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Monograph
Green ICT: Trends and Challenges
(published jointly with Novática*)

Guest Editors: *Juan-Carlos López-López, Giovanna Sissa, and Lasse Natvig*

2 Presentation. Green ICT: The Information Society's Commitment for Environmental Sustainability — *Juan-Carlos López-López, Giovanna Sissa, and Lasse Natvig*

6 CEPIS Green ICT Survey – Examining Green ICT Awareness in Organisations: Initial Findings — *Carol-Ann Kogelman on behalf of the CEPIS Green ICT Task Force*

11 The Five Most Neglected Issues in "Green IT" — *Lorenz M. Hilty and Wolfgang Lohmann*

16 Utility Computing: Green Opportunities and Risks — *Giovanna Sissa*

22 Good, Bad, and Beautiful Software – In Search of Green Software Quality Factors — *Juha Taina*

28 Towards the Virtual Power Grid: Large Scale Modeling and Simulation of Power Grids — *Peter Feldmann, Jinjun Xiong, and David Kung*

41 Artificial Intelligence Techniques for Smart Grid Applications — *María-José Santofimia-Romero, Xavier del Toro-García, and Juan-Carlos López-López*

49 Green Computing: Saving Energy by Throttling, Simplicity and Parallelization — *Lasse Natvig and Alexandru C. Iordan*

59 Towards Sustainable Solutions for European Cloud Computing — *Kien Le, Thu D. Nguyen, Íñigo Goiri, Ricardo Bianchini, Jordi Guitart-Fernández, and Jordi Torres-Viñals*

67 A State-of-the-Art on Energy Efficiency in Today's Datacentres: Researcher's Contributions and Practical Approaches — *Marina Zapater-Sancho, Patricia Arroba-García, José-Manuel Moya-Fernández, and Zorana Bankovic*

UPENET (UPGRADE European NETwork)

75 From **Mondo Digitale** (AICA, Italy)
IT for Education
IT in Schools. A European Project for Teachers Training — *Pierfranco Ravotto and Giovanni Fulantelli*

CEPIS NEWS

81 Selected CEPIS News — *Fiona Fanning*

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The Five Most Neglected Issues in "Green IT"

Lorenz M. Hilty and Wolfgang Lohmann

Many studies in Green IT/Green ICT have been published, focusing on the energy consumption of ICT or the role of ICT as an enabler of energy efficiency. In this article, we argue that such an approach is too narrow, and that a broader perspective is needed to utilize the potential of ICT to make our lives more sustainable.

Keywords: Critical Infrastructure, Energy Efficiency, Energy Prices, Green ICT, Green IT, Green Software, Life Cycle Assessment, Rebound Effects, Scarce Metals, Sustainability.

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1 Introduction

The notion of Green IT has become hype after the publication of Gartner's report "Green IT: a new industry shock wave" [1]. Many projects have been conducted and seminal studies published by industry associations (e.g. The Climate Group), NGOs (e.g. WWF[2]) and international organizations (e.g. OECD[3]). Most of the existing studies focus on the impacts of ICT on CO_2 emissions, either related to the power consumption of ICT or to the role of ICT as an enabling technology for conserving energy in various fields.

However, the Green IT/ICT discussion is still lacking awareness of systemic interrelations among the technological, economic and environmental aspects of ICT. This results in a neglect of five issues which we discuss below. We argue that these issues will be essential in the long term, i.e. addressing and resolving them may decide the sustainability of ICT.

2 Five Challenging Issues

2.1 A Lack in the Transparency of Energy Costs in ICT Services

It is unusual for a provider to bill customers for ICT services with accurate accounting for hardware utilization and resulting energy use; instead, there is almost no correlation between the price of a service and the energy cost it creates. ICT services are often cross-subsidized, which may create misdirected incentives. For example, telecommunications service providers usually charge high fees for SMS and attract customers with low flat rates for Internet access.

We are not arguing here against cross-subsidization for dogmatic reasons, but when the prices of ICT services and their actual energy and material costs diverge too much, that is definitely a problem. The example of e-mail spam makes this clear. According to estimates spam e-mail caused in 2008 worldwide an energy consumption of 33 TWh [4]. This roughly matches the total power generation of Bangladesh for its more than 150 million people. If the senders of spam had to bear the energy costs themselves, there would presumably be no more spam in circulation.

Adequate allocation of energy costs would be the first issue for an economist to think of in a "Green IT" context. However, only in exceptional cases has the allocation of energy cost been mentioned in the Green IT literature thus far. One exception is a report by the German Ministry of the Environment on best-practices in energy-efficient data centres [5], mentioning that the Dutch co-location data centre EvoSwitch bills energy costs to the customers.

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2.2 The Material Demand of ICT Hardware Production

The variety of materials contained in ICT hardware makes recycling difficult and less efficient. Digital ICT is the first technology claiming more than half of the periodic table of the elements. For example, 57-60 chemical elements are used to build a microprocessor today; in the 1980ies, a microprocessor contained only 12 elements [6]. Memory components, peripheral devices and external storage media are also increasing in material complexity.

Miniaturization and integration work against efforts to close material loops by recycling electronic waste. Some metals are contained in very small concentrations (such as indium in flat screens) and could therefore only be recovered in centralized industrial processes – as far as recovery is profitable at all, both in economic and energetic terms. If not recovered, these resources are dissipated and therefore irreversibly lost. The combination of highly toxic and highly valuable materials in digital electronics adds to the challenges of recycling, which are not only of a technical nature, but also involve trade-offs among environmental, occupational health and economic objectives.

By focusing on the reduction of CO_2 emissions caused by power generation from fossil fuels, the Green ICT de-

Technology (A: servers, B: network, C: end-user devices; D: embedded)	Energy Consumption	Enabling Effect on Energy Efficiency
A1: servers outside data centres	high	Medium
A2: corporate data centres for in-house services	high	High
A3: data centres of ICT service providers	high	High
B1: terrestrial and marine communication: optic fibre cables & copper cables	Low	Medium
B2: wireless communication: GSM, WiFi, 3G antennas	medium	Medium
B3: wireless communication: telecom satellites	low	Medium
B4: supporting Internet infrastructure: routers, DNS servers	high	Medium
C1: personal computing devices: desktops, laptops, netbooks	high	Medium
C2: home telecommunication devices: landline phones	medium	Low
C3: mobile telecommunication devices: cellular phones	medium	Medium
C4: TV sets, set-top boxes	high	Low
C5: portable media (music and/or video) players, e-books	medium	Low
C6: digital cameras	medium	Low
C7: peripherals (scanners, printers, etc.)	medium	Low
D: embedded ICT	high	High

Table 1: Results of an Expert Survey on the Effects of Different Types of ICT on Energy Consumption [11].

> The variety of materials contained in ICT hardware makes recycling difficult and less efficient

bate tends to underestimate the supply risks and resulting geopolitical and ecological problems following from ever increasing hardware churn rates combined with miniaturization and integration.

The demand for rare metals is growing fast: For the elements gallium, indium, iridium, palladium, rhenium, rhodium and ruthenium, over 80 percent of the quantities extracted since 1900 were mined in the past 30 years [7]. There will be no really Green ICT until we learn to reverse the trends towards higher material complexity and shorter service lives of ICT hardware.

2.3 Insufficient Understanding of the ICT Life Cycle

Not all ICT products are the same in terms of production, use and end-of-life treatment. For some ICT products (such as servers or set-top boxes) it is essential to reduce the power consumption during use, because the use phase comprises the largest share in their total life cycle impact; for others it is more important to optimize their design for recyclability or to avoid negative effects during end-of-life treatment. For example, RFID chips and small embedded ICT products entering the waste stream can affect established recycling processes, such as paper, metals, glass or plastics recycling [8][9] or textile recycling [10].

Even if the focus is restricted to energy aspects, different types of ICT have different life cycle profiles. Table 1 shows the result of an expert survey in which the experts were asked to give a rough estimate of the energy consumption of each type of ICT and the energy efficiency created by the enabling effect of the same type of ICT [11]. There is much more variation among ICT types if material aspects and typical life spans are included as well. Given these differences, becoming "green" may have a different meaning in each case.

Many Life Cycle Assessment, LCA, studies have been done in the ICT sector: for PCs [12][13]; mobile phone networks [14][15], screens [16] or lighting technologies [17], but the standardized methodology of LCA and the inventory databases that LCA relies on [18] have not received much attention in Green IT/ICT studies thus far.

If ICT is viewed as an enabling technology to improve or be substituted for processes in other sectors (manufacturing, transport, housing, energy), the effects in the target sector – called second-order effects – must also be evaluated from a life-cycle perspective. This leads to the approach of linking life cycles (introduced by Hilty [19] and cited in OECD [3: 15f] to assess the net environmental impacts of an ICT application. ICT applications can have effects on the design, production, use or end-of-life treatment of non-ICT products. The vision of "Greening through IT" [20] can only become a reality if methods for systematic assessment of these effects are in place, including optimization, substitution and induction effects [19].

2.4 Rebound Effects and the Role of Software

Progress in the efficiency of producing a good or service means that the same output can be provided using less input. By increasing efficiency, input factors (e.g. energy input) can in principle be saved in absolute terms. However, what we usually see in practice is that these savings are soon balanced out or even overcompensated for by an increase in demand for the output, because the output is getting cheaper in terms of money or time. Even if the demand for this specific output does not increase, saved income can be spent on other goods or services, the production of which requires additional input. These effects are known as rebound effects [21].

Saving resources such as energy by improving the efficiency with which the resource is used therefore is not as straightforward as it may appear to be from a technical perspective. From an economic perspective, the situation is more complex, because the dynamics of markets has to be taken into account to predict the outcome. Efficiency is a necessary, but not a sufficient condition for saving resources.

Not surprisingly, many rebound effects have been observed in the ICT field, such as the "IT productivity paradox", "featurism", "software bloat", the "miniaturization paradox" and growth of organizational bureaucracy (for details see [22][19: Chapter 4]. Rebound effects are usually categorized as "systemic" or third-order effects, together with structural change effects such as structural dematerialization [23][24], which would hopefully reduce the overall material intensity of the economy.

A recent comparison of the 10 most influential studies assessing the effects of ICT on CO_2 emissions revealed that only a few of them even tried to take rebound effects into account. The five studies published in 2007 or later (i.e. after the beginning of the Green IT hype) almost completely ignored systemic effects, whereas the older studies showed more ambition to account for these effects [25].

Software development plays a specific role in creating rebound effects. The usual response of software engineers (and users as well) to an increase in the processing power and storage capacity available at a given price is to capture

> Different types of ICT have different life cycle profiles

> "Software development plays a specific role in creating rebound effects"

more of the same. One example is the development of computer games using a combination of fast action and graphics. Each new gain in performance is greedily translated into increasing the reality of the scenes. New patches delivered to increase the resolution of textures and improved graphics can even slow down the speed of the game [26].

Gaining a better understanding the role of software in inducing or avoiding rebound effects is essential. This could lead to "green" software design principles.

2.5 ICT as a Critical Infrastructure

Organizations and facilities that are important for the public good are called critical infrastructures if their failure or impairment would have serious effects on public safety or other consequences. The more dependent we make ourselves on ICT networks, the more they become critical infrastructures for us. The problem of controlling the increasing complexity of ICT systems paired with their criticality presents an emerging risk for society. System failure and intrusion into critical infrastructures may have severe implications that are not only economic, but also social and environmental in nature. Arguments to use the precautionary principle in the information society apply here [27].

Can ICT become "green" before we have done our homework in the discipline that E. W. Dijkstra called "how to avoid unmastered complexity"? [28: p. 107]. As software engineers, as designers of information systems and communications networks, we are creating part of society's infrastructure; we should therefore take this warning of one of the greatest computer scientists seriously: "*Because we are dealing with artefacts, all unmastered complexity is of our own making; there is no one else to blame and so we had better learn how not to introduce the complexity in the first place*." [29].

3 Conclusion and Outlook

We have argued that the Green IT/ICT discussion is neglecting some aspects of the relationship between ICT products and the economic, social and ecological system in which they are embedded: markets, material resources, life cycles of products and their interactions, systemic effects (in particular rebound effects), as well as the uncontrolled complexity emerging with ICT infrastructures.

The solution to this problem is to take a broader view – a systemic perspective. Truly inter- or transdisciplinary research is needed to establish a deeper understanding of the multifaceted relationships between ICT, society and nature. The aim of this research is to provide comprehensive conceptual frameworks, methodologies of integrated assessment and dynamic models which will help to utilize the potential of ICT to make our lives more sustainable.

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