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SPECIAL SECTION: HUMAN AND ENVIRONMENTAL IMPACTS OF PERVASIVE COMPUTING

Introduction: Technology Assessment for Pervasive Computing

Danielle Buetschi[1] and Lorenz M. Hilty[2]
[1]Swiss Centre for Technology Assessment, Berne, Switzerland; [2]Swiss Federal Laboratories for Materials Testing and Research, EMPA, St. Gallen, Switzerland

Pervasive Computing refers to visionary new ways of applying Information and Communication Technologies (ICTs) to our daily lives. It involves the miniaturization and embedding of microelectronics in non-ICT objects and wireless networking, making computers ubiquitous in the world around us.

In 2002 the Swiss Centre for Technology Assessment (TA-SWISS) launched a study on potential impacts of Pervasive Computing on human health and the environment, one of the first technology assessment studies on Pervasive Computing. This special section of the *Journal of Human and Ecological Risk Assessment* (HERA) presents the main results of the study as viewed from different perspectives and also includes related recent work, specifically from the Mobile and Ubiquitous Computing Lab (M-Lab), a joint initiative of ETH Zurich, the University of St. Gallen, and the Massachusetts Institute of Technology, Cambridge.

Since the Internet and mobile phones first penetrated our daily and professional lives some 10 years ago, we have now entered the so-called "information society." We live today in a network to which we are connected always and everywhere. But technological progress will not stop there. In the near future, many objects will host microprocessors able to perceive their environment, adapt to it, and communicate with other devices. Computing will thus become pervasive. The range of possible applications is wide, be it for traffic management, for increasing work efficiency, or for monitoring health.

However, as we learned from the case of mobile phones, new ICTs may be suspected of causing harm to human health. For example, it is still not clear what the effects of non-ionizing radiation related to mobile communication might be on the human organism. If the vision of Pervasive Computing is to become reality, and if our environment is to host more and more radio transmitters—or perhaps our bodies

Address correspondence to Lorenz M. Hilty, Swiss Federal Laboratories for Materials Testing and Research, EMPA, Lerchenfeldstrasse 5, CH-9014, St. Gallen, Switzerland. E-mail: lorenz.hilty@empa.ch

will—do we have to expect new and acute controversies over non-ionizing radiation to arise?

New ICTs can also have direct or indirect environmental impacts. For example, how will waste recycling be affected when "smart labels" containing a microchip are put on all consumer goods?

Such questions certainly deserve consideration and discussion, which may lead thoughtful researchers to serious doubts in some cases. However, blocking a technology would also exclude any positive effect that might arise from it. Researchers should look for paths on which ICTs might evolve in a direction where risks can be minimized and advantages maximized. The principle of precaution, which is a crucial element of sustainable development, provides a good analytic framework in which to discuss the opportunities and risks of ICTs with respect to their environmental and health impacts. The idea of precaution, which states that action is needed at an early stage, even though no damage has occurred, or no acute danger is threatening, is clearly applicable to ICTs because many unexpected and unpredicted consequences, with more or less severe implications, can result from ICTs. It is thus essential to try to identify these consequences, to assess them and to propose actions in order to reduce the risks and, simultaneously, preserve—if not promote—the opportunities of the information society.

The mission of the Swiss Centre for Technology Assessment (TA-SWISS) is to assess the risks and opportunities related to new technologies. ICTs are thus at the core of its work and have been the subject of several publications (available at www.ta-swiss.ch). These publications, written by interdisciplinary teams and condensed in popular short versions, are mainly intended to inform policy-makers, but are also directed toward other professional communities (scientists, engineers, non-profit organizations, *etc.*) and toward the general public via the media. The aim of these publications is to raise awareness about issues related to new technologies and to suggest possible action. TA-SWISS also aims to foster dialogue between science and society, by organizing participatory projects (such as PubliForums, publifocus, and publitalks) where citizens can express their hopes and fears about new technologies.

In 2002, TA-SWISS launched a new project examining the promises of Pervasive Computing and its impacts on health and the environment. This was the opportunity to consider new developments in ICT that would go beyond the narrow treatment of the Internet and mobile phones and focus on the implications of ICT for health and the environment. Up until then, TA-SWISS—and other institutions as well—had mostly discussed ICT from the point of view of privacy, security, and the digital divide, whereas its impacts on the environment and human health had been only marginally discussed.

The Technology and Society Lab at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) in St. Gallen carried out this project in the context of its "Sustainability in the Information Society" research program, which is co-funded by the ETH Board. The aim of this program is to contribute to a sustainable information society, *i.e.*, a society in which ICTs are successfully applied in the service of sustainable development. The Institute for Futures Studies and Technology Assessment (IZT), Berlin, contributed significantly to the study on Pervasive Computing.

The study was completed in 2003; publication of its final report has been received with a lot of interest from different circles. Results of the study are presented in this

special section of HERA. However, as promoters and authors of the study, we wanted to open up the discussion to people representing other viewpoints, in order to put the different approaches into perspective with one another. This special section is thus intended to give a multidisciplinary view of the potential effects of Pervasive Computing on human health and the environment, including discussion of the methodology that can be used for the assessment of technological risk in the ICT field.

Jürgen Bohn, Vlad Coroamã, Marc Langheinrich, Friedemann Mattern, and Michael Rohs from ETH Zurich give an introduction to the topic in making a first attempt to classify the social, economic, and ethical implications of the development toward Pervasive Computing, or ambient intelligence.

Claudia Som and Lorenz M. Hilty from EMPA and Thomas F. Ruddy from Webster University discuss the Precautionary Principle in the context of ICT and the information society. If this principle is to be used to minimize risks of Pervasive Computing or other future ICTs, it must be reformulated to match the specific characteristics of these technologies.

Felix Würtenberger from the Boston Consulting Group, Munich, and Siegfried Behrendt from IZT, Berlin, discuss the major technological trends and innovation paths in ICT with respect to their effects on the levels of exposure of the human organism to electromagnetic fields.

Elgar Fleisch from the University of St. Gallen analyzes the implications of Pervasive Computing from a business perspective. The most concrete application of Pervasive Computing is automatic identification systems, a technology that can support incremental process changes such as an automatic quality check and enhance the overall efficiency of controlling intensive processes. Object value logging and embedded services are examples of more radical changes, which not only affect processes, but also business models.

Lorenz Erdmann from IZT, Berlin, and Andreas Köhler from EMPA present a synopsis of the potential environmental effects of Pervasive Computing, including results from various recent studies. In some fields, this technology turns out to have ambivalent effects. Dematerialization effects achieved with Pervasive Computing may be counteracted by rebound effects, turning expected benefits for the environment into additional stress.

In the last article, Lorenz M. Hilty, Claudia Som, and Andreas Köhler from EMPA summarize the TA-SWISS study, with a focus on methodological problems arising from the uncertainty surrounding both the future development of the technology and causal models linking the technology to its health, social, and environmental impacts. A "risk filter" consisting of qualitative risk assessment criteria is introduced and used to identify the major risks of Pervasive Computing.