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Energy Consumed vs. Energy Saved by ICT – A Closer Look

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Abstract

For quite some years now, there has been a growing debate under the label of "Green I(C)T" about reducing the energy consumption of ICT equipment. More recently, the discourse started to partly shift towards a novel discussion on using ICT to induce energy savings in sectors other than ICT. Advocates suggest that the cumulated potential for ICT-induced savings is several times larger than the entire energy consumption of ICT itself.

Numerous studies on ICT-related energy consumption exist, and also an increasing number of studies looking at ICT-induced energy efficiency. The few studies, however, considering both aspects, typically do so independently, without relating the two aspects. Moreover, in the energy efficiency discourse, ICT is usually treated as a monolithic block of technologies – only the application areas that are expected to benefit from it being differentiated.

In this paper, we make the case that ICT energy consumption and ICT's potential for inducing energy efficiency can – and should – be related to each other. We further argue that this can only be obtained by decomposing the "ICT monolith" and look at its (naturally heterogeneous) parts separately. Based on a first round of expert interviews, we show that it is possible to qualitatively determine for every single technology subsumed under ICT its potential for inducing energy efficiency. We finally argue that only by consequently following low energy consumption targets for technologies with a low energy efficiency potential, while at the same time not suffocating technologies with a high energy efficiency potential through restrictive consumption targets, the full ICT-related energy saving potential can be unleashed.

1. Introduction

Despite the fact that Information and Communication Technologies (ICTs) are responsible for only a small part of worldwide greenhouse gas emissions – current estimates attribute around 2% of man-made emissions to ICT (Mingay 2007; GeSI 2008) – this sector is the one with the fastest growing emissions. As a result, there is an increasing concern about the environmental impact of ICT, especially the climate change potential induced by ICT-related energy consumption.

At the same time, there is a growing perception that ICT can also substantially reduce the environmental impacts of other sectors, in particular by increasing their energy efficiency. Due to ICT, all economic sectors can become more energy efficient – since ICT allows existing processes to be optimized or enables entirely new, more energy-efficient processes. The energy that could be saved by ICT-induced energy efficiency is estimated to be several times larger than the overall energy consumption of ICT itself (GeSI 2008). The European Commission recognizes this potential and hopes that Europe will achieve its target of 20% greenhouse gas reduction by 2020 to a relevant degree through the deployment of ICT.

In this paper, we summarize the results from a recent study (Hilty, Coroama et al. 2009), which looked at these two main issues at the intersection between ICT and energy: ICT's own energy consumption and ICT's potential to induce energy efficiency across the economy. We make the case that, unlike most existing studies, the two should be considered together, since only then the full energy saving potential can be unleashed.

2. Relevance of the Field

Compared to the total amounts of energy consumed by the industry, residential, or transport sectors, ICT-related final energy consumption does not seem to be very relevant at a first glance. In 2005, 4.5% (120 TWh/a) of the electrical power in EU-27 were consumed by consumer electronics (mainly TVs and HiFis) and 3.5% (97 TWh/a) for ICT in a narrower sense (PCs, telephones and the communication infrastructure including data centres) (European Commission 2009a). The 2020 business-as-usual (BAU) projection of the same study predicts that ICT-related energy consumption will rise to over 400 TWh, mainly driven by the expected diffusion of larger-screen TVs, higher-speed broadband access, and higher-capacity data centres.

Overall, one could conclude that ICT-related energy consumption is less relevant than the energy demand of other types of technologies, such as industrial machines, non-ICT household appliances (heaters, ovens, fridges), and vehicles. After all, ICT will account for 2.55% of EU-27 total energy (as opposed to electrical power only) demand in 2020 according to these estimates. However, the energy demand of ICT is growing much faster than the total energy demand. From 2005 to 2020, the latter is expected to increase by 15.5%, but the former by 84.3%. For specific sub-sectors, some authors predict even much faster growth. For example, the BAU scenario for data centres in Germany, extrapolated until 2020, would lead to an increase of 396% (Fichter, Beucker et al. 2009).

The idea of an information society, on the other hand, raises hopes for solving the dilemma of sustainable development, which is: Providing quality of life to all people without overusing the ecosystem. This dilemma can only be solved if society manages to create value with much less material and energy input. As has been discussed for decades now, a 'dematerialization' of the economic system by a factor of 4 – 10 is a precondition for sustainability. Creating an information society which makes use of ICTs to provide immaterial services where previously material goods were produced, transported and disposed of, could be a key to economic dematerialization (Hilty 2008).

The European Commission recently defined the role of ICTs in a similar way (although focusing on energy) by stating that "… the continued growth of the European economy […] needs to be decoupled from energy consumption […] Indeed, if nothing were to change, final energy consumption in the EU is predicted to increase up to 25% by 2012, with a substantial rise in greenhouse gas emissions. Information and Communication Technologies (ICTs) have an important role to play in reducing the energy intensity and increasing the energy efficiency of the economy" (European Commission 2008a), p. 2.

At a recent high-level event on ICT and energy in Brussels, the European Commission stated that "the Commission has recognized that ICTs and ICT-based innovations may provide one of the potentially most cost-effective means to achieve the 2020 targets" (ICT4EE 2009). It is only natural then that Viviane Reding, the European Commissioner for Information Society and Media, puts "making better use of innovative ICT solutions to meet our objectives of a low-carbon economy" among the top four research priorities for the next five years (Reding 2009).

The next question to ask is then: How can the "two faces" of ICT, fast-growing own energy consumption and an untapped enabling potential for energy (and materials) efficiency, be reconciled?

3. State of the Art

Both ICT energy consumption and (more recently) ICT-induced energy efficiency have been considered in numerous studies, as well as in research programmes and projects. Overviews of existing programmes and projects are given by (European Commission 2009b; OECD 2009; Hilty, Coroama et al. 2009). The studies are presented below.

3.1 ICT Energy Consumption

The concern with ICT's energy consumption being older, there are quite a number of studies referring to it. Starting from the per-unit consumption of specific technologies, such studies typically use a bottom-up approach to aggregate consumption. The aggregation can be done along *two* axes: a technological and a geographic one. *Technologically*, the aggregation can include all instances of a specific technology (e.g., "corporate data centres"), or the sum of similar technologies – all data centres, for example, as in (IBM 2006; EPA 2007), or all technologies needed for mobile communication – up to the entirety of ICT. It is obvious that the results are sensitive to definitional issues, i.e. the boundary drawn between technologies included or excluded from the system under study. *Geographically*, the aggregation can be done at a regional, national, supra-national (e.g., EU or OECD), or global level.

Studies exist to almost any possible combination alongside these two axes. (Fichter, Clausen et al. 2008), for example, look at data centres in Europe, Asia, and the US. (DEFRA 2008), on the other hand, has a narrower geographical scope (the UK), but a larger technology scope, looking at the entirety of commercial and domestic ICTs. The more comprehensive the aggregation, the larger the insecurities of the estimations also get. Although the per-unit consumption is relatively straightforward and the total number of units sold is usually known from statistical data, assumptions have to be made for the usage patterns of the equipment, the intensity of use (as far as energy consumption depends on it), and the service life of the equipment.

The studies differ substantially in what they consider as being ICT and what not. As we have outlined in (Hilty, Coroama et al. 2009), this is a non-trivial conceptual issue, reflected in the studies. When looking at end-user ICT devices, for example, some studies include printers, others do not. TV sets and set-top boxes are sometimes categorized as ICT and sometimes not. For data centres, depending on whether their related cooling and lighting services are considered or not, rather different results can be expected. From the studies considering the entirety of ICT, some take into account only servers and end-user devices (DEFRA 2008), while others include the communication infrastructure with cable connections, network nodes, etc as well (Fraunhofer IZM-ISI 2008).

Finally, the studies also differ with respect to the life cycle phases of ICT equipment they cover. While most studies consider only the energy consumption in the use phase (which reduces to electricity), some pursue a life-cycle approach. As we have argued in (Hilty, Coroama et al. 2009), as for any other product, life-cycle assessment (LCA) is the most comprehensive method that should thus be used. The usual focus on the use phase of end-user devices reveals only a part of the energy used to finally provide an information and communication service. A study on ICT-related energy consumption in Danish households, for example, provided the following rule of thumb: "When 1 kWh is consumed in the residence 1 kWh is consumed to manufacture, transport and dispose of the hardware and ½ kWh is consumed to run the Internet and the applied ICT infrastructure outside the residence." (Willum 2008), p. 14. The study looked at production, use and disposal of PCs and their peripherals as well as the hardware infrastructure needed at telecommunication providers (for the households' ADSL access) and data centres. This result, even being a rough estimate, makes obvious that the entire life cycle of the whole system providing a given service should be studied in order to correctly assess the environmental impact of producing one functional unit of the service.

3.2 ICT for Energy Efficiency

Estimating ICT's potentials for energy efficiency across the economy is a particularly challenging task. The difficulty has its origins in several factors. Firstly, ICT cannot induce energy efficiency by its own, except in very few cases where embedded ICT directly controls energy flows. For large applications such as smart electricity grids or virtual presence, ICT has an enabling potential for energy efficiency which can only be realized in conjunction with further conceptual, technological and organizational solutions that lie outside ICT (e.g. a fundamental paradigm shift in the topology and control of electricity grids), the political will and economic incentives for such changes, and finally with the individual and corporate readiness to accept and deploy novel solutions (such as telework or virtual meetings instead of travel). As one participant in our survey (presented in the next section) put it, while referring to increasing the quality of data available on ICT-related energy efficiency, "it is rather an allocation problem to explicitly identify ICT's contribution to energy efficiency – it is mostly a mix of many measures, where ICT might be the enabler but efficiency gains are reaped only in conjunction with other measures."

Secondly, for implementing such energy efficient solutions, more ICT components have to be produced, used, and finally disposed of – which induces more energy consumption in the ICT sector itself. We will come back to this point in the next section.

Finally, the mere measurement of energy efficiency effects is rather challenging. Unlike for the relatively straightforward ICT consumption, direct measurements are impossible. An ex-ante analysis is inherently just an estimate, while an ex-post analysis necessarily compares the ICT solution with a non-existing hypothetical situation ("what if the ICT-induced solution did not exist?"). The definitional issues related to this idea of relative energy efficiency are discussed in (Hilty, Coroama et al. 2009).

Despite these difficulties (and to some extent ignoring them), some studies have published estimates of ICT's potential for inducing energy efficiency. Arguably the best-known global figure has been put forward by the (GeSI 2008) report. It estimates for 2020 a global, ICT-induced energy efficiency potential corresponding to greenhouse gas emission savings of 7.8 Gt CO_2e (as compared to a business-as-usual scenario). This corresponds to approximately five times more than the projected emissions of the entire ICT sector (1.4 Gt CO_2e) in that year. The largest per-sector potentials (as predicted by the study) lie in: smart grids (2.03 Gt CO_2e), smart buildings (1.68 Gt CO_2e), smart logistics (1.52 Gt CO_2e), and smart motor systems (0.97 Gt CO_2e).

While (GeSI 2008) takes a global view, the (Bio-Intelligence-Service 2008) study looks at the EU-27 situation. It considers three of the above-mentioned domains: buildings, motors, and the power grid. Taking their estimates for energy and applying the study's emission factors, the following potential savings result: 250 Mt CO_2e for buildings, 15 Mt CO_2e for motors, and 17 Mt CO_2e for smart grids.

A European Commission ad-hoc advisory group compiled some data as well. Their report (European Commission 2008b) complements the studies mentioned above by looking at the ICT-induced energy efficiency potentials in industry in more detail. They do not provide absolute figures, but estimate the following efficiency potentials in the manufacturing industry: process optimization (25-30%), optimized logistics (16%), integrated process chains (30%), development of new products (10-40%), and for the process industries: cement industries (27.5%), steel industry (10-15%) (European Commission 2008b).

If ICT contributes to the energy efficiency of the economy, this should also be observable at the macro level. Despite the difficulty to attribute an observed effect to ICT (as argued above), some authors argue that the networking enabled by ICT has already led to a decrease in energy consumption per unit of GDP. (Romm 2002) observed that in the US between 1992 and 1996, the GDP and the energy consumption grew at a similar rate of 3.2% and 2.4% per year, respectively. Between 1996 and 2000, however, the average annual growth rates were 4% and 1%, respectively, the energy demand being thus clearly decoupled from the GDP growth. In other words, the macro-economic energy demand per unit of GDP was decreasing more rapidly than before. According to (Romm 2002), this can be explained by two factors, both related to the diffusion of ICT. First, the ICT producing sector (growing at a rapid pace in the years 1996-2000 and being partly responsible for the GDP growth) is less energy intensive than other production sectors. Second, and more relevant to our discussion, the Internet seems to have increased the energy efficiency in different sectors of the economy in those years.

4. The Big Picture: Relating Consumption and Efficiency

Which types and applications of ICT deserve being pushed by environmental or climate policies (because their contribution to energy efficiency clearly exceeds the increase in energy consumption one would have to accept), and which ones don't?

Few of the existing studies deal with both ICT's own energy consumption and its potential for energy efficiency throughout the economy. The best known are the above-mentioned (GeSI 2008) and (Bio-Intelligence-Service 2008) studies. (The latter one, despite its title "Impacts of Information and Communication Technologies on Energy Efficiency", does look at ICT energy consumption as well.) However, these studies look at consumption and efficiency *independently*. While they provide in-depth analyzes of numerous sectors, putting forward complex, detailed, and all-encompassing data, they fall short of conceptually contrasting ICT's own consumption and the energy efficiency it can induce across society. Putting it bluntly, the studies argue that ICT's own energy consumption should be as low and the induced efficiency as high as possible.

Obviously however, pushing the second goal will compromise policies focusing on the first one. Fostering the use of ICT for energy efficiency beyond baseline- or BAU scenarios will necessarily lead to a faster increase of ICT-related energy consumption in certain application fields. This consumption, however, will have to be accepted since the very reason for its existence is that it is over-compensated for by the energy saved as a consequence of the energy efficiency induced by the ICT applications.

In short, we are proposing to distinguish "good" from "bad" ICT energy consumption. Without this difference, policies that effectively limit ICT energy consumption risk to undermine policies fostering ICT for energy efficiency. Viewed from the other side, policies boosting ICT diffusion based on the belief that this will advance energy efficiency in any case are at risk to create a net increase in energy consumption.

In order to do so, we must decompose the "ICT monolith" and acknowledge the natural differences between specific Information or Communication Technologies, to then be able to analyze and then treat each of them separately. We have started this process based on a first round of expert interviews.

In the interviews, we presented 4 broad categories of ICT to the experts: "servers", "network infrastructure", "end-user devices", and "embedded ICT". The "embedded ICT" category was not further refined, the other categories had between 3 and 7 sub-categories. It would go beyond the scope of this paper to summarize all consumption- and efficiency-related findings from the interviews – a more detailed report can be found in (Hilty, Coroama et al. 2009). Here, we will focus only on the *relation* between the two.

The table below contrasts the experts' opinions about the level of energy consumption for the individual categories with their potential of inducing energy efficiency across society. The (very general) questions we put were: "Is the category relevant to the overall energy consumption of ICT?", and "Is it relevant for reducing the energy consumption in other areas?", respectively. The answers to these two simple questions already show some clear trends, which we present in the table below. Since for most questions, the experts agreed with a large majority on either "yes" or "no", the table lists a "low" for less than 35% "yes" answers, "high" for more than 65% "yes", and "medium" for the values in between.

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

From the table above, several interesting conclusions can be drawn. Firstly, servers are seen by a clear majority as the big energy consumers. This observation refers not only to the three "data server" categories A1, A2, and A3, but also to the category B4, comprising "communication servers," such as Internet nodes.

Communication cables, antennas, and satellites, on the other hand, are not associated with a high own energy consumption. Nevertheless, for all these categories the potential for energy efficiency is rated as more relevant than the own energy consumption – which might come to little surprise when thinking that the networking enabled by these technologies is a necessary basis for applications aimed at inducing more energy efficiency by automated control, metering, information gathering, etc., and has a potential to optimize and substitute physical transport.

Personal computing devices, while contributing significantly to the overall ICT energy consumption, are regarded as less relevant for inducing energy efficiency than servers, communication infrastructure, or embedded ICT. This observation actually applies to all "end-user devices" subcategories – where the ratio between own energy consumption and potential for energy reduction is the least favourable, as compared to the other three main categories.

This insight applies particularly to the category C4 "TV sets and set-top boxes." From all the technologies that are not servers, it sticks out in a negative sense – without exception, all interviewees think that it is responsible for a relevant part of the overall ICT energy consumption, while almost no one thinks that it could contribute towards energy efficiency.

Finally, the group D of "embedded ICT" is worth a look at. While the majority of interviewees thinks it has an important own energy consumption, even more (91%) also thought that it is relevant for inducing energy efficiency throughout the economy – the largest number of any category or sub-category. And indeed – embedded ICT include, for example, sensors which are necessary in smart meters for providing fine-granular, real-time data about a building's energy consumption, or for gathering the information needed in intelligent transport systems (ITSs). Embedded ICT further includes both the sensors and actuators needed for smart engines, along with numerous other categories, and is thus the technology expected to have the largest enabling potential for energy efficiency.

Comparing these last two categories C4 and D, underlines very well the point we are trying to make in this paper. Both categories "TV sets and set-top boxes" and "embedded ICT" are expected by experts to significantly contribute to the overall ICT energy consumption, but should not be lumped together. This is because the returns in terms of energy saved by efficiency-enabling effects are completely different.

In subsequent parts of the interview (which we do not cover here) we asked more detailed questions. One of these questions was about how the overall consumption in the individual categories would evolve until 2020, assuming either

- a business-as-usual (BAU) scenario (along the expected technological and market developments), or
- an energy-optimistic scenario (in which the full potentials to reduce the energy demand of ICT would be consequently tapped).

While in the BAU scenario, the experts agreed that the consumption will significantly increase for both categories, in the energy-optimistic scenario, "TV sets and set-top boxes" scored much better than "embedded ICT". Obviously, the experts assume that consumption in the first case can be reduced substantially if incentives for low energy consumption are in place.

Here we thus have two categories: both ICT, and both significantly contributing to the overall ICT energy consumption today. Both are expected to rapidly increase the consumption in a BAU scenario. For one of them, this future development can better be influenced towards less consumption. Yet it would be one-sided and short-sighted to conclude that "TV sets and set-top boxes" are therefore somehow "better" than embedded ICT! Only by taking into account the rightmost column in the table above (the technologies' potential for inducing energy efficiency), the picture gets complete. The fact that the experts see a potential for reducing the energy consumption of consumer electronics is indeed good news, since their "bad consumption" does not contribute to macro-economic energy efficiency. That for technologies such as embedded ICT (but also others, most prominently servers), however, a further increase in consumption seems inevitable, is not necessarily bad news, as far as this increase is due to meaningful applications that boost energy efficiency.

With this example we have shown that it is crucial to differentiate between specific technologies and to contrast their prospective consumption with their prospective contribution to efficiency in each case. Looking at the energy consumption of "the ICT sector" or for the contribution of "the ICT sector" to energy efficiency does not provide the data needed for effective environmental or climate policies.

5. Conclusions

We conclude that ICT energy consumption and ICT-induced energy efficiency are two areas of research that should be integrated. A conceptual and methodological integration is a necessary condition for assessing net energy impacts of ICT in specific application areas. This comes along with decomposing the "ICT monolith" into more specific technologies and their application fields. In each field, then, consumption can be related to efficiency potentials.

In a context of environmental or climate policies, it is crucial to focus on specific types of ICT, their application fields, their energy consumption and potential contribution to energy efficiency. Otherwise, if ICT is treated as a (however defined) monolithic block, but the energy consumption issue separated from the efficiency-enabling issue, it is hard to see how a coherent policy leading to true energy savings could ever emerge.

The work we presented, including the expert interviews, forms only a beginning of the type of research we want to encourage. More can be done by systematically screening ICT application fields for hot spots of increasing energy consumption and unused ICT-induced energy efficiency potentials.

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