ICT and climate change

Essay written as a contribution to the COOL dialogue

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1 Introduction

What do technological developments in the area of information and communication technology have to do with climate change? At first glance, nothing. But on closer consideration the connection is easily made. The rapid pace of technological developments in the field of ICT may lead to major changes in the economy. The Netherlands Bureau for Economic Policy Analysis (CPB) (CPB, 2000) suggests that ICT has the character of a “breakthrough technology”, similar to the invention of the steam engine and electricity. Such breakthrough technologies can substantially change the structure and shape of the economy. ICT could have a major impact on how we work, live, shop, spend our leisure time, move around, etc. ICT applications make it possible to perform certain actions faster, in a smarter way and at any time and anywhere. For example, it is easy to order a book from the US via the Internet. Such changes will be felt at the micro-level (the behaviour of consumers, producers), but also at macro-level (the economy, globalisation)

These changes can in turn prompt changes in energy consumption. This is the link to climate change, since the emission of CO_2 which is directly related to energy consumption has a significant impact on the climate.

This essay, which looks at the relationship between developments in ICT and climate is therefore mainly concerned with the possible effect of the introduction of ICT (via changes in the economy and society) on energy consumption.

This essay has been written for the Climate Options for the Long Term (COOL) project. The aim of the COOL project, which is part of the National Research Programme on Global Air Pollution and Climate Change, is to create a dialogue between scientists, policymakers and the various sectors of society who are facing the stiff challenge of reducing energy consumption. In this dialogue, the various groups are considering how to achieve a reduction of 80% in CO_2 emissions in the various sectors by the year 2050. This 80% reduction is needed not only to cope with climate change but at the same time to facilitate a fair distribution of emission reductions between different countries so that Third World countries can still allow CO_2 emissions to grow.

The dialogue has raised the question of what social and economic changes could be prompted by the rapid pace of developments in ICT and what they might signify for energy consumption and the resulting CO_2 emissions.

In this essay we want to:

- present an overview of the developments in ICT,
- provide an insight into the changes that could occur as a result of these developments, as well as the background to these changes,
- highlight the uncertainties,
- further define the relationship with the climate problem (read: energy consumption),
- indicate what policy options there are.

The developments outlined above can be looked at in a number of totally different ways. We have opted for an approach in which we consider the changes that technology causes in a technological system in a social context. The role of the government, the market, companies and consumers are assessed in a balanced way. So we consider not only the technology itself (in other words, we do not regard the development of technology as autonomous), but review developments at system level, in which different related technologies, infrastructure, and last but not least various societal actors play an important role. The use of technology by the various actors, how it is applied, will have an effect on energy consumption.

2 The questions

The central question asked in this essay is:

What are the consequences of the rapid pace of developments in the field of information and communication technology for climate change, in this case translated into the effects for energy consumption on different scales (global, national and sector-specific)?

This problem is broken down into the following questions:

1. What developments are taking place in the area of information and communication technology and which are relevant for climate change? What trends, dynamics and processes can be identified?
2. What positive and negative consequences could ICT developments have for the climate? These aspects will be considerd in both general (international, national) and sector-specific terms.
3. Under what conditions can the positive consequences arise (behaviour, infrastructure, policy, etc.); What are the maximum effects you can then expect?
4. What major questions and points for discussion can be identified to feed the debate at the COOL meetings?

In this essay we will start by defining what we mean by technology in the social context (section 3). In the following sections we will then address each of the above questions in turn. In section 4 we look at the technological developments surrounding ICT and their social implications. In section 5 we look at the relationship between these developments and climate change. In section 6 we discuss the possible effects and the conditions under which these effects could occur. Finally, in section 7 we will present the main conclusions, discussion points and questions for the COOL project.

3 Technology in a social context

In the introduction we mentioned that we are looking at the entire technological system in the social context. For this we want to use a simple but transparent model (Slob, 1999). This model (see figure 1) has three central elements:

- **Arrangements**: all institutional, organisational or commercial arrangements that are needed to direct technological development and the behaviour of individuals and companies in a particular direction. These include, for instance, environmental laws and regulations, but also tax measures or public information, the institutions to implement them, etc. In this context, services can be seen as a commercial arrangement whereby technology is used more efficiently and at the same time behaviour is influenced. Services may therefore have a worthwhile environmental benefit.
- **Behaviour**: this refers to the behaviour of companies and individuals. The behaviour in the technological system will have a major impact on the resulting environmental effects. Both quantitative and qualitative aspects are relevant in this regard. The quantitative aspects (volume) of production and consumption are closely related to the quantity (amount) of the environmental aspects, while the qualitative aspects (quality of products and services) are largely responsible for the nature of the environmental aspects.
- **Technology**: the artefacts that are developed and used to meet the needs of consumers and producers. In this context, improved and innovative technologies that cause far less pollution are

interesting. These technologies are also referred to with the "factor-metaphor" which describes the extent to which the technology is improved (e.g. by factor of 4, a factor of 20).

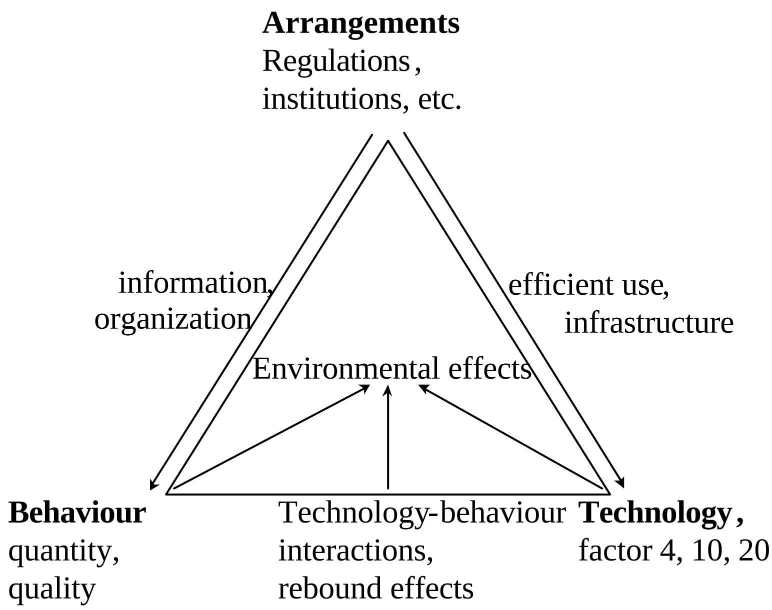

Figure 1: Technology in social context

These three elements are not independent but interact along the sides of the triangle:

- **Organisation and information** as the link between arrangements and behaviour. Information and organisation can be seen as a weak form of guiding behaviour. Environmental information and eco teams are examples of this. On the other hand, information and organisation can be used to provide feedback to arrangements (monitoring): have the envisaged effects of policy or regulation been achieved? Should targets be revised?
- **Infrastructure** as a physical form of an arrangement, particularly with a view to directing the application of technology. We also include the R&D infrastructure which directs the development of technology in this.
  Infrastructure offers an important (technological) context for the application of technology and can therefore direct the efficient use of technology and the environmental benefits arising from it to a large extent. Infrastructure is essential if we are to profit from new technological possibilities. After all, new technological possibilities sometimes require an entirely new infrastructure. At the same time, the old infrastructure can sometimes slow the process enormously. There may be interests associated with the old infrastructure (especially those of the owner of the infrastructure) which can form a significant barrier to the optimal use or introduction of new infrastructures. The discussion in the 1980s concerning the delivery of electricity from windmills in the Netherlands to the national grid is an example of this. This only changed when the Electricity Act was amended (an arrangement).
- **Technology-behaviour interactions** determine the way in which the user ultimately deals with the technology. There is a lot of evidence from the past showing the existence of a rebound effect: the phenomenon that the potential environmental benefits resulting from technological improvements are not secured because behaviour also changes (see Slob et. al., 1996). The technology is used differently than was intended or new applications are thought up so that the environmental effects arising from the volume of use cancel out the environmental consequences of more efficient use. Examples of this are the introduction of the long-life light bulb, which led to

new applications (outdoor lighting etc.) rather than the desired substitution of ordinary light bulbs in the living room. The behaviour of the user has to be carefully considered in estimating the environmental aspects resulting from the introduction of new technology.

The behaviour of users and the technology used (artefacts) are jointly responsible for the resulting effects on the environment. The arrangements influence environmental effects via the technology used and the manner in which it is used (the behaviour). New technology incites new behaviour: new, previously unexplored applications (behaviour options) are found for new technologies. Changes in behaviour can in turn call for new arrangements. Infrastructures can also induce certain behaviour, while at the same time old infrastructures can prolong certain forms of behaviour. The introduction of new technology leads to change at each corner of the triangle. So when considering new technology, one also has to examine the other aspects from the triangle: behaviour, arrangements, organisation, information, infrastructure and the technology-behaviour interactions

4 Trends in ICT applications

4.1 Trends

The pace of innovation in information and communication technologies is high. New generations of products succeed one another in quick succession. For instance, the current expectation is that a mobile telephone will be followed after nine months by the next generation of mobile telephone, which is smaller, uses less energy and provides more services. Many owners of a PC with a 486 processor, which three years ago was still ‘top of the bill’, now keep them stored in their attic. The basis for these rapid developments is expressed in Moore's Law (Cohen et al., 2000). The law, which dates from the early 1980s, predicts that the capacity of chips will double every eighteen months while the price remains the same. This law could still apply for many more years (the estimate is until 2020) and forms an important driving force behind numerous ICT trends (miniaturisation, etc.).

There is not enough space in this paper for an in-depth and systematic survey of the developments in the technological basis of ICT. Nor is it crucial for our purpose, since we assume that it is not so much the technology itself as the organisation of the technology in specific social arrangements and in specific user contexts that counts. Nevertheless, to get a feel for the background to the current developments, we will briefly present a number of interesting trends, which together give an impression of the ‘push’ side of this wave of technological innovation (see Bozetti, 1999; Bozetti, 2000). We identify five interesting trends:

1. Continuous *miniaturisation* of individual components (chips, digital cameras (the size of a sugar cube), mobile telephones, monitors).
2. *Digitisation* of text, image, voice, data making it possible to develop applications that can handle all sorts of data; this enables, for instance, telephony via the Internet (Voice over IP) and vice versa, Internet via the telephone (WAP: Wireless Application Protocol).
3. *Convergence* of formerly separate networks; telecommunication networks, computer networks and TV networks converging into a single infrastructure carrying text, images, voice and data. Two remarks need to be made here. First, the formerly ‘vertical’ structure (vertical segmentation: separate telephone, TV and computer networks) is being replaced by a layered structure (horizontal segmentation: infrastructure – network services– applications), which has major repercussions for the organisation of market players. Secondly, a single infrastructure that carries everything does not mean that the entire infrastructure is completely transparent; many individual networks are being created.

4. *Integration* of architectures, standards and protocols; the Internet protocol currently seems to be dictating the direction of network developments, from internal business applications to public networks.
5. Added *intelligence* to networks and applications. In a dialogue with the user, Smartbots develop an impression of what the user wants, and provide the link between 'front office' and 'back office'.

It is impossible to forecast whether these trends will still manifest themselves in the same way in fifty years' time. At the moment, the technological horizon for most companies extends not much further than two years at most. What we can say with certainty is that for the time being the technical potential of ICT will only increase. The fact that the computer is everywhere nowadays, from refrigerators to high-tech business systems, is known as 'ubiquitous computing' (ICT everywhere, under any circumstances and at any time). Nevertheless, it is going too far to assert that the availability of ICT automatically leads to its application. Against the potential of ICT as an *enabling technology* there is the problem of its integration and acceptance in society. As emerged in the introduction, we assume that ICT and the social context within which it has to function go hand in hand. Each influences the other and they cannot be seen separately from each other. There are plenty of examples of promising technologies that failed to take off or whose use fell far short of expectations. While we can regard the rapid introduction of the mobile telephone as a success story, the other side of the coin is represented by the failed introduction of the electronic purse (chipknip and chipper), the failure of digital money to get off the ground and the failure of steadily more advanced office accessories to increase productivity by as much as anticipated (CPB, 2000). So the success stories have to be treated with a certain reservation.

4.2 The new economy

ICT seems to be turning old economic laws on their head. There is currently a transition taking place from a product economy, in which supply and demand focus on finding a market equilibrium for scarce goods, to a service economy, where the same service can be repeatedly sold at marginal additional cost. Illustrative of the current economic order is the fact that mobile telephones are given away or sold for a very low price with a subscription. The profit is no longer to be found in the added value of the physical production but in the services provided along with the telephone (the use of the telephone, the SMS options, its use abroad, connection to the Internet). The new economy is further characterised by the emergence of new giants in the telecommunication, media and amusement markets. Enormous sums are being paid in the mega-mergers between formerly independent companies (media giant Time Warner merges its activities with Internet behemoth America Online, and amusement colossus Endemol goes into partnership with Spain's telecommunication company Telefonica). Even the proceeds from the auction of the third generation of mobile telephone frequencies (UMTS) are – with the exception of the Netherlands – enormous: the sale of licences raised 80 billion guilders in the United Kingdom, and as much as 120 billion guilders in Germany. The sale has boosted economic growth in Germany by a few tenths of a percentage-point this year and the German government will close the financial year with a budget surplus rather than a deficit (De Volkskrant, 30 August 2000). One final factor that we want to point out is the imbalance between the 'virtual' value of Internet companies in particular and their actual earnings. The share value of large new e-services, like the famous electronic bookstore Amazon.com, the browser Netscape and many other familiar and less familiar initiatives, is far higher than the sales of those companies would justify. In fact, there are signs that this is about to change. The collapse in the share price of WorldOnline in the Netherlands, but also the fact that financiers are starting to pull out of loss-making e-commerce activities on the Internet, point to a possible turning point.

The growing economic importance of the ICT sector also emerges from a recently published study by the CPB (CPB, 2000). The ICT sector makes a relatively large contribution to economic growth. And for the first time the increase in labour productivity in the ICT sector is also higher than average. The CPB study breaks the ICT sector down into producers of ICT products and ICT service providers. The latter category encompasses services relating to ICT products (system management, software maintenance, installation of software) and telecommunication facilities. In relation to the environment, it is interesting to note that, according to some, for the first time economic growth and environmental burden have been decoupled. A study in the US shows that the economic growth in the last two years has not led to a proportionate increase in the environmental burden (Romm, 1999). This is partly attributed to the new economy, in which services cause less environmental harm than the traditional economy with its material production. However, the arguments presented in support of the correlation shown in the study are not particularly strong.

4.3 ICT and sustainability

ICT can contribute to reducing environmental effects in different ways via different mechanisms (see for example Ducatel et al, 1999).

First, it can do so through the technology itself. The trend towards miniaturisation and digitisation can contribute to *dematerialisation* of the economy. After all, miniaturisation means that in computers and similar products fewer materials are needed to perform the same function. Digitisation means that products are available digitally rather than materially, such as sending an e-mail instead of a letter.

Second, there can be a *decoupling of time and place*. Thanks to the increased possibilities of communication, actions can be carried out from anywhere. This means that various activities can be performed from the home: shopping, learning, working, etc. The potential effect of this for the environment will be substantial if there is *substitution* of movements. We will look at this in more detail in the following section.

Third, ICT can lead to *more efficient organisation* which is facilitated by the faster exchange of information in companies and in chains. Various activities can be performed more efficiently.

Fourth, it is increasingly possible to provide consumers with *tailor-made information* for purchasing decisions and about the use of appliances. Moreover, it may be possible to buy environmentally-friendly products via the Internet. Through its “catch all effect” ICT solves the problem of a diffuse market in which the buyers are initially few and far between.

Fifth, miniaturisation means that ICT can be built into a growing number of appliances, so that more and more *smarter, intelligent appliances* will come on to the market. This will make it possible for appliances to provide instructions for use (feedback technology) or programme themselves for optimal use. In other words, it will be possible to delegate user's behaviour in an intelligent manner to appliances.

But the relationship between ICT and sustainability is double-edged: substitution (of raw materials, transport movements) and optimisation lead on the one hand to a reduction in the use of raw materials, but on the other hand these gains are totally nullified by the explosive growth in the use of ICT. The few thousand mainframes of twenty-five years ago bear no relation to the many tens to hundreds of millions of computers worldwide with a shelf-life of little more than three years. The rise of e-mail has up to now led to scarcely any reduction in the flow of paper. The arrival of Internet companies in Amsterdam has led to extra demand for electricity. However, there are also more positive reports

(Forsebäck, 2000). The Japanese Telecommunication Council forecasts a reduction of 3.81 MTon of CO_2 by 2008 (or approximately 7% of Japan's CO_2 emissions) if teleworking, intelligent transport systems, paper reduction through the use of Local Area Networks, household management systems, electronic publishing and e-learning are exploited in a realistic fashion. The question ultimately is whether the balance of savings and new and additional activities is still positive. The uncertainties in this respect are considerable.

5 ICT and climate change

5.1 The home and the built-up environment

The home environment will become more important in the society of the future. Besides being a place to live, many activities in the house lend themselves to digitisation and development of virtual services, ranging from television viewing and telephoning to electronic banking, telelearning, teleshopping and teleworking.[1] The home is an ideal place for decoupling processes formerly linked in time and space. A person can bank electronically at any time of the day and no longer needs to visit the bank.[2] The energy saving from teleactivities arises from the fact that the suppliers (for example banks) need fewer people, fewer offices, fewer activities (in fact the work shifts to the consumer), that less transport and distribution of physical goods is needed (video-on-line means a reduction of transport between the video store and the central warehouses) and the saving of paper (thanks to electronic communication). These savings are empirically demonstrable but are probably not significant in terms of the total energy consumption of a household.[3]

A second aspect is the degree to which ICT regulates overall energy consumption, starting with the provision of information prior to the planned purchase to the installation of equipment or software in the information architecture in the home and optimisation of the use in combination with the intelligence built in to appliances. Even energy management itself has energy saving potential. But the direct contribution of ICT to the savings will be modest, and because more appliances will be purchased with a higher replacement rate, may even be nil or negative. If the new style of living also involves the need for more rooms (for example because of teleworking, but also in connection with higher demands on home comfort) this will have a negative effect on the amount of energy needed. It should also be pointed out that although appliances may become more energy-efficient the energy balance will shift more towards production, distribution and disposal of the appliances.

A final aspect that we want to mention in connection with homes is the way in which they are an element of spatial planning. If ICT contributes to reducing the importance of distance as a factor in the choice of where one lives, a possible consequence of this is that distances travelled (to work, to the shopping centre, to leisure centres, to school) will increase. If this is attributed to a household it generates additional energy consumption. On the other hand, it is conceivable that carefully considered locations for new housing in relation to each other and to business parks, shopping centres, schools, etc. could lead to energy saving. It is also possible that advantages of scale could arise in the intelligent linking of intelligent energy infrastructures between home and working environments (combined heat and power generation plants in districts, district heating complexes, options for

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[1] We return to teleworking in the section on transport.

[2] As Forsebäck argued in a recent study: we need banking, but we don't need banks (Forsebäck, 2000).

[3] In a case study of the replacement of individual answering machines with a single central *on-line* answering service, Telia produced energy savings of a more than a factor 200. Although measured over a million households it is a substantial effect, the benefits per household remain small.

supplying heat back to the national grid, etc.). Up to now, there has been little or no research into such possibilities and effects of spatial planning. Generally speaking, it is disappointing to have to observe that ICT developments are very seldom assessed for their spatial planning implications, and vice versa. ICT has scarcely been mentioned in the debate that has preceded the (forthcoming) Dutch Fifth Policy Document on Spatial Planning. In a project like Gigaport, the aim of which is to produce the successor to the existing Internet infrastructure and applications that can use it, considerations of sustainability play scarcely any role.[4]

5.2 Transport and mobility

The use of ICT can promote sustainability in the traffic and transport sector in a number of ways:

1. by optimising the use of the infrastructure (including promotion of the 'modal split');
2. by optimising the logistics chain;
3. by reducing the pressure on mobility through alternatives (teleworking, teleshopping, telelearning);
4. with intelligent vehicles and monitoring of cargoes.

The optimisation of the infrastructure does not automatically lead to a reduction of CO_2 emissions. More efficient use of the infrastructure could help to spread traffic through the day, so that if the traffic flow increases there will be greater emissions of CO_2. Promoting the modal split is a way of stimulating the most efficient form of transport from an energy perspective (especially transport by water compared with transport by road). However, ICT mainly further reinforces the competitive advantage of the door-to-door approach of road transport, in part because the use of ICT increases the opportunities for customised service.

Optimising the logistics chain fits in with the *Just in Time* approach. Greater control of the entire transport and distribution process means that smaller inventories need to be held and consequently smaller storage systems. With the use of a comprehensive logistics system, the utilisation of capacity of goods transport can be increased: fewer empty runs and optimisation of the length of trips. But in a recent study Transport en Logistiek Nederland (TLN) pointed to the likely increase in the number of trips with (small) vans if e-commerce really takes off (TLN, 2000). In the next five years TLN expects an increase of 38% in the number of trips for freight transport. Of this 38% increase, 21% will be 'autonomous' growth and 17% due to developments in e-commerce (8% growth in the Business to Consumer sector, 9% in the Business to Business sector). A scenario study by the ministries of Transport, Public Works and Water Management, Economic Affairs and Housing, Spatial Planning and the Environment concluded that with the conscious use of ICT tools CO_2 emissions could decline sharply but would probably still remain above the target of 168 billion kilos (Nederland digitaal, 2000).

Teleworking leads to substitution of commuter traffic. The savings could rise to 40% of the number of trips per week (ICT & Sustainability, 2000; Forsebäck, 2000, p. 34). The increased use due to the car becoming available generally seems to be less than the savings (Puylaert et al, 1999). In other words, the sum of the effect of a car being freed up for secondary purposes (social and recreational traffic), other work-related movements or instigation of new commuter traffic is less than the savings achieved. In combination with the assumption that the house is a more energy-efficient place to work than the office (ICT & Sustainability, 2000), large-scale introduction of teleworking could make a positive contribution to reducing CO_2 emissions. Besides teleworking, teleshopping can also save trips. Up to now the expectations for teleshopping have scarcely been converted into quantifiable data.

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[4] Interview with Ms. J. Tammenoms-Bakker, April 2000

Following the TLN study, a certain degree of scepticism is therefore justified about the direction these developments will take.

5.3 Industry

There is some literature on the effects of ICT at macro level, but we found no literature for specific sectors of industry. What follows, therefore, is based mainly on our own forecasts of those effects. ICT could have two major influences on industry. On the one hand, optimisation in companies and collaboration in chains so that energy and materials can be used more efficiently. On the other hand, ICT could reinforce the existing trend of the growing importance of services in the economy, because services can be provided via e-commerce and tailored to the individual customer. Transport activities relating to industry are not considered here. They were discussed in the previous section.

The greater accessibility of information and the speed with which information is exchanged will make it easier for companies to share information worldwide about the environment and to monitor flows of raw materials and waste substances. This information is essential for chain management, where the various steps in the production process, from raw material to product to waste, can be linked in such a way as to keep pollution to a minimum. In this respect, ICT acts as a facilitator for collaboration between suppliers and customers and hence can help to optimise the entire chain. This aspect will have a positive effect particularly for the substances emitted to the environment and not so much for energy consumption. To grasp these benefits an organisational structure setting out the protocols for information exchange (method of exchanging information, infrastructure, assurance of reliability, confidentiality, etc.) is needed.

Various industrial production processes can be made more intelligent and can be better monitored with ICT applications. This could generate savings of raw materials and energy, although for the time being we do not estimate this effect as being very great. Production processes in companies are already largely optimised. ICT could make a minor contribution to this.

Finally, ICT can help to increase the transparency of the market for raw materials, waste and residual products. For instance, industrial ecological complexes could be formed at local level, in which the waste from one company becomes the raw material for another, or in which companies swap heat and electricity with each other. But ICT can contribute little to the creation of these complexes: it is not so much the “market” that is the problem but rather the need for collaboration between companies, which poses a number of dilemmas, such as the creation of mutual dependency, the division of costs and benefits and the risks for business operations. The introduction of ICT is expected to have at best a modest impact on energy consumption.

The trend towards the increasing importance of services in the economy has been apparent for years. For the COOL project, an important question is therefore how the industrial sector will develop in relation to the service sector. Will we have a fully service economy in 2050 or will there still be substantial industrial activity?

From the ICT perspective, what we can say is that ICT can make a significant contribution to the creation, sale and delivery of services. The literature (Bilderbeek et al., 1998, Miles, et al., 1999) shows that ICT plays an important role in service innovation. Many new services are born from ICT applications. Take for instance the “booming business” of e-commerce. It is therefore likely that ICT will reinforce the trend towards the service economy.

What does this mean for the likely environmental effects? Generally speaking, environmental scientists take a very positive attitude towards services, based on the idea that the material component in services is smaller than in products. However, in another study we showed that this relationship is not so straightforward (Nijhuis et al., 2000). After all, services often also need products (for example, computers when we are talking about e-commerce), and since people have to do the work there is often a significant transport component involved in getting the service providers to the client.

Another aspect that emerged in this study was that the "rebound effect" of services can be considerable. Simple access to the purchase of services can easily lead to far more services being bought than would be necessary purely on the basis of substitution. The volume of demand hence increases, as do the related environmental aspects, so savings can be cancelled out.

We therefore do not simply assume that an increasingly service-oriented economy will automatically lead to reductions of emissions or energy saving.

5.4 Agriculture and food

We will look here only at ICT applications in the production phase and not in the processing or consumption phase. In the previous section we considered the consequences for industry and there is no reason to believe the mechanisms described above should work differently for the food industry. At the same time, we considered the consumption phase in the section on "home".

Precision agriculture is a promising application of ICT for the cultivation of crops in agriculture. Precision agriculture is a form of farming where growers respond to the natural variability of the soil with the help of different technologies. By sowing, tackling weeds and diseases, applying nitrogen and harvesting according to the requirements of a specific location, it is possible to improve the quality of the harvest, increase yields and curb harmful effects for the environment.

Satellites are an important element of precision agriculture, as with the aid of GPS (Global Positioning Systems) objects, in this case harvesters and sowing machines, can be followed and steered. The yield from a plot is measured using a harvesting machine fitted with a yield meter and a GPS. The result is a yield map, which shows the yields for each location in the plot of land. The differences in yields are explained, for instance by differences in soil composition, ground water level etc. The data acquired in this way are processed and converted into charts for manure spreading, spraying and sowing. With the aid of sensor technology, muck spreaders, sprays for pesticides and sowing machines can adapt the doses to the exact needs of a particular point in the plot. All the calculations are entered in a single central computer, which helps the farmer to determine the optimal time and route for harvesting. Precision agriculture increases productivity, improves the quality of the crops and the efficiency and effectiveness of the use of resources such as seed, manure and pesticides (Nijhuis, 1999, Nijhuis et al., 2000). Precision agriculture therefore contributes mainly to the efficient use of raw materials and can also help with the more efficient use of energy. We do not feel the effect on energy consumption will be particularly large.

Processes in horticulture and livestock sector are already heavily mechanised. ICT applications could make these processes even smarter and further optimise them. We do not estimate the effect on energy consumption as particularly great.

6 The effect of ICT on climate change

In this section we will try to translate the applications of ICT technology described in the previous section into the consequences for energy consumption in the various sectors. But we wish to stress that the estimates are very tentative. We found no basis for them in the literature, nor is this the time or place for a more in-depth analysis. However, a quantitative estimate does provide an insight into the mutual relationships and further elaborates on the qualitative estimate. Table 1 lists the various applications in the different sectors and explains how these applications contribute to reducing pollution and energy consumption, with references to the different mechanisms mentioned in section 4.3 (dematerialisation, decoupling of time and place, efficient organisation, information provision, intelligent appliances).

	Mechanism[5]	**Technically feasible energy saving**[6]	**Likely energy saving**
Home			
• Energy in the home	3, 4, 5	10%	5%
• Electrical appliances	4, 5	5%	0
• On-line services	2	5%	0
• Spatial Planning	2, 3, 4	?0?	0
Transport			
• Infrastructure/ modal split	2, 3	20%	- x%
• Logistics	2, 3, 4, 5	15%	5-10%
• Intelligent vehicles	1, 5	20%	15%
• Teleworking, teleshopping, etc.	2, 3	40%	20-25%
Industry			
• Chain management	3, 4	5-10%	0
• Smart processes	5	10%	0
• Services	1, 3	?0?	- x %
Agriculture			
• Precision agriculture	1,3,5	10%	0

Table 1: The contribution to energy conservation by the various ICT applications.

The table makes a distinction between the technically feasible energy savings and the most likely energy savings. Under the technically feasible savings we indicate the maximum effect that ICT could have if other aspects are ignored, such as behaviour, organisation, infrastructure, etc. In the column "likely energy saving", we indicate what effect is likely if ICT is used in a traditional manner, in other words without a complete "redesign".

We estimate that the energy savings actually achieved are likely to be less than what is technically feasible. This relates to the model that we outlined in section 3. In our view, when new technology is introduced attention should be given to all aspects mentioned there: the behaviour of societal actors,

[5] The different mechanisms are: dematerialisation (1), decoupling of time and place (2), more efficient organisation (3), tailored information (4), intelligent appliances (5).

[6] The quoted percentages are for savings that could be realised in the relevant domain. Savings of 10% for energy in the home means that through the optimal use of technology the total energy consumption of a household can generate savings of up to 10%. For the interpretation of the percentages, therefore, it is a question of the potential savings in the given situation. For an overall impression, the mutual proportions of energy consumption in the home, transport, industry and agriculture have to be included in the calculations. We don't do that here.

new arrangements, infrastructure, organisation and information, and the technology-behaviour interactions. Many of the technical possibilities are not properly exploited because of:

- rebound effects: for example, with teleworking the car is not used for work but for extra private trips; a more efficient organisation means that there is time left over for extra production, etc. We therefore expect that the extra 'room' created will be swallowed up by new activities, which leads to extra energy consumption.
- too little attention to accompanying organisation and infrastructure.
- failure to provide information to the user.
- divided interests and power positions of actors, so that no one takes the lead in directing the use of ICT technology. Neither the government nor companies feel compelled to create new arrangements or institutions.

This table shows that our estimates of the potential savings through optimal use of technology are generally modest and nowhere near the desired 80%. The savings in transport (traffic and transport) produce the highest returns from a technological perspective. But the interaction between the various aspects is highly complex: optimising logistics chains, for example, could have a negative effect on the modal split, and to a certain extent also on the use of the infrastructure (more capacity available, hence less need to shift to a different form of transport). Because of the interdependencies between the various actions the savings cannot simply be added up. From the (we repeat: tentative) table, it follows that the potential savings in homes, industry and agriculture remain around ten percent, and for traffic around 30%. The expected savings (from incorporating ICT in current activities, in other words without substantial reversal of trends) in the case of homes, industry and agriculture are slightly positive or possibly even negative. The savings will be highest in transport.

What policy options do we feel should be adopted?
First of all, we want to stress the importance of collaboration between the government, companies and civic groups, in which they start a dialogue about what measures have to be taken, and by whom, to supervise the ICT applications in order to gain the maximum benefit from energy-saving effects. The COOL dialogue is itself in fact a good example of this.

Within this context, agreements can be made with respect to:

- the monitoring of the use of ICT in society, which would have an important function in identifying the following aspects;
- influencing technology-behaviour interactions; preventing rebound effects;
- ensuring that the infrastructure is adequate;
- providing information to users and ensuring there are adequate organisational models for information-exchange and feedback;
- developing intelligent appliances;
- desired rules and regulations.

7 Major conclusions and points for discussion

- ➢ Technologically, a lot if not everything is possible, especially in view of the rapid developments with respect to information and communication technology. A far more important question is how we can and want to take advantage of the new possibilities. As we have tried to indicate in this essay, the social context of the technology has a major, if not decisive, influence on its ultimate use, and hence on the resulting energy consumption. Can we and do we want to influence this social context by means of various arrangements and policy options? What additional policy will we use to do this?

- The use of ICT can contribute to the 80% reduction targeted by COOL, but will never in itself be enough.
- Our analysis shows that transport and traffic can make a particularly significant contribution to the reduction of CO_2. Other sectors can also achieve additional energy conservation, but to a lesser extent. If we want to "reap" these benefits, consideration will have to be given to new institutional arrangements, new organisational and information structures, infrastructure, and to understanding and influencing the behaviour of the users of technology.
- In our essay we have placed a major question mark against the energy-saving effects of the growing service-orientation of the economy. It is impossible to say in advance whether a service will lead to additional energy conservation since services could lead to extra demand as well as extra transport movements. However, services can play a role in saving energy. It is therefore essential to find out more about the relationship between the growth of services and energy consumption and to use the findings to provide more direction for the development of services.
- There are enormous uncertainties surrounding the effects of the rapid developments in ICT. The future interaction between the technology and the user (the rebound effect) is particularly difficult to predict. It is precisely this interaction that will account for the ultimate effect on energy consumption. Additional or different use of the technology could turn a potential benefit for energy consumption into a disadvantage. Intelligent appliances can be used to direct user behaviour. But there is still little known about technology-behaviour interactions. We therefore call for the creation of a research programme "Technology and Behaviour" to increase our understanding of this phenomenon and conduct practical experiments.
- Who feels compelled to take the initiative to implement the various conceivable and possible arrangements: the government, the private sector? In this essay we have given some (global) indications of arrangements that could be made. Something will have to be done if we want to avoid a social dilemma, in which everyone sits and waits for everyone else.
  In this context, we call for collaboration in which the public and private sectors jointly study policy options, conduct research, assign responsibilities for actions and carry them out, all with a greater emphasis on shared responsibility and interactive policy-making.

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