Sustainable Development: The Role of Information and Communication Technology

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Abstract: Information and Communication Technology has a significant footprint in global resource consumption, greenhouse gas (GHG) emissions and waste, particularly considering the high growth rates. Yet, intelligent use of ICT can support other domains in mitigation (e.g. in reducing GHG emissions and resource consumption), monitoring of resources and environmental impacts and adaptation to unavoidable changes, for instance due to climate change. This paper gives an overview on activities to reduce the direct ICT footprint and on positive indirect effects in other domains. Finally, it briefly outlines the potential of ICT to support education, public awareness and policy-making.
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1 Introduction and Motivation

For a long time, people read “globalisation” as a buzzword used by marketing or politicians. Lately, the occurrence of the current “economic crisis” made it clear to everyone that most problems we are facing in the 21st century are global in nature. This is true for the connected economy (which strongly relies on information and communication technology) as well as for environmental and natural-resource issues. *“A principal result has been the evolution of an anthropogenic Earth in which the dynamics of major natural systems are increasingly affected by human activity.”* (Allenby, 2007). Therefore humanity is currently facing a range of serious problems like global warming, the degradation of biodiversity (e.g. due to excessive fishery and illegal logging), dependence on non-sustainable (carbon-based) energy sources, a lack of management of valuable natural resources and at the other end of the production-lifecycle, lack of proper waste-treatment, to name a few. The editorial comment of Nature (Nature Editorial, 2003) named our age *anthropocene*, due to the huge influence of human activity on the planets ecosystems. Political and scientific activities that try to deal with these problems have to take place on a global scale and with an interdisciplinary approach.

Information and Communication Technology (ICT) came under surveillance also due to strong growth rates. This paper discusses the *direct impacts* of ICT and the steps the ICT industry and science have to take to reduce the future impact of ICT. The main focus however, is on the fact that *ICT has a strong leverage properly applied in other fields* and can grow from being part of the problem to becoming part of the solution. That is, ICT’s role to support mitigation of our economy and adaption to future problems, ICT for monitoring, ICT for public awareness, policymaking and teaching, and finally briefly the question how resilient ICT and the depending systems are in case of disruption (e.g. due to catastrophes). .

2 Direct ICT Footprint

ICT systems have three obvious impacts: *resource consumption*, *energy consumption* and *waste* (during the production cycle and at the end of the lifecycle of ICT devices). The performance of ICT devices per Watt has been steadily increasing over the last decade; between 1999 and 2007 the overall performance increased by a factor of approximately 75 and the performance per Watt increased 16 fold (Belady, 2007). But the growth rates of ICT are so high, that overall energy consumption is still increasing significantly. Since energy density has increased as well, in current data centres only about 50% of the energy is consumed for actual data processing, the other 50% is used for cooling (and other support functions). Cremer et al analysed the situation in Germany, which is quite typical for industrial countries, where ICT devices and infrastructure counted for approximately 8% of total electricity consumption (excluding industrial production) in 2001. This report estimates a growth of 45% until 2010 (Cremer et al, 2003). Mankoff et al predict for all OECD countries an energy consumption of 8% (of total consumption) for 2010 (Mankoff et al, 2008). From the greenhouse gas emissions viewpoint, the ICT sector is currently responsible for approximately 2% of the overall carbon emissions in Europe (EU PR, 2009), but with strong growth rates in "business as usual" scenarios.

One reason for the high energy consumption of devices is presumably the fact that product selection of customers is driven by performance and features and not (yet) by resource consumption. Consequentially, the parameter "energy consumption" is only optimised in product development when it directly affects the usability of devices. The following is one such example: desktop computers usually consume 5-10 times as much energy as notebooks do without providing 5-10 times the performance. The optimisation in notebooks is done because it affects the battery life, which makes it (as opposed to energy consumption in desktops) an important feature. On the software side, the current situation is also far from being ideal. The average usage of servers in data-centres is down from about 70% (mainframes in the 80s) to 10% and less (Bundesministerium für Umwelt, 2008). Energy consumption, however, is not the only important issue. Consumption of (rare) elements in ICT devices is increasing every year. Microprocessors in the 1980s incorporated around 12 chemical elements, but in recent products more than 60 (!) chemical elements are used (Hilty, 2008); some of which (e.g. Tantal extracted from the mineral Coltan) are produced under very questionable conditions.

Other important yet indirect footprints of ICT are its "side-" and rebound effects. Dramatic increases in efficiency have reduced the footprint of the individual ICT device (e.g. a mobile phone), but at the same time have also reduced the price so significantly that the increase in the adoption rate has by far outbalanced the efficiency gain (Hilty, 2008). ICT is also the basis of modern logistics in a globalised economy that allows to produce on demand and to send products around the globe during the production cycle. Inception of new technology often also leads to “unplanned” side-effects: virtualisation of communication like email, voice over IP, chat and social networks does not necessarily lead to a reduced footprint in the “real world”, but might even lead to increased impact, e.g. due to more travel activity to visit business partners or friends that we are connected to via ICT in the first place. Opportunities and risks of de-materialisation will be discussed in the next section.

To leverage the impact of ICT and particularly to stop the exponential growth of resource consumption, a series of activities need to be done, in alignment with which “Green IT” has been recently highly promoted, particularly by IT companies. These activities typically refer to energy-efficient hardware technology, reduction of hazardous chemicals used and data centre architecture (e.g., efficient cooling technologies and use of waste heat). However, more steps have to be taken, notably in product design (McDonough et al., 2002). McDonough and Braungart do not focus particularly on ICT equipment in their work; yet it is clear that true “Green IT” starts in the planning phase of new products. The whole life cycle including production and usage resource consumption and end-of-life has to be taken into consideration.

On the software-side, cloud computing, virtualisation and software as a service promise to make software services easier to manage and much more efficient. Instead of operating small-scale and inefficient server infrastructures in-house, outsourcing of data centres to more efficient (larger) ICT companies is recommended, e.g. “renting” virtual machines and storage services (e.g. Amazon, Google) or whole-software packages from Office products (e.g. Google Docs, Zoho) or Customer Relationship Management softwares (e.g. Salesforce). IT services might be seen as a commodity like electricity consumed from a grid at a cheaper price, yet with higher efficiency. If appropriately implemented, the energy consumption should at best stop rising despite significant growth of IT services in the next decades (Laitner, 2003).

3 ICT Supporting Mitigation

In the previous section the direct impact of ICT services on resource consumption and waste production has been outlined, yet the probably more important aspect is *ICT supporting mitigation efforts* in a broad variety of domains. In a *flat world*, i.e. in a globalised world problems are global and so should be solutions, that have to be thought of on a connected, global and interdisciplinary scale. ICT also supported significant changes in the way management works: Thomas Friedman describes this as a change from *command and control* towards *collaborate and connect* (Friedman, 2007). And *connect* also means that 3 billion people reaching for western lifestyle mediated through ICT channels. Thus, ICT already plays a significant role in our today’s world-order and hence has to take its responsibilities in the future.

But ICT can also help on various levels (Laitner, 2003): ICT can provide new insights, e.g. by applying new algorithms in better understanding climate models, can help to reduce energy use (e.g. by using demand-side management or smart grids) and provide real-time data, hence reduce time and distance between measured effects and actions to be taken. Web-based access to this data will provide real-time information to different user-groups and help influence their decisions (e.g. home-owners energy consumption). New algorithms and near real-time data allow to get end-to-end insights into systems that were not accessible until now. Laitner also suggests value-added materialisation, meaning that in a modern "knowledge-based" economy more money is made per "material unit", e.g. comparing the pharmaceutical or ICT industry with mining. This point is however under dispute. Many other authors (e.g. Hilty, 2008) point to rebound effects that usually lead to a significant increase in resource and energy consumption even in knowledge-based economies. Industrial production is still the largest energy consumer (approximately 23% in 2002, globally) and ICT can help to increase efficiency by smart-motor systems (Climate Group, 2008), end-to-end optimisations or demand-side management.

De-materialisation is nevertheless an important area where ICT can provide services. Physical travel can (partly) be replaced with virtual meetings and communication systems. Yet the effects of virtual replacements show different modes, namely substitution, complementarities (virtual systems supporting physical meetings), modification and neutrality (e.g. digital communication that does not influence travel) (Mokhtarian, 2003). This means that the effect of virtualisation is more complex than initially anticipated and actual positive effects strongly depend on boundary conditions, e.g. prices of material goods like fuel. Another often cited aspect of dematerialisation is the "paperless-office" (e.g. Climate Group, 2008): in particular usage of online media versus print documents, e-commerce and e-government initiatives (electronic files) and tele-working (Toffl, 2004). The potential is significant, but until now printing has been deeply engrained in the conventional business-work done by "digital immigrants". This might change, however, with a new generation of office workers that are "digital natives". In academia, but also in business, traditional conferences can and should be replaced with virtual "green" conferences to a significant extent. Conventional conferences tend to be ineffective, time- and resource-consuming. Again, a young generation of professionals might find virtual interaction much more appealing than the current workforce (as it is seen e.g. in Open Source communities).

Finally, ICT can help develop sustainable "green supply chains". Environmental Resource Management (for example in fishery and forestry) is long overdue. Countries like Indonesia lose huge amounts of essential resources for illegal activities. Many research groups work on integrating lifecycle activities with IT monitoring. One example is "trash that thinks" (Saar et al., 2003): RFID tags on products should help select appropriate recycling methodologies for specific sorts of waste. This can of course only be the beginning. The goal should be an end-to-end accounting; a "green supply chain", through which the whole footprint of a product is measured and tracked and paid by the consumer (including costs that are seen as "externalities" today or take place in other countries). E-government and international organisations should participate in such systems to allow monitoring international trade and environmental agreements (Schatten, 2009).

4 ICT Supporting Adaptation and Monitoring

Even under optimistic assumptions, climate change and the degradation of the ecosystems are so far advanced, that adaptation of the society to the inevitable effects will be required. Also mitigation efforts need data and models as previously mentioned. ICT will play an important role in monitoring and adaptation efforts. Already today a wide range of environmental information systems are in place or are being rolled out, e.g. the GMES (Global Monitoring for the Environment and Security) system of European Union (Kušėis, 2006). It is important however, that these different information systems are not isolated and provide synergies through data- and process integration. Connected sensor systems are additionally important to predict events, as input for models (e.g. prediction of the impact of global warming on farming, tourism, etc.) and in case of catastrophes. Parallel to sensor networks, our global ICT infrastructure has to be given more consideration, as it is too fragile in many respects. Next-generation de-centralised distributed communication networks will be required that allow communication also in case of unreliable parts of the infrastructure or attacks and in remote areas. Thus R&D should target not only performance but also resilience (Allenby, 2005).

5 ICT for Public Awareness and Teaching

Our unsustainable behaviour is resulting from the interactions of very complex systems of systems. Public awareness, appropriate political decisions and education are only possible when also laymen are able to understand the consequences of certain actions, e.g. effects of climate change on specific regions. Also interaction of systems (e.g. population growth, economy, resource-consumption, waste, etc.) is very difficult to understand and predict. ICT brings modelling skills, data-integration, user-interface design and visualisation skills that allow making even complex systems transparent to different audiences. Different interfaces are conceivable, from simulations for politicians to video games for teenagers[1].

6 Conclusion

The direct negative impact of ICT is sometimes overestimated, yet has to be treated seriously, particularly due to the high growth rates in ICT. A lot of potentials are already identified and covered in the Green IT movement. Virtualisation, Software as a Service and Cloud Computing also offer more efficient services for the future. On the hardware side, cradle-to-cradle design has to be incorporated in the design of new products. Usage of rare elements, hazardous chemicals and waste-treatment require special consideration. However, more important seems to be the impact of ICT on other fields to

[1] This type of video games is also called “serious games”; it is however still in its infancy compared to other genres of games.

promote a more sustainable economy. ICT has significant leverage to reduce e.g. the carbon footprint in other industries and by far over-compensate the own footprint. Studies suggest that impacts of ICT on other fields can lead to emission reductions five times the size of ICTs own footprint (Climate Group, 2008). Finally, ICT is required for adaptation, modelling and public awareness and as supporter for political decision-making.

Albeit the potential impact of ICT, it seems that the communication among disciplines needs to be improved to give computer scientists a better idea where their services can be of help and vice versa.

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