both have reached a level of academic culture so that they have become promising branches within the "sustainability sciences". The two fields have their intellectual heritage today in professional international societies. Further, both provide numerous tools, studies, publications, resources and other characteristics that may make them a "discipline" – at least to a certain degree. Consequently, the scientific profiles and constitutive characteristics share common features. An indicator that there are actually overlapping areas is the current re-launch in 2007: The technical committee "Environmental Informatics" has formally broadened its scope, moving away from a solely environmental focus now also addressing sustainable development and risk management in its community headline. This development is mirrored in the new term of the expert group as "Environmental Informatics – Informatics for Environmental Protection, Sustainable Development and Risk Management" (http://www.iai.fzk.de/Fachgruppe/GI/index.html).

Resulting from overlapping areas, several attempts have been initiated to start co-operation and establish joint research between Environmental Informatics and Industrial Ecology, even on using environmental ICT applications for eco-industrial development. As an indicator that some preliminary work has been done in the last years, five milestones are highlighted here:

- The Journal of Industrial Ecology (JIE) published a special issue on: "Electronic commerce, the internet and the environment" in 2002. This special edition was an early attempt to pull together, and critically examine, the research on ICT and the environment. The focus was primarily on data, analysis, and reasoned interpretation (http://www3.interscience.wiley.com/journal/120133161/issue).
- The 22nd International Conference on Informatics for Environmental Protection, EnviroInfo 2008 in Lüneburg (Germany), was explicitly announced under the converging banner: "Environmental Informatics and Industrial Ecology" (http://www.enviroinfo2008.org/). This banner implies connections, linkages, and common characteristics between Environmental Informatics and Industrial Ecology. Environmental ICT applications like data processing techniques, simulation tools, environmental accounting systems, geographical information systems (GIS), visualization modules, environmental management information systems (EMIS), and reporting wizards are enablers and could be considered as facilitators for various Industrial Ecology applications like environmental monitoring and life cycle assessment, material flow analysis, environmental risk management, environmental management accounting & reporting.
- The JIE (www.yale.edu/jie/cfp-ict.html) currently invites submissions for a special issue on: "Environmental applications of information and communications technology (ICT)". The call for papers is open to autumn 2009 (deadline: September 15th). The aim of this second special issue explicitly focused on the intersection of Environmental Informatics and Industrial Ecology is to describe innovations in ICT used for central concerns and methods of Industrial Ecology.
- The International Society for Industrial Ecology (ISIE) has launched a new section on eco-industrial development (EIDC, http://www.is4ie.org/sections). This new section is particularly devoted to industrial symbiosis projects, bringing together academics and practitioners with a passion for translating concepts of Industrial Ecology theory into practice. The news was announced at the 5th International Conference on Industrial Ecology, 2009 Lisbon (Portugal): "Transitions Towards Sustainability".
- The latest effort is an expert workshop: "The role of ICT in industrial symbiosis projects" (http://www.enviroinfo2009.org), embedded in the 23rd International Conference on Informatics for Environmental Protection, EnviroInfo 2009 in Berlin (Germany). As a part of the FP7 EU project "ICT-ENSURE, http://www.ict-ensure.eu/), the objective of the expert workshop is to investigate the role of ICT in industrial symbiosis projects, and describe significant synergies that could be exploited by using innovations in ICT for industrial symbiosis projects.

The milestones above could be taken as a sign for three developments: first, in both communities the issue of environmental ICT applications for eco-industrial development is regarded as of increasing relevance; second, the issue provides an excellent example that Environmental Informatics and Industrial Ecology share common features, and hence both communities may foster co-operation and joint research; third, while Industrial Ecology has its early focus in the 1980s in an engineering/technological- and resource/industry-focused bipolar view (Ayres and Ayres 1996), largely concentrated on physical phenomena, today the community has broadened its scope to the immaterial world of bits & bytes, data, information, knowledge and the critical intersection with computational sciences.

2. Classification scheme for environmental ICT applications

Currently, a vast number of environmental ICT applications is in use or under development. To obtain order in the great variety, a classification scheme is presented that helps to classify environmental ICT applications. This classification scheme consists of five different approaches:

- methods- and technologies-driven approach (2.1),

- approach related to information processing (2.2),
- environmental management-focused approach (2.3),
- approach based on empirical studies (2.4), and
- impact-driven approach in terms of sustainability (2.5).

These five approaches highlighted here are regarded as prototypical for the Environmental Informatics literature and community, at least to a certain degree.

2.1 Methods- and technologies-driven approach

The methods- and technologies-driven approach identifies on which core methods environmental ICT applications are primarily based on and which key technologies these applications are actually using. For example, environmental ICT applications used to detect and visualize potential physical exchanges in an urban planning context have probably their roots in geographic information systems (GIS) (Fernandez and Ruiz; Massard and Erkman in this volume). A wizard for sustainability reporting in eco-industrial parks is likely based on internet technologies and the use of XML (Isenmann et al. 2007; Isenmann and Marx Gómez 2008).

The criterion of the methods- and technologies-driven approach highlights so-called core methods and key technologies that could be seen as exemplary for the Environmental Informatics literature, so far. Based on empirical evidence, Page and Hilty (1995, 21) and later on Rautenstrauch and Patig (2001, ii) presented a pool of eleven methods and technologies that makes the Environmental Informatics tool set:

- data analysis,
- computer graphics and visualisation,
- remote sensing,
- geographic information systems (GIS),
- environmental database systems,
- current markup languages like XML (extensible markup language),
- modelling and simulation,
- knowledge- and expert-based systems, neuronal networks and artificial intelligence,
- software ergonomics and user interfaces,
- world wide web and internet technologies and services, and
- ERP systems (enterprise resource planning).

This approach related to methods and technologies may provide a proper categorization of environmental ICT applications for a certain time period. As methods and technologies depend heavily on the progression made in computer science as well as on latest trends in hardware and software, it becomes clear that the tool set changes over time. It has a dynamic nature. Despite emerging innovations in ICT − e.g. web services and semantic technologies − the tool set above probably gives an impression what in the Environmental Informatics community is regarded as the basis in terms of methods and technologies.

2.2 Approach related to information processing

The criterion that makes this approach particular is the different nature of information and – as a result –the certain type information is processed. Following this approach, five different environmental ICT applications can be distinguished (Page and Rautenstrauch 2001, 3):

- Monitoring and control systems are processing data gathered through continuous measurements in water, air, soil, noise, and radiation control. Monitoring and control systems are often equipped with data analysis techniques, e.g. to aggregate time series data, classify environmental objects, or identify hazardous substances. These systems usually need to process vague information and handle with data defects.

- Conventional information systems include basic features like input, storage, structuring, integration, retrieval, and presentation of environmental data. These data are usually available in various forms and formats, e.g. as raw measurement data, description of environmental objects, and structured text in documents. As standard database technology is limited in dealing with spatial and temporal queries, relational data base systems may need certain extensions to process environmental data properly.
- Computational analysis systems provide sophisticated mathematical-statistical analysis methods and modelling techniques. These systems enable environmental data processing in a more detailed and in depth manner. Core functions include the aggregation and visualization of environmental data, provision of conclusions based on structures found in environmental data, as well as statistical evaluation and data mining. Modelling and simulation techniques are applied for forecasting, model calculations, and scenario-analyses.
- Decision support systems (DSS) assist all phases and aspects of decision making, be it group and participatory decision making processes. DSS are used at corporate or any higher level across single entities like in municipalities for urban planning or local waste management. DSS help in particular to evaluate different possibilities and justify why and how certain decisions have been made, e.g. for environmental impact analyses, handling hazardous substances, water resource management, and technical risk assessment.
- Integrated environmental information systems take into account that pure types of environmental ICT applications focusing one issue like legal compliance or material input and energy consumption merely provide limited managerial support. Hence current environmental ICT applications available today are more and more designed as distributed systems enabling the integration of certain modules later on, like data base systems, GIS, and simulation or visualization systems.

An approach related to information processing seems to be useful when defining specific requirements that environmental ICT applications need to fulfil. These requirements are influencing which information is actually needed and how a certain type of information is then processed. For example, dealing with spatial and temporal environmental data as it is typical for long-term measurements in water, air, and soil control requires tailored environmental ICT applications to be found in monitoring and control systems. If − in turn − the central purpose is to support environmental management systems (EMS), then companies may implement an integrated environmental management information systems (EMIS), with certain specialised modules, e.g. for analyses, planning, implementation, controlling, reporting and communication.

2.3 Environmental management-focused approach

The approach focused on environmental management indicates the degree environmental ICT applications are supporting environmental management systems (EMS). Probably the most known and famous examples of EMS are the world-wide standard ISO 14000 series (ISO 2008) and the European Union's Eco-Management and Audit Scheme (EMAS) (EC 2008). These EMS are applicable for companies and other organizations to evaluate, report and improve their environmental performance. Organizations run EMS to improve their environmental performance on a continuous basis. In particular, EMAS-registered organizations are legally compliant, and evaluate and report on their environmental performance through the publication of an independently verified environmental statement. These publications are recognised by the EMAS logo which guarantees the reliability of the information provided (EC 2001).

Environmental ICT applications implemented as a part of their EMS are called Environmental Management Information Systems (EMIS). Embedded in a certain organizational context, EMIS are socio-technological systems. They are used as business applications with the aim to gather, process, and provide environmental data, inside organizations and in exchange with other actors in industry or local administration. EMS prototypically fulfil a number of tasks and include various processes, i.e.: analysis, planning, implementation and controlling, and check (Hilty and Rautenstrauch 1995). These tasks and processes make the heart of EMS. Any task and process in EMS again correspond to certain functions that EMIS may support. Hence, environmental ICT applications can be grouped according to EMS support, e.g. for gathering, processing, and providing environmental data, be it inside or in exchange with external stakeholders.

- Legal compliance and other external requirements are driving forces pushing companies to do more than just smart "green-washing". First, EMIS help to comply with laws and regulations. They provide insights into complex legal frameworks, e.g. on information retrieval networks for environmental regulations. Further, they assist decision makers in discovering business activities that are of relevance for environmental regulations, e.g. by emission monitoring.
- Second, EMIS provide mechanisms to get feedback from external stakeholders and to capture requirements from a larger audience, not just from business partners. Such feedback loops are usually installed in the form of stakeholder relations management systems.
- Next, EMIS support material flow management, including material flow modelling and evaluation. For example, EMIS provide help when identifying material and energy inputs, collecting relevant data, and preparing eco-balances. Based upon insights drawn from an eco-balance, EMIS further assist impact assessments and balance valuations in order to assess environmental impacts due to material and energy flows. Once material flows are modelled and evaluated, EMIS help to improve eco-efficiency. The measures that could be taken range from product life cycles and production processes to whole companies. Elaborated methods offer support, e.g. Life Cycle Analysis (LCA) and Design for the Environment (DFE), just to mention a few.
- When the measures for improvement in EMS have been implemented and controlled according to eco-efficiency, then all activities and results need to be documented in reports and communicated. Here EMIS provide an array of benefits to improve communication and reporting both, for companies and their stakeholders (Isenmann 2008d). For example, EMIS can overcome the restrictions of freestanding documents with limited contents, print media fixation, disclosure in a one size fits all fashion, and one-way-communication.

Together, the basic tasks and operational processes in EMS and corresponding EMIS functions are building a closed loop procedure, finally leading to a process model of continuous environmental improvements. Ideally, the different EMIS functions are combined to a coherent system and fully integrated into an organization's ICT infrastructure, while supporting all tasks throughout an EMS (Rautenstrauch 1999).

Just recently, Teuteberg and Straßenburg (2009) provided an overview of the state of the art and future research in EMIS. Based on a comprehensive analysis and review of literature in Environmental Informatics dated from 2000 and 2008, they found five clusters in EMIS-related articles:

- EMIS in general, e.g. development & implementation, integration in ERP systems,
- sustainability reporting, e.g. technical issues, automation,
- material flow, e.g. development & implementation, simulation, data defects,
- waste management, and
- environmental information management.

The analysis to EMIS-related research shed light on current foci in Environmental Informatics. Despite progression companies have made in running EMIS in recent years and though concepts of enterprise application integration (EAI) have been proposed, however, EMIS are usually not incorporated elements, today (Isenmann and Rautenstrauch 2007). Particularly they are no standard element of ERP systems which are common for business information systems; − this is also true for management accounting systems. Such integration has just partly taken place. For example, in my SAP® PLM (Product Lifecycle Management), there is a module on Environment, Health and Safety (EH&S). Its focus though is rather limited to the documentation of waste management following national laws for handling hazardous substances (SAP 2005).

2.4 Approach based on empirical studies

The three classifications mentioned above take a deductive perspective, more or less. The approach based on empirical studies follows an inductive principle. In terms of empirical studies, pretty less had been done, yet. An exception is the analysis Grant (2007) has conducted. He analyzed case studies publicly available in the Industrial Ecology literature with the aim to assess the current progress of environmental ICT applications in supporting industrial symbiosis projects.

In total, Grant (2007, 22-23) identified 16 environmental ICT applications built to facilitate industrial symbiosis projects (tab. 1). Of the sixteen environmental ICT applications identified, one software tool is available for purchase on the internet; two are in use though they are not publicly available; for nine there is no publicly available evidence whether they are still in use.

Of the 12 environmental ICT applications identified, seven were developed in USA, three in Europe, and two elsewhere. Interestingly, the three operational applications were developed in Europe. Of course, these numbers merely provide a first impression of how environmental ICT applications are being developed and where they are being used.

Based on his review over the past ten years, Grant (2007, 40) considered usability, training and expertise and high start-up costs as common critical challenges. He particularly found that environmental ICT applications he examined have strengths in technical opportunities when identifying potential physical exchanges. The applications identified, however, show much room for improvements in building relationships between people, enabling communication and facilitating co-operation.

2.5 Impact-driven approach in terms of sustainability

The impact-driven approach focuses on the effects ICT – and hence environmental ICT applications – are causing in terms of sustainability (Hilty 2008). The point is that environmental ICT applications surely provide an array of benefits and increase efficiencies on the one hand (Hilty et al. 2005); on the other hand, however, they also imply consequences, e.g. in terms of scarce resources, energy consumption, and electronic waste, just to mention a few (Geibler et al. 2005).

No.	Environmental ICT application & country of development	Country & geographical scale	Status	Availability
1	Knowledge-based decision support-systems New Zeeland and Canada	Trinidad Industrial park	Completed	None
2	Designing industrial ecosystems toolkit USA	Burlington Vermont, USA Industrial park	Cancelled	Public, reportably unusable, requires MS Office 95
3	Industrial Materials Exchange Tool USA	City of Brownsville, USA; Tampico, Mexico City	Cancelled	None
4	Dynamic Industrial Materials Exchange Tool USA	Greater Yellowstone-Teton region, USA Region	Completed	None
5	MatchMaker! USA	USA, Vietnam, United Arab Emirates, Saudi Arabia City	Completed	None
6	Industrial Ecology Planning Tool USA	USA Industrial Park	Completed	Source code available, requires ArcView GIS
7	WasteX Commonwealth Caribbean, Jamaica, Australia	Jamaica Nation	Completed	None
8	Industrial Ecosystem Development Project USA	USA Region	Cancelled	None
9	Residual Utilization Expert System USA	USA City & State	Completed	Available to the original project funding organizations, requires level 5 software shell
10	Institute of Eco-Industrial Analysis Waste Manager Germany	Germany Region	Operational	Reporting software; purchase and demo available over the web – analysis and optimization systems under development
11	Industrie et Synergies Inter-Sectorielles and Presteo France	France, Switzerland Region	Operational	In use by the developer
12	Core Resource for Industrial Symbiosis Practitioners UK	UK Nation	Operational	Restricted to NISP participants and practitioners

Table 1: Environmental ICT applications for industrial symbiosis projects (Grant 2007, 22-23)

In order to describe the complex relationships between ICT and sustainability, the working group "Nachhaltige Informationsgesellschaft" (Sustainable Information Society) of the German Society for Informatics proposed a two-dimensional grid (Dompke et al. 2004; Isenmann 2008c). This grid comprises fundamental criteria for sustainability set against three different levels of impacts of ICT. Three dimensions describe the fundamental sustainability criteria:

- Human compatibility: Individuals should not suffer damages from development. Their personal dignity must be respected.
- Social compatibility: Relationships of people with one another and the resulting society should not be infringed. Individual participation in our communities needs to be protected and supported.
- Ecological compatibility: The natural environment must not be irreversibly damaged, and our life support systems must be protected.

The impacts of ICT on individuals, society, and nature are classified according to three different perspectives:

- Effects of ICT provision, e.g. use of resources and energy in manufacturing, use and disposal of ICT hardware.
- Effects of ICT use, e.g. energy savings from process optimisation or commuter traffic reduction as a result of telecommunication.
- Systemic effects, e.g. rebound effects as a reaction to efficiency gains, changes of economic structures, institutions and consequences for individual lifestyles.

The combination of sustainability criteria and levels of ICT impacts results in a 3x3 matrix. For all nine fields, status quo and practical recommendations towards a more sustainable information society are described. For example, recommendations for ICT provision cover measures to create and maintain an ICT infrastructure in a more sustainable manner. Apart from direct effects of provision and use, ICT lead to a number of rebound effects which must be neutralised so that achieved efficiency gains and possible resource savings are not offset by other, wasteful ways of using ICT (ecological compatibility).

The impact-driven approach is a reminder that the development of environmental ICT applications for industrial symbiosis projects is not merely a technical issue for computer scientists within Environmental Informatics. It is also an issue for users involved in eco-industrial developments, and hence it is a matter of Industrial Ecology, particularly in terms of environmental impact assessment.

3. Inventory of industrial symbiosis projects in Europe

The basic idea underlying industrial symbiosis projects is that economic entities share information, services, utilities, and by-product resources among one or more industrial actors with the aim to add value, reduce costs, and improve environmental performance (Côté and Cohen-Rosenthal 1998; Chertow 2007). Typically, these projects have a particular focus on material and energy exchange, while economic entities are often from separate industries. They are brought together in a collective approach. The characteristics are collaboration and synergistic possibilities offered by geographic proximity. Economic entities involved in industrial symbiosis projects may collectively optimize material and energy use across single entities. Consequently, considering efficiencies goes beyond those achievable by any individual process alone. It is ideally more like behaviour of a local community.

Due to the promising approach, industrial symbiosis projects have been initiated worldwide (critical: Gibbs and Deutz 2005, 2007). Various examples could be found in Europe (e.g. Eilering and Vermeulen 2004; Liwarska-Bizukojc et al. 2009), USA & Canada (e.g. Chertow 2007; Gibbs and Deutz 2007), Asia (e.g. Chiu and Yong 2004; Park et al. 2008), and Australia (e.g. Roberts 2004; van Berkel 2006;). Though is seems useful to having a full record of industrial symbiosis projects available, a central inventory is missing, yet. No comprehensive catalogue exists that is online or publicly available, not even offered by the ISIE.

An inventory − preferably accessible online − would be a valuable source to better analyze industrial symbiosis projects, e.g. to identify success factors and detect obstacles. Particularly an inventory would also be fruitful to investigate the role of ICT in industrial symbiosis projects. The following table may be a starting point for such enterprise. The collection includes a total of more than 70 examples, located in 12 European countries. The collection is just a snapshot. It is not based on a systematic research method. The examples identified have been extracted from the current Industrial Ecology literature and a survey in the internet.

Example: Name & City	Description & Number of industrial symbiosis projects identified in the certain country
Austria (2)	
Hartberg Öko Park, Hartberg	Public-sector led project to redevelop an industrial estate dedicated to firms pursuing environmental goals and developing/researching environmental technologies, particularly renewable energy. http://www.oekopark.at/flash6.htm
Denmark (3)	
Industrial Symbiosis, Kalundborg	A highly evolved and self-organising network of manufacturing firms and local partners involved in the by-product exchange of waste materials, water, and energy. http://www.symbiosis.dk/; Start: 1959
Finland (4)	
Ecopark Oulu, Oulu	A business park to promote environmental improvement of products and services through innovation and R&D on one site. The Ecopark is part of a wider regional strategy to develop an environment cluster in the area. http://nortech.oulu.fi/eng/palvelut.html
France (4)	
Ecosite du Pays de Thau, Meze, Montpellier	A municipal authority-led project established to promote local sustainable development, pollution abatement and tourism. Start: 1985
Germany (16)	
Zero Emission Park	A research project funded by the Federal Ministry of Transport, Building and Urban Affairs and the Federal Office for Building and Regional Planning, including four industrial parks with more than 600 entities. http://www.zeroemissionpark.de, Start: 2008-2009
Italy (4)	
Optimisation of Resource Use and Waste Management, Langhe area	A project carried out with the Politecnico di Torino and a consortium of small and medium enterprises (SMEs) on a planned eco-industrial park. Start: 2001-2004
Netherlands (14)	
Agro Industrial Complex Dinteloord, Dinteloord	The complex under development is intended to strengthen the economic position through lower production costs on the one hand, and to generate environmental and spatial gains on the other. Start: 1996
Poland (1)	
Sunflower Farm Ecological Technology Centres	Five initiatives currently under development. The first is planned for Stryszow, near Cracow and will act as a demonstration site for environmental technologies based around water, energy, and waste.
Spain (1)	
Instituto Technologico y de Energias Renovables, Tenerife	A local authority-led research and demonstration centre established in 1991. Based around renewable energy and environmental technology, the site also includes a visitor centre. Start: 1991
Sweden (3)	
Landskrona Industrial Symbiosis Project, Landskrona	An industrial symbiosis project in Landskrona, Sweden, initiated in 2002 by the International Institute for Industrial Environment Economics (IIIEE), Lund. Start: 2002
Swiss (1)	
Industrial Symbiosis Project in Geneva, Geneva	Project focused on territorial and industrial planning with the aim to go beyond recycling systems by locally reusing material and energy flows through by-product exchange networks. Start: 2006
UK (20)	
National Industrial Symbiosis Programme, Birmingham	NISP is an innovative business opportunity programme that delivers bottom line benefits for members whilst generating positive outcomes for the environment and society. http://www.nisp.org.uk/, Start: 2006

Table 2: Industrial symbiosis projects in Europe, selected examples

4. Conclusion and outlook

The aim of this discussion paper was to provide an overview of environmental ICT applications for eco-industrial development examples in Europe. Therefore, a classification scheme was presented that helps to obtain order in the vast number of ICT applications and software tools. Five different approaches prototypical for Environmental Informatics were highlighted: (i) methods- and technologies-driven approach, (ii) approach related to information processing, (iii) environmental management-focused approach, (iv) approach based on empirical studies and (v) impact-driven approach in terms of sustainability. A comprehensive classification including all five approaches would result in a multidimensional grid. This grid may help to analyze which environmental ICT applications are in use or under development when to advance eco-industrial development. As a starting point for an inventory of industrial symbiosis projects in European countries, more than 70 examples were identified through an exploratory analysis.

As a larger goal, the paper is an attempt to bring together the ICT-driven field of Environmental Informatics on the one hand and the environmental-focused area of Industrial Ecology on the other hand. Although the two fields share a number of common features, institutional co-operation and joint research could be improved, still. Progression in environmental ICT applications enable an array of unique capabilities to be employed for industrial symbiosis projects, especially for the management of physically exchanging materials, energy, water, and by-products and – no less important – for the management of relationships. Further to a mere one-sided transfer from Environmental Informatics to Industrial Ecology, Environmental Informatics may benefit from Industrial Ecology: For example, the certain requirements and specific needs of actors involved in industrial symbiosis projects may deliver fruitful ideas for the Environmental Informatics community as the types of eco-industrial development follow a more systemic view, across single entities. Software engineers might be interested on how to further develop isolated environmental ICT applications like standalone EMIS in single companies to an integral ICT infrastructure, enabling inter-organisational exchange of environmental data, finally to the benefit of all decision makers involved in long-term eco-developments, be they managers, suppliers, consumers, local authorities, non-governmental institutions, or other organizations affected by such projects based on collaboration, synergistic possibilities, and geographic proximity.

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