

Lessons from Foresight on Information Society Technologies

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Abstract. *“Foresight on Information Society Technologies (IST) in the European Research Area” (FISTERA) is a thematic network of researchers. FISTERA intends to accelerate the process of decision-making in research and development for IST in the EU. It is designed to provide useful information about key technological developments and potentials, applications that have social and economic benefits and the challenges and opportunities that arise in this context¹.*

FISTERA analysed trends, drivers and challenges –more generally speaking factors- which will influence future IST development and deployment. Europe’s position with regard to these “influencing factors” were analysed trying to find answers to questions like: What are the elements of Europe’s strengths and weaknesses in ICT as compared to its global competitors? What are the opportunities, threats and challenges for Europe? What should be done to improve Europe’s situation? This paper presents the FISTERA methodology and summarizes some of the FISTERA work.

Introduction

“Foresight on Information Society Technologies (IST) in the European Research Area” (FISTERA) is a thematic network of researchers. It was launched by DG Information Society to support the creation of a European Research Area (ERA) in IST by providing new elements for the definition of a European vision and approach in the field. The network aims to understand the key factors driving IST in a future Europe. FISTERA reviewed the current literature and carried out its own research on a range of IST issues in order to feed the discussion on gaps and paths towards the Lisbon Objectives (2010) and beyond. In other words, FISTERA aims at contributing to the elaboration of options that may lead to strengthen Europe’s position in crucial IST areas.

To offer insights on the prospects of ICT, one needs to understand the underlying forces and environments that influence ICT research, development and

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¹ “Key Factors driving the IST in the ERA a Synthesis Report of FISTERA”, Sept 2004, IPTS, EUR . by R. Compañó, C. Pascu, J-C. Burgelman, M Rader, K. Boehle, G Spinelli, R Saracco, B. Dachs, M. Weber, R. Popper, L. Green, I. Miles.

(<http://www.jrc.es/home/publications/publication.cfm?pub=1204>).

development. These forces are influenced by “drivers”, “trends” and “challenges”. Drivers are factors that have an important influence themselves on the developments of a technology. They may cause a direct influence on the IST deployment; give impulse in particular research directions and stimulate particular technological trajectories. Challenges, in contrast, contain a certain normative component. They are hurdles that one needs to overcome in order to move in a certain direction. They are frequently the result of conflicts between various trends and/or aims, which require resolution to integrate IST use in European society. Challenges may become drivers (“the need to...”) and vice versa (“capabilities to cope with...”). Trends will affect whatever you foresee and plan to do. Thus, they need to be considered seriously. For instance, one major trend is the ageing population, which will influence labour and consumer market development, requirements for ICT applications in education and health, and so on.

FISTERA analysed first a number of important National Foresight studies, reviewed some major European IST scenario studies, and identified major trends, drivers and challenges that these portrayed as likely to be important influences on future societal changes. The relationship and dependency between these different factors revealed to be complex. The factors are of technological (e.g. miniaturisation), social (e.g. increasing demand for mobility) or economic (e.g. reduction of the cost per unit of functionality) nature and they often do not reconcile. They can even be juxtaposed. For example, ‘more personalization’ or ‘more security’ is at the expense of the factor ‘cost’ or ‘privacy’. Thus, a fully consistent picture cannot be established, but we can assert that in order for ICT to further conquer the market, a number of factors need to coincide and it should respond to a real need. It must respond to a demand, be appropriately priced and functional, and be in line with the political structure.

Key factors important for the development of the ICT industry and services sector can be of social, technological, political and economic nature. For instance, the miniaturization of chips and devices and the integration of devices into reliable and robust systems are such technological drivers. Similarly, IST has been triggered by the social context, such as the need to provide services for the ageing population, eHealth solutions, new tools of community learning or the increasing demand for personal mobility. These factors are embedded into the macro environment, such the evolution of trade and economic affairs, or the political quest for increased home security. FISTERA extracted potential factors from the review of scenario studies, technological reviews, national foresight studies, and augmented the analysis in discussions by the consortium.

An important element in the FISTERA project was to combine a range of “classical” foresight tools. Elements of this classical toolbox are fully fledged foresight exercises, technology road-mapping, Delphi studies and scenario development exercises. Taken in isolation, each of these tools offers useful, but partial information. In FISTERA, we tried to combine a number of tools and to adapt them to make best use of their complementarily to analyse specific tasks. As

much as possible, we tried to integrating all the findings in a systematic fashion. Where necessary, research was complemented by a bibliometric analysis of patents and publications, interviews with experts in the field or industrial roadmaps.

European IST Futures

A series of IST-oriented scenarios have been developed over the past years. The most recent ones are the Delphi-based EUFORIA scenarios, the survey-based STAR scenarios², the projection-based SEAMATE scenarios³, the workshop-based ISTAG scenarios⁴ and the panel-based FLOWS scenarios⁵. These five scenarios are quite different studies in terms of methodologies and rationale as well as the substantive content⁶.

Taking advantage from the existing scenarios and the feedback from a number of FISTERA road-shows, new scenarios were generated for a workshop to identify key drivers and challenges for IST⁷. The focus was to understand how the EU performs in the context of global competition in IST production and use; and how well different areas of the EU are performing in these terms. Four scenarios were derived from a two by two matrix. The two underlying parameters here are the “European competitive performance” and “European internal techno-economic heterogeneity”. With respect to the “European competitive performance” the two poles are (a) the EU overall attains leadership in many areas of IST, becoming a substantial competitor to the US and other regions in production and export of hardware, software and services and (b) the EU overall lags in most areas of IST, only rarely becoming a serious competitor to the US and other regions in production and export of hardware, software and services. For the “European internal techno-economic heterogeneity”, the extremes are (a) variation across EU countries/regions in techno-economic performance intensifies, with differences

² Scenarios for the Information Society (October 2003) A report by Telecom Paris, École nationale Supérieure de Télécommunications for the STAR project, available at:

<http://www.databank.it/star>

³ “Assessment of IST trends, impacts on growth and outline of scenarios (June 2003). A report by ISIS incorporating contribution by RAND for the SEAMATE project, available at: http://www.seamate.net/dwl/seamate_d1.pdf

⁴ “Scenarios for the Ambient Intelligence in 2010 (February 2001) A report by K. Ducatel, M. Bogdanowicz, F. Scapolo, J. Leijten and J-C. Burgelman (IPTS-Seville) for the ISTAG group, available at: <http://www.cordis.lu/ist/istag.htm>

⁵ “FLOWS Scenarios and Definition of Services” (December 2002) A report by the University of Edinburgh for the FLOWS project. available at: <http://www.flowsist.org/main/outputs/D6.pdf>

⁶ “Overview of selected IST scenarios”, February 2004, Rafael Popper, Ian Miles, with Lawrence Green and Kieron Flanagan, PREST available at

http://fistera.jrc.es/docs/Scenario_Pool_version_1.7.pdf

⁷ Exploring Emerging Applications- Report of the FISTERA Trends, Drivers & Challenges Workshop 16th - 17th June 2004 Seville, Spain, Ian Miles, Rafael Popper, Lawrence Green. PREST available at http://fistera.jrc.es/docs/CD-ROM%20oct2004/Seville_RP_version_12.2.pdf

between cities/regions/countries being even more intensified; and (b) variation across EU countries/regions in techno-economic performance decreases, with differences between cities/regions/countries being substantially reduced.

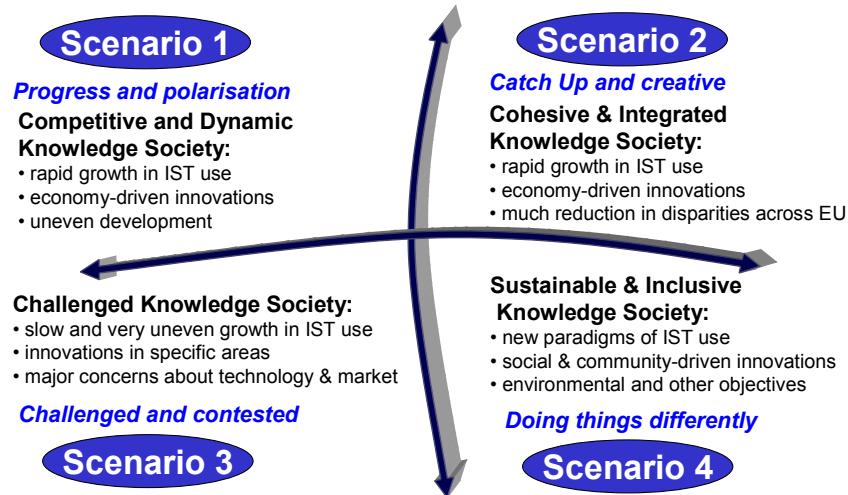


Figure 1. Classification of Scenarios by competitive performance and techno-economic structure. The four scenarios were designed along a set of different indicators. For sake of illustration the y-axis presents different levels of a European competitive performance, while the x-axis shows the range from a low to a high degree of techno-economic heterogeneity in Europe. The arrows are bended to visualize that the scenarios are not completely excluding, but may have a level of overlap.

The scenario workshop investigated issues related to IST in Europe and R&D challenges. 31 participants that were asked to brainstorming on IST application areas. Four visions of future possibilities and range of developments, depicting different patterns of the use of new IST were proposed, namely a “Competitive and Dynamic Knowledge Society” (Scenario 1), a “Cohesive and Integrated KS” (Scenario 2), a “Challenged KS” (Scenario 3) and a “Sustainable and Inclusive KS” (Scenario 4). The four scenarios were assessed against the eight “Lisbon goals”, i.e. competitiveness/innovativeness, job creation, social cohesion, economic growth/ wealth creation, sustainability/environmental quality, social inclusion, employer-employee relations, and work-life balance. Each of the participants was asked to consider how and how far it considers that each of the Lisbon goals might be realized, how far the initial scenario radar needed to be revised. Similarly, the four scenarios were analysed in terms of the Business models and industrial development; Consumers, markets and lifestyles; Technology and infrastructure; Politics and global affairs. Concluding, the participants felt no one of the four paths was thought to completely reflect the future. However, the most likely scenario would involve elements of all four, but mostly from scenario 1 and the least from scenario 4.

Comparison of Selected National Foresight Exercises

In this section we discuss IST sector-specific analyses that have been performed taking into account national foresight exercises, and building upon existing general comparisons of foresight studies. FISTERA aimed to draw differences amongst foresight studies in different countries and draw conclusions on IST developments and IST-foresight requirements at the European level. The comparison of recent foresight studies is novel because it focuses particularly on Information Society Technologies (IST).

In 2003, the FISTERA team analysed work eight foresight exercises from Austria, the Czech Republic, France, Germany, Hungary, Spain, Sweden, and the United Kingdom were analysed⁸. Most foresight studies were drafted before 2001; thus before the terrorists attacks and the burst of the internet bubble. In an intermediate stage, a “fast track” analysis⁹ involving three recent Foresight exercises from Canada, Germany (2nd Futur) and Sweden (2nd foresight) was carried out in 2004 in order to examine the influence of the “bursting” of the e-commerce or “new economy” bubble in the late 1990s, and the terrorist attacks of 11th September 2001. In 2005, the analysis was extended again, including recent European foresight exercises (Greece, Sweden) and *non-European* studies (Israel, USA^{10, 11}, Korea¹², Canada¹³ and Japan¹⁴).

Generally speaking, national foresight reports tend to be application driven and do contain little on emerging key technologies or future technology trajectories. Most of the studies limit themselves to identifying subjects worthy of support at the national level only and they are generally not driven to define a pan-national research strategy in the given field. Many national studies employ scenarios building exercises in the internal foresight process. Unfortunately they are mostly not particularly technology-specific, and often they give the impression to provide a justification for supporting ongoing activities contributing to progress in key areas of technology.

⁸ *A first Synthesis of selected foresight exercises at the national level*, April 2003, Michael Rader, FZK-ITAS, <http://fistera.jrc.es>

⁹ *A Supplemented synthesis of selected foresight exercises at the national level*, May 2005, Michael Rader, Knud Böhle, Brigitte Hoffmann, Carsten Orwat, Ulrich Riehm (FZK-ITAS) <http://fistera.jrc.es>

¹⁰ “Global Trends” report by the Rand Corporation for the National Intelligence Council, USA. In particular, “The global technology revolution: bio/nano/materials trends and their synergies with information technology by 2015” Antón et al.(2001).

¹¹ “*Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technologies and Cognitive Science (NBIC)*” Roco and Brainbridge, National Science Foundation, June 2002 (see www.technology.gov/reports/2002/NBIC/Part1.pdf)

¹² The “Vision 2025” (2000); The “National Technology Road Map” (2002); and The “Master Plan for KBE” (2002) a various foresight-like activities focussing on IST-related fields

¹³ The “Canadian Science and Technology Foresight Pilot Project” included two pilot studies on “Biosystemics” and “Geostrategics”. Both have a strong IST element.

¹⁴ Based upon the “*7th Japanese Technology Foresight*” (2001). (The 8th foresight is planned to be completed by the end 2005).

Generally speaking, national foresight exercises do generally not cover the whole chain from technology assessment to assessment of technology's impact on society and offer limited value for conclusions on the EU as a whole.

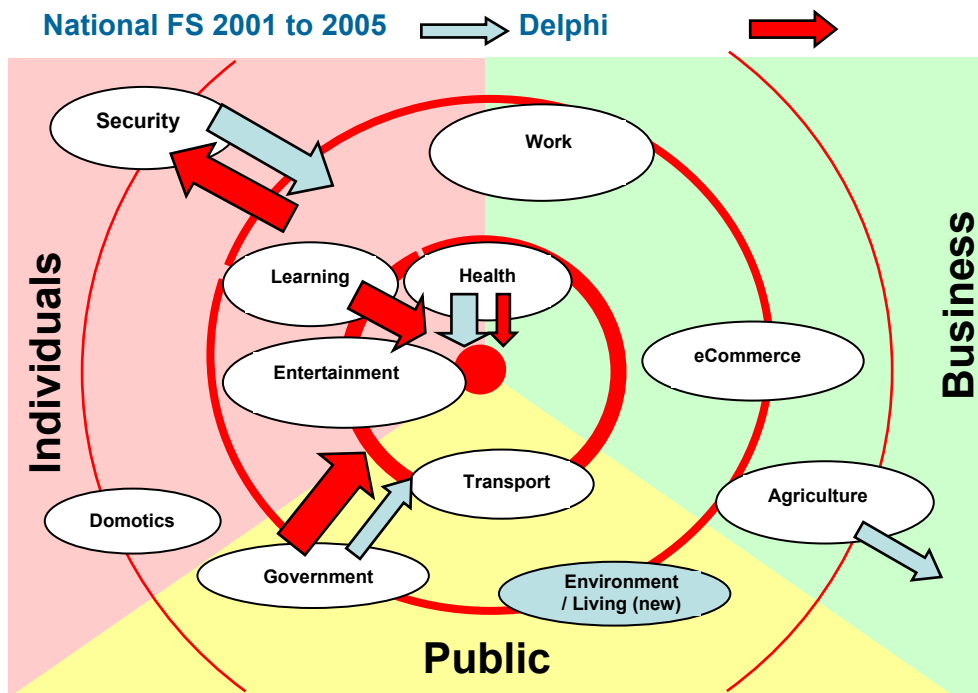


Figure 2. Comparison of the change of priority of the National Foresights exercises 2001 and 2005 with respect to Delphi results (2005). The white ovals indicate major application areas mentioned in eight National Foresight exercises until 2001. The more the ovals are in the centre, the more they are 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. “Environment”(green oval) as a major application area emerged in 2005. The red arrows show the comparison of the Foresight results of 2005 with the FISTERA online Delphi. Red arrows towards the centre indicates that the experts consulted in the Delphi give more emphasis to the theme, while red arrows to the exterior indicate a lower importance perceived. As can be seen, the most important IST application areas comprise learning (including life-long learning), healthcare (including support for disabled/elderly people), e-government (including the participation of civil society), tele-working, and virtual companies.

The comparison of the studies before and after 2001 is interesting as, three major issues happened with relevance for IST in this time-frame. Economically speaking, the major issue was the burst of the e-commerce or “new economy” bubble. From a political point of view, the terrorist attack of 11th September 2001 was the major event that influenced the perception of the role of IST. Finally,

convergence between nanotechnology, nanotechnology, information technology and cognitive science was identified as a possible future technology mega-trend that will transform our future lives. These issues will be discussed in the following:

Security. Up to recently, security had been treated in foresight studies as an important aspect only as regards individual technologies. But since the terrorist attacks in New York and Madrid, in national foresight exercises produced since fall 2001, security has figured heavily [Rader 2004]. Fear or “*Angst*” receives express mention as a factor driving IST research and the development of technology. The quest for personal integrity and security is a fundamental human need and its importance is manifested in the so-called “Maslow pyramid of needs”. Basically, Abraham Maslow proposed to classify and prioritise human needs based on two elements: deficiency needs and growth needs^{15 16}. The deficiency element implies that a specific need must be fulfilled before moving to the next higher level. By order of importance the levels of needs are the following: first “physiological”, including hunger, thirst, bodily comforts, etc., second “safety and security”, third “belongings and love”, i.e. to socialize and be accepted; and forth “esteem”: to achieve, be competent, and gain approval and recognition.

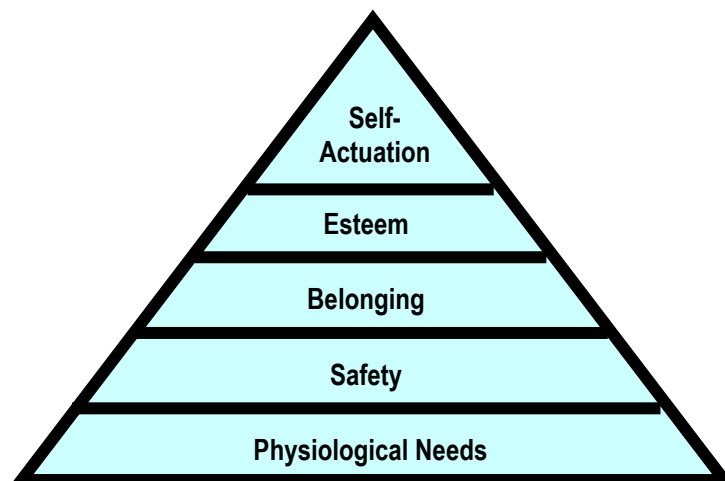


Figure 3. Maslow’s Pyramid of Needs. Note that the need for security is situated directly after the satisfaction of basic physiological needs and before all others (belonging, esteem and self-actualization needs).

In view of the basic importance that security represents for the individuals, it is not astonishing that it applies also for the society. After the terrorist attacks there was a public demand for more national security, and ICT-as the key building

¹⁵ “*The farther reaches of human nature*” A Maslow , The Viking Press, New York 1971

¹⁶ “*Toward a psychology of being* (3rd ed.)”. A Maslow and R. Lowery (ed). New York: Wiley & Sons. New York, 1998.

block- for enhancing security re-gained importance in national foresights and in research programmes. Simply speaking, the latent argument for a higher investment in ICT is that more research enhances the probability to provide technology for security and more security leads to more trust of the citizens. Such a linear model is surely somewhat simple, but illustrates quite nicely the underlying perception a number of stakeholders. Cause-effect correlations are far more complex the case of biometrics shows¹⁷.

New Economy. It is well known, that the burst of the “new economy bubble” had a massive impact on the ICT industry. Many companies went bankrupt, other firms had to re-think their business model and even established companies – like in telecommunications- passed difficult times. The private investment in ICT and research suffered stagnation or were reduced. The crash of the Internet bubble revived the debate whether ICT will lead to profound changes in the economic system. Innovation economists argued that new key technologies – such as ICT-produce long-term business cycles that aggregate economic growth by restructuring of the economy and producing benefits in multiple sectors.^{18 19} According to a model articulated by Perez,²⁰ major economic benefits of any new key technologies emerge only after the society had time enough to adjust its institutions and practices to reap the gains of the new technology. This adjustment may include new laws, educational and work practices, organizational processes, new ways of decision-making, etc. In the Perez model, high expectations lead to overinvestment and subsequent disappointments. Only after a crash, technology starts to generate sustainable growth.

There is broad consensus that the ICT revolution underlies such a long-term business cycle. As the beginning of the “IST era” can be attributed in the early 70ties with the appearance of mass production monolithically integrated circuits and the length of the previous techno-economic cycles persisted for 70 or more years (electricity, railways, steam engine, etc), IST would be situated in somewhere in the middle of the cycle. In view that foresight aims at investigating long-term trends; it is not astonishing the internet bubble had not a visible impact on many foresight IST reports. In fact all three foresight studies produced after 2001 and analysed by the FISTERA team continued to emphasise the importance of the systemic role of IST and the importance of the their applications. In fact, foresight studies consider e-Commerce and e-Business to be highly important. They identified “trust and security” (in networks and throughout the systems) as major

¹⁷ “Biometrics at the Frontiers: Assessing the Impact on Society” I. Maghiros, Y. Punie, S. Delaitre, E. Lignos, C Rodríguez, M. Ulbrich, M. Cabrera, L. Beslay and R. van Bavel. EUR No: 21585 EN, (2005) <ftp://ftp.jrc.es/pub/EURdoc/eur21585en.pdf>

¹⁸ E.g., Freeman, C., Clark, J. & L. Soete (1982) *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development*. Westport, Conn.: Greenwood Press.

¹⁹ E. Helpman (Ed.) (1998) *General Purpose Technologies and Economic Growth*. Cambridge, MA: The MIT Press.

²⁰ C Perez (2002) *Technical Revolutions and Financial Capital*, Edward Elgar.

critical factors for the deployment of the “new economy” and these continue to be so in foresight studies elaborated after the burst of the internet bubble.

At least as important or more than the effect of the burst of the past internet bubble, is a implications of IST in the political will from the information society to the knowledge society. The emerging knowledge economy is supposed to lead to a new growth paradigm combining social and technical innovation. This economy may be based on new applications emerging simultaneously with new social practices. Here ICT is unique; as they play the role of “social technologies” facilitating communication and new ways of handling knowledge processes. In a certain way, the long waves of economic development of the ICT cycle can be broken down into a large number of ripples.²¹ In other words, the IST wave may be enhanced. A possible reason for such an extension originate on the emerging technological “mega-trend” of the convergence of previously separated technologies such as ICT and biotechnology or ICT and nanotechnology.

Convergence. In 2002 a conference took place with the name: “Converging Technologies for Improving Human Performance”. The conference report²² had a seminal role in the discussion of the convergence of nanotechnology, biotechnologies, information and communication technologies and cognitive sciences. This so-called “Nano-Bio-Info-Cogno” or NBIC convergence is supposed to trigger the next technological revolution. “Convergence”, however, is not new information technology that has been subject of the centre of convergence of different kinds of technologies, such as the information processing, content generation or communication technologies. Now, technologies combined under the NBIC heading have critical features in common and their combination is more demanding. This combination makes them an exciting field for front-edge research with an expected huge impact. NBIC holds the promise to be potential technological “disrupters”, which could change the playing field in innovation processes. At the same time concerns arise with regard to their misuse and possibly negative impact.

Since the NBIC discussion was launched in the USA, there has been a lot of excitation all over the world. But there are also a number of recent foresight studies, notably in Canada,²³ the UK and Germany, are more critical²⁴. All reports confirm that the intersection of nanotechnology, biotechnology, ICT and cognitive sciences are exiting areas for research with economical potential, but many highlight the risk that supporting massively NBIC may be at the expense of other promising growth fields. They seem to support the view that society is possibly suffering the current “Zeitgeist” whereby decision makers are desperately looking

²¹ I. Tuomi, (2002) *Networks of Innovation*, Oxford University Press, pp. 216-7.

²² “*Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technologies and Cognitive Science (NBIC)*” Roco and Brainbridge, National Science Foundation, June 2002 (see www.technology.gov/reports/2002/NBIC/Part1.pdf).

²³ see for instance <http://www.etcgroup.org/>

²⁴ The portal www.nanoforum.org contains a great deal of critical papers.

for investment opportunities after the internet crash and put NBIC the political and popular discussion. Confusion about the potential is caused by the fact that term “converging technology” appears to include a great deal of research previously covered under other “labels”. Another point of concern is of ethical nature and it is well captured in the title of the seminal US report: “Converging Technologies for Improving Human Performance”. It elucidates military applications raising concern of social relevance. Therefore, it does not astonish that -since its publication- a considerable number of ethical and social concerns have been voiced. In response of the US approach, a European high-level expert group defined the objective broader by calling for a model to use “Converging technologies for European Knowledge Society (CTEKS)”²⁵ differentiating from the US model and the possible military applications.

Summarizing, the convergence of ICT with other emerging key technologies as biotechnology of nanotechnology may give a new impulse to research and applications and further enhance and expand the IST revolution. Scientifically speaking, some ground breaking progress has been made recently and a number of promising applications are under discussion. The real potential and impact is largely unexplored and hard to assess at this stage. This uncertainty is not uncommon for emerging technologies and it is part of the reason for the hype on the economical impact and ethical concerns on how the future application may affect society.

Challenges, Applications and Priorities for Socially Beneficial IST

FISTERA carried out a web-based Delphi study involving policy-makers, the business sector and researchers. A two-round Delphi was launched in the summer of 2004 and concluded in February 2005. Respondents were invited to revise their inputs to the second round in light of the results of the first round. Participation in the survey was 515 respondents. The FISTERA Delphi examined the period to 2010 and beyond. In view that 2010 is the date the Lisbon Strategy will be assessed, these objectives (i.e. improvement of job and wealth creation, competitiveness, social cohesion and inclusion, and environmental quality in the European Union) were particularly analysed. More generally, the Delphi aimed at determining the main R&D challenges needs to address in IST and the main impediments for the development and deployment IST applications. Some actions were proposed to the participants to achieve a more effective and socially beneficial IST development and application. The participants were also interrogated about the

²⁵ “Converging Technologies – Shaping the Future of European Societies”, Report of the High Level Expert Group on Foresighting the New Technology Wave, Rapporteur Alfred Nordmann, Brussels 2004 (see ftp://ftp.cordis.lu/pub/foresight/docs/ntw_report_nordmann_final_en.pdf)

role of the stakeholders, including public and private research organizations, as well as their capacity to that active action of promoting the knowledge-based society. The Delphi revealed the following perceptions²⁶:

R&D Actors. Most EU organisations associated with research and development in IST are positioning on the average on a world-wide scale. Only few were felt to be cutting-edge as regards their capability in developing and exploiting IST in the various areas. Generally speaking, researchers feel “moderately” prepared to seize new IST opportunities in the application areas. Only in a couple of areas (e.g. transport) researchers are perceived generally well-prepared.

Application Areas. The strongest IST endorsement is for “Education and learning”. This application area repeatedly emerges as the most important one for IST. It contributes to numerous EU social and economic goals and is central to the construction of a European knowledge society. IST applications in government, social welfare and public services, and cultural diversity contribute several EU goals. Applications in work organisation and in management are seen as contributing particularly strongly to the economic goals. It is interesting to note that the priorities correspond largely to the applications areas identified by the experts in the national foresight studies. Comparing the priority application areas, the Delphi results (see red arrows in the Figure) confirm largely the trend seen from the national comparison of foresight studies (see green arrows – corresponding to the shift from 2001 to 2005).

Stakeholders. The majority of respondents see first national governments, Large firms and SME (small and medium sized enterprises) in IST as the ‘key players’ improving IST applications in almost any application areas, followed by the EU institutions and regional governments.

The role of the EU. The EU is believed to contribute mainly to the improvement of the following applications areas: social welfare and public services; cultural diversity; transport and work organisation. A number of priorities emerged for the EU would to undertake special care: “Social and institutional innovations” and “reducing the “digital divide” are ranked top together with” improving the communications infrastructure; Developing new and improved IST applications”, and achieving “better IST training and awareness programmes”.

Impediments. There is no unique problem impeding the deployment of IST applications. Main problems of concern include social inequalities in access to IST, and the lack of adequate finance for innovations. Two major development challenges are perceived to be more user-friendly systems, and enhancing the security of transactions and personal information.

²⁶ “FISTERA Delphi - Future challenges, applications and priorities for socially beneficial ISTs” April 2005, Rafael Popper and Ian Miles, PREST available at http://fistera.jrc.es/docs/RP_The_FISTERA_Delphi.pdf

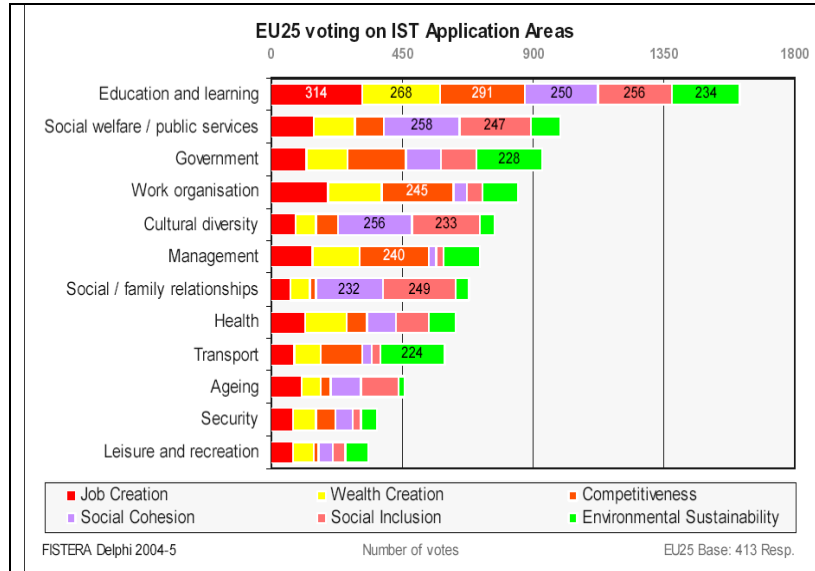


Figure 4. Contribution of IST to the Lisbon Goals (job creation, social cohesion, wealth creation, social inclusion, competitiveness and environmental sustainability) by application area.

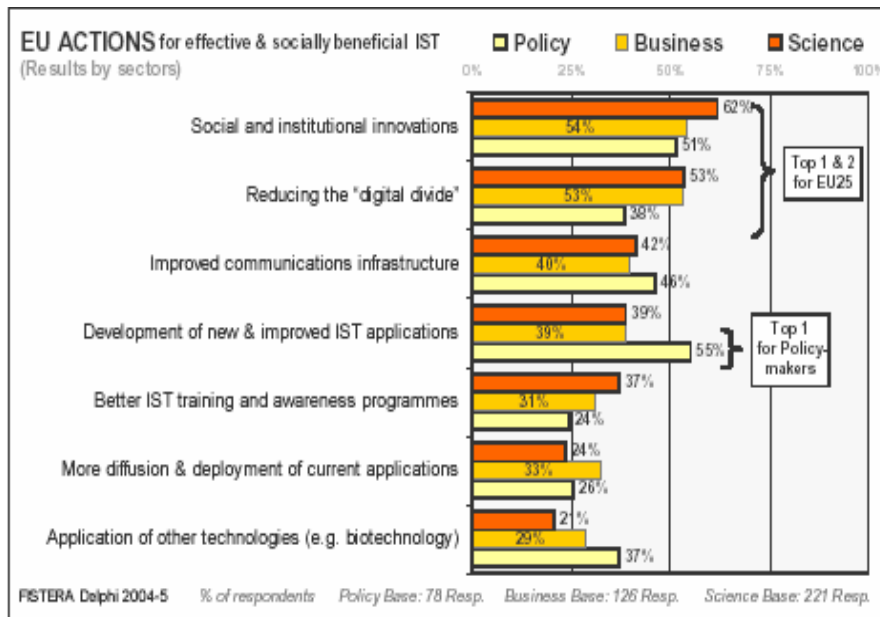


Figure 5. EU Actions for effective and socially beneficial IST by sectors. An occupational view on EU Actions for effective and socially beneficial IST The Business and Science-base sectors confirm EU25 findings for the first two actions, whereas for Policymakers the Development of new & improved IST applications (rank 4 in EU25) is considered as the most important action (55%).

Technology Futures

FISTERA designed a concept^{27, 28} to monitor the progress of technology and perform ICT foresight, which we call *Technology Trajectories* (TT). The concept investigates technology clusters from the point of view of what they offer – i.e. their *functionality* – what a particular technology does (or could do, when applied in a societal context). One technology can provide different functions, and a range of technologies can compete to offer the same functionality. Each functionality supports applications (services) that can be constructed and offered in different environments (at home, on the road, at work, etc.). The TT concept links technologies to functionalities to applications to environments, allowing a top-down (from environments to technologies) and a bottom-up (from technologies to environments) analysis.

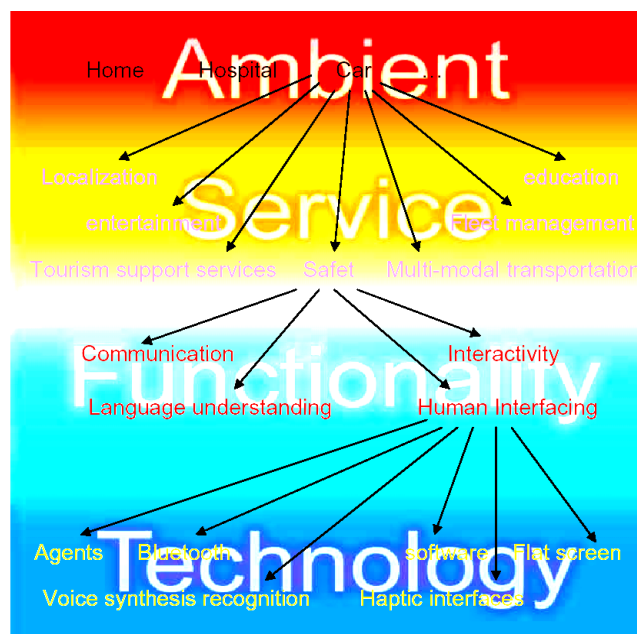


Figure 6. The technology trajectories concept is based on a four layers model as show above. The range of information and communication technologies (technology layer) are attributed depending of which function they perform (functionality layer) to provide a certain service (third layers). These services may be located in several environments (uppermost layer). For a given ambient, the relationship to the underlying layers can be broken down as in the example on the car.

²⁷ “A Timeline for the 1st group of selected emerging technologies” , December 2003, Roberto Saracco, Annaflavia Bianchi, Roberto Dalla Mura and Graziella Spinelli, TILAB available at <http://fistera.jrc.es/docs/D2.1RevLast.zip>

²⁸ Revised Timeline for the 2nd group of selected emerging technologies, December 2004, Roberto Saracco, Edson Azevedo and Graziella Spinelli (Telecom Italia Lab, TILab) available at <http://fistera.jrc.es/docs/D2.2.doc>

The Technology Trajectories result from intensive discussions with many experts in the field. First, functionalities are appropriately defined. Then all expert's information are introduced into a dynamic database, which provides a picture of the state of the art and the perspectives for 2010 and 2020. The database is accessible online.²⁹

In addition to the technological trends potential trend breaks have also been analysed. These so-called disruptions in IST that may be anticipated on the basis of emerging developments in scientific research and expectations regarding the future evolution of performance parameters of current technologies. Possible disruptions with relevance to IST are expected in the nine areas are listed in the table underneath. Of particularly high relevance FISTERA expects the shift from products to services, the availability of unlimited bandwidth and intelligent terminals, the convergence of IST with other S&T areas like cognitive sciences, nanotechnology and biotechnology, and the disappearance of the computer in conjunction with the availability of embedded systems.

Table 1
Possible disruptions in IST³⁰

Disruptions	From Year
From Products to Services	Under way; main impact from 2010
Disappearance of the PC	2008-2010
Ubiquitous Seamless Connectivity	2008-2015
Changing Traffic Patters	Under way; main impact from 2010
Unlimited Bandwidth	2015
Disposable Products	2009
Autonomous Systems	2007
From Content to Packaging	2010
Virtual Infrastructures	2015

FISTERA analyzed the relationships between technologies to identify critical information and communication technologies. A database was established including ca. 140 (IST) technologies, 20 IST functionalities, a variety of services and environments. The database contains thousands of links. The database was used to detect technologies that have a potential to become instrumental in "attracting" or influencing the future development path of other technologies. Thus, an "attractor" is a technology whose evolution affects deeply other technologies, generating a multiplying effect on the entities it attracts. Out of the 140 technologies and 20 functionalities analysed, only seven strongly clearly an "attractor pattern", in particular batteries, embedded systems, micro-kernel / ad-hoc-protocols, bandwidth, storage, information semantics and radio propagation. The data on these technology trajectories has been enriched by an analysis of the comparative strengths and weaknesses of European IST research using triadic patent statistics.

²⁹ <http://fistera.telecomitalia.com>.

³⁰ "Revised Timeline for the 2nd group of selected emerging technologies" December 2004, Roberto Saracco, Edson Azevedo and Graziella Spinelli (Telecom Italia Lab) available at <http://fistera.jrc.es/docs/D2.2.doc>.

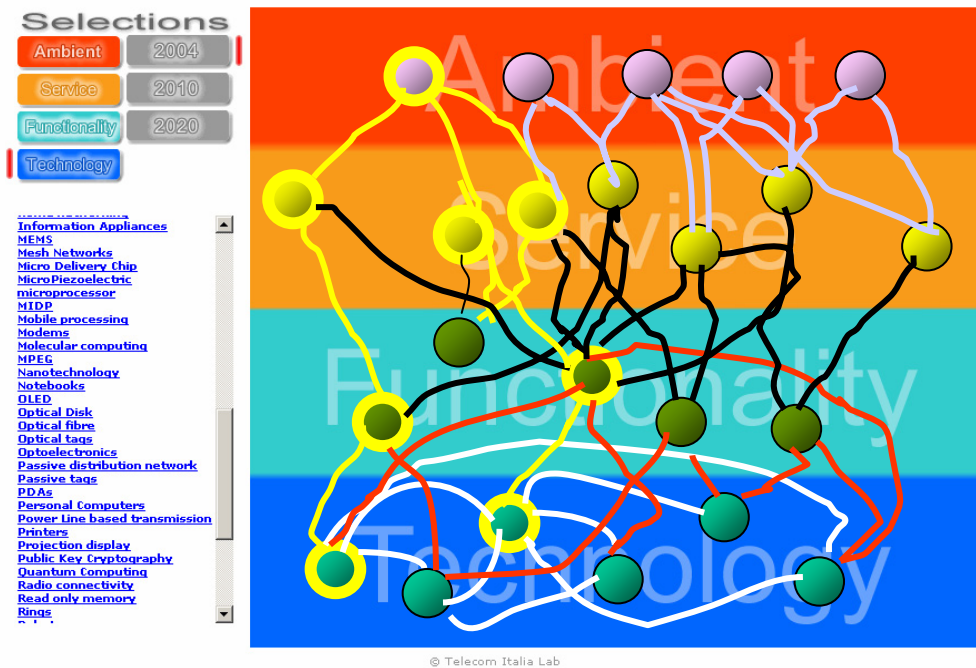


Figure 7. Visualisation of the links between different technologies in the database. Based on expert judgments, technological trajectories up to the time horizon 2020 have been mapped, together with the interdependencies by which they are characterized across the four layers of the model.

Example: Embedded Systems

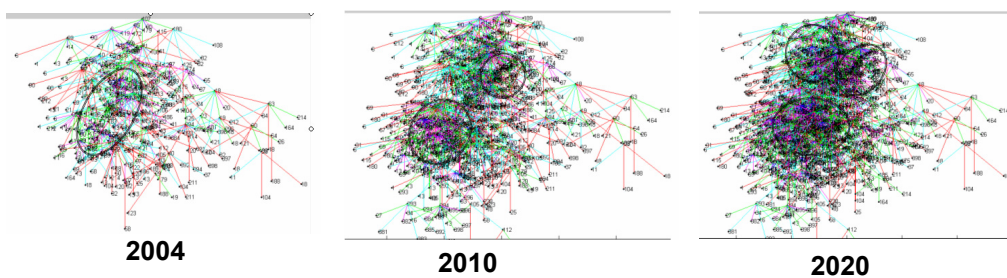
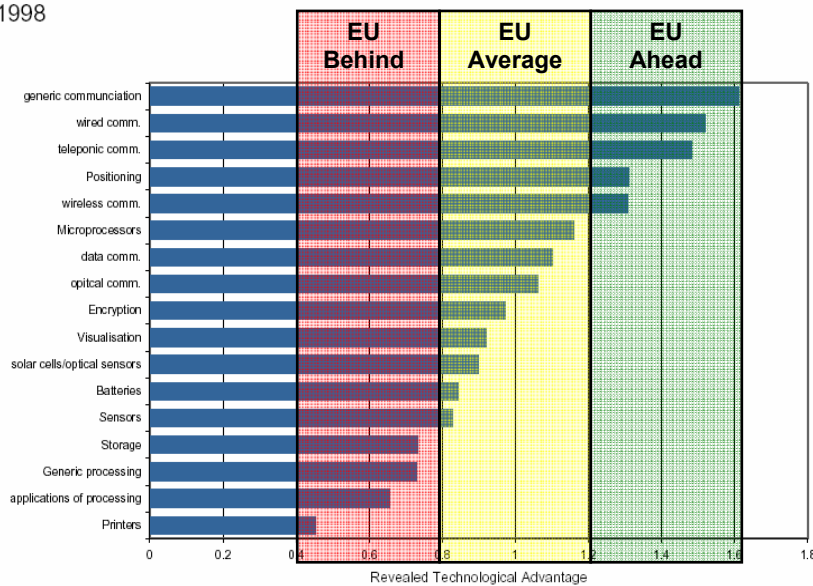


Figure 8. Visual representation of technology attractors as exemplified in the case of “embedded systems” as they result for the model explained in the figure above. The links between technologies between “embedded systems” on one side and other technologies or functionalities on the other side are represented with connections, whereby the strength of the link is represented by the length (the shorter the stronger) and the colour (the darker the stronger). With respect of the year 2004, the graphs for 2010 and 2020 appear far more dense and a number of new cluster appear, which are indicated with ovals (two in the case of 2010 and three in the case of 2020).

The R&D Capacity Europe for IST

FISTERA aimed to gain insights on Europe's position in the field of IST by analysing patent data by comparing the situation of the EU to that of the US and Japan at an aggregate level and by studying the relative position of European companies for particular technological fields. To ensure a well-balanced picture of the ICT patents worldwide, data from patent offices in Europe (European Patent Office), the US and Japan were considered.

Europe's Revealed Technological Advantage in various Information Society Technologies, 1996-1998



A value > 1 means a higher specialisation than the world and therefore a strength, a value < 1 means that Europe is less specialized in this technology

Figure 9. Patent analysis of selected information and communication technologies for the period 1996 to 1998. To determine the “revealed technological advantage”, all patents for a given technology filed in the Triade (EU, US and JP) is compared with the European patents. In the case the value is greater than 1 (like in the case of communication technologies) Europe has a competitive technological advantage, otherwise below³¹.

The aggregate data indicates that Europe lags behind the US and Japan in terms of overall patent activity in IST. The positive message is that Europe was catching up in the course of the nineties. This was partly due to a favourable position in

³¹ “Europe's strengths and weaknesses in Information Society Technologies – a patent analysis” Bernhard Dachs, Matthias Weber, Georg Zahradnik, January 2005 available at <http://fistera.jrc.es/docs/FISTERA%20SW.pdf>

communication technologies, which is a European strength, as can be seen from the Revealed Technological Advantage (for the RTA analysis see figure below). In some information and communication technologies, Europe's position with respect to US and Japan is better than commonly believed; for instance in data processing.

Europe owes this favourable development largely to the small and medium-sized countries, notably the Nordic countries, while IST patent applications from German, French and UK firms grew slower than the EU average³². At company level, the data confirm that the IST patenting is largely concentrated to a number of few key players. Half of all patents between 1976 and 2002 were awarded to 33 groups of companies, amongst those Philips, Nokia, Ericsson, Thomson, ST Microelectronics, Siemens, Infineon and Alcatel. The list of most relevant actors is stable over the past decades underlining a solid competence base of major firms even in a highly dynamic area like IST. Amongst these companies, Siemens, Nokia and Ericsson are outstanding in terms of R&D spending and are among Top 10 IST actors in all sectors examined. However, European companies are clearly under-represented amongst those ranking 10-100.

European ICT industries generally invest in research and development similar to their US or Asian counterparts (in some sectors, even more). Europe's lower overall R&D investment in the ICT sector, however, can possibly relate to its industry structure. Europe has a number of very prominent large players (Philips, Nokia, Ericsson, Alcatel, etc), but, unlike the US, it has fewer medium-sized ICT companies active in R&D. This may indicate that a challenge for Europe is to promote create more ICT firms doing R&D. Leading European companies file between 30 and 70% of their IST patents outside their home countries. This seems to indicate that the actual inventor is based either in other European countries or in the US (although the patent may be filed by the European parent company). At the same time, the number of patent inventions by European companies is higher than the number of patent applications, which indicates a strong presence of R&D by US firms in Europe. In the overall balance, there seems to be a constant flow of knowledge from Europe to the US for about 25% of all European patent applications.

These patent patterns have to be taken in consideration for policy in the field of IST. As the barrier of entry is high in the ICT sector, national strengths and weaknesses in IST change relatively slowly over the years, the policy strategy should be long-term strategy to achieve a sustainable change in specialisation patterns. Similarly, the technological competence of actors must cover a quite broad range fields in order to react to with disruptions and take up unexpected opportunities, it seems reasonable for IST policy to strike a balance between the setting of targeted priorities on the one hand, and the stimulation of more generic competencies on the other. This is also an experience from technological disruptions of the past in IST, when it was decisive in several cases to be well-positioned and prepared to take advantage of unexpected "windows of opportunities".

³² *idem*.

Table 2

The 2004 EU Scoreboard on industrial R&D

FTSE Sector	EU Top 500		Non-EU Top 500	
	Sector R&D	R&D/	Sector R&D	R&D/
	Investment	Sales ratio	Investment	Sales ratio
	as % of all	(%)	as % of all	(%)
	sectors		sectors	
Automobiles & Parts	23.8	4.6	15.7	4.1
Pharma & Biotech	17.0	15.2	18.5	15.1
IT Hardware	12.4	15.6	22.9	8.6
Electronic & Eletr. Equipment	10.3	6.5	10.9	5.7
Chemicals	7.2	4.2	4.2	3.8
Aerospace & Defense	6.8	8.0	2.1	2.7
Engineering & Machinery	4.6	2.5	2.5	2.8
Telecom. Services	2.8	1.0	2.0	2.5
Software & Computer Services	2.6	12.8	7.8	10.0
Oil & Gas	1.9	0.3	1.2	0.5
Others (21 sectors)	10.6	1.5	12.2	2.1
Total (31 sectors)	100.0	3.2	100.0	4.5

Despite that in seven of the top ten sectors, including the IT Hardware and Software & Computer Services, EU companies have higher R&D/sales ratios than non-EU companies which the IPTS published, demonstrates that there is a differential between EU-firms and non-EU-firms in term of overall industrial R&D intensity (the average ratio of total industrial R&D investment of companies listed in the Scoreboard to their total sales was 3.2% for the EU, lower than for Japan at 4.2% and for the US at 4.5%). This is mainly explained by size difference in ICT sectors (i.e. IT Hardware and Software & Computer Services) between the EU companies listed in the Scoreboard (with only 3.2% of the sales, 15% of the R&D investment and 17.4% of the number of top 500 companies) and non-EU firms from the Scoreboard (with 15.5% of the sales, 30.7% of the R&D investment and 30.4% of the number of top 500 companies). Because these sectors have high R&D/sales ratios relative to other sectors, their larger size in the non-E raises the average R&D/sales ratio for the whole group of non-EU companies".³³

Public research organizations

A FISTERA studied the R&D priorities leading public research organizations³⁴ [Dachs 2005] in the field of Information and Communication Technologies. The analysis included the following organizations CEA-LETI (France), NMRC (now called Tyndall National Institute, Ireland), TNO (The Netherlands), IMEC (Belgium), INRIA (France), FORTH-ICS (Greece), Fraunhofer IuK Alliance and Microelectronics Alliance (Germany), VTT Information Technology and VTT Electronics (Finland).

Most centres focus around generic technologies, like processing technologies, microprocessor research, optical networks, or various communication technologies.

³³ "Monitoring industrial research: The 2004 EU industrial R&D investment scoreboard", European Commission Directorate General Joint Research Centre and Directorate General Research <http://EU-IRIScoreboard.jrc.es/>

³⁴ *R&D Priorities of Europe's leading Public Research Organisations in the Field of ICT*, April 2005, Bernhard Dachs and Georg Zahradnik, ARCSys available at <http://fistera.jrc.es/docs/priorities%20dokument%20final.doc>.

On the contrary, near-consumer areas like cell phones, PDAs and PCs, digital video recorders were hardly subject of research in these 10 centres. The same applies to positioning techniques like tagging, GPS or Galileo. This is understandable as these topics are closer to the markets, or very specialized. More astonishing, however, is that the convergence of ICT with biotechnologies is hardly a subject of research except in LETI, NMEC or IMEC, where they deals mostly with lab-on-a-chip applications and medical diagnostics. Emerging topics, like molecular computing, bio-printers or wetware seem only be marginal in the strategy plans of big centres.

Table 3

Priorities of ten large public research organisations in Europe

	IMEC	LETI	NMRC	INRIA	FgH IuK	FgH ME	FORTH ICL	TNO	VTT Electr.	VTT IT
Bluetooth	x	x			x		x			
Cable TV								x		
Communication Infrastructures		x		x		x	x	x	x	x
Digital cellular base stations						x				x
Mesh Networks	x			x		x		x		
Optical fibre			x			x				
Radio connectivity	x					x				x
Software Radio				x					x	
xDSL								x		
UWB	x				x	x		x		
WiFi	x	x			x	x		x	x	x
WPAN	x	x		x	x	x	x	x		
Home networking				x	x		x	x	x	x

The table shows the example of the field of activities for a limited set of communication technologies.

Structured processes on how to set priorities are in place in a number of organisations. One example is IMEC, where the priorities seem to be, at least partly, to follow industrial technology roadmapping (here the International Technology Roadmap for Semiconductors) and scenario analysis. Other organisations that have no commonly accepted industrial roadmap justify their priorities more on a general ground. Here, projections of market demands seem to influence most the strategy of the research centres. This may be the reason why some centres were hesitant providing information as they feared that competitors could learn too much about their strategy. A strong market orientation requires a high degree of flexibility. Although there may be more or less market influence, public research centres do differ from corporate research in ICT in several ways. They are usually committed to long-term research; they are involved in training activities and they are engaged in technology transfer.

Conclusions

FISTERA aims at contributing to get insights on the future of IST. The FISTERA team developed new tools and integrated them with already existing ones within (outside and inside the consortium). After putting together many pieces of information and having analysed them, we can make the some worthwhile comments:

Many countries – in Europe and developed countries around the world – have made considerable efforts to develop national visions on how IST can contribute to their futures. Comparing these country specific exercises, we can say that although the countries may differ different considerably in terms of their economy and culture, they arrive often at similar conclusions technological priorities and application areas for IST. Consequently we can say that “basically sharing the same future”. This agreement of the majority of the national foresights is fully in line with the Lisbon objectives and the general views of the European institutions.

Despite the basic consensus of priorities in terms of the broader technical and application areas across the Member States, the European Union is not a central dimension. In the Member States national exercises interests do prevail and they influence the national vision. Consequently the sum of national foresights does not produce a vision for IST in the European Union. One option could be the creation of a pan-European dialogue trying to define a European Vision. The establishment of such a discussion platform is complex and requires a lot of resources. For instance, FISTERA’s experience with the pan-European web-based Delphi at pan European level has shown that creating functioning virtual communities has sill a long way to go and requires a lot of effort.

Gathering all information, FISTERA made an attempt to make prioritize areas. In this respect, for technology-driven priorities seem to emerge, namely technologies that enable the transition from products to services, that contributes to the disappearance of the computer (such as intelligent terminals) and basic technological building blocks such as embedded systems. The convergence of technologies with biotechnologies and nanotechnologies requires special attention. Socio-economic priorities are applications for education and learning, the enhancement of eGovernment and enablers for Health.

Economically speaking, there are doubts on the length and the intensity of the current ICT revolution, but there seems to be consensus that we are just in the middle of this technology wave where the deployment of real applications are still to come. Experts consider middle of this cycle to be critical to ripe the benefits for economy and society and decision makers shall be aware that we are at such a turning point. The analysis of strengths and weaknesses seems to indicate that the European Union has all necessary ingredients to lead the second part of the wave, if the appropriate actions are taken.

NOTE. *The orientation and content of this paper cannot be taken as indicating the position of the European Commission or its services. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of the information in this paper.*

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