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# "ENVIRONMENTAL IMPACT OF THE INFORMATION-COMMUNICATION TECHNOLOGIES AND THEIR ROLE IN SUSTAINABLE DEVELOPMENT «

*Abstract*

*Many companies, from traditional manufacturing to e-commerce, are adopting information-communication (ICT) solutions and applications as part of their business growth and development. Yet the implications for sustainable development arising from the adoption of these new technologies and systems are far from certain. The advance of ICT has been so rapid that we do not yet know, for instance, under what circumstances tangible gains or losses will arise for sustainable development from these technologies. The paper aims to: examine the impacts and opportunities created for sustainable development by the rapid penetration of ICT into business, society and culture;describe the general relationship between e-business and the environment;and to suggest the means for mitigating adverse affects and encouraging positive outcomes for all in the penetration of ICT. A framework has also been discussed that allows a detailed and comprehensive analysis of the environmental, social and economic effects and opportunities of ICT in the context of sustainable development.*

## 1. Introduction

The concept of sustainable development has been primarily derived from the concern about the ability of the world's ecological system to support the growing world population and growing use of resources. The current pace and direction of industrial and economic growth cannot be sustained without addressing poverty and environmental degradation. Today, the wealthiest 20% of the world's population consume 80% of the natural resources while half of all people live in poverty.

Technological development and economic growth have widened the gap between the rich and the poor and increased inequity among people, nations and regions.

The paper aims to: examine the impacts and opportunities created for sustainable development by the rapid penetration of ICT into business, society and culture;describe the general relationship between e-business and the environment;and to suggest the means for mitigating adverse affects and encouraging positive outcomes for all in the penetration of ICT. A framework has also been discussed that allows a detailed and comprehensive analysis of the environmental, social and economic effects and opportunities of ICT in the context of sustainable development.

In this article we accepted the following definition of sustainable development: Sustainable development is a dynamic process which enables all people to realise their potential and improve their quality of life in ways that simultaneously protect and enhance the Earth's life-support systems. (EITO 2002, 250). Implicit here is that economic, social and environmental dimensions are equally vital and inter-connected:

- Economic sustainability means economic growth without making undue demands on social or natural resources.
- Environmental sustainability means not only minimising impacts on the environment, but building natural resources and safeguarding them for the future.
- Social sustainability means building, and not undermining, social equity.

Sustainable development in some countries was defined also in terms of four broad objectives:

1. Social progress which recognizes the needs of everyone;
2. Effective protection of environment;
3. Prudent use of natural resources;
4. Maintenance of high and stable levels of economic growth and employment

The term information technology (IT) is included already in a larger term, which is information-communication technologies (ICT). So, ICT = IT + Telecom. This context includes hardware such as computers, telephones, televisions, cables etc. and the software that run them. This is the equipment part of the ICT, while the application part of ICT is for example teleconferencing (both audio-conferencing and video-conferencing), teleworking, etc. .The Internet is just one form of IT. Whereas the personal computers, cables, softwares, etc. are the equipment of the Internet, the

application side (the use) of the Internet comes in many aspects of daily life: chatting, researching, mailing, advertising, trading, presenting oneself, etc.

## 2. ICT and sustainable development

The effects of the information revolution on environmental sustainability of development programs will be many and varied. It may be self evident, but rich people usually manage to live in healthy surroundings. To the degree that ICT is used to promote social and economic growth, and to the degree that such benefits are widely shared, they will indirectly but most probably enable more people to live in healthier environments.

The most fundamental effects of ICT involve:

- reducing the costs of transactions carried out over distances,
- the ability to obtain and manage (environmental) data on scales and in situations previously impossible,
- the ability to conduct quantitative analysis (of environmentally relevant information) in real time at unprecedented depth,
- the ability to communicate between public, civil society, government and the private sector with unprecedented coverage and efficiency, and
- the ability to control processes electronically, enabling great precision to be achieved in real time control of complex systems.

All of these characteristics will be used in ways that change society, and all offer opportunities to improve environmental sustainability. ICT will result in new industries, and in radical changes in the efficiencies of existing industries and indeed of entire economies. It will change the incentives people face in deciding where to live and work, thus changing the growth of cities and the migration of peoples. It will allow resources to be used with greater efficiency than ever before, but also seems likely to raise demand for the products manufactured from those resources.

Advances in ICT have made it possible for the first time in history to detect environmental problems at very large and at very small scale. They permit unprecedented monitoring of environmental quality, and unprecedented accuracy in detection of the sources and projection of

the development of environmental problems. ICT can be used to empower people with unprecedented understanding of environmental systems, and of the interplay between environment and development. It can be used to allow unprecedented intensity of communication on such issues among all sectors of society. Almost any intervention that can be identified to improve sustainability or reclaim degraded environmental systems can benefit from appropriate applications of ICT.

Narrow views focusing on applications of ICT in environmental monitoring or natural resource protection projects have an important place, but reductionism taken too far will result in radical underestimates of the effects of ICT on the environment. Indeed, it may be more important to environmental sustainability of development programs to see that ICT is fully applied to agricultural and land use planning, to improving industrial processes and reducing industrial pollution, and to appropriate agricultural and silvacultural intensification, than to focus on narrowly defined "environmental" applications of ICT. Similarly, it may be more important to understand the effects of the ICT revolution on trends of urban growth, and to incorporate such considerations in national planning, than to focus on ICT in planning for the sustainability of "environmental projects".

### 2.1. Social aspect

Interactive relations between government, business and social groups in the form of e-government create potential for the real participation of citizens but also for the total and missused control,
Some affraid it could lead to misuse and creation of some formof totalitarian society. These ideas resembe the idea of a megamachine introduced by Lewis Mumford.
ICT enable new forms of e-learning – long life learning, interactive learning, having evident and significant benefits; but at the same time there is a problem: alienation of people, lost of human communication – communication with machine; exchange of explicit knowledge and not implicit knowledge which is the basis of sustainable competitive advantages.
One of the benefits of widespread use of ICT presenting itself in the form of network communities that enable exchange of information and ideas of SD, contributing to a stronger social cohesion

### 2.2. Cultural aspect

ICT usage, through the abolishing of the geographical distance in many aspects, lead to the creation of so salled global vilage. That create the problem of identity in different aspects: local versus global cultural values;

- cultural indoctrination and homogenization versus ICT supported cultural diversity and heterogeneity of cultures and languages as a precondition for the individual and social development;
- particularism versus globalism – strong nationalistic and separatistic forces in a more and more globalized and connected world;
- universalistic ideas and values – realization of the common human potentials through ICT enabled cross cultural communication.

**2.3.Economic aspect:**

Many companies, from traditional manufacturing to e-commerce, are adopting information-communication (ICT) solutions and applications as part of their business growth and development. Yet the implications for sustainable development arising from the adoption of these new technologies and systems are far from certain. The advance of ICT has been so rapid that we do not yet know, for instance, under what circumstances tangible gains or losses will arise for sustainable development from these technologies. The rapid progress and spreading of Information and Communication technology (ICT) in society creates opportunities as well as risks for the environment and for general strategies pursuing the goal of sustainable development. The most important opportunity is the dematerialization potential created by the fact that ICT can help to:

- optimise processes and products as regards their material and energy efficiency
- organize innovative services, especially information services, that can replace
- material products in many cases
- avoid traffic by using telecommunication services instead.

However, progress in the direction of dematerialization is only a necessary, but not a sufficient, condition for approaching the goal of sustainability. There is a high risk that efficiency gains will be compensated for by rebound effects, and that the material and energy demand as well as pollution caused by ICT production, use and disposal will grow to serious problems. In other words ICT can be a part of the sollution but also part of the problem.

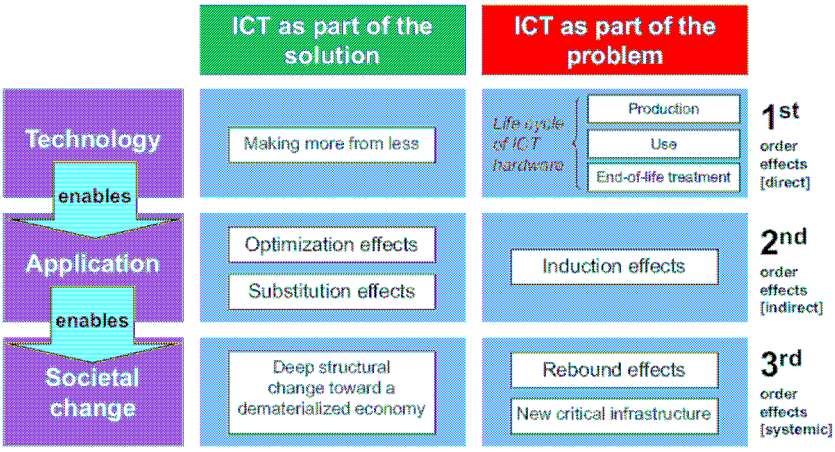


Figure 1: ICT as a part of solution and as part of the problem

Source: Hilty (2008)

There is ample evidence concerning the characteristics of diffusion of new information technology both within and between firms, and the dramatic changes in the organization of firms that parallel the diffusion of new information technology. However, little empirical analysis has been conducted into the effects of adopting information technologies on the reduction of environmental waste and productivity growth.

Nevertheless, the large body of case-study evidence, based on analysis at the firm level, suggests that the adoption and effective implementation of information and communication technologies (ICT) requires radical complementary technological and organizational innovations. Their effective use therefore implies some a break with pre-existing technologies and organizational set-ups and consequently the need for learning. *ICT can have significant effects on the organization of the productive process, modifying the sequence of production steps, the length of the process, and the quantities of goods and materials at all stages*

The available empirical evidence suggests that the substitution of natural-resource-intensive production processes made possible by the adoption of new networking technology has significant effects on the organization of the productive processes, modifying the sequence of the various productive phases, the length of productive processes, as well as the quantitative and temporal relationship between the stock of intermediate goods and final goods. In this way, adopting ICT facilitates networking and the emergence of economies of scale at batch, department and plant

levels. The adoption of ICT can make it possible to modify the organizational relationship between phases of the productive process, so that market relations can be strengthened by systems of electronic communications and bureaucratic coordination can be replaced by a mix of cooperative relationship implemented by on-line communication systems.

When organizational changes of this type take place, the adoption of new networking technologies can have important economic effects on the firm. These effects can include: reduced stocks of inputs, reduced paperwork, better control of quality standards, increased access to multi-sourcing, reduction of minimum efficient size of production lots, 'footloose' plant location, reduced negotiation costs, increased scope for cooperation between different firms, increased coordination between R&D, production and marketing, reduced stock of final products, reduced waste and pollution, reduced environmental impact of the production process, shorter delivery times, quicker invoicing, greater production differentiation and customization, greater ease of recycling, etc.

### 2.4. Environmental aspect

Previous analysis suggests that the adoption and implementation of ICT in production processes can result in both an increase in total factor-productivity and better organization of the production process. These in turn can lead to a reduction in energy usage and so environmentally-cleaner production processes. *ICT can affect the impact production processes have on the environment in a great many ways, ranging from reducing the need for physical mobility to optimizing designs of products and processes.* Specific examples of how this may occur include:

- The increased use of telecommunications service reduces the need for people and for documents to move.
- Overseeing work using information technologies helps organize it better and make it more efficient (including in terms of energy usage): stocks of goods can be managed better, there will be less movement of semi-finished and finished products between different areas.
- Intra- and inter-company information networks can link remote plants and offices, even when they are located in different countries. This makes it possible to reduce the need for movement of people and materials, for example, by shifting internal communications from memos to e-mail.

- Computer technology has facilitated the development of environmentally-focused design, for instance through the development of electronic equipment that allows better control of the combustion processes. Data processing has also made it possible to exploit alternative energy sources which, although known, were under-exploited because the available methods were inefficient or ineffective (for example the manufacture of wind generators or the exploitation of biomass energy).
- Transmitting data over long distances reduces the need for much routine travel. An example of this is the way equipment on power lines can position faults remotely, avoiding the need for maintenance crews to travel the whole length of the line to locate them.
- Network monitoring of air quality, plant efficiency and other environmental parameters enables immediate decisions and rapid intervention, thus avoiding the tendency of problems to snowball.
- Information technology makes it possible to manage and so regulate traffic on motorways and in urban areas more efficiently, so traffic jams can be avoided or reduced by using intelligent traffic lights controlling critical points in traffic flow, etc.
- Other interesting examples can be drawn from the car manufacturing industry. In some cases, the possibility of developing innovation in the production process which satisfies environmental limits depends on information technology, as in the case of life cycle assessment studies, the efficiency of which depends on mathematical software. The adoption of new information technology is an essential component, both at the level of individual firms and between firms, to organize the chain of complementary actions needed to manage the disposal and recycling of vehicles (like Fiat's Auto F.A.R.E System).

Institute for the Prospective Technology Studies made a research study of the possible effects of ICT on environmental indicators in the year 2020 (Erdman et. alias 2004). An innovative combination of qualitative (scenario-building) and quantitative (High Level System Dynamics) methodologies was used to shed light on the future importance of ICT developments in policy decisions for environmental sustainability, with the aim to estimate the range of potential impacts of ICT on a series of environmental indicators in 2020: greenhouse gas emissions, energy intensity, transport intensity, modal split, urban air quality, municipal waste and share of renewable energy.

A general observation from their research and analysis is that the impact of ICT is roughly between -20 and +30 % across the range of chosen indicators. It can be concluded therefore that the impact of ICT on the environmental indicators is relevant and should be taken into account by environmental policies. ICT areas of key environmental importance include the use of ICT to rationalise energy management in housing (or facilities), to make passenger and freight transport more efficient, and ICT's capacity for enabling a product to service shift across the economy. Policy has an important role to play in realising the positive environmental outcome of the ICT applications, and, at the same time, to suppress rebound effects.

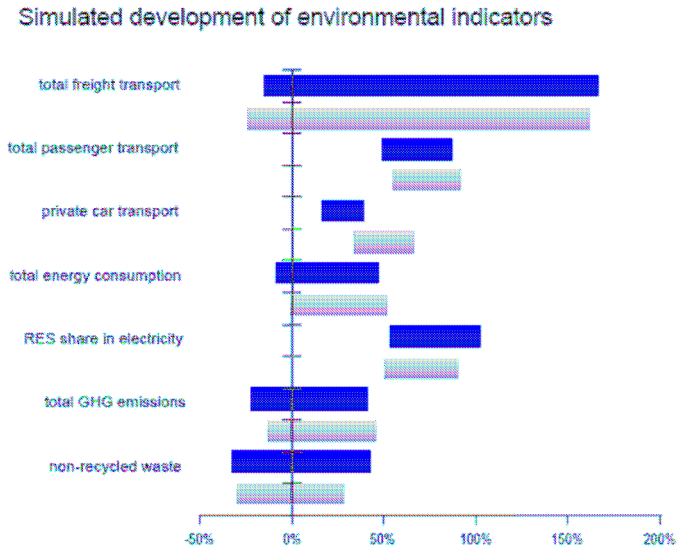


**Figure 2: Simulated development of environmental indicators by 2020 as a percentage increase or decrease against their values in the base year (2000).**

Source: Erdmann et.alias. (2004)

The length of the bars on the Figure 2 indicates the uncertainty of the results that is caused both by future scenario variation and data uncertainty. There are two bars per indicator, the upper (dark blue) bar showing the results for the projected ICT development, the lower (light grey) bar showing the results for the so-called "ICT freeze" simulations (i.e. ICT applications remain on the level of 2000).

The effects of ICT have also been separated according to the different stages in their development and deployment. This allows the identification where possible of how a positive opportunity may over time have a negative spill-over or vice versa and hence where action could be taken to maximise the positive outcomes. Effects are divided into first, second and third orders.

**First order** – The impacts and opportunities created by the physical existence of ICT and the processes involved. This includes the design, manufacture, operation and disposal of ICT.

**Second order** - The impacts and opportunities created by the ongoing use and application of ICT. For example, this includes E-business.

**Third order** - The impacts and opportunities created by the aggregated effects of large numbers of people using ICT over the medium to long term. For example, this includes the changing nature of relationships betweenbusiness and markets.

| First order effects | Second order effects | Third order effects |
|---|---|---|
| **Design and manufacture of ICT equipment**<br>ICT production is a relatively lightweight industry<br>Use of toxic components<br>New waves of technology are more energy-efficient | **Increase and decrease in use of transport**<br>Increase in home deliveries as a result of E-commerce will have significant environmental impact unless well co-ordinated<br>Telework reduces travel miles for employees<br>Telematics reduces traffic congestion, journey times and therefore pollution<br>Rebound effects from increased leisure travel | **De-coupling economic growth and energy consumption**<br>Possibilities of reducing energy used per unit GDP |
| **Operation of ICT equipment**<br>Energy use even in stand-by mode | **ICT in business systems**<br>B2B E-commerce and ICT-managed control systems create efficiencies and reduce environmental impact | **De-coupling economic growth and carbon emissions**<br>Possibilities of reducing carbon dioxide emissions per unit GDP |
| **Disposal of ICT equipment**<br>Problematic disposal<br>Recycling and safer designs increasing | **Virtualisation of material products**<br>Possible environmental savings from increased trade in intagibles | **Changing settlement patterns**<br>Conflicting pressures on local settlement<br>Possible increase in environmental pressure on regions |
| | **Effects on product lifetimes**<br>Some E-commerce business models extend product lifetimes | |

| | | |
|---|---|---|
| | Product development cycles are often reduced by use of ICT | |
| | **Distribution and manipulation of environmental information**<br>– Significantly enhanced by ICT | |

Table 1 Environmental sustainability and ICT

Source: EITO (2002)

In an interim report of Digital Future project of the European Community (Ermann 2004), a similar classification is adopted but from a life cycle perspective (see Table 2).

| Effect | Caused by | Examples | Aspects |
|---|---|---|---|
| **Primary effects** | Infrastructure | Terminal equipment such as the PC, mobile phoones<br>Network infrastructure<br>Servers, routers,etc. | Energy consumption<br>Material consumption<br>Toxicity of end-of-life equipment |
| **Secondary effects** | Application | B2B<br>Change in warehousing<br>Change in transportation<br>Change in packaging | Energy consumption<br>Material consumption<br>Traffic<br>Land use |
| **Tertiary effects** | Changes in consumption pattern, new habits, rebound effects | Increase in consumption<br>Substitution effects<br>Side effects | Energy consumption<br>Material consumption<br>Traffic<br>Land use |

Table 2: ICT environmental effects from a life cycle perspective

The asessment of the overall environemntal, societal and economic effects of ICT could be shown as a diagram as follows:

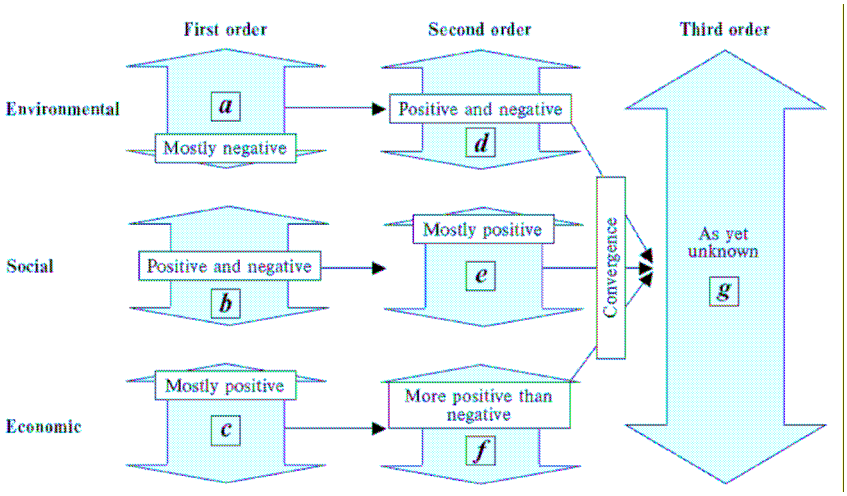


Figure 3: Evaluating the effects of ICT on sustainable development

Source: EITO 2002, 280

The impetus for the development of ICT has been primarily economic, and so the immediate effects of ICT on economic sustainability are expected to be positive (c in Figure 3). This is the case, despite the current depressed state of the ICT sector. The immediate effects on the environment are quite the opposite (a in Figure 3). Production of ICT equipment does not place the same level of demands on natural resources, nor is it as polluting, as many other industries, but nonetheless the manufacture, operation and disposal of ICT equipment all have negative environmental impacts. Although efforts are being made to mitigate these effects from within the ICT industry, action is also required at a policy level:

– to attain greater environmental efficiency inproduction;
– to produce greater environmental efficiency of the equipment itself and
– to encourage “design for the environment” making equipment suitable for recovery and recycling schemes.

**3. Possible next steps**

Some concrete actions are necessary that would aim to make a significant reduction in the predictable negative effects of ICT by taking preemptive measures. These measures are necessary if the historic opportunity to use ICT for the goal of sustainable development is not to be forfeited. Possible key actions to reduce negative impacts and to foster sustainable development and dissemination of ICT, according to Working Group on the impact of ICT on the Environment-EPFL would be as follows (EPFL 2002):

- Eliminate unnecessary standby losses of ICT equipment and ICT-systems
- Increase the useful life of ICT equipment, in particular by prolonging the period between updates and new versions of operating systems and applications
- Build-up a system of local collecting points and central disposal/recycling facilities for used batteries and electronic components and foster the re-use of electronic components

**Why these three directions?** They are relevant from the point of view of environmental impacts of ICT; They cover three distinct areas: direct electricity demand, embodied (or grey) energy and local pollution of soil, water and air (local ecosystems); and it's possible to rely on current initiatives supported by powerful organisations/institutions and on case studies. **These three directions offer potential benefits for the different actors** (stakeholders):

1. Eliminates unnecessary standby losses
    - Consumers have reduced electricity bills, reduced heating loads, reduced cooling demand; an increase in reliability and security (if switched off);
    - Governments/utilities will reduce demand for power capacity and therefore reduce air pollution and CO2 emissions from power plants;
    - ICT industries that use these technologies will have at low cost a more environmentally friendly image and a market advantage as innovative industries.
2. Increases useful life
    - Consumers save money
    - Governments reduce the risk of a digital divide, and the risk of "stranded investments"
    - Develops new jobs and provides better development opportunities for countries in the Global South.
3. Builds-up a disposal/recycling system
    - Governments either get support in the disposal/ recycling problem from industry

or can delegate it to industry

- ICT industry has a more environmentally friendly image;

Possible next steps with the aim of further stressing positive effects while diminishing the negative effects would be as follows: **For governments:**

- Appoint a responsible person for ICT and climate change and allocate a budget.
- Set targets for use of ICT in key areas, not only CO2 reductions, but jobs created, number of patents etc.
- Support companies that set targets for CO2 reductions for the use of their products/services.
- Ask companies for a product/sale catalogue for CO2 saving services.
- Set targets for export of ICT solutions that reduce CO2 emissions.
- Review rules and legislation from a dematerialisation perspective.
- Explore a sustainable innovation zone.
- Ensure economic policies support incremental improvements and disruptive new solutions that ensure more than marginal improvements of CO2 reductions.

and **for business:**

- Report on targets for CO2 reductions for use of your products/services,
- Produce a product/sale catalogue for CO2 saving services
- Ask the government to set target for use of ICT in key areas
- Work with the government to set targets for export of ICT solutions that can reduce CO2-emissions
- Ask the government to review current legislation and organization from a dematerialization perspective
- Establish an internal (and later and external) sustainable innovation zone.

## 4. Conclusion

Since great potentials for positive effects of ICT usage are evident but also great risks and roundabout and negative effects, sustainable development principles should be the most important to guide the future development and usage of ICTs with the primary goal of development of

human beings. Three broad principles should govern any attempts to maximise the synergies between sustainable development and ICT:

1. Institutional innovation must be as radical as technological innovation in order to keep up with the pace of change.
2. Business, government and non-governmental organisations (NGOs) must work in partnership for action to be effective.
3. Successful policy will depend on a longer term view, beyond the ups and downs of ICT stocks prices.

Although, in different projects and academic research, certain areas have been identified where the development of ICT could have a significant impact, one could say that a great deal of uncertainty still exists. Further research in these areas is necessary for a fuller understanding of the role of ICT in meeting environmental policy goals. The areas are:

- e-materialisation: the shift from products to services, dematerialisation and rematerialisation;
- ITS's impact on increasing transport performance;
- ITS's impact on promoting a shift from passenger cars to public transport;
- ICT equipment's electricity consumption in the domestic and tertiary sector;
- efficiency in electricity generation and distribution;
- energy savings through ICT-based facility management;
- the use of virtual utility promoting RES and CHP;
- ICT-based systems for recovery and recycling of MSW in general and WEEE in particular.

ICTs help us by making resource and energy consumption more efficient. However, so called rebound effects counterbalance these effects by increasing consumption. Therefore, the decisive question of whether ICT will actually help us to create sustainable production and consumption systems comes down to whether ICT will be able to influence the demand side towards more sustainable consumption patterns. It brings us to the interesting statement given by Evan Davis: „Can technology reduce environmental degradation? is the wrong question.The relevant question is whether we will in fact choose to exploit technologyfor environemntal gain, or whwther we simply exploit it to increase our material living standards. As far as this is concerned, there is

little room for complacency. Our experience so far suggests that the benefits of technology are typicaly directed towards making us richer, rather than greener“. (Wilsdon 2001, 37).

Technology does have the potential to enable us to live more comfortably and susstainably. That is not as much a new economic fenomenon as a continuation of the old economy trend toward more productive use of resources. If we are worried about resource use, let us be clear that technology is potential ally, so long as we find ways of effectivelly deploing it to that end. The mere fact that this path to a greener future might be a possibility does not mean it will become reality. Far from, it. The political will – and intervention – required to steer the new economy toward sustainability should not be underestimated.

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