Digitalisation for sustainability? Challenges in environmental assessment of digital services

Johanna Pohl[1] and Matthias Finkbeiner[2]

Abstract: The expectations for Information and Communication Technology (ICT) to tackle climate change are massive, but successful implementation is by no means assured. Contrasting resource saving potential of ICT, energy and resource demand of end-user devices and digital services are growing. The overall question is, how great must the net enabling effects of specific digital services be in order to balance or exceed direct effects of ICT devices and the infrastructure used. To contribute to a more coherent assessment of digitalisation´s implications for sustainability, the authors suggest the following points: to cover all potential impacts, an environmental assessment of ICT has to follow a life cycle approach. Both ICT infrastructure as well as changing use patterns (direct rebound effects) have to be included into the system boundaries; only addressing energy issues is not sufficient. In addition, the material basis and resulting environmental and social impacts from mining, production and disposal have to be addressed.

Keywords: ICT, direct effects, enabling effects, rebound effects, environmental assessment

1 Background

Digitalisation and Information and Communication Technology (ICT) use is spreading, and it goes hand in hand with the massive energy saving potential through optimisation and virtualisation [Mi10]. Many see them as the solution to the energy crisis and climate change [We17; HA15; OE 2015]. ICT is thereby widely seen as a key enabling technology: environmental impacts can be reduced by using *green ICT* (ICT with a better environmental performance) and *ICT for green* (ICT as an enabler for other processes to have a better environmental performance). The expectations on digitalisation are massive, but with all factors considered, what is the real impact on the environment? The paper at hand will thus focus on the following questions: has resource use decreased so far thanks to ICT, and what are the chances it will do so in the future? What are the challenges when assessing the environmental and sustainable impact of ICT?

Environmental effects of ICT can be divided into direct effects (first order), enabling effects (second order) and structural effects (third order) [Mi10]. While direct effects trace back to production, use and end-of-life treatment of ICT, second order effects refer to enabling effects due to the application of ICT on a micro perspective, such as optimisation, virtualisation or substitution. Third order effects are concerned with the societal structures

[1] TU Berlin, Center for Technology and Society, Hardenbergstr. 16-18, 10623 Berlin, pohl@ztg.tu-berlin.de
[2] TU Berlin, Chair of Sustainable Engineering, Straße des 17. Juni 135, 10623 Berlin, matthias.finkbeiner@tu-berlin.de

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and the economy [Mi10]. For slightly different taxonomies see [Ho16] or [HA15]. In the following review, only direct and enabling effects of ICT will be considered, as it is focusing on consumer-side environmental effects of ICT. ICT here will be divided into end-user devices and ICT infrastructure (network infrastructure, data centre computation and storage).

2 ICT between resource optimisation and resource demand

Despite the promise of *green ICT* and *ICT for green* to contribute to a reduction of resource usage, the overall energy demand of ICT has increased continuously over the last few years from 3.9 % in 2007 to 4.6 % in 2012 in terms of total worldwide electricity consumption [Va14]. Although the relative energy efficiency of devices itself strongly improved, the total amount of energy increased. This is due to numbers of end-user devices and digital services used worldwide increasing significantly, with numbers continuing to increase [AE15]. Concerning future trends of ICT's energy demand, predictions range from a decrease due to further increasing energy efficiency of devices [ML16; St15] and an increase due to strongly increasing energy demand of ICT infrastructure [AE15; Ha16; Va14].

Estimations on ICT's enabling effects and its implications for the environment are rare [Im08; EH10; Sm15]. For example, calculations by the Global e-Sustainability Initiative (GeSI) expect ICT's reduction potential in other economic fields to be 20 % of global CO_2 emissions until 2030 [Sm15]. Methodically, the authors offset actual direct effects of ICT against hypothetically avoided indirect effects in other fields. Further impacts caused by specific applications, which might lead to differences between potential and actual reduction, were not considered [Hi14].

3 Challenges

At the moment, we are able to assess the growing environmental impact of increased direct effects of ICT. However, enabling effects in a complex and connected world are hard to estimate. With this in mind, we propose that the overall assessment should measure, how great net enabling effects of specific digital services must be in order to balance or exceed direct effects of ICT devices and infrastructure used. Five points shall be highlighted, which are crucial in assessing enabling effects of ICT towards sustainability:

1. *Life Cycle Perspective:* The assessment of ICT's environmental impacts is still conducted in various ways [Ar14]. To cover all potential impacts and to contribute to an overall comparability of results, the environmental assessment has to occur during all phases of the product life cycle. Depending on the life span and the use scheme, both the use phase and the production phase can be decisive for overall results [Ar14; CA13]. A tool for assessing all potential impacts of a service is Life

cycle assessment (LCA). The research community currently works on harmonising LCA methods measuring direct effects of ICT [An11]. Further methodological challenges exist when defining system boundaries, collecting inventory data, or defining allocation rules [Hi14].

2. *Estimating ICT infrastructure*: As digital services become more and more relevant, we face upstream-shifting of electricity demand and resources used from users to providers of digital services and infrastructure [AE15]. This goes hand-in-hand with an upstream-shifting of environmental impacts. While assessing direct impacts of ICT, effects due to ICT infrastructure must not be underestimated. However, what makes the particular assessment more complicated, are structural changes in data centre architecture [Sc15; Hi15] or unknown material basis of data centres [HC16]. Consequential life cycle assessment could be an approach to assess these more complex and dynamic systems [EH11].

3. *Integrating Rebound Effects:* Next to positive net effects of ICT application (e.g. enabling effects reducing resource use by optimising other processes), negative effects of ICT application also need to be addressed, that happen precisely because of an increase of efficiency – the rebound effect. The most common classification of rebound effects distinguishes between direct rebound effects, which lead to additional consumption of the same good, and indirect rebound effects, which lead to additional consumption of other goods. A third category counts economy-wide rebounds [Sa16]. How to integrate rebound effects into environmental assessment of ICT has already been identified as a research gap by some researchers [Bö14; Fi14; Ho16]. In current taxonomies of environmental effects of ICT, rebound effects are mostly considered as third order effects [HA15; Mi10], which does not reflect all types of rebounds. Direct rebound effects occur on end-consumer level and thus need to be included into the environmental assessment of ICT's enabling effects. This calls for enhanced methods. In order to estimate these rebound effects, changing usage patterns need to be included into the environmental assessment [Po16], indicating the need for interdisciplinary approaches. By using consequential life cycle assessment, potential changes in the environment due to rebound effects could be integrated [Be14; EH11; FV14].

4. *Resource use and environmental degradation:* Currently, environmental assessment of ICT devices and digital services focuses mainly on electricity demand and related emissions [AE15; Ar14; Sm15], thus neglecting the material basis of ICT. With growing numbers of ICT devices, the issues of availability of resources and resource depletion become more and more important. Global production of smartphones and tablets demands between 8 to 10 % of the world's primary production of cobalt and palladium. Furthermore, the ICT sector is also relevant for global demand of tantalum, silver, gold, indium and magnesium [Ma16; Wä15]. In addition to resource depletion, further environmental impacts resulting from the mining, production and disposal of ICT devices need to be taken into account when assessing environmental impacts of ICT. Examples of these are land use, contamination of soil or water, or loss in biodiversity.

5. *Social Impacts:* The global production system of ICT devices comes with social impacts resulting from the mining, production and disposal [Ma16]. Deteriorated living conditions resulting from environmental degradation (4), poor working conditions, safety and health issues, corruption or involvement in areas with armed conflicts are part of the ICT sector [BP10; EF13]. These social impacts need to be taken into account, especially when assessing enabling impacts of ICT for sustainability.

4 Conclusion and Outlook

The process of digitalisation goes hand-in-hand with a massive growth in absolute numbers of end-user devices as well as data traffic, which currently leads to growing energy and resource demand. Whether this will be compensated by changed life span or use scheme of ICT devices (e.g. reuse or longer use of devices), improvements in resource efficiency of ICT itself and enabling effects in other economic fields, is by no means assured. As shown above, the current discussion on energy efficiency of devices and applications is not sufficient. In addition, the reduction potential of specific ICT applications depends on energy and materials used, user behaviour and further effects resulting from the application of ICT. Future research should address the challenges named in order to paint a more coherent picture of digitalisation´s implications for sustainability matters.

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