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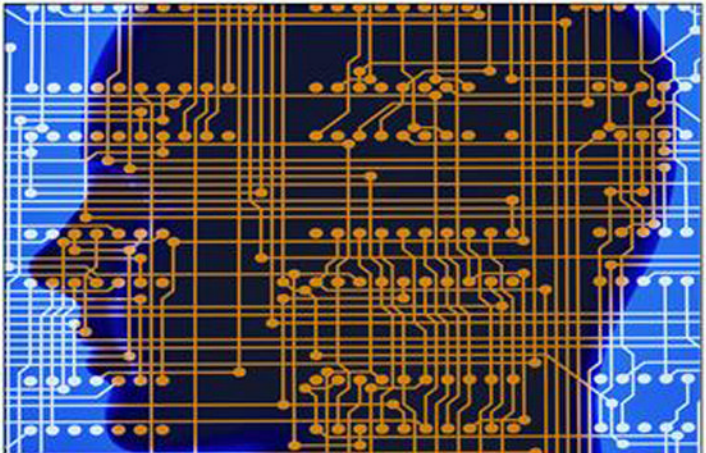
# Information and Communication Technologies, Society and Human Beings

## Theory and Framework



DAREK M. HAFTOR & ANITA MIRIJAMDOTTER

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## Theory and Framework

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## Chapter 33

# Information and Communication Technologies for a More Sustainable World

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## ABSTRACT

*As has been discussed for decades, a reduction of the input of natural resources into industrial production and consumption by a factor of 4-10 is a necessary condition for Sustainable Development. This paper discusses the potential contribution of Information and Communication Technology (ICT) to such a dematerialization of the industrial societies and introduces a conceptual framework which accounts for positive and negative impacts of ICT on physical flows. This framework addresses three levels: the ICT life cycle itself, life cycles of other products influenced by ICT applications, and patterns of production and consumption. The conclusion is that ICT will only contribute to Sustainable Development if this technology is recognized and used as an enabler of a deep structural change; a transition towards an economic system in which value-creation is mainly based on information processing while keeping the physical properties of material within some limits that ensure that it can be recycled. This structural change will include the transition from a material-property-transfer mode to a service-transfer mode of consumption in areas where this is technically feasible and beneficial in terms of resource productivity. In such a post-industrial society, which may also be called a sustainable information society, open technological standards will play a crucial role, since they allow for complexity reduction while keeping competition alive, thus minimizing the risk of unmastered complexity in new critical infrastructures.*

## INTRODUCTION

The most prominent definition of Sustainable Development was given by the World Commission on Environment and Development, also known as the "Brundtland definition": In order to be considered sustainable, a pattern of development has to ensure "that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

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Read as a normative statement, this definition combines two ethical claims, intragenerational justice (meeting the needs of the present) and *inter*generational justice (not compromising future generations). This double claim leads to a dilemma, since it is impossible to extend the present consumption patterns of the rich industrialized countries to all parts of the world without putting a great burden on future generations.

In order to solve or at least mitigate the dilemma, the global economy will have to learn to produce more quality of life with less input of material and energy.

It is apparent that the widespread use of Information and Communication Technology (ICT) is changing our world, a development taking place even faster than political decision makers can react to the changes. The Internet (with e-mail, the Web, VOIP and unlimited future applications), the mobile networks (with 4 billion subscribers world-wide), Radio Frequency Identification (RFID) systems and embedded ICT systems (to which 98% of all microprocessors belong) have massive economic, social and ecological effects on a global scale.

This chapter brings together the issue of Sustainable Development with perspectives of an information society that is post-industrial in the sense that the throughput of material and energy needed to satisfy human needs would be much lower than today. The chapter also presents a conceptual framework to assess the material effects of ICT, providing a basis for political strategies towards a sustainable information society.

## PERSPECTIVES OF ICT AND SUSTAINABILITY

Starting from the issue of economic dematerialization as a necessary condition for Sustainable Development, a conceptual framework will be presented and exemplified which accounts for positive and negative impacts of ICT on material and energy flows at different levels: the ICT life cycle itself (first-order effects), life cycles of other products influenced by ICT (second-order effects), and patterns of production and consumption (third-order effects).

### The Dematerialization Issue

The dematerialization discourse was started about two decades ago with statements such as the following:

"Considering the fact that for every person in the United States we mobilize 10 tons of materials and create a few tons of waste per year, it is clearly important to gain a better understanding of the potential forces for dematerialization. Such an understanding is essential for devising strategies to maintain and enhance environmental quality, especially in a nation and a world where population and the desire for economic growth are ever increasing" (Herman et al., 1990, p. 346).

At the global level, 58 billion metric tons of resources were extracted from nature in 2005 (OECD, 2008). This includes fossil fuels, metals, industrial and construction materials as well as biomass. Although the current rate of resource extraction seriously affects the global ecosystem, the increase is expected to continue. This even includes the use of fossil fuels, although that is supposed to be limited by climate policies. The OECD estimates that global resource extraction will exceed 80 billion tons in 2020. This means that mankind will have doubled the annual global rate of resource extraction within only 40 years (1980-2020).

Let us look at some more specific examples: The *per capita* consumption of aluminum in industrialized countries today is higher that in a typical developing country by a factor of 14 and that of steel by a factor of 130. An average North American consumes about 340 kg of paper per year, whereas an Ethiopian – on the other end of the scale – about 300 g. This list could be continued almost indefinitely. Even if the figures are only snapshots, very imprecise and some of them outdated, their magnitude reveals the basic dilemma of all sustainability policies: the lifestyle of the rich industrialized countries cannot be adopted in its present form by the whole globe, nor can any lifestyle that is as material-intensive as that of today's richest countries.

Since the mid-1990s estimates have been discussed according to which the material intensity per service unit must be reduced by a factor of 4 to 10 if the lifestyle of the rich North is to be applied across the whole globe. By and large, there are no doubts as to the technical feasibility of such a big leap in resource productivity (Von Weizsäcker et al., 1997; Schmidt-Bleek, 2009).

Viewed from this perspective, there is only one relevant role ICT can play in supporting Sustainable Development: enabling or facilitating the dematerialization of production and consumption processes, i.e. to contribute to a drastic increase in resource productivity. This idea leads to the vision of an ICT-enabled 'weightless economy' or 'sustainable information society', as suggested by Heiskanen et al. (2001), Schauer (2003), Isenmann (2008), as well as by the author (Hilty, 2008a).

## The Role of ICT in Dematerialization

Given that dematerialization is so important, the next question we must address is whether and under what conditions ICT can contribute to this change.

Unfortunately, we have to face the fact that the richest economies – which also have the highest penetration of ICT – are not the most dematerialized ones. For example, the consumption of an average inhabitant of Switzerland causes a material flow through the global economy of roughly 48 tons per year, which is about five times the current global average (based on data provided by FSO, 2008, and OECD, 2008). It is remarkable that the material throughput per capita is highest in rich societies in which 'light' and 'virtual' are attributes with positive connotations.

The sobering observation that ICT does not automatically create a dematerialized society, however, does not imply that this is impossible in principle. The following two arguments shall explain why there is still a chance to unleash the dematerialization potential of ICT.

The *first argument* is based on an analogy, replacing resource productivity with labour productivity for a moment. In the 1980s and 1990s, the so-called 'IT productivity paradox' was discussed in economics and management literature for a long time. Robert Solow, the 1987 Nobel laureate in economics, initiated the debate by stating that "we see the computer age everywhere except in the productivity statistics" (Solow 1987). The common belief that computers increase labour productivity was surprisingly not supported by macro-economic data (just as it is the case for resource productivity today). The subsequent controversy motivated a range of interesting research projects on the question as to how computers affect the productivity of organizations. The firm-level data showed substantial variation across firms, leading to the conclusion that the effect of introducing the new technology was depending of the organizational conditions under which it was applied (Brynjolfsson and Hitt, 1998).

In a very similar way, it may turn out in the near future that ICT does enable massive increases in resource productivity under specific organizational conditions; conditions which are not common so far, but may spread in the future.

The *second argument* is based on the idea that positive effects of ICT are already there, but cancelled out by negative ones when all effects are aggregated to the macro level. To create a 'selective environment' for ICT applications, one which clearly prefers the 'truly dematerializing' ones, would then be the silver bullet to dematerialize the economy. A simulation study commissioned by the Institute for Prospective Technological Studies (IPTS) of the European Commission concluded that, under conditions generally conducive to environmental protection, ICT reduced the overall environmental impact by around 20% (from 2000-2020), whereas under the least favourable conditions ICT was responsible for 30% of the additional environmental impact. However, under business as usual conditions, the positive and negative effects of ICT on the environment had the tendency to cancel each other out, so that no clear effect at the macro level occurred (Erdmann et al., 2004; Hilty et al., 2006a).

It is therefore possible that the dematerializing effect of ICT would dominate if there would be a selective environment (the framework conditions set by politics) encouraging the "dematerializing" applications and to inhibit the others. In particular, rising prices for materials and energy can be expected to create dematerializing changes in production and consumption patterns, using (and as well needing) ICT as an enabling technology.

However, there will only be room for big leaps if people's view of material goods changes: In many fields, consumption patterns will have to change from purchasing *material goods* (transferring material property), which are then used and destroyed, to purchasing *services* instead. Since the material goods needed to produce the service are owned by the service provider, this company has a strong incentive to see them being put to optimal use and to maximize service life (which slows down material flows). ICT is an enabling technology to implement the business models needed for this type of change.

## The Full Picture of Material ICT Effects

In general, there are three levels of material ICT effects that must be taken into account (Erdmann and Hilty, 2010):

- 'First-order' or 'primary' effects: effects of the physical existence of ICT (environmental impacts of the production, use, recycling and disposal of ICT hardware).
- 'Second-order' or 'secondary' effects: indirect effects of ICT due to its power to change processes (such as production, transport or consumption processes), resulting in a decrease or increase of the material impacts of these processes.
- 'Third-order' or 'tertiary' effects: effects of the medium- or long-term adaptation of behavior (e.g. consumption patterns) and economic structures to the availability of ICT and the services it provides.

The third-order effects include the widely discussed rebound effect. A rebound effect occurs if and when the efficiency of providing a service is increased but there is no factor limiting the demand for this service, such as the price to be paid or the time needed for consuming it. The economic system adapts to the higher efficiency level at which the service is provided by increasing the demand for the service (Hilty, 2008a).

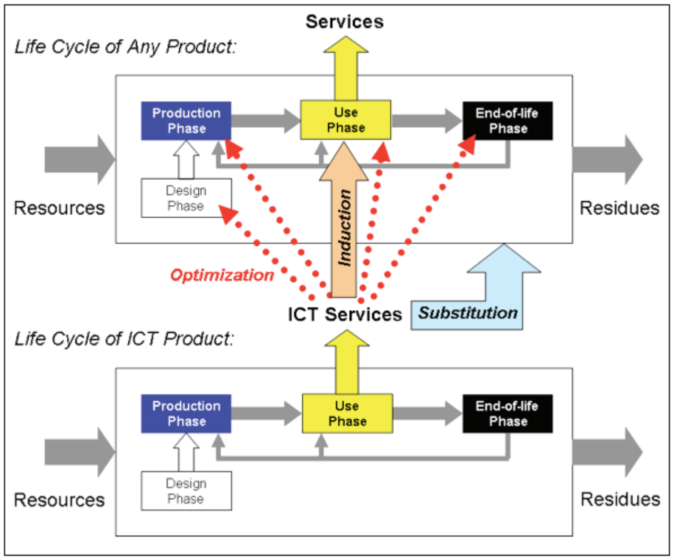
## Linked Life Cycles: A Framework to Assess First- and Second-Order Effects

Figure 1 shows how the service provided by using an ICT product can have an effect on the life cycle of another product. There are three types of effects: optimization (dotted arrows), induction (straight arrow), and substitution (bent arrow).

*Optimization effects* (denoted by the four dotted arrows) may occur in all phases of the life cycle, as well as in the design phase. CAD tools, for example, can be used to optimize a product for environmental criteria (eco-design). Design has a strong impact of the life cycle because it constrains the optimization potentials that will exist in the production, use and end-of-life phases. For example, if the variety of materials or the complexity of the product can be reduced in the design phase, it will be possible to reach a higher efficiency level in end-of-life treatment.

*Induction effects* (denoted by the arrow in the middle) occur when an ICT service stimulates

*Figure 1. How ICT products influence the design, production, use, and disposal of other products (Hilty 2008a)*



the use of the other product, i.e. more functional units per unit of time are consumed (e.g. the text-processing service provided by a PC system with a printer may stimulate paper consumption).

*Substitution effects* (denoted by the bent arrow) occur when an ICT service replaces the use of a physical product, e.g. when e-mail replaces the use of conventional paper-based mail.

With Life Cycle Assessment (LCA) methodology, it is possible to quantify the potential environmental benefit of specific optimization and substitution effects. For example, a given conference can be hypothetically virtualized and the difference in environmental impacts assessed (see Figure 2). We did so for *EnviroInfo 2001,* which was held at ETH Zurich, assuming that all travel of participants would have been replaced by Internet connections for video streaming, online discussions, upload and download of presentations, etc., including the estimated environmental

*Figure 2. CO2 emissions caused by an international conference, physically or virtually (Hischier and Hilty, 2002)*

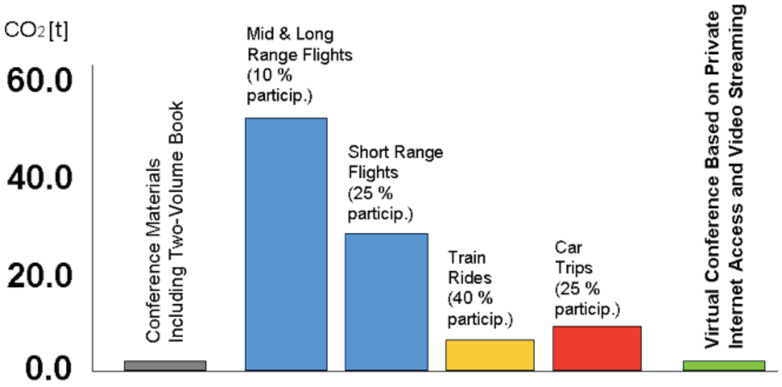
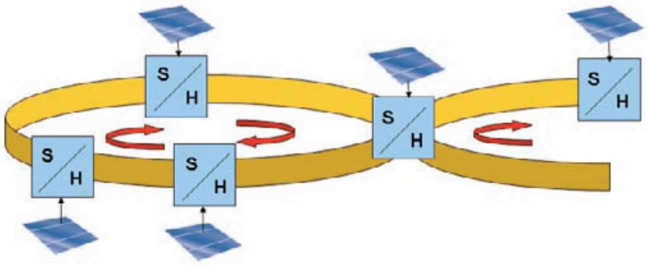


*Figure 3. The idea of a largely dematerialized closed-loop economy. The transformations of material resources at nodes denoted 'S/H' add value by creating structure without devaluating the material. Each value-creating node is driven by renewable energy (symbolized by a solar panel) and consists of a hardware part H (capital goods for transforming material and energy) and a software part S (the knowledge of how to control these transformations in a manner that adds value).*



impact of the Internet connections. It turned out that the virtual conference would only have caused 2-3% of the actual $CO_2$ emissions of the physical conference.

The main part of the total emission was due to travel activities, as can be seen in Figure 2. Only 6% of the participants who had to take a long-range flight accounted for 60% of the overall emission of the conference (Hischier and Hilty, 2002).

## Positive Third-Order Effects

What is needed from the perspective of sustainability is a deep structural change which would make the above-mentioned substitution effects into an essential feature of the economy. In an economy that has been dematerialized in this way, value-added would depend a lot more than it does today on the creation of structures at the symbolic level and not on the churning of material and energy.

Figure 3 sketches the basic idea of such an economy. In such an economic system, all scarce substances are carried in closed cycles which are maintained by renewable energy. All value creation takes place alongside these closed cycles, transforming the (symbolic) structure of material while keeping its physical properties within some limits that ensure that it can be recycled. The whole system consists of a network of such closed cycles.

The hardware/software dichotomy of the ICT sector is generalized to the whole economy: Each node of the network consists of hardware (capital goods for transforming material and energy) and software (the knowledge of how to control these transformations in a manner that adds value). Today's distinctions among raw materials, product and waste will become obsolete, since there is no beginning or end of the cycles. Innovation will mean the introduction of new nodes into the system.

## Negative Third-Order Effects

There are two types of negative effects at the systemic level that should be counteracted by policies for a sustainable information society:

- rebound effects and
- dependability on highly complex infrastructures.

Rebound effects occur if and when the efficiency of providing a service is increased but there is no factor limiting the demand for this service, such as the price to be paid or the time needed for consuming it. The economic system (as a functional system of society) adapts to the higher efficiency level at which the service is provided by increasing the demand for the service (Hilty et al,. 2006b). Therefore, as pointed out above, ICT will only succeed as an enabler of dematerialization if an adequate selection environment is in place.

But, even worse, the system does not only adapt to higher efficiency, it also adapts to stable availability of a service – by becoming dependent on it. The Internet and other ICT infrastructures such as mobile phone networks are therefore becoming critical infrastructures for society and should be applied with precaution in order to maintain a margin for future developments (Som et al., 2004). ICT has also "has pervaded other infrastructures, rendering them more intelligent, increasingly interconnected, complex, interdependent, and therefore more vulnerable" (IRRIIS Consortium, 2006). These other infrastructures include transport, energy, water, finance, and national security (Hilty, 2008b).

The actual level of vulnerability of an ICT system is almost impossible to assess due to the problem of "unmastered complexity". This term was coined by one of the world's most influential computer scientists, Edsger W. Dijkstra. He repeatedly warned the community of computer professionals against the complexity of their own artifacts: "Computing's core challenge is how not to make a mess of it. … Because we are dealing with artifacts, 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." (Dijkstra, n.d., pp. 1 f). No single programmer has a truly comprehensive grasp of the code that has been written for even one of today's operating systems or large application programs. If these systems are connected via networks, systems of an even higher level of complexity are created the behavior of which is no longer predictable.

Dijkstra's warning hasn't been heeded much in commercial practice, as shown by today's most popular systems. It is because of this general and deeply rooted flaw that catastrophic attacks against ICT infrastructure can't be ruled out. For the same reason, the risk of such attacks cannot be quantified in advance. What we do know for sure is that software diversity mitigates the vulnerability of critical information infrastructures, whereas software monoculture makes them more fragile. Open standards make it possible to reconcile interoperability and diversity: They specify the 'What' based on a cooperative process and leave it to the market to find the best solution for the 'How'. By contrast, so-called proprietary standards (which are no standards, *de-facto* standards at the best) are used to create consumer lock-in effects and lead to technological monocultures.

So-called proprietary standards have even more disadvantages with regard to sustainability: They are not based on a consensus and can be modified arbitrarily by their proprietor: Even small changes may invalidate capital invested in the standard, such as fully operational equipment (with all its ecological backpack), skills created by adaptation to the standard (human capital), and confidence in infrastructures, institutions and people (social capital). Since an open standard is defined in a consensual process, it can usually not be changed arbitrarily to the disadvantage of parties who have made investments based on the present version. Proprietary *de facto* standards thus concentrate destructive power, bearing a high risk for society and nature.

From the perspective of complexity reduction, it is clearly better to have a reliable and stable specification (the definition of the 'What') and a variety of competing approaches to the implementation (the 'How') – which is then irrelevant and may be hidden – than to have an unreliable specification with only one implementation, which is then replicated millions of times with all its errors and security holes.

Information infrastructures based on proprietary standards are therefore not sustainable. The fact that many commercial software products are peppered with errors and consequently depend on regular updates creates an additional problem because this leads to a concentration of power in the hands of any actor who is recognized as the legitimate provider of an update.

## CONCLUSION

We have shown that the Brundtland definition of Sustainable Development, read as a normative statement, leads to a fundamental dilemma at the metabolic level of the economy for which we introduced the term 'sustainability dilemma'. If ICT is to solve or at least mitigate this dilemma, it is vital to purposefully deploy this technology for the dematerialization of production and consumption processes.

ICT will grow into this role if and when the economic incentives pass a certain threshold to change behaviour and trigger innovation towards dematerialization, which has not been the case so far.

While many activities to use ICT for Sustainable Development focus on first- or second- order effects, it is particularly important to use the enabling potential of ICT for long-term structural change. This means to use ICT with the awareness that "doing more of the same" with the help of this technology (e.g. guide more cars though a congested road) will not solve the critical problems the world is facing, because it will not contribute to solving the sustainability dilemma. It could even create rebound effects and consolidate old structures.

What we need is a deep structural change towards an economic system in which value-creation is mainly based on information processing while keeping the physical properties of material within some limits that ensure that it can be recycled. This structural change will include the transition from a material-property-transfer mode to a service-transfer mode of consumption in areas where this is technically possible and leads to a higher resource productivity (assessed from a life-cycle perspective).

In such a post-industrial society, which may also be called a sustainable information society, open technological standards will play a crucial role, since they allow for complexity reduction while keeping competition alive, thus minimizing the risk of unmastered complexity in emerging critical infrastructures.

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## REFERENCES

Brynjolfsson, E., & Hitt, L. (1998). Beyond the Productivity Paradox. *Communications of the ACM*, *41*(8), 49–55. doi:10.1145/280324.280332

Dijkstra, E. W. (n.d). The next fifty years. Retrieved April 12, 2008 from http://www.cs.utexas.edu/~EWD/ewd12xx/EWD1243.PDF

Erdmann, L., & Hilty, L. M. (2010). (accepted for publication). Scenario Analysis: Exploring the Macroeconomic Impacts of Information and Communication Technologies on Greenhouse Gas Emissions. *Journal of Industrial Ecology*.

Erdmann, L., Hilty, L. M., Goodman, J., & Arnfalk, P. (2004). *The future impact of ICT on environmental sustainability. Synthesis report. Institute for Prospective Technology Studies*. Sevilla, Spain: IPTS.

FSO - Federal Statistical Office. (2008). *Environmental Accounting. Swiss Confederation*. Neuchatel.

Heiskanen, E., Halme, M., Jalas, M., Kärnä, A., & Lovio, R. (2001). *Dematerialisation: The Potential of ICT and Services*. Helsinki, Finland: Ministry of the Environment.

Herman, R., Ardeni, S. A., & Ausubel, J. H. (1990). Dematerialization. *Technological Forecasting and Social Change*, *38*, 333–347. doi:10.1016/0040-1625(90)90003-E

Hilty, L. M. (2008a). *Information Technology and Sustainability: Essays on the Relationship between ICT and Sustainable Development*. Norderstedt, DE: Books on Demand.

Hilty, L. M. (2008b). Emerging Risks in Information Infrastructures – A Technology Assessment Perspective. In *Proceedings of IDRC 2008, International Disaster Reduction Conference*, Davos, Switzerland.

Hilty, L. M., Arnfalk, P., Erdmann, L., Goodman, J., Lehmann, M., & Wäger, A. P. (2006a). The Relevance of Information and Communication Technologies for Environmental Sustainability - A Prospective Simulation Study. *Environmental Modelling & Software*, *21*(11), 1618–1629. doi:10.1016/j.envsoft.2006.05.007

Hilty, L. M., & Köhler, A., Von Schéele, F., Zah, F., & Ruddy, T. (2006b). Rebound Effects of Progress in Information Technology. *Poiesis & Praxis . International Journal of Technology Assessment and Ethics of Science*, *4*(1), 19–38.

Hischier, R., & Hilty, L. M. (2002). Environmental Impacts of an International Conference. *Environmental Impact Assessment Review*, *22*(5), 543–557. doi:10.1016/S0195-9255(02)00027-6

IRRIIS Consortium. (2006). *Integrated Risk Reduction of Information-based Infrastructure Systems*. Retrieved May 18, 2008 from http://www.irriis.eu

Isenmann, R. (2008). Sustainable Information Society . In Quingley, M. (Ed.), *Encyclopedia of Information Ethics* (pp. 622–630). Hershey, PA: IGI Global.

OECD. (2008). *Measuring material flows and resource productivity. Synthesis report*. Paris, France: Organisation for Economic Cooperation and Development.

Schauer, T. (2003). *The Sustainable Information Society: Vision and Risks*. Ulm, DE: Universitätsverlag.

Schmidt-Bleek, F. (2009). *The Earth: Natural Resources and Human Intervention*. London: Haus Publishing Limited.

Solow, R. M. (1987). We'd better watch out. *New York Times Book Review, 12*(2), 36-50.

Som, C., Hilty, L. M., & Ruddy, T. F. (2004). The Precautionary Principle in the Information Society. *Human and Ecological Risk Assessment*, *10*(8), 787–799. doi:10.1080/10807030490513801

Von Weizsäcker, E. U., & Lovins, A. B. L., & Lovins, L. H. (1997). *Factor Four: Doubling Wealth, Halving Resource Use – A Report to the Club of Rome*. London: Earthscan.

WCED – World Commission on Environment and Development. (1987). *Our Common Future*. London: Oxford University Press.