Preface

Information and Communication Technologies (ICT) bring about new opportunities as well as new risks for the goal of sustainable development. This book focuses mainly on the opportunities that show how information systems can help society to approach sustainable development, that is, to reach a kind of economic activity that is compatible over the long run with human and social welfare, and with nature.

Even after the first UN World Summit on the Information Society in Geneva 2003, the relationship between issues of the global information society and of sustainable development is not being discussed adequately. It seems that the interdisciplinary and international research in this field is just beginning.

However, there have been large projects to develop information systems that contribute to sustainable development in recent years, most of them on a national level in European countries. This book gives an overview of the background and the current state of these efforts in presenting the basic principles of such information systems and giving practical examples.

Sustainable Development and the Information Society

The most widely cited definition of sustainable development was given by the World Commission on Environment and Development in 1987: In order to be considered sustainable, a pattern of development has to ensure “that it meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987).

The world summits on environment and development in Rio de Janeiro in 1992 and in Johannesburg 2002 have shown that the goal of attaining sustainable development has become a predominant issue in international environmental and development policy. It is widely accepted that sustainability has an environmental, a social and an economic dimension. A number of national and international research programmes and activities have been set up in order to refine the scientific basis for the sustainability concept.

But while these issues are being discussed, the world is rapidly changing under the growing influence of ICT and globalization, which are mutually reinforcing factors. This process, which is transforming our industrial society into an information society, has the potential to substitute information and knowledge for material products to some extent. But besides this so-called dematerialization, the change process also entails a progressive globalization of the economy that has thus far boosted goods production, freight volume and passenger transport. Finally, the information society also means acceleration of innovation processes, and thus an ever faster devaluation of the existing by the new, whether hardware or software, technical products or human skills and knowledge.

The rate at which the information society is coming about is determined by Moore's Law, which says that the performance of ICT doubles about every 18 months. The result is that people can take advantage of more and more computing power and data transfer without requiring more space, energy or cost, thus giving rise to new services based on this technical infrastructure almost daily, services which are penetrating more and more areas of our lives.

In this introduction, we want to classify the relationships that exist between the goal of attaining sustainability and the transition to an information society.

Environmental Information Processing

Computer-based systems for processing environmental information have been in use for more than three decades now. A broad range of applications is covered by these systems, including monitoring and control, information management, data analysis, as well as planning and decision support. Some of these systems comprise so-called "micro-macro linkages" between corporate and regional or national information systems (Krcmar, 2000; Seifert, 2002). The generic name for this type of system is *Environmental Information System (EIS)* (Rautenstrauch & Patig, 2001).

Progress in informatics has made an invaluable contribution to our ability to analyze the biological, chemical and physical processes taking place in the environment. Inversely, the complex nature of problems occurring in environmental contexts is a great challenge to informatics. From this process of mutual stimulation, a special discipline has emerged known as *Environmental Informatics.* It combines computer science topics such as database systems, geographic information systems, modelling and simulation, knowledge based systems and neural networks, with respect to their application to environmental problems (Avouris & Page, 1995).

The environmental informatics community maintains an international annual conference series that started in 1986. The 15th conference in 2001 opened the scope of environmental informatics to the broader perspective of ICT and sustainable development (Hilty & Gilgen, 2001). The 2004 conference continues this process in focusing on sharing information and technologies, in particular between the global North and South (Susini & Minier, 2004).

The categories of applications described in the following sections show the type of work being done in environmental informatics. Examples can be found in this volume and in the proceedings of the regular environmental informatics conferences.

Applications in the Public Sector

Computer applications for processing information related to the natural environment have been under development in the public sector since the early days of computing. For instance, simulation models were in use in water supply already in the 50s. Today, most developed countries operate environmental *monitoring systems* that regularly provide up-to-date information about the state of the environment. One part of the data is gathered by fully automated telemetry networks that are used to monitor air quality, water quality and radioactivity. Telemetry means that automated sensor systems are placed in the medium (e.g., air, water) and transmit data to a central control office, usually operated by a municipal, regional or national environmental agency. Another part of environmental data is obtained by increasingly powerful remote sensing techniques based on processing aerial or satellite images in combination with geographical information.

EIS in the public sector fulfill at least the following three important functions:

Public awareness: Agencies in many countries are legally compelled to publish data from environmental monitoring. When such data are published, the public becomes more aware of the condition of public goods (such as the atmosphere or recreation areas), which would otherwise not be the case because public goods, having no price by definition, cannot create awareness by means of price signals. Furthermore, publishing environmental data has other important effects such as enabling citizens to judge for themselves the success or failure of the government's environmental policy.

Decision support: Environmental information is an indispensable basis for making political decisions that have effects on the natural environment or inversely are dependent on the condition of the environment. Decision support consists not only of providing information about the status quo, but also about making predictions (e.g., short-range forecasts on ozone-related summer smog) and in considering the effects of various available alternatives (scenarios, *what if* questions). Informatics makes an important contribution to decision support by providing methods and tools for modelling and simulation.

Executing environmental policy: Environmental policy instruments can only be implemented effectively when accurate and up-to-date information is provided continuously. EIS aid in checking for violations of regulations (such as tracing illegal emissions back to their *source*), help to monitor the success of measures taken, and provide the information needed for immediate action in case of crises and disasters.

Applications in the Private Sector

EIS were used mostly in the public sector until a decade ago. However, recently a market has come about for software systems that support environmental management in companies (Krcmar et al., 2000); these are known as *Environmental Management Information Systems (EMIS)* (Hilty & Rautenstrauch, 1997). EMIS can be viewed as the ICT infrastructure of Environmental Management Systems (EMS). Most EMIS today fulfill the following functions:

Legal compliance: For one thing, EMIS help to comply with laws and regulations by providing insight into *complex legal frameworks* (cf. Riekert & Kadric, 1997), for example on information retrieval networks for environmental regulations. Secondly, the information systems aid top managers in *discovering and understanding developments in their own company* relevant to environmental regulations. Examples of the second type of application are systems for company-internal emissions monitoring and systems for modelling material flows.

Environmental reporting: EMIS also enable a company to fulfill its many *reporting requirements* to stakeholders (government agencies, banks, insurers, suppliers and customers, employees, neighbours, and the general public) as regards its environmental impact and risks. There has been a trend in recent years to make environmental reporting software suitable for use on intranets to share data among subsidiaries and employees, and to publish a subset of the data to wider circles of interested stakeholders such as suppliers. Such HTML-based solutions then can automatically sift out the subset of the data public enough for publishing on the Internet. Applied properly, this efficiency could give a further boost to reporting.

Eco-efficiency: EMIS help to improve *ecological efficiency* (or *eco-efficiency* for short). In order to determine at which stage of the value-added chain eco-efficiency can be improved, Life Cycle Assessments (LCAs) are done, which investigate the life of a product or service "from cradle to grave" – starting with extracting natural resources from the environment, running through all production and use phases and ending with disposal of the waste – and evaluate its ecological impacts. Product life cycles, production processes and thus whole companies can be viewed as *material flow systems* that can be optimized for eco-efficiency. Such *material flow* management can be done on different levels, from the most strategic to the most operative level, and may include, for example:

- building up strategic corporate networks (especially recycling networks),
- using LCAs to rank product or process alternatives when making or buying products or parts,
- "Design For the Environment" (DFE) with the goal of reducing the life-cycle-wide material flows and environmental hazards caused by the future product,
- real-time process control for minimizing emissions or increasing energy efficiency.

Material Intensity and ICT

With regard to sustainability, a crucial aspect of ICT is how they could help to reduce the *material intensity* of economic processes (including production, consumption, and disposal, as well as the connecting logistical processes such as transportation and storing). The goal of reducing material intensity has been debated for about a decade under the heading "Factor X" discussion (Weizsäcker et al., 1995). An important project on the role of ICT in "Factor X" dematerialization was the *Digital Europe* project (Alakeson et al., 2003; Kuhndt et al., 2003).

As is common in discussions on this topic, we use the term "material intensity" in a very broad sense. It includes every transformation of mass or energy involved in providing a product or service. The spread of information society technologies affects the material intensity of an economy directly and indirectly, classified as follows (see also Forum for the Future, 2002):

- *directly* through the production, use and disposal of the ICT hardware itself (first order effects),
- *indirectly* by the impact of their application (*second order effects*) and by the changes in structure and behavior that their application causes in the long term (*third order effects*).

The *first-order effects* have been discussed widely in recent years under the aspect of how ICT industry could change its products and services in order to make them more environmentally compatible (Park & Roome, 2002).

According to a widely accepted scheme, the *second-order* effects of ICT can be classified under the following three types:

- Substitution effects
- Optimization effects
- Induction effects

Let us demonstrate this scheme using paper consumption as an example. The PC as the modern form of a typewriter and in particular the PC used as a medium to access e-mail, WWW and other Internet services do in fact have the potential to reduce paper consumption. Plenty of textual and graphical information can be received directly from the screen, which in fact is *substituted* for paper in many cases. There is also an *optimization* effect, since for instance many errors can now be corrected before a text or picture is printed for the first time. However, as the reader may know from everyday experience, the *induction* effect offsets the other effects by far, because today's PC and printer technology enables the user to print out hundreds of pages with just a few mouse clicks. Therefore, all in all, ICT contributes to the same general trend for paper that has been observed for the past 60 years.

The counter-intuitive trend that can be observed in paper consumption is an example of the most typical third-order effect, known as the *rebound effect*. This concept refers to a potential created by efficiency gains that is balanced off or even overcompensated for by quantitative growth (Binswanger, 2001; Radermacher, 1996). Every substitution or optimization effect achieved by ICT creates new degrees of freedom which tend be used for quantitative growth. This should be kept in mind in order not to promote purely technical solutions for attaining sustainability, but rather to analyze the problems and possible solutions to them from a broader, more comprehensive perspective.

A recent prospective study assessed potential first-, second- and third-order effects of ICT on environmental sustainability by modelling three scenarios for the European Union in the year 2020 (Hilty et al., 2004). This project was carried out by the Institute for Futures Studies and Technology Assessment (IZT), Berlin, the Forum for the Future, London, the International Institute for Industrial Environmental Economics at Lund University (IIIEE) and EMPA, St.Gallen.

Organization of Book

This book is organized in three parts, each of which consists of several chapters which cover the topical spectrum ranging from theory to practice. Each part starts with chapters devoted to background knowledge and basic principles, and ends with chapters describing application examples.

Section I focuses on the "classical" approach to support the environmental efficiency of companies, their production processes and products by systematically providing information on material and energy flows. This includes methods such as Life Cycle Assessment and other elements of environmental management that depend on the availability of accurate information.

Section II reports on approaches that explicitly address and support processes of change towards sustainability, involving social processes such as mediated discussion processes, institutional innovation, the creation of virtual communities, and new types of producer and consumer networks. All change processes mentioned can be supported by information systems.

Section III, finally, shows how the safety and risk issue, which has been underestimated for some time in the sustainability discourse, can be integrated in management systems, and how risk monitoring and management can be supported by information systems.

Chapter I opens the first part with an introduction into the ISO standardization process for environmental performance evaluation. The ISO14000 series defines basic principles of environmental management along whose lines many environmental information systems have been built.

Chapter II describes how national strategies for sustainable development, integrated product policies and product life cycle assessment are connected. These strategies and policies largely depend on the availability of high-quality life cycle inventory data.

Chapter III shows an example of providing such data by building a harmonized life cycle inventory database with clearly defined data quality standards, using the case of the Swiss national database "ecoinvent".

Chapter IV reports on the research project OPUS, which provides solutions for the organization of product development and production processes in and between companies. The goal is to support production-integrated environmental protection.

Chapter V describes how a system supporting industrial ecology can be successfully integrated in the workplace IT environment. The core idea is to provide the formerly missing link between material flow management and the working environment in companies.

Chapter VI presents a methodology with similar goals, but takes a different approach. Here, existing business management software such as an enterprise resource planning (ERP) system is used to match the requirements of consistent material flow management, called flow cost accounting.

Chapter VII introduces a middleware system, developed in the ARION project, to support the search and retrieval of scientific information. The system has been used for ocean wave statistics as well as for the inter- and inner-organizational workflow management in scientific organizations.

Chapter VIII shows how a software tool for modeling material flow networks can be methodologically and technically linked to economic optimization and simulation approaches. This approach has been applied to transport optimization as well as discrete-event production and inventory simulation.

Chapter IX closes the first part by applying environmental information processing to the ICT sector itself, in particular to the Internet. The impacts of this technology on resource consumption and environmental pollution must be taken into account to create a complete view of the effects of ICT in the context of sustainable development.

Chapter X opens the second part by introducing a social context model for the analysis of discussion processes. This model can be used to construct information tools that enable more effective discussions.

Chapter XI explores the link between ICT and organizational and institutional patterns, which are crucial for sustainable development. A normative framework is proposed for judging the sustainability effects of organizational designs and supports the creation of "e-organizations" contributing to sustainable development.

Chapter XII gives an introduction to state-of-the-art corporate sustainability reporting supported by the Internet. Companies are shown how to develop from early environmental reporting stages towards the more comprehensive sustainability reporting, while exploiting the Internet's specific capabilities.

Chapter XIII describes the principles of "ecoradar," a Web portal that creates knowledge communities of small and medium-sized enterprises cooperating in environmental management. The system provides the users with low-threshold introductions to environmental management, lists of common mistakes to be avoided, checklists and benchmarks for comparison with other enterprises.

Chapter XIV shows how recycling networks of industrial companies can evolve to sustainability networks, and how this process can be supported by information systems. As an example, the case of the sustainability network in the Eisenerz region in Austria is described.

Chapters XV and XVI both show examples of how a change toward sustainable consumption can be organized by the use of Web-based information systems, the first one in the field of organic food, the second one in carpooling.

Chapters XVII and XVIII discuss examples of information systems that contribute to environmental awareness by making environmental information available, in the first case by the dissemination of high-quality information via multiple channels, in the second case by creating a national portal for public sector environmental information.

Chapters XIX and XX open the last part of the book by describing how safety and risk management can be integrated in other management and information systems, including in-plant monitoring data in the second case.

Chapter XXI shows an example of a risk-oriented information system, providing remote monitoring of nuclear power plants.

Chapter XXII closes the third part by describing a GIS-based decision support tool for technological risk management, which is able to process remote sensing data.

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