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(published jointly with *Novática**)

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Presentation

Green ICT: The Information Society's Commitment for Environmental Sustainability

Juan-Carlos López-López, Giovanna Sissa, and Lasse Natvig

ICT and Sustainability

A growing social awareness of environmental problems and the rational use of the planet's resources has caused Public Administrations to show an increasing concern for these issues and, in consequence, to deal with economical and social development from this new perspective. Thus, one of the pillars of the Information Society strategy of the European Union (i2010 Lisbon Strategy) is precisely the application of Information and Communication Technologies (ICT) to improve the quality of life, and to foster environmental care and sustainable development.

The ICT sector has been and will be a basic element in the generation of wealth, not just in the sense of allowing new business models, but by offering new services which foster innovation in other more "traditional" sectors. Besides its role as a support for future economical growth, this sector shows a great ability to contribute with innovative solutions towards a productive model based on sustainable development.

Several reports have already shown the capacity of ICT to help reduce CO₂ emissions, either by decreasing the carbon footprint of the own sector activity, or by helping, by means of applications and services, to efficiently manage energy resources in other critical sectors, such as industry, power, transport and others.

Thus, ICT help reduce the environmental impact of human activity, by working on both the design of new hardware devices and systems (low power devices and systems, efficient solar cells, sensors...), and the development of new software technologies, applications and services (information management, communications, artificial intelligence, etc.).

This monograph reviews how ICT can play multiple roles towards improving environmental sustainability.

Managing the ICT Sector's own Activity

According to a Gartner report (see the "Useful References" box), the total footprint of the ICT sector in 2007 was about 2% of the estimated total emissions from human activity released that year. This amount is expected to reach more than 6% in 2020. This means that one of the targets of this sector regarding environmental sustainability should be the reduction of its own environmental costs, arising from the use of equipment and ICT solutions. Efforts should be concentrated on two main areas:

The Guest Editors

Juan-Carlos López-López received the MS and PhD degrees in Telecommunication (Electrical) Engineering from the *Universidad Politécnica de Madrid*, Spain, in 1985 and 1989, respectively. From September 1990 to August 1992, he was a Visiting Scientist in the Dept. of Electrical and Computer Engineering at Carnegie Mellon University, Pittsburgh, PA USA. His research activities center on embedded system design, distributed computing and advanced communication services. From 1989 to 1999, he has been an Associate Professor of the Dept. of Electrical Engineering at the *Universidad Politécnica de Madrid*. Currently, Dr. López is a Professor of Computer Architecture at the *Universidad de Castilla-La Mancha*, Spain, where he served as Dean of the School of Computer Science from 2000 to 2008. He has been member of different panels of the Spanish National Science Foundation and the Spanish Ministry of Education and Science, regarding Information Technologies research programs. He is member of the IEEE and the ACM. <juancarlos.lopez@uclm.es>

Giovanna Sissa was awarded a degree in Physics in 1978. She has been involved in ICT since 1980, as Strategic Consultant for Industries and Public Administrations, for the identification of emerging technologies and technological trends in informatics. She is a member of the Italian Register of Technological Innovation Experts (Ministry of Economical Development) and a member of the Scientific Committee of the Piedmont Regional System for Research and Innovation. In 2000 she founded, and managed until 2009, the "*Osservatorio Tecnologico*" of the Italian Ministry of Education. Engaged in research on ICT and sustainability, she has written books and papers about the environmental impact of ICT. As a PhD student of Informatics at the *Università degli Studi di Milano* her research focus is on ICT-driven societal behavioral changes and their effect on environmental sustainability. <sisssa.giovanna@gmail.com>

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“This monograph intends to review some of the issues related to the *green* side of ICT, but also tries to encourage the scientific and professional ICT community to play an active role in the Green ICT challenge”

- Energy consumption of ICT infrastructures (data centres, computers, communication equipment, etc.).

- Disposal and recycling of ICT equipment (electrical and electronic devices, materials and components of diverse nature, such as plastic, magnetic, or chemical).

ICT Solutions to manage other Sectors' Activities

The use of ICT for intelligent resource management has been well known for decades. Different types of applications have already shown ICT potential, and it is time now to extend their capabilities to other fields in which several studies have evaluated their impact as really promising (see the Smart 2020 report). In fact, these fields constitute priority areas for the R&D programs of various administrations, providing solutions for the most energy intensive sectors. Among them, it is worth mentioning:

- Smart cities/buildings: utilities (electricity, water, etc.) management, early detection and, potentially, self-healing of failures and breakdowns, etc.

- Smart transportation of goods and people: logistics, positioning and routes (reduction of fossil combustion greenhouse gases), and electric vehicles.

- Smart grids: grid operation and management (load balancing, active demand management), Wide Area Monitoring and Control (WAMC).

ICT as a Driving Force towards a more Sustainable Social Model

The potential of ICT to offer new ways of interaction between people and their environment as well as new mechanisms to ease the management of the production processes (industrial, innovation...) is unquestionable. This can bring about a reshaping of the social model, incorporating ways to address the growing environmental concern, and thereby reinforcing the information society's commitment to sustainable development.

In this sense, one of ICT's main contributions to the development of both social and industrial and corporate activities is based on the elimination of unnecessary displacements, offering the so-called solutions "*by substitution*". That is, ICT allow the replacement of physical movements by information movements, thereby reducing the consumption of energy and materials. This has led to services such as telecommuting, distance education and remote learning, telemedicine, teleconferencing, electronic commerce and business, remote assistance for the elderly and disabled, and electronic government. On the other hand, the so-called *dematerialization* enables material intensive

physical products and services to be replaced by their virtual equivalents: e-billing or e-health services, for example, avoid the production of paper tickets or X-ray films. These ICT-based opportunities offer important savings in energy and material and, therefore, environmental improvements, but they impact enormously on people's relationships both with one another and with the social environment, leading to new individual and collective behaviours.

On the other hand, information systems help to efficiently manage production and business processes, allowing the automation of information processing, information that nowadays also includes energy and environmental parameters that can be useful in decision-making processes.

Green ICT Challenges

As we have seen, ICT can be pivotal towards a more sustainable world, increasing environmental awareness and fostering *greener* behaviours. In this sense, the role played by ICT is important. But not just ICT-related skills are required. Both the reduction of the environmental impact of the ICT sector itself or the use of ICT applications to enable green behaviours in other sectors, also involve environmental skills together with a better awareness of the environmental implications of people behaviours. Moreover, ICT professionals should be conscious of the Green ICT opportunities, but also of their potential risks.

A green ICT strategy has to start by increasing public knowledge about ICT and their effects on the environment, and by supporting environmental-related ICT skills and education. If computer scientists and professionals have to *go green*, a new awareness and culture has to be encouraged. This is the key to really fostering Green ICT.

This monograph, thus, intends to review some of the issues related to the *green* side of ICT, but also tries to encourage the scientific and professional ICT community to play an active role in the Green ICT challenge.

“One of the pillars of the Information Society strategy of the European Union is the application of ICT to improve the quality of life, and to foster environmental care and sustainable development”

“ ICT allow the replacement of physical movements by information movements, thereby reducing the consumption of energy and materials ”

In this Monograph

The monograph starts with the paper "*CEPIS Green ICT Survey – Examining Green ICT Awareness in Organizations: Initial Findings*" which describes the initial results of a survey carried out by the CEPIS Green ICT Task Force. It includes over three dozen comprehensive questions about "green awareness" in ICT companies and has gathered more than 300 responses. The final results, which will be compiled into a pan-European report, depict how ICT Managers in different countries implement energy efficient methods in their organizations.

A focus on sustainability from a broader point view is given in "*The Five Most Neglected Issues in Green IT*". The authors focus on five issues concerning the "greening" of ICT which are usually overlooked and that in the long term, they argue, will be essential for the sustainability of ICT. Consequently it will be necessary to understand the ICT life cycle better, so as to be able to support a green strategy for the sector.

In "*Utility Computing: Green Opportunities and Risks*", the author puts the accent on green potentials and risks of computing for the environment. The view is taken from the software developers' side, alluding to fact that they have great power but a great responsibility, as a result of the possibility of available computing resources being used like a utility (like gas or water).

The contribution "*Good, Bad, and Beautiful Software - In Search for Green Software Quality Factors*" goes deeper into the software life cycle approach, with a visionary and specific accent on the role played by software in a "green software engineering" perspective. The author looks for some "green software quality factors" that enable some metrics for green software to be established.

The Smart Grid is currently one of the main fields of application which demonstrates the green capabilities of ICT. The paper "*Towards the Virtual Power Grid: Large Scale Modelling and Simulation of Power Grids*" reviews the major disciplines that need to be evolved and converged to meet the challenges of future energy grids. The authors propose a model of distribution network that increases the efficiency of power production, control and management. The

core of this model is a virtual power grid (VPG) which is able to provide complete real-time visibility of the grid at a full dynamic system level.

Focusing once again on the Smart Grid, the paper "*Artificial Intelligence Techniques for Smart Grid Applications*" shows how one of the main computing fields offers an efficient way to wisely manage the energy distribution network. Both artificial intelligence and computational intelligence techniques are being applied to address different issues such as the real-time management of the dynamic behaviour of the electricity network, by integrating renewable energy sources or by providing fault tolerance and self-healing.

In the paper "*Green Computing: Saving Energy by Throttling, Simplicity and Parallelization*", the authors start by giving a broad overview of the techniques used in making computers more energy efficient in all market segments from embedded systems to supercomputers. They introduce energy-saving techniques in hardware, continue at the operating system level and end by describing techniques at the application level. They explain how parallelization in both HW and SW can help reduce the energy consumption, and how throttling and simplicity can give the same effect.

The paper "*Towards Sustainable Solutions for European Cloud Computing*" discusses different issues related with the emerging Cloud Computing paradigm. Besides issues such as the privacy and availability of data, the efficient use of energy resources poses new research challenges. In particular, the authors centre the discussion on how to wisely manage applications execution according to the dynamic behaviour of renewable energy sources. They propose scheduling applications so as to maximize green energy consumption while meeting job deadlines.

Finally, the dramatically increasing energy consumption of datacentres is also addressed by the paper "*A State-of-the-Art on Energy Efficiency in Today's Datacentres: Researcher's Contributions and Practical Approaches*". The authors explain how the concept of energy efficiency has become an increasingly important design issue. The paper also addresses the importance of reliability, how it interacts with energy efficiency and how cooling turns out to be another important concern. Finally, the gap existing between research contributions in this field and the products offered by industry is highlighted.

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“ ICT professionals should be conscious of the Green ICT opportunities, but also of their potential risks ”

Useful References on "Green ICT"

In addition to the materials referenced by the authors in their articles, we offer the following ones for those who wish to dig deeper into the topics covered by the monograph.

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Some Web Sites Worth Visiting

- **ClimateSavers**. Started by Google and Intel in 2007, the Climate Savers Computing Initiative is a not-for-profit group of eco-conscious consumers, businesses and conservation organizations. Their goal is to promote the development, deployment and adoption of smart technologies that can both improve the efficiency of a computer's power delivery and reduce the energy consumed when the computer is in an inactive state. <<http://www.climatesavers.computing.org/>>.
- **ERCIM on Green ICT**. ERCIM news, special Theme Towards Green ICT. <<http://ercim-news.ercim.eu/en79>>.
- **Green500**. Rankings of the most energy-efficient supercomputers in the world. <<http://www.green500.org/>>.
- **MINECC**. EU 7FP FP7: FET Proactive Initiative: Minimising Energy Consumption of Computing to the Limit (MINECC). <http://cordis.europa.eu/fp7/ict/fet-proactive/minecc_en.html>.
- **Mont Blanc Project**. Is a newly started EU project with the objectives to develop a fully energy-efficient HPC prototype using low-power commercially available embedded technology. <<http://www.montblanc-project.eu/objectives>>.
- **Smart Grids in Europe**. The European Technology Platform for Electricity Networks of the Future, also called SmartGrids ETP, is the key European forum for the crystallization of policy and technology research and development pathways for the smart grids sector, as well as the linking glue between EU-level related initiatives. <<http://www.smartgrids.eu/>>.
- **Smart Grid in the USA**. Web site of the US Department of Energy that gathers all the information on federal initiatives supporting the development of technologies, policies and projects transforming the electric power industry. <<http://www.smartgrid.gov/>>.
- **Smart Grid News**. <<http://www.smartgridnews.com/>>.
- **The Green Grid**. The Green Grid is a not-for-profit, open industry consortium of end-users, policy-makers, technology providers, facility architects, and utility companies collaborating to improve the resource efficiency of data centres and business computing ecosystems. <<http://www.thegreengrid.org/>>.
- **ZeroPower**. The goal of this project is to create a coordination activity among consortia involved in "Toward Zero-Power ICT" research projects (FET proactive call FP7-ICT-2009-5, Objective 8.6) and communities of scientists interested in energy harvesting and low power, energy efficient ICT. <<http://www.zero-power.eu>>.