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Managing (un)sustainable transitions – bringing the broadband society on the right track?

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Abstract
Information and communication technology (ICT) can be seen as a general purpose technology with wide-ranging socio-economic and environmental implications across sectors. ICTs also constitute a system of technologies where the internal links have been strengthened through the emergence of the internet and the broadband as a new information infrastructure. The present changes can be studied as a system-level transition process, often referred to as the emergence of the broadband society, and the paper deals with this transition from an environmental perspective. By bringing together three different and usually separate literatures – transition theory, economic studies on ICT and environmental studies on ICT – the paper explores the energy impacts of the transition, how the broadband society is taking form, and why environmental concerns do not figure more prominently. In conclusion, it is argued that these processes illustrate the need for transition theory to focus more on how to cope with emerging unsustainability.

Keywords: transition theory, broadband, green ICT, selection environment, energy

Introduction

Information and communication technologies (ICTs) have a long history where they laid the foundations of separate industries such as telecommunications, recorded music, film, radio, television, and office equipment. In spite of the long history, the concept of ICT is of a more recent origin related to the merger of technologies for communication, broadcasting and data processing. The basis for the merger was the emergence of the transistor and later the microchip, which made it possible to install an ever-increasing number of transistors in a very limited space. This miniaturization enabled the inclusion of advanced data-processing facilities for monitoring, management and manipulation in a multitude of products, as well as development of the general-purpose personal computer. Digitalization led to increasing intertwining between the different industries related to telecommunications, entertainment and office equipment, and the appearance of the internet reinforced the process considerably. ICTs have developed into a cluster with large social and economic importance, and although Winston's account of the historical development of media technologies emphasizes that the present changes are far from being as "revolutionary" as the hype sometimes suggests (Winston, 1998), it is probably safe to say that the potential for future change related to ICTs is enormous.

How is this potential going to be used in relation to the great challenge of transforming societies in a more sustainable direction? ICTs can be used in many different ways, and the different paths are decisive for the resulting environmental impacts. Already in the early phase of microelectronics and digitalization much hope was attached to the potential for environmental improvements through ICT (Freeman, 1992), and surely, ICTs have contributed to such improvements in various ways – from environmental information systems to better management of production processes. Unfortunately, however, ICT also gives rise to considerable environmental costs, not the least in relation to the integration of ICT in everyday life.

Considering the socio-economic and environmental importance of ICT, it could be expected that ICT would be a core topic for discussions on transitions towards sustainability. This is, however, not the case: the expanding field of transition theory and transition management offers little explicit treatment of ICT. Sustainable transition studies cover a variety of systems related to, for instance, energy, transport, sanitation, and agriculture, and the studies tend to focus on emerging "green" innovations that may change or replace an incumbent unsustainable regime (Elzen et al., 2004). Of course, many of the environmentally motivated innovations in relation to energy, transport and other systems make use of ICT, but ICT is the core of many other innovations that are not environmentally motivated. While it may seem reasonable that studies on sustainable transitions focus on innovations that are environmentally motivated, this focus implies a danger of overlooking important unsustainable trends that ought to be counteracted. Since many niche innovations as well as ongoing system changes may be unsustainable, it would be useful if more transition studies focused on whether and how such transformations can be steered in a more sustainable direction.

Transition theory applies a multi-level perspective, highlighting the interplay between niche innovations, landscape developments and regime changes, and including a broad array of actors. Still, however, the studies are usually biased towards the production side and tend to treat the user side more sparingly, which the proponents of transition theory are well aware of. The focus on production calls for dealing with efficiency and potentials for environmental improvements. Focusing on consumption, in contrast, increases the awareness of the unsustainability that may follow in the wake of technological innovation. Dealing with consumption aspects and dealing with unsustainable transitions thus tend to go hand in hand.

This paper applies a sustainable transition perspective to the present ICT-related transformations of everyday life. The purpose is partly to discuss how these transformations may be influenced politically so as to become more sustainable, and partly to contribute to the development of transition studies dealing with unsustainable transitions and including consumption aspects more explicitly. The paper brings together three different literatures that tend to develop in isolation from each other:

1. Transition theory in a sustainability perspective
2. ICT and the environment
3. Economic studies on ICT.

In addition to literature studies, the paper is based on an empirical study on the use of ICT in Danish households and the related energy impacts (reported in detail in Røpke et al., 2010).

The paper starts by a brief presentation of transition theory and by discussing how a transition perspective may be applied in relation to the ICT-related transformations. Then the energy impacts of the present transition processes are briefly outlined, and the energy-related regulation of ICT is introduced. ICT has many other environmental impacts than those related to energy use, but these are only briefly mentioned when their inclusion is relevant for the argument. Since the energy regulation has neither succeeded in curbing the growing ICT-related energy use, nor in realizing the sustainability potential of ICT, the following section explores how the broadband society is taking form and why environmental considerations do not figure more prominently. The concluding section summarizes the results.

Transition theory

The knowledge interest of transition theory and transition management is to understand social and technological change at a system level and to improve the basis for political intervention in the processes. Part of the field – transitions for sustainability – focuses on governance for sustainability. Since this paper is motivated by the same aim, it is worth exploring whether transition theory may be helpful when studying ICT in an environmental perspective.

Transition theory focuses on systems innovation. On the one hand, systems innovations concern more than just one industry, and on the other hand, their scope is more limited than the scope of techno-economic paradigms which change the economy as a whole (Freeman and Perez, 1988; Geels and Schot, 2007; Perez, 1985). Sometimes the system level is defined in relation to "societal functions" such as transport, communication, and housing (Geels, 2002) – an approach inspired by Hughes' idea of a seamless web of elements combined in order to achieve functionalities. In other cases, the system level is defined as an organizational field: a recognized area of institutional life with a community of interacting groups (Geels and Schot, 2007). Emphasizing organizational fields rather than functionalities is a more open approach and maybe a response to the critique from Smith et al. (Smith et al., 2005) of transition theory for being "overly functionalistic". Simultaneously, the two approaches are overlapping when organizational fields are organized around societal functions.

At the system level it is possible to identify socio-technical regimes. A socio-technical regime is defined as semi-coherent rule-set that coordinates the activities within a community of interacting groups (Geels and Schot, 2007) – or in other words, configures and aligns a network of heterogenous elements. The concept of rules is synonymous with regulative, normative and cognitive institutions, which both enable and constrain the activities of the actors (Scott, 2001). The rules only exist through their enactment by the social groups, and through this reproduction, activities are coordinated and aligned in a way that gives the regime stability and a recognizable form. The concept expands on Nelson and Winter's concept of technological regimes which focuses on the community of firms and engineers who share routines in relation to the development of a new technology. The socio-technical regime includes more social groups and a wider set of activities than technological development. The constitution of a socio-technical regime is relatively weakly conceptualized. Geels (2002) provides a list of seven heterogenous dimensions of a regime (technology, infrastructure, industrial networks, user practices and markets, culture and symbolic meaning of technology, sector policy, techno-scientific knowledge), but systemization and operationalizing is lacking.[1]

Over time socio-technical systems change. In spite of the relative stability provided by the rule-set, a regime includes tensions and dynamics for gradual change. The main interest of transition theory, however, is qualitative change – processes of reconfiguration where one socio-technical configuration is replaced by another. Such transitions are seen as outcomes of alignments between developments at multiple levels, so-called multi-level processes. For instance, system change may

[1] Comparing with practice theory, Geels' list reminds of Reckwitz' long list of components of a practice (Reckwitz, 2002), while operationalization like that of Shove and Pantzar is lacking (Shove and Pantzar, 2005).

result from the building up of radical niche innovations that challenge the incumbent regime and get a breakthrough, if the regime is destabilized by changes in the external context for the regime, the so-called landscape level.

System innovations – regime changes – are characterized by the coevolution of supply and demand, radical changes of both production competences and markets, the involvement of many actors, and a long timescale (Elzen et al., 2004). Rather than directly applying the evolutionary metaphor for change where the creation of diversity precedes the selection process, the approach emphasizes the co-evolution of innovation and selection environment. The selection environment is actively influenced by the innovators as well as other actors, so technology, market, users, institutions, policies, and discourses coevolve. System changes have an emergent character where visions and activities are aligned through a longer period of time. Government intervention is part of the process, but as one actor among many others, government can only influence, not manage the process. Still, however, transition management is seen as an important possibility for promoting sustainability.

A system perspective on ICT

How can the transition perspective be applied in relation to ICT? Does it make sense to talk about ICT in a system level perspective? Historically, many transition stories could be told in relation to, for instance, the transformation from one generation of media technology to the next (Winston, 1998). In some cases, the changes may not qualify as system level innovations, while in other cases they surely do. The focus here, however, is not on these particular stories, but more broadly on the ICT cluster of technologies that took shape with digitalization. ICTs are generic or general purpose technologies – in the sense that they can be widely applied and influence the economy as a whole: ICTs can be used for all kinds of activities that involve the acquisition, storage, processing, and distribution of information (Bresnahan and Trajtenberg, 1995; Steinmueller, 2007), and the technologies offer an ever increasing acceleration of these processes (Hilty, 2008). The generic character of ICT and the economy-wide implications call for applying the perspective of techno-economic paradigms, as suggested by Freeman and Perez (1988). While it is surely relevant to consider the ICT cluster of technologies as a techno-economic paradigm with wide-ranging implications for economic growth across sectors (Jorgenson, 2001), it is also possible, as a complementary perspective, to study the cluster at a system level. The emergence of the internet has strengthened the links within the cluster, and the ICT sector increasingly appears as a whole which is subject to political intervention.

Fransman offers a system-level account of ICT, inspired by basic understandings from Schumpeterian evolutionary economics that are largely shared by transition theorists (Fransman, 2010). The account is motivated by an interest in exploring innovation processes as a basis for government intervention to increase competitiveness. Fransman applies an ecosystem metaphor and describes the ICT ecosystem as a set of organisms that interact within an environment. The first set of organisms comprise firms that may be involved in both competitive rivalry and cooperative symbiotic interactions. Other organisms are final consumer-users and various non-firm organizations like universities, government research institutes, standard-setting bodies and policy-makers that are all involved in interactions, sometimes in symbiotic relationships which are decisive for learning and innovation. The players are embedded in institutions, rules of the game, both at the national level and internationally, and the ICT ecosystem interacts with other sectoral ecosystems like the financial services system.

Fransman argues that the ICT ecosystem is undergoing radical change, largely as a result of the evolution of the internet, which began to be widely diffused from around 1995. The internet has transformed its parents, telecoms and computers, and added complexity to the sector by incorporating and transforming previously unrelated sectors, such as media, into the ICT sector. New groups of key players have been created, such as internet content and applications providers, and new forms of consumer interaction have emerged. The new ICT ecosystem can be conceptualized as a layered system which is at the same time defined by a technical architecture and by economic-institutional relationships. In a simplified model Fransman identifies four layers including both objects and actors:

1. Networked elements and the providers of these items: telecoms equipment, computers, consumer electronics, intermediate goods, and the software needed to run the products.
2. Communication and content distribution networks and the network operators: the creation and operation of mobile, fibre, copper, cable, and satellite networks – networks that have become increasingly intertwined from the 1990s.
3. Contents and applications and the providers of these outputs: contents and applications for final users include, for instance, textual information, music, video services, electronic commerce, email, and Voice-over-IP. In the simplified model this layer includes functionalities such as search and navigation software needed for the provision of contents.
4. Final consumption and consumers.

Fransman emphasizes that the ecosystem is restless with changing boundaries between the layers, influenced by both innovation, market development and regulation.

Relating to transition theory, the description of the ICT ecosystem fits well with the idea of a socio-technical regime coordinating the activities within a community of interacting groups. Although the description here is mainly structural, it indirectly indicates that the interactions involve a set of rules or institutions providing the organizational field of ICT with some coherence. In addition, it may be argued that the converging ICT networks constitute an infrastructure that provides a societal function by processing, disseminating and storing information and facilitating communication.

From a consumer and everyday life perspective various changes appear in relation to ICTs. The traditional distinctions between different kinds of equipment become partly dissolved: consumer electronics for entertainment (television, radio, music, games), telephones for communication, and equipment for administrative tasks like word-processing and calculations are increasingly merged, and they are often bought from the same shopping outlets. Simultaneously, the simple links between devices and the social practices in which they are involved, tend to become more complex. The 'old' ICTs tended to be integrated into practices defined by the technology itself: phoning, listening to the radio, or watching television. When the 'new' ICTs like the home computer and the mobile phone were first introduced, they were also dedicated to a limited number number of practices, such as playing games, word-processing and communication, just as the introduction of the internet first introduced a specific new practice of 'surfing on the internet'. However, the interpretive flexibility of the 'new' ICTs is much wider than that of the 'old', and the core technologies of computer, mobile phone and internet are open for integration into a wide variety of everyday practices. In particular, the internet has been decisive for the usefulness of other technologies.

In a qualitative study of ICT use in Danish households, we have highlighted the integration of computer and internet into 48 activities organized into the following 10 groups: communication, entertainment, information, purchase and sale, work at home, education, hobbies and volunteer work, administration and finances, domestic work and management of the dwelling, and finally health (Røpke et al., 2010). Applying a practice theory perspective (Christensen and Røpke, 2010; Røpke, 2009), the study demonstrates how the generic functionalities are integrated into all sorts of practices, and how many practices are transformed in the process, including practices with no obvious relation to the classical use of ICTs such as different sports and do-it-yourself activities. In addition, the integration of ICTs into a practice is often accompanied by diversification of this practice, adding more variety and new features to the practice. Whereas ICTs are perceived as a category of consumer goods, the use of these goods is thus not limited to a particular category of everyday practices. Of course, ICTs play a particularly prominent role in entertainment practices and practices with a large element of communication (like keeping in touch with family and friends), but their place in most practices is growing. This calls for a system perspective with a focus on the infrastructural changes that are taking place – changes that are often referred to as the emergence of the broadband society.

Both from a production and a consumption perspective the internet is at the core of the present ICT-related changes, and the establishment of high speed networks is seen as the basis for realization of the great potential for social and economic change related to ICT. As Melody puts it, the broadband as the new information infrastructure will be the most important public utility in the 21st century economy (Melody, 2007). Now, what are the environmental implications of these ongoing transition processes?

Environmental implications of ICT

While ICT has been studied in relation to various social issues since the 1970s, the systematic study of the environmental implications of ICT did not take off before the late 1990s resulting in a number of publications coming out in the early 2000s (Berkhout and Hertin, 2001; Erdmann et al., 2004; Hilty et al., 2005; Kuehr et al., 2003). Several studies organize the environmental impacts of ICT into three groups, using slightly different terminologies (Hilty, 2008):

1. First-order effects: the environmental impacts directly related to the life cycle of ICT, including the production, use, recycling and disposal of ICT. These effects are sometimes referred to as direct effects. (Note that they include also, for instance, CO_2 emissions from power plants or the impacts of mining, which, in the terminology used in life cycle assessments, are referred to as indirect effects).
2. Second-order effects: environmental impacts due to the application of ICT that has the power of changing the processes of production, transport and consumption. These are sometimes referred to as indirect effects.
3. Third-order effects: environmental impacts related to the medium or long-term adaptations of behaviour and economic structures that follow from the availability of ICT and the services it provides. These are sometimes referred to as systemic effects.

In general, the sum of the first-order effects is negative, while the net impact of the second- and third-order effects, respectively, may be either positive or negative.

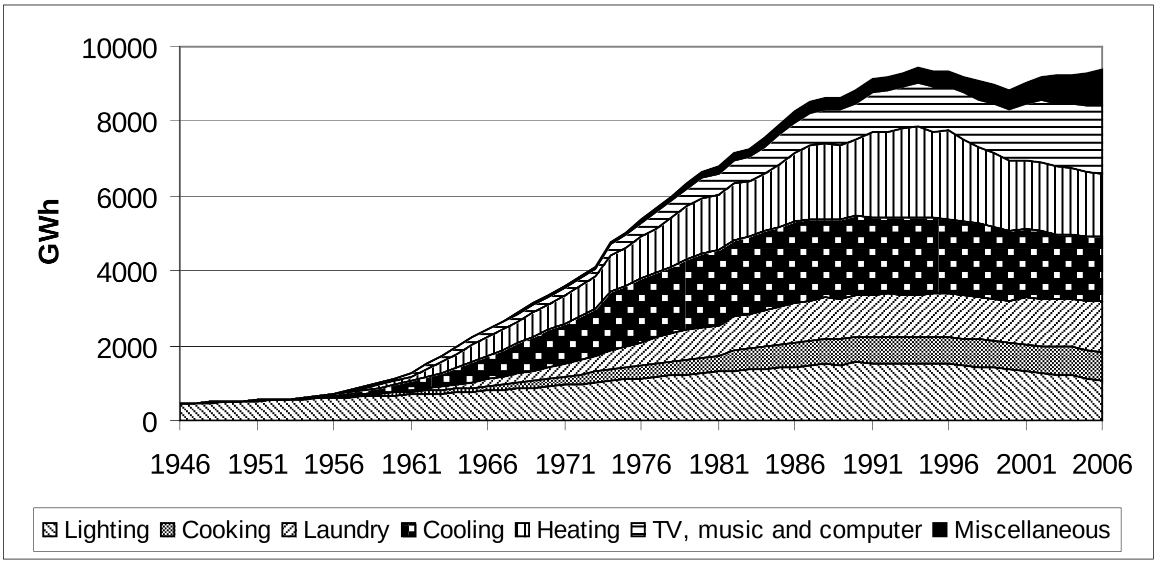
The first-order effects are studied most thoroughly. In particular, the enormous impact of ICT (including consumer electronics) on residential electricity consumption has been highlighted (Crosbie, 2008; IEA, 2001; IEA, 2009). Digitalization of television, set-top boxes, increased screen size, standby, the increasing number of PCs and many small devices imply that ICT takes up an increasing share of residential electricity consumption: “While efficiency improvements have been made, savings have been cancelled out by the demand for equipment which provides more functionality, or is larger or more powerful, and therefore uses more electricity” (IEA, 2009: 21).

Global residential electricity consumption by ICT equipment grew by nearly 7% per annum between 1990 and 2008, and even with foreseen improvements in energy efficiency, consumption by electronics is set to increase by 250% by 2030 (IEA, 2009: 237).

Our own study (Røpke et al., 2010) suggests that the integration of ICT into everyday practices can be seen as a new round of household electrification, comparable to earlier rounds that also led to higher electricity consumption. Electricity is used for such basic functions as providing light, transmitting sound, heating, powering mechanical devices, and processing data, and in a historical perspective, the use of electricity for new basic functions in the home has given rise to three rounds of electrification: first lighting, then heating and powering, and most recently data processing. The changes in the composition of electricity composition over time is illustrated in Figure 1 for the Danish case. The figure shows that without the growth in ICT, residential electricity consumption would have fallen in recent years. While electricity consumption from 2000 to 2007 for non-ICT fell by nearly 10 percent, electricity consumption for ICT increased by 135 percent (Gram-Hanssen et al., 2009). The scenarios provided by IEA suggest that this trend can be expected to continue worldwide, although interrupted by economic crises.

Other first-order effects relate to the energy consumption in other phases of the life cycle, the mining of scarce metals and other resources, the use of toxic substances such as brominated flame retardants, and the handling of electronic waste. The production of ICT equipment can be just as energy consuming as the use phase, and running the necessary infrastructure like sending masts and server parks also requires much energy (Hilty, 2008; Willum, 2008). The chemicals give rise to a variety of problems, and the extraction of resources is the root of serious social conflicts as well as environmental degradation. The amount of e-waste is increasing rapidly, and some of the recycling activities are not handled properly (Hilty, 2008: 127ff). The recycling challenges can be expected to increase with the trend towards embedding ICT components into all sorts of products that are not considered to be ICT products (the diffusion of RFID tags can be seen as a frontrunner of such pervasive computing) (Hilty, 2008: 132).

Figure 1. Danish household electricity consumption distributed by final use (GWh), 1946-2006



Source: ELMODEL-Bolig. See Røpke et al., 2010.

Second-order effects are often expected to be positive, firstly because ICT can contribute to optimization of production processes and transport systems, and secondly because ICT can substitute other processes, for instance, when a service replaces a physical product (like e-mail replacing letters). It should be noted, however, that optimization and substitution may work in the opposite direction, for instance, when the aim is to optimize for just-in-time production rather than for resource savings, and when energy-using products (like the digital photo frame) replace simpler products. In addition to these modifications, negative impacts are particularly related to the induction effects that occur when an ICT application stimulates increased use of a product or service. Hilty (2008: 37f) uses paper consumption as an example: paper may be saved when errors are corrected on the PC before printing (optimization), and when information is received directly from the screen (substitution). But these effects are more than offset by the induction effects, since PC and printers make it so easy to get print-outs that the potential is used for increased convenience and higher quality rather than saving paper. The induction effect is familiar to the rebound effect that occurs when the intention of savings through efficiency increase is balanced off or even overcompensated by quantitative growth that is stimulated by the efficiency increase (Binswanger, 2001). But since the induction effect is not restricted to situations where the intention is to save resources, it can be seen as more general than the rebound effect. The development of ICTs offers good examples of the rebound effect, such as the miniaturization paradox: ICTs are continually getting smaller in terms of mass, but simultaneously the prices fall, and since "processing power is getting cheaper faster than it is getting smaller" (Hilty, 2008: 95), the total mass tends to rise. Pervasive computing is expected to add to the accumulation of mass (Hilty, 2008: 96).

The positive potential of third order effects is related to environmental information systems and structural dematerialization. Environmental information systems are decisive for monitoring and understanding processes in the environment and for the implementation of environmental policies and environmental management (Hilty, 2008: 25-33). Structural dematerialization is based on the long-term potential of substitution effects related to, for instance, telework and videoconfering that may reduce transport, and more generally, the management of scarce resources in closed cycles maintained by renewable energy (pp. 153-156). On the other hand, ICT contributes to the globalization of markets and distributed forms of production that cause increasing transportation of products and people, and ICT accelerates innovation processes which leads to ever faster devaluation of the existing by the new (p. 38; p. 24).

Until recently, the study of ICT in an environmental perspective has been the preoccupation of a relatively small community, and except from the work of IEA, the public and political impact has been limited. During the last few years, however, "green ICT" emerged as a new catchword promoted by both green NGOs (see WWF publications: (Buttazoni, 2008; Pamlin and Pahlman, 2008)) and governmental organizations like OECD that has organized two international conferences on the topic. While IEA has taken on the task of warning against the negative energy impacts, the hype on "green ICT" tends to focus on the promises of ICT, but few of these promises are fulfilled without public intervention.

Public regulation of ICT and energy use

The environmental regulation of ICT is first of all concerned with first-order effects, in particular, related to electricity consumption and waste. The electricity consumption of ICT equipment emerged on the regulatory agenda in the late 1980s, when it became apparent that offices were developing into much more energy consuming places with ICT. Both for economic and environmental reasons energy savings were encouraged, and the U.S. EPA, for instance, introduced the Energy Star labelling for office equipment in 1992. In households, the first implications of digitalization became visible in relation to standby power. With the emergence of teletext services in the late 1970s, more advanced wireless remote controls were developed for televisions and later for many other appliances. Since remote controls only work when appliances are (partly) turned on, this development implied a massive increase in standby electricity consumption – reinforced by the increased standby consumption of appliances not managed by remote controls. Over the last 15 years particular attention has been devoted to the reduction of standby power consumption, partly because standby came to take up a significant share of electricity consumption (around 10% of residential electricity consumption in many OECD countries, IEA, 2009: 346), and partly because much of this consumption is considered not to serve any useful purpose. The contribution of each appliance to standby consumption is usually small, but over 100 appliances have a standby component, and the number is growing. Since policies tend to focus on up to 15 appliance types, which account for only about 25% of household standby consumption, standby consumption is still high (IEA, 2009: 345-350). The focus on standby consumption has, to some extent, pushed the on mode energy consumption into the background, although this has grown substantially for televisions and computers, in particular.

The IEA has played an active part in promoting energy saving regulation of ICT through monitoring, policy development and encouragement of "policy borrowing" and international cooperation. The Agency emphasizes that, in most cases, energy savings cannot be expected to come about without public regulation. In the case of mobile devices there are clear market drivers for energy efficiency due to the interest in decreased size and weight and increased battery life, but the results achieved in this area are not transferred to the majority of technologies unless public regulation makes it happen (p. 243). Among the reasons for the lack of focus on energy efficiency are: each appliance (except television and computer) consumes little energy; functionalities and features are often changed, and devices are frequently displaced; energy efficiency is discarded, if it reduces the time a product takes to get to the market; it is costly, if efficiency features (like power management) cause confusion for consumers and increase technical enquiries; consumer information on running costs is poor, and little market value is placed on lifetime costs; principal-agent issues occur when the choice of a device or core component is made by an actor, who does not pay the running costs – as in the cases of external power supplies and set-top boxes (chosen by the television service provider and not by the final consumer) (IEA, 2009: 237-243, 309, 336).

Most regulation has been based on instruments such as endorsement labels (or comparison labels based on energy performance), minimum energy performance standards, government procurement policies and consumer education to reduce standby consumption. Improvements have been achieved, for instance, through the combination of endorsement labels and government procurement for computers in some countries (p. 298), but in many cases, the instruments are not used very effectively, much regulation is based on voluntary agreements rather than compulsory programmes, and the results are far from meeting the challenge. The missing regulation for much ICT equipment reflects a lack of political attention, but it is also due to various difficulties such as the lack of credible test methods, the prevalence of proprietary technologies, difficulties with maintaining compliance in a market with large imports, the lack of tradition for energy regulation of electronics (pp. 270f), and the fast entrance of new products and the changing functionality of existing products, which makes it difficult to define individual devices and establish appropriate energy performance targets. To cope with the last issue and to regulate the full range of digital products, IEA suggests to increase the use of horizontal policy measures that apply to functions rather than appliances. A first step has been taken by limiting the maximum standby power level to 1 watt per device (with a few minor exceptions) as in the EU Ecodesign Directive from 2008 (effective from 2010), and this approach could be extended by relating energy performance to functions such as visual display, computing, audio and video recording and playback, printing and copying, and TV reception (p. 246). IEA also suggests to restructure the traditional use of scaling factors which allow for more energy to be used by products relative to their capacity, size or volume, so that larger appliances are required to meet higher efficiency levels. To deal with the principal-agent problem mentioned above, IEA suggests that service providers could be obligated to pay most of the running costs or that it could be part of the license (necessary to supply television services) to offer customers energy efficient services (pp. 318-321).

Further complexity arises when devices are connected to networks, as they increasingly are. A few network applications have energy efficiency as their primary purpose, but most residential applications are designed for comfort, control, security, or entertainment. The dedicated network products like routers and switches as well as the network interface components within each connected device consume relatively little energy, but with billions of connected devices the impact is considerable. In addition, the connection to networks may affect the ability of an appliance to utilize power management functions. Therefore, public intervention is highly needed to ensure industry-wide standards that combine interoperability with the support of power management (pp. 356-359).

Although IEA is far ahead of realized policies, the scope of their suggestions is limited. IEA tends to focus on the use phase and the direct electricity consumption in households. They are aware of the importance of the energy consumption related to running the ICT infrastructure (networks, servers etc.) (pp. 295-297), but no specific policies are suggested, and the energy consumption related to the production of the ICT equipment is not even mentioned. Hilty (2008: 124-126) argues that even when new products are more energy efficient in use, environmental considerations call for extending the life of most ICT products (except those that are run all the time), but IEA discusses how to limit the second-hand market (p. 302). In the same vein, IEA does not consider the negative effect of the short software innovation cycles with increasing hardware requirements – software-induced hardware obsolescence – which could be counteracted by labelling software products for the efficient use of hardware resources (Hilty, 2008: 170-173). IEA's lack of focus on extending product life is probably reinforced by the exclusive focus on energy, leaving out problems related to scarce resources, mining, waste and toxic substances.

The second- and third-order environmental effects of ICT are strongly related to the actual use of the technologies – to which extent they are applied for providing increased comfort, entertainment and security in everyday life, to which extent they are used for reducing resource use, and how strong the rebound effect is. Few policy-makers would dare to question the social desirability of the increasing amounts of equipment and the ever-higher standards – larger screen sizes, 3D television and so on – so no policies deal with the growth issue. Politically, it is more acceptable to deal with the positive potential for saving energy with ICT, and as mentioned, there is much hype around "green ICT". It is also possible to find examples of policies encouraging the realization of the potential, for instance, in relation to 'smart metering'. Several countries support or require the installation of smart meters that provide feedback to households about their energy use and thus encourage savings – at least when the information is sufficiently frequent, disaggregated and appealing (Darby, 2006; Fischer, 2008). Smart meters are also expected to play a role in relation to the integration of wind energy and other sustainable energy sources into energy systems, by encouraging consumers to use energy when the sustainable sources are available and to store energy for later use (e.g. in batteries for electric cars). Still, this is mostly a vision, and other examples are less encouraging. A much advertised promise of ICT relates to telework that may save energy for transport, but public policies do not always encourage the realization of this potential: for instance, tax exemptions for work-related transport motivate people to combine telework with moving further away from their workplaces (Jørgensen et al., 2006). There is much scope for developing public policies to promote the realization of the potential for environmental improvements based on ICT.

Shaping the broadband transition

Summing up, the ongoing transition processes related to the broadband society have large environmental impacts, which are only partly modified by regulation, and the large potential for second- and third-order improvements is only realized to a limited extent. Certainly, when the environmental implications are studied from a production perspective, the results regarding improved micro level efficiencies are obvious, and at the macro level ICT has probably contributed to the relative decoupling of energy consumption from economic growth, although a large potential for improvements is not realized. But when the attention is turned towards the consumption side, the problematic aspects are more conspicuous. This calls for a closer inspection of how the broadband society is taking form and why environmental concerns do not figure more prominently. Applying concepts from transition theory, both landscape and regime levels are considered.

Landscape level

First, it is worth considering the basic conditions that have made the dramatic increase in the application of ICT devices possible through falling prices. Usually, this is attributed to the developments in semiconductor technology (Jorgenson, 2001), which is surely important, but other basic conditions – which may be seen as landscape elements influencing the supply side – play a key role as well. The material resources for the production have to be available at low prices, including energy, various metals and minerals. This availability is often based on large unpaid environmental and social externalities, and some key minerals are extracted at great social costs at the commodity frontiers. Furthermore, the basic electronic components have to be assembled into final products, and much electronic equipment is produced in the sweatshops of poor countries where the wages are extremely low (Schor, 2005). Cheap transport based on a low energy price is another key condition, without which the organization of global supply chains would not be so attractive. At the end of the product lifecycle, heavy social and environmental externalities occur in relation to waste handling. The low price of electronics is thus also a matter of large global inequalities in income and power.

Also the demand side is influenced by landscape elements. The low energy price is decisive for the application of ICT – both for the limited focus on energy efficiency of appliances in general and for the kind of appliances and solutions developed. An effective increase in energy prices combined with mechanisms to ensure continued increase over time would change demand patterns and the direction of R&D efforts. Demand, obviously, also depends on who has the ability to pay. Until the present economic crisis, a long period of income increases and capital gains for the affluent and middle classes provided a market for those products and services that could make their life more comfortable, interesting, stimulating, social, safe, and entertaining – improving (or at least changing) aspects of all the meaningful practices in which ICT could be integrated (Røpke et al., 2010). While most final products and services are developed for customers in the Global North, it is important to notice that profitable markets can also be found among the poor, since a large number of people spending small amounts of money add up to a considerable demand. Related to ICT, for instance, several mobile services have been very successful in poor African countries, but the overall effect on the direction of R&D is minor.

Among the landscape elements that already influence demand and can be expected to do more so in the future, are the demographic changes in OECD countries towards a growing share of elderly people which, in combination with increasing problems of funding the welfare state, create a market for labour-saving technologies for health and care. The public sector also offers an example of the coevolution of technology and demand in relation to the development of new public management where the ideology of control would have been impossible to implement without ICT and, simultaneously, creates an increasing demand for ICT.

Both supply and demand are influenced by dominant social discourses which may also be considered a landscape element. No doubt, the increasing public attention to climate change fuels the wave of interest in "green ICT" and encourages responsibility on the part of both producers and users – as well as efforts to prevent public regulation by demonstrating due attention. In addition to the initiatives taken by individual firms, several organizations actively promote energy efficiency, such as *Green Grid* and *Climate Savers*[2], and Greenpeace pushes the agenda by providing a guide to greener electronics ranking the top manufacturers of computers and mobile phones[3]. While such initiatives are surely useful, a very different landscape event, the Icelandic ash cloud, demonstrated what would be really effective in the promotion of videoconferencing. This window of opportunity saw a cloud of advertising for videoconferencing in business papers and magazines.

Regime level

Turning to the regime level, it is outlined which issues the regime actors are occupied with, and where this leaves the environmental concerns. In addition to literature studies this section draws on participation in the Danish Broadband Days from 2007 to 2009 – an annual event bringing together a broad group of actors from telecoms and other IT businesses as well as service providers. The conferences and related exhibitions cover many technical renewals, but they are also very informative regarding commercial and regulatory issues.

Since the new infrastructure of internet and broadband is decisive for the dynamics of the new ICT ecosystem, this infrastructure is the obvious center of interest. Since the take-off for the internet in the mid-1990s, the access technologies have developed rapidly. Presently, users can get access through different technologies, such as the copper net of the old telephone system, the cable TV net, the optical fibre net, and various wireless transmission systems, and much discussion concerns the relative competitive positions of the different methods and the respective providers: To which extent are they substitutable? Can technical improvements ensure a long life of the old technologies? Will the mobile technologies be sufficient in the longer term? Particular interest is attached to the optical fibre technology which provides the highest speed, but is costly to install: Is a fibre-based net an absolute necessity for a country to be competitive in the long run, and how quickly should it be established? Is it sufficient to have a fibre-based backbone net, and then combine it with other access technologies? If the fibre net is really important, should public money then be used for the establishment? The answers to these questions differ between countries, dependent on many factors such as the power of the incumbent telecoms and political traditions.

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[2] See http://www.thegreengrid.org/ , http://www.climatesaverscomputing.org/

[3] See http://www.greenpeace.org/international/en/campaigns/toxics/electronics/Guide-to-Greener-Electronics/

In general, the diffusion of the internet has taken place at the backdrop of a period of liberalization. Often societal infrastructures are organized as monopolies, either publicly owned or based on authorization of private owners, because parallel infrastructures would imply a large societal waste of resources, and because economies of scale and network externalities would make a monopoly the most efficient solution. This natural monopoly argument was challenged in the mid-1980s, when the USA, Japan and the UK, for different reasons, took the first steps towards liberalizing the telecoms sector (Fransman, 2010: 117f), and this trend since spread to most other OECD countries. Liberalization creates a problem: it is not enough to open for new entrants, since competition is continually threatened by high fixed and low marginal costs, economies of scale and scope and network externalities, and the incumbents usually have significant market power. Market power has to be regulated, and the dominant regulatory paradigm in telecoms is based on the idea that new entrants should pay the incumbent for access to its network based on an optimal price that would have resulted from perfect competition. The rationale of this idea is that competition will reduce prices for consumers as much as possible, but the idea is difficult to implement in practice, and much regulatory attention has been absorbed in the concern for promoting competition, also through "several pipes to the home".

Fransman is critical towards the high priority given to the regulation of layer 2 in the ICT ecosystem and to the regulatory paradigm, first of all because the paradigm does not adequately deal with the dynamics of innovation and change, and it may not leave the incumbent with sufficient incentive to invest in the country's telecom infrastructure (pp. 77-79). He argues that it is too narrow to focus only on competition as a the key driver of innovation: innovations largely emerge from the six symbiotic relationships between the four groups of players in the new ICT ecosystem as well as symbiotic relationships at lower levels of aggregation (pp. 37-41). These relationships involve flows of information that are decisive for innovation, for instance, in relation to specification processes or through direct involvement of final customers in content-creation, and the relationships both contribute to the generation of variety and act as part of the selection process (p. 48). European regulators and policy-makers are criticized for their obsession with the reduction of short-term prices rather than facilitation of the transition to a modern infrastructure, which is important to ensure long-term competitiveness (pp. 94f). From the mid-2000s Fransman finds the first signs that the regulatory paradigm is about to change again and that investment and innovation are placed higher on the agenda (pp. 81-85) (this observation is confirmed in the Danish case by the recent report of the High Speed Commission, see below).

Another core issue concerns the relationship between bandwidth and content – a classical "chicken or egg" problem: as long as most people have relatively low-speed access, it does not pay to develop services requiring high bandwidth – but customers are not willing to pay for higher speed, if there is little to use it for. For years business has hoped for identifying the "killer application" that would make everybody need high bandwidth, but so far in vain. An oft repeated message during the Broadband Days is that "Content is King": the technological nerds in the IT business sector want to sell technology to consumers, but these are intested in what they can use it for. Much hope has been and still is attached to the development of television and other video services – HDTV, video-on-demand and 3D video streaming – which require high bandwidth, in particular, when several household members want to watch different channels at the same time. Still, however, the demand for bandwidth is lagging behind the hope of fibre-providers, because most applications only require lower-speed connections.

Also, the development of business models is high on the agenda, including related issues such as proprietary standards and net neutrality. The internet has completely changed the conditions for earning money in industries such as music and newspapers, and the present struggles related to television are tough. The services – television, telephone and internet – are increasingly bundled, and the providers struggle to sell all services to consumers through one "pipe". Television is the main arena, and the search for new business models is highly complex: consumers want free choice between all channels and television on demand rather than fixed packages, but prevailing business models cannot accommodate this interest, and the actors in the supply chain draw in different directions. The issue of business models is pertinent also for the providers of all kinds of internet applications and services.

Many other issues draw attention in the development of the broadband society. For instance, safety issues are extremely important for the use of the internet, and the development of the population's competences is considered decisive for a nation's competitiveness. In Denmark, government ICT priorities are summarized as follows: 1) Broadband to everybody (based on competition between several "pipes" to the home), 2) Competences – supported by monitoring and plans for e-learning, 3) E-safety – for instance, development of a digital signature and campaigns to increase awareness of safety issues, 4) E-contents – public services and increased accessibility to public registers as a basis for development of commercial services, and finally 5) Green ICT – Denmark has hosted the two OECD conferences on this topic, and the first steps towards monitoring ICT and environment have been taken. In general, the liberal government (since 2001) has concentrated on the micro-management of competition and the improvement of general conditions, and also on the digitalization of various administrative systems and services in the public sector (sometimes in unsuccessful ways). There are examples of support for development of ICT applications in gaming (support for "experience economy") and in the health, care and education sectors, but relatively little has been done to use the public sector as a locomotive for industrial development with the purpose of solving core social problems. The High Speed Commission emphasizes the need for increased efforts in this direction both to realize potential social benefits and to lay the foundation for strong competitive positions – just as the welfare state has been important for Danish competitive advantages in the past (Højhastighedskomiteen, 2010).

Concerning the technological changes within the ICT ecosystem, some directions for the innovative processes emerge as trajectories based on established technological paradigms (in the sense of (Dosi, 1982)) in different areas: more integrated circuits per chip, increased storage capacity, greater speed for each of the transmission technologies, longer reach for wireless technologies, higher screen dissolution, longer battery lifetime, better graphics, larger screen sizes, flatter screens, better sound reproduction, more effective sensors, increased mobility of devices and services, and so on. Energy efficiency is indirectly part of some trajectories (like longer battery lifetime), and the regulatory focus on energy increasingly calls for more independent efforts to improve energy efficiencies. For instance, the recent achievements in the development of LED and OLED screen technology seem to be motivated not only by the search for better reproduction and contrast, but also by energy concerns. Regarding the applications, it is striking that so many resources are devoted to the development of entertainment like television, music and gaming – the entertainment-related uses are completely dominant in quantitative terms in spite of the very broad field of ICT applications. The head of the Danish High Speed Committee, Erik Bonnerup, expressed some frustration with the priorities when he, in a presentation of the committee report (at the Broadband Days 2009), referred to "fun and games" (tant og fjas) as the main driver of the broadband society and called for applying the technologies for solving core societal problems. Others argued that "fun and games" can be great for exports, that people acquire computer skills by playing games, that games are increasingly involving users in creative and social activities that are important for other competences, and that gaming is about to become serious business in relation to education (edutainment). Still, however, this is a niche compared to the overwhelming importance of entertainment, and although entertainment may be both great and useful, it is not the obvious way to solve the present global challenges.

Where do regime developments leave the environmental concerns? Due to landscape developments environment and energy have emerged on the agenda, but till now it has been a minor issue for regime actors. For instance, digitalization of television has taken place with little concern for environment although the implications are considerable, the same goes for the establishment of the broadband infrastructure, and few question the enormous growth in entertainment devices. Fransman's book provides an illustrative example of the inferiority of the environmental issue. He criticizes the dominant regulatory paradigm in telecommunication and the related academic discussion, because it largely ignores key aspects of the innovation process, and as an example, he mentions that a core work on the topic (Laffont and Tirole, 2000) has only two references to innovation in the index (Fransman, 2010: 79). Applying the same perspective, Fransman's book mentions the environment only once (in the introduction p. xii), and there are no references in the index to energy or sustainability: innovation is considered important, but the direction of this innovation is not discussed. Considering the importance and complexity of all the concerns related to regulation of competition, business models, safety, competences and so on, it is not surprising that environmental concerns tend to be an add-on to the main concerns – for business how to make money, for government how to ensure national competitiveness and the tax base, and for consumers how to go about everyday life. A real breakthrough for environmental concerns only appears when they become decisive for attending to the main concerns.

Conclusions

ICT can be explored both in terms of an economy-wide transformation of the techno-economic paradigm and as a system-level transition related to the establishment of the internet and the diffusion of broadband. Going into more detail, it would be possible also to explore the system level as a configuration of several interacting (sub-)systems. The system-level perspective highlights the interplay between the regime-internal processes and the landscape developments that shape the broadband society. In general, the broadband transition takes place with relatively little concern for the environment. The regime-internal processes are centered on the transformation of the infrastructure, the development of business models within different industries, and the establishment of the institutions and competences needed for using the infrastructure – based on commercial motivations and concern for national competitiveness, and strongly influenced by liberal ideology. Users integrate the internet and other ICTs in all sorts of practices, but in quantitative terms, commercially encouraged entertainment is completely dominant. This is a result of the co-evolution of supply and demand within a market context – which may differ widely from the result that would emerge from democratic processes considering the socially desirable applications of ICT.

Landscape developments like the climate change agenda call for an integration of environmental concerns in the shaping of the broadband society. The regulatory efforts have concentrated on dealing with the first order effects such as the energy use in offices and households, where the environmental impacts are particularly visible, but the results fall far behind the challenges because of considerable barriers to effective regulation. ICTs are applied for improvements of resource efficiencies, but due to rebound and other induction effects as well as other priorities for the development efforts, the overall results in terms of sustainability are limited. As Hilty (2008: 63) summarizes the situation: “the economic system in its present condition is unable to transform efficiency into sustainability”. Landscape elements on both the supply and the demand side are decisive: large environmental and social externalities based on global inequalities imply that ICTs are provided with little concern for the environment, and the same inequalities form the basis of the demand for entertainment devices and services. Till now, environmental considerations have remained an add-on to the core concerns.

Since ICT is a generic or general purpose technology, and since the functions of monitoring, management and communication are really useful, there are great potentials for environmentally beneficial applications. The realization of the potentials depends on the development of the selection environment for innovations. Making regulatory environmental policies more effective, and to increase their scope as suggested by Hilty (2008), would be useful to encourage increased efficiency, but these policies tend to have a narrow focus on first order effects and do not capture applications. A development of “green” innovation policies, rather than just policies to encourage innovation in general, could be a step in the right direction by promoting useful applications, but they do not change the basic conditions of provision. To develop long-term sustainability strategies, it is essential also to focus on changes of landscape elements – access to and price of resources and large inequalities of income and power.

Most transition theorists prefer to deal with “green” niche innovations and transitions from unsustainable incumbent regimes to more sustainable ones. This may be due to the political legitimacy of dealing with more optimistic topics, which do not question economic growth in OECD countries in more fundamental ways. Simultaneously, the studies tend to avoid including the importance of landscape elements such as the large inequalities of income and power, maybe because of the difficulty of influencing such conditions through transition management strategies, as these are usually conceived. The ongoing broadband transition illustrates both the need to supplement the interest in “green” innovations and the dismantling of unsustainable regimes with an increased focus on the avoidance of developing new unsustainability and the need to include core landscape elements in transition management.

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