THE FUTURE IMPACT OF ICTs ON ENVIRONMENTAL SUSTAINABILITY

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Information and Communication Technologies (ICTs) not only constitute an industry in their own right but they also pervade all sectors of the economy, where they act as integrating and enabling technologies. ICTs have a profound impact on society, and their production and use have important consequences for development in economic, social and environmental areas. The extent to which ICTs also affect progress towards environmental sustainability in an economy is an issue that is still under debate. There is, however, increasing evidence that significant opportunities and threats are involved. These deserve more research and more attention in energy, climate change and technology policies.

The Institute for Prospective Technological Studies (part of the Joint Research Centre - European Commission) has commissioned a study entitled 'The Future Impact of ICTs on Environmental Sustainability', which aims to explore (qualitatively) and to assess (quantitatively) the way that ICTs will influence environmental sustainability between now and 2020. This study is the first quantitative projection to be carried out on how ICTs could affect the environment in the European Union. In order to estimate the effects of ICTs on a set of five environmental indicators, the project team adopted an innovative methodology combining qualitative scenario-building and quantitative modelling.

The general conclusion was that ICTs can modify the value of these five indicators. ICTs could improve the situation, reinforcing positive effects in the environment, or they could worsen the situation. This suggests that environmental policies have to be designed to ensure that ICT applications make a beneficial contribution to environmental outcomes, and, at the same time, suppress rebound effects. There are significant opportunities for improving environmental sustainability through ICTs, which can rationalise energy management in housing (or facilities), make passenger and freight transport more efficient, and enable a product-to-service shift across the economy.

The methodology used in the study had five steps. Firstly, a set of environmental indicators was chosen and the economic sectors and ICT applications with the greatest impact on these indicators were identified. For this purpose, the project team adapted the indicators that were developed in response to the conclusions of the European Council in Gothenburg, obtaining the following:

1. volume of transport relative to gross domestic product,
2. modal split of transport,
3. energy consumption and share of renewables,
4. greenhouse gas emissions,
5. municipal waste collected but not recycled.

The impact of telecommunications (equipment and services) and information technologies (defined as the combined industries of hardware for office machines, data processing equipment, data communications equipment, software and services) on these indicators was analysed.

The second step was to gather data for use in later stages of the project by means of an extensive review of the literature on environmental impacts of selected ICT applications: ICT industry,[1] ICT use,[2] e-business,[3] virtual mobility,[4] virtual goods,[5] waste management,[6] intelligent transport systems,[7] energy supply,[8] facility management[9] and production process management.[10]

[1] ICT industry including manufacturing and services

[2] ICT use, including entertainment, communication, data processing and home networks

[3] e-business comprises e-commerce plus e-based and/or e-supported activities

Three kinds of impacts and opportunities were considered:

- those created by the physical existence of ICTs and the processes involved (first order effects),
- those created by the ongoing use and application of ICTs (second order effects), and
- those created by the aggregated effects of large numbers of people using ICTs over the medium to long term (third order effects).

The third step was to develop three consistent scenarios for the development of ICTs and the environment, including future uncertainties, by choosing highly unpredictable factors likely to influence the development and use of ICTs in the future. As each of these factors can be varied over several levels, it would be easy to create hundreds of scenarios, even from this small set of factors. In order to avoid this, specific combinations of factor levels, perceived as internally consistent, were sought. The table below shows the combination of uncertain factors for the three scenarios.

Uncertain Factor	**Scenario A "Technocracy"**[11]	**Scenario B "Government First"**[12]	**Scenario C "Stakeholders democracy"**[13]
Technology Regulation	Incentives for innovation	Government intervention	Stakeholder approach
Attitudes to ICTs	Moderate, conservative	Receptive	Highly receptive
ICTs in business	High level of cooperation	High level of competition	Between A and B
Attitudes to the environment	Moderate / controversial	High awareness and interest	High awareness and interest

In the fourth and fifth steps, results were obtained using the refined and quantified scenarios. The project team created a simulation model[14] to quantify the impact of ICTs on the selected environmental indicators. A unique aspect of the applied methodology was the combination of qualitative scenario making and quantitative modelling. This led to projections of future impacts and the identification of areas where policy interventions could have a positive effect. Finally, recommendations for action were drafted and then discussed and validated by a panel of experts.

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[4] Virtual mobility refers to teleworking, virtual meetings and teleshopping

[5] Virtual goods refers to the dematerialisation potential of ICT for information goods (examples are the use of e-mail and the reading of e-books instead of using letters or reading books)

[6] ICT impacts on the amount of daily waste (ICT waste, effect of virtual goods and demand for packaging) and has the potential to increase efficiency of collection and sorting systems.

[7] Intelligent transport systems, or telematics, for which there is not a clear definition but includes control and guidance, road pricing, parking, assistance, freight and fleet control and management.

[8] Energy supply changing due to initiatives to foster renewables and Green House Gas and by liberalised electricity markets.

[9] ICT is one measure to reduce energy consumption of buildings. Facility management targets space heating, water heating, cooling, lighting, cooking and electric appliances.

[10] ICT for production process control is used to increase production yield and to minimise energy demand.

[11] Government and business collude to produce high speed, growth-focused technology development

[12] Heavy-handed government steers technology development to favour social outcomes, while business competes to exploit a slowing market

[13] A positive environment for sustainable development, with all eyes on what ICT can deliver, but outcomes are not always straightforward

[14] Simulations are based on a System Dynamics model

RESULTS

It is possible to estimate the isolated effects of ICTs on different indicators. However, the most important information is not the direct impact of ICTs on one indicator, but the whole picture, including the evolution of all the indicators in relation to the development of ICTs.
The following figure presents the development of environmental indicators envisaged in the scenarios by the end of 2020. The figures are percentage increases or decreases from the base year (2000). The length of the bars indicates the uncertainty of the findings, as a result of both future scenario variation and data uncertainty. There are two bars per indicator: the upper (dark blue) bar shows the results for projected ICT development, the lower (light grey) bar shows the results for the "ICT freeze" simulations (i.e. ICT applications remain at the same level as in 2000). The impacts shown are aggregated values of all ICT applications considered in all the scenarios simulated.

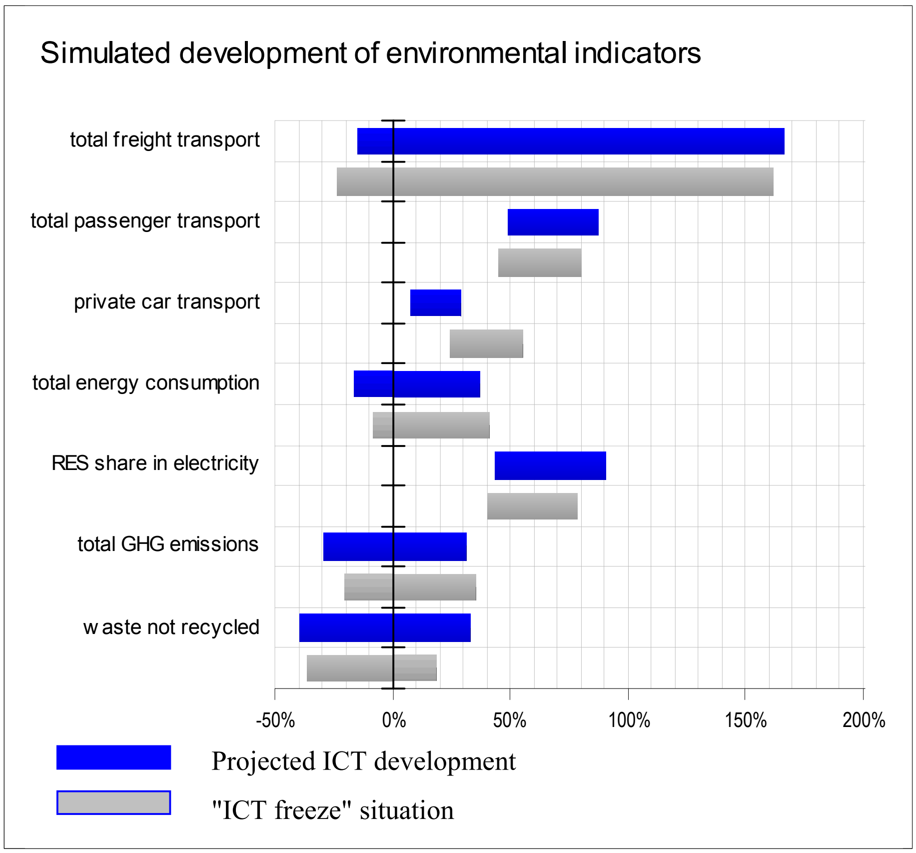

Figure: Simulated development of environmental indicators by 2020.

This model also takes into account rebound effects, which occur when efficiency gains stimulate new demand that counterbalances or even outweighs positive environmental gains. For example, the efficiency improvements (time, fuel, energy) made possible by technological advances are counteracted by an increasing demand (growing consumption volumes) of energy, products, services, passenger and freight transport. In the model, rebound effects are managed by determining *elasticities*, quantified by assigned numbers, for example by determining the proportion of savings that are offset by increased consumption, or vice versa. Another rebound effect is *rematerialisation*, e.g. virtual information products are accessed via the Internet and then printed out or burned onto a CD. Rebound effects should be acknowledged and addressed by all policies, and especially ICT policies, which aim to increase efficiency.

RECOMMENDATIONS

1 & 2. Freight and passenger transport.

ICT-related efficiency improvements in transport need to be combined with demand-side management in order to achieve an overall reduction in environmental impact. Time reduction and network capacity increases achieved by Intelligent Transport Systems will pave the way for more demand for transport, unless measures are taken to limit growth. The research indicates that the internalisation of environmental externalities, in particular raising energy prices and fuel prices, could bring demand down to a level where transport is no longer linked to economic growth. The option of complementing such measures by including transport in emissions trading schemes also seems reasonable.

Moreover, Intelligent Transport Systems (ITS) could support public transport by:

- directing the research focus and allocating resources to multi-modal, seamless travel and public transport supported by intelligent transport systems;
- increasing the attractiveness of public transport by developing and implementing systems for tailor-made information, such as adaptive time-tables, route-planning, and so on;
- in the case of passenger transport, providing prerequisites for ICT-supported work (such as wireless internet access) during train travel and on public transport.

Virtual mobility applications will not automatically generate significant transport savings unless policy initiatives are introduced to support this. Promotion of virtual meetings is probably the most effective e-application for reducing the environmental impact of passenger transport. Attention should also be given to a potential increase in passenger transport caused by a growing number of mobile workers. Specific policy recommendations are:

- to promote development of affordable and reliable broadband access;
- to promote the establishment of corporate policies and agreements for efficient e-work and
- to establish policies and routines for virtual meetings and, at the same time, increase the cost of passenger transport, which would encourage a shift towards the “virtual” alternatives.

3. Energy consumption and the share of renewables

Suggested energy measures apply to both energy consumption and the supply side.

ICTs could play two main roles in energy consumption. Firstly, they could support energy saving measures in buildings and could have an important impact on the rational use of heating energy. Although it is highly uncertain under what conditions “soft” measures supported by ICTs (such as intelligent heating systems) operate effectively and satisfactorily for users, this issue deserves consideration because of the high levels of energy consumed. Heating accounts for roughly 30% of total energy consumption, and the most effective “hard” measures only apply to the small numbers of buildings that are renovated or newly built annually. “Soft” measures, even though they are less effective, have the advantage of being, in principle, applicable to every building. Secondly, ICTs could also influence the demand side by encouraging more sustainable consumption patterns. These would avoid the rebound effect of increased consumption which would outweigh positive effects.

On the supply side, the deployment of ICT support systems for decentralised electricity generation from renewable sources and the use of small Combined Heat and Power devices are recommended. The development of low-cost metering and communication systems for the electricity grid, making small-scale electricity production easier to operate and maintain and more cost-effective than conventional approaches, is also recommended.

4. Greenhouse gas emissions

The recommendations for greenhouse gas emissions are cross-cutting, as they concern energy use in industry, transport and housing. This study's main findings suggest the need for ICT-supported monitoring and reporting schemes, and the adjustment of consumption of energy and transport to a sustainable level. They also suggest that research into ICT-supported measures for the reduction of greenhouse gas emissions (to find more cost-effective ways than the more traditional investment in energy savings) should be promoted. For instance, ICT-based demand-side management measures could be prioritised, making it possible to adjust consumption of energy and transport to a sustainable level using economic instruments.

5. Municipal waste collected but not recycled

ICTs affect waste volumes, both in the generation and management of waste electrical and electronic equipment, and the management and recycling of municipal solid waste. It is foreseen that the 6th Environmental Action Programme objective to break the link between economic growth and increases in municipal solid waste will be achieved. However, ICTs would add significantly to non-recycled municipal solid waste if no measures are found to limit the growth of ICT waste. Recommended actions include:

- Further enhancement of the implementation of the 1994 Directive on Packaging Waste, by developing incentive systems for teleshopping retailers to reduce packaging waste (e.g. by designing their product, retail and shipping systems in ways that reduce the need for and use of packaging).
- Reduction of the amount of waste electrical and electronic equipment by:
  - providing incentives for producers to design and sell ICT products with a long life-span, thus reducing the churn rate.
  - effectively implementing the Directive on waste electric and electronic equipment[15] which is based on the extended producer responsibility principle. This would encourage product designers and producers to minimise the waste stream, particularly if producers are held responsible for managing the waste of their own products;
  - limiting sales models that make ICT products of little or no value in a short period of time, such as subsidised mobile phones and subscription packages; and
  - extending the depreciation time for ICT equipment (minimum time to 'write off' ICT equipment investments).
- Adaptation of the policy to limit the environmental impacts of trends towards "pervasive computing" and electronics embedded in non-traditional ICT products, which are not covered by the current policy framework (e.g. Directives on Waste Electrical and Electronic Equipment and Restriction of Hazardous Substances[16]).
- Support for intelligent systems for recycling and other forms of recovery, thereby decreasing the waste fraction that goes to final disposal and incineration.

[15] Directive 2002/96/EC on Waste Electric and Electronic Equipment, of 27th January 2003.

[16] Directive 2002/95/EC on Restriction of Hazardous Substances in Electrical and Electronic Equipment, of 27th January 2003.

Crosscutting issues

The influence of ICTs on potential material and energy savings in production processes, leads to the following recommendations:

- Customers should be supplied with sufficient information to enable them to take environmentally aware decisions when selecting not only ICT products, but also services. This could include product declarations, energy-labelling and eco-labelling schemes. This information should cover the whole life-cycle impact and make it possible to benchmark the environmental performance of different products and services.
- Direct attention should be given to the product design stage, and to strengthening industrial designers' capacity to take environmental considerations into account. This could be realised by promoting demonstration projects that involve actors from the entire life-cycle chain in finding sustainable solutions for product and service design. The increased dissemination of information on cost-effective, energy- and material-optimising ICT solutions for industry, paying special attention to reaching small and medium enterprises, would also be advisable.
- The promotion of efficiency improvements in industry should be combined with the stimulation of innovation, placing particular emphasis on the shift towards product-service systems (also called functional thinking) which do not sell the product itself, but rather the service that is offered by the product. Although there are widely diverging opinions concerning an ICT-based product-to-service shift and its possible energy saving and dematerialisation effects up until 2020, it is again the significant potential for change that makes this issue important. In the model, almost every output turned out to be directly or indirectly linked to the product-to-service shift variables, mainly freight transport performance, but also waste and the energy used by the industrial sector.

The existing and developing policy framework (the Proposal for a Directive establishing a framework in which eco-design requirements for energy-using products are defined[17]) should address these issues and support implementation. The implementation of this policy framework would help in advancing many of the recommendations suggested here. In the light of the project findings, the suggested integrated product policy framework should stress the issues of promoting dematerialisation and suppressing re-materialisation. Systems for monitoring and following-up progress should also be put in place.

[17] Proposal for a Directive COM(2003) 453, establishing a framework for the setting of Eco-design requirements for Energy-Using Products and amending Council Directive 92/42/EEC.

CONCLUSIONS AND FUTURE RESEARCH

Even if the direct impact created by the physical existence of ICTs is negative, their overall impact on environmental sustainability may vary, depending on the applications and the aggregated effects of large numbers of people using ICTs. If ICTs are to enable a decrease in absolute energy consumption, policy must be designed so that it promotes the environmentally positive impacts of ICTs, whilst inhibiting the negative ones.

On the one hand, significant opportunities for improving environmental sustainability lie in the potential impact of ICTs on the rational use of heating energy, and the support of decentralised electricity production from renewable sources and its important role in the product-to-service shift.

On the other hand, ICT applications that make freight and passenger transport more time efficient (cheaper or faster) will immediately create more traffic and possibly more energy consumption. There is no empirical evidence for assuming anything other than a strong price rebound effect here, which could have severe environmental consequences in terms of energy use and greenhouse gas emissions.

As a great deal of uncertainty still exists, further research is necessary for a fuller understanding of the role of ICTs in meeting environmental policy goals. A holistic approach is needed, encompassing the following areas:

- e-materialisation: the shift from products to services, dematerialisation and rematerialisation;
- Intelligent transport systems' impact on increasing transport performance and promoting a shift from the use of the private car to public transport;
- ICT equipment's electricity consumption in the domestic and tertiary sector;
- efficiency in electricity generation and distribution;
- ICT-supported facility for the management of energy savings;
- the use of a virtual utility to promote renewable energy and combined heat and power;
- ICT-supported systems for recovery and recycling of municipal solid waste in general and waste from electrical and electronic equipment in particular.