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Foresight on Information Society Technologies in the European Research Area (FISTERA)
Key Findings

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Institute for Prospective Technological Studies

Foresight on Information Society Technologies in the European Research Area (FISTERA)

Key Findings

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In the course of this three year project, FISTERA had face-to-face dialogues with approximately 600 experts, each of whom participated in one of the 21 workshops or thematic meetings in the EU Member States and in the final conference. We would like to thank them all.

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Executive Summary

The thematic network "Foresight on Information Society Technologies in the European Research Area" (FISTERA) was set up to contribute to a common vision and approach towards the Information Society in an enlarged Europe in 2010. It aimed to create a pan-European platform on foresight in Information Society Technologies (IST), involving a wide range of key EU and national IST policy makers and players.

FISTERA was launched in September 2002, just after the 'burst of the Internet bubble'. At that time there was some scepticism about the future role and impact of ICT and FISTERA was confronted with the need to use foresight to explore reliable developments and trends that would allow it to contribute to future IST policy and research in Europe. These trends needed to be compared with the European Commission's ambitious vision, with respect to IST, of *"a world where every citizen is able to access public services anywhere, anytime; where every business is plugged into worldwide trading communities; where every individual is able to create and deliver compelling forms of interactive digital content; where every patient can be treated within the comfort of their own home; where every driver can be guided so as to avoid traffic congestion; where every child has access to personalized learning resources; and where every engineer has the power of global computing resources at their fingertips"*.[1]

This represents a formidable challenge and collective strategies will require coherent action. Public policy has an important role to play as an initiator and facilitator of coherent actions to realise such visions. Part of this role is to provide elements for creating and updating a European-wide IST vision. Another part involves the setting of priorities in terms of support for targeted R&D funding. In this respect, FISTERA performed strategic priority-setting exercises at European level, focused on Information Society Technologies.[2]

For this priority setting, FISTERA employed a combination of top-down and bottom-up approaches. As part of the bottom-up approach, FISTERA focused on the analytical dimension, making use of its findings to set functional, S&T and socio-economically-driven priorities. The top-down approach concentrated on the normative, process-oriented dimension in terms of identifying and prioritising policy options, building on what FISTERA calls the "success scenario" for the European information society. This scenario portrays a vision of the information society which is regarded as realistically achievable. The two approaches turned out to be complementary and delivered a set of recommendations and priorities for IST policies, which can be categorised as follows:

"Socio-economically driven priorities". FISTERA analysed and assessed social and environmental needs and possible technological solutions. The areas where it is considered that ICT could contribute most, in order of importance, are: ICT for *education and learning*, *health applications*, *governmental applications*, and ICT for a better *work* environment.

"Functional priorities". FISTERA analysed generic trends where emerging social needs and technology trends are integrated, and positioned vis-à-vis functional constraints in the respective sectoral or thematic innovation systems, such as the availability of a sufficiently skilled labour force

1 Source: European Commission Information & Communication Technologies in FP7 – Proposal from DG INFSO, 30 November 2004: http://europa.eu.int/information_society/activities/policy_link/documents/ict_fp7_proposal.doc

2 Some priority-setting exercises have been initiated and undertaken at the local and national levels. Prominent approaches over the last decade include "Technology Foresight" programmes and "Critical Technologies" exercises (typically involving a mixture of scientific examinations, stakeholder engagement, and strategic intelligence exercises). However, FISTERA is unique due to its European dimension.

or the existence of a well-developed educational system. In this category, FISTERA considers *knowledge-production environments, user-centred ICT innovation, support for individuals, business use of ICT, and internationalisation* as particularly important issues.

"S&T driven priorities". FISTERA investigated current developments and explored possible future trends in science and technology with a view to identifying emerging technology gaps and needs associated with the possible applications of the technology. Within this category, FISTERA considered the following items as top priority: (a) technologies at the cross-roads of ICT with nanotechnology, biotechnology and cognitive sciences, leading to *'converging' applications*, (b) technologies favouring the transition *from products to services*, (c) technologies striving at offering *'unlimited' bandwidth* and terminals as network infrastructure, (d) *embedded systems* and (e) technologies favouring the *'disappearance' of computers*.

This set of priorities is the result of a process made up of various steps, including the exploration of technological developments and trends, the assessment of the European research capacity and the investigation of the evolution of behavioural changes in society. In the following paragraphs, some selected results which feed the prioritization process are briefly summarized.

Changing socio-economic priorities

FISTERA finds that the relative weight of a number of socio-economic IST priorities have changed over the past decade. The most important application areas identified by the FISTERA Delphi, in order of importance, are *ICT for education, health,* and *government*. The biggest increase in importance has taken place in 'ICT for the health care sector', as a result of a number of factors. First, there seems to be a higher social awareness of the challenges arising from changing demographics towards an older population structure. Second, policy makers are more and more concerned about the increasing cost of health care and tend to be more open to considering ICT options to stabilize this cost. Third, good progress in the past has raised expectations for the future; promising applications for health are expected to emerge at the cross-roads between ICT and biotechnology and ICT and cognitive sciences. With respect to governmental applications, its high ranking is partly due to a growing awareness of the key role governments can play and the contribution they can make to building the knowledge society.

Some areas in the spotlight today are there as a result of particular circumstances. Fear is specifically mentioned as a factor driving the development of technology in general, and ICT in particular, by those foresight exercises performed after 11 September, 2001. As a consequence, ICT for security-related issues ranked higher in the list of priorities in the majority of foresight studies and other forward-looking documents produced after this date. FISTERA tried to understand if security concerns are only transitory. Though literature research showed that 'security' was one of the most prominent topics in practically all forward-looking documents after 2002,[3] the pan-European Delphi carried out by FISTERA in 2005 with nearly 600 participants showed a different picture where security was given a far lower level of importance. This mismatch in perception may indicate that though the contribution of ICT for security is clearly acknowledged, some technology experts have *probably overestimated the role and impact of ICT for security* in the aftermath of the terrorist attacks. Society is now moving towards a consensus view of the real contribution of ICT to security.

Although both are "one-off events", the terrorist attacks and the stock market crash in 2001 had dissimilar effects on the vision for IST. The burst of the Internet bubble caused a considerable

3 The last foresight study analysed was published late 2004.

impact on the ICT industry and forced a re-assessment of company strategy.[4] It had, however, an astonishingly moderate influence on the view of the role of ICT towards achieving the knowledge society. Economists questioned by FISTERA interpreted the stock market crash as a necessary correction to the mismatch between the 'paper' (expected) and 'real' economies, but the vision and perception of the role of ICT in the economy remained intact. Similarly dramatic events have also been observed in previous technological revolutions. These cases did not stop the revolution either – they did, however, mark the start of a wider deployment phase at all levels of society. In a FISTERA workshop on socio-economics, there was agreement amongst most of the economists present that society is on the brink of entering the second deployment phase of ICT applications.

A positive message arising from the FISTERA Delphi is that the need to move towards a knowledge-based society and economy is largely agreed across different social levels, irrespective of Member State. Practically *all the Member States of the enlarged Europe share the same vision* and concerns for the long term future for IST despite their different cultural roots and dissimilar economic conditions. This is encouraging as regards the design of a pan-European policy for IST. Having similar visions, however, does not mean that countries share the same priorities. In fact, the vast majority of forward-looking documents produced by the EU Member States (and other countries) are targeted at identifying those key technologies and promising application areas most worthy of support at the national level. While the increasing use of foresight exercises as a tool for priority setting for IST in the Member States is encouraging, the availability of national results and strategies has only limited value for the EU as a whole. In other words, the *aggregation of (mostly inward-looking) national foresight studies in the EU Member States does not automatically lead to a vision and strategy for Europe as a whole.*

This dichotomy between the European Union as a whole on the one hand, and its Member States on the other is reflected in the perception of Europe from the outside. Some non-European foresight studies virtually ignore the existence of the European Union as an entity, focusing instead on individual member states, while others see the EU as a potential partner (e.g. Canada) or competitor (Korea). While Japan frequently appears to dismiss Europe altogether as having fallen behind in the technological race, the US has a more favourable perception, placing Europe between itself, the leader, and Japan. Given these outside perceptions of the prospects of Europe's R&D capacity, the question arises of how ICT can contribute to the Lisbon Objectives and what foresight can contribute to it. In this respect, FISTERA saw the need to contribute by defining a realistic long-term scenario for Europe.

Foresight scenarios on the future of European ICT are often generated around two fundamental extremes: one where Europe becomes a dominant leader in ICT and the other where Europe falls completely behind and "loses the race". Neither extreme is likely in a foreseeable time horizon, but a careful analysis is needed to develop a realistic scenario, which takes into account the current and future boundary conditions and gets Europe as close as possible to the Lisbon objectives. FISTERA investigated what might realistically be achieved if the EU is successful in technology and its application areas; and what the implications would be for business models and industrial environments, consumers, markets and lifestyles, technology and infrastructure and politics and global affairs. In this scenario, mobility demand will continue, and consumers will become co-developers or 'prosumers'.[5] Overall the scenario is positive, although the blurring between work and non-work spaces may have a detrimental impact on work-life balance.

4 Critical issues like *trust, privacy* and network *security* related issues which were already identified as such before the crash, regain prominence in current foresight exercises.

5 The term 'Prosumers' combines producers and consumers. It was introduced in the 80s by the futurist Alvin Toffler. It refers to a consumer who becomes involved in the creation of products, so they can be made to individual specifications.

IST and social change

ICT is recognized as a systemic technology, the applications of which penetrate all social levels. FISTERA analysed a number of social factors and challenges that are likely to play a substantial role in shaping the Information Society. Amongst these, *enhancing relationships and communication, supporting an ageing population and health-care related applications, maintaining the European diversity of languages, cultures and lifestyles, contributing to community learning and planning processes*, and *enhancing "governmental efficiency"* were considered to have increasing weight as driving forces for IST development in Europe. In particular, many experts consider the ongoing demographic change as both a major challenge and an opportunity for IST in the long run.

FISTERA also studied the potential constraints on future integration of ISTs into European society. The following have been identified as the five biggest challenges: 'privacy and trust', 'security and robustness', 'ethical concerns', 'digital divide', 'infrastructure and investment gaps', 'social innovation and IT literacy'. The latter point is also connected to the availability and skills of qualified labour in IST research and jobs. According to experts attending a FISTERA workshop, Europe could soon be faced with a skills mismatch rather than an absolute skills shortage. The magnitude of Europe's skills problem in IST research in the future will depend on the balance between the demand for and the supply of skilled labour. On the demand side, technical change coupled with general economic growth will affect the overall demand for IST labour. Increased demand for IST goods and services in particular will affect growth in certain occupations and qualifications. On the supply side, demographic and social developments will influence the size, age, and ethnic and gender composition of the labour force.

Technology futures

FISTERA investigated current developments and explored possible future trends in science and technology with a view to identifying emerging technology gaps and needs associated with the possible applications. For a technology to have a deep impact on society and economics, a number of factors must coincide. For example, applications must respond to user needs, be reliable and affordable and comply with minimal ethical standards. The problem is that ICT-based innovation is progressing at an impressive rate, causing ever greater problems for foresight practitioners in assessing the potential of competing technologies, the 'winning' applications and speed of adoption. Due to this limitation, FISTERA decided to focus on general ICT trends, i.e. clusters of technologies, rather than the perspectives for particular technologies.[6] FISTERA assessed more than 200 different information and communication technologies. These were classified into 20 functionalities needed for particular applications and services that would be used in different physical environments. FISTERA identified some technologies as having a very important influence on the development path of other technologies. These technologies have a 'multiplier' or 'attractor' effect on others. Of the 200 technologies analysed, seven showed an 'attraction' pattern. These key technologies are *'embedded systems',* and *'micro-kernels and ad-hoc protocols'*, and those technologies enabling more *bandwidth*, more *storage*, *information semantics*, and *radio propagation*.

The above technologies, together with others, are expected to provide new functionalities or enhance existing ones that will pave the way for new services and products. An innovative blend of technology, production, distribution and adoption will 'disrupt' some market segments as we know them today. Such disruptions may offer opportunities to new entrants and may

6 In other words, the FISTERA approach aimed to assess the magnitude and evolution of a whole 'forest' rather than reporting on the progress of a particular 'species of tree'. However, considerable knowledge on the individual components ('trees') must be amassed first, before trends and the impact of the ICT ensemble ('forest') can be indicated.

even change the competitive position of whole countries. A particularly high relevance was assigned to the transition *from products to services* and promoting the *'disappearance' of computers,* as two important examples of technology-driven disruptions. *'Ubiquitous seamless connectivity with (practically) unlimited bandwidth', the availability of reliable and robust autonomous systems', 'the emergence of virtual infra-structures', and the move from 'content to packaging',* are other examples of ICTs enabling these trends.

Having identified major technological and socio-economic trends, FISTERA then looked at how the European R&D system is performing today and considered whether it is flexible enough to adapt to future changing trends. The next section reveals some of the insights achieved.

The performance of the R&D system

FISTERA assessed the R&D research capacity and industrial competitiveness, taking into account bibliometric indicators. A qualitative indicator for measuring industrial performance is national patent activity, as it gives a measure of the ability to create inventions and to turn them into market innovations. *In terms of IST patent filing,* it appears that *Europe has gained momentum* (in the 90s and early in the new millennium) but still lags behind the US and Japan. To a large extent, Europe's catching up is due, on the one hand, to keeping the leadership in a number of technologies, particularly in communication technologies and, on the other hand, to reducing the gap with respect to other technologies, as in the case of 'data processing' technologies. This is a very encouraging result that shows a negative trend can be reversed. The success is partly due to the active and committed role of particular Member States and EU policies adopted years before. Notable examples of successful national strategies in the ICT field are the technology poles created in Grenoble and Dresden. The rising stars of dynamism in ICT have generally not been the bigger EU countries, but rather the smaller ones, with the Nordic countries, the Netherlands, Ireland and Belgium in front. The fact that medium-sized countries have contributed proportionally more to Europe's catching up in ICT means that there is still latent potential to improve in the other EU member states. Though these are promising signs, the FISTERA analysis shows that a nation's R&D capacity in ICT (including strengths and weaknesses) varies only slowly over decades. This implies that, although the ICT sector is highly dynamic in terms of generating novel applications that have impact, the knowledge and capacity to get to this stage requires a consolidated research environment and culture over a long period of time. Consequently, an effective IST strategy and policy for nations must be long-term.

With regard to the ICT industrial research capacity, the FISTERA analysis indicates that the big European ICT industries are highly competitive world-wide and their R&D structure and investments are similar to their peers outside Europe. However, Europe seems to lack medium-sized ICT companies, which play a very important role in the ICT industry sector as they offer two important features. They are (usually) more flexible than big companies as regards adapting to new ICT trends and responding to customer needs. At the same time, and in contrast to the also very flexible small-sized companies, they tend to have better conditions in terms of financial and human resources for R&D. According to the EU Industrial R&D Investment Scoreboard,[7] this lack of medium-sized companies also appears to be a common pattern in other industrial sectors and is a structural weakness. This weakness is more serious in the ICT sector than it is in many other industries, as ICT is an R&D intensive sector and competition is (practically) world-wide. This produces a high barrier for newcomers and small companies to compete with in the long run.

7 The EU Industrial R&D Investment Scoreboard 2005, available at http://eu-iriscoreboard.jrc.es/index.htm

A significant amount of R&D in Europe is performed in public research centres. FISTERA analysed a representative selection of world-class European public research centres. A general pattern is that most research centres find a balance between close-to-market applications and long-term research. They therefore focus research around generic technologies, like semiconductor research, optical networks, or communication technologies. A surprising result is that high-risk long-term research is less pronounced than was anticipated in these non-university environments. For instance, subjects like the convergence of ICT with biotechnologies or ICT with cognitive sciences –although widely discussed in the literature- are less in the spotlight of investigation than expected.

Creating an IST foresight platform

Using foresight tools for decision making is gaining popularity worldwide. With some notable exceptions, however, foresight activities in Europe have been targeted at national or regional levels. This local focus influences the objectives and the European dimension usually plays a minor role in such foresight considerations. FISTERA has found that a comparison of national foresight studies reveals interesting differences, but the aggregation of these studies does not contribute to identifying common interests for Europe as a whole. A European vision for IST cannot, therefore, be based on integrating national visions, nor can a European strategy become the lowest common denominator of the national ones. If fragmentation is to be overcome, and attention drawn to the potential offered by European cooperation, regular foresight exercises at pan-European level are needed. This would allow collaboration in IST-related endeavours to face challenges which exceed the capacity of the individual Member States. FISTERA has taken several steps towards the creation of a suitable platform for European dialogue which would support the construction of a common IST vision. First, it has developed a methodology specifically designed for IST, sharing this experience with the foresight community. This methodology has influenced foresight exercises in several countries including Romania, Hungary, Austria, Poland and Colombia. Second, FISTERA has involved a large number of experts across Europe. Over the past three years, FISTERA has had face-to-face contacts with more than 600 people, each of whom has participated in one of the road-shows, thematic workshops or the final conference. Another 600 people were consulted through the use of large scale participation tools, such as the online Delphi or the (webpage-based) technology trajectory interaction tool. FISTERA found that the face-to-face and the indirect contacts were complementary. Face-to-face contact is efficient, but cannot be scaled up easily, because of cost, the broadness of participation, etc. On the other hand, indirect participation tools are cost efficient, though online animation of the process cannot replace the creativity arising from human interaction. Third, FISTERA made a specific effort to involve decision makers right from the start of the project. Industry representatives and Commission officials have been regular and active participants in FISTERA events. As a result, these actors are not merely receivers of the end products but have become part of the foresight process.

1. The Policy Background to FISTERA

In March 2000 at the Lisbon Summit, the European Union established, as an objective for 2010, that it should aim to become "… the most dynamic and competitive knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment". In support of this objective, the Lisbon Strategy proposed a set of interdependent reforms at national and European level aiming at –inter alia- creating an economic framework in which innovative companies are stimulated by dynamism and competitiveness. With the Lisbon objectives in mind, Commissioner Busquin launched the concept of the European Research Area (ERA) in 2001. The ERA aimed to create a pan-European market for research and development and to enhance the effectiveness of research in Europe by exploiting synergies between national and European RTD. Commissioner Busquin proposed a set of initiatives to provide Europe with a stronger public research base, minimize efficiency losses given the overlaps between research infrastructures in different Member States, and make Europe more attractive to private investment in research and innovation. The ERA concept was complemented by the European Council objective (Barcelona, March 2002) to increase the research investment level to 3% of GDP by 2010 (currently at 1.9% of GDP), to which the private sector should contribute 2/3 of the total.

In 2005, at the mid-term of the process envisaged by the Lisbon Strategy, the situation is not as expected in March 2000: economic growth is still modest, unemployment is considerable, and there is still a deficit in the technology trade balance. This unsatisfactory progress over the first years led the High Level Group, chaired by the former Dutch prime minister Wim Kok, to launch a strong warning in November 2004, saying that "The Lisbon strategy is even more urgent today as the growth gap with North America and Asia has widened, while Europe must meet the combined challenges of low population growth and ageing.", and they stressed the need to "… focus on growth and employment in order to underpin social cohesion and sustainable development".[8] The Kok report highlighted the economic importance of the direct and indirect role of Information and Communication Technology (ICT) in meeting the Lisbon goals: "In order to ensure future economic growth, the EU needs a comprehensive and holistic strategy to spur on the growth of the ICT sector and the diffusion of ICT in all parts of the economy." The Lisbon Strategy's Mid-Term Review concluded that a refocus of tasks was necessary and, in spring 2005, the European Council proposed a re-launch of the Lisbon Strategy, focussing on two priorities: "delivering stronger, lasting growth and creating more and better jobs".[9] Like the Kok report, the Spring 2005 Council Review explicitly emphasises IST and lists four Information Society policy areas, each of which was translated into specific 'work programme' topics in this Review. These four areas are ICT research and innovation, content industry development, security of networks and information and, convergence and interoperability.

This re-launch of the Lisbon objectives opens the door for a revised strategic orientation for new policies, and asks for the development of new mechanisms for public action to propel

8 'Facing the Challenge, a Report from High Level Groups', European Commission, Brussels, November 2004. As the High Level Group was chaired by Wim Kok it is often referred to the 'Kok Report'.

9 'Working together for growth and jobs – a new start for the Lisbon Strategy', European Council, 2005.

Europe towards the knowledge society. Part of this re-launch is the "i2020" initiative proposed by Commissioner Reding in February 2005. The objectives of 'i2020' are as follows:

- first, create a "borderless European information space" including an "internal market for electronic communication and digital services". The aim is to steer the convergence between Internet, telephone and TV through increased competition in key "enabling" services such as high-speed broadband connections.
- second, increase innovation and investment in ICT by both the private and the public sector.
- and third, make the information society more inclusive. This includes promoting easy and broad access to the information society, by, for example, the disabled and the elderly. ICT solutions for assisted living should be sought, thereby increasing the time that older people can live independently in their own homes. This will reduce pressures on social welfare and health care budgets.

The main recommendations of the principal Commission papers are summarized in the following box.

An important tool for achieving the Lisbon objectives is the Commission's framework programmes (FPs) for research and development. The European Commission research and technology development programmes are structured around these four yearly framework programmes, and contain the IST research programme. The current IST research programme has been shaped to realise European policies towards the knowledge society as agreed at several Councils (Lisbon 2000, Stockholm 2001, and Seville 2002). It aims at a wider adoption and broader availability of IST applications and services in the public sector and all industrial sectors, and thus society as a whole. Its objectives are to ensure European leadership in a number

Table 1: Overview on the main recommendations expressed by principal Commission documents with relevance for IST.

'Facing the Challenge, a Report from High Level Groups', November 2004. As the High Level Group was chaired by Wim Kok it is often referred to the 'Kok Report'. It recommended:

- attracting and retaining world-class researchers;
- making R&D a top priority;
- promoting broadband communication to reach a penetration rate of 50% by 2010;
- reaping the full benefit of ICTs; and
- protecting intellectual property to promote innovation.

'Working Together for Growth and Jobs: A New Start for the Lisbon Strategy', COM (2005) 24 February 2005. This Commission Communication, presented by President Barroso recommended to:

- reform of state aid policies to support research and innovation by small and medium enterprises;
- support and encouragement for the development of 'innovation poles' designed to help regional actors move ideas from the laboratory to the workshop;
- promote European technological initiatives for public–private partnerships and 'eco-innovation';
- create a European Institute of Technology to attract 'brains', ideas, and activities to Europe.

"i2010: the new European program for the competitiveness of ICT", January 2005. This Commission Communication was propelled by the Directorate General on Information Society and Media and recommended:

- creating a borderless European information space with an internal market for electronic communication and digital services;
- stimulating innovation through investment in R&D and encouragement of industrial applications of ICT; and
- promoting actions aiming to make the European Information Society as inclusive and accessible as possible.

Strategic orientations for growth and employment (2005–2008): COM (2005) 141, April 2005. It recommended:

- increasing investment in R&D, by launching the Lisbon objectives (by 2010 to increase the R&D/GDP ratio of 3% and a private/total research expenditure of 2/3);
- developing business services, technological poles, and networks of innovation;
- transferring knowledge derived from foreign direct investments;
- providing more risk capital financing;
- reinforcing centres of excellence;
- increasing fiscal incentives;
- promoting scientific and technical training;
- enhancing the social status of researchers;
- stimulating innovation and the adoption of ICTs;
- improving the definition of property rights; and
- creating a solid industrial base by developing public–private partnerships, encouraging European technological initiatives, and developing regional and local innovation poles.

of generic and applied technologies that will increase innovation and competitiveness in European businesses to the benefit of all European citizens.

The FP's research priorities reflect the prioritization of EU policies over time. The second FP (1987-1991) was conceived as means of creating a European RTD policy. In 1989, a review of the second FP concluded that there should be a stronger focus on promoting basic research skills and infrastructures. FP3 (1990-1994) regrouped activities around three strategic areas with 15 separate programmes. It stressed the aim of convergence among the regions and a new programme was inserted on human capital and mobility. FP4 (1994-1998) raised the European RTD budget to 11,879 M€. A quarter of these resources were assigned to research in Information and Communications Technologies (27.8% of the budget) and in particular to Information Technologies (ESPRIT) (budget: 2,084 M€ or 15.8%), Advanced Communications Technologies and Services (ACTS) (671 M€ or 5.1%) and Telematic Applications (913 M € or 6.9 %). FP5 was structured around socio-economic problems. "Key actions" were established to deliver research results contributing to the solution of these problems. Here, the

IST programme bundled all information and communication technology efforts into striving towards a European "Information Society", as opposed to the American model of "information highways".

FP6 (2002 to 2006) was conceived as a tool for achieving the "European Research Area" (ERA). The IST programme in FP6 was constructed around the "Ambient Intelligence (AmI)" vision,[10] where the user or smart player is placed at the centre of future developments. This human-centred approach aims to offer every European Citizen anywhere and anytime, any service, technology or application. It focuses on technologies in which computers and networks will be integrated into the everyday environment, making a multitude of services and applications accessible through easy-to-use human interfaces. Realising the AmI vision requires research efforts that: (a) address the major societal and economic challenges, and (b) ensure the co-evolution of technologies and their applications. With respect to the former (a), the main challenges are enhancing "trust and confidence" so as to improve dependability of technologies, infrastructures and applications. Issues range from security, privacy and protection of property and individual rights, to enabling the solution of complex technical systems in science, society, industry and businesses. Here, the development and deployment of computing and knowledge management resources across Europe is the key to strengthening social cohesion by providing efficient, intelligent and easy to use systems for health, transport, inclusion, risk management, environment, learning and cultural heritage and also to enabling sustainable growth and improving the competitiveness of both large and small businesses, as well as the efficiency and transparency of governments. This includes the development of mobile eCommerce and business and eWork processes and will provide more and better jobs.

The 7th Framework Programme is currently under discussion at the relevant European institutions. With regard to IST, the recent proposal from the Directorate General Information Society and Media (DG-INFSO) highlights the choices that must be made if the Lisbon Objectives of a competitive, inclusive and sustainable Europe are to be realised. A key recommendation in this report was for a strategy: "The EU needs a comprehensive and holistic strategy to spur on the growth of the ICT sector and the diffusion of ICT in all parts of the economy." (EC 2004) [11]

The European Commission has specified the nine main themes for co-operation activities within its proposal for the 7th Framework Programme (2007-2013) for research, technological development and demonstration activities, one of which is the area of Information and Communication Technologies. The Commission proposal suggests 12.7 b€ for ICTs in the cooperation budget line. The objective of this specific programme is to improve the competitiveness of European industry and enable Europe to master and shape the future developments of Information and Communication Technologies (ICT) so that the demands of its society and economy are met. The activities proposed should strengthen Europe's scientific and technology base and ensure its global leadership in ICT, help drive and stimulate innovation through ICT use and ensure that ICT progress is rapidly transformed into benefits for Europe's citizens, businesses, industry and governments.

In the rationale for the 7th Framework Programme, it is argued that information and communication technologies are critical to Europe's future and underpin the realisation of the Lisbon agenda. It is also argued that ICT has catalytic impact on productivity and innovation, modernisation of public services and advances in

10 ISTAG reports on Ambient Intelligence are available at www.cordis.lu/ist/istag-reports.htm among those 'Scenarios for Ambient Intelligence in 2010' K. Ducatel, M Bogdanowicz, F Scapolo, J Leijten, JC Burgelman, IPTS, February 2001.

11 European Commission, "Information and Communication Technologies in FP7 – Proposal from DG INFSO", http://europa.eu.int/information_society/activities/policy_link/documents/ict_fp7_proposal.doc 30 November 2004.

science and technology. It is calculated that in the period 1995-2000, about half of the productivity gain in Europe could be attributed to the impact ICT had on the organisation, production, use and diffusion of products, services, work methods and organisational changes. The ICT contribution to innovation is even more impressive in ICT intensive sectors, such as the automotive industry, aerospace, pharmaceuticals, medical equipment, and particularly financial services. The European Commission recognizes the strategic importance of IST to address major societal challenges in areas such as health, transport, environment, culture and learning. Ambient intelligence remains the guiding vision of "a world where every citizen is able to access public services anywhere, anytime; where every business is plugged into worldwide trading communities; where every individual is able to create and deliver compelling forms of interactive digital content; where every patient can be treated within the comfort of their own home; where every driver can be guided so as to avoid traffic congestion; where every child has access to personalized learning resources; and where every engineer has the power of global computing resources at their fingertips."[12]

An underlying assumption of this vision is the availability of an advanced technological basis and know-how, complemented by the identification of key societal needs requiring technological solutions. In this respect, the Commission's proposal for FP7 describes four pillars as main activity lines for future ICT research.[13] The four action lines are 'ICT technology pillars', 'integration of technologies', 'application's research' and 'future and emerging technologies'. Supplementary information and references to these action lines are given in the annex. As said before, the programmes and actions of the European Commission are geared to the design of a pan-European vision and strategy in IST. To be successful, the strategies and corresponding action must comply with the overall socio-economic context.

Socio-economic studies of technology provide evidence that social, economic, and political factors influence technological change and vice-versa. Empirical evidence has given rise to innovation theories which identify various stages in technologies and technological 'regimes', where they emerge, grow, mature and finally retreat over time. Identifying historical patterns of technological revolutions and learning from past techno-economic paradigms can provide lessons for strategic decisions and public policy.

As shown by economists, there have been five technological revolutions in the past two centuries, which are usually labelled by their most prevalent technologies. The first industrial revolution originated with the mechanization of the cotton industry (in England, at the end of the 18th Century). The second revolution began in 1829 with the invention of the steam engine. The third industrial revolution was based on steel as a new material and on electricity as a new power supply. The fourth is the age of automobiles and mass production. The current and fifth industrial revolution is the age of information and telecommunications. This began in 1971 with the introduction of the first mass-produced microprocessors. Since then, low-cost microelectronic components and ever more sophisticated software have been the drivers of many ICT applications. In fact, each of these revolutions produced a range of new products, industries and infrastructures. What makes them 'revolutionary' is that fact that completely new markets were created, which were supported by an enhanced movement of materials, goods, services, money, people etc. After an initial phase of resistance from established business and people, superior productivity ends up transforming

12 *"Information and Communication Technologies in FP7" – Proposal from DG INFSO*, 30 November 2004, http://europa.eu.int/information_society/activities/policy_link/documents/ict_fp7_proposal.doc

13 Commission Proposal for a Decision of the European Parliament and of the Council concerning the seventh framework programme of the European Community for research, technological development and demonstration activities (period 2007-2013), Brussels, 6 April 2005 COM(2005) 119 Final.

industry structure and, more importantly, peoples' ways of life.

From a societal point of view, each revolution must confront old practices, values, habits and routines embedded in the minds and lives of individuals and consequently in the social and institutional framework also. According to the Freeman-Pérez model, technological revolutions can be characterized by some common patterns. Each revolution has two basic stages: the 'installation period' and the 'deployment period', both of the same length (each revolution lasts around 50 to 70 years). During the installation period a "creative destruction" takes place; new technologies and their respective industries flourish and the obsolete ones are either destroyed or modernized. The first decades are driven by new entrepreneurs, financial capital (with short-term criteria) and the adaptation of new industrial giants which are the new engines of growth. During the deployment period, the potential of the technological revolution is widely deployed across the economy. In this period of expansion, new giants are established and production capital focuses more on long-term goals. One of the features of the deployment period is market expansion which is related to innovation.

From a policy point of view, the introduction of ICT contributes to "creative destruction" and causes a dilemma. It devalues traditional skills, contributes to the disappearance of obsolete industries, may cause the geographical displacement of production and service sites and reinforces unemployment from higher productivity branches. At the same time, new and extraordinarily profitable industries are created and "nouveau riches" emerge. A new kind of polarisation, i.e. the digital divide, can result. If not adequately mastered, political tensions may be generated (when the growing desperation of the poor turns into violence), migratory fluxes may be provoked or problems of governance created. One of the challenges of this phase is to counteract the pressure on jobs and incomes.

The period between installation and deployment, the so-called turning point, is a particularly critical time, because it causes instability. This instability is partially generated though high investments in new technologies, creating unfulfilled expectations in the short term. The financial markets get heated and eventually collapse, as happened with the Internet bubble.

Many experts believe that, since the burst of the Internet bubble, the world has been at this critical transition stage and that we are still moving towards the deployment phase. In these unstable times, governments play a particularly important role because the transition to deployment needs adequate policy to ensure that it happens smoothly. The short-term expectations of the finance world must be replaced by stable longer-term projects and investment in production. Foresight is an important tool for decision makers to assess and set their priorities.

2. Foresight and the European Perspectives towards the Knowledge Society

Since FISTERA started, globalisation has continued, if anything, more rapidly than ever. Developments associated with the accelerated globalization rate are not yet truly reflected in the foresight studies examined by FISTERA, although some non-European studies regard it as likely that the German and French economies, in particular, will be unable to successfully master some of the necessary changes. During the FISTERA study, Sweden was the only country that produced two full foresight studies. In the two years between the studies, perceptions changed quite drastically. In the first study, the underlying tone was optimistic, underlining Sweden's "e-readiness", potentially underpinning a strong position in the coming knowledge society. The second study is overall more pessimistic, stressing in particular the need to start a debate on the future in order to avoid complacency. Complacency is also a danger spelled out by another recent foresight study from an EU member country, namely Greece. This pinpoints the Greek attitude of already "having given much to the world". It is also the only foresight study from an EU member state to actually explore (four) different scenarios for the future of Europe, instead of developing different scenarios for the country's future in Europe, (which has been the case in some foresight studies, particularly those of the New Member States).

Although the studies described above are too few to draw general conclusions, there are indications of stronger orientation in more recent studies towards the European level, at least on the part of the smaller new Member States. This is due to an awareness that they cannot survive without cooperation, preferably with their European neighbours. They need to expand their customer base, at least to the single market. Not surprisingly, in view of shared cultures and histories, the European orientation tends to be regional rather than EU-wide, e.g. the Baltic region for Sweden or the Eastern Mediterranean and Balkans for Greece. The aim is to strengthen these regions playing a leading role, but also, in so doing, to strengthen the EU as a whole. Many of the New Member States and Candidate Countries base their prospects on the fact that their populations are generally well-educated, which gives them a good chance of attracting foreign direct investment.[14] However, the reports on these countries also emphasise that jobs in these countries will be threatened in the not-too-distant future by off-shoring, particularly to China and India. This asks for a reassessment of the vulnerability of Europe performance. A condensed SWOT analysis of a number of major European issues extracted from foresight studies is given below.

European strengths, weaknesses, threats and opportunities

Strengths and weaknesses are frequently two sides of the same coin: the strength of one country can be the weakness of another. Additionally, strengths can turn into weaknesses over time, e.g. low labour rates may attract investors into a country, forcing labour costs to increase to the extent that they are no longer a strength. In general, both the EU 15 and the New Member States and Candidate Countries have well-established, good education systems. While some have adapted to new circumstances, others are in need of modernisation to take full advantage of the potential offered by residents in these countries. Need for modernisation is reflected

14 Skulimowski, A.M.J. (2005): Framing New Member States and Candidate Countries Information Society Insights. Kraków, draft of 14 June 2005.

by such phenomena as education systems which favour children of privileged parents and prejudice children from immigrant or minority families.

Most European countries generate well-trained personnel for research, science and engineering professions, but their number is usually insufficient for the needs of local industry as young people consider that these professions are not very attractive or have only moderate prospects. In addition, many are attracted to other countries, principally the United States, by higher salaries and advantageous working conditions. The US is considered to have deficiencies in its public education systems which need to be compensated by attracting personnel trained elsewhere. Although Korea has a good education system, Korean companies nonetheless appear unable to find sufficient qualified personnel for its research and development requirements. As a result, recent programmes aim to attract foreign researchers to Korea. In the future, it is likely that there will be increasing competition at company level for qualified staff world-wide, but local conditions can play a role in decisions on where to locate research laboratories. Europe has several advantages which could tip the balance in its favour.

Generally speaking, the EU15 offers a well-developed infrastructure for industrial activity, including telecommunications. This infrastructure needs, however, constant modernisation and upgrading, if the region is to remain competitive. The infrastructure in the New Member States and Candidate Countries requires more modernisation efforts than in the EU15. This offers New Member States and Candidate Countries the opportunity to "leap-frog" some of the incremental changes taking place in the EU15. Unfortunately, state of the art infrastructure is expensive. Also, inadequate R&D spending with respect to the gross domestic product is increasingly perceived as a major weakness. There has been some progress toward the 3% target but most EU15 countries, with the notable exception of Sweden, are still behind and in some cases, for example Germany, there has been stagnation. There are major deficits regarding industrial spending on R&D in Europe, sometimes because of shareholders' pressure to get a short-term return on their investments and because funds have been invested outside the EU. The "venture capital" culture in Europe is still underdeveloped, despite considerable efforts in the past, including governmental ones. Governments have not yet played an active role in driving the use of ISTs through applications in e-government, health systems or in coming to terms with ageing populations. However, their potential role and impact, particularly through procurement should not be underestimated.

In smaller EU countries, there is possibly a greater awareness of the importance of international integration of research and development activities than in the larger countries. This is due to more stringent requirements to concentrate on areas of expertise. Additionally, many of the major future challenges for society are too complex for most countries to tackle on their own. FISTERA findings indicate that -despite the existence of the EU programmes- there is still a need to integrate European research. Fragmentation also appears to be a weakness of Korea's R&D, but future activities are directed at Korea playing a leading role in Asian cooperation.

Europe can also offer the advantages of quality of life and social stability. Since its creation, the EU has been relatively peaceful with little armed conflict. Living conditions are generally favourable, the political systems are democratic, and the natural and cultural heritage is well preserved. This quality of life could help attract qualified and highly skilled staff into Europe, e.g. to work in research facilities including those set up by large internationally active companies, not necessarily European-owned.

Foresight studies identify inappropriate legal frameworks as a major barrier to innovation. In the case of IST, there is, however, a dilemma: ICT is progressing so rapidly that it is difficult to decide when to change existing legal regulations. Changes made too early may not have the desired effects. If, however, changes are made too late, technology may have already established de facto standards. Regulation *a posteriori* may prove unacceptable to many stakeholders.

Most countries would like to attract foreign investment to create highly skilled jobs. At present, the EU's single market puts the New Member States in a favourable position to exploit this opportunity. One option would be to develop niche products and services offered throughout Europe and beyond, based on particular skill and knowledge specialisations at national or regional level in these countries. In some cases, there is a chance that niche products and services of sufficient importance will serve to attract larger businesses, which could otherwise be located virtually anywhere, due to synergies or other economic benefits outweighing (higher) labour costs. Usually, this also depends on public policies to provide support to potential investors. Once such decisions have been taken, efforts are needed to keep the investors in the location over a reasonable period of time.

In the advent of specialised and culturally-influenced applications, such as e-health, e-government and other areas in the public interest (transportation, environmental monitoring and control), opportunities for high-quality software development and services at the local level emerge. Parts of this work may be out-sourced, but effective applications require considerable local knowledge which is not easily accessible from a distance. Similarly, specialised user groups offer opportunities for the development of software and user interfaces able to understand the user's needs. European cultural diversity creates awareness of the need to cater for specialist needs, and the small size of many domestic markets coupled with the opportunities provided by the single European market, could lead to the emergence of innovative firms in this field. The second Swedish foresight exercise proposes the creation of centres of excellence for higher education at universities, based on areas of national strengths. Foreign students may come into the country this way and experience shows that some will choose to seek employment near their place of education.

Among the major threats are complacency, a problem discussed in several foresight studies, and too great a reliance on subsidies, both of which act as barriers to innovation. This applies to industry sectors as well as to whole countries. Another frequently mentioned threat is the taxation system. High taxes are perceived as a barrier even in those countries which have relatively low taxation rates, e.g. the NMS or CC. The brain-drain of skilled IST professionals is another frequently mentioned threat. EU15 countries fear the emigration of talent to the US, whereas the NMC and the CC fear the loss of talent to both the US and the EU 15. The threat of skilled teachers leaving the education system for better paid jobs elsewhere is symptomatic. This has been reported for the Czech Republic[15] and Poland.[16]

A very 'European' threat is lack of cohesion either at the European level, where cohesion is an important condition for the realisation of such visions as the single market, or a "United States of Europe", but also at the regional or national levels, e.g. in the integration of minorities or immigrants, who could grow in importance due to the ageing of the indigenous population. Lack of cohesion is one possible reason for the emergence of digital divides. These are frequently mentioned in the literature, where the availability of computers and online access are seen as the main indicators. Another important symptom of divides is (lack of) computer literacy. However, there is also the danger of new kinds of divide emerging as the result of the pervasiveness of IT

15 Skulimowski, A.M.J. (2005): Framing New Member States and Candidate Countries Information Society Insights' in 'Prospects for a Knowledge-based Society in the New Member States and Candidate Countries', EAR, Bucharest 2006 ISBN 973-27-1379-4.

16 Brandsma, A. (2002): IPTS/ESTO Studies on Reforms of Agriculture, Education and Social Systems within the Context of Enlargement and Demographic Changes in the EU. Seville: IPTS, EUR No: EUR 20248 EN.

in the coming knowledge society. There are likely to be individuals or societal groups with very basic computer literacy skills, while others have a high degree of command of both computer programmes and information retrieval techniques. Divides of this nature are discussed in one of the Korean documents and there they are described as a possible threat to the foundations of what is a basically an egalitarian society.

The table below gives a high-level summary of the analysis of strengths, weaknesses opportunities and threats as derived from the foresight studies elaborated in the Europe Member States. FISTERA wanted to investigate how much this analysis was shared by non-European countries. Interestingly, the 'outside perceptions' of Europe vary a great deal: some non-European studies virtually ignore the existence of the European Union as an entity, focusing instead on individual member states, while others see the EU as a potential partner (e.g. Canada) or competitor (Korea). While Japan frequently appears to dismiss Europe altogether as having fallen behind in any technological race, the US has a slightly more favourable perception, placing Europe between itself, the leader, and Japan. In one US scenario for the future, the EU has political and economic power rivalling that of China.

There are suggestions that the expansion of the EU will lead to a decrease in cohesion with widely divergent living standards across the Union. Ageing and cultural diversity are important parameters for the future development of Europe. Europe's current population is irrevocably ageing, creating pressure to devise ways of prolonging the activity of older citizens and of enabling such citizens to lead independent, active lives for longer than is presently the case. One possible solution are the so-called 'silver society' industries, which are attracting attention, not only in Europe or the similarly affected Canada, but also in Korea, which sees this as a niche for industry. In fact, many developed countries

Table 2: Summary of European Strengths, Weaknesses, Opportunities and Threats (some differentiation for NMS/CC and old EU15)

Strengths	Weaknesses
■ Education system ■ Higher education systems ■ Labour costs (Southern, Eastern Europe) ■ Infrastructure (most of EU 15) ■ Quality of life (lack of serious conflict, environment, cultural and natural heritage, no famines) ■ Industrial base in EU15 ■ Cultural diversity	■ Education provided to minorities and disadvantaged groups ■ Attractiveness of jobs in R&D ■ Labour costs (in particular D, F, Nordic countries, Benelux) ■ Infrastructure in parts of S. and E. Europe ■ Industrial base in NMC/CC ■ Lack of international integration of R&D ■ Inadequate public spending on R&D (3% target) ■ Legal framework ■ Public sector not able to fulfil pioneer role ■ Existence of digital divides ■ Lack of cohesion
Opportunities	**Threats**
■ Attracting foreign investment (particularly NMS/CC) ■ Development of niche products and services ■ Localised applications ■ Creation of centres of excellence in higher education to attract foreign students	■ Complacency, reliance on subsidies ■ Taxation systems ■ Brain drain to US (EU15), US and EU15 (NMS/CC) ■ Outsourcing to India and China ■ Barriers due to vulnerability, reliability, trustworthiness and privacy concerns ■ Unrest due to growing lack of cohesion ■ Emergence of new digital divides

share similar challenges, but sometimes develop different approaches to master them.

Depending on the approach, cultural diversity can prove a particular advantage of Europe or a new threat to cohesion. In Canada, attracting highly skilled immigrants into the country was regarded as a partial solution to the ageing problem and attendant skill shortages. In Europe, there are problems currently integrating immigrants in the field of education: Germany's weak performance in the OECD's PISA study is partly due to a polarisation between pupils from socially advantaged and disadvantaged backgrounds, in particular immigrant families. Similarly, the second Swedish foresight report indicates that problems exist for the integration of "the new Swedes". In view of the overall geopolitical situation, success in social integration, particularly of the Muslim population, is considered as a critical factor for European cohesion. The US analysis for the National Intelligence Council indicates that current concepts for integration are inadequate. It is doubtful that IST can play any decisive role in this, but IST applications can certainly support measures involving e-learning or multimedia, to effectively implement policies for integration.

With regard to IST visions of non-European countries, some interesting patterns arise which are worth mentioning. With respect to former governmental activities, *Korea*'s visions have recently included some socio-economic elements, although it is not entirely clear whether these apply equally to the Korean population or to an undefined "society at large". Generally speaking, however, Korean studies examined by FISTERA are still strongly oriented towards planning and the achievement of certain measurable targets within a given time frame. This is probably motivated by the very successful 'Cyber Korea 21' vision, which reached major milestones well ahead of schedule and needed to be upgraded. At present, the Korean government and many companies have the necessary funds to invest in infrastructure, such as broadband, or in measures designed to secure and maintain long-term competitiveness.

A surprising finding of the 7th *Japanese* Technology Foresight study was the loss of importance in the ranking of information and communication technologies (ICT) compared with previous foresight studies. The study concludes that this decline is due largely to the pervasiveness of ICT, meaning that when it is embedded or integrated in other technological systems it disappears from direct view and perception of its importance is lower. It does not follow that ICT is any less important than in the past. To the contrary, these changing perceptions bring with them a danger of underestimating the importance of progress and investments in ICT.

Turning back to foresight exercises in Europe, FISTERA finds that –with some very few notable exceptions- these exercises have been targeted at the national or regional level only. This implies a strong focus on the interests of the geographical area covered by the respective study. The European dimension usually plays a minor role in such foresight considerations. Therefore there is a genuine need for regular pan-European monitoring and foresight as a means of resolving this apparent fragmentation and drawing attention to the unexploited potential in European cooperation and collaboration in IST-related endeavours to overcome challenges usually exceeding the capacities of the individual member states. FISTERA aimed to contribute to this goal by starting to identify the trends, challenges and drivers for IST across Europe. The next chapter will discuss mostly non-technical drivers of the European society with implications for IST.

3. Societal Challenges and Drivers

This chapter describes some of the social factors and trends that are likely to play a substantial role in shaping the knowledge society and some of the challenges that arise in this context. FISTERA identified these by reviewing existing studies and performing its own scenario exercise.

With regard to the reviewed work, it can be said that some studies focus on socio-cultural alternatives, i.e. different socio-cultural configurations in which IST might be applied. Policy interests concern avoidance of social ills (digital divides, threats to privacy, etc.) and maximisation of benefits. Some studies have a more economic focus, examining general economic issues (growth rates, employment implications) and also the experiences of the EU (competitiveness vis-à-vis other major economies, internal disparities in terms of regional convergence/divergence, etc.). Policy issues here are generally to do with stimulating IST supply and use in order to maximise EU prospects. A third kind of study focuses on markets and the patterns of adoption of new ISTs in different areas of life. Policy interests here are mainly in lowering or removing barriers that hinder the uptake of the applications.

The review of the scenarios with their different foci and orientations served to highlight the key socio-cultural, economic, technological and market-related drivers that are likely to be implicated in fashioning the IS as it unfolds in the coming decade and a half. Many of the scenarios go some way towards explaining the interactions between these drivers, and thus provide compelling, if partial, images of domestic, leisure, working and business life in the developed, information- and technology-rich economies/societies of the near future.

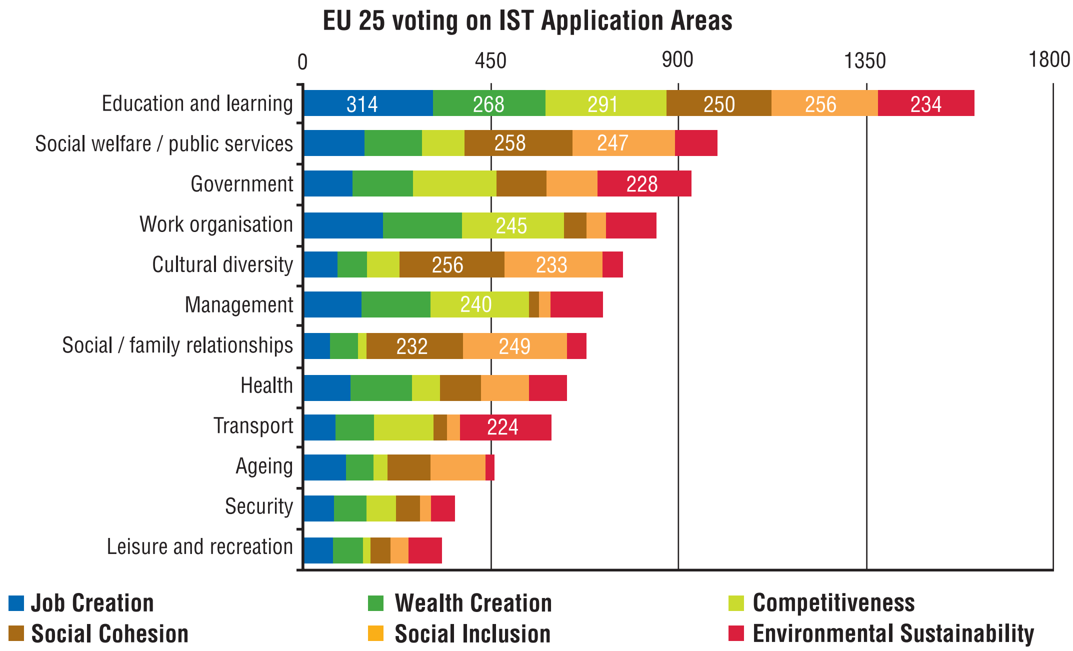
In addition, FISTERA carried out a specific scenario-building exercise. The result of the workshop was the identification of the *'top ten'* driving factors for European IST development and the *'top five'* challenges, i.e. those factors perceived as a potential constraint on future integration of ISTs into European society. The drivers and challenges are summarized in the following table. A full explanation of the range of driver and challenge factors and of the process by which they were identified is available in a separate report.[17] Sometimes factors are interrelated and do not fall into a single category. For instance, the ageing of the population,

Table 3: Key Drivers and Challenge for IST in the EU

Main Drivers	Main Challenges
• Relationships and communication	• Privacy and trust
• Ageing population and health	• Security and robustness
• Languages, cultures and lifestyles	• Ethics
• Community learning and planning processes	• Digital divide, infrastructure/investment gaps
• Miniaturisation of communication devices	• Social innovation and IT literacy
• Interconnectivity and systems integration	
• Economic and trade conflicts	
• Global environmental concerns	
• Governmental efficiency	
• Security concerns	

17 'WP4 First Synthesis Report' available at: http: //fistera.jrc.es/docs/Scenario_Pool_version_1.7.pdf.

Figure 1: FISTERA Delphi on future challenges, applications and priorities for socially beneficial IST. Ranking of twelve IST application areas contributing most to the six Lisbon objectives. Education and learning is the undisputed top ranked application area for all six objectives.



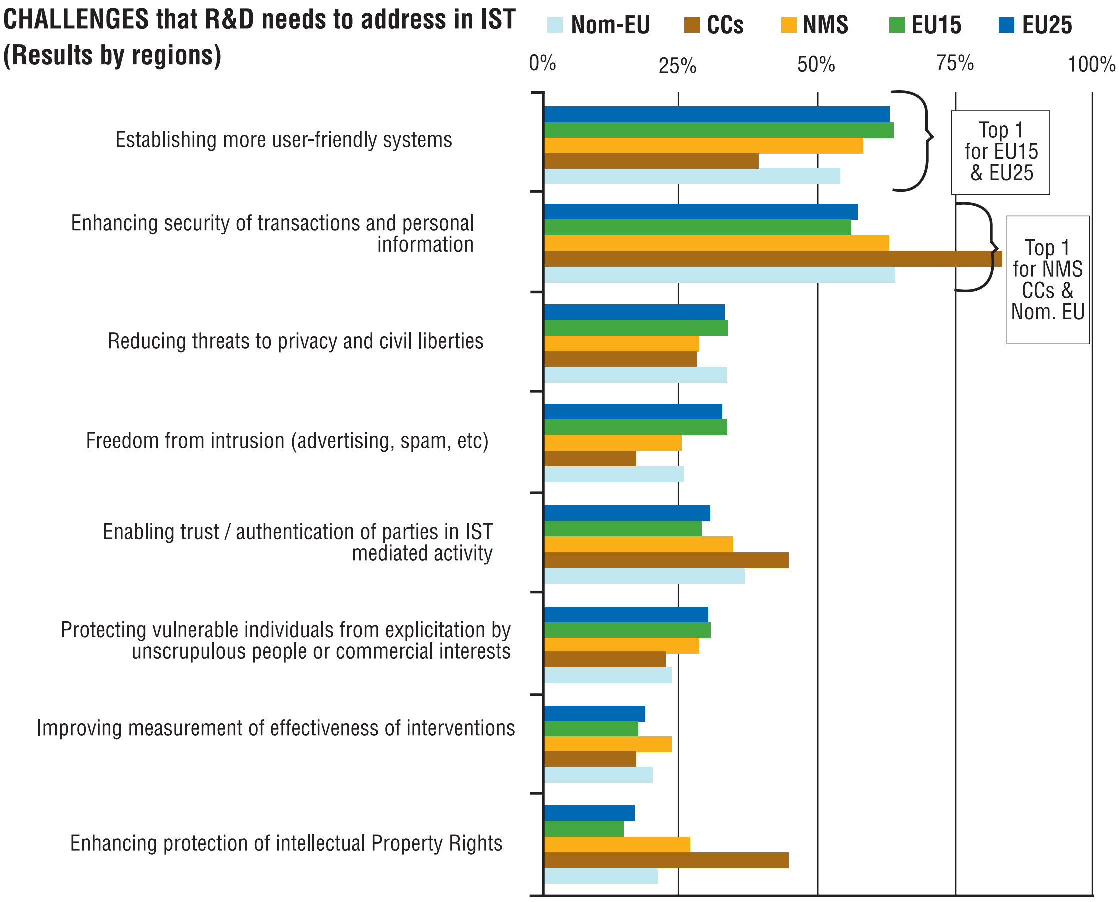
involves a social, technological, economic and political dimension.[18]

Basing its investigations on this understanding of the basic drivers and challenges, FISTERA looked at how IST could most effectively contribute to the Lisbon objectives. In order to do this, FISTERA set up a specific Delphi study gathering views from key stakeholders and informed commentators.[19] In this survey FISTERA asked which areas of *IST application* were most likely to yield benefits in terms of a set of six major *goals on the Lisbon agenda*, [20] i.e. job creation, wealth creation, competitiveness, social cohesion, social inclusion, and environmental quality. The twelve areas of IST application offered for consideration were (a) social and family relationships, (b) cultural diversity, (c) transport, (d) ageing, (e) health, (f) education and learning, (g) social welfare and public services, (h) leisure and recreation, (i) security, (j) government, (k) management and (l) work organisation.

Which applications contribute most to EU goals? The findings are presented in *Figure 1*. The outstanding result of the survey is the strong endorsement given to one particular application area – 'education and learning'. This repeatedly emerges as the application area for IST that contributes to most EU social and economic goals and is considered central to the construction of a European Knowledge Society. It is, however,

18 Trends are placed in categories that seem most logical, but very often there will be interconnections and relationships between trends in different categories.
19 In total 515 participants, of which 413 from the EU25 and 102 from non-EU countries.
20 Classifying the Lisbon goals for use in the Delphi survey is not straightforward and raises concerns relating to the goal definition and the adequacy of selected parameters. For example, the goal of 'Job Creation' at European level is frequently bound-up with notions of 'more and better jobs', 'improved work-life balance' and 'improved employer-employee relations'. However, equally important notions, such as 'increased autonomy and flexibility' tend to be missed, and the authors fear that participants in the Delphi might have been operating with relatively narrow conceptions of the meaning of each 'goal'.

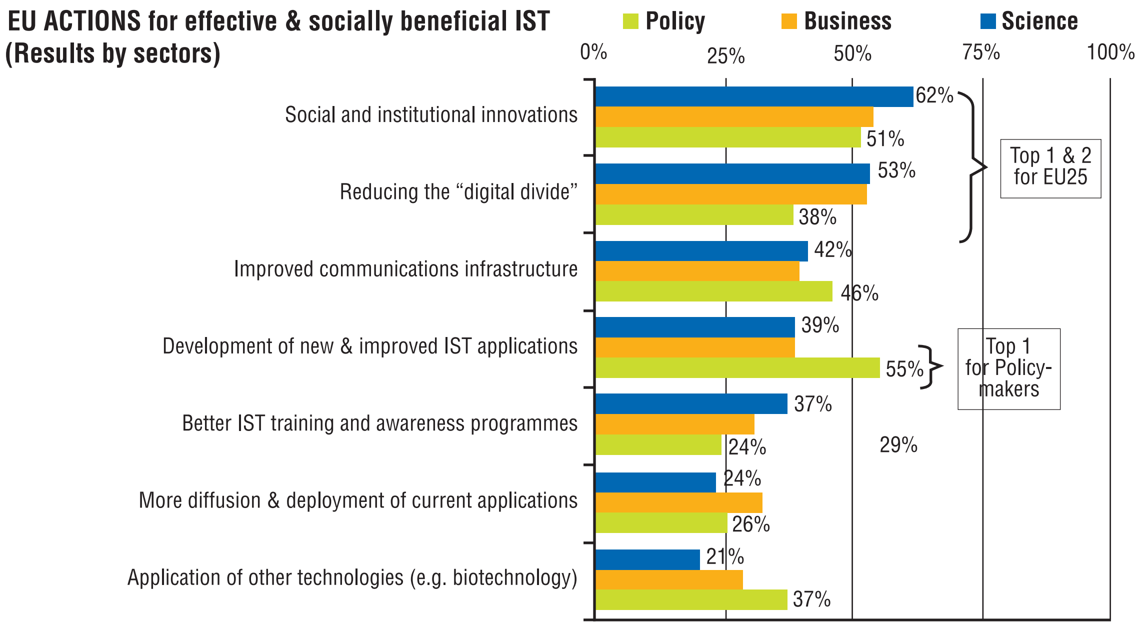
Figure 2: FISTERA Delphi on Challenges that R&D needs to address in IST by Countries. 'Enhancing security of transactions and personal information' is the most voted challenge by New Member States respondents, while 'establishing more user-friendly systems' is the most voted challenge by EU15 participants.



a typical application area in terms of European 'capabilities' and 'preparedness', with these being perceived as 'average' and 'moderate' respectively. Education emerges as an area that is important across a range of six EU goals. More generally, however, there is some divide between applications which are seen as contributing to more 'social' goals (social cohesion, social inclusion), and those which contribute more to 'economic' goals (competitiveness, job creation, wealth creation). Environmental goals are rather more closely associated with the economic than the social goals, in terms of the application areas that contribute most to them. IST applications in government, social welfare and public services, and cultural diversity contribute to many EU goals. However, applications in work organisation and in management are seen as contributing particularly strongly to economic goals.

With regard to the question of what challenges confront research and development in EU IST, the two issues which received most endorsement in the survey were establishing more user-friendly systems, and enhancing the security of transactions and personal information (see *Figure 2*). In fact, the latter ('enhancing the security of transactions and personal information') was considered the top challenge for experts from the New Member States and Candidate Countries. This is worth mentioning, because this is the only case in the whole Delphi study in which a noticeable difference between newer and older Member States could be detected. For all other questions, there was practically no divergence, so that FISTERA concludes that new and old Member States share the same vision, challenges and impediments for the future. The top ranking of 'user-friendliness' is not surprising.

Figure 3: FISTERA Delphi on the ranking of the most urgent EU actions for effective and socially beneficial IST. For policymakers, the development of new and improved IST applications (rank 4 in EU25) is considered as the most important action (55%). The business and science-base sectors confirm EU25 findings for the first two actions ('social and institutional innovations' and 'reduction of the digital divide').



In fact the issue of user-friendliness is one that provokes impassioned commentary, with a common argument running like this: 'if the Information Society in Europe is to be inclusive, its benefits widely diffused, and its citizens fully engaged, then attention to the expressed and particular needs of IST users (and research with respect to current and future demands) is of the highest importance'. More surprisingly, however, 'improving IPR protection' came last amongst the challenges proposed.

Confronted with the question of what actions the EU will need to undertake (see *Figure 3*), the topics 'social and institutional innovations', and 'reducing the digital divide' come ahead of many other actions, including such familiar ones as improving the communications infrastructure, developing new and improved IST applications, and achieving better IST training and awareness programmes. This result seems to indicate some frustration with the pace and quality of modernisation and social renewal, and some evidence that innovations generated at the micro, local, institutional and community levels are not given sufficient space and support to flourish.

Though there was agreement on which actions should take priority, there was no strong consensus on major problems impeding the development of IST applications. None of the problems came to the fore significantly with respect to the others. The main problems were seen as those concerning social inequalities in access to IST, and lack of adequate finance for innovations.

With regard to who are the key actors able to improve IST applications, it is interesting to note that –in almost all areas- the majority of respondents see national governments as the most important ones, followed by large IST firms and small and medium sized IST firms. The EU institutions are clearly considered to play a less important role than national governments. The areas where the EU is believed to contribute most to the improvement of applications are 'social welfare and public services', 'cultural diversity', transport and 'work organisation'.

Finally, Delphi participants were asked how far EU organisations are associated with IST and applications areas capable of developing and exploiting IST. The picture emerging from the survey was that most EU organisations were perceived to be average, with only a few at the cutting-edge in a world-wide comparison. While there was little evidence that many were perceived to be serious laggards, it was clear that there is no room for complacency (and much for improvement) as the pressure of globalisation is experienced ever more severely. Connected to this was the question of how far research communities are ready to seize new IST opportunities in the various application areas. Similarly, it was common for most researchers to be perceived as only 'moderately' well prepared in the academic area and slightly better prepared in the private sector.

3.1. From options to priorities

The FISTERA scenario exercise identified twelve important social issues, which were proposed to the Delphi participants. *Table 4* shows the five top issues in terms of the ranking given by the Delphi survey participants as to their contribution to the success of European knowledge economies.

Table 4: Ranking of social issues on the basis of their contribution to the success of European knowledge economies.

Issue	Weighted score
Education and learning	1489
Government	623
Health	593
Work organisation	590
Management	492

The ranking shows that the top three issues, perceived as contributing most to the European knowledge economies, are education, government and health. This is an interesting choice since none of these belong to primary market-oriented issues, but are related to public services. It underscores the importance attributed to public services in creating and contributing to the European knowledge society. The ranking also shows that while it is natural to rank education as a top priority for a knowledge-driven economy, government, health and work are also of high importance to the development potential of IST. The socio-economic priorities identified above by the Delphi participants were supplemented by a number of questions to elaborate further the link between the socio-economic needs and the technological priorities, among which was the following: How would these socio-economic needs influence R&D challenges in IST in Europe?

IST education and learning

New knowledge and new skills are the pillars of the European 'Information Society'. It is no exaggeration to say that it is perhaps in education and learning where IST may have the greatest impact on achieving a European social-development model that emphasises social inclusion, participation and consensus. This is also reflected in the voting by the participants in the Delphi exercise. IST-based education and learning allow for a greater proportion of society to participate in learning regardless of age, gender, and location. This is primarily because of its independence of time and place. In a knowledge-based economy, education and learning have direct effects on job creation, wealth creation, social inclusion, and competitiveness. It is a particular priority to target through IST training disadvantaged groups and users such as senior citizens, low income groups, and people with low educational attainment. Thus, without access to education and learning geographic and societal divides will emerge quickly. IST is an increasingly important platform for providing and receiving education and learning, which are key factors for social cohesion.

IST priorities in this area will continue to be about enhancing and updating the knowledge capacities of Europe. This goal may be attained by revolutionizing delivery methods (physical and social), diversifying and enhancing content, and expanding and setting up new learning infrastructure. In other words, IST priorities will continue to be shaped by the need to provide learning opportunities in remote regions, rural areas, specific communities and groups as well as to physically challenged individuals and immobile groups. These needs are essential factors in the shaping of new education and training systems that are both socially inclusive and responsive to changing business environments, which may involve new labour structures, professions and skills.

The IST priorities in the area of education and training can thus be summarized as the following: (1) Reducing all regional and societal digital divides; (2) Supporting life-long learning; (3) Inducing the creation of responsive and flexible education and training systems; and (4) Strengthening the link between education and competitiveness.

E-government

The priorities here are derived from the need to deliver and expand public services on a 24/7 basis and to accelerate and facilitate the interaction and information exchange with citizens, small businesses on the one hand and public administration on the other. The 'old' paradigm of e-government mainly focuses on a more efficient government that offers existing services in a more **cost-efficient** manner. The following trends will continue to push towards a new paradigm in government services:

- the trend towards a flexible and more responsive government will continue;
- not technology per se but applications matter: what can be offered?
- services will be integrated into service platforms that offer a bundle of services;
- personalisation of services becomes more important; personalisation is still in its infancy, but there will be a future for 'My-Gov' approaches;
- service platforms will be different from today's physical platforms; Internet and mobile platforms will start to play a role;
- services will become dematerialised, meaning that there will be no physical counterpart for the services offered;
- the kind of integration that one may expect may be of different kinds: front office driven, back office driven, process driven.

This new paradigm stresses the importance of creating public value by means of ISTs. The changing demographic situation of Europe will lead to an increased demand for flexible governmental arrangements. The ageing of the population, the increasing cultural diversity within Europe, and the changing patterns of living, working and consuming will have their implications for governmental services. Personalised 'My-Gov' services may use AmI technological surroundings, offering context aware services and may respond to needs not yet visible to the citizens (such as the fulfilment of specific e-services).

The workshop participants emphasized a broad approach of e-government services. Actions promoting e-Government should include: social care, governance, citizens participation, public procurement, education and tax incentives. Government should be accessible by a diversity of private and public Internet access points. EU monitoring should collect data on all types of Internet access. E-government applications are seen as drivers of change, and thus should receive sufficient political attention.

Regarding the correlation with important science and technology drivers, we should first acknowledge that much innovation within governments still relates to improving information processing procedures and related issues such as identity management. Public-private partnerships may be a more dominant way of organising public services than it is today. This requires primarily organisational innovations, but will be linked to technological innovations such as 'Services on the move' (mobile services) and use of agent technology in a personalized context with citizens. These relate to the emergence of intelligent platforms, offering convergence in services and infrastructures, an issue that will be spelled out later in the section on emergent new technological applications. Another technological incentive relates to the development of systems that enable inter-operability across national contexts and multiple layers of government and that support multiple languages. These technologies might also facilitate greater social and economic mobility in an enlarged EU, for instance by offering full electronic services across borders, on the basis of public key infrastructures.

E-health

Providing a fair distribution of health care services means finding a balance between various objectives, including broad and equal access to health care services, high quality health care services and financial sustainability of health care systems. This will have to be done against a background of major shifts within the health care system, relating to the following set of issues:

(a) an increased blurring of boundaries between public and private sectors;

(b) more emphasis on the prevention of illness;

(c) growing pressure for moving healthcare to extramural settings (such as Independent Living Services);

(d) institutional changes;

(e) stronger decentralization and individualisation;

(f) seamless health care provision, especially in secondary health care structures; and

(g) development of trans-European R&D capacity.

These shifts, though not as far reaching as those related to e-Government, reflect profound institutional changes based on technological progress in the field. New delivery systems will emerge, for example, the information components of health services will be delivered through new media linkages between medical staff and patients. These delivery systems may change the value chain of medical practices and may lead to alteration in the balance between public and private actors (including patient organisations). Likewise, the rise of Telecare and Telemedicine (including handling of patient files) and the ability to diagnose at a distance or to offer care at a distance is made possible by the existence of a properly functioning IST infrastructure. The electronic patient file, in particular, will require appropriate organisational and institutional settings.

The FISTERA Delphi results indicate that three classes of stakeholder are particularly important in IST health applications, namely health and insurance companies/schemes, national governments, and large IST firms. We should note that there are many companies with highly specific technologies relevant to health applications – e.g. specialist medical imaging and radiology companies, manufacturers of prosthetics and mobility aids, biomedical firms and consultancies; etc. As with e-Government, there are numerous consultancy firms and lobbies actively promoting products and visions here. However, one of the main differences between e-Health and e-Government practices is the huge R&D capability within public health systems and their associated university departments. eHealth research could build on this once it is ready to be exploited on a larger scale. In order to build a critical mass in these areas, investing in trans-national R&D is one of the recommendations following from the priority setting workshop.

The FISTERA Delphi results highlighted the following applications and systems which allow:

- medical experts in different locations to pool resources in providing treatment;
- rapid retrieval of information on health history and needs;
- much speedier diagnosis of health problems;
- adequately informed self-diagnosis, monitoring and treatment at home.

IST and work

IST is widely used in many forms of organising work, for example, planning, staffing, contacts with customers, and various functional responsibilities. As a matter of fact, 'management-related applications' were identified by many Delphi participants as having a significant contribution to job creation, competitiveness and environmental sustainability and quality.

Furthermore, the continuous expansion and creation of virtual work environments, virtual teams, and organisations, bring new opportunities for individuals and companies in (usually disadvantaged) remote regions, physically challenged people or immobile groups (e.g. new parents, senior citizens, etc) to integrate more efficiently and more effectively in the economy. The greater dependency on, and demand for, IST in work life will prioritize the need to develop reliable, stable, fast and user-friendly technological platforms that allow a better utilization of the available workforce. Thus, an advanced and improved communication infrastructure will allow an expansion and increase in the possibilities for flexi-work and telework, which should also have a positive impact on social inclusion (including gender relations). The Delphi participants identified the following players who could take the lead in each of the priorities described above:

- national governments are viewed as the main actors for the improvement of IST applications in nearly all selected areas (leisure and recreation is the exception);
- large IST firms are expected to lead (or at least, strongly influence) improvement of applications in all areas;
- the EU can contribute much to improvement in most areas. It is believed that its major contribution will be in the areas of security, health, ageing and transport;
- three stakeholder classes shared position four in terms of number of votes cast, however participants perceive distinctive roles for each. SMEs are seen as key contributors to the improvement of applications related to social and family relationships, and to those linked to health, leisure and security. Local and city authorities are expected to make a moderate contribution to nearly all areas (excepting social and family relationships);
- communities and citizens are expected to contribute primarily to areas such as social and family relationships, cultural diversity and social welfare and public services.

4. Foresight at the Service of Defining Functional Priorities

The results of the Delphi study reveal current perceptions of the actual role of IST in achieving the Lisbon targets. FISTERA wanted to go beyond this by investigating possible scenarios with a time horizon of 2015. FISTERA therefore elaborated multiple scenarios to analyse the plausibility of several diverse futures. Substantially different "worldviews" concerning drivers of change and how they interrelate were compared and the way in which various trends and countertrends interact in different ways was studied.

Four scenarios were proposed (see Figure 4). Scenario 1 was characterised by uneven development. While social applications will have a role, most applications will be market-driven, demand driven and -in the case of the most advanced applications- used by very few people until ongoing innovation has triggered price reductions. Expensive niche developments will proliferate and basic applications may not be available for everybody. The influence of the US economy and culture is expected to be profound. In Scenario 2, socially-oriented applications will be available at different levels of service. The most basic services will be available to all, with subsidies for those in need. Compared to the first scenario, there are larger markets and more even patterns of development – with a larger critical mass and much R&D and public support, there could be more rapid development. More emphasis on user interfaces was expected, and the technical skills needed to facilitate use of IST should not be too high. Scenario 3 features more conflict and controversy, reflected by the persistence of conflicting standards. Increased concern about private data and other security issues will limit some applications, and the political crises faced by governments may make it difficult to develop major programmes and common standards. In Scenario 4, customisable systems, driven by open source developments will make it easy for final users to conceive of new applications. There will

Figure 4: Four Profiles of the Future

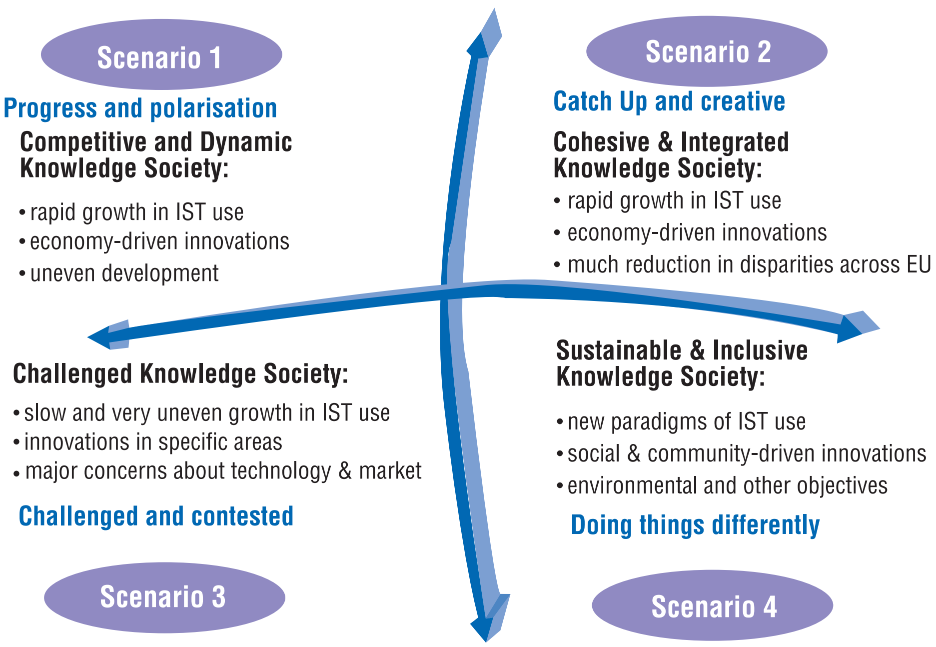
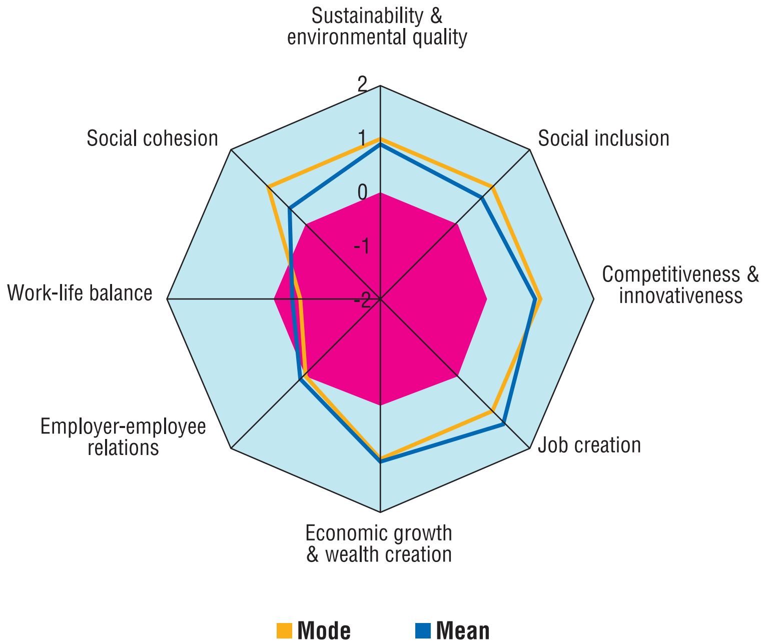


Figure 5: IST Success Scenario for the EU. The orange line shows the most voted (mode) views for the success scenario. The blue line shows average (mean) of the views for the success scenario



be greater public participation in development and funding for R&D, and progress will be driven by social and environmental objectives. High levels of literacy and education will be required if this scenario is to be realised successfully.

While Scenario 3 (the 'challenged' vision) was thought to be closest to what Europe might expect, the FISTERA workshop experts agreed that a mixture of elements from all four profiles will arise over the coming decades. The workshop participants were then asked to define a 'success scenario' based upon those scenario components likely to be reflected in the future. Two elements basically define a success scenario: desirability and credibility. The result of the best possible scenario by experts and foresight practitioners is visualized in *Figure 5*. This 'success' scenario for IST in Europe is given in terms of the Lisbon goals, namely sustainability and environmental quality, economic growth and wealth creation, social cohesion, social inclusion, job creation, competitiveness and innovativeness, employer-employee relations and work-life balance.

FISTERA then set out to deduce the impact and consequences of the above 'success' scenario for IST in Europe by 2015 on some key elements of the IST landscape (business models, consumers, technology and global affairs) and the implications of these for EU goals:

Business models and industrial environments. Within the framework of sustainable industrial development, Europe needs to have a long-term planning life-cycle that reduces wastage and transaction costs and ultimately improves productivity. Whilst governments should not control the market, they need to have direct input into the setting of objectives and into long-term market-policy development. Services need to be centred on the citizen and there must be an element of social accountability on the part of both government and industry. For this reason, business models should attempt to balance profits with social responsibilities. Importantly, employers (both public and private) must recognise and accommodate the workforce's new composition. By 2015, most of the jobs in Europe will be targeted at highly skilled people. As a result, more investment in education, training and life-long learning will be required.

By 2015, Europe will be moving towards a service-oriented economy where ICT will be an enabler. However, disparate platforms and the relative slow pace in R&D and innovation (as compared to main competitors US, China, India, Korea and Japan) is seen as a barrier. More and easier access to funds is required. Europe needs to become an exporter of intellectual capital and must make a concerted effort to encourage innovation. The appropriate business model should reward risk and innovation, in order to retain Europe's competitive advantage and help channel innovation into the market. The stronger the technology basis and the research capacity, the longer Europe's competitive advantage will persist.

Consumers, markets and lifestyles. Consumers will demand cheap and high-quality, but also sustainable products. Therefore, it is expected that the number of "bio-products" will increase. IST can support (sustainable) non-IST products (traceability, transparency, access) and the role of consumer organisations and their impact on regulations will increase. Mobility demand will not decrease, but higher energy efficiency will be important.

This scenario implies more demand for communication infrastructures, a growing market for IST products and services and more complex and intuitive IST services. There will be more 'cross-Europe' selling with products and standards becoming relatively easy to customise. The main trend is towards IST services, rather than products. Ageing, health and leisure are fast growing markets and are recognised as key application areas. Consumers are also seen as co-developers, with special business frames to support this trend.

Education rate and quality improves for young people and e-learning is a central aspect since the purchasing power for education is increasing as well as the individual responsibility for education and life-long learning. The State will be responsible for enabling infrastructure and education systems for young people. In terms of employer-employee relations, there will be changing responsibilities for learning and education. The blurring boundaries between work and non-work spaces could have negative impacts on work-life balance.

Technology and infrastructure. By 2015, there will be embedded processes in every activity system. Intelligent transportation and smart buildings will abound and the substitution of physical communications by electronic alternatives will be well advanced ("more fibre and less asphalt"). E-democracy, e-learning, e-government and e-health will be strong European assets. Social inclusion will improve thanks to improved and increased information service infrastructure and skills development. Social computing and online communities will flourish.

Web offices and applied research leading to new products and services will result in more jobs. The promotion of European *de facto* standards and a 'European brand' will foster an entrepreneurial culture and have a positive impact on economic growth and wealth creation. By 2015, a web-enabled mindset will be evolving and governments will have strong programmes to support basic research and high-risk long-term research (whilst there may not be a 'blank cheque' for innovators, funding systems should become much less restrictive).

Despite the regional promotion of European values of solidarity, tolerance, and equality, employer-employee relations will not improve and the power and influence of Trade Unions could have diminished by 2015. Concerns will arise in relation to the impacts of technology on health and the risk that work-life balance will be negatively affected by codes of practice, smart technologies and GEO spatial technologies.

Politics and global affairs. Political systems in Europe will be mostly described as a market-oriented 'benign capitalism'. Social cohesion will result from investment in high bandwidth communications, the Bologna education process and training, and increased mobility. Social inclusion will improve thanks to new education programmes coupled with work-related learning and other developments across Member States. There will also be a reduction in the digital divide through planned incentives of the private sector.

Technology will improve productivity and fewer employees will be needed. Governments will need to help the working population adapt during their working life cycle. Mechanisms may include lifelong-learning and public-sector stimulated workforce development.

Economic growth in Europe will be enhanced by reductions in divisive regulations and regional policies which will stimulate the private sector to conduct more R&D. Governments can also encourage the private sector to move to higher value business sectors which will be more reliant on R&D. In this scenario, the EU will promote high value 'projects' that stimulate technological development.

Employer-employee relations will be poor and probably degenerate further. Relationships will need to change to reflect a changing employment landscape. Work-life balance is likely to worsen as a result of gender issues related to child care services and domestic responsibilities, flexibility in working hours, and the growing numbers of women as a percentage of the working population.

4.1. From options to priorities

The above mentioned FISTERA scenario studies brought together the S&T developments and social application areas as a basis for workshop activities. FISTERA used a 'success scenario' approach to examine the policy priorities required to bring about a desirable future for the EU, where the Lisbon Objectives are met as far as possible. Participants in the workshop were asked to suggest policies relevant to the various challenges, actions and impediments identified in early phases of the project, and then asked to rate these in terms of importance for EU goals and feasibility.

The main policy priorities were classified into two categories: "immediate" (high importance and feasibility) and "intermediate" (important but less immediately feasible). This set of results is an important output of the study, but will need to be explored in more depth in later work. (Which areas are more or less feasible? – participants seem to have had some difficulty with the "ethical" dimension. What is the right policy level to tackle these priorities - EU or national? For which goals are these priorities important?).

Immediate IST Policy Priorities:

The following priorities refer to different actors, such as governments and regulatory bodies in the Members States, and the EU. The priorities are to:

- raise awareness of the citizens and business community, in particular the SME community, of the importance of IST in the future economy of the EU;
- sponsor end-user education in security policies for user empowerment (to control the process) at EU level to balance security and privacy;
- educate users about regulations to generate competence in the communities public debate, awareness raising, ethical curriculum to educate young people;
- directly encourage interdisciplinary R&D;
- encourage research into security technology, hardware and software, communication;
- allow communities to take control. Allow regional/local communities more say in major public IST investment (the principle of subsidiarity);
- allow e-government applications to drive change. Governments should move directly to adopt e-government service delivery;
- train for IST at all levels in society including SME development, and educational programmes at all levels including universities. This includes lifelong learning for pleasure and for the workforce;
- promote European standards;
- ensure compatibility of past-present-future systems at EU level;

- install an IST infrastructure at European level to provide a uniform infrastructure to promote IST;
- encourage the use of IST through fiscal measures, for example tax relief for purchase of PCs and related applications;
- adopt more flexible public procurement policies which recognise the important role public procurement can have in driving innovation in this technological area (as it has done in the US).

Intermediate IST policy priorities:

- encourage a diversity of access including both private and public Internet access points. EU monitoring, for example through EUROSTAT, should collect data on all types of Internet access;
- provide incentives for innovating organisations that involve users centrally in the design of IST systems and applications. Strengthen legislation to ensure that the needs of users with disabilities are met;
- introduce policies to motivate public-private cooperation and partnerships in the IST sector;
- simplify administrative processes. IST capacity should be used to support e-administration;
- increase provision of public access to IST (free broadband connection, public terminals, subsidised equipment and training);
- embrace local incentives and experiments: motivate and support the work of grass-root organizations and the formulation of local community activities in the IST sector.

FISTERA examined some important factors enabling the above priorities. They include 'knowledge production environments', the involvement of users both in innovation and application, 'business use' and internationalisation. Each will be briefly introduced in the following paragraphs:

Knowledge-production environments

On the knowledge production side, a number of critical generic issues have been identified in FISTERA, most prominently the issue of IST skills. Skill shortages in IST are resulting from a systemic mismatch between supply and demand for different types of skills. The problem of mismatch requires greater cooperation between universities and industry in the area of skills development. A review carried out by the FISTERA team of various information and labour market intelligence sources on the labour market in the IST sector revealed the following trends:

- firms need hybrid skills that combine technical expertise, an understanding of the IST market, the business acumen to know what products have market potential, and customer-relations (i.e. communication) skills;
- changing sets of activities and the changing roles of firms mean that new skill-sets are necessary. The components of these skill-sets may have existed separately within the industry in the past, but reconfiguring those means that they cannot be easily bought off the shelf from the education system;
- there is increasing demand for some of the more specialized technical skills;
- the speed of change means individuals need to be flexible and open to continuous learning;
- organization structures and cultures need to be flexible and responsive to facilitate inter-disciplinary learning and knowledge production. The access to a wide range of knowledge sources could be based on network models of organisation, supported by the use of IST tools;
- the rate of growth of the industry means that more skills of all kinds will be needed, and quickly.

Closer and more regular cooperation with industry will be necessary to update university teaching with the latest developments in industrial research in order to reduce the gap between technical change and training. This should also help link parts of university teaching to industrial needs. The results from FISTERA therefore suggest three concrete initiatives: a) creation of competence centres to reinforce collaboration between universities and industry, b) cooperative education systems involving both industry and academia, and c) joint research activities between industry and universities.

However, skills shortages are also sometimes the results of an inadequate utilization of potential labour reserves – often because of prejudice - such as women, immigrants, or older workers in the labour market. Utilizing the skills of traditionally marginalised groups remains a major challenge. More opportunities should be given to these groups, to participate in greater proportions in the labour market. In the wider European context, brain drain, skills and learning also represent a challenge for so-called less favoured regions and the New Member States. While outsourcing and business relocation may continue to flow from the West to the East, the migration of specialised advanced skills and younger generations of IST workers from East to West may hamper the long term socio-and techno-economic development of the New Member states and the less favoured regions within the Union.

User-centred IST innovation

It is increasingly recognised that a great many of the most exciting developments in IST – and indeed in other areas of technological and social innovation – come from communities of what are typically labelled as "users" or "consumers". FISTERA results point towards the essential need to adopt a user-oriented approach to future IST technologies- i.e. placing the people in the centre. Users should become more involved in the process of identifying potential prospects, problems and solutions, thus fostering greater and deeper bottom-up innovation in IST. This is a priority not least because of the nature of areas of rapid growth in IST applications, such as e-government and e-health, which are, by definition, user-oriented. While 'technologically deterministic' innovation might succeed in developing the best technical solutions for certain predictable problems, 'socially-processed' innovation helps ensure a wider and faster adoption of new solutions. This is important not only for the development of user-friendly and useful technologies, but also for reducing the risk of market failures (i.e. user-relevance).

A major issue is how such "bottom-up" innovative energy can be facilitated in practice. Attempts to build and support European communities of end users that can define (and possibly meet) their own needs with respect to ISTs need to be explored. If users can become 'agents of change', then 'top down' governance and producer-dominated technology and applications development can be challenged. As a pre-condition, it will be necessary to identify and create the (user) entities that have the potential to cause and implement change. Such agents could be engaged in creating visions - i.e., asking the questions 'where do we want to be in 10 years?', 'what will we need?', and 'how do we move towards this desired future?'

With respect to research, the requirement of user-orientation translates into the realisation of experimental settings that allow involving individuals, groups and communities to identify and shape the future developments in IST related to the various socio-economic application areas such as education/learning, ageing, localisation of work, etc. This participatory approach to innovation in IST is crucial to help identify and adapt to factors that enable or constrain the diffusion and adoption of certain IST developments. The result may be more economically and socially-viable products that stem from complex social and individual needs, reflecting, and capitalising on, a wealth of European diversity and idiosyncrasies.

Support for individuals

Rapid technological change as in IST should be underpinned by sound research on the ways in which individuals are impacted by usage/non-usage of technologies. As familiar contexts, routines and practices are unravelling or changing, new requirements for understanding these relations are created. Such research should be complemented by study of the usage patterns and impacts of ISTs across a range of different social groups. A more differentiated perspective on users is necessary. Insufficient attention is afforded to issues of competencies and skills (particularly the distribution of IST practitioner and user skills among Europe's citizenry) – the 'young' tend to be advanced users but many other social groups are lagging behind. This lack of attention to the requirements of different user groups and the resulting gaps and lags give rise to potential dangers and costs that need to be anticipated and addressed.

Business use of IST

Though there is significant (research) attention directed towards IST and IST policy development, there is little targeted at 'Business Usage' of technologies. Whilst personal use of IST offers scope for major market growth, business use of IST is likely to have wide-ranging economic significance. More research concerning use/application (across a variety of sectors) is required, and this should be linked to IST development research. A consolidated effort to understand the dynamic linkages and relationships between policy, IST production, and business use of technologies would be beneficial. An important question to address here relates to convergence/divergence of visions – to what extent do producers and (business) users have shared visions with respect to existing and future needs and functionality with respect to ISTs?

The dominant preoccupation with macro factors/trends and large IST producers/users may mean that insufficient attention is paid to innovation and development in smaller organisations, not least in statistical terms. Many small companies and individual entrepreneurs are highly dynamic, but their visibility is low and they find it difficult to attract and secure development funding. There is a serious paucity of evidence with respect to small-scale (IST and applications) development and its effects on national and supra-national economies (and where little evidence exists it is not possible to design adequate support policies). In particular, the role and importance of start-ups tends to be underestimated. They could benefit from financial and fiscal measures to reinforce research and innovation in order to overcome difficulties of funding the up-scaling of innovative solutions. Efforts have been made to oblige large business to work with small businesses on grant-funded projects, but these should be enhanced so that, for example, subcontracting becomes the norm for many R&D projects.

Internationalisation

Whilst there is clear evidence of internationalisation of the science base, too much IST research focuses on European, national or regional/local issues. It is important to avoid thinking of Europe in isolation and to consider the implications of globalisation. In particular, research should address the implications of recent trends in standard-setting, the ways in which major commercial organisations, such as Sony, are able to establish global standards and the implications of and scope for intervention in this process. Timely establishment of standards in Europe could be instrumental in underpinning the competitive advantage of Europe as a lead market for application-oriented research and innovation. Thus, though attention to trends and opportunities in Europe should not be abandoned, a focus on global collaboration and the activities and performance of competing global blocs would be of use.

5. Technological Options and their Economic Impact

In the previous chapter, the Delphi study offered insights on societal trends, their challenges and impediments as perceived today by a large number of experts. The scenario-building exercises complemented this effort by offering options for a long-term development of IST for society and economy. Investigating a suitable vision for the future, however, is only one side of the coin. The other is to identify technology trends and prospectives that can support this vision. Trying to match socio-economic needs with future technological possibilities will offer insights on more realistic options. This chapter elaborates on possible technological trends, possible applications and the consequences of technological progress for the IST vision.

Due to the systemic nature of ICT and the rapid progress of technology in the field, it is not easy to monitor the breadth of ICT trends and make forward looking assumptions on applications and their use. In view of this complexity, some methodological compromises have to be made. As the key issue for FISTERA was to derive insights on the impact of ICT on society and economy, rather the potential of (particular) technologies themselves, FISTERA used a methodology that embeds ICT in the context of its use, i.e. the environment or ambient of application. The price to be paid for this is that single technologies will not be individually monitored even though some of these are very promising. Instead, the focus is on clusters of technologies. These clusters comprise those technologies that offer similar functions. At the same time, the cluster may include technologies that are either competing or complementary. The state-of-the-art of these clusters and their underlying technologies are assessed and assumptions on their evolution are made. FISTERA calls this methodology, used to track technology trends and foresight for ICT, 'technology trajectories'.

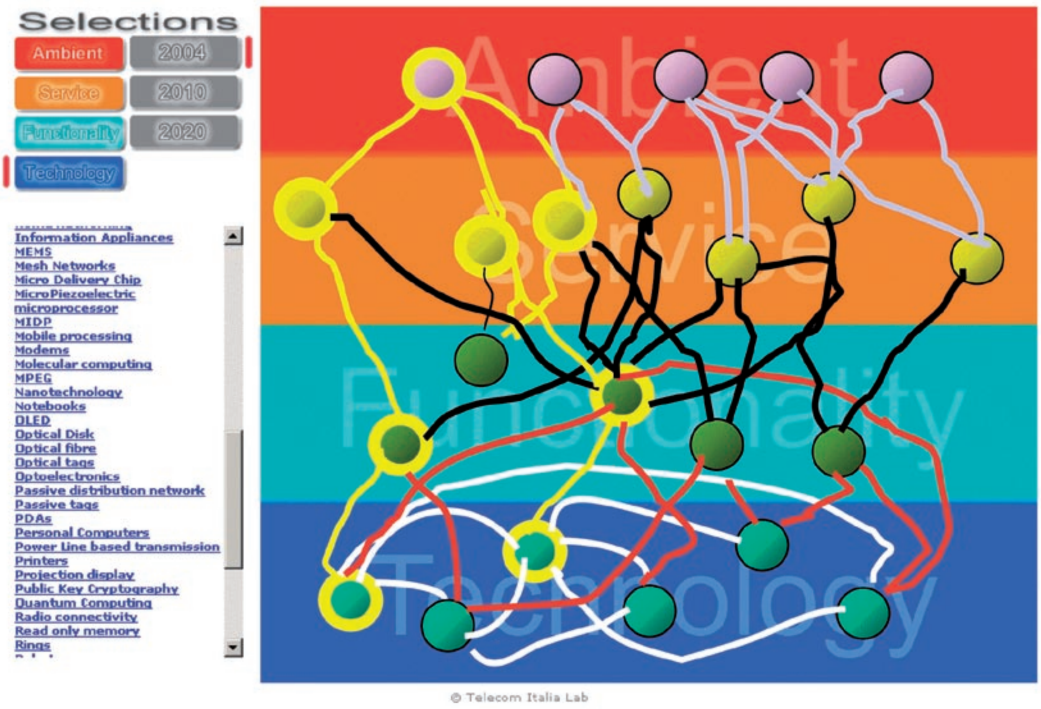
A technology trajectory (TT) has a number of steps. First, a trajectory is defined. Then, all technologies contributing to this particular TT need to be identified and available information about the individual ICTs need to be collected, including technical and market information on the expected evolution, and the respective stakeholders.[21] In a third step, these technologies are related to possible applications and services. The FISTERA model consists of four layers (technology, functionality, services and ambients - see Figure 6): The first layer takes into account the influences, opportunities of individual technologies and of connections amongst these. The second layer describes the functionalities offered by technologies and the services they may activate (third layer). Finally the fourth layer (ambients) describes the physical spaces where services can be offered. Each of the elements, i.e. entries in one specific layer, is related to one or more relevant elements in the upper and lower layers and also in the same layer. Each link receives a value depending of the strength of the relationship between the two elements. This value (for the links) has three components depending on the prospects for the year 2004, 2010 and 2020. Similarly, the importance of each of the elements (for the nodes) is assessed for these three time intervals and a value is allocated to them.[22] The information and data as a whole is gathered into a data base which is available online.[23] Figure 6

21 Depending on the maturity and information of the technology available, the depth of knowledge may vary significantly from one trajectory to another.

22 The model operates through an interactive consultation involving the opinions and contributions of many experts in the field. The validity and quality of the information is checked by a moderator who has the ultimate responsibility for introducing data and modifying them.

23 The FISTERA database contains (November 2005) about 200 technologies, 150 functionalities, 21 services and 55 ambients. The set of relationships between these entries exceeds 2.500. The FISTERA web site (http://fistera.jrc.es) offers also over 500 commented pieces of information resulting from a filtering of over 2.000 news.

Figure 6: Visualisation of the relationships between different technologies in the database. More than 200 technologies and dozens of functionalities, services and ambient have been introduced, for three different time horizons 2004, 2010 and 2020 Technology Trajectory is the name given to FISTERA's concept to track technology trends and foresight for ICT. The concept aims at monitoring clusters information and communication technologies offering a given functionality for a given time horizons. The database links all technologies to their application fields and the environments in which the services and products are likely to be operated.



shows a sketch of the model. The online system allows visualisation of the elements and links at each of the four layers (technology, functionality, service and ambient) and for three different time horizons (2004, 2010 and 2020).

FISTERA used this database to investigate, for instance, the pattern of emerging relationships between technologies and detect key technologies whose evolution might result in an acceleration of the evolution of others. In particular the following technology trajectories have been assessed in detail for three time horizons (2004, 2010 and 2020) and are considered very important: "storage", "processing", "information visual display", "printing", "information retrieval", "communications", "bandwidth", "human interfacing", "data capturing", "pin-pointing", "artificial life", "artificial intelligence, robots, smart applications", "content creation", "embedded systems" ,"seamless ubiquitous access", "person identification" and "wearables". Table 5 offers a brief overview of the expected evolution and impact for each of the technology trajectory. Detailed information on these technologies is available in two specific FISTERA reports[24] and is updated online.

In addition to the general technology trends, FISTERA also tried to use the database to identify particular technologies with the potential of becoming instrumental or influencing the future development path of other technologies. It was done by assessing emerging patterns in the relationships between technologies. The aim was to find those technologies whose evolution

24 'Key European Technology Trajectories' Report D2.1 (Aug 2003) and D2.2 (Aug 2004) available at http://fistera.jrc.es/pages/wp2.html

Table 5: Technology trajectories considered by FISTERA. The table gives a rough overview on some of the major evolution and the expected impact of each of the trajectories in the timeframe 2010 to 2020 as derived from the analysis of the technology database. Detailed information of each of these trajectories is available on the FISTERA web page.

Technology Trajectory	Expected Evolution in the 2010 - 2020 timeframe	Expected Impact
Storage	More and more capacity available at a very low cost. Storage infrastructures play a key role.	The traffic quality (and quantity) may vary significantly. New architectures may be required.
Processing	The cost of processing spirals downward. Processing power will be embedded everywhere. Grid architectures are not going to play an important role before 2010.	Progressive growth of autonomous systems, more objects become "users" of communications facilities generating significantly different types of traffic with respect to voice traffic.
Information Visual Display	Low cost flexible screens make image display possible on many objects. Large screen will become, beyond 2010, a usual sight in homes. Better capabilities for image manipulation.	Increasing demand for image transmission, including on the move. Demand for bandwidth to "fill in" large screen so that close range vision is not blurred. Images become an important part of interactive communications.
Printing	Possibility to print tags along with text and images make printed stuff interactive, when needed. Possibility to print 3D objects extends the range of demands. Foils may come to embed printing capability.	The amount of printed material, that will keep growing, will turn into a generator of traffic. Interactivity will see printed matter as an important component. E-books become terminals and will play a significant role in service offering.
Information Retrieval	The amount of information produced in various format will keep increasing (doubling every 3 years for the next 15 years at least). Retrieval will become a fundamental issue and will be context sensitive.	The value is shifting from accessing information to getting the information that makes sense to the retriever in that particular situation. Profiling, context aware, "push", "hyper linking" services will make a difference.
Communi-cations	Alternative ways of communications will be the norm, a variety of access types mostly hidden from the user perception. Voice remains the leading perceived communications, plus lot of backstage "traffic".	New network and service requirements to support seamless synchronization among different communications streams, merging of network and local data, piggyback on a variety of access points in a seamless transaction.
Bandwidth	Growth of bandwidth offer pushed by technology availability, very seldom driven by market demand. Fibre spread in the distribution network, wireless in the home environment and public access.	Burst communication takes the upper hand because of economic advantage. Information transfer speed becomes a premium service offering (diverging from bandwidth which will tend to become a commodity).
Human Interfacing	Terminals become more sophisticated supporting a variety of direct and background communications, local storage, local environment exploitation. Affective computing, agents play a significant role.	Local area networks are becoming a crucial part of the network. They may over-ride the network itself by being perceived as the ones really important for the service (not just for service delivery). Will there be any network service left?
Data Capturing	Millions of low cost sensors, organized in local networks, able to detect a variety of parameters. Local processing capability and, in perspective, the potential to react to perceived changes in the environment also on command.	Sensors networks may be seen as terminals accessing the network through a gateway or become part of the network. Operators may consider management services and deploying sensors networks, then selling data as services.
Pin-pointing	Localization information available everywhere, potentially to any object. Tracking capability, with features to protect privacy, makes it possible to link with any inanimate or living thing.	Significant amount of transaction oriented traffic. Very low revenues unless it is priced in terms of service. Who will provide the service: the telecom operators or some independent service providers?
Artificial life Artificial Intelligence, Robots, Smart Applications	Progress in processing capacity, in sensors, in storage, in knowledge coding will lead by 2010 to an 'operational intelligence' that can compare to the one of a lizard and by 2020 compare to that of a mouse.	Possibility to develop software and hardware systems with a considerable degree of autonomy. Decreasing need for standards since interfacing can progressively be managed through negotiation. At the same time growing need for transparency and trust. New actors in the service domain will be offering increased possibility of customization and adaptability to the context and experience.
Content Creation	Content creation has shifted towards a prevalence of individuals rather than majors. These have to sustain ever growing cost to differentiate their offering and are competing for consumers' eye balls. The availability of content is growing at an increased pace, with new technologies (often embedded in the terminals) making it easily available at any time and in any place. Meta content technologies will develop rapidly creating value out of "free content".	This trend is going to have significant impact on traffic pattern, local storage and services "about information", like filter, profiling…New actors may enter the value chains leveraging on profiling services, becoming the new intermediaries. Strong ties with the social and cultural evolution with potential emergence of new communications paradigms. Stronger role of communities and community oriented services.
Embedded Systems	The growing capacity to produce highly complex chips (over 1 billion transistor equivalent by 2010, hundreds of microprocessors per chip within the next decade) and the possibility to embed in the same chip processing and communications (also wireless communications) and sensors lead to the creation of very low cost systems on chip potentially becoming part of any object.	In the future, objects will increasingly deliver their functionality through a chip (this will require sophisticated design capability) and through a "design" that shapes the object according to its function. This increases the importance of 'on demand electronics' and challenges the industries that are today in the central part of the value chain. At the same time the availability of embedded systems increases the opportunity to deliver services.

Table 5 (Cont.)

Technology Trajectory	Expected Evolution in the 2010 - 2020 timeframe	Expected Impact
Seamless Ubiquitous Access	Technology in the access will be ever more abundant. Its very diversity creates a big problem to the end users that will naturally result in many providers to find agreement to provide seamless connectivity. Both agreements and technology will make this happen.	The ease in accessing the variety of networks will translate, from the point of vie of the relation customer-provider into a fading away of the association infrastructure-provider. This, associated to the ever lower investment required in deploying connectivity will shift the balance towards service rather than infrastructure as the "core" value.
Person Identification	Increasing number and effectiveness of technologies that can provide secure identification. This will be true both for the one sought by the person and for the one sought by authority (which clashes on privacy issues). Today's gap between false positive and false negative will decrease to a point that these technologies, likely applied jointly will become widespread.	A variety of services become enable by an effective personal identification, coupling with profiling. Privacy issues may be a stumbling block till the end of this decade but should dissolve in the next as culture evolves. Terrorism and general consideration on safety and security may accelerate the adoption. New actors may emerge and may become intermediates in the value chain.
Terminals, Wearable	The number of features per terminal will keep growing but they are likely to remain bells and whistle with each terminal focusing on one single thing. At the same time terminals may become new service infrastructure and morph into everyday objects. Wearable should take steam from this evolution.	The shift from network to terminals is unstoppable. However in the future there are going to be other infrastructures, at higher level, that will become possible because of terminals. As an example, the iPod is now in the process of generating a new communications infrastructure, the private radio, and here there are new actors emerging. There is a big risk for telcos to be left behind.

is likely to deeply affect other technologies, generating a multiplying effect on the entities it "attracts". Technology 'attractors' were identified by a specific algorithm that analysed the strength and pattern of the link of a particular technology with other technologies and in function of time. Figure 7 shows the links (links are represented by lines, the shorter the stronger) for the technology 'batteries' for the years 2004, 2010 and 2020. The density of links increases drastically and a number of agglomerations are visible (one in 2004, two in 2010 and three 2020 – indicated by and oval). When such a pattern evolves with time, FISTERA considers it a technology attractor. Out of the numerous technologies and functionalities analysed, only a few clearly exhibited an "attractor pattern", namely batteries, embedded systems, micro-kernel/ad-hoc protocols, bandwidth, storage, information semantics and radio propagation.[25]

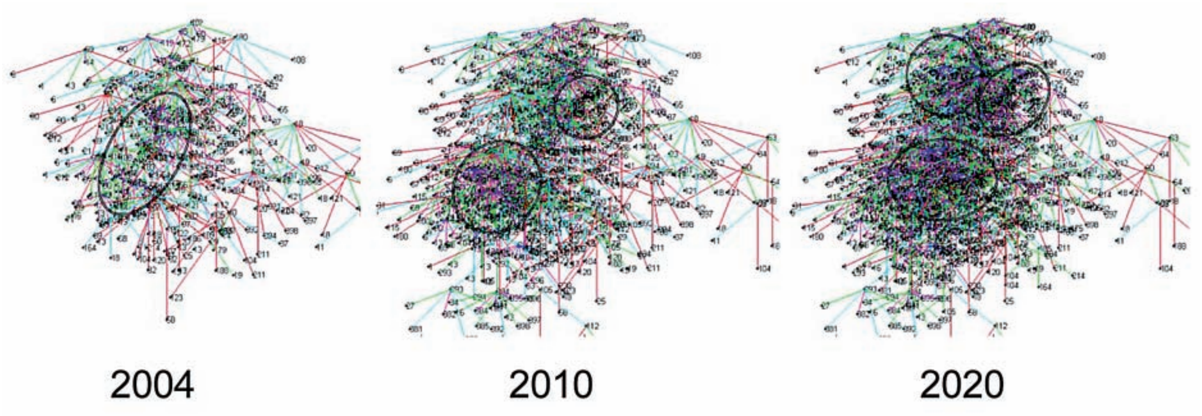
These technology attractors have been one element that has fed the discussion on priority setting. To illustrate what is meant under each of the seven headings, a short summary of the expected evolutions will be presented for each of the seven technology attractors:

Attractor: Batteries

Batteries are an essential element in all mobile communications systems and also play an important role in some appliances. Today, batteries are not driving technology evolution - instead, they are considered to be a constraint. Major research efforts aim at synthesizing chemicals with higher specific energy capacitance, development of easily rechargeable materials (like in fuel cells), or systems with minor recharge times, like the ultra-capacitors being developed by Samsung.

25 Exploiting the technology database in the proposed way has some limitations. First, the quality of the results depends on the size of the database population. Generally speaking the more data is introduced; the better the expected result. However, the results will always be influenced to a certain extent by the way the database has been designed and the quality of the underlying data. Second, radical innovation may come along with changes in social and cultural patterns that would favour or hamper deployment and cannot be taken into account in the model. As a matter of example, a sudden discovery of potential health hazards caused by electromagnetic fields would block deployment of wireless networks, thus negatively impacting on mobile communications. In view of these limitations, the proposed results should be regarded as an alternative way of gaining new insights into possible technology futures.

Figure 7: Typical pattern of a technology attractor as it derives from the FISTERA technology database. An "attractor" is a technology whose evolution will affect deeply other technologies, functionalities or services. The figure shows the case of 'batteries' for 2004, 2010 and 2020. Each line in a figure represents one link between batteries and another technology. The colour and the length of the line (a light and long line represents a weak link, while a 'dark and short' one a strong one) is an indicator for the strength of the link. The density of links increases as time goes by and the emergence of clusters of links become apparent, indicated by ovals.



No drastic disruptions are expected until 2010, although fuel cells should become available and flexible, mouldable materials may be available. The latter would support the spread of a range of wearable devices. The evolutionary progress of batteries and fuel cells will be used in a variety of appliances, like portable lap tops, video screens. Some breakthrough in this area may speed up the development of energy intensive services. Video on cell phones, already enabled from a tech point of view from OLED technology and storage in the portable device, is massively hampered by lack of adequate portable energy sources. It is unlikely that processing intensive local interactive video applications will be possible in this time horizon.

It is more likely that there will be a number of breakthroughs in the energy storage, creation and delivery by 2020. Induction, ultra-capacitors, nanotube-based technologies could solve the power supply problem for a number of portable applications. Fuel cells should have become standard in energy intensive (fixed) devices, like lap-top type devices (e-book readers may use them extensively). In addition, progress in batteries should boost the tremendous increase in the use of sensors in the environment. Solar cells will become a more important source of energy in the next decade, given the progress in construction technology, but are unlikely to provide any significant impact on portable devices due to high energy requirements. A higher impact may be expected for sensors used in open environments.

Energy storage will, however, remain a pressing issue. (The 2020 diagram in Figure 6 shows that the "density" of use of batteries will be very high.) Better performing batteries will make a difference in several fields. Equally important will be the effectiveness of using energy. The research challenge is to cover the whole range of energy use, rather than focusing exclusively on the batteries as such. An important issue, that may or may not become a stumbling block, is the recycling of exhausted batteries. If this becomes an issue then longer-use batteries (and related technologies) may become very important.

Attractor: Bandwidth

By the term 'bandwidth', the transmission capacity at access level is meant (rather than the network capacity on backbones). Fibre capacity is likely to continue to increase, reaching hundreds of Tbps in the next decade. Progress in both optical, optoelectronics and electronics will contribute to this growth in capacity. For services in the home, connections at speeds close to 100 Mbps will probably satisfy 99% of needs well beyond 2020. However, research into ways of increasing bandwidth is likely to continue in order to satisfy very specific needs (holographic projection, GRID support in the scientific – medical – security environment). This research will trickle down to the level of general infrastructures and applications. Currently, the main actors in terms of deployment are, by order of importance, Korea, Japan, USA, and Europe. The quest for higher broadband capacity will be steered by the potential market demand for access to it. This will be more important in Europe and the USA than in Korea or Japan. The success of broadband, particularly in Korea, and to a lesser extent in Japan, was achieved through significant government intervention. This could stimulate thoughts on alternative ways to proceed in Europe.

Copper-based technologies (xDSL) will progress in speed, reaching a plateau by the end of this decade in the range of a few hundred Mbps. For new installations, the shift towards fibre is inevitable, motivated by cost factors rather than increased speed. For older installations, fibre-based technologies could provide extreme bandwidth, but the higher cost makes this proposition viable only in a few environments (business connectivity).

Mirroring technologies are likely to grow in importance, allowing service, content and network providers to ensure that users perceive high bandwidth without the need to actually transport information across the network. The issue of managing large quantities of data through optimised architecture is an increasingly important research topic.

Irrespective of wireless local loop technologies, WiFi-based services will become more and more widespread throughout Europe in homes and in those areas where there is a high demand for data connectivity. The total coverage will be insignificant compared to that offered by GSM or 3G, even into the next decade. However, the volume of traffic carried by these networks may be quite significant. UWB will provide very high bandwidth in small areas, and its major advantage is low power consumption. Research in this area is important for Europe since it will enable several applications, including sensor networks. The advent of software radio by the end of this decade may blur the borders between technologies that can enable a single terminal to use whatever wireless network is available in a particular area.

The quest for ever more *bandwidth* will continue. By the end of this decade, most local loops will carry data at several Mbps and by the end of the next decade the bandwidth provided is likely to exceed demand in most cases (with offers of bandwidth in the Gbps range – demand, however, will probably stabilise in the hundreds of Mbps). In terms of perception, users will continue to measure bandwidth in terms of response time and this may be more dependent on the global architecture than on the channel speed. Local storage of information may greatly improve response time. For this, a local user profile would be established in order to improve the user's perception of broadband. By the end of this decade, mobile devices will have multiple interconnections and be able to download large amounts of information. WiFi and UWB will offer 'data-follow-me' functions, able to upload onto the device information as required. For example, a tourist would load only the video clips relevant to a particular stage of a city tour, rather than all the clips at the start. As he moves from place to place, he enters a different connection gateway range (a pico-cell) and can upload information appropriate to that place.

Attractor: Storage

Currently, there is no sign of a slow down in capacity increase or in price reductions. Capacity is rapidly reaching a point where it can support local storage of huge quantities of information, creating a virtual local "Internet". In the future, everything will be potentially recordable, enabling new services and creating a completely new industry. It is interesting to note that there is no sign of convergence between the various storage media: progress in polymer memory is unlikely to replace optical storage, or progress in flash cards is unlikely eliminate hard disks. Silicon-based memory will grow in capacity in the order of GBs and it will be integrated into the processing chip to increase the speed of the reading cycle. Currently, American companies have the upper hand, but there may be an opportunity for reversing this trend in the growing area of information appliances and 'white goods'. The system-on-a-chip may make massive use of read only memories and Europe may play some role in this development. Another application area is portable storage for appliances (Compact Flash and the like). Compact flash cards will evolve towards (limited) processing capability, mostly to support communications in the next 5 years Polymer memory will become available by the end of this decade and may become the main distribution media by the middle of the next decade for encrypted content where access can be enabled by an appropriate decrypting algorithm. Terabit content capacity will be "normal". This is still an open field with no main actors and Europe could take the lead.

Another area is SIM card evolution, and Europe and East Asia are particularly interested in the possible applications. In the next decade, optical storage memory will reach Terabit capacity. Today, the USA and Japan are at the forefront of this development, followed by Korea. Europe may be able to have a say, if appropriate research is funded. Non silicon-based nanoscale memories are still in their infancy although some prototypes have been developed. Their potential for delivering very high-density storage is unlikely to be fulfilled before the next decade. Though this research is high risk, it may also create significant disruption and lagging behind would seal off several areas in the coming two decades.

Within the next decade it is expected that storage will continue to increase in capacity and decrease in price. The demand for storage in the consumer market will be sustained by a variety of appliances (like video cameras and digital cameras, security systems, and entertainment systems). By the end of the next decade, business market estimates indicate an enterprise spending of 10 m$ in ICT for 2000 PCs, 2 Petabyte of disk space and an Internet connection of 2 Gbps. with processing power 10 million fold larger than today, 200 Exabyte of storage space - that is, 200 million GB (possibly not hard disk), and a connection with an aggregated capacity of 200 Exabit per second.

Home appliances with 1 Terabit of storage capacity should become a reality from 2008 onwards. By the end of the next decade, most homes in Europe will have storage capacity devices in the range of hundreds of Terabits. There will be a shift from capacity-driven demand to management-driven demand. In the business world, this shift will open up new business opportunities in the next decade. In spite of expected large improvements to storage capacity in terms of performance, the capacity for retrieving information will remain a big challenge.

Attractor: Embedded Systems

Embedded systems" are one of the most crucial areas for the future evolution of the overall market. The embedding of systems will radically change the way we look at objects and our motivation to buy them. At the same time, this will create a completely new demand on companies' skills and procedures. The market size of embedded system is estimated to be 100 times that of PCs.

Embedded systems will be applied basically in all application domains: agricultural, health care, environment, road construction, ship building, automotive, and security. According to the usual accepted meaning of "self consistent system", an object may contain several embedded systems. In a more forward-looking sense, there will be only one embedded system per object providing the various features. These embedded systems may be composed of several "chips" or components that are deeply functionally integrated. It is not yet clear in which direction the market will evolve: it may be a horizontal market, like the one for chips today, with a few big manufacturers providing the basic platform that will be used, after appropriate customization in the various objects/products, or it will be a multiplicity of vertical markets, each one developing custom-oriented embedded systems. It might turn out to be a mixture of the two. Note that the customization phase, that also has to be present in the hypotheses of a horizontal market, requires companies to prepare themselves in terms of new skills for embedded systems.

Embedded systems are a reality today: an average household may have as many as 50 of them. However, in the future embedded systems will no longer be a component to be placed in an object but it will be, in a sense, the object itself. This is what radically changes the scenario. Embedded systems apply to a diversity of fields and increase the complexity of applications. At the same time, they increase the challenges for the integration of the various parts and the networking with other parts (given the higher complexity of the features involved). Notice that embedded systems need to interact with the object in which they are embedded and with the environment "on behalf" of the embedding object. Therefore they need to have sensors and actuators. Sensors and actuators are a fundamental part of embedded systems and technologies related to them translate into the ones of interest to embedded systems. Embedding systems give rise to a technological issue but their use has many implications outside technology. There is a need for a multidisciplinary approach to products and services and the inherent flexibility results in a shorter time to market and many releases introducing upgrades. Software and software management become key issues.

A particularly interesting case is the contribution of embedded systems to Systems-on–a-chip.[26] One of the crucial aspects will be the interconnection network with new ways to synchronize the various components. One possible approach is the GALS (Globally Asynchronous, Locally Synchronous technology). Another fundamental issue is energy consumption and heat dissipation. System-on-a-chip (SoC) will need to be designed with these constrains up front. This will lead to a lower availability of energy for communications within the chip and hence more sensitivity to noise.

To have more flexible systems-on–a-chip, some researchers are calling for independent functional blocks within the SoC with flexible interconnection that can be programmed depending on the specific application. Their evolution will progress in two conceptual directions: an increase in library component (and related issues on common description of these components to share them across different companies) to make it possible to create very specific SoC for vertical markets; and an increase in programmability and flexibility in the use of SoC leading to the creation of a SoC as a platform to be configured and customized as required by the vertical sector of application.

The drive to create a platform to support embedded systems is sustained by development cost considerations and the variety of potential application fields. It may be convenient to develop a core SoC (embedded system) that will be supplemented by specific components in order to deliver those functions that are specific to a particular field. Clearly, the discussion is on what should constitute the platform and on its interface. Over time, more and more basic functions are likely to become part of the platform and it may get so extended that in the next decade the platform itself will suffice in many applications.

26 A system-on-chip is a broad set of technologies that allows the development of a complex set of functionalities to build up a complete system on a chip.

The overall architecture of the embedded system, once it has been accepted that it should be composed of a platform plus specific components, is an important issue. The existence of agreed standards or, even better, of published interfaces and split components (one part to be found in the platform and the other to be included in the specific component) will greatly simplify the adoption of platform. Software is going to play an important role both within the platform, the components and in the object itself to create a single functional system.

Attractor: Information Semantics

There are signs of a profound change in the area of information value. While information was scarce and difficult to reach, the availability of information had value. As soon as information multiplies and is readily available, the value is no longer in the information itself, but in its relation with the context and with the specific user.

Semantics, i.e. the meaning of the information, moves to the forefront. This meaning is a combination of the information as such, of any other related information (visible and not visible), the specific situation the user is experiencing (in terms of environment and needs) and the history of the user (his/her previous exposure to that or similar information, his/her cultural capability to understand and assess it, etc.). Note how important the selection of information can be. An Internet search engine can hamper access to information not by omitting it, but simply by relegating it among thousands of other links and sources. Any link from the third page onwards has virtually no value to the information provider associated to that link. The probability that any user will click on it is basically zero.

Whoever can create a semantic value, based on the set of contextual parameters mentioned above is poised to reap the most benefit from the market. Information semantics result from merging storage, computation and communication. While these three capabilities are intertwined in living beings, they are clearly separated in the virtual world created by technology. In the coming years, probably by the beginning of the next decade, we might be witnessing a merging with a deep impact on the way we look at information. The information is likely to be attached to the individual, and when information is needed such local information will be connected into a computation environment (for example, the surrounding ambient may be equipped with a kind of desk upon which somebody can place his personal storage containing the local information) and also to the network.

Information semantics acts as an attractor, because information becomes a platform where -in principle- anybody can provide features (applications, services, links, other information) that will lead to the creation of semantic value. Semantics will turn "unrelated" information into usable information. There is basically no limit either to how much can be added on or to the value increase. Without semantics, adding information would soon run into conflict (e.g. information overload, technical limits, etc). This would decrease the value to whoever is adding information and has information to "sell". However, when semantics are used, any new information adds value to all participants.

Attractor: Radio Propagation

The use of radio propagation for applications has, so far, been very limited due to the scarcity of frequency spectrum. Progress in technology is likely to change the situation. In the future, probably by the next decade, we will be overwhelmed by the capacity offered by the radio medium, as we already are with fibre. This new "unlimited" resource is likely to change the rules of the game and hence the disruption is brought forward. New applications will be triggered by dynamic spectrum allocation, localised use of spectrum, negotiation of spectrum by terminals, creation of mesh networks, and "infrastructure-less" infrastructures. The infrastructure-less infrastructures are automatically created by existing terminals. The paradigm is reversed with regard to today's infrastructure: Today, as more terminals use the infrastructure, less capacity exists for each of them since capacity is shared. In tomorrows' paradigm the more terminals there are, the more capacity will grow, since each new terminal brings more capacity that can be shared by anyone. One consequence for business is that the value shifts from the infrastructure to the services that unlimited bandwidth can provide.

Unlimited bandwidth -identified above as another attractor- stimulates new business, and new applications are feasible at a lower cost thus stimulating market acceptance. It is achieved through a completely new set of terminals and appliances. Therefore advances in radio propagation stimulate the terminals' market which in turns shortens their life cycle leading to more innovation and to the possibility of offering even more services, no longer constrained by the bandwidth scarcity and related high price.

The USA on the one hand, and Korea/Japan on the other, are positioning themselves to lead this change and possibly become some of the biggest beneficiaries. Progress in radio propagation is already visible with WiMax and UWB, and more will be coming in the next few years. So far, these technologies are far from offering the prospects for future unlimited bandwidth, but are already serious competitors to those who paid high licence fees for getting small spectrum portion.

Attractor: Micro Kernels / Ad hoc Protocols

Most of today's applications run on consolidated and "large" operating systems (OSs), such as Windows, Apple OS, or Linux. A lot of manpower, (which can be measured in tens of thousands of person years) has been devoted to the development of such operating systems. Progress has largely been of an evolutionary rather than revolutionary nature. These operating systems have two major weaknesses. On one other hand, their evolution is too slow for some applications. On the other hand, they are too large to fit into small systems (for instance, cell phones have either stripped out versions of operating systems or have been specifically developed for this sector, like Symbian). Even stripped down versions will not work for systems as tiny as sensors. For these areas new, tiny OSs, are emerging.

The concurrent evolution of mesh networks and the proliferation of sensors and appliances with embedded computers create a new environment where computation is intrinsically distributed. It is not the decade-long issue of distributed computing, where an application is spread over several computational structures. Rather there are several systems that by being connected generate a distributed computational environment. The rate of evolution of these OSs is likely to exceed the one we see today for large OSs. The multiplying factor brought in by the number of connected systems will increase the performances of the overall computational environment. Real evolution will happen here. The environment is by nature an open one with many contributors.

These microkernel-OSs will create a distributed computing environment, operating on ad-hoc protocols, that is communications mechanisms that will be negotiated as communication progress based on the specific requirements of that transaction. This allows the optimisation of energy consumption, which is a critical issue in these systems.

Micro-kernel operating systems and ad-hoc protocols will act as attractors by stimulating the development of new applications that are more flexible and adaptable to the environment than current ones. Today's cutting edge research is partially based on "smart dust" and "viral communication". Both concepts have in common the vision that communication is evolving towards an "infrastructure-less" infrastructure or at least one without a central point and a central authority. If successful, micro-kernels and ad-hoc protocols are poised to change dramatically the way we look at communications infrastructures. By the end of this decade, they will probably contribute to the creation of new business opportunities at the edge of the network structure where most of the value will be located.

Disruptive developments and implications of ICT on value chains

The above mentioned attractors are important technologies to 'keep an eye on' when discussing and assessing the likelihood of important disruptive processes, but they are not the only ones. A disruptive element may also result from the systemic nature of ICT as a body, rather than from the increasing importance of one single determinant. Such disruptive developments require that an important technological contribution is absorbed by a favourable socio-economic environment, i.e. there is a market demand which can be enabled though ICT, providing a considerable impact on the industry. An interesting view is to understand how future ICT development may change the way we do things in services and production. Understanding the potential impacts on the value chain is of great importance since it leads to macro economic implications for the European business fabric and leads to the definition of strategic initiatives to fill gaps (e.g. in education), promote investments (e.g. in infrastructure), revise the regulatory framework and look into societal, ethical aspects. With this reasoning in mind, FISTERA tried to identify in the various FISTERA conferences and workshops a number of developments where ICT can introduce a 'disruptive' element. A number of such developments were identified and these are briefly introduced in the following paragraphs:

a) *'From product to services'*. Manufacturers aim to make money not only by selling products, but also by selling services afterwards. They aim to skip –as much as possible- the distribution and supply chain and deliver services (and products) directly to the end-user. In doing so, some manufacturers also create a platform enabling third parties to offer new services. Distribution and supply chains become a link, rather than a 'de-coupler'. Today, the current manufacturing industry is largely not prepared to deal with end users, or to create and maintain fluent contact with them. Outsourcing will require a different approach. The present use of call centres is generating angst rather than creating business opportunities. They have been set up as a way of reducing cost but the quality of relationship with the clients has deteriorated. They will require novel technology to deliver better relationships and become business generators.

b) *'The disappearance of the personal computer'.* The embedding of microchips able to communicate with the environment opens up the opportunity to transform the ambient and our relation with it. This ambient does not just become richer in services; it can also be used as a platform for service delivery. The ambient becomes, at the same time, a network and (aggregated) terminal(s). Both the variety of existing production industries and the service industry need to adapt their view of the market in these terms. The transformation of the ambient (both physical and virtual) is possibly the single most important factor in the business changes lying ahead.

c) *Ubiquitous seamless communication.* Providing connectivity devices in potentially every object and ambient will accelerate the fading away of the need for traditional infrastructures to communicate. At the same time, the increasing access to infrastructure will reduce prices, changing the perception of cost to the user. Bundling of communications access has started and will become a common reality in the next decade all over Europe.

The service industry is likely to embed communications in their services and users will consider communications as a standard feature of any service. They will pay for services, rather than communications. Most value chains will embed communications as a supporting feature. The usual relationship between a client using communications facilities and the operator providing them will fade away for most services.

d) *Changing traffic pattern*. Upcoming 'always on' services, like video demand or transaction, will change the data traffic pattern of the networks. This will have a significant impact on communication providers as they will have to readjust their architectures to the new traffic patterns. From a perceptual view point, infrastructure will provide steady always-on connectivity that will be paid for as such, while transaction support tariffs based on usage (charge per transaction based on a variety of parameters) and service-based tariffing.

Many services of today, like voice communications, will shift from a transaction-oriented tariffing (where time is the measuring stick) to 'always on' connectivity. The implementation of service-based tariffing requires the integration of concepts such as virtual networks, environment, application, content and information from a business model point of view. The regulatory framework will have a substantial impact in this area, stimulating or hampering the pace of this evolution.

e) *Unlimited bandwidth*. In the past, storage was a scarce resource and thus expensive. Now that prices have fallen drastically, the perception of the use of storage has completely changed ('as it is so cheap, simply buy more when you need it). Similarly, with practically unlimited bandwidth, the end user will show a kind of 'indifference' to the actual size of the bandwidth and the consumer focus will be more directed to the pricing, than the bandwidth itself.

Unlimited bandwidth will provide completely new business opportunities, based on the commoditisation of bandwidth, low prices and the possibility of bit-based distribution services. These opportunities will not arise from exploiting bandwidth but from the services themselves (In analogy with road: The main business is not the motorway toll, but business generated through traffic). This represents a cultural change for telecom operators, who –in the past- have been investing and exploiting increasingly powerful infrastructures. But the time may come when they exceed demand and the new drive should be to make them "more convenient" so that people linger with them. In road infrastructures, this translates into service areas, parking facilities, etc. In telecom infrastructures, this can translate into data management, data repository, platforms for service aggregation, etc.

f) *Disposable products*. Progress in manufacturing and the volume of scale is driving prices down. At the same time, the speed of innovation is shortening the life cycle of products. This combines in increasing the number of products that will be designed and marketed to serve a specific function at a specific time.

Companies will progressively adopt these products, particularly in some service areas where the (low) price of the product can be hidden in the price of the service. On the manufacturing side, there will be a push towards generating higher volumes and selling on many markets. This in turn will probably shift some of the functionality outside of the product and, at the same time, increase the requirement for flexibility to customise the product to specific markets (geographical, application, vertical).

g) *From content to packaging*. The rise of massive content production in the private, public and business sectors and the ease with which it can be accessed, is threatening content producers. This abundance of unstructured content is shifting value towards those services that can retrieve specific information from the multitude, customise it and deliver it in the form that is most suitable for a specific use. Today, Google-like companies seem in the best position to leverage benefits from the abundance of content. Other companies that offer good packaging of content (like Apple's iPod) may also leverage on content availability.

The packaging business, both physical packaging and virtual packaging (based on user profiling), will become very important. Software technologies as well as an appropriate regulatory framework are essential. The regulatory framework needs to take into account privacy and ownership aspects. In view of ongoing globalisation, policies should be applicable on a trans-national level. The current treatment of digital rights management is

Table 6: Possible ICT-based disruptions

'Disruption'	Technology Enabling Factors	Market Pull Factors	Impact on Industry
Transformation of products into services	Embedding of communications capabilities into any product; competitive advantage derives from profiling, cheaper manufacturing	Products are becoming commodities; loss of differentiation capabilities, increased copycat possibilities	Enterprises become service companies; Shortening of product's life cycle, Strong increase of call centres; More global market, Restructuring of the value chain
The disappearance of the computer	Diminished processing cost; System on chip; Wearable computers; Increased connectivity and ubiquitous access	Need to increase volumes; Need to increase flexibility; Need to provide easier access to functions	Skill to exploit increased processing capabilities in any object; New level of competence required; New actors and competitors in the value chain
Ubiquitous seamless communication	Increased connection capabilities for any object as result of object capabilities and access points availability; Ubiquitous, seamless communications infrastructures leveraging on WiFi, UWB, Multimode terminals, WPAN; Wireless broadband; Increased local storage; Agents technology; Intelligent Ambient; Mixed Virtual Reality Software radio	Mature market drifting toward flat rate; Demand for transparency; Drive to decrease cost; Bundling communications into services and goods; Globalisation of business; increased circulation of people; Leveraging global investment;	Shift from connectivity to service; Bundling of services; Seamless service hopping; Crucial importance of profiling; Embedded connectivity demand; Increasing opportunity to offer new services Telecom Operators see a growth of competition with a growing loss of the network ownership advantage; Emergence of Virtual Telecom Operators; Computer industry used as underlying platform
Changing traffic pattern	Huge amount of local storage; Sensors, tags; Digital Camera, Camcorder; Agent communications	Growth of peer to peer as content production is more and more dispersed and shared; Flat rate and always-on tariffs	Push towards the transition from ADSL to VDSL; Push towards optical access; Always on, ubiquitous wireless access and seamless connectivity across access points
Unlimited bandwidth	Advances in propagation studies; Terminals as network nodes; Cognitive radio; Software radio; Mesh Networks	Need for ubiquitous connectivity; Variety of local access operators; Great variety in traffic demand	Incumbent Mobile Operators; New Mobile Operators; Service and Product industry; Regulatory Framework
Disposable products	Diminishing cost of production "per item"; Increased flexibility and customisation; Long lasting batteries; on-site production; Short range embedded connectivity	Faster pace of evolution for fashion and design; Shift from products to services; Function oriented interface	Evolution in the value chain; Faster evolution life cycle; Evolution in customer care; Recycling as a problem: as part of production and as a service
From content to packaging	Diminished cost of content production; Consumers' based content production; Information as a "by product"; Multimedia and multimode; Profiling	Abundance of information; Need to get rid of information; Difficulty in controlling the ownership of content	Reshaping of the content industry shifting towards content bundled into services; Rise of the packaging industry; Ambiguity in the telecommunications industry biz to be resolved

likely to change in the next decade and the regulatory provisions of today will need to be reconsidered.

The developments presented above are likely to affect the business value chains if technological progress in ICT goes along with a market pull responding to user needs. Table 6 summarizes the enabling technologies and the market pull effects for each of the seven developments. How both these factors are likely to impact on industry is shown in the last column.

5.1. From options to priorities

With the help of the technology trajectories concept, FISTERA identified promising technologies. Some of these are considered to be 'disruptive', meaning that their application may well lead to profound changes in technological systems as we know them today. For a well-known example, the use of 3rd generation mobile communications has the potential to alter business models, ways of working and acting and to change the mind set of people with respect to concepts such as working environment, leisure and gaming. As a more long-term example, 'disruptive' technologies might result from a convergence between several diverse technological trajectories: for instance, the fusions of elements of Nanotechnology, Biotechnology, Information Technology and Cognitive Sciences (the NBIC Quartet). These are just two of a range of crucial technology trends. In a consultation meeting FISTERA presented all options mentioned in the previous paragraphs and left experts the possibility to add topics or modify (e.g. cluster) options provided by FISTERA.

From this event, FISTERA extracted four top technological developments with the potential to become critical for shaping the priorities of the European IST future. They are: the 'NBIC convergence paradigm', the trend from 'products to services', the 'emergence of intelligent terminals', and the development and use of 'embedded systems'. These four were supposed to have significant impact on the market, provided that important R&D challenges were overcome. Decision makers would have to consider important policy issues in order to make this happen. Table 7 gives a brief overview of the implications of these four technological developments for the subjects. Each of the four technology priorities is then described.

Converging applications

Converging technologies is a term used in literature to capture sciences and technologies that enable each other for the achievement of a common goal.[27] According to a strategy pursued by the US National Science Foundation, converging technologies usually refer to the

Table 7: IST developments and associated priorities

Priority/ Technology	Policy issues	Market issues	R&D issues
Converging Applicatons	Ethics/Public Awareness	Health/Medicine	Convergence between ICT and cognitive sciences and nanotechnology
From Products to Services	Procurement/Public eServices	Utility-type services	Communication/ delivery technology
Intelligent Terminals	Regulatory frameworks	'Bandwidth-on-Demand' /Tele-Services	Terminals as infrastructure/ greater processing capabilities
Embedded Systems	R&D Support	'Intelligent Ambients' /Smart Appliances	'System on Chip'/Chip storage, processing, sensing and communication capabilities

27 Nordmann, E. (2004): 'Converging Technologies – Shaping the Future of European Societies', Final Report of the High-Level Expert Group on Foresighting the New Technology Wave, Brussels.
28 'Converging Technologies for Improving Human Performance' Roco, M.C.; Bainbridge, W.S. (eds.) (2002), available at www.wtec.org/ConvergingTechnologies

cross-fertilisation between nanotechnology, biotechnology, information and communication technologies and cognitive sciences.[28] It is understood as a co-evolutionary process, where progress in one area accelerates progress in many others.

Applications arising from this co-evolutionary process promise huge economic benefits. FISTERA would like to emphasize that the impact is on Converging Applications (CA), i.e. the applications arising from the convergence of previously separated scientific disciplines and technologies, rather than on the technologies themselves. Many of these applications fit the ambient intelligence vision, i.e. a human-centred concept for the whole environment (at home, in hospitals, on the move, whilst driving or during transportation, etc.) with embedded intelligence that helps with everyday life. The impact of such applications would be even greater if "design for all" principles and usability were to prevail.

How the technologies converge and how this convergence may foster the rise of novel applications has been the subject of much debate in literature. Unfortunately, reliable quantitative data is scarce. In order to shed light on this subject, a recent IPTS sponsored consortium performed a bibliometric analysis with a view to understanding the areas where different sets of technologies (ICT-biotechnology, ICT-nanotechnology, etc.) intersect.[29] The analysis of scientific publications about the areas where information technologies and cognitive science intersect indicates high levels of activity in the following five areas:

- learning techniques, including machine learning, genetic algorithm, support vector machine, principle component analysis,
- imaging, including visualization,
- pattern recognition, including face recognition, speech recognition, object recognition,
- artificial cognitive systems, including artificial neural networks, expert systems, virtual reality, and
- information retrieval.

Similarly, biotechnology and ICT appear to converge around two major areas:

- The first area includes artificial neural networks, genetic algorithms, super vector machines, machine learning, pattern recognition, and gene expression. Possible applications include analysis of stained cell cultures and micro-array data, DNA tests for authentication of raw materials in meat products, development of patient-specific biomaterial scaffolds directly from computer tomography or magnetic resonance imaging data, dynamic modelling of bio-molecular interaction, computer-based molecular design, and computer aided tissue engineering.
- The second area comprises relational databases, databases, data mining, bioinformatics, and functional nucleotide sequences. Future applications include the identification of candidate disease genes with high performance computing, ribonucleic acid (RNA) expression profiles, web based tools for mining the national cancer institute database for anticancer drug discovery, and data mining the protein databank.

In the two areas mentioned above, biotechnology and ICT enhance each other. An even higher degree of enhancement occurs in non-invasive monitoring/diagnostic techniques, biosensors, biomarkers linked to smart ICT environments, lab-on-a-chip, factory-on-a-chip, functional brain-machine and brain-brain

29 "Converging Applications to Enable the Information Society" TNO, University of Leiden and VDI , IPTS EUR report, June 2006.

interfaces, virtual reality and augmented reality computer technology (which visualises the cell from inside: you can see what you are doing as you manipulate individual molecules), and biological / molecular computing.

With regard to the relationship between ICT and nanotechnology, strong links already exist in electronics, and are the result of miniaturization, where micro-electronic components have reduced down to the nano-scale dimension. Nano-electronic applications are already on the market, and nano-photonics, which benefit from ICT and nanotechnology, are an upcoming component wave. Further simulation and modelling in both ICT and nanotechnology research areas is needed for the development of future electronic and photonic components. Bibliometric analysis also indicates that "neural networks" and "image processing and pattern recognition," are promising application areas.

Converging applications may give Europe a good position in the development of medical implants, such as cochlear and retina implants. In the United Kingdom, a foresight programme on cognitive systems identified the national strongholds on a number of scientific fields. Robotics and sensory information processing were amongst the fields in which the UK has quite a good position. It differs from the Japanese and Korean Humanoid Robotics approach by not caring too much about the precise configuration of the robots, but focusing on the application areas (such as deep sea and outer space missions). In Germany, a foresight study called 'understanding thought processes' was engaged in the field of neuroscience. It underpinned the importance of artificial implants (particularly cochlear implants with an outlook on artificial retina implants) for Germany.

In view of changing demographics in Europe, demand is expected for devices for disabled and older citizens.[30] Examples are medical applications, such as cochlear or retina implants or treatments for neural disorders (e.g. Parkinson's disease or tremors). Although it is to be expected that there would be little debate on the ethics of such applications, there has been some debate on "the right to imperfection". Other applications, such as mood control or enhancement of memory and manipulation of brain functions are rather more controversial. Cognitive ergonomics is directed at enhancing the functionalities of human-machine interactions. It coincides with the need for better and more intelligent peripheral devices that can be used in ambient settings. Neuro-IST, the convergence of neuroscience and IST, is developing at an increasing speed. Brain imaging techniques, such as functional MRI, are combined with sophisticated machine learning techniques. This creates interesting information on the functioning of the human brain and its relation with specific disorders (such as Parkinson and autism).

From products to services

There are several indications pointing toward a transformation of products into services. Technologies (both those involved in production and those actually making up the product) are getting cheaper and cheaper. At the same time, accessibility to central management, distribution centres is becoming easier (and cheaper as well). This is enabling the transformation of products into services. Rather than selling hardware, companies are moving into providing hardware (at very low cost or even for free) to run the services. It is, in a way, the telecommunications operator's model. Car manufacturers are starting to sell services along with the car. Here the hardware is still too expensive to allow a full transition into a full service paradigm but the shift may start by the end of this decade and may have some effect by the end of the next one.

Information is "soft", as are applications, and this may eventually drive us towards a Service Society rather than a Product Society.

30 "Converging Applications for Active Ageing Policy", R Compañó, A-K Bock, JC Burgelman, M Cabrera, O. Da Costa, P Mattsson, N Malanowski, Foresight Journal, April 2006.

Mass production enabled by the production chain is giving way to a "personal" mass production, enabled on the one hand by the greater flexibility of the production processes and, on the other hand, by the surplus capability embedded in many products letting users customise them to their needs. These two factors are still difficult to manage (ordering process, personal customisation, etc.) and do not meet dynamically changing possibilities (on the producer side) and needs (on the user side). The step towards a service paradigm would address these aspects, disrupting, at the same time, whole value chains.

In order to advance the service model over the product model, a number of technological priorities will have to be met. First of all, it seems essential to embed communication capabilities in any product that makes it possible to keep an open line with the user. This open line will then be exploited both to deliver the service (added value services to the original product) and to increase the market opportunities. Second, there will be a rise of profiling technologies that enable a shift from a marketing targeted profile to a function delivery targeted profile. The emergence of Radio Frequency Identification is a key asset in this respect, enabling the provision of after sales information to the client and, in the longer future, enabling direct communication links by way of Near Field Communication devices. A third priority is related to the decreasing value of production processes, squeezing the value of the objects produced (an example is printing on demand in 3D). These production processes will have to be marketed more as services than as products.

Europe has a good tradition in services. However, the services it offers through telecommunications infrastructures are –in average- less developed than those offered by the US. Here there are two issues to be tackled. On the one hand, the culture of using e-services is less widespread in Europe than in the USA. Hence we might expect a slower uptake of e-services and therefore lower European competitiveness. On the other hand, e-services by their nature can be offered from far away by companies leveraging on their better production technology (USA) or lower labour cost (East Asia).

The shift from products to services may affect various kinds of market sectors, both in the public sector and in the private sector. Examples in the public sector are the health care services (including preventive care, telemedicine, drugs delivery/monitoring) and education (books and tutorials may be bundled into a service). Examples in the private sector affected by this trend are: the entertainment sector including music and movies (where an important role within the value chain is coping with piracy aspects); public, private and goods transportation (in goods transportation especially the distribution chain may change considerably); and consumer appliances (cell phones with targeted services; digital video recorders, etc.). In all cases, the value chain will change, putting a premium on services that can be offered through purchased goods more than in the purchasing power itself.

Unlimited bandwidth and terminals as network infrastructure

This technological development is related to the increasing importance of intelligent terminals, over intelligent infrastructures. It used to be that terminals were low cost appliances with very limited local capabilities. Their evolution was basically steered by the network they were supposed to interface. The embedding of communications capability in any object is transforming them into "terminals", changing significantly the perception of what a terminal is from the user's point of view.

The implication of this change is twofold: on the network side, the number of terminals is increasing exponentially and their functionality is no longer a decision of the network (the network is no longer an enabler for terminals). On the user side, the terminal is much more important in terms of the functionality provided and how this is provided than the connectivity it offers. The network is not just hidden to the user, it is not intermediated. A terminal in the future will be able to decide which network to use, most of the time in a completely transparent way to the user. Already a cellular user is no longer able to determine if the connection happens through a GSM, EDGE or UMTS network, and basically he does not care. Evolution of services and "culture" is now led by terminal evolution. Operators need to understand how terminals are going to evolve in order to plan the evolution of their networks. In the longer term (i.e. the next decade), the terminals may create themselves a communications infrastructure, making the classic telecommunications infrastructure of today even less relevant.

In order to advance the model of (intelligent) terminals in network infrastructure, several technological developments become priority areas for IST research in Europe. First of all, there is a need for advances in theoretical studies on propagation that deal with interference problems and with the trade-off between reasonable calculation times and required processing power.

Second, the terminal as a network node requires increased processing capacity within the terminals (as well as improved storage and battery). There is a trend towards multimodal terminals able to deal with varying networks at once. On the software side, the development of cognitive radio with intelligent antennas will provide increased opportunity to use the spectrum while 'reducing' interference by the end of this decade. This could possibly solve the issue at the base station side by the end of the next decade. The software radio may provide an intermediate solution to increase the utilization of the radio spectrum by dynamic frequency use.

Third, from a market perspective, the need for ubiquitous connectivity will steer us towards solutions providing 'bandwidth on demand', which in turn will require flexible reallocation of the spectrum. Yet, the emergence of a variety of local operators makes pre-allocation of spectrum an increasingly complex issue. The unlimited availability of spectrum will decrease the appeal for new mobile operators to enter the 'carrier' spectrum. This issue needs to be resolved.

Fourth, the great variety in traffic demand, both in quantity and in quality (e.g. transaction based and high volume burst) demands a more flexible spectrum usage. On the side of the terminals, Europe has some strengths in appliances and in terminals but is losing ground to East Asia, particularly South Korea, Taiwan and Malaysia, and to a lesser extent to Japan. The USA may lead in some basic technologies (e.g. terminal components) and in certain new kinds of terminal devices like sensors. China, however, is also about to become a powerful player. In view of these developments, the current outsourcing of terminal manufacturing and design to East Asian companies may turn into a problem over the coming five years when the economic exploitation of the emerging technology areas becomes a reality. Europe may by then have lost its capacity to manufacture latest generation terminals.

These technological developments are also priority areas because of their impact on European competitiveness, especially with regards to the change of business value from infrastructure to the services provided over the infrastructure. The consequences for this change have been spelled out earlier. Regulatory frameworks will both act as facilitators for this disruption and be deeply affected by its occurrence. Finally, the service and product industry can leverage from the spectrum availability and can be transformed by embedding of communications into every service and product.

It is worth mentioning some of the possible links between such technological and market developments with the social needs mentioned later in this chapter. The healthcare system, for instance, will be revolutionised by tele-consulting and monitoring options. 'Independent Living Services' for ageing people will use the communications capabilities for tele-operations and safety and security services, which are remotely operated. Other sectors will expand through the increased availability of communication facilities, ranging from tele-learning options to environmental monitoring.

Embedded systems and the "disappearance" of computers

For every PC sold, there are more than 100 microprocessors being embedded in other everyday objects, from television remote controls, to wrist watches, hotel room locks, etc. This is nothing with respect to what is likely to happen in the next 5 to 10 years. The ratio of microprocessors produced versus those employed in a PC will skyrocket. Additionally, the PCs themselves are going to become less and less conspicuous, fading into the background. As new appliances will embed connectivity and processing capabilities, and they will seamless interconnect with each other making it possible to display information on the most appropriate device (a television for a video clip, a personal screen for "that" particular clip, a cell phone screen for an e-mail, a Bluetooth enabled earphone for music or voice messages, etc.), the PC will disappear from sight.

At the same time, the appearance of storage, processing, sensing and communication capabilities in every day object and in the environment will create tremendous opportunities for new services. The continuously decreasing cost of computation, along with new technology allowing the packaging within a single chip of storage, computation, communications and ambient interfacing (sensors and actuators) is leading to a significant change in the way objects provide their functionality. More and more of this can be electronic-based, thus supporting greater flexibility, adaptation to users and ambient instantaneous needs, and remote control. Any objects can become a terminal to deliver services.

This technological transformation, and the growth of embedding systems, which are expected to progress in synergy with the transformation of products into services and with the increasing role of terminals, becomes a European technological priority. As objects embed more and more function and technology, producers need to grasp this new technology. Those that are left behind will be ousted from the market. The drive towards an intelligent ambient depends on the availability of embedded systems, percolating into the ambient. Embedded systems may, in the long term, become an infrastructure to be exploited by a variety of businesses. This requires the establishment of platforms, standards, local and long distance connectivity. All of this can be fostered by appropriate actions at European level. With respect to embedded systems, Europe has some strength in basic technologies, like MEMS, and communications, but is lagging behind in microelectronics (processing) and integration of communications and processing. Europe may have a significant role in establishing standards and fostering platforms.

Many market sectors will be affected by these technological developments (or disruptions). The enabling characteristics of embedded systems will contribute to the realisation of the 'Ambient Intelligence' vision. For example, the household environment will behave 'intelligently' as a result of appliances embedded increased processing capacities and communication facilities. Control of the environment will be heavily based on intelligent processing and communication enabled artefacts (intelligent video cameras on power lines, illumination poles, etc.). Europe has a few big players in this domain (e.g. ST and Philips), but an important role might also be played by major telecom operators if they can find a way of working together to define standards. Europe should focus its efforts on the development of platforms, the establishment of cooperative projects which raise the awareness of the importance of embedded systems in any business, and the provision of field trials, to gain a better understanding of user requirements.

Market-driven technological priorities can be characterized in terms of three needs. First, there is a need to increase volumes in order to ensure the widespread embedding of PCs in everyday objects. Second, there is a need to increase flexibility in the usage of objects which will foster the embedding of processing power inside many of them. Third, the need to provide easier use of objects demands modes of interaction design with one object, one design, and one function. Embedded processing power can provide the necessary interface user-friendliness and give the objects the capability to understand their users' needs and adapt to them.

These topics comprise FISTERA's selected choice of four technological priorities. Other areas also deserve an important analysis. Additionally, in view of the fact that ICT is a highly dynamic field, the list of technological priorities need to be revised regularly. For this purpose the FISTERA technology database is regularly updated online and in-depth discussion on important technological trends are presented and discussed in FISTERA reports. Technological trends, together with socio-economic goals, need to be assessed against Europe's capacity to perform R&D in the respective technology fields and the capability to transform this research into usable outcomes for the economy and society. The performance of the R&D system in Europe is discussed in the following chapter.

6. The Performance of the European R&D System in ICT

A European vision for the future was presented in Chapter 2. It was discussed in the light of changing societal needs and trends (Chapter 3) and how future ICT can contribute to it (see Chapter 5). This Chapter analyses Europe's position in R&D by technologies and at national level. It looks at the performance of enterprises, industries and countries in ICT. It aims to identify the existing strengths and weakness in R&D and from there, to draw conclusions on the absorptive capacity of the already existing infrastructure and its flexibility to adapt to a changing and increasingly competitive environment.

The work is largely based on a patent analysis and complemented by a short discussion of the research strategies of leading research laboratories in Europe. Patent analysis is one way to get facts about a nation's techno-economic competitiveness. In this Chapter, FISTERA uses patents as one indicator in a comparison of the European Union with the United States, Japan (these three are sometimes called the Triade) and other countries in the world. We will first draw the broad picture by comparing Europe's patterns of specialisation to those of the US and Japan, and then move to the level of specific technologies to analyse who the main players at company level are. ICT-producing industries and their exports have a noticeable influence on growth in some countries, like Finland or Sweden. However, economists still expect the major contribution of ICT for economic growth to come from productivity, although there are major controversies as to whether productivity is an appropriate measure in a knowledge-based economy and which other indicators would be more suitable. The application of ICT in all sectors of the economy may, by increasing labour productivity, raise Europe's overall wealth. By increasing the extent to which ICT is applied, European policy may help to maximise these benefits from ICT.

A patent is an intellectual property right issued to protect technological inventions. By granting exploitation rights to inventors, the patent system stimulates innovation and technological creativity. Patents are the outcome of innovation and are, therefore, expected to be economically valuable in one way or another; either exploiting them or by preventing competitors from doing so. Therefore, patents reflect the competitive dimension of technological change. With the unified classification scheme of World Intellectual Property Organization (WIPO), developments for countries can be followed over time.[31]

Patent analysis, however, also has some important limitations as an indicator of technological change. First, not all inventions are patentable. Although some patent offices have enlarged their patentability criteria, innovative activities in some important technological sectors of ICT, like software or services, may not be adequately reflected by patent statistics. Second, it is up to the inventor to apply for a patent or rely on other means of protection, like secrecy. We know that the propensity to patent varies considerably between sectors, even if these sectors have a similar rate of innovative activities.

FISTERA follows the OECD concept of the *Triadic patent families, i.e.* patents filed at three patent offices: the US Patent and Trademark Office, the European Patent Office and the Japanese Patent Office. ICTs are not a single group of technologies in the International Patent Classification (IPC),[32] but span a number of

31 The International Patent Classification (IPC) of the WIPO is much more detailed than the classification scheme for publications (Science Citation Index) or industrial activities (NACE).

32 http://www.wipo.int/classifications/fulltext/new_ipc/

groups. FISTERA used 18 broad technology categories; each of these technologies consists of at least one class of the International Patent Classification.[33] The following table presents the number of patents for selected technologies during the period 1995 to 1998:

Table 8: Technology categories in ICT, and average number of patent applications in these categories, world-wide and EU25, average 1995-1998, application date. Source: OECD, Triadic Patent Families Database, own calculations[34]

Fistera Technology Classification	Number of new patent applications, 1995-1998	
	World	EU25
Processing	3,284	582
Communication	3,062	886
Storage	628	88
Visualisation	543	104
Sensors	487	88
Printer technologies	400	38
Batteries	355	63
Encryption	81	18
Positioning	17	5
Total ICT patents	8,822	1,847

Empirical analysis at national level[35]

ICT patent applications have more than doubled between 1984 and 1989, followed by a small decrease at the beginning of the 1990s and again ramping up during the New Economy boom of the late 1990s. The latest patents in the OECD patents dataset refer to 2002 (their number is still small - about 800 ICT patents, compared to 32,000 in 1999). Over a longer time line, the number of ICT patent has grown steadily in the US, Japan and Europe since the 1980s, from 1,649 applications in 1980 and to 8,800 in 1998. In the second half of the 1990s, the US applied for, on average, 3,700 ICT patents per year followed by Japan (2,800) and Europe (1,800). Generally speaking, ICT technologies represent a higher share in the technological output worldwide. While ICT patents accounted for only 15% in 1984, they rose to 24% in 1996 worldwide. For Europe, ICT patents accounted for 18% in 1998, compared to a share of 10% in the mid-1980s.

In relative terms, Europe raised its share for ICT from 10% (1990) to 19% in 1998 at the cost of Japan and the US. All other countries, including Switzerland, India, China and Korea, together apply for no more that 5% of all new patents. Assuming a link between technological capabilities and competitive position, Europe seems to have increased its competitiveness in ICT over the past 15 years.

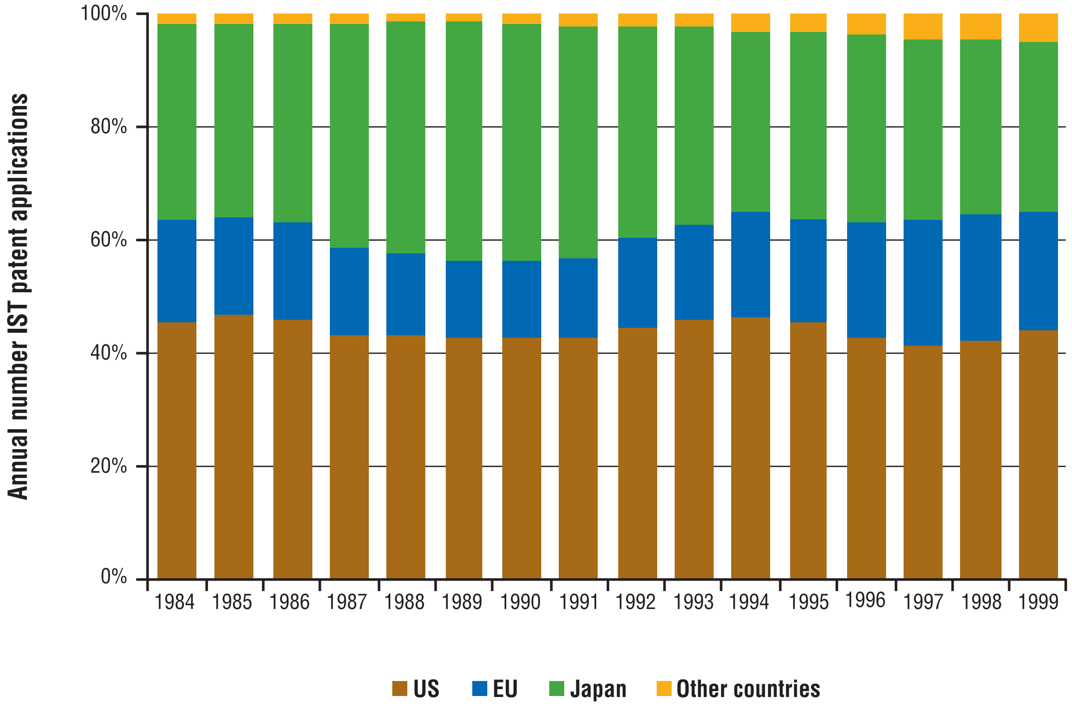
The increase of ICT patent applications was uneven throughout the EU Member States. Nordic countries and other small and medium countries like the Netherlands, Belgium or Austria, increased their rate of annual applications considerably. These countries are the main drivers for Europe's rising share in ICT world patents in the 1990s. The patent share of small and mid-sized countries with respect to all European activity increased from 10% in the mid 1980s to 45% by the end of the millennium. In contrast, the three largest applicant countries together - the UK, Germany and France - decreased their share of the European total from over 80% to 50% over the same period. Patent applications in ICT have stagnated or even declined in France, Great Britain and the Mediterranean countries (Italy, Spain, Portugal, and Greece). Very few patents are owned by companies (or individuals) from New Member States and Candidate Countries (NMS/CC).[37]

33 "Europe's strengths and weaknesses in Information Society Technologies: A Patent Analysis". Dachs, B. and Zahradnik, G. (2004) FISTERA Report, Vienna.

34 As some patents belong to more than one technological category the numbers of the classes add up to more than the total number of ICT patent applications.

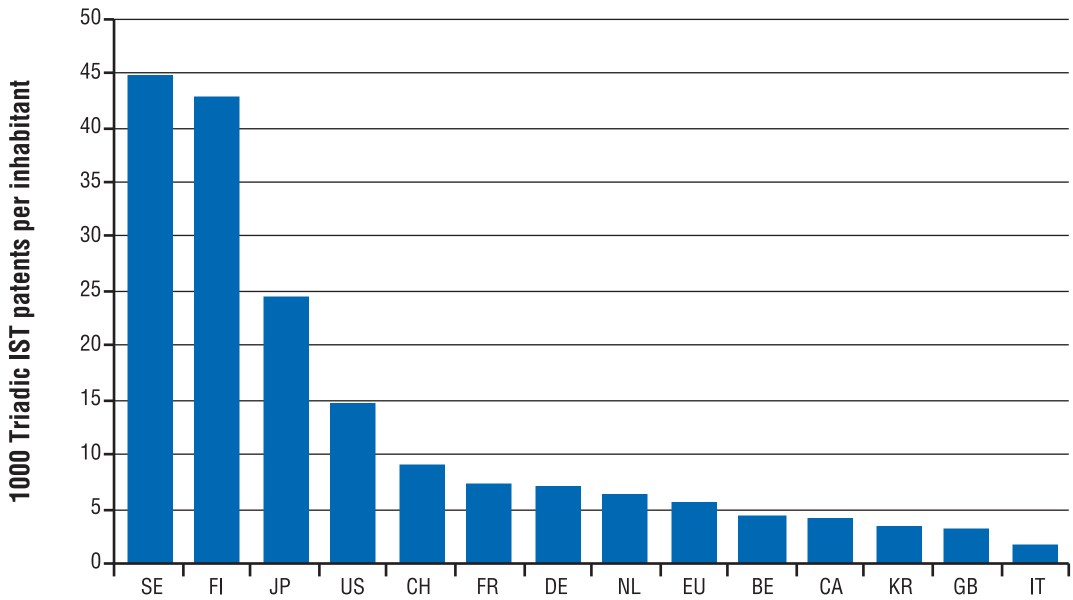
35 Patent statistics have been compiled according to the ownership of patents. This supports the best view that technology is an asset contributing to the competitiveness of firms. As reference date, the priority date has been selected which is closest to the invention.

Figure 8: *Share of different countries in annual patent applications in Information Society Technologies, 1984-2000, application date*[36]



However, given the traditionally strong potential in ICT science and engineering, the NMS/CC are interesting locations for performing ICT research. Enterprises like Ericsson, General Electric, Nokia, Samsung, or Knorr Bremse have –for instance- set-up considerable research activities in Hungary. So far, the fruits of R&D activities in the NMS/CC have not shown up in patent statistics and sometimes patents are filed in the country of the headquarters.

Figure 9: Number of ICT patent applications related to the countries' population, 1997. Source: OECD, Triadic Patent Families Database, own calculations



36 Source: OECD, Triadic Patent Families Database, own calculations.
37 Following the OECD Triad ICT patents.

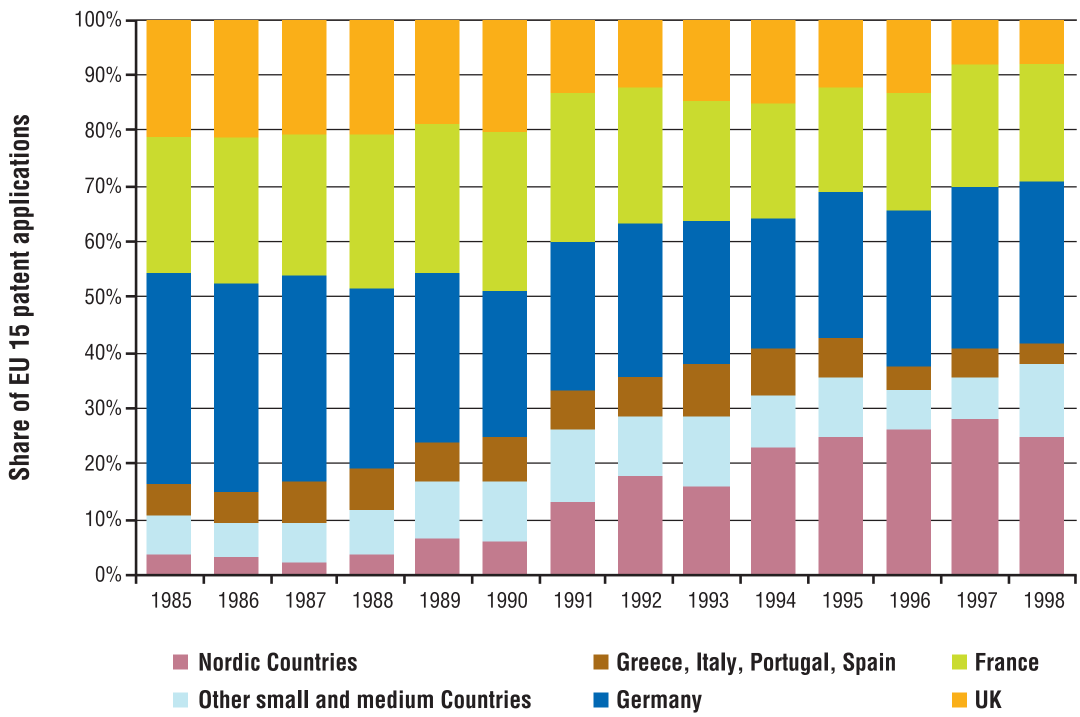
To summarise, it can be stated that the rise of IST is remarkable, both worldwide and in Europe. It is a clear indicator of the rapid diffusion of IST and points also to its systemic nature that penetrates every field of modern life. The fact that it took only a couple of decades to increase considerably its share of total patent activity is uncommon as technological specialisation generally changes only slowly over time.[38]

Europe's position in various technologies

There is considerable inertia when changing specialisation. This is important when trying to catch-up in promising fields. First, it is worthwhile assessing Europe's strengths in terms of technological strengths. For this, FISTERA calculated the Revealed Technological Advantage (RTA),[40] which measures a nation's specialisation in relative terms, i.e. by relating to that of the whole world. Specialisation can be determined by the ratio of the number of patents (of a country or firm) with respect to all patents (of the company or country).[41] An RTA value of 1 indicates that the ICT specialisation for Europe equals the average patent applications in the world. When RTA is greater than 1, this indicates that Europe is stronger (more specialised in the ICT) as compared with the rest of the world (basically the US and Japan) and when it is smaller than 1, then it is weaker.

Figure 11 gives the RTA, i.e. the relative strength in particular technologies, for a specific period in time. According to this RTA analysis, Europe's strengths are mostly technologies related to communication, while processing technologies seem to be the major weakness. Moreover, fields like sensors, batteries, storage, or printing technologies are also weaker than the world average.

Figure 10: Share of the member states in all new patent applications in the EU15, 1985–1999[39]



38 The two German states, for example, although separated for a long period, shared most of their technological specialisation over time. Or, like Grupp and Hinze phrased it "40 years of division were not sufficient for a differentiated development of the basic specialisation patterns of research".

39 Source: OECD, Triadic Patent Families Database, own calculations.

40 RTA is the share of a certain technology of a country on all patent applications of the country, divided by the share this technology has on all patent applications world-wide.

41 A firm can be considered highly specialized in a certain technology domain if it holds a large share on its technology portfolio.

Figure 11: Europe's Revealed Technological Advantage (RTA) for various fields of ICT. The data averages the period 1996-1998[42]

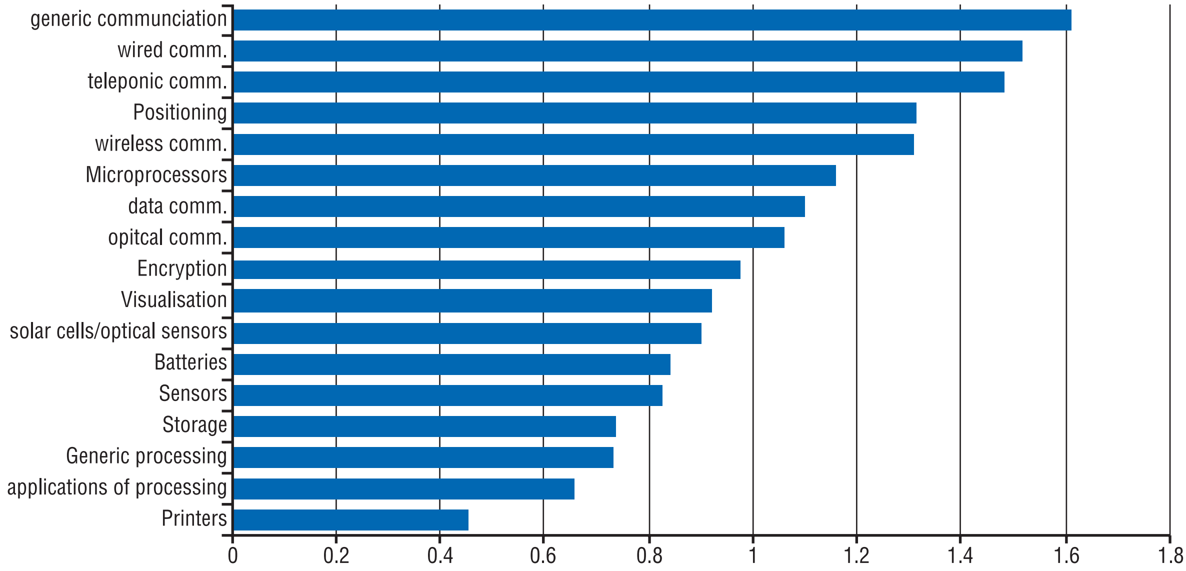
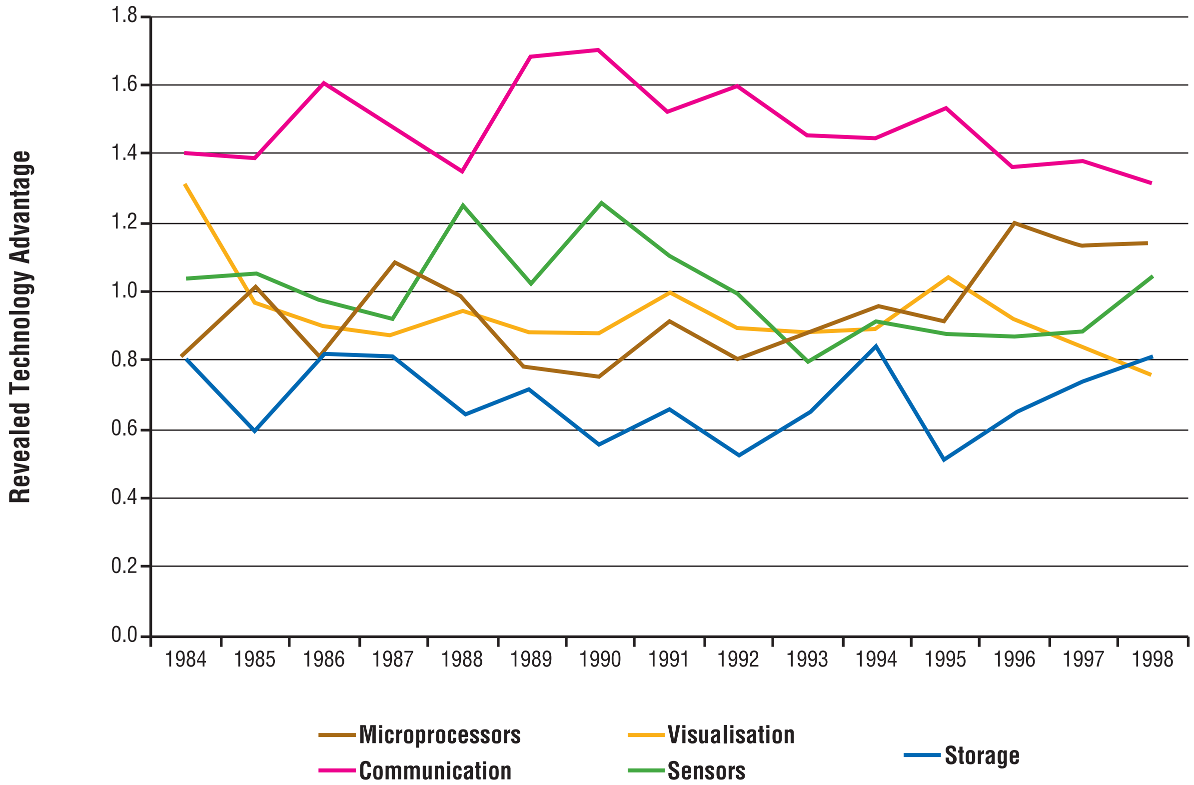


Figure 12: Revealed Technological Advantage (RTA) of Europe in five fields of ICT, 1984-1999 priority dates[43]

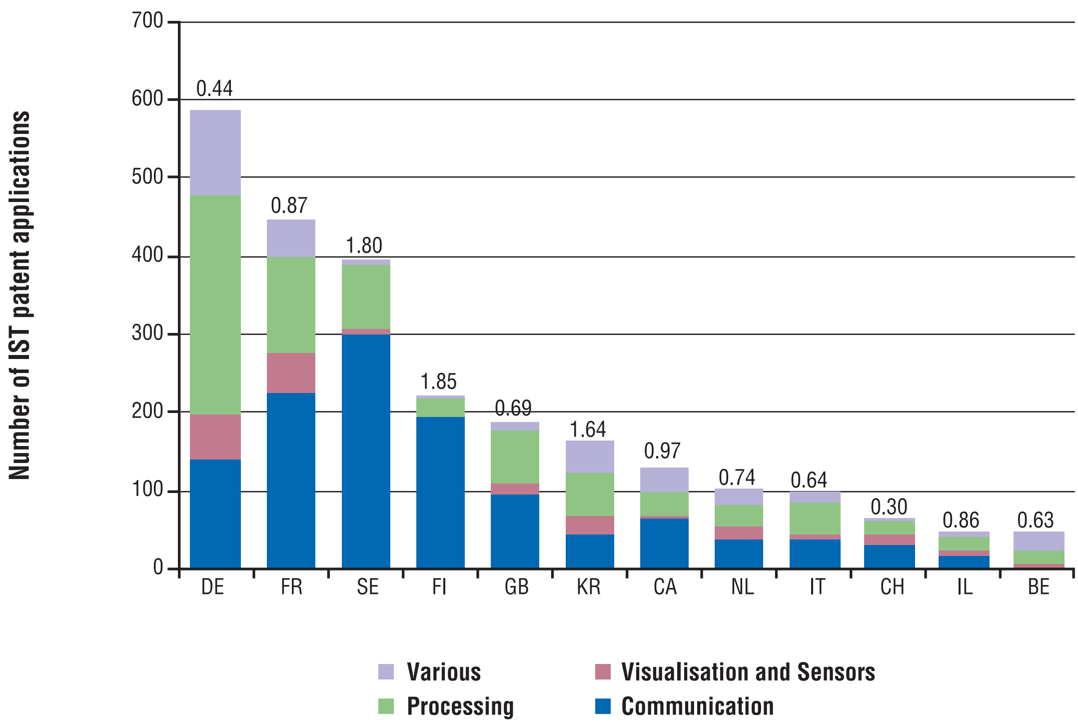


42 Source: OECD, Triadic Patent Families Database, own calculations.
43 Source: OECD, Triadic Patent Families Database, own calculations.

How RTA changes over time for microprocessors, sensors, visualization techniques, and technologies for communication and storage is presented in *Figure 12*. These five technology clusters are expected to be important in the future. Note that the evolution of specialisation patterns is remarkably stable for all five clusters of technologies irrespective of the level of RTA. The fact that a number of important breakthroughs and new technological progress have occurred since 1984 has not resulted in any drastic change in the stability of these curves.

Though this stability is an asset for countries wanting to maintain an established leadership, it can represent a considerable hurdle for new or weak entrants. In view of this inertia, establishing a consolidated and effective R&D capacity is a kind of guarantee for long-term impact, as it tends to be easier to adapt dynamic R&D structures rather than build them from scratch. As an example, we can say that Europe has 'always' been good in communication technologies, not just since the beginning of the 1990s. This knowledge could be exploited advantageously in times of mobile communications. Similarly, Europe's weakness in storage and processing has been a persistent phenomenon, which, in the case of microprocessors has started to turn around over the past few years, due to massive and committed effort. In the this particular case, the role of the member states and the regions (particularly Dresden and Grenoble) has been decisive, but it would be interesting to also examine in more detail the contribution of EU policies to this catching up process. In general terms, this confirms the argument that tomorrow's strengths will to a large extent build on today's specialisation patterns.

Figure 13: Number of ICT patent applications in various fields and share of ICT patents on all national applications and RTA value (value on top of the column), 1997. Source: OECD, Triadic Patent Families Database and own calculations



44 It may be assumed that a considerable part of non-communication patents are indirectly related to the communication field, e.g. processing technologies applied in data switching. It confirms other findings in other domains that the technological competences of firms, measured by patent applications, are often broader than the range of technologies that become manifest in their products.

Which countries are strong in Europe? *Figure 13* gives a partial answer to this question. It gives the number of ICT patents for selected countries by main technology categories for the year 1997. Not surprisingly, Finland and Sweden are amongst the nations with the highest specialisation in ICT in the world. These two countries are also powerful in absolute terms, offering the third and fourth highest number of ICT patents in the EU. Finland and Sweden owe their rank largely to communication technologies. Without communication technologies, Finland would rank at the level as Italy or Switzerland in numbers of new patents.[44] It is worth noticing that Finland and Sweden are the only two European countries with an RTA greater than 1; all other European countries are less specialised in ICT. In 1997, Europe as a whole had an RTA of 0.75. Even Germany, which applies for the largest number of ICT patents in Europe, has a quite low value of 0.44, which shows that this country is more specialised in technologies other than ICT.

Communication technologies are the field where Europe performs better than Japan and the US. This specialisation explains Europe's 'catching-up' in the 1990s which is the result of two connected trends: (a) communication technologies increased the share of all ICT patents, rising from 24% (1984) to 35% (1998), and (b) Europe has been highly specialised in these emerging technologies and could win a competitive advantage from this. In 1997, nearly half the ICT patents filed in Europe originated from this field, compared to 32% in the US and 28% in Japan.

Europe was able to gain market share in ICT because firms engaged in the right technologies at the right time. Generally speaking, a country can reap the benefits from specializing early in a growing technology area, but a high degree of specialization also entails a big risk of being 'locked-in' to a given technology. There is evidence that patterns of specialisation in a technology become rigid through institutional, organisational and political interdependencies. These are difficult to overcome, even when technologies (and related industries) are approaching the end of their life cycle. Policy makers obviously wish to support transition towards a promising technology and industries, but there remains such a high level of uncertainty in the anticipation of realistic future markets that decision are complicated. Foresight and technology road mapping as applied in FISTERA may help to reduce uncertainties, structure future options and create shared visions.

7. Confronting FISTERA Results with National Foresight Studies

In Chapter 4, we presented Europe's vision for the knowledge society and the role of IST. FISTERA used foresight methodologies to offer new insights into trends and drivers. In Chapter 6, a number of technological trends were studied to identify technologies and applications that are supposed to play a major role with regard to societal needs and economic demands. The purpose of this chapter is to compare FISTERA results with the views of national foresight studies on IST. To this purpose, we will compare both critical technologies and applications and their use.

Key information and communication technologies

Generally speaking, the methodology and the depth of national foresight studies vary a great deal. For instance, the UK programme published a number of reports by panels and working groups which go into considerable depth in discussing technologies, while the German programme reports concentrate mainly on the four visions produced as the main result of the exercise, hardly discussing technological matters in the selection process preceding the production of visions. The Spanish studies very thoroughly discuss IT, while the French study is focused on a limited number of 'key technologies' (119 in total of which 30 belong to ICT). Foresight studies on New Member States and Candidate Countries[45] contains little on actual physical technologies, apart from the occasional mention of computer or mobile phone assembly, semiconductors or systems integration. Since these national foresight exercises employed a wide range of methods, there is no point in comparing them. The following brief summary gives, therefore, only quantitative information on technologies at a general level. Detailed information on the technologies for national case studies is available at the FISTERA web site. The following paragraphs contain some views on key technology extracted from the national foresight studies:

- *Intelligent agents* were mentioned in foresight studies from seven countries and *avatars* are discussed only once in the context of the Canadian S&T foresight project on coding (encryption). The German "Futur" report was the only one giving emphasis to *coding technology*, and in particular public key cryptography.
- *Networks and communications* were a prominent topic in most of the studies. The second Swedish Foresight Study Report describes networks as a pre-eminently valuable resource and the Rand report characterises high-speed, *all-optical networks* as a possible disrupter likely to change development in general. The *3rd generation* of mobile communications was addressed in most studies. *Antennas* were discussed in only two: Spain and Korea, and *bluetooth* in three. Optical fibre was mentioned as an important development in several studies, but in general the different types of communications technologies were usually addressed only in very few studies. Surprisingly, mobile phone *handsets* were mentioned explicitly only in the Korean study, and touched upon in the Swedish and Hungarian studies. With respect to bandwidth, it is worth mentioning that it is addressed in the majority of European and Asian studies, but it does not seem to be as

45 Skulimowski, A.M.J. (2005): Framing New Member States and Candidate Countries Information Society Insights' in 'Prospects for a Knowledge-based Society in the New Member States and Candidate Countries', EAR, Bucharest 2006 ISBN 973-27-1379-4

much of an issue in the two North American countries.

- The Korean and Japanese foresight studies mention *multimedia portable terminals* as a future key technology. European studies hardly mention such devices explicitly, but there is mention of personal digital assistants (France, Spain, Sweden) or notebooks or laptop computers (the UK). New types of physically flexible notebooks are mentioned as a likely development in the Japanese Delphi Study. One of the US studies also mentions card-sized telecommunication appliances.

- Display technology is mentioned in several studies, referring to a variety of types, from large *screens* (UK, Japan, Korea, and Canada) over flat screens (UK, France) to 3D screens (Japan). Interesting to mention is the Japanese foresight study that addresses the possibility of recycling as much as 90% of screens for reuse and the Canadian pilot study on holographic displays.

- *Processing power* is expected to become a commodity (UK foresight). It will therefore be necessary to think what to do with the abundant capacities that will be available (Japan). This vision is supported by several studies which assume the validity of "Moore's Law". There seems to be a consensus that it will continue for another 15 years, by which time other technologies are expected to have made sufficient headway to replace silicon: nanofabricated processors and quantum computing in particular. Biochips are mentioned in the Canadian pilot study and the convergence of nano, bio, information and cognitive (NBIC) science is expected to lead to *novel processing technologies*. The most optimistic studies expect a quantum computing prototype to be in place by 2015 and perhaps common-place by 2030, although there is still no clear vision of the probable architectures. Artificial intelligence is increasingly being discussed in connection with NBIC convergence, although there was already a link with cognitive sciences before there was ever any talk of convergence. Understanding thought had already emerged as a major topic prior to any real discussion on convergence (e.g. in the German "Futur" process).

- Research in the *cognitive sciences* is expected to produce new findings on signal processing which could be replicated in machine form. Progress in cognitive sciences may trigger many applications, including robotics. In fact, *robots* were mentioned frequently, covering a broad range of applications, including domestic or healthcare uses.

- *Software* is addressed in practically all studies and many countries see opportunities in this field, usually on the basis of the particular strengths of that country. Korea specifically mentions the importance of software for information storage. Only a few *storage* technologies are mentioned in the foresight studies considered. New initiatives are expected from technological convergence, in particular at the nanoscale level.

- *Sensor networks* are crucial technologies in many fields with ideas ranging from networks of artificial sensors to harnessing biological systems like plants into networks where these fulfil the role of sensors.

- *Mechatronics*, understood as high performance systems combining mechanical device with electronic circuits and control technologies" are mentioned only by the Korean Vision 2025 study and the Czech Foresight study. In these cases, the country is regarded as having particular strengths in the field. GRID computing is specifically mentioned surprisingly seldom.

- Complexity and *complex systems* are subjects running through many foresight studies. Several countries identify research on complex systems as a national strength and an area in which the country concerned should be particularly active, e.g. Sweden, the Czech Republic or Israel.

- The only technology mentioned specifically in connection with power is *batteries* (UK, Korea), but several studies mention a general need for low power consumption if many of the devices and applications discussed are to achieve widespread diffusion. Low power devices are crucial if certain applications such as UMTS are to achieve any measure of success.

The above findings of the national foresight studies have been compared with the findings arising from the FISTERA technology trajectories. Generally speaking, the overall picture is coherent and there are no major divergences on key technologies. This is not surprising as many studies often rely on similar thematic technology background work. For instance, most studies and the FISTERA technology trajectories rely on the work of semiconductor industry associations for semiconductor devices (international technology roadmap semiconductors). However, where differences become apparent are in the perception of priorities of technologies, rather than the prospective for each individual technology. The results of all the foresights as a whole combined with the FISTERA technology trajectory insights, offer some common patterns: In order of importance, FISTERA detects that technologies that improve communications, increase bandwidth, or introduce or improve human-machine interfaces, stand out in most of the studies, while trajectories such as 'data capture' or 'information retrieval' are very low in the ranking. In particular, information retrieval is discussed in only three studies, mainly in the context of rapid retrieval of various types of information, including multi-media. Communications are acknowledged in virtually all studies. The Greek study characterises Greece as being determined by mobile communications rather than fixed solutions, although this applies mainly to policies on service provision rather than on devices. The Rand study from the US identifies all-optical high-speed communications as a possible disrupter which could threaten the existing computer and communications industries. In the context of foresight, communication is increasingly understood to include not only communication between humans, but also between the physical world and the "cyber world".. The Swedish foresight recognises that Sweden, as a country with particular strengths in the telecommunications area, has particular opportunities, for example, in consumption and lifestyle.

Key application areas

The following table provides an overview of those application areas for which ICT is – according to national foresight studies - going to play a particularly important role. For the sake of comparison, the application areas used in this chapter are the same ones employed in the FISTERA Delphi survey in Chapter 3. The following table lists in which of the national foresight studies a specific field of application has been considered for discussion.

The discussion of application areas is – to a certain extent - a consequence of the design of the individual foresight study and its structure, i.e. the division into panels or subject areas. It is well known that the results of Delphi studies tend reflect decisions taken in the design of the questionnaires and a foresight study seeking to identify science and technology priorities for programmes with given structures will bring together many of the proposed topics, as was the case, for example, in the Czech Republic. Foresight studies, like the recent ones in the UK or Germany, which focus on well-defined topics, are in themselves already the result of an amount of priority-setting.

Some comments on each of the areas in Table 9 will precede a comparison of these results with the FISTERA work:

The most important area of application is clearly education and learning. In view of the importance of education in general, and for the knowledge society in particular, it is not surprising to find that this topic is very prominent in practically all foresight studies. This area is broad and covers a range of topics of high importance

Table 9: Occurrence of important applications areas for ICT. The country code[46] indicates if the application area has been mentioned in their national foresight study

Application Areas	Mentioned in Studies from…
Education and learning	KR, GR, JP, AT, DE, HU, SE, UK, all NMS/CC
Government	SE, GR, KR, all NMS/CC
Health	GR, KR, CA, US, IL, all NMS/CC
Work organisation	IL, KR, US, AT, HU, SE, UK,
Management	IL, JP,PL
Cultural diversity	CA, SE
Social welfare/public services	KR
Transport	KR, JP, CA, AT, CZ, HU, SE, UK
Security	CZ, GR, SE, US, CA, JP, KR, HU, PL, EST, RO
Ageing	KR, JP , CA, SE
Social/family relationships	CA, US
Leisure and recreation	US, CZ, DE, FR, HU, SE, UK

such as technologies for distance learning and the development of software for learning, frequently for specific target groups. This is still an important field for research, since current applications are far from mature in every case.

e-government is a major field of activity in many countries. An important aspect in this context is the possible pioneering role of government, addressed in the second Swedish study. In several of the studies, doubts were expressed with regard to the ´e-readiness´ of governments and public administrations. The Korean studies focus more on the technological aspects, such as e-voting and e-polling, but as a result of the transition of society, one Korean study expects demands from citizens for greater democracy and transparency of governance. These would involve the use of ICTs.

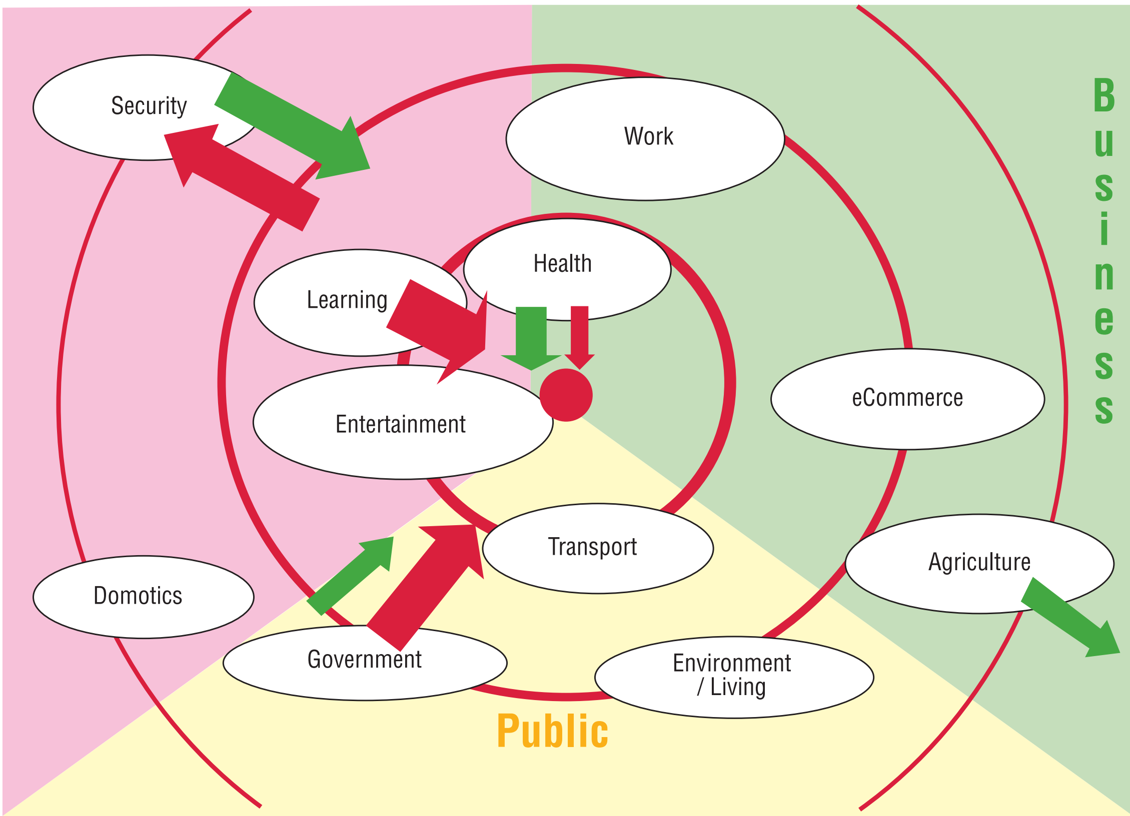
Cultural diversity is addressed in the Canadian and Swedish studies, on the one hand as a challenge facing society, and on the other, as an opportunity to develop specific strengths which could clearly have a strong impact on IST development.

Health is mentioned as an important application area in most studies, usually with the expectation that there will be sufficient money for a broad range of applications, which in some cases could also bring about savings for health systems by increasing efficiency or enabling patients to participate more in their own treatment. Similar to health and cultural diversity, ageing is treated as an important topic in the development of future society and is consequently gaining protagonism in many European foresight studies. In spite of the acknowledged importance of the demographic change, the potential of IST applications for the ageing are addressed specifically in only a few studies.

Work organisation covers a broad range of activities, including robots, devices for working in hazardous environments, mechatronics, machine tools, simulations and entire concepts, such as "agile manufacturing". Management specifically refers to supply chain management. Several studies mention a shift ´from product to services´ as one of the major future trends (see also previous chapter). While it is not listed separately in the above Table, e-commerce continues to

46 NMS/CC = new Member States and candidate countries, , AT=Austria, CA=Canada, CZ=Czech Republic, DE= Germany EST=Estonia, FR=France, GR=Greece, HU=Hungary JP=Japan, KR=South Korea, PL=Poland, RO=Romania, SE= Sweden.

Figure 14: Comparison of the change in priority in the national foresight exercises 2001 and 2005 with respect to Delphi results (2005). The ovals indicate major application areas mentioned in eight National Foresight exercises until 2001. The more the ovals are to the centre; the more they are more mentioned. The green arrows indicate if the foresight exercises until 2005, give more (arrows towards the centre) or less (towards the outside) importance to this application area. The red arrows show the comparison of the Foresight results of 2005 with the FISTERA online Delphi. Red arrows towards the centre indicate that the experts consulted in the Delphi give more emphasis to the theme, while red arrows to the exterior indicate a lower importance perceived



be an issue in most foresight activities, more recently with a strong focus on aspects such as security, privacy and data protection.

Security in many fields was already covered by the foresight studies before the 11th September 2001 terrorists attack, but after this date, it popped up in all studies, covering again a very broad range of applications. This may indicate a possible change in perception in that security is now treated as a separate important issue, rather than an aspect of many fields of human activity. It is important to note that several of the New Member States and Candidate Countries have already made names as producers of software related to IT security, the most prominent examples being Hungary, Poland, Estonia and Romania.

Family and social relationships as an application area for ISTs do not receive much attention in any of the foresight studies. The only application remotely related to this is automatic translation, which is mentioned by both the US and Canada. Domotics are mentioned in the Austrian study and the Korean study sees a role for government in fostering home applications. A major application in leisure and application, a driver for IST development as a whole, is gaming, and also edutainment, both of which are mentioned frequently in foresight studies. Transport, as an application area, figures in almost all foresight studies, reflecting the urgency of many transport-related issues on political agendas.

The above statements give an integrated view of national foresights for each of the application areas. FISTERA analysed in depth each of the national foresight studies in order to get insights into the relative weight of importance of each application area. It appeared that for the studies in the period 1997 to 2001 (eight national foresights in total) the most prominent areas were – in order of importance - health, education/learning, entertainment, work, transport, commerce, government, security and agriculture. FISTERA repeated this exercise, also taking into account foresight elaborated between 2001 and 2005. With respect to the previous ranking, we realized that ICT applications related to health, government and particularly to security, come higher on the list of priorities. ICT for agriculture practically disappears, while ICT for environmental issues and better living environments gets prominence. For the majority of the other areas, their perceived importance over the two periods remains practically unchanged. The comparison of the changes in priorities in the national foresights between 1997-2001 and 2001-2005 are sketched in Figure 14. The ovals stand for application areas before 2001 and the more they are located in the centre, the more often are more mentioned. The green arrows indicate changes of importance for foresight exercises elaborated after 2001.

FISTERA also investigated how much the project results matched the findings of the foresights and in particular the results of the FISTERA Delphi study carried out in 2005. In this survey (see also Chapter 3) participants ranked the importance of applications, with education, health (including ageing) and government coming out on top. In Figure 14, the national foresights are compared with the results of the FISTERA online Delphi by using red arrows. Red arrows pointing towards the centre indicate that the experts consulted in the Delphi give more emphasis to the theme, while red arrows pointing to the exterior indicate a lower importance than the national foresight studies.

From the comparison of the Delphi ranking to the updated priorities of the national foresight studies, FISTERA concludes that the importance ICT for health, government and education is increasing, while the mismatch in the case of security may indicate that the technology experts are probably overestimating the impact of ICT for security.

8. Conclusions

FISTERA analysed future societal and economic needs and identified the likely contribution of ICT to their solution. FISTERA found that ICTs could contribute most to the following areas, in decreasing order of importance: ICT for 'education and learning', 'health applications', 'governmental applications', and ICT for a better work environment. Although it only comes second in the list, ICT for health appears to be gaining the most momentum and is becoming a major driving force. Main reasons are the increasing social awareness of the challenges arising from the ageing population and policy makers' demands for technological solutions to stabilize health-care costs. With regard to generic trends where emerging social needs and appropriate technology trends come together in an integrated way, FISTERA considers the most important ones to be 'favourable knowledge-production environments', 'more user-centred IST innovation', 'better support for individuals', 'business use of IST', and 'internationalisation'.

FISTERA investigated current and possible future technological developments. It recommends that attention be paid to a number of technology clusters. Technologies favouring the ambient intelligence vision remain important, particularly those supporting the 'disappearance of computers'. The basic idea is that ICT and processing power gain popularity and become more human-centred. One continuing trend is to have large access capacity everywhere at an affordable price. This would require progress in technology and network infrastructure, which could offer 'unlimited' bandwidth practically for free. Business would rely on charging for high-level services, rather than for the use of the infrastructure or lower-value services. In fact, as products become more like commodities, the shift to selling services rather than products, is of a more general nature. This will call for enabling technologies to offer a competitive advantage derived from profiling or cheaper manufacturing, such as inserting communications capabilities into any product.

Many of the above mentioned applications have similar technological building blocks, for which the critical technologies are 'embedded systems', and 'micro-kernels and ad-hoc protocols', and those technologies enabling more bandwidth, more storage, information semantics, and radio propagation. In the long term, technologies at the cross-roads of ICT with nanotechnology, biotechnology and cognitive sciences will become very important. Many experts consider that these 'converging technologies' hold huge potential for a wide range of applications from both an economic and social point of view.

FISTERA also studied the performance, capacity and adaptability of the R&D system. In terms of ICT patent filing during the 90s and early new millennium, it appears that Europe has gained momentum but still needs to close the gap with the US and Japan. The most competitive and dynamic European countries (in terms of patent filing per inhabitant) are the Scandinavian and other medium-sized countries (notably the Netherlands, Ireland and Belgium). FISTERA measured the range and degree of specialization as one determinant of a nation's R&D strength. An important observation is that though the ICT sector is highly dynamic in terms of generating highly influential applications, countries' ICT specialization varies only very slowly over decades. In view of the time and effort needed to create knowledge capacity, effective IST strategy and policy must be long-term. With respect to the industrial competitiveness, FISTERA observes that big European ICT industries are as competitive as their peers abroad. Europe, however, lacks medium-sized ICT companies, which play a very important role in the ICT industry sector.

FISTERA has identified the need to establish a pan-European platform on foresight in IST. The timing is favourable as foresight tools for decision making and priority setting is gaining worldwide popularity. This proliferation of forward-looking exercises and foresight activities in Europe is mostly targeted at national or regional levels. A European vision for IST, however, cannot be based on the integration of national visions alone, nor can a European strategy become the lowest common denominator of the national ones. This calls for a for regular foresight exercises at pan-European level. FISTERA has taken the first steps towards creating a discussion platform for foresight in IST, but there is still a long way to go. FISTERA has also gained positive experience with both face-to-face and indirect measures, which were found to be complementary. Face-to-face contact is efficient, but cannot easily be scaled up, because of cost, broadness of participation, etc. On the other hand, non-direct participation tools are more cost efficient, but online animation of the process cannot replace the creativity arising from human interaction.

9. Annex: FISTERA's Approach to Priority-setting in IST RTD Policy

Priority-setting involves choosing some options rather than others. Of course, not all options can ever be chosen: some selection is required. In the domain of R&D, it is practically impossible to share limited funds out among all of the available contenders. Selection procedures may be expected to reflect judgements as to where the best opportunities lie, and how capacities can be established, mobilised and/or enhanced. Where funds are so highly limited that there is no way that they can be distributed across a wide range of topics, some specialisation may be inevitable. Firms will always specialise in particular areas of technology. Smaller countries, too, cannot hope to excel in all areas of science and technology (S&T). They may invest modest amounts in enough research in a wide range of fields to keep an eye on developments that may require a rapid response, but they will usually specialise on a few areas of comparative advantage in terms of major funding. Wealthier and larger countries may fund R&D across a very wide range of fields, but even so they will have to select among alternative lines of research within these.

Prioritisation should allow for more than just efficiency, but should also allow for establishment of economies of scale and scope. On the other hand, a very high degree of specialisation entails also certain risks - for instance the vulnerability to external shocks: a country with a highly specialised technological and industrial profile strongly depends on the ups and downs in its few areas of specialisation.

Priority-setting efforts became increasingly prevalent in the last decades of the twentieth century, with the larger countries being confronted with the need to develop new ways of making their R&D investments. This way strategic R&D programmes have been set-up and used as ways of mobilising efforts to address new fields where the distinction between pure and applied research is too limited – where fundamental understanding is intimately associated with commercially and/or socially significant applications. Initiatives such as Commission's ESPRIT and RACE programmes, represented responses in the 1980s to the strategic interest in what was then known as ICT.

Foresight studies where introduced in Japan in the 1970s and in many other countries in the nineties. They seek to examine the potential synergies between long-term developments in S&T and ongoing evolution of social, economic, and environmental problems and market opportunities. The first waves of Foresight study typically examined a very wide range of S&T topics, providing intelligence for directing priorities across the board. Some more recent exercises (e.g. the current UK or German projects) are more focused; exploring opportunities around rather tightly specified socioeconomic issues or fields of S&T. Critical technology studies have been used in many countries, including France and the USA in efforts to identify key technology areas where R&D efforts are required.

Rationales for prioritization

Insights into these priorities can be gained on the basis of thorough analysis, but for translating into priorities for policy, further requirements need to be met. Public policy intervention requires specific justification, and good arguments need to be made to make a point for policy intervention or even European policy intervention. Usually, public policy intervention in research and technology development can be justified primarily on the basis of three general principles. First, markets do not allocate enough resources for conducting research, for instance in fields of societal demand or in basic research ("market failure argument"). The market-failure arguments can be applied in a straightforward manner to justify public funding for basic research, which otherwise would suffer from private under-investment. They are not sufficient to justify targeted funding priorities in applied research – unless there is evidence that market failures are more characteristic of some fields of work (e.g. basic research) than others. Second, interdependencies in innovation systems impose rigidities that do not allow exploiting fully existing technological and innovation potentials ("systems failure argument"). And third, the public sector can have its own specific technological needs, which, by their very nature, cannot be satisfied in a purely market-driven environment ("procurement argument"). In the end, most claims for policy action to support the creation of competitive industries, technological leadership, or strategic sectors, etc. can be traced back to one of these three principles.

In recent years, priority-setting in RTD policy has been influenced by the emergence and consolidation of the Innovation System concept, which requires the consideration of all the components of the system in effective priority-setting. Policies will aim to concentrate efforts on the improvement of functions of innovation system as a whole, for instance by strengthening science-industry relations and stimulating the setting up of new technology-based firms. These kinds of argument are increasingly applied also to specific sectoral or thematic innovation systems, for instance in different areas of IST. Moreover, policy priority-setting mechanisms in Europe tend to link S&T priorities to socio-economic needs.

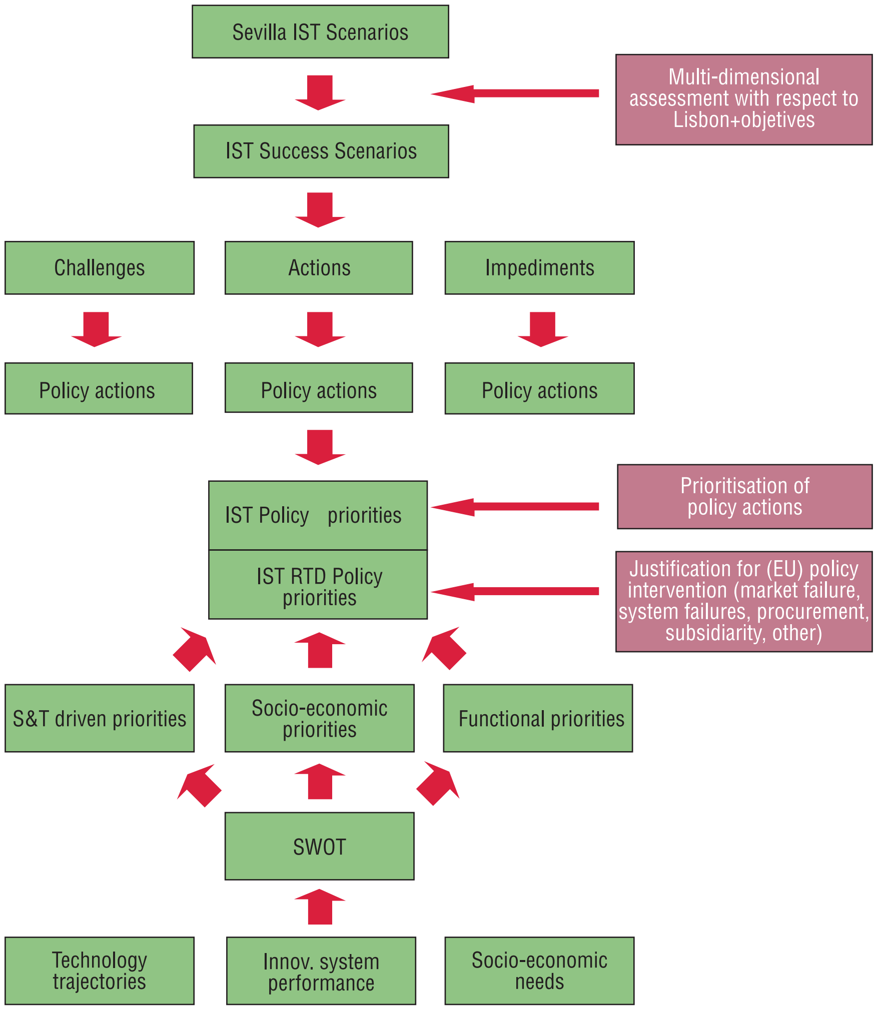
The FISTERA project was geared towards providing insights into future RTD priorities for Europe as a whole. FISTERA did not delve into the depth of the arguments regarding the justification for (EC) policy action,[47] but rather concentrated on the collective requirements for Europe to be successful in the area of IST on its way towards the Lisbon objectives and beyond. In this respect, FISTERA distinguishes between generic (or functional) priorities and thematic priorities, the latter further sub-divided into socio-economic (needs)-oriented priorities and S&T (supply) - oriented priorities. This leads to the following set of priorities:

- "Functional priorities" where emerging social needs and appropriate technology trends are identified in an integrated way, and are positioned vis-à-vis functional constraints in the respective sectoral or thematic innovation systems, such as the availability of a sufficiently skilled labour force or the existence of a well-developed educational system).
- *"Socio-economically driven priorities"* where social and environmental needs are defined and assessed, and possible technological solutions identified.
- *"S&T driven priorities"* where current developments in science and technology are explored into the future to identify emerging technology gaps and needs associated with the possible applications of the technology.

For this priority setting, FISTERA employed a combination of a top-down and a bottom-up approach. The bottom-up direction focuses on the analytical dimension of priority-setting highlighting some key findings of FISTERA in terms of functional, S&T driven and socio-economically driven priorities. The top-down approach is devoted on the normative, process-oriented dimension in terms of identifying and prioritising policy options, building on what FISTERA calls the "success scenario" of European information society. Such a success scenario is a desirable future vision of the information society within confines of what is regarded as realistically achievable. The block diagram in Figure 15 indicates how different analytical and normative building blocks have been put together for the identification of RTD policy priorities. The two inroads turned out to be complementary in the sense that the process-based element delivered several priorities for IST policies, whereas the analytical elements led to priority areas for IST RTD policies.

47 In the case of EC priorities there are arguments concerning why and when priority-setting at European level is more appropriate than at national level. (The principle of subsidiarity argues that action should always be taken at the lowest policy level possible, so the question becomes one of whether there is added-value resulting from action at European level).

Figure 15: *Combination of top-down and bottom-up approaches for priority-setting. The block-diagram indicates how different analytical and normative building blocks have been put together for the identification of RTD policy priorities. The two inroads turned out to be complementary in the sense that the process-based element delivered several priorities for IST policies, whereas the analytical elements led to priority areas for IST RTD policies*



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Abstract

IPTS hosted a thematic workshop on the "Socio-Economic Aspects of the Knowledge-based Europe: The role of Information Society Technologies (ISTs)", which set out to diagnose major problems for Europe in achieving the Lisbon 2010 objectives. It also aimed to elaborate on possible new initiatives which would go beyond conventional wisdom and which would contribute to defining Europe's future role in a globalised society, taking into account the socio-economic drivers for better quality of life. After the Workshop, a number of well known economists were commissioned by FISTERA to write papers suggesting possible lines of analysis that were not included in the core FISTERA design, but which can be seen as crucial elements for a holistic view of the future of ISTs. This report summarizes and analyses the workshop findings and the views of the economists.

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