EUROPEAN COMMISSION
DIRECTORATE-GENERAL JRC
JOINT RESEARCH CENTRE
Institute for Prospective Technological Studies (Seville)
TECS – Futures Programme

The Futures Project

Technology Map

Series No: 11

Eamon Cahill, Fabiana Scapolo

With contributions from: Ken Ducatel, Thomas Münker, Miguel Aguado, Peter Eder, Fabio Leone, Hector Hernandez

EUR 19031EN

December 1999

Table of Contents

Executive Summary

The Technology Map setout in this report offers a selected vision of some of the most probable key technologies impacting on society by the year 2010. The main sources used to prepare the report were the various national Technology Foresight studies carried out in recent years. The predominant focus is therefore on emerging technological developments. However, it should be borne in mind by readers that many existing technologies will still be of critical importance ten years from now and merit the same analysis carried out in this study.

Selection of Technology Sectors

Six Technology Sectors have been selected for this study on the basis that they are either extremely pervasive in the economic and social sphere or they are associated with the priority concern of sustainable development. The six sectors are

- Information and Communication Technologies (ICTs)
- Life Sciences
- Energy
- Environmental and Clean Production Technologies
- Materials and Related Technologies
- Transport

For each of the sectors the analysis reviewed the results of the national foresight studies to establish the fields of technology in which Europe was strong or weak. The results are represented graphically in Sector maps where a selection of important technological topics are depicted in relation to the time scale over which they are expected to impact. The topics are colour coded to represent the degree of strength or weakness revealed y the analysis and have an index of importance to economic development and quality of life or social development. From this analysis the following broad results can be established.

European Position on Emerging Technologies

Highlights include:

Strengths in

- Software development
- Mobile Communications
- Development of Sensors/Actuators
- Consumer Electronics
- Digital TV
- Drug Development
- Combined cycle Energy production
- Waste management and Recycling
- Telematics for Transport Applications

Weaknesses in

- Imaging and Visualisation technologies

- Basic chip production
- Artificial Intelligence
- Agrofood applications of Biotechnology
- Photovoltaics
- Battery development
- Ceramic material Developments

In general, the US holds the lead or shares the lead in all of the technology sectors except transport. Japan and the EU are more comparable.

Indicative Position of Europe			
Technology Sector	**EU**	**US**	**Japan**
ICTs	☆ ☆ +	☆ ☆ ☆ ☆	☆ ☆ ☆
Life Sciences	☆ ☆ +	☆ ☆ ☆ ☆	☆ ☆
Energy	☆ ☆ ☆	☆ ☆ ☆	☆ ☆ ☆
Environmental and Clean Production	☆ ☆ ☆	☆ ☆ ☆	☆ ☆ ☆
Materials	☆ ☆	☆ ☆ ☆ ☆	☆ ☆ ☆
Transport	☆ ☆ ☆	☆ ☆ +	☆ ☆ ☆

☆ The star symbol indicates strength in the sector. The number of stars indicate the approximate level of the strength. The + sign indicates higher but less than an additional star.

Within the sectors, different technology fields show quite different patterns. In the ICT sector, Europe suffers from some significant weaknesses in the area of ubiquitous computing and displays some considerable strength in the area of information and knowledge management. However, in the emerging technologies, Europe's strength in cell and molecular biology positions it well in the development of molecular computing and its strength in mobile communications and some areas of communications technology gives it the lead in many aspects of high density communications.

In the Life Sciences sector, although the EU trails the US overall, it has made great strides in several areas of medical technology including the software interfaces between processor based automation linked to bio-sensors and actuators and therapies for physical disabilities. Europe also has considerable strength in disease diagnosis and therapies based on emerging gene-based data and genetic processes. The danger to Europe's development in these areas is its general weakness in information processing which may hamper its development even in areas that are currently strong. The issue of technology interdependency is major in this sector and weak links in the chain reduce capability.

In the Agro-food area Europe has technological strengths but the development of those strengths will be significantly effected by the outcome of the debate on acceptability. The US has a lead over Europe in this area and the gap cannot be bridged without a concerted effort. The outcome of the debate will be critical to this effort.

In the Energy and Environment sectors Europe has a position of approximate parity in technological terms with the US and Japan. However, the governing factors in determining which technologies will find favour in developing markets for energy will be global and international policies and agreements and subsequent regulations. Europe holds leadership positions in combined cycle generation technologies and in areas of renewable energies.

In environmental technologies Europe is recognised as being strong in recycling technologies and waste management. In Clean Production technologies, Europe has strengths in catalysis.

Materials and Material Processing is a sector where The EU is trailing the US but there has been steady progress in bridging the gap. The Framework Programmes have contributed to this improvement but much more needs to be done by industry and research bodies. Materials are major bottlenecks in a number of sectors particularly Energy and the Environment. On the other hand the EU is rated strong in the area of certain polymers.

The principal areas of opportunity for the future lie in the application of ICT to the various aspects of living and working. Medium term opportunities exist in building on the strengths in communications technologies. The interface with Life Sciences offers a platform for expanding on areas of success in the application of ICTs in the medical field. However, one of the major threats to full exploitation of Europe's Life Science capabilities is its weakness in areas of IT such as imaging and visualisation, and artificial intelligence.

Both the Energy sector and the Environment sector can avail of global opportunities for environmentally friendly technologies particularly in Asia. However, the full adoption of international conventions will be a necessary condition for these markets to develop. In the Transport sector Europe's technological strength can also be exploited if associated policies to combat congestion are adopted.

Main Policy Conclusions

From within the various technology sectors there are a variety of policy issues, which have been set out in the respective section of Chapters 2 to 7. The main policy messages are the following:

1) Strengths in ICT applications areas in Life Sciences, Transport and Materials are threatened by Weakness in basic ICT enabling technologies,

2) A policy agenda backed by solid research is needed in the area of risks in Life Sciences, such as for food safety and privacy and security of information in ICTs.

3) In some sectors, Energy, Transport and Environment, technology will assist in alleviation of problems but cannot solve them alone.

4) The connection between people and technology is critical to successful technological exploitation.

5) Full development processes for technology systems take extended periods of time.

6) Technology Maps can be structured as technology management tools.

These messages are elaborated in the conclusions of the report.

The broader overarching policy issues are outlined here.

A pervasive issue for public policy, covering all the sectors in this Technology Map, is **the availability of the human resource capabilities needed to develop and exploit the technological opportunities**, which will emerge. This has particular relevance to education and training for those who are to be directly involved in the creation and diffusion of technology. It is also relevant to **society** as a whole where **understanding and critical assessment of technology and its effects on life and living** will be a determining factor in how societal development will take place. This issue is explored and discussed in greater detail in the section of the Futures Project final report devoted to Knowledge and Learning.

It is clear that public research programmes such as the 5^{th} Framework Programme, contribute substantially to the effort to bridge the gaps in technological capability outlined above. Historically success or failure of these programmes was judged largely on whether or not exploitable technical solutions emerged from the research. Modern thinking would suggest that **equal importance and emphasis should be placed on the effect of the research projects in terms of their impact on the knowledge space between the research partners core knowledge and the frontiers of the research activities**. This aspect of research activity deals with a range of **soft technological issues**, which tend to be implied in many of the foresight topics that are included in the studies. The issue for research policy is to **include 'soft' as well as 'hard' technological criteria** in their selection and evaluation of projects.

An area of public policy hotly and continuously debated and critical to technological development is the issue of intellectual property rights (IPR). It is well recognised that **weak** IPR policies hamper innovation by removing incentive and **too strong IPR policies hamper innovation by stifling competition**. In the future resolving this complicated trade-off will call for careful crafting of policy and being prepared to be **selective and targeted** in contrast to traditional legislation, which has tended to be something akin to a blunt axe for dealing with what is actually quite subtle surgery.

The competing aspirations of citizens between natural desires for improved living standards and the requirements of sustainable consumption will set the context in which the prospect of significant economic prizes will exert strong pressure for technological advance. In areas like Environment, Energy and Transport **difficult balances in policy making will be required to ensure that results obtained raise total social welfare**. There will arise many policy dilemmas between private aspirations and overall social welfare. The policy context will be continuously shifting and **technological developments may not always help in finding the balance**.

Life Sciences may prove to be the most vibrant and most complex policy arena where educating the ageing cohort of the population will be needed to ensure that their political choices in these important areas are well informed in a period when the international economic forces will be carving out their shares of this important field. The current dilemmas in relation to **difficulties with acceptability will not easily be resolved** and there is a clear need for **a research agenda to support policy making** in this area. Despite the rapid pace of developments the likely time span for this research will be long, as the issues are complex and politically sensitive.

The issues of **technological interdependencies suggest** that again despite the rapid pace of individual technological changes exploitation through **the full development process** will take longer than is popularly expected. The case of materials where this process **can take up to 15 years** is an example. This must form part of the context in which public research policy is crafted.

Finally, to support this complex task of providing balanced public policy, which meets all the realistic aspirations of citizens in their many roles in an increasingly technological society, there will a need to continuously employ prospective analysis.

1. Introduction

This Section of the report is devoted to outlining the components of the Technology Map, which will offer a vision of the most probable key technologies impacting on society by the year 2010. These impacts will include improved health, enhanced care of the elderly, increased participation by citizens and sustainable economic growth. In order to ensure completion of this phase of the project within a reasonable time frame, it was necessary to limit the range of technologies and fields of application studied. The rationale for these choices is outlined later in this introduction. However, it must be stressed that the areas omitted are still important and merit analysis similar to that carried out in this study.

1.1 Choice of Technologies

The two principal areas focused on in this report are ICT and Life Sciences. The choice of ICT reflects its wide spread pervasiveness in every field of economic and social activity. Developments over recent times have created a paradigm shift to a knowledge-based society in which human activity is increasingly focused on ideas, an area in which considerable progress remains to be made. ICT, in many ways, has revolutionised commerce and the way Governments conduct business, that is, in its ability to bring people of like interests and needs together in real time in a borderless world. After some false starts during the 1980's, biotechnology is now going into a huge expansion driven by genomics, DNA chips, combinatorial chemistry, phage display libraries, the polymerase chain reaction, robotics and perhaps other potentially high impact technologies which are now producing a torrent of data. These and other arcane disciplines moved the US National Science and Technology Council to conclude in 1995 that biotechnology

> "may well play as pivotal a role in social and industrial advancement over the next 10 to 20 years as did physics and chemistry in the post-World War II period".

More prosaically, the EuropaBio Report of 1997 considered that

"the value of products and services using biotechnology in Europe could reach ECU 250bn. by 2005 and affect more than 3 million jobs".

More recent evidence in Europe would temper these glowing testimonials. It is quite clear that in Europe an acceptance of the legitimacy and benefit of genomic reseach and development in health and life sciences is matched by a deep unease and suspicion of the corresponding activities in food and agriculture.

The other fields of technology chosen include those most closely associated with the priority concern for the world in the coming decades, sustainable development. The fields of energy, transport and the environment are moving to a seamless interaction in which technology is both the source of societal concerns and the major provider of solutions to those concerns. Finally the area of materials is not only a significant horizontal component of each of the other areas, it covers the critical issue of physical resource use within environmental sustainability.

1.2 Method

Placing, with any pretence of accuracy, time horizons against key technology breakthroughs stretches the credibility of the activity even further than does identifying the most important technology trends and events. Nevertheless, *this section tries to provide a timeline map of some of the main emerging features of key technologies*. The value of the exercise lies in its potential to provoke thinking about the interactions between technological trends.

The procedure adopted was a straightforward reanalysis of a series of recent national level foresight reports. The initial work for the reports was undertaken on behalf of the Spanish Office of Science and Technology (OCYT) at the end of 1998 (Fleissner et al., 1998). Later studies ongoing or completed in 1999 were added to the analysis. A full list of relevant studies is provided in Annex 1

A further word of caution before proceeding: variations between the different foresight exercises mean that the result is indicative rather than precise. There are differences of timing, approach, scope and method between the foresight exercises. There are also differences in methodology used. These include Delphi studies, Key/Critical technology studies, Scenario-based studies and expert panel reports. For example, many of the reports aimed to identify only technologies deemed crucial for the nation concerned, rather than in terms of their overall strategic importance. However, the countries concerned represent some of the largest of the advanced international economies (certainly at European level), so in general, the results can be taken to be quite reliable.

Second, in selecting out critical technologies different procedures were adopted, even down to the number of critical technologies identified, which varied from about ten to twenty. Some of the reports consistently refer to first commercial introduction, others to widespread usage and others to invention and development. These differences affect the time scales somewhat but the essential issue is that any country wishing to exploit these technologies must have its basic capabilities in place by the earliest realisation dates. Thus the basis for comparison requires to be viewed with some flexibility to cater for these differences.

Third, even within the reports there is always a range of opinion on the likely date of introduction, this can vary quite widely. For instance, see the chart for Ubiquitous Computing which indicates a range for the 1Gb Memory Chip between 2002 (the UK estimate) and 2004 (the Italian estimate).

1.3 Position of Europe

In each section the strengths and weaknesses of Europe are assessed in broad terms. The strength of a region or country cannot easily be set in a future time scale but the current state of capability is at least a solid starting point for considering likely future positions. If significant weaknesses can be discerned in areas of technology and these technologies will underpin mainstream developments in the future, then clearly, without well defined and focused actions to strengthen the position, there will be no prospect of being a strong player in the field. The presence of significant strengths now, while no guarantee of future strength, is at least a strong positive indicator of ability and opportunity to lead in the future. Even the acquisition of technology can be hampered by weakness in the appropriate area of skill and knowledge and the systemic nature of technological exploitation and innovation means that any such weakness must be regarded as a threat to competitiveness and growth.

The position of Europe in each technology sector has been derived from the results of those Foresight studies where the respondents expressed their views as to which country or bloc was the leading country in the technology topic.

To set the issue of strength or weakness in context each technology topic or individual technology has been assigned the "Importance index" given to it in the individual studies. In general this index refers to the expected impact on economic development or wealth creation but in some instances it also encompasses the expected impact on social development or quality of life. The index is on a scale from 1 to 100.

1.4 Technology Interaction

A particularly important aspect of the Technology Map is where the conjunction of technologies requires two or more technological developments to be available in order to spur innovative opportunities. Main technology interactions are listed in each technology sector.

Many of the most radical and influential innovations can be expected to occur at these cross-over points and interstices between technology platforms. The report has assembled a range of interactions involving the fields of technology selected. Each of the technological sectors has multiple interactions with the others. To attempt to show all of them would lead to confusion, so three principle interactions have been outlined as examples. These are set out in Annex 2. Even these have been restricted somewhat in terms of the interactions shown, in order to clearly illustrate the functioning of the Map.

The Technology Map has been constructed at a level of aggregation of detail appropriate to the target audience for the overall project, that of the European/Member State policy maker. For lower levels of aggregation, at individual firm level or technology platform level, the scope of a technology map would be much narrower and would be much more detailed.

It is important to understand that the Technology Map can be disaggregated into a series of more detailed maps down to the level of individual technologies. However, for the purposes of examining interactions between technologies the aggregation level at sector level is appropriate. It permits the influence of same technology in different sectors to be seen.

2. Information Communication Technologies

2.1. Introduction

Information and Communication Technologies (ICTs) are arguably the most pervasive of all advanced technologies. The ICT industries are major (and growing) contributors to GDP in many countries (in the UK the ICT sector is 8%, in the US electronics is estimated to be 10% of GDP). ICT is a broad and highly interconnected set of technologies, which affects all sectors of economic activity and many social arenas. It is also a very dynamic sector, with very short cycle times, especially in some of the basic 'enabling' hardware technologies such as semiconductors and peripheral devices (displays, sensors and actuators). In short, ICTs are a key driver of technology and social and economic change. For example, of 100 'Critical Technologies' across all disciplines identified by US Council on Competitiveness (1995) 55 were specifically ICT topics, which increases to 69 when new materials, which are ICT related, are included. For these reasons, ICTs figure prominently in all 'Technology Foresight' investigations.

ICTs do not comprise one single technology or even a single system of technologies. There are in fact many ICT systems, built-up of layers of enabling technologies. These systems themselves often interact through communication networks and because they are software based they are reconfigurable. The result is an almost organically complex technological architecture from which it is hard to isolate a few key technological types and trends that are the most important. Likewise, it is hard to identify single points of breakthrough, which are significant (for other technologies, for industry or indeed for society).

The discussion in this section builds upon an earlier international review of Foresight studies (Fleissner et al., 1998). For the present report, a technology roadmap has been constructed, based upon expert forecasts of the 'date of commercial introduction' of an ICT. These are derived from the various foresight reports - <u>where such predictions are provided</u>. For ICTs this meant restricting the analysis to the following reports: Germany 1998 (D98); Italy 1996 (I96); Japan 1997 (J97) and UK 1998 (UK98). In addition, the British Telecom (1998) Technology Calendar was added, as it provides a very useful timeline, which is also a summary of other expert forecasts. The technologies charted are those which were identified as having some kind of critical importance, a definition which varies substantially from report to report.

In order to simplify and structure the presentation two general ICT fields of development were selected from the earlier work from the ICT Panel of the Futures Project (Ducatel, 1999).[1] These are used to provide a structure for the underlying enabling technology trends.

The ICT Panel report identifies three broad trends. Here the first two, the shift towards seamless interoperability and the growth of information appliances, are combined into a general trend towards <u>ubiquitous computing</u> (Chart 2.1a). This leaves the third broad trend, the movement towards <u>knowledge management</u> as the second main structuring element of this section (Chart 2.1b).

Before proceeding, caution is needed in using the results of the exercise, as the various surveys do not in fact produce directly comparable results. For example, slight differences in the descriptions of technologies can cause variations in timing of the innovation event. For instance, Next Generation Internet (NGI) is proposed for 2003 by the J97 report, but

---

[1] Ducatel, K. (1999) The Futures Project: Information and Communication Technologies and the Information Society, IPTS-JRC, Sevilla.

only by 2005 by D98. However, the German description specifies that the NGI will include secure voice and television over Internet, which is absent from the Japanese description. This kind of variation is relatively easy to deal with as it merely indicates a range of opinion, rather than starkly different opinions.

In fact, perhaps the interpretation should operate in the other direction, that we might draw comfort from the very high levels of overlap and the surprisingly high level of coincidence in the time horizons between the different reports. However, generating a succinct and accurate descriptor of the technology innovations has been difficult given different levels of detail or specificity that are offered in the reports. As noted above, it would be desirable to carry this procedure out in a more systematic way, but this would require developing a common set of technology descriptions. Only this would allow a direct comparison of the technological event horizons faced in this complex area of ICTs.

2.2 Priority ICTs

- Ubiquitous computing (Chart 2.1a)
- Knowledge management tools(Chart 2.1b)

Ubiquitous computing: describes a state in which computer-based devices become so cheap, seamlessly interoperable and easy to use that they will find application across a broad swathe of everyday activities. The implications of these changes for policies on technology, employment and competitiveness will be profound.

For ubiquitous computing, microelectronics will continue to be at least up to 2010, one of the most enabling of enabling technologies. In all reports this trend was given a high priority, if not as a technology in which it would be necessary to have technological and production capacities, then as one which will require a technological response. The forecast continuation of Moore's Law in the production of silicon based processors and computer storage devices is expected to lead to the production of very high frequency components, including features etched down to .01 micron (2005) and very large 1 Gbit memory chips. The expectation is that very large scale integration (VLSI) design, miniaturization and the automation of its production will be very important, continuing into the second decade of the 2000s.

But in parallel, key trends towards new processing methods have been identified, especially based upon molecular and even single electron devices and, on the other hand, neurochips and biochips. These then are appearing on the research agenda of today as the potential drivers of processing and storage for tomorrow.

Further key technological trends of the time span relate to the development of systems, including input-output and power components, which can be embedded into non-PC devices. This generally means making devices smaller, lighter and interconnectable. Batteries are expected to improve markedly up to the point where their energy densities approach that of explosives. These improvements will depend upon new chemical materials for energy storage. Change will be driven by concerns about lightness and longer lasting battery power for mobile, wearable and other portable devices. However, environmental concerns will encourage a shift towards low or no heavy metal content. Further development of new materials is taking place, especially for (non-cathode ray tube(CRT)) displays, smart textiles and even smart ink. Key areas of such development will be in a growing use of "magic eyeglasses", very large and high definition video walls, and even active contact lenses (by 2005). Three-dimensional display and holographic display (especially in motion) is expected to lie beyond the 2010 target, if only because the computing processing capacity will not yet be available to render such highly demanding video imagery. It is also unlikely that a market demand for such sophisticated applications could be created by then. Although not strictly speaking a technical constraint, the heavy transmission demands of real-time holographic video also means that the telecommunications infrastructure will also be unlikely to be able to handle 'holodeck' videoconferencing for most users during the timeframe.

The ease of use of information technology devices is being achieved through a gradual liberation from screen and keyboard with automatic data capture (especially various forms of sensors), voice, speech and pattern recognition (see also the second chart on knowledge management). Here there is an expectation of many end-user devices, which offer full machine voice, remote noses, and continuous natural language translation. Such devices will be very important in applications such as driving and piloting, working with machinery, security and access control and for travellers and tourists.

The necessary complement to these computerized devices is a massive expansion in interconnection and communication both fixed and mobile. The recent unanticipated growth of the Internet and of mobile phones can be seen as the first steps towards a Networked Society, in which people will expect to be able to be in communication anywhere and anytime and in full-motion multimedia. A key requirement for this vision is low-cost broadband access. This is a question more of evolving market structure than technology availability. By 2007/8, fixed-line telecommunication systems are likely to reach 34Mbps (D98) or even up to 150Mbps in fixed cable systems (at least in the major cities - J97). Portable, even wearable, communications systems are also likely to see very large-scale roll- out, based on terrestrial, and to a lesser extent, satellite communications (e.g. LEOs - Low Earth Orbit Satellites are already with us). This is one of the main themes. However, for these applications bandwidth is scarce, current plans (UMTS and Teledesic) being limited to 2Mbps (still easily sufficient for multimedia applications - but at a high cost and with users competing for capacity). By about 2006, though there is an expectation of bandwidths of about 10Mbps for mobile and fixed devices.

Communications bandwidth, though, has to be accompanied by seamless interconnection for users, if the dream of ubiquitous computing is to be realized. One key event along the way will be the introduction of the Next Generation Internet that is expected to arrive around 2002, capable of offering real-time voice and television services. A seamless interconnection between the proliferating modes of communication access is expected as early as 2006, although this may be optimistic given proprietary interests and proliferating standards. Ubiquitous computing implies that people and devices will be connected in such a way that they will not want to have to worry about network boundaries and incompatibilities. It is for these reasons that smart software (middleware), which plugs the gaps between technological systems, is going to be a critical element of the technological trajectory in ICTs in coming years, which leads to the second main trend the shift towards knowledge based software systems.

Knowledge management tools: here refers to a cluster of software technologies spanning, software programming, data processing and artificial intelligence. The very fast rollout of ubiquitous computing with the implicit pervasive application across all industries and activities and the complexity effects of interconnecting all these devices could create a software bottleneck of gigantic proportions. On the one hand, over the past fifty years hardware has achieved an eight orders of magnitude increase in performance, whilst software is still largely a craft industry. Thus, it is not surprising that software related innovations were repeatedly at the top of the priority lists of ICT technologies in the Foresight reports.

Virtually all the foresight reports identified the crucial role of new software construction methods, with emphasis on formal software modelling, object orientation and reusable libraries being the main breakthroughs in the period to 2010. Software certification and testing was also identified as a challenge, but was generally seen as a longer-term issue which was associated with the formalisation of programming and eventually the development of self-learning and self-writing software.

Data capture, data mining and warehousing technologies are critical technologies of the moment, and are beginning to achieve widespread use. However, as the scale of use expands, new techniques for identifying patterns in data are required, and it is expected that a crucial area of demand will be for large-scale data retrieval. These will be live issues right up to the end of the 2010 time period, especially with the global growth of e-commerce and requirements for distributed networks, personal ID authentication, security and monitoring of illicit activities. The fact that the biggest investors in raw computer power in the world today are the security services (CIA) and the credit/debit card companies (e.g. Amex) indicates that managing global databases is likely to be one of the major areas of demand for the growing computer power. The global data system is expected to fuel demand for supercomputing and for software tools to sort and manage this information, right through to 2015.

Making distributed databases inter-operate is one of the two key drivers of development efforts in software agents (i.e. software which can be programmed to reflect user preferences in order to automate searching for information, management of data and so on). They will be needed for instance to develop self-regulating computer resources (such as the automatic computer virus vaccines predicted for 2008). Software agents also play the role of making the information in information systems easier to cope with use for humans. These are two of the principal areas of development of artificial intelligence over the period to 2010.

The other crucial group of artificial intelligence techniques that will be evolving rapidly up until 2010 will be voice, language and pattern recognition systems. Voice synthesis systems are already well developed, but it is expected that by 2006 they will be indistinguishable from human voices. Similarly, translation of natural languages is an area of challenge particularly for European countries. Breakthroughs are expected here through to around 2010 so that portable translation devices ('Babel Fish') and instant text translation will be available for all on-line material. Pattern recognition is more difficult, because the meanings of patterns are often not related to easily recognised variations in their surfaces, distributions or topologies. For example ideogram recognition is not expected until around 2012 and for more general vision systems very low error rates are not expected until beyond 2015.

An important, component of these artificial intelligence developments will be context sensitive systems. Again, perhaps optimistically, several of the reports suggested that true artificial intelligence, which understands its context and which has the capacities to see, hear, touch and act in a reliably way, will arrive around 2017-2018. However, the history of such predictions is not encouraging. Rather more likely are development software agents (knowledge management tools) in support of human to human working in the form of groupware and/or expert systems management tools. These technologies will be able to learn about user behaviour and adapt their responses, and will even adapt their responses according to social rules, so that for instance they will offer prompts which are appropriate to the task being carried out and the people involved.

From the perspective of our current period of information overload, such tools may provide a necessary lifeline. Indeed, as they become smarter, they may reduce the knowledge bias in the Information Society, which currently seems to polarise people not just into information haves and have nots, but those with know how and those who know not. The target for such knowledge-based technologies will be hit when computer devices become very intuitive and easy to use. This would require a much higher degree of reliability and less complexity for the end user than 'user-friendly' computing can achieve today. Some technological opinion formers call this the coming age of ‘calm technology’, where the technology is not only commonplace, but gets on with its job without continually reminding us to be aware that there is a technology getting between us and the task we want to achieve.

2.3 Position of Europe

The position of Europe, as reported in the studies, is generally one of weakness in the ICT areas of ubiquitous computing and the underlying electronic technologies. A starting platform for ubiquitous computing is digital TV and consumer electronics and it will be possible to build on Europe’s experience of dealing across national boundaries with interconnectivity issues. A more encouraging picture is discernible in the area of knowledge management although again weakness in the representational technologies is a worrying factor. The Japanese study (J97) and the German study (G98) both explicitly address the issue of assessing the leading country or countries under each topic in the Delphi questionnaires. When the replies are analysed in the Japanese study the US is rated as the leading country overall, Japan is rated some distance behind the US and the EU is rated behind Japan by a considerable margin. In the German study, the rating of the respondents of Germany’s position was closer to Japan with the US in the lead, but the rating given to the rest of the EU was very much lower. Overall both studies indicate a substantial level of weakness in the EU relative to the US and Japan.

Within the individual technology fields however, Europe has some very strong positions. In the area of mobile communications and consumer electronics technology Europe has moved into the lead with Japan leaving the US trailing somewhat. In the emerging field of molecular computing Europe is building a strong position from its strength in cell and molecular biology and molecular physics. Biological computing has the potential to introduce machine architectures, which respond to more intuitive instruction sets and this make a crucial contribution to the advance of knowledge management and applications processing. Europe also has strength in information and knowledge management and software.

Areas of weakness include aspects of artificial intelligence and chip manufacture. The position on imaging and visualisation technologies is also weak and would give cause for concern in many application areas. Having to depend on other countries for technologies may have some major drawbacks for the development of application and related technologies (See Charts 2.1a and 2.1b in separate pdf file.)

2.4 Policy Relevant Conclusions

The ICT area is not only vast in its own right but provides an essential underpinning to all other technology areas and to all areas of industry and services. With the roll out of the Internet and the possibility of Ubiquitous Computing, it is increasingly becoming a defining feature of private life as well. For these reasons it is not an option for any Member State in Europe to ignore developments in ICTs. By the same token and in contrast to today’s PC-oriented environment, it will become increasingly difficult for any country or firm to alone dominate the supply and production of ICT technologies.

The, breadth, complexity and inter-relatedness of the technology systems, and the speed of development, means that the high costs of surmounting formidable technical barriers are increasingly being tackled on a broad front around the world. However, there are differences between the different technologies in terms of the possibilities and consequences of national specialisation. For example, the production of certain enabling hardware technologies, most notably chip manufacture, is likely to be constrained to a few manufacturing sites world wide because of the very high costs of building fabrication plants. By contrast, software systems will be differentiated. There will be some high levels of concentration in vertical applications (e.g. operating systems, word processors and spreadsheets). But considerable decentralisation is possible in the location of software development efforts (constructing software libraries, components, sockets and dataplugs, tools for modelling and testing, knowledge visualisation techniques, and so on). In fact, software tools are being created and adapted wherever there are users. A good illustration of this is the way that the Internet, and by extension the vast population of on-line computer users, are operating as an enormous (global) community of systems developers and testers, especially in the area of software systems.

A key conclusion is that for all countries, the strategic ICTs are software tools and systems, especially in making breakthroughs that are related to high priority end user functions. Thus for non-native English speakers, natural language tools will be a strategic area. For, countries such as the Netherlands with significant transport sectors (and traffic problems) there will be big demands for transport telematics applications and so on. However, the adoption of these technologies at individual country level will be less than optimally effective unless standards are interoperable. In general it is also worthwhile for countries to support the evolution of highly important generic expertise such as the extracting of value from information, for tools that permit systems to interoperate and artificial intelligence. This can operate through fostering a position in the basic research, but it would need technologically dynamic industrial spinoffs that are experimenting with such techniques to make such support worthwhile. Thus again, what makes an ICT strategic depends upon the potential competitive advantage of industry that can result. Similar arguments pertain to the potential high growth in areas such as systems integration and industrial robotics and mechatronics. The questions which remain are which systems will require integration and which hardware competences exist and for which industries? The embedding of smart microsystems into products also calls for a combination of software and hardware engineering, but here the challenge is to interact with traditional approaches and attitudes in mature industries such as construction, furniture and wood products, textiles and so on.

Overall, the first recommendation is to build on what exists - develop systems that can be test bedded in practical application in industry. Second, given that the real bottlenecks are likely to be in software the support for fundamental research and, especially, the development of human capital in this area is a priority. Finally, platform building is likely to be important. This means creating an environment for developers, one example is the stimulation of multimedia broadband systems, which can provide the possibility for trying out new techniques.

It should be noted that the onward and upward progress of ICTs is not free from particularly thorny issues. One area of human interface with the technology, which could apply a severe brake on progress, is the issue of privacy and the security of information. Policy makers may have to contemplate stringent policing of the information highway to ensure public confidence. Other regulatory issues which remain to be resolved in the ICT area are the overall regulatory structure, technology independent regulation, arms length regulation and “light touch”regulation. To a lesser extent health issues related to long duration usage of equipment or cumulative effects of waves or whatever, remain to be explained sufficiently to allow consumers the opportunity of making informed choices about using the technologies. This in turn has implication for standards and regulation.

2.5 Technology interactions

The focus so far has been on the ICTs and their interactions. However, although ICTs are a major stream of technologies in their own right breakthroughs here depend upon and may provide a platform for other technological trends occurring in other areas. It would be trivial to state that ICTs in the form of computing power and telematics have a dramatic impact across all other technological fields. For example, gene sequencing is unimaginable without computing. Also, a full cross-impact analysis is outside the scope of the current exercise. However, in this section some of the areas of interactions are identified below

ICTs and materials

The key areas of dependency of ICTs on materials concern:

- Materials for semiconductors (e.g. Gallium arsenide)
- High temperature superconductor materials (polymers and ceramics)
- Flat display technologies (polymers)
- Power storage materials and chemistry

In the other direction Materials and Materials Processing will rely on ICTs to provide the support capabilities to

- Modelling and simulation
- Large scale database management for material attributes and performance.

ICTs and bio-sciences

Key techniques depend upon:

- Breakthroughs in the understanding of human cognition and reasoning
- Transfers of knowledge about genetic programming (both ways)
- Neuroscience applications to artificial life
- Prosthetics (human machine integration)
- Bio-chips and cellular-computing and memory
- Biosensors and imaging

Many of these applications will not be in the commercial field until after 2010 but the significant R&D will be needed in that period. The field of medical prosthetics is one in which Europe has many engineering and clinical strengths and needs the complementary strengths in human/machine interfaces from the ICT sector.

Mechatronics/production technologies

Key developments depend upon:

- Developments in micromachines/nanotechnologies
- Sensors - biological and chemical
- Molecular manipulation techniques

ICTs and Transport technologies

Key developments in this area are:

- Developments in transport telematics and traffic control systems
- Automatic operation of vehicles and driver support systems.

3 Life Sciences

3.1. Introduction

Life Sciences represent undoubtedly one of the most important and decisive technologies for the forthcoming century. Life Sciences, and in particular modern biotechnology, will contribute in many ways to improving human health, food production and environmental protection. In this sense, biotechnology appears to be of major importance for the future development of both health care and agriculture.

Biotechnology will provide the health care system with new approaches to fighting the major diseases of today such as Cardiovascular diseases(CVD), Cancer and some of the infectious viral diseases like Hepatitis or HIV. High throughput screening and sequencing activities of today will give us insight on the structure and the details of the human genome. Legitimate hopes exist that we will also be able to understand the molecular mechanism of some of the neurodegenerative diseases such as Alzheimer's and Parkinson's. In this context, the expected demographic changes including the ageing of European society will cause a technology pull. Both services and products will develop to satisfy a growing demand from the elderly population.

Many of the diseases in modern society are directly related to life-style and environmental factors as well as the influence of genetics. They contribute substantially to increasing the number of patients suffering from obesity, diabetes and cardiovascular disease. In this sense, there are two different but complementary approaches to attenuating disease incidences: Firstly, the *management of diseases* including intelligent nursing and remote surgery connected with ICT developments; and secondly, *technological solutions* including new drugs for CVD, AIDS, Cancer and Life Style Drugs.

For agriculture and food, the recently acquired and improved knowledge on genetics and molecular biology facilitates genetic intervention in crops, micro-organisms and animals. The future will bring crop varieties better adapted to consumer and industry needs with in-built resistance to pests, diseases and environmental stress. Biotechnology will also have an important role on food ingredient and additive production, enhancing freshness and flavour in foodstuff. Modern biotechnology is also entering the improvement of livestock productivity and even beyond: production of high-added value products such as pharmaceutical drugs in plants or milk. Despite the fact of production improvement, biotechnology appears also as a valuable tool to ensure food safety through the use of hazard or micro-organism detection and analysis methods.

3.2 Life Science Applications

The different national foresight studies, which were reviewed to establish this technology map in the area of Life Sciences, have mentioned the following fields as the most important for future applications:

Cardiovascular Diseases

Cardiovascular incidences and heart diseases represent the most severe human illness in terms of total deaths. Apart from heart diseases, cardiovascular system disorders include: blood clotting, congestive heart failure and hypertension (high blood pressure), which is a major risk factor for potentially life-threatening diseases such as stroke. Interesting data from the World Health Organisation show that in 1997, of a global total of 52.2 million deaths 15.3 million were due to circulatory diseases. Moreover, most deaths from circulatory diseases were coronary heart disease (7.2 million), cerebrovascular disease (4.6 million), other heart diseases (3 million). In this line, among the most relevant events and associated timeframes are the followings:

Event	Timeframe	Report)
- Identification of genes related to hypertension		
and arteriosclerosis	2012	*(J97)*
- Treatments for arterial occlusion		
and myocardial infarction	2000-2004	*(UK95b)*
- Interaction between lifestyle an genetic		
susceptibility	2000-2004	*(UK95b)*
- Guidelines for adult disease preventing life style	2006	*(J97)*

Cancer

Cancer is the second leading cause of death in the developed world, with half these deaths occurring in patients under 50 years of age. Not only is the illness distressing, but associated chemotherapy and radiotherapy can also be traumatic.

Much of our hope and optimism for combating cancer relies on novel cancer therapies that will be developed in the near future. These hopes are being triggered by the fact that nearly all the human genes have been isolated and identified and that their complete characterization (gene function) is now just a few years away. Out of these 100,000 genes many will represent targets in cancer research. The detailed study of the components involved in signalling pathways, responsible for behavioural changes in cancer cells, appears as the most interesting research area for cancer treatment. A good understanding in this field will lead to the determination of the consequences of tumour growth, as well as the inhibition or reparation of cell damage. In this line, among the most relevant events and associated timeframes are the followings:

Event	Timeframe	(Report)
- Identification of multiple genes related to cancer	2014	*(J97)*
- Development of anti-cancer agents (gene level)	2009	*(J97)*
- Widespread use of treatment methods		
for dys-differentiating carcinogenic cells	2020	*(J97)*
- Drugs preventing the occurrence of cancer	2010	*(J97)*
- Effective means to prevent metastasis	2013	*(J97)*
	2000-2004	*(UK95b)*
- Impact of environment and behaviour (nutrition)		
on carcinogenesis	2012	*(J97)*
	2000-2004	*(UK95b)*

Neuro-degenerative Diseases

There is a growing consensus among researchers studying Parkinson's disease, Alzheimer's disease, Huntington's disease, amyotrophic lateral sclerosis, and other late-onset neurodegenerative diseases that they may all be looking at the same process: aggregation and accumulation of abnormal proteins.

Alzheimer's disease (AD) is a progressive brain disorder that occurs gradually and results in memory loss, unusual behaviour, personality changes, and a decline in thinking abilities that cannot be reversed. Identification of genes implicated in AD provides new opportunities for analysing the initiating cellular events, as well as how the protein products affect these events and how the initiating events lead to the well-recognised pathology of AD.

Amyotrophic lateral sclerosis (ALS) and Werdnig-Hoffmann disease (WHD) are neurodegenerative diseases for which nowadays there exists no cure or prevention. ALS and WHD are involved in progressive degeneration of motor neurons (the nerve cells which control muscles), leading to paralysis which becomes fatal, specially if vital muscles are affected. Nevertheless, recently significant achievement have been made by INSERM (Paris) in collaboration with RPR Gencell, the gene therapy division of Rhône-Poulenc Rorer and other groups. In this line, among the most relevant events and associated timeframes are the followings:

Event	Timeframe	*Report)*
- Cure for Alzheimer's disease	2016	*(J97)*
- Molecular basis of schizophrenia	2016	*(J97)*
- Genetic/biochemical tests for schizophrenia and depression	2005-2009	*(UK95b)*
- Molecular basis of two degenerative diseases	2005-2009	*(UK95b)*

Biotechnology in the Food Chain.

Modern biotechnology, which is being triggered by new knowledge on molecular biology and genetics, involves a set of applied techniques for the genetic selection and the genetic modification of organisms. The former uses biotechnology to enhance traditional selective breeding techniques, and the latter actually changes the organism's DNA so as to introduce new traits and characteristics in a much more targeted way. In a general sense, modern biotechnology enters the food chain to achieve two main objectives: ensure healthy as well as stable food supply and to enhance the competitiveness of the agri-food sector.

Three technology clusters will guide further developments in the area of agriculture: Marker aided selection for crop and livestock production; Genetically modified crops with enhanced morphology, nutritional and stress/disease resistance*;* And transgenic animals for disease resistance and improved productivity. In this line, among the most relevant events and associated timeframes are the following:

Event	Timeframe	*(Report)*
- Use of modern biotechnology for feedstuff production:	2004	*(D98)*
- Broad use of herbicide resistant crops:	2005	*(D98)*
- Genetic engineering techniques are routinely used to produce new strains of plants and animals:	2008	*(US96)*
- Cloning of cattle:	2008	*(D98)*
	2014	*(J97)*

- Genetically modified cattle:	2009	*(D98)*

The impact of modern biotechnology in the food chain comprises not only implications for agriculture but also to food manufacturing and even food distribution and retailing. Thus, biotechnology is a very sensitive and delicate issue in the construction of the Single Market in Europe. In this line, among the most relevant events and associated timeframes are the followings:

Event	Timeframe	(Report)
- Test for gene-food in use	2003	(D98)
- To detect misuse of property rights	2004	(D98)
- Gene food market share 10%	2004	(UK95b)
- Gene food market share 30%	2010	(D98)
- Functional foods and nutriceuticals:	2010	(D98)

Moreover, biotechnology is meant to play a decisive role in other important fields associated to the Food Chain. Among these are: improved food safety through the wide application of disease/pathogen diagnostic systems (inmunological, enzymatic, DNA-based); improved fermentation technology and biocatalysis, with a special impact in the Food & Drink Industry: and improved aquaculture practices. Concerning the latter, it has been predicted *(US96)* that seafood grown using aquaculture will provide the majority of seafood consumed by year 2014.

These items were all considered in the various studies by experts in the various areas and other people of considerable experience in related areas. But all of **these studies predated the BSE crisis** in the UK beef industry and it is clear that the context in which these developments are now taking place has changed significantly. Even in the US, where the acceptance of genetically modified foods by the public was much higher than in Europe, a new debate on the subject has been initiated.

This new context will inevitably change the timescales and may shift the focus in the development programmes but the underlying sciences will continue their search for new and better ways. The problem for public policy will be to create a framework in which reasoned and informed debate can take place and in which some form of public trust in public organisations and the S&T community can be re-established.

Cropping high added-value products, new materials, and biopolymers

Modern biotechnology is turning crops into plant-cell factories, developing plants that produce high added-value molecules mainly as secondary metabolites. The production of high added-value products within plants include novel and/or foreign proteins, chemical polymer synthesis, medical bio-material and other new materials usually coming from the modification of structural genes. In this line, among the most relevant events and associated timeframes are the following:

Event	Timeframe	*(Report)*
- Biopolymers as bio-compatible materials	2000-2004	*(UK95b)*
- Broad use of Biodegradable packaging material:	2005	*(D98)*
- Biomaterials account for 10% of bulk chemicals:	2005-2015	*(UK95b)*
- On-site down stream processing:	2008	*(D98)*

- Biopolymers for medical purposes: 2008 *(D98)*
- Biomaterial crops comprise 20% of production area: 2009 *(D98)*
- Biomaterials represent 20% of chemical raw materials: 2010 *(D98)*
- New fibre crops 2010 *(D98)*
- Bioplastics represent 10% of world plastic production: 2013 *(J97)*

A society-driven trend towards the use of biocompatible materials and renewable resources is triggering this area. Car manufacturers are testing new biocomponents and biofuels, the textile industry is looking ahead for new fibres, and also the medical industry appears highly interested in novel applications of biopolymers (e.g. as medical implants for bone fractures). Nevertheless, the most significant advantage of using renewable resources such as plant-derived biomaterials and biofuels lies in the fact of neutral contribution to CO_2 emissions and therefore to greenhouse effect. In this sense, cropping high added-value products, new materials, and biopolymers has a great potential to abate exploitation of fossil resources such as mineral oil and coal.

3.3. Position of Europe

The position of Europe in Life Sciences has been rated in the Japanese study (J97) as roughly comparable to that of Japan but lagging the US by a significant margin. In the German Study, despite a stronger rating for Germany, the lower rating for the rest of the EU would point to a similar gap with the US and parity with Japan. In the Health area Europe is rated as having strengths in diagnosis and therapy but the worrying weakness mentioned earlier in the chapter on ICTs appears again under the heading of information systems. The position of Europe in relation to the Agro-Food area also exhibits strengths but the ability to exploit these will be significantly influenced by the outcome of the societal debate on acceptability. (See Charts 3.1a and 3.1b in separate pdf. file)

3.4. Policy Relevant Conclusions

A steadily growing number of new biotechnologies are expected in the health-related area within which technologies like genetic testing, gene therapy, cloning, xenotransplantation and the production of stem cells, could be mentioned. Biotechnology developments have entered into a “exponential phase”, where the pace of inventions is rapidly increasing, and thus the implications for society.

One major issue of importance in this area is the issue of intellectual property rights (IPR). This is a global issue in which public opinion must play an important role. The need for balanced IPR rules and laws is well documented so as to encourage research and development and to foster innovation. But there are significant ethical issues of great public and personal concern to the individuals in society who are the subjects and the targets of many of the advances. This aspect needs to be part of the policy debate also.

Assuming that GMOs in agriculture are proven to be harmless to human health and to nature, and therefore will be authorised for the European market, many farmers will adopt the new technology in order to improve productivity and be competitive. The products are easy to handle for the farmers and the expenditures for crop protection are low. At present industry has not been convincing on the issue of added value for consumers (e.g. nutritional benefits).This may be needed to get European citizens to finally accept GMOs even when their safety is confirmed. On the contrary, some consumers will still have principled aversions to genetically modified food and thus demanding organic products, which are not genetically modified and are pesticide free. This difficult debate highlights the need for a policy agenda, which will have to be supported with extensive research in the socio-technological sphere.

Policy is required to find a balance between these two directions and to mediate between the conflicting trends. The triggering factor for the future development is the safety and the public acceptance of GMOs in the food chain. The 5th Framework Programme is addressing some aspects of both questions and the results will support further decision-making.

The great challenge for policy makers is to maintain the pace of technological development, while ensuring benefits for society. On the one hand, legislation will create a “playing field” for the biotech companies, where they have a rewarding and stimulating business environment. On the other hand, and in order to ensure public acceptance, one has to assess and present clearly the benefits and drawbacks of applying new technologies.

3.5 Technology Interaction

The principal areas of interaction for Life Science technologies are to be found in the interfaces with ICTs, Environment, Energy and Materials

ICTs:

- Bio-sensors and actuators
- Imaging and visualisation technologies

Environment:

- Enzymes for clean production processes

Materials:

- Biocompatible Materials

4. Energy Technologies

4.1. Introduction

Non-renewable energy resources predominate today in the world primary energy mix. This situation is not likely to change in the mid-term future. Renewable energies (for instance, solar, wind and hydro energies), are certainly increasing their contribution to fulfil energy demand, but it is not clear whether their market share would also increase. This will heavily depend on the characteristics of each market, as well as on the boundary conditions imposed from policy-making, international developments, environmental constraints, etc.

For the time being, world energy demand grows at such a rate that it doubles every 33 years, but in some parts of the globe (Asia, some Latin American countries), the growth rate will be much faster. Therefore, a structural shift in the shares of world energy demand in different regions is likely to occur, and the OECD share of demand will fall. This demand dynamic is an important driving force on advances in energy technologies, including alternative technologies.

Several factors have contributed to the globalisation process in energy markets in recent years. The building of large interconnection infrastructures (gasoducts, oleoducts, liquefaction/regasification terminals and electricity lines), the expansion of the free-trade zones all around the world, are fostering international trade. The Multilateral Investment Agreements are reducing barriers to trade and investment, in particular in the energy area. Corporatisation, privatisation and changed regulatory frameworks are also boosting international trade and investment in this sector.

Political and economic developments, such as the end of the cold war and the expansion and increasing integration of the European Union, have boosted prospects for energy sector trade and investment. Economic growth in a number of developing countries also means that they will become much more important players on both the supply and demand sides of the energy market than previously, creating new opportunities and challenges for established players.

4.2. Main drivers of development of energy technologies.

Although the focal point of the energy policy implemented by many countries remains a security of supply issue, attention is increasingly being placed on environmental issues. The pollution problem has changed its nature and territorial dimensions: the local energy induced problems prevailing in the past (SO_x and NO_x emissions inducing acid rain) have been overcome to a great extent, via technology improvements and regulatory measures. The prospect of climate change and the threat to the stratospheric ozone layer have not only set off an alarm regarding the future of energy but also raised new and complex questions relating to energy technology policy and R&D. The emphasis should be on energy technologies involving an acceptable level of environmental impact should be produced at moderate prices. Energy technology programmes must be tailored to help ensure benefits in the light of costs and macro- and micro-economic effects of measures to contain greenhouse gas accumulation.

It is clear that in order to meet potential environmental emissions targets in the future (Kyoto protocol), a different energy technology mix than the one existing today will be required. To achieve the reduction goals, at reasonable cost, will require technology improvements to become available. These may include cost reductions for the technologies which are available today (e.g. wind or biomass), the maturing of technologies currently under development (e.g. solar) or development of new technologies (e.g. carbon dioxide capture and sequestration).

Liberalisation of the energy market and the new concept of competitiveness to be faced by established players in the energy sector are, in parallel, another reason in favour of the development of cleaner and more efficient energy systems.

4..2.1. Energy technology changes foreseen in the next decade.

The energy technologies have been aggregated in five groups and they contain:

a) Nuclear energy (nuclear fission and fusion)

In the next decade it is foreseen that nuclear energy will remain as it is or with a minor increase. The reason for that is the construction of nuclear power plants in developing countries like in India or China. There are 434 nuclear reactors over 32 countries, amounting 350,000 MW today (16.2% world wide electricity generated in 1998). There are plans in 14 countries for erection of 36 units. Russia and China are planning low power nuclear plants (<80 MW, re-load time 4 years), designed for seawater desalination and district heating. Modular power plants, around 100 MW, are being planned in South Africa. nuclear fission is not going to be developed significantly during the next decade.

Technology priority goals for nuclear fission energy are:

- Developing and deploying economically competitive nuclear power generating technologies with standard or modular designs while maintaining and enhancing safety;
- Developing and deploying acceptable nuclear waste management technologies and systems;
- Widening the safeguarded applicability of nuclear fission energy and expanding its resource base.
- Technology priority goals for nuclear fusion energy are:
- Continuing efforts geared towards demonstration of the technical feasibility of nuclear fusion power systems;
- Assessing the potential impact of fusion power on future energy supply

b) Fossil fuel clean technologies (clean coal technologies, oil and natural gas)

Coal

Technological challenges and priority goals for the coal lie primarily in:

- Improving the conversion efficiency, environmental acceptability and economics of coal use as a competitive energy source;
- Diversifying clean uses of coal with a view to preserving flexibility and coping with changing energy needs in the long term. (ultra super-critical power plants, integrated coal gasification combined cycle and pressurised fluidised-bed combustion)

Commercial feasibility for these emerging coal technologies has already been demonstrated for pressurised fluidised-bed combustion and integrated coal gasification in combined cycles, which are presently in a pre-commercial phase. Moreover, emission values are around 50% of those in a conventional power plant and, in particular for the NO_x emissions, which are below 350 mg/Nm^3 (value proposed in the draft for a New EU Directive). As a reference for the impact of these technologies, 100.000 MW ICGCC are planned for the next 10 years in the US, which means the renovation of 1/3 of the present power generation capacity.

Oil and natural gas

Technology goals are:

- Reducing the environmental impact of power generation, including conventional emissions such as sulphur dioxide and nitrogen oxides as well as greenhouse gas emissions;
- Encouraging greater energy source diversification and, where feasible, fuel flexibility;
- Developing and applying advanced load and demand-side management techniques to increase the efficiency of the electricity supply system.

Regarding gas, the technology goals will also include the combined-cycle power generation with gas turbines with internal combustion chambers, in a wide range from 10 to 500 MW. This technology (lead today by ABB, General Electric, Siemens and Westhinghouse/Mitsubishi) is the most competitive in the short to mid-term. The reasons for the above are the following: half of the present capital investments (400 to 500 €/kW installed), higher efficiencies (>60%), less construction time (less than 2 years), less emissions (half of CO_2 emissions and ten times less of NO_x). However, the gas market liberalisation has delayed the expected full penetration of this technology so far, which in spite of the uncertainties of the NG's prices during the coming years, is expected to occur by 2010.

c) Renewable energy technologies (Geothermal, wind, solar thermal, photovoltaic, biomass and waste, wave, tidal)

Two technology priority goals have been identified in these technologies.

- improving the efficiency and economics of renewable energy systems;
- expanding their deployment and effective integration into existing or evolving energy systems, amid the widespread restructuring and privatisation affecting energy utilities.

Renewable energies are foreseen as the most promising technologies for development and implementation in all the studies analysed. The most important renewable energy technology considered in each country depends more on the availability of the country to be competitive in a global market rather than to the potential country resources of that technology. This is also applicable for regions.

The Commission's White Paper on Renewable Energy Sources (COM /97/599) defined the target of doubling the share of this form of energy in the European Union's total energy consumption from the current 6% to 12% in 2010. Taking the EU, the US and the Japan RE Programs as a reference, it can be concluded that objectives and expected results in efficiency and costs are similar for each technology.

Hydrogen technology is a promised horizontal activity supporting the penetration of RE (not only for PV), and is a priority option for the deployment and effective integration of RE in the energy sector, in particular, fuel cells, which are an emerging technology for power generation around 2005. In general, penetration is estimated around 1% for the 2005, rising to higher percentages within the new liberalisation scenario. The expected power installed will be around 6.7 GW in the year 2020. The relevance of fuel cells may be appreciated, for instance in the US program, which gives special attention to the hydrogen technologies with a budget of 30 M$ for 1999.

d) Energy prospecting, transport, distribution and storage (superconductors, hydrogen)

- Increasing access to economically exploitable oil and natural gas reserves;
- Lowering the environmental effects and risks involved in hydrocarbon production.
- Increasing market access for remote reserves through alternative energy carriers and lower transport costs;

- Enhancing the diversity of liquid fuels;
- Mitigating the environmental impact and risk to public health and safety of natural gas transport and delivery.

e) Rational use of energy (reduction of energy demand)

Technology priority goals are:

- Enhancing the demonstration and market deployment of existing technologies to improve the efficiency, economics and flexibility of energy use;
- Encouraging further development and application of next-generation technologies, with a view to maximising their potential environmental benefits, including reduction of greenhouse gas emissions.

4.2.1 Changes in Energy demand in Europe:

Table 4.1: Primary energy demand by fuel for Europe

Source: European Energy to 2020 Units: Mtoe						
	Primary energy demand by fuel					
Year	**EU-15**	**Scenario. Business as usual**				
	Renewables	**Nuclear**	**Gas**	**Oil**	**Solids**	**Total**
1995	70	205	280	575	240	1370
2010	95	200	420	615	220	1550
2020	105	150	500	620	200	1575
	Central and Eastern European Countries (Associated countries)					
1990	16	10	60	110	190	386
2010	10	12	95	100	160	377
2020	12	13	110	115	140	390

European events foreseen:
Gross consumption increases within a range of 0.6 to 0.9% per year
Decrease of nuclear share and coal share
Increase of gas share.

Central and Eastern Europe events foreseen for the near future:
Further contraction of primary energy output (mostly coal due to economics and environment)
Primary energy demand recovers to somewhat above 1990 level by 2020
Gas demand grows, displacing oil, while oil share remains stable
CO_2 at or below 1990 levels by 2020
Oil and gas imports increase, coal exports fall

Table 4.2: Primary energy demand by fuel for US and Japan

Source: World Energy Outlook Units: Mtoe						
	Primary energy demand by fuel					
Year	**USA**	**Scenario. Business as usual**				
	Renewables	**Nuclear**	**Gas**	**Oil**	**Solids**	
1995	60	130	460	780	470	1900
2010	100	170	640	850	580	2340
2020	110	180	700	900	660	2550
	Japan					
1990	10	55	55	210	100	430
2010	15	75	75	260	110	540
2020	25	75	80	270	115	570

4.3. Position of Europe

In the energy sector the ratings of the position of the various countries shows no significant difference overall between the US, Japan and the EU. The Japanese study rates Japan slightly ahead of the US with the EU slightly further back. The German study rates Germany ahead of the US and Japan in that order but the gaps are not large and when the lower rating for the rest of the EU is considered, the overall picture is one of comparable strengths. Each of the countries tends to have different energy mixes in its energy production and this tends to be reflected in the individual technology strengths. The overall parity of technological strength also reflects the fact that energy technologies tend to be concentrated in large global companies, which means that they are well distributed geographically. (See Charts 4.1 in separate pdf file)

4.4. Policy Relevant Conclusions

Technology developments will have a decisive impact on the future shape of the Energy sector and in particular on the fuel mix. New technologies will emerge in the medium to longer term but their rate of penetration will depend on public policy support for research and development. Technological progress will tend to be gradual and cumulative in the meantime. A continuous review will be needed of how regulations, standards, advice, education, subsidies and investment incentives are employed to positively improve energy intensity in the economy.

In Europe, there is a clear need for common regulation in a number of RE related areas, especially now that first negative effects on RE, caused by the liberalisation of the market and in particular the EU directive on internal electricity market, become evident. The reduction of prices is unfavourable towards clean technologies and RE on one hand. On the other hand, it should not be forgotten that industrial competitiveness remains a key driving force in the energy sectors.

The longer term gains from renewable sources, in particular bio-fuels and the introduction of hydrogen into the energy system for power generation and vehicle propulsion, and improvements to energy intensity on the demand side, will not happen through the application of market solutions alone. Some level of public policy impetus will be required.

Environmental imperatives are likely to be the principal drivers of radical technological innovation. On the demand side market requirements for short payback periods may militate against some energy efficient technologies. Both these influences on energy technology policy suggest that effective integration between energy technology policy and other policy instruments will be necessary conditions for achieving the potential improvements.

- The opening of the energy market to free competition may allow increased use of energy production technologies, which, though cheaper, may not be cleaner than those of the current generation. Therefore, more than ever, public commitments on both RTD programs, policy and legislation are needed in order to respond to environmental and sustainability problems shared at global level. Use should be made of all available instruments, fiscal and otherwise, to bring in line private costs to reflect social ones.
- Regarding policy and legislation instruments aiming to integrate RES into the energy sector, any future legislative framework for RE should foster competition between the different RE, in controlled settings e.g. pilot experiments. This would contribute to an increasing competitiveness of the renewable generated electricity compared to electricity produced by fossil fuels and nuclear. Feed-in tariffs have proven to be highly effective for increasing RE electricity production. This achievement has also an impressive positive effect with regard to job creation. Other tools or combination of them, like the fixed-premium proposed by the Commission's Working Paper on Electricity from RES, are important. Premia should be paid per kWh feed into the grid and the amount of these premia should differ between the different RE technologies.
- Favourable conditions should also be set for energy consumption by enterprises from their own installations, which allows the avoidance or reduction of costs of transportation and grid connection.
- Regarding the new emission normatives, it should be based on specific emission per kWh produced, rather the mg/Nm^3 but again use should be made of all available instruments..

4.5. Technology Interactions

The principal technology interactions within the energy sector involve the field of materials where there are currently a number of bottlenecks. The slower than anticipated development of ceramic materials for high-temperature combustion is hampering the improvement in thermal efficiency and in reduction of emissions.

Materials are also a problem in the development of photovoltaic technology and in the development of fuel cells. The development of new catalyst materials for cleaner processes will also have applications in the energy production field. Superconductor materials for energy distribution have considerable potential for conservation and sustainability.

ICTs have made considerable advances in the field of energy and do not at present hold back development. Like most other fields, however the Energy sector will be a significant user of more sophisticated modelling and simulation techniques as the advances in computer power support them. The Energy sector's principal contribution to ICTs lies with the development of low cost batteries with enhanced power to weight and size ratios.

The big issue for Energy sector is its impact on the Environment directly from exploration and exploitation of sources and power generation, and indirectly through its contribution of fuels and propulsion systems to the Transport sector. The pace of developments in these areas will be critical and the many technological interdependencies involved call for integration processes among the actors which current policy structures may not be best equipped to deal with.

5 Environmental and Clean Technologies

5.1. Introduction

Sustainable growth requires an improvement in the environmental efficiency of products, processes and activities. The impact of energy production and consumption and of transport on the environment is excessive and improvements in both areas are paramount and critical. This is not solely a European problem but technologically Europe can play a significant role in the provision of global solutions. The Dutch Environment-oriented Technology Foresight Study[2] concludes that a considerable saving on energy consumption and the use of materials, as well as a substantial reduction in emissions and waste, can be achieved by optimising the technological systems of today. Even larger efficiency improvements can be realised either by radically changing the design of contemporary technological systems or by developing new systems to take over the functions of existing systems in a completely new way.

The technological area “Environment and Clean Technologies” is not defined by certain technological characteristics but by a problem (the necessity of environmental protection) for which solutions are provided. The solutions are very heterogeneous and comprise the whole spectrum of technologies and a variety of different approaches. Strictly speaking, the word “technology area” is not even very suitable. Logically, the studied references mostly did not categorise the topics according to technological criteria but to the different types of environmental problems.

Environmental technology is defined by its objective of protecting the environment than by specific applied fields of science like biotechnology or microelectronics. Foresight results show that environmental technology is diffuse and often interdisciplinary. It is also an area that requires long time horizons to develop. Sustained government research support is crucial in areas where industry may underinvest. Environmental policy needs to join forces with technology policy in driving the development of the key technologies, which will underpin sustainable growth.[3].

Since environmental technology is so diffuse and varied, it is especially difficult to come to simple conclusions on clear-cut strategies and priorities. Nevertheless, a review of literature reveals certain trends. The following section deals with trends and priorities set in recent national foresight studies carried out in Germany (D98), Japan (J97), UK (UK95) Austria (A98). It is followed by a short appraisal of the findings of other work.

Two approaches can be taken to the subject of environmental and clean technologies. The first one understands environment and environmental protection as a separate issue that requires an own set of technologies that are added on to the production system in order to make it more environmentally friendly. The other approach is to consider environmental protection and ecological factors as an intrinsic part of production technologies throughout all economic sectors, which makes them, clean technologies. This gives rise to a number of special problems when analysing the role of environmental and clean technologies in foresight studies. Some studies define explicitly technology areas related to environment others do not. Even if there are explicit environmental technology areas defined in a study, not all environment-related technologies are usually subsumed in these areas. Especially clean technologies can still be found in a whole range

[2] Weterings R, Kuijper J, Smeets E, 81 Options – Technology for Sustainable Development, TNO Centre for Technology and Policy Studies (TNO-STB)

[3] OECD 1998: DSTI/STP/TIP(98)11: Working Group on Innovation and Technology Policy: Technology Foresight: Environment-related Issues

of other sectors. Only one of the analysed studies (Austrian Delphi) has defined an individual technology area with a focus on clean technologies.

5.2. Highly ranked technologies in various foresight studies

Clean Technologies

Despite the fact that "Clean Technologies" are dispersed throughout the different chapters of the different studies, some explicit tendencies can be extrapolated. There is a clear shift towards a number of new concepts that describes a vertically integrated approach when analysing production systems. These 'life cycle approaches'(LCA) take explicitly into account the whole product system from cradle-to-grave, including the extraction and processing of raw materials, the manufacture of products, their distribution, their use, and the management of the waste residuals along the product life cycle.

Modern industrial systems are typically energy and material inefficient and improvement opportunities through the application of new technology or changing behaviour of actors across the product chain are usually believed to exist. Life cycle approaches can be used to reorient environmental management towards reducing the total resource intensity and environmental burden of delivering services to the final consumer.

Five main lines or strategies through which integrated environmental protection can be realised by clean technologies crystallise from screening the different studies as follow:

- new production technologies in the hard-core sense of technology
- dematerialisation (through ICT use) and improved energy efficiency,
- renewable raw-materials and natural substances and materials,
- greening of products and services,
- networking and new forms of co-operation.

New production technologies

New specific production technologies can be found in the Austrian Delphi study, which devotes a separate chapter to cleaner production, but also amongst the French 100 key technologies and in the German Delphi. The technologies deal with alternatives to the use of solvents (e.g. the use of supercritical carbon dioxide or powder technologies for paints), catalysis, clean combustion engines, and several more.

Dematerialisation and improved energy efficiency

Technologies with improved energy efficiency are especially abundant in the German Delphi. In many cases they are related to traffic or transport. The topics comprise 2 litre/100 km cars, fuel cell cars, hydrogen cars and aircraft, substitution of air traffic, combined traffic with intelligent containers, public transport services on demand, and several more. Another important area for improved energy efficiency is the construction and building sector. Examples of topics are: intelligent windows and facades, energy-autarchic buildings, or intelligent use of daylight for illumination. A third focus for energy efficiency improving technologies is the basic industries, for which energy-saving iron production technology and non-electrolytic reduction of aluminium are mentioned. Finally there are a number of individual technological options that cannot be grouped. Examples are, electronic control of revolutions of electric engines, reduced stand-by times of electric devices, highly energy efficient electricity-light conversion or using heat cascades between companies.

Mainly in the German Delphi, ICT is seen as an opportunity for dematerialising the economy in several topics. Amongst them are IT based energy management, the paper-free office, teleworking and video conferencing, or generally the decoupling of economic and transport growth through ICT use.

Renewable raw materials and natural materials:

The use of renewable raw materials and natural substances and materials are a major issue in the Austrian Delphi and have also some importance in the German and French studies. It represents a focus at the upstream production level with a shift towards the reduction of the use of toxic and dangerous materials and an increase of use of natural and renewable resources. In all three reference is made to the use of renewable raw materials and natural substances for chemistry. Other issues are biopolymers and biodegradable plastics and packaging, the use of natural fibres and colours, the use of detergents and emulgators of oil and starch plants for cleaning and cosmetics, or raw-material from genetically modified plants, which represents and interesting but certainly controversial link to life sciences.

Greening of products and services

There has been a growing awareness that the traditional focus on production processes may no longer be appropriate in environmental policy and regulation. While industrial and energy production remains an important source of pollution, the relative importance of consumption-related emission and wastes has been raised over the past two decades. The emerging "integrated product policy" approach is evident also in a number of topics of the analysed foresight exercises, which refer to the greening of products and services. In many cases the topics refer more to concepts and methodologies than to technologies in a narrow sense. Eco-design is such an example and can be found in the Japanese and UK Delphi studies. Eco-design includes a number of different concepts such as, pollution prevention (P2), design for environment (DfE), design for recycling (DfR), as well as extended product life (i.e. lower demand for energy and materials by designing durable and upgradeable products with a long-life span). Extended product life, a topic found repeatedly in the German and Austrian Delphis, is one of the premises for industrial restructuring towards a sustainable services economy. The topic of eco-efficient services can be found in these studies as a general concept as well as in the specific variants of integrated pest management and offering energy as a service.

Networking and new forms of co-operation.

The Austrian Delphi highlights organisational strategies for sustainable development that are based on networking and new forms of co-operation and have a regional or local character. Corresponding topics are regional centres for sustainable product design to support SMEs, networks for product repair and reuse, networks for shared use of capital intensive technologies, and regional centres for disassembling and recycling technologies. The recent Spanish Delphi refers to European by-product markets. A special concept in this context is industrial ecosystems, which are included in the Japanese and German Delphis as well as in the US96 study. Industrial ecosystems have the purpose of enhancing co-operation between companies in order to improve their capability to react and to foster "closed loop" industrial networks. An example is the establishment of an inter-firm exchange of material and knowledge that could assist synergies between different companies of a region, which are not always possible on a single company level, especially for SMEs.

The topics of the clean technologies area can be looked at from the viewpoint of innovation research, which considers different levels of environmental improvement that can be achieved through different types of innovation. A Dutch study for example distinguishes optimisation, redesign and function innovation. Optimisation focuses on improving existing products, processes or infrastructure. The main concern here is to modify the systems, which already have a commercial use, increasing its efficiency by making only slight modifications. In the second kind of innovation, redesign, the actual design of existing products, processes or infrastructure is partly changed. Specific features of the system are changed, for instance by choosing to use materials that can be made suitable for reuse at the disposal stage. More far-reaching environmental improvements can be expected from the shift towards new type of systems performing the same functions of old ones but with an increased efficiency. This kind of innovation, called function innovation, can result in a radical change as to how a function is fulfilled.

Looking at the topics we have identified in the clean technology area of the different national foresight studies, it becomes very clear that topics related to the less radical improvements of environmental performance are clearly dominating. New production technologies in the hard-technology sense, improved energy efficiency, renewable raw materials and natural substances and materials, as well as the greening of products correspond mainly to optimisation and redesign. It seems that dematerialisation through ICT use and new forms of co-operation can give room to more radical innovation.

Recycling

In the medium term, recycling is clearly the most important technology area in most of the references.

The German and Japanese studies focus on product recycling. They expect that around the year 2010 manufacturers of consumer goods with long service lives will be legally obliged to accept the return of their goods at the end of their service life and dispose of them, resulting in a recycling system that includes planning, production, collection and recycling or re-use, with the aid of which, a practically completely closed material cycle can be achieved. The Japanese foresee for 2011 green product design concepts that encourage recycling and reuse. Wide spread use of plastics recycling technology is foreseen for 2007.

The study from the United Kingdom puts a focus on recycled building materials. It foresees for the period from 2005 to 2009 the widespread use of recycled building materials, composites incorporating synthetic materials such as plastics and alternative forest products, resulting from modified construction concepts and design standards. Generally, the different studies coincide largely in the timing, with the Japanese study seeing the advent of recycling solutions only slightly later than the German Delphi.

Global management of the environment

Another important issue in the long term is technology for global management of environment (understanding of global ecosystem, desertification, soil quality). Especially the German study gives importance to this field. For example, it expects for 2016-2020 that techniques to landscape deserts will be applied throughout the world to stop desertification.

Most other technologies are forecast to be realised in the medium-term, with topics in the fields of marine and earth sciences and urbanisation and construction tending towards short-term.

Megatrends

In addition to the more discrete topics, the German Delphi study also investigates the time horizons of megatrends. The long term requirement for and development of new renewable energy sources is brought into focus by a forecast long-term megatrend on energy scarcity. However experts were divided on whether a world-wide scarcity of fossil fuels will enforce the rationing of energy consumption for private households by 2016-2025.

No clear correspondence in the availability of technological means can be found for another megatrend: Increasing environmental problems will negatively affect the health of most people in the medium term (2004-2015). Again the opinions of experts is divided (53% agree, 42% disagree, 5% no opinion) on this topic.

Clearly, more conclusive information is needed to guide policy making on these major issues.

OECD consensus list

A consensus list of important environmental technologies presented by OECD 1998 brings in additional topics than can be ranked as of high importance. It consists of the following issues: advanced sensors, biotechnology, clean car technologies, product recycling, smart water treatment, smart waste treatment, micromanufacturing, renewable energy and photovoltaics.

Forecast dynamics:

Comparing the topics in the fifth and sixth Japanese Delphi surveys, we see that many new topics are found in electronics and information technology areas whereas environment-relevant areas of 'environment', 'marine and earth science', and 'resources and energy' include relatively fewer new topics. This may imply that in the present phase, the pace of innovation in information and electronics is very rapid, and many new, important topics come up within a relatively short period of five years. On the other hand, in environment-relevant areas, topics, which were recognised to be important five years ago, largely remain unrealised. (OECD 1998).

5.3. Position of Europe

As in the case of the energy sector, the relative positions of the main competing blocs is roughly similar. The Japanese study places the US slightly ahead of the EU and Japan who are rated equal. The German Study rates the EU very slightly behind the US (when the ratings for Germany and the rest of EU are combined), with Japan slightly further back. Europe is generally seen to be the leader in recycling technologies and waste management. It is also considered to have significant strengths on issues of combating global warming and acid rain. (See Charts 5.1 in separate pdf.file).

5.4. Policy relevant conclusions

To date the goals of improved competitiveness and economic growth have driven innovation policy formulation. In future there will have to be a broader goal set and agenda. Socio-economic well being and sustainable development will complement competitiveness and growth as the key themes of innovation policy.

Recycling is the one issue, which is identified as very important in the medium-term in all of the references studied. It is clear that it will be a critical technology for the European economy.

Therefore, it will be worth investing strategic efforts in this field and to make best use of the respective European knowledge base. A first mover advantage can be achieved by measures that facilitate recycling in Europe. Examples of such measures are[4]:

- the introduction of regulations that block low-cost outlets like uncontrolled landfills
- product standards based on performance characteristics rather than material prescriptions
- avoid too tight standards that make recycling technically impossible
- avoid the stimulation of use of well-known primary materials through strict liability demands
- tackle uncertainty about the overall environmental effectiveness of recycling
- public authorities acting as front runner in applying secondary raw-materials
- product certification of secondary raw-materials
- stimulate R&TD
- quality improvements of secondary raw-materials

In order to achieve radical environmental efficiency improvements, as required for sustainable development in the medium- to long-term, there is the need for public RTD policy to focus especially on innovation in areas which offer genuine alternatives to present day socio-technical systems. It is in the immediate interest of the private sector itself to conduct work likely to lead to incremental improvements in the efficiency of existing technological regimes. Because of the problems of lock-in, however, there are strong disincentives to explore radically new technological options irrespective of their implicit potential for reduced environmental impact. In such cases there is a strong market failure argument for the public sector to support RTD into these longer-term, radical options. It is also clear that in areas such as the time scale of effects and solutions there is a requirement for much more publicly funded independent research.

5.5 Technology Interactions

ICT interactions with the Environment sector:

Production Related Tools

- Design, Modelling and Simulation
- Life Cycle Analysis
- Concurrent Engineering
- On-line production control
  - Sensors (also with Life Sciences)
  - neural networks
  - image processing
- Dematerialisation
  - embed IT into products to reduce energy consumption and wasted resources

Environmental management support systems and control

- Sector specific tools for:
  - Environmental Audits
  - Risk analysis
  - Assess modelling methodologies behind the tools
  - Reliable generic technologies such as parallel processing

[4] Driessen R, van Mechelen A C A, van der Steen J J D, 1992, Inventarisatie van knelpunten in de bouwwereld met betrekking tot acceptatie en toepassing van secundaire gondstoffen; Resultaten van de interviews, 92-419, TNO-MEP, Apeldoorn, The Netherlands.

Geographic Information Systems
Global Positioning Satellite systems

Other:

ICT for rural communities to reduce rural to urban migration
Research into the relationship between Land use, transport use and use of ICTs.

The other main areas of technology interaction involve Energy and Transport and in both cases emission controls and elimination are principal fields of interaction. In the area of Materials interaction with the Environment sector involve new catalyst materials, life cycle issues and recyclability and waste elimination and reduction.

6 Materials and Related Technologies

6.1 Introduction

Materials and materials manufacturing technologies are generally recognised to be key underpinning and critically enabling areas of R&D upon which most industrial sectors and fields of technology application directly or indirectly depend. Materials research will still providing new solutions capable of optimising and enabling the application of technologies, minimising their negative side effects and reducing production costs.

The long development time and slow return on materials research investments make industry somewhat reluctant to take on the associated risks alone. This makes materials an ideal area for policy initiatives with regard to the sustaining of long-term research efforts and the stimulation of wider co-ordination of effort and the networking of actors.

The strategies can be devised to deal with the identified drivers of change and to achieve a European, national (or regional) objective. For example, strategies may aim at:

- concentrating on materials of high value density,
- keeping international competitiveness with a given set of materials,
- strengthening regional or local competitive advantages,
- influencing the international materials standardisation process.

6.2 The Technologies

Various foresight studies consider that materials are essential for solving environmental problems. Structural materials have by far the best chance of success. Development of new materials and the implementation of new production technologies need longer development time. A central question is whether the industry can harmonise economy and environment. In general many topics are expected to lead to environmental problems as well as being a potential solution to some environmental problems

The field of 'Materials and processing' can be divided in two parts:

In the first part the following characteristics are taken into account:

- thermal;
- mechanical;
- photo-electromagnetic;
- biochemical.

The section focusing on material processes can be divided into:

- designing and compounding;
- processing;
- evaluation and measurement

Materials science and engineering aim to understand and control the properties and phenomena of materials, which render them useful. This is a multidisciplinary field, by excellence. Practically all fields of science and engineering are involved including aspects of materials science, e.g. physics, chemistry, electronics, biology and mechanics.

Following a German study (Grupp[5], 1993) which classifies material fields into 8 different areas:

1) Metallic Structural and Metal Matrix Composites;
2) Ceramics Structural and Ceramic Matrix Composites;
3) Polymers and Polymeric Matrix Composites and Hybrid Materials[6];
4) Electrical and Magnetic;
5) Electronic and Photonic;
6) Bio-materials;
7) Packaging and Storage;
8) Recycling and Reusable.

We can observe that the technologies in this list are not mutually exclusive, repetition occurs within this materials list or across other domains. This reflects the increasing interdisciplinary trends.

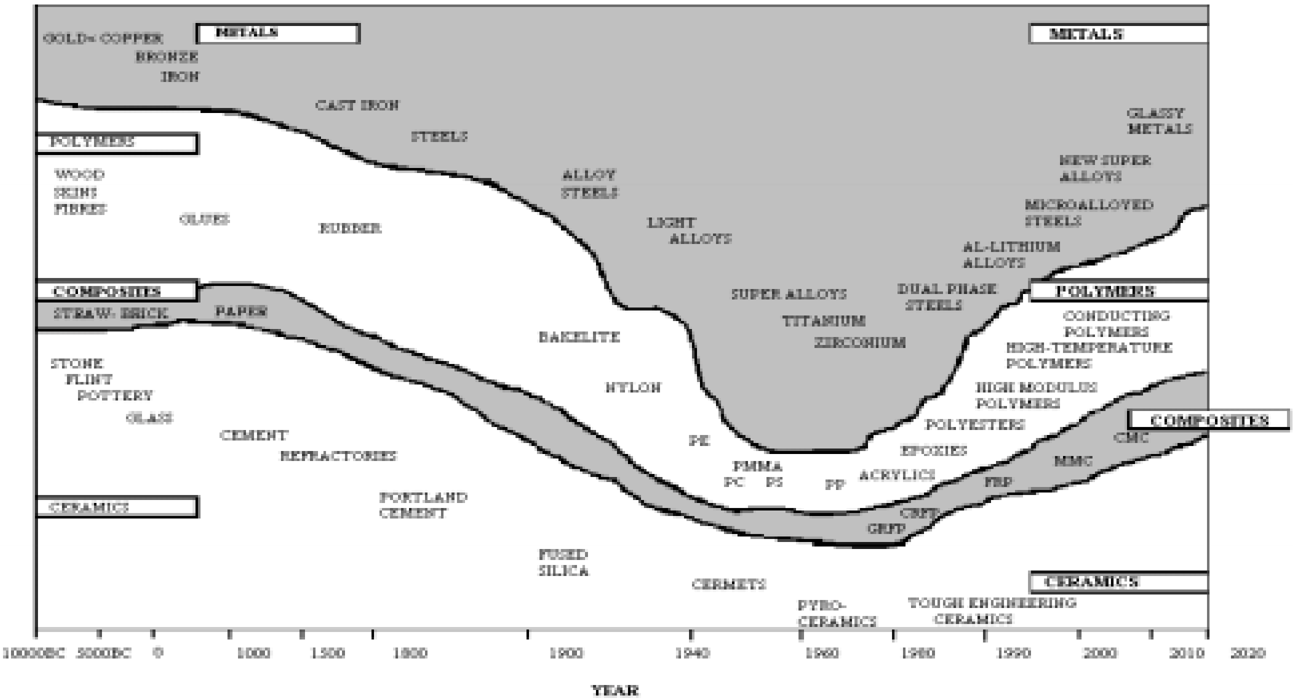


Figure5-1: Historical and projected development of materials categories

The following diagram by Prof. M.F. Ashby of Cambridge University in the UK shows clearly the historical and projected development of different categories of materials from pre history into the next century. It shows that the trend is for a return to major importance of ceramics, polymers and composites with a relative decline in the importance of metals.

[5] Grupp, H. (1.993): Technologie am Beginn des 21. Jahrunderts. Heidelberg, Physica-Verlag.
[6] For completeness, we included in this group materials that incorporate both, organic and inorganic compounds.

The main points which emerge from the analysis of recent technology foresight studies are:

Advanced Materials relevance, from the viewpoint of their present industrial applications in Europe can be summarised from the following volume distribution by sector:

Transport	24%
Electric and Electronics	20 %
Mechanical	18%
Building	15%
Packaging	8%
Biomedical	5%
Others such as sports and leisure	10 %

(I96).

In some cases there exists a significant overlap between the different areas. For example, the main bio-compatible materials segments are:

Polymers	45%
Metals	30%
Composites	15%
Ceramics	5%
Biological tissues	5%

Biological tissues are also partially included in other groups.

Some trends indicate increased links between broad technology areas. These are considered as new challenges and opportunities for research and they include new materials (synthesis and processing); increased interaction across related areas, e.g. medicine, biology. They are likely to involve a higher level of analysis e.g. holistic approach, global thinking; equilibrated tech-push and demand-pull and top-down versus bottom-up research and innovation approaches, dealing with emerging needs: quality of life issues (ageing population, crime control), sustainable development, future manufacturing challenges with special emphasis on organisational aspects, new education skills and training.

There are some recurrent synergetic and emergent topics revealing how the development and processing of materials underpin topics which occur in different sectors, in particular in those more relevant and included in this report: ICTs, Biotechnology, Transport, Energy, Environment and Manufacturing.

6.3. Position of Europe

This is an area of general weakness for Europe in comparison to the US. Both the Japanese and German studies rate the US as the leading country. However both studies rate themselves as following closely. The German study rates Japan as behind Germany but rates the rest of Europe very low. The Japanese study rates the EU in general quite low. Within the more detailed areas growing strengths for Europe are found in areas of biosensor materials and bone replacement biocompatible materials. Europe or Japan do not seriously threaten the US lead in polymers. The US lead in magnetic materials is now shared with Japan and the EU. Europe is also stronger in materials synthesis and processing than the US and some erosion of the US lead in favour of the EU and Japan can be expected in composites and catalysts. (See Charts 6.1 in separate pdf file.)

6.4 Policy Relevant Conclusions

Materials and materials technologies are widely recognized to be key underpinning and critically enabling areas of R&D on which most industrial sectors and fields of technology application, directly or indirectly depend. Materials is an ideal area for policy initiatives in regard to the sustaining of long term research efforts and the stimulation of wide co-ordination of effort and networking of actors. Materials research is capital intensive and needs a large base of research facilities. Equipment needs for research are increasingly sophisticated in the characterisation, synthesis, processing and analysis areas.

However the time from first synthesis to practical, reliable application can be long, particularly for advanced materials, which have work in increasingly severe environments. Periods of up to 15 years are not unusual and long-term research is expensive. This should be kept in mind by policy makers funding public research.

There appears to be many cross-linkages between technology areas – such as New Materials and Energy for “energy storage”. This synergy will be more evident in the future. Relative strengths in particular areas could facilitate developments in weaker areas.

The most recurrent priorities will still relate to lightweight, high-temperature, bio-materials and bio-compatibility, multi-functionality and smartness, computer modeling of materials and their fabrication processes, sustainability requirements, miniaturization and bio-mimetics.

New and improved materials will open up

- new market opportunities arising from trends or issues and driving causes
- new products, processes and/ or services to meet the need of some of the market opportunities; and
- Identified technologies, breakthroughs, scientific advances or innovation needed to underpin products, processes or services.

However, materials and materials processing represent a bottleneck in a number of areas, particularly in energy and the environment where the drive for sustainability is only beginning to take root. This will be a crucial problem in achieving sustainable development.

6.5 Technology Interactions:

This diagram presents the selected emerging technologies in another format, reflecting the sectors in which these materials are used.

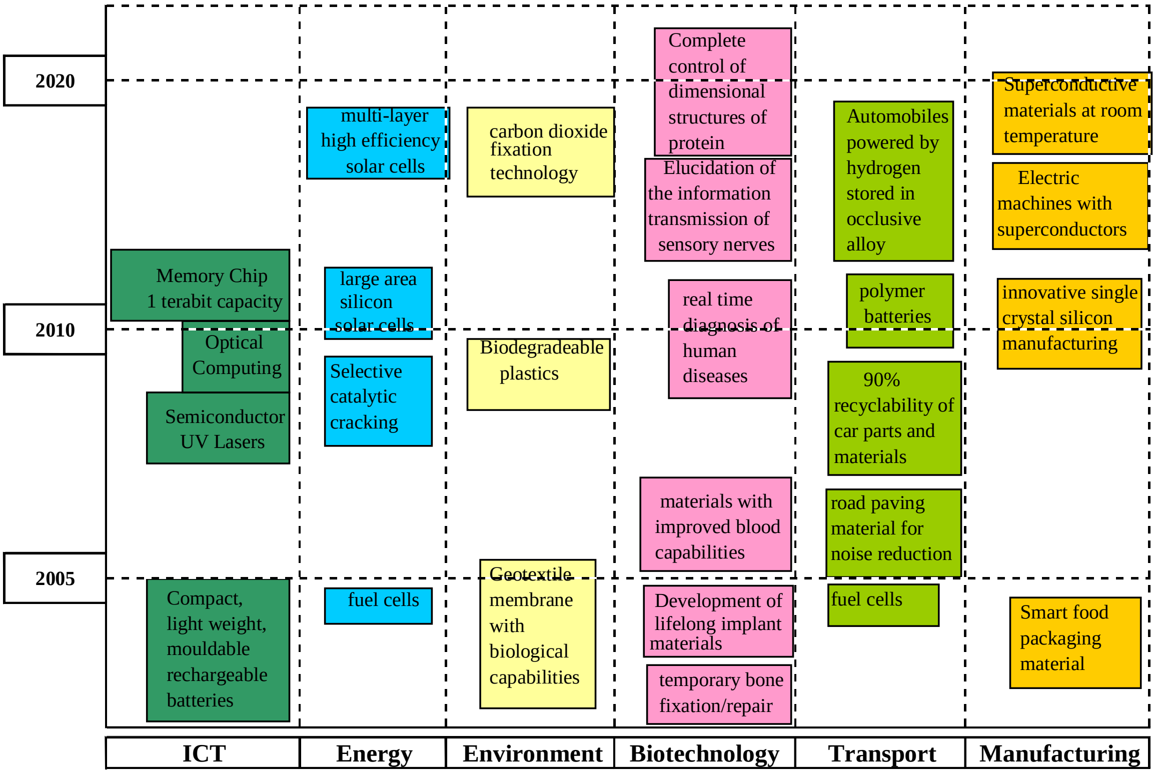
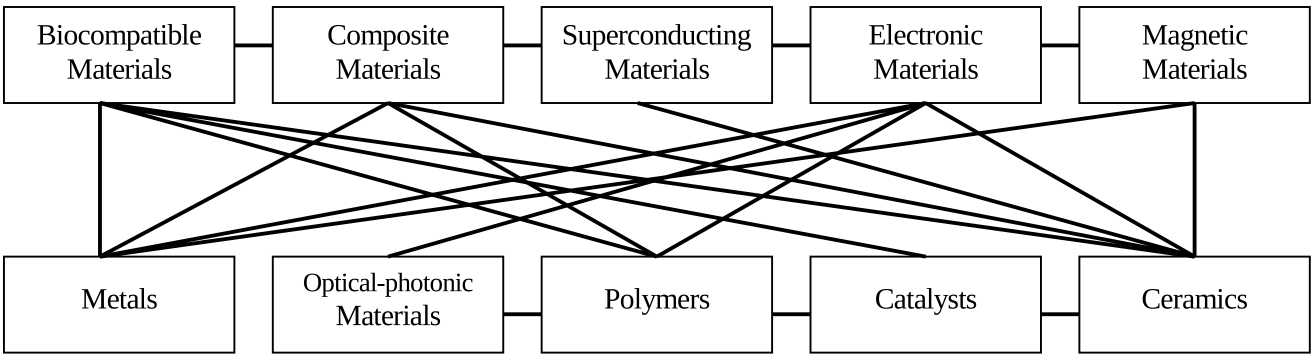


Figure 6-2: Technology interaction areas

Further within the materials sector itself, there are many interrelationships between material categories as indicated in the following diagram:

Figure 6-3: Interrelationships among materials categories



Technological Areas	Application areas
METALLIC STRUCTURAL AND METAL MATRIX COMPOSITES - Ferrous alloys and- Non-ferrous alloys - Intermetallics alloys - Metal and intermetallics matrix composites for low and high temperature; and gradient materials	Develop lighter, stiffer airframes automobile frames; enable high temperature structural applications in aerospace, shipbuilding, and other transportation vehicles. Improved industrial applications of high purity alloys. Enable high performance aircraft engines, auto engines, advanced armor; hypersonic aircraft and ultrahigh temperature aerospace applications. "Smart materials" More economical materials to maintain surface transport infrastructure; retrofit reinforcement for earthquake damage prevention. Industrial catalysis. *Other applications*: Electrical and electronic (superconductors, electrodes), medical, coatings, membranes. New joining technologies and surface treatments.
CERAMICS STRUCTURAL AND CERAMIC MATRIX COMPOSITES - Cement matrix composites - Structural glass and- Thermostructural ceramics - Glass and ceramic fibres. Catalysts - Ceramic and Ceramic matrix composites - High hardness and strength sintered ceramics	Improve interconnection/data rates for multi-IC assemblies; improve wear characteristics in high speed moving parts; hard materials for high efficiency machining (e.g. cubic boron nitride); turbine engines, cutting tools and other applications needing super-hard materials; catalysts for process industries (e.g. petrochemical, fine chemicals); enable high performance aircraft engines, auto engines, advanced armour; hypersonic aircraft and ultrahigh temperature aerospace applications; economical materials to maintain surface transport infrastructure; retrofit reinforcement for earthquake damage prevention. *Other applications*: in energy sector (heat exchangers, turbines), surface engineering (coatings, …); sensors, "smart materials", catalysts, membranes, superconductors, optical applications, biocompatibility; personnel and property protection.
ELECTRIC AND MAGNETIC - Metals: alloys, amorphous and intermetallic magnetic composites - Superconductor and ionic conductors metals, polymers, ceramics and glasses*	Develop advanced sensors, low power electronics, power transmission, energy storage, powerful magnets for research, medical diagnostics, and maglev (rapid rail technology). *Other applications*: Energy saving in electrometallurgical processes.
ELECTRONIC AND PHOTONICS - Metals: special alloys and high purity metals - Semiconductors: fast electronics, sensors and optoelectronics - Polymers, Ceramics and glasses superconductors, electro-luminiscent and non-linear	Enable 'smart building"; further miniaturisation of microwave communication devices. Laser detector technologies, support communications and optical data processing. *Other applications*: Multimedia entertainment, medical diagnostics, high definition display devices Molecules (including DNA) as active components for miniaturised electrical circuits (biosensors, bacteria-chips and gene-chips).

- The breakthrough came with the discovery of non-metallic materials – crystalline solid oxides called perovskites – which become superconducting at temperatures easily obtainable with the common, cheap, coolant liquid nitrogen.

BIOCOMPATIBLE MATERIALS - Polymeric - Metallic - Ceramic - Composites - Biocompatible	More durable materials for replacing of natural tissues or bond (tissue engineering, integrating cellular biology and textile manufacturing); implants, sensors and electrodes; artificial blood, cardiovascular prosthesis, skin, tendons; tailoring of immune system response; developing agents to suppress rejection reactions. *Other applications*: Bionics and bio-mimetic materials and "smart" materials (those that respond to specific stimulus), shape memory materials for medical applications.Molecules (including DNA) as active components for miniaturised electrical circuits (biosensors, bacteria-chips and gene-chips).
POLYMERS, POLYMERIC MATRIX COMPOSITES AND HYBRID MATERIALS - High performance thermoplastics - New composites for structural applications - Polymeric alloys - Adhesives - Sensors - Optical polymers	Applications Develop lighter, stiffer airframes automobile frames; enable high temperature (up to 450 ^{o}C) applications in transport. Hybrid materials applications as coatings, membranes and optics. Enable high performance aircraft and automotive applications , advanced armor. Transparent coatings and vernish for solar cells. Other applications: Rechargable batteries (up to 400 Wh/lt, from current Ni-Cd 180 Wh/lt), fuel-cells (proton exchange membranes – PEM- for automotive applications) , membranes,selective catalytic cracking, superconductors (up to 77 K), sensors, biomedical applications, photonic devices, low environmental impact applications.
PACKAGING AND STORAGE -Innovative and polymeric packaging -Intermetallics and carbon nanotubes for hydrogen storage - Tailored materials for packaging	Packaging of consumer goods such as food, chemicals, biological and cosmetics. Packaging films able to selectively activate the content's treatment (selective gas separation) or to allow inertisation (e.g. food packaging for long term conservation. Smart packaging (e.g. incorporating sensors and signalling). Lower environmental impact packaging. *Other applications*: Design of multipurpose containers (e.g. for multimodal transport).
RECYCLING AND REUSABLE - Innovative technologies for metallic materials - Innovative technologies	Environmental benign materials (increasing efficiency of industrial, energy and human waste treatment mechanism). Materials for improving decontamination and rehabilitation of polluted soils. Biodegradable packaging, coatings for restoring and recharging used industrial components and diminishing energy and environmentally intensive materials and waste disposal (e.g. applications in aeronautics and nuclear components).

7. Key Transport Technologies

7.1. Introduction

Transport technologies and related equipment play a major role in the economic activity of the EU. The automotive sector *directly* contributes to ca. 10 % of turnover and 8 % of jobs of total EU manufacturing and generates a significant positive trade balance. In addition, it *indirectly* produces an important leverage effect on related activities such as material and component suppliers, vehicle distribution, repair and maintenance.

However, the automotive sector is facing a difficult restructuring period, mainly arising from strong competition and tighter regulatory requirements due to environmental concerns. For these reasons, transport technological developments are particularly important and could provide, in the future, a determinant competitive advantage for the EU industry.

Over the next 10 to 15 years, the groups of technologies expected to hold the most relevant transport applications are Propulsion Systems, In-Vehicle Telematics (for intelligent transport systems), Advanced Materials and Vehicle Manufacturing.

7.2. Technologies

The complexity of issues involved in transport requires to consider the context where technology development takes place and to identify among the high number of factors, the ones determining technology evolution.

Innovations in transport are mainly driven by tougher market competition, tighter regulatory standards, efficiency requirements and emerging opportunities induced by other developments, namely by information and communication technologies.

However, in order to succeed in the market place, transport technologies should also meet future demand requirements including the following issues: public acceptance, new flexible and fast delivery of goods, and overcome entry barriers such as the need of dedicated infrastructure.

Over the time-horizon of this study (2010-2020), the groups of technologies expected to hold the most relevant applications to improve vehicle efficiency are:

- Propulsion Systems,
- Information and communication technologies applied in transport (in particular in-vehicle telematics to build intelligent transport systems),
- Advanced Materials,
- Vehicle Manufacturing.

These technologies find application primarily on the road transport area, where they contribute to more than three quarters of the added value of the transport equipment sector. However, many of these technologies are also, to a large extent, applicable to the manufacturing of vehicles for maritime, rail and air transport. In particular, the integration of these technologies will contribute to the following applications in each transport mode:

- *Road transport*. To develop dedicated vehicles for specific purposes, e.g. all-purpose cars, urban cars, long distance buses, multifunctional trucks and vans and traffic management systems.

- *Guided transport*. To improve and develop concepts for conventional and high speed rail, magnetic suspension, light rail, people movers, elevators and underground guided transport, including logistics, tracking and tracing technologies.
- *Air transport*. To improve or develop subsonic and hypersonic aircrafts, helicopters and rigid and semirigid airships (dirigibles).
- *Maritime transport*. To develop fast water vessels (inland and sea ferries) and all-electric ships.

The results of this preliminary analysis are presented in the following tables. Table 2.1 summarises the most relevant technologies to improve single vehicles and their related driving factors within the four identified technological groups. Table 2.2 presents the integration of the first set of technologies into promising applications by transport mode.

Table 7.1: Relevant technologies to improve vehicle's performance and their driving factors

TECHNOLOGIES	MAIN TECHNOLOGY DRIVERS
Propulsion systems - Internal combustion engines, running on gasoline/diesel or burning alternative fuels such as natural gas, methanol or biofuels. - Electric propulsion systems, including the technology to provide on-board electricity, either by fuel cells, electro-chemical battery, flywheels, or ultracapacitors. - Hybrid electric technology, consisting of a double propulsion system. In complement to these propulsion systems, other critical technologies are related with exhaust and inlet systems, design for recycling, maintenance, fuel production, energy storage, and refuelling.	- Need to contribute to improve air quality in urban areas. Vehicle pollutant emissions (so far carbon monoxide, nitrogen oxides, hydrocarbons and particulate matter) should comply with future more stringent exhaust emissions regulations (Euro III due on 2000, and Euro IV due on 2005). - Requirements on greenhouse gas emissions, in particular vehicle CO_2 emission, should be reduced to contribute to meet international agreements for which transport will be bounded through mandatory or voluntary measures (e.g. so far automakers accepted CO_2 targets for average new cars are 140 g/km by 2008 and 120 g/km by 2012). - Energy security concern, transport ever taking a higher share of the total energy demand and representing a major concern for Europe over the long term. - Other factors driving propulsion technologies are noise abatement, reduction of acid deposition, recycling, cost reduction and public acceptance.
In-Vehicle Telematics - In-vehicle traffic information, including dynamic route planning and multi-modal information - Anti-collision devices - Navigation systems - Combined emissions and engine management - Automatic vehicle location - Smart on-board card	- Optimise use of vehicle and infrastructure - Reduce traffic congestion in urban areas - Minimise rate of accidents and related losses - Management of transport demand

Advanced Materials - Metals, mainly steel, aluminium, magnesium and copper - Plastics, thermoplastics, elastomers - Composites	- Need of lighter materials to reduce vehicle energy consumption and emissions - Improve vehicle body strength - Ease vehicles recycling - Allow production flexibility
Vehicle Manufacturing - Vehicle design, including rapid modelling, prototyping, knowledge-based techniques, virtual reality, design for recycling, platform strategies. - Production process, comprising virtual manufacturing, lean production, process oriented production, automation, tooling, maintenance. - Resources management and organisation. Logistics, supplier chain structure, operations integration, marketing strategies.	- Competition, globalisation, emerging markets, trend on mergers and acquisitions - Flexibility, increasing pressure from customers - Improve quality - Lower costs - Tighter environmental requirements

Table 7.2: Integration of basic transport technologies into promising transport concepts.

Transport mode	Promising concepts
Road transport	- Specialised cars: All purpose cars, urban cars, powered two wheelers, man-wide car, individual public transport (based on electric cars) - Dedicated buses: Urban bus, long-distance buses -
Rail transport	- integrated door-to-door services - conventional rail, - high speed rail, - magnetic suspension, - light rail - people movers, - elevators - underground transport - logistics, tracking and tracing systems
Air transport	- subsonic aircrafts - hypersonic aircrafts - helicopters - rigid and semirigid airships
Maritime	- fast water vessels (inland and sea ferries) - all-electric ships based on fuel cell technology.

Main technological developments

Over the time-horizon of the Futures project, the most likely scenario for commercial and technical developments regarding these technologies is:

- Large inertia of the transport market will continue to shape the demand for new vehicles, in particular in developed countries where market is close to saturation and foreseen vehicle annual renewal rate is less than 10% (although interesting export opportunities will arise in developing countries). It is therefore expected that dominance of *ICE technology* will continue over the medium term.
- Conventional gasoline/diesel *ICE technology* will continue to show significant improvements in terms of fuel efficiency and emission levels, and are likely to meet regulations due on 2010. Diesel technology holds the best potential in terms of fuel efficiency (e.g. DI common-rail diesel engine), but present serious drawbacks concerning NOx and PM emissions. Gasoline engines surpass diesels' with respect to pollutants emission (e.g. port fuel injection, GDI, lean burn engines). However, it is likely that developments on exhaust gas treatment such as de-NOx catalytic systems and particulate traps may be the determining factors.
- Quality of fossil fuels will move forward under regulations pressure, namely to reduce content on noxious compounds, e.g. targets on sulphur and volatile compounds will be achieved through chemical processing and/or using fuel additives.
- Technology to produce alternative fuels will show significant progress, in particular those derived from fossil fuels such as methanol which outdoes other alternative fuels in terms of cost, pollution, versatility and energy density. Biofuels are also expected to show significant progress though they will continue to be restrained by low production capacity and high costs over the medium term.
- Over the short - medium term, *hybrid technology* will be produced cost-effectively and wont be significantly less reliable or costly than competitors. This will enhance the market penetration of *hybrid technology* for a transitory period and will stimulate in the future the rate of introduction of *electric propulsion systems*.
- Over the long term, improvements in technology to produce/store on-board electricity will enhance the market penetration of *electric propulsion systems*. In particular, *fuel cell/reformer* technology will reach significant maturity to be put into the mass market around 2010. *Fuel cells technology* holds the best potential in terms of efficiency and as a means to progressively replace fossil-fuels, i.e. using renewable sources as feedstock for hydrogen production.
- Market penetration of In-Vehicle Telematics will steadily growth, in particular those functions that do not require ground infrastructure, such as anti-collision, cruise control and drive-by-wire systems. These technologies will show higher public acceptance as long as safety and comfort standards are maintained or improved. However, up-take rate of telematics will be limited by high purchase and operating costs, and particularly for those requiring expensive dedicated infrastructure.

The integration of the technologies described above will enable the following applications by transport mode:

Road transport

The road mode will continue to be the main beneficiary of these developments. Promising transport concepts will include the construction of specialised vehicles such as all-purpose cars, urban cars, long distance buses, multifunctional trucks and vans and traffic management systems. The incentives to develop dedicated systems are similar to the ones described above for the basic technologies, i.e. environmental and business requirements, but in addition, development of these transport concepts are driven by the need to increase the efficiency of the whole transport system and to exploit business opportunities offered by innovations in other fields such as information and communication technologies. Critical technologies to develop dedicated road transport concepts will be the aforementioned components (propulsion systems, advanced materials (including recyclability), manufacturing and telematics) and in particular, new design concepts to develop flexible and convenient vehicles for increased public acceptance.

Guided transport

The applications here refer mainly to the rail sector but also to other interesting guided transport applications such as cable drawn vehicles with rubber tyres. This also concerns vehicles guided by ground-based infrastructure either functioning in automated or dual mode ways, which will become available over the longer term.

The scope of guided systems is being extended to cover door-to-door services integrating other critical technologies such as advanced logistics, tracking and tracing devices and interoperable systems. Main innovations will aim at improving conventional and high speed rail, and to develop new applications for magnetic suspension, light rail, people movers, elevators and underground transport. Here, freight transport has a special relevance, for example to develop automated freight-train concepts for urban areas. There will appear also interesting concepts for driverless guided passenger public transport in urban areas.

Air transport

The air transport sector which will benefit of significant increase of demand, will receive important innovations concerning development of subsonic and hypersonic aircrafts, helicopters and rigid/semirigid airships for niche market applications. The driving factors for subsonic aircrafts are increase capacity, e.g. 600-800 passenger, decreasing pollutant emissions, noise and fuel consumption. Critical technologies for subsonic aircraft are high efficiency propulsion systems and advanced materials, particularly light-weight high-strength materials for aircraft structure and materials for enhanced engines. Development of rigid and semirigid aircraft concepts are driven by needs in specific niche markets, for example for transport of industrial bulky components (e.g. cargo lifter), monitoring and earth observation and transport of passengers in tourism areas.

Maritime transport

In maritime transport, relevant applications will include fast water vessels (inland and sea ferries) and all-electric ships based on fuel cell technology. The applications for fast ferries, in regions with available inland water ways will provide alternative for congested road traffic. The critical technologies for fast ferries applications are the ship design (to improve passenger convenience) efficient propulsion systems and lightweight materials. Electrically powered ships will become highly interesting in the medium term as they will be main recipient of fuel cells developments.

7.3. Position of Europe

The Transport sector is one in which the particular local and regional conditions colour the perception of respondents to foresight studies on leading countries. The overall position from the studies would rate Japan slightly ahead of the US and Europe. In commercial aircraft technologies Europe has reached a position of strong leadership in many technologies while the position in land transportation would place it slightly behind the Japanese. In transport telematics Europe is relatively strong although the big prizes in this field are yet to be played for. In the critical area of environmental technologies Europe's position is one of reasonable strength.(See Chart 7.1 in separate pdf file)

7.4. Policy relevant conclusions

The transport market over this period (up 2010) is not expected to undergo major technological change due to its large inertia and stiffness. However, the success of a long-term policy strategy may require a number of policy actions to be taken now. In particular for radically new propulsion systems such as fuel-cells-based ones, whose development and diffusion require a harmonised framework of legislation, standards, test procedures and infrastructure-related issues. It is also important that governments define their long term strategies concerning propulsion and fuel systems and send to the market clear signals in order to encourage investment in alternative technology.

Concerning telematics, policy actions are required to provide the adequate regulatory framework to overcome barriers for deployment of these technologies. In particular the development of standards for interoperability of systems across national boundaries will be necessary. Here, particular requirements are the establishment of a common definition of route guidance and driver information, co-operation amongst the services concerned, allocation of competencies and responsibilities and protecting personal privacy.

The technical developments described above bear also important implication for European industry, since the world market demand of alternative vehicle technology is expected to growth as environmental concerns spread world-wide. On the one hand, high European environmental standards oblige Europe to produce forefront transport technology and make it ready to catch up huge export opportunities. On the other hand, The European industry has to face the risk of costly structural adjustments – also due to mergers and acquisitions to cope with overcapacity in developed countries.

Over the short term, the main policy implications for vehicle technology are the air quality standards in urban areas and the reduction of greenhouse gas emission. With respect to R&D and innovation policies there is a need for complementary actions to facilitate the market up-take of new propulsion systems in order to allow them to overcome the entry barriers imposed by conventional propulsion systems.

7.5. Technology Interactions in Transport:

In ancient Rome, congestion, noise, one way streets, access restrictions and toll bridges were a part of everyday life by the time of Julius Caesar.

The examination of this aspect of the Transport Technology Map requires that the context for transport be outlined. This in turn requires that the underlying driver of the transport sector, mobility, be examined also. Mobility is an expression of the relationship in urban areas between time and space. People can be very mobile over a large area with the assistance of vehicles and roads, but only at the cost of consuming fossil fuels, land for roads and car parking and producing large amounts of greenhouse gases and pollutants that damage respiratory health. Much of twentieth century development in advanced economies has opted for land uses, which support this concept. In the process the point has been reached where in most urban areas the demand for mobility has outstripped the capability of society to provide matching supply.

Key Features of the Landscape

- Deep social forces promoting increases in demand for road and air travel will continue
- Despite technological change, supply growth will not match demand growth
- Government sets the framework; delivery is by hundreds of agents setting prices/service levels for millions of final users
- Resources, especially public finance, will continue to be scarce
- Concerns re local and global pollution, health effects, biodiversity, loss of assets are real and will not go away.

Technological developments have played their part in the development of mobility on both the supply side and on the demand side.

On the supply side;

vastly improved means of transport in terms of safety, reliability, quality, consumer appeal, range of operation and cost of operation have been developed,

significant improvements in *infrastructure*, with better accessibility and improved cost performance have been introduced

more sophisticated *transport systems* in terms of management of traffic flows and improved information provision.

On the demand side;

The improvements in means of transport have brought personal transport within the reach of large numbers of people and increased market demand.

similarly the provision of more and better infrastructure has increased its usage.

At the same time the improvements in technology have not been sufficient to offset the effects of growth in demand in terms of the negative impacts of mobility on the environment, from pollution and on congestion. It would appear that the major negative impact on the effectiveness of mobility is congestion, which in turn exacerbates the problems of environmental pollution.

Emerging technological developments will continue to enhance the efficiency of existing systems through improved propulsion systems lowering energy consumption and polluting emissions. Improved vehicle controls and materials will contribute to greater safety and combine with improved transport management systems to increase infrastructure usage and overall system effectiveness. However it does not appear that these improvements will alleviate in any significant way the increase in congestion at critical points in urban an peripheral networks, which projected growth in demand will cause.

Other aspects of mobility, which have complicated interactions with technology and technological development, involve freight transport. Freight is the lifeblood of any nation's industry and commerce and the restructuring of production and distribution systems have been the main driver for freight traffic growth over the last twenty years (MacKinnon (1999).

Current developments in IT and telecommunication offered enormous potential for companies to improve their logistical systems to reduce demand on the transport system. But to most people the benefits of IT were thought of only in terms of road transport telematics and making better use of the network. However, individual companies will be able to deploy in-cab communication systems, and use dynamic rescheduling of vehicles to economise on their use of the road network. A study conducted last year suggested that if companies were to exploit the full range of IT and telecommunications fully, they could perhaps reduce the amount of road freight transport required by as much as 12 per cent (MacKinnon, 1999).

One difficulty arising from modern management practice is that companies are becoming involved in sophisticated supply chain management. This development will grow with improved information management offered by ICTs. It is likely that concepts such as Just In Time (JIT), will lead to making more frequent deliveries of smaller quantities in an effort to minimise inventory. Even with flexible changes in vehicle types this development will tend to reduce the efficiency of vehicle usage and infrastructure usage. Care must be exercised in the analysis of these effects, as aggregate data may be misleading. Effects in different regions or sectors may cancel one another out showing an aggregate position of little consequence. However the individual regional effects may be very significant.

There is a major requirement for improvement in analysis and appraisal of the interactions and relationship between elements of the systems involved in logistics and transport. Once again the issue of modelling and simulation technologies raises its head. Political factors will limit the scope for change but this should not prevent the development of a better understanding of how existing arrangements could be improved so that when opportunities for change arise informed choices can be made on which direction to move in.

The impact of transport policies on competitiveness is crucial. Looking at the relationships between urban distribution systems and local transport plans would facilitate addressing the trade-offs between the movement of people and the movement of goods and services.

Outline of main cross-cutting issues and interactions regarding transport

Transport and Energy

- Fuels supply, energy security, global emissions
- Fuel quality, fuel production, standards and local emissions
- Fuel distribution, refuelling and related infrastructure

Transport and Infrastructure

- Increasing marginal costs
- Sophisticated underground infrastructure
- Traffic management
- Logistics

Transport and Materials

- Weight reduction
- Strength improvement
- Feasibility, design and manufacturing
- Recyclability

Transport and Environment

- Trends on emissions, at global, regional and local levels
- Materials consumption and recycling
- Degradation of resources

Transport and ICT

- High business potential
- Improvement of efficiency and safety
- Substitution potential (communication for transport)

Transport and spatial planning

- Rational use of land
- Cohesion of peripheral regions
- Integrate with urban and regional planning

7.6 Enlargement Issues:

The prospect of an enlarged European Union, bringing in, in phases, 12 more countries located to the east raises a series of problems, which need to be considered in an integrated way with EU15 developments. The specific enlargement-related aspects are as follows:

- New transport technologies for infrastructure development in CEEC
- New technologies and the growth of demand for transport
- The role of new transport technologies for the modal split in enlargement countries
- The appropriate levels and requirements of new transport technologies for the CEEC
- The adoption of standards and norms
- Transport and economic development in the CEEC
- Social acceptance

The key question with respect to enlargement seems to be in how far it will be possible to avoid the same development path of the transport system in Eastern Europe as has been seen in Western Europe in the past. It would be desirable to avoid a fast growth of uni-modal road transport and a decline of more sustainable modes such as rail. Instead, the current EU policy objectives of introducing more sustainable transport technologies, strengthening inter-modality and efficiency should be taken on board right from the beginning. However, this may not be easy because of financial and economic constraints. In other words, the issue is whether the CEEC will be able to achieve a “leapfrogging” in modernising their transport system or not, and thus be able to avoid a repetition of West European problems in transport system development.

8. Conclusions

8.1 Introduction

The Technology Map as drawn in the previous Chapters has laid great stress on the importance for future development in Europe of Information and Communications Technologies and Life Sciences. It is expected that ICTs will continue for the foreseeable future to influence the changes in the way people live, work and interact and that Biotechnology, as the manifestation of Life Sciences advances, will be as pervasive in the first part of the 21st century as ICTs have been in the latter half of the 20th.

What then does the Technology Map tell us about Europe’s future. This aspect of the Map’s application is dealt with under the following headings:

Europe’s Position in relation to Emerging Technologies –Strong or Weak,

How will Enlargement impact,

Main policy relevant conclusions from the six technology sectors.

8.2 Europe’s Position in Relation to Emerging Technology

These results are based on outcomes on the national Foresight studies considered. The representations of the six sector maps are shown in each Chapter. In each map the expected timing of individual technological breakthroughs, as set out in Foresight studies, is given with an assessment in each case of Europe’s relative strength or weakness. In addition an indication of the importance of the area for economic development or societal development can be gauged from the Importance index shown, the principal results from the sectors are presented here in tabular form.

ICTs Ubiquitous Computing	**European Strength or Weakness**	**Importance Index**
Personal Mobile Telephony >10Mbps	Very Strong	89
1 Mega Neuro chip	Very Strong	86
High Frequency chips	Strong	86
Digital TV	Strong	95
Single chip real time speech translation	Weak	78
High performance Batteries,500Wh/kg	Very Weak	87
VLSI Chips 256 Gb	Very Weak	94

Europe exhibits considerable strengths in many application areas, but the weaknesses in enabling technologies present a threat to future developments even of applications.

ICTs Knowledge management	**European Strength or Weakness**	**Importance Index**
Sensors and Microsensors	Strong	99
Network based authentication of contracts	Strong	78
Large scale data retrieval	Moderate	90
Reusable software components and libraries	Moderate	85
Real time portable translators	Weak	63
Security systems based on individual ID	Very Weak	84
Imaging and 3D representation	Very Weak	88

The weakness in security systems under knowledge management will be critical areas for societal acceptance. Other major weakness in 3D representation will pose a threat to developments in health services and transportation.

Life Sciences: Biotechnology in Health	**European Strength or Weakness**	**Importance Index**
Regulatory Framework for non-laboratory diagnostic kits	Very Strong	62
Nutritional supplements for cancer prevention	Strong	82
Target specific "missile" drugs for cancer	Strong	76
New treatments for myocardial infarction	Moderate	89
Therapies that contain cancer	Moderate	84
Remote surgery and robotic techniques	Weak	53
Hybrid artificial intelligence combining ICs and living cells	Weak	54

Europe is considerably strong in areas of medical technologies and the organisation of health services. By strengthening the related ICTs Europe can become a major provider of global expertise.

Life Sciences: Biotechnology in Agro-food	**European Strength or Weakness**	**Importance Index**
Biodegradeable packaging materials	Very Strong	86
Genetic engineering for new strains of plants	Strong	61
New fibre crops for technical applications	Strong	76
Reduction in use of chemical fertilisers and pesticides	Moderate	78
Cloning for cattle breeding	Moderate	67
Acceptance of transgenic food	Weak	72
Hypoallergenic food by Genetic engineering	Weak	73

The development of European advantages in this area will depend almost entirely on the outcome of the societal debate on ethics and acceptance of the application of biotech in agrofood.

Energy	**European Strength or Weakness**	**Importance Index**
MW class Wind Power Generation systems	Very Strong	66
Large scale Combined cycle power gen. with high efficiency gas turbines	Strong	92
Treatment and re-use of wastes to obtain energies	Strong	65
Direct coal liquefaction	Moderate	69
Large area amorphous silicon solar cells	Moderate	77
Tidal and wave energy	Weak	59
High density secondary batteries	Weak	91

Technologically Europe is strong in advanced power generation systems. The new liberalisation regimes will determine the rate of the global exploitation of these strengths.

Environmental and Clean Production Technologies	European Strength or Weakness	Importance Index
Plastic recycling	Very Strong	78
Recycled building materials	Strong	75
Drought and Salt resistant strains in plants	Strong	67
Closed material cycles for products	Moderate	98
Separation and membrane technologies	Moderate	78
Network coupled photovoltaic systems	Weak	82
Energy conversion of solar cells > 50%	Weak	65

The European strengths in recycling and waste management are positive drivers towards sustainable development. Further developments of moderate strengths in product lifecycle management present major opportunities for global development.

Materials and Related Technologies	European Strength or Weakness	Importance Index
Biodegradable plastics	Very Strong	76
Signal responsive missile drugs	Strong	81
Computer simulation technology for growing thin films from 1st principles	Strong	75
Implant material that lasts a lifetime	Moderate	83
Temporary bone fixation material	Moderate	82
High performance switching elements made from 3rd order non-linear optical mat	Weak	82
Diagnostic technologies foe estimating remaining life of mechanical components	Weak	76
Semiconductor UV lasers	Very Weak	70

Materials represent the major bottleneck for the developments of all other technological areas. Therefore efforts targeted at areas of weakness need to take account of relatively long total development process times.

Transport	European Strength or Weakness	Importance Index
In-vehicle traffic information systems	Strong	85
External control of vehicles (speed, emissions, access…)	Strong	80
Vehicle fuel efficiency 30% greater than today	Strong	78
Cargo tracking and inter-modal booking of freight	Moderate	90
H2 production from non-fossil fuels	Moderate	71
Hybrid electric vehicles compete with conventional cars to meet Euro V Stds.	Weak	75
Electric car for 200km with 15 min. recharge	Very Weak	78

Europe is strong in vehicle technologies and in traffic management technologies. However, in the area of implementation and integration of these technologies much remains to be done.

8.3 How will Enlargement impact

The Technology Map has been drawn in relation to the current profile of the EU. The addition of a range of Central and Eastern European countries will not alter the basic situation in the map. However, two aspects will be affected in terms of actions that may be taken in relation to the technological profile in the map. Accession countries will compete for some share of resources allocated to the improvement and strengthening of critical areas of technology. At the same time they may have considerable skilled personnel resources to offer to those programmes.

However, the main issue related to pre-accession countries refers to implementation of existing technologies, rather than on the local development of emerging technologies.

8.4 Main Policy Related Messages

1. Strengths in ICT applications areas in Life Sciences, Transport and Materials are threatened by Weakness in basic ICT enabling technologies,

Europe’s weakness in areas of basic ICTs, such as silicon based chip technologies, display and representational technologies and areas of software development in the artificial intelligence field will hamper the development of areas of Life Sciences such as medical telematics and remote delivery of specialist medical services. The problem lies in the need for technological capabilities even to use technologies acquired from elsewhere, particularly in a development mode.

2. A policy agenda backed by solid research is needed in the area of risks in Life Sciences, such as for food safety and privacy and security of information in ICTs.

The level of public acceptance will determine the future of biotech in the food chain. For the debate to be informed public policy will need to be balanced and rigorously based in the best available information. Benefits and risks must be assessed and it is clear that policy makers will need more selective and precise instruments to guide the processes. Trust in scientists and policy makers has been eroded and needs to be re-established.

3. In some sectors technology will assist in alleviation of problems but cannot solve them alone.

Many of the currently available and emerging technologies can significantly help in alleviating pollution and resource consumption problems by improving efficiencies. However, for example in Transport, the major problem of congestion requires many other socio-economic policy actions to bring about reductions. Similarly in the energy sector the adoption of environmentally friendlier technologies depend on economic and regulatory policies.

4. The connection between people and technology is critical to successful technological exploitation.

This applies at all levels of society. The S&T and Business actors need high-level technology capability while the consumer needs basic technological literacy. This suggests that Technology Mapping needs to be complemented by Competence Mapping. A more detailed analysis of location issues, specialisation and competence development would complete the picture for policy makers in terms of the fostering of centres of excellence and other such hubs of developmental energy.

5. Full development processes for technology systems take extended periods of time.

Individual technologies may change at a rapid pace but technology interactions and interdependencies mean that exploitation through innovation and a full development process take longer than is popularly suggested. A technology cannot be said to be developed until it is affordable. A case in point is materials where the process can take up to 15 years. This suggests that public research policy will need to recognise this issue in formulating programmes and allocating funding.

6. Technology Maps can be structured as technology management tools.

Technology maps can be used to plot the path of development of technologies from their discovery stage to their commercial application. Particularly important is the identification and parallel development of essential complementary technologies, critical pathways and gap analysis in critical technological components of strategic technology systems.

Annex 1

List of Foresight Studies used:

ITA, Institute of Technology Assessment of the Austrian Academy of Science, Delphi Report Austria (three volumes), Vienna, 1998.

OST, Office of Science and Technology, Technology Foresight, Progress through Partnership, HMSO, London, 1995.

Fraunhofer Institut and BMBF, Delphi ’98 – Studie zur Globalen Entwicklung von Wissenschaft und Technik, Karlsruhe, 1998.

STA, Science and Technology Agency, The Sixth Technology Forecast Survey, Future Technology in Japan – commissioned by NISTEP, National Institute of Science and Technoogy Policy, Tokyo, 1997.

OPTI, Observatorio de Prospectiva Tecnológica Industrial, Primer Informe de Prospectiva Tecnológica Industrial – Futuro Tecnológico en el Horizonte del 2015, 1999

George Washington University, Department of Management Science, Delphi Forecast of Emerging Technologies, Washington, 1996.

Ministry of Economics, Finance and Industry, Les technologies clés pour l’industrie française à l’horizon 2000 – 1995, Paris, 1995.

RAND, New Forces at Work: US National Critical Technologies Review Group, Rand Corporation, Santa Monica CA, 1998.

Fondazone-Rosselli, Le priorità nazionali della ricerca industriale, Primo rapporto, Franco Angeli, Milano, 1998.

Ministry of Research, Science and Technology, Blueprint for Change, Wellington, New Zealand, 1998.

Australian Science, Technology and Engineering Council, Developing long-term strategies for science and technology in Australia, 1996.

RAND Europe and Coopers & Lybrand (1998): Technology Radar (4 volumes) - study commissioned by Ministry of Economic Affairs, Drukkerij Plantijn, Capelle a/d Ijssel

Other References:

British Telecom (1998) Technology Calendar

EEA (European Environment Agency), Environment in the European Union at the Turn of the Century, Copenhagen, 1999.

R. Weterings, J. Kuijper, and E. Smeets, 81 Options: Technology for Sustainable Development – Final Report of the Environment-Oriented Technology Foresight Study, Apeldoorn, 1997.

OECD, Technology Foresight: Environment-Related Issues, DSTI/STP/TIP(98)11, Paris, 1998.

The Futures Project: Information and Communication Technologies and the Information Society, IPTS-JRC, Sevilla.

The Futures Project: Life Sciences and Frontiers of Life Panel Report IPTS-JRC, Sevilla.

Eder, P., Leone, F., Environmental and Clean Technologies (ECT) in Recent National Foresight Exercises, Institute for Prospective Technological Studies (IPTS)

Driessen R, van Mechelen A C A, van der Steen J J D, 1992, Inventarisatie van knelpunten in de bouwwereld met betrekking tot acceptatie en toepassing van secundaire gondstoffen; Resultaten van de interviews, 92-419, TNO-MEP, Apeldoorn, The Netherlands.

Grupp, H. (1.993): Technologie am Beginn des 21. Jahrunderts. Heidelberg, Physica-Verlag.

Annex 2

TECHNOLOGY INTERACTIONS: Examples

Introduction

In each of the sectors in main report the question of technology interactions within the sector and between sectors was raised. In this chapter a broader view will be taken of technology interactions as they occur across two or more sectors. The main concern is to highlight how a Technology Map can be utilised to track potential for valuable innovations, which utilise technologies from a number of sectors. Three examples have been selected to show how this process operates.

Cross-Sectoral Interactions

In Fig.Ann.2.4 (see separate pdf file) the six technological sectors have been set out, each with ten/twelve technology issues listed. A range of connecting lines has been drawn to indicate where the issues are linked by technological dependency. This means that an emerging technology in one sector needs the development of a technology in another sector to allow the viable exploitation of the former.

It is clear that not all the possible technology issues in each of the sectors are included in the selections made for Fig Ann.2.4. To attempt to incorporate all the issues would sacrifice clarity and ease of use to complexity. However it does highlight the issue that users have to specify their range of interests to allow the relevant map to be constructed. The choices made for this map are those technologies and technological issues, which are scheduled for realisation up to the year 2010 and were identified in the earlier sections of Chapter 2.to 7

To draw all the linkages between all the technologies in the six boxes would result in an unintelligible web of lines. Consequently only a small selection have been drawn to illustrate the principle. As with any other map, the user normally concentrates on a limited area of the map appropriate to the immediate problem. So, in this case, three particular sets of interactions have been set out to illustrate the analysis.

The first set shows the interactions between a technological topic in the field of Life Sciences and a range of technology issues in ICT and Energy. Although the technological issue in Life Sciences is “Specialist level diagnosis assistance systems,” the interactions recorded are similar to those for a wide range of Healthcare developments. Consequently the example which will be outlined for these interactions will cover the wider issue of Healthcare Informatics.

The second set of interactions involves the Transport sector and its technological dependencies on ICT and the related interactions with Environment. It should be noted that another important set of interactions, not dealt with here, connect Transport to Energy, Materials, ICT and Environment in the area of improved propulsion systems.

The third set of interactions outlined in this chapter link Environment with ICT in the pursuit of sustainable development.

Each of these sets of interactions is set out as a separate story.

Technology Interaction and the Challenge for Medicine

Much emphasis and public attention is focused on developments in Life Sciences, which promise significant technological breakthroughs in the area of health and health care. The success of the scientific method is increasing medical knowledge down to a fine-grained molecular and genetic level fuelling expectations of significant benefits for citizens. But events at the other end of the scale are forcing the change. The business of medicine has become so large that it now absorbs more national resources than any country is willing to bear. Despite extraordinary efforts to control this growth in consumption, healthcare budgets continue to expand. Thus there is a social and economic imperative, coming from outside healthcare, that is striving to control its processes.

At the same time, the structure of medical practice is also coming under pressure from within. The scientific method, long the guiding paradigm of medicine, is now being challenged. The reason for this is not that experimental science is unable to provide answers for the ever-crucial questions about the nature of disease and its treatment. Rather, it has been almost too good at its job. As medical research ploughs ahead in laboratories and clinics across the world, like some great theory machine, medical practitioners are being overwhelmed by its results. So much research is now published each week that it can literally take decades for the results of clinical trials to translate into changes in clinical practice.

Modern medicine no longer views disease in isolation and has moved to understanding that illness occurs at a complex system level. Infection is not just the result of the invasion of a pathogenic organism, but the complex interaction of an individual's immune system, nutritional status, environmental and genetic endowments. By observing things at a system level, a greater understanding is gained of what it really means to be diseased, and how that condition, however defined, can be reversed.

The same conceptual leap is now needed to begin to see the great systems of knowledge that enmesh the delivery of healthcare. These systems produce the knowledge, tools, languages and methods. Thus, a new treatment is never created and tested in intellectual isolation. It gains significance as part of a greater system of knowledge, since it occurs in the context of previous treatments and insights, as well as the context of a society's resources and needs. Further, the work does not finish when it is scientifically proven that a treatment works. The developers must try to communicate this new knowledge, and help others to understand, apply, and adapt it.

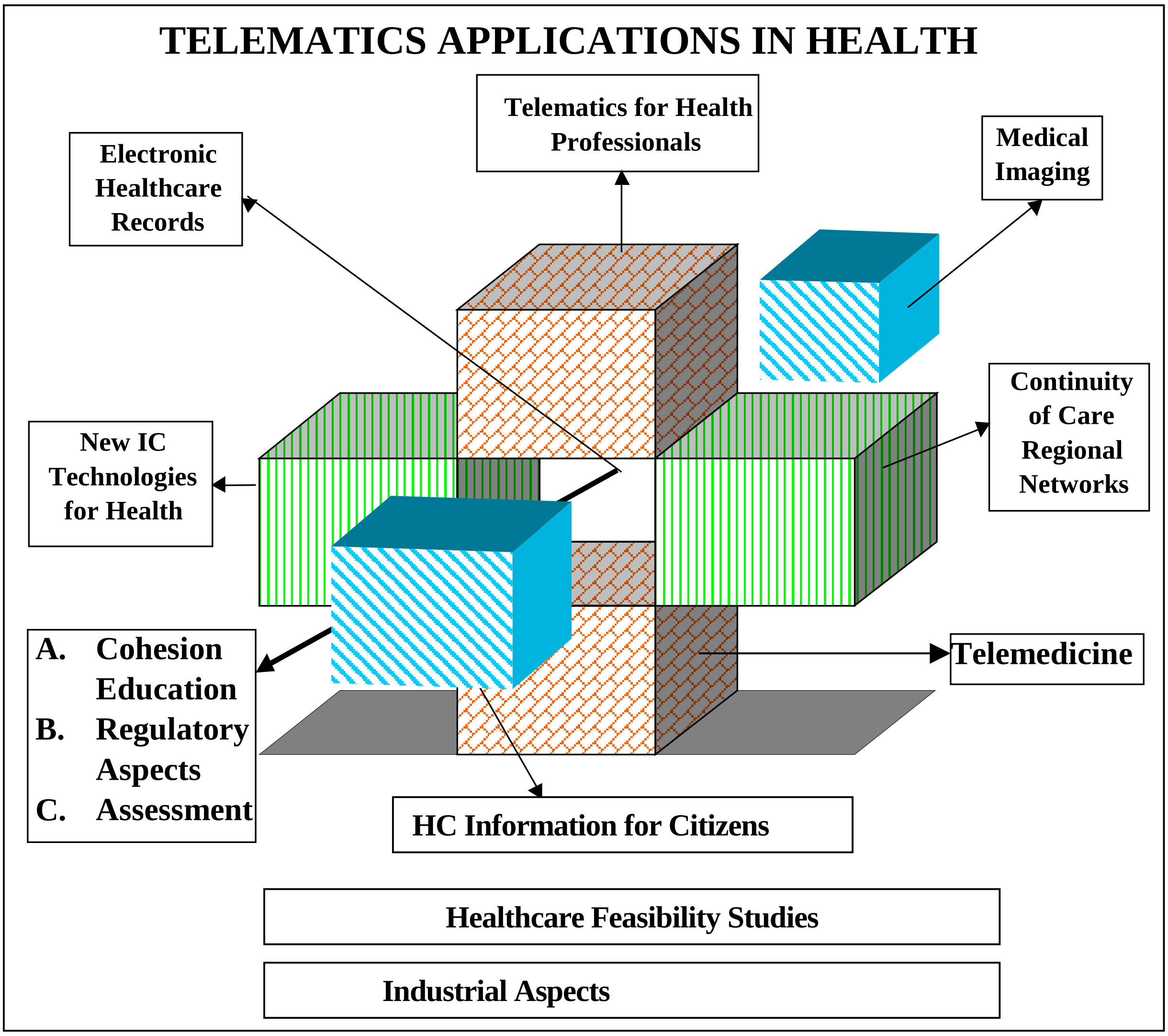
These then, are the challenges for medicine. Can rational structures for the way clinical evidence is pooled, communicated, and applied to routine care be put together? Can organisational processes and structures that minimise the resources used, and maximise the benefits delivered be developed? What tools and methods need to be developed to help achieve these aims in a manner that is practicable, testable, and in keeping with the fundamental goal of healthcare - the relief from disease? The field of ***medical informatics*** can help develop a rational basis to answer these questions, as well as help create the tools to achieve these goals.

The technologies of information management and processing are important components of these knowledge systems and over the period to 2010 and beyond the healthcare sector will increase its demands on these technologies significantly. Already steady progress is being made in many separate fields in diagnosis and therapy. However the untapped benefits of integration of data sources and yet to be developed expert systems and artificial intelligence applications hold the promise of increased effectiveness and efficiency in the delivery of health care.

The construction of national and international databases of patient data, which link vital statistics through intelligent agents to diagnostic images and research results, will call for major developments in computing power, data storage and retrieval, expert systems and visualisation and graphical technologies, as well as portable power sources for accident and emergency use.

Numerous references in the literature attest to the demand emerging for computing power in this area. "3D visualization for medical applications will become a major core technology over the next decade, with image acquisition, storage, computing and networking having requirements in the terabytes and petabytes. Thus, cluster computing and high bandwidth networking will be essential." Richard Satava, DARPA.

The following diagram, originally produced in the EU Report on "97 Healthcare Telematics



illustrates the context of telematics applications in healthcare and the pervasiveness of ICT in the delivery of healthcare in the future. Although originally conceived in the context of managing the projects on health telematics under the 4th framework Programme, this diagram succinctly captures the interactions of information management in healthcare delivery.

The resulting picture accords with the emerging view that the knowledge domain of healthcare can be represented by a three dimensional space with one dimension covering information, computing and communications, the second dimension covering medical research, medical education and medical practice, and the third dimension covering science, engineering and technology.

A second area of significant technology interaction between ICTs and healthcare has a realisation period much later in the time horizon. This area involves the interface between humans, in the persons of medical personnel, and digital information. Display of critical medical information within a complex clinical setting presents a number of challenges, aside from standardization of the electronic patient record. Among these are the development of clinically acceptable data input methods, fail-safe access and communication methods, and the partitioning of the user interface across the variety of potentially useful devices.

A rich interface "toolkit" can be envisioned for the medical practitioner of the future. Along with traditional workstations and device monitors, the medical interface environment of the future will incorporate four key emerging technologies:

Virtual Reality (mediated by head-mounted displays (HMD), "cave"-type environments, and "holographic" or stereographic systems)

Augmented Perception (mediated primarily by HMDs and other see-through devices)

Ubiquitous Computing (including interface devices, such as wall panels, wireless pads and PDAs, which permit ubiquitous access to a common database)

Virtual Retinal Display (VRD) Among the more promising new enabling technologies for advanced interfaces is the Virtual Retinal Display (VRD) approach, the rapid modulation and scanning of light directly onto the retina to create a high-resolution coherent image.

These solutions to the problems of real time interfacing with the flows of information from sensors and imaging patterns carry with them enormous challenges in the organisation and management of healthcare delivery.

Technology Interaction and Challenge for Transport

The second set of interactions involve the Transport sector and the ICT sector. Here again there are significant problems of information collection, processing and management with much of the demand for real time responses. The contributions of ICTs to the improvement of efficiency and effectiveness have already been referred to in the context of their not providing the complete solution to the overall problem of sustainable mobility. Nevertheless, their contribution will be critical in the management of increasingly sophisticated demands on transport systems and infrastructures.

The example chosen here to illustrate the situation is the joint EU and European Space Agency (ESA) “Galileo” Programme to establish a Global Navigational Satellite System (GNSS). This system is intended to be the independent system for Europe managed and controlled in Europe.

The system is intended to support the development of intelligent infrastructures for data capture, processing, exchange and distribution covering all transport modes. Its aim is to support traffic and demand management, collective and individual transport, fleet and freight operations for the whole logistics chain, and integrated sustainable transport operations in cities, rural areas and Trans-European networks. These objectives include the development and enhancement of surveillance, positioning, navigation, management, guidance and payment systems. Emphasis is placed on the enhancement of terrestrial and satellite communication, positioning and observation infrastructures in view of their adaptation for traffic surveillance and control, tracking and tracing, telepayment and guidance. An important priority issue will be provide to media-independent and open architectures adapting mobile network intelligence and terminals for optimal use in transport. Image processing, monitoring technology and sensors need to be further developed for surveillance. The development of new traffic control systems integrating processing, simulation, prediction and decision-support tools, including tools for managing large-scale events and crises, will be a feature.

The current state of the art in Transport Telematics includes the following:

Traffic and transport data collection based on inductive loops is an available technology for automatic measurement of average speed and traffic flow, which enables automatic detection of congestions.

Image processing techniques are under development to supplement and perhaps replace some inductive loops, but remain more expensive. Field Trials and trials in the USA have shown the feasibility of this technology. Floating car information is being collected using beacon based or mobile telephone.

Variable message signs, weather detection and forecasting and short term traffic forecasting hare being further developed.

Traffic mode and simulation tools exist in most fields; however, they mainly concern planning (rather than real time) activities although there are many ongoing developments; progress is still necessary on multi-modal tools.

Many software programmes have been developed in Europe around Advanced Transport Telematic applications: fleet management, payment or debiting systems, control aids, etc.

Geographical Information Systems (GIS) are coming to maturity, and often appear as major components of integrated systems, with geographical data bases covering many urban areas and the interurban road network in many countries. Efficient GIS software for workstations and micro-computers (even for personal digital assistants (PDA)) is becoming available. Links with GPS equipment is possible. Data modelling in the field is being standardised.

Fleet operators are still awaiting location systems that have wide range geographical coverage at a viable price. There has been little development in the decision and software aids for route controllers, although there have been constant improvements in the information displays as graphic systems developments from other domains are imported.

All of these will be enhanced under the Galileo programme and developments in integration and standardisation of protocols and architectures will ensure the interoperability that systems will require to be effective and economic. The pace of development is rapid and competition will be vibrant. The projected prize in terms of market is large with the expected levels of revenue for satellite navigation systems and services estimated at 270 billion Euro, between 2005 and 2025.

Technology Interaction and the Challenge for Environment[7]

An example of the interaction between technologies from the Life Science sector, the ICT sector and the Environment sector can be found in the area of land fill and waste management. There will be a need to co-ordinate both sensor research and development and landfill and waste management. Innovations and technical solutions such as the uptake of microbial biodegradation of toxic xenobiotic chemical compounds, the remote tracking of airborne compounds such as organophosphates using electronic noses, enzyme-linked immunoassay (ELISA) kits, or enzyme-based biosensors and identifying compounds using 'lab on a chip' or 'DNA chips' can acquire application areas in landfill management, recycling, composting and contaminated land remediation. In addition, further development requires more detailed knowledge of chemical interactions such as bonding. Here, there is much scope for the involvement of research in chemical and biotechnical engineering in the development process of novel sensors. The most promising directions in this involve novel chemical sensor technology based on detecting the changes in a polymer, or series of polymers, due to the impinging of an analyte molecule. By detecting the degree of swelling of an array of several polymers, the type of analyte can be deduced.

A range of technologies has already been developed and more are under development. However, landfill sensors currently involve a trade-off between selectivity, sensitivity, scope and price. Current systems detect total organic content (TOC) levels in industrial effluent, which correlates directly with the biological oxygen demand (BOD). These can be easily adapted for use with landfill leachate. As legislation governing landfill and waste management becomes more stringent, simple monitoring of carbon for organic load on the environment, or simply presence of leachate within and below landfill sites, becomes less important. What is required, at low cost and in robust packages, are systems, which detect certain specific hazardous analytes. Detection not only of the presence of gas or leachate, but also of the types of chemical compounds contained, as well as their concentrations, are required for effective landfill management.

Sensor fusion may be needed to obtain the range of selectivity, sensitivity, detection of concentration, robustness and price applications of the type required. This takes the outputs of a range of different sensors, and, using sophisticated data processing, builds a picture of the types and concentrations of the analytes present. A major cost for many landfill operators is the employment of personnel to monitor conditions using the currently developed sensors. However, this cost can be reduced by developing smart arrays of sensors which monitor remotely, and then download data, either via land lines or mobile communications, to a monitoring base station. The bandwidth requirements of such a system can be minimized by signalling to the operator only when concentration levels fall outside pre-defined parameters.

One of the main factors in facilitating development of robust markets for environmental sensing and monitoring technology for landfill sites will be a clear consensus on toxicology of species and compounds that may emerge from such sites. There are clear threats in terms of local communities and, possibly, surface and groundwater contamination. There are also clear threats to traditional sewage treatment works if they become overloaded with industrial-strength pollutants, after, for example, heavy rainfall over landfill sites, that can cause sewage plant failure. Here, there is clear opportunity for the uptake of remote sensing and data logging and downloading devices in order to signal such threats to sewage treatment plants. However, until there is clear understanding of toxicology and associated risks --at local, regional and global levels-- of compounds arising from landfill sites, the case for taking up and developing sensors, in order to offset the costs of environmental hazard insurance premiums, will remain difficult to make.

[7] Adapted from anrticle in the IPTS Report No 28. Environmental Sensors in Waste Management by Simon Proops (CEST)

It is clear from this case that the area of Life Sciences has to contribute in the area of the development of bio-sensors and in the area of research into toxicology of waste compounds. ICTs must contribute to the smart software and integration of the data systems and Materials may have to contribute in the area of separation membranes for treatment action following the detection of hazardous levels of contaminants.

Technology Interactions – Conclusions

The other interesting facet of technology interaction is the question of direction. Is the direction of the flow of influence from one sector to another one way or two way. In the case of ICTs and Materials, because they are largely enabling technologies, the flows of value and knowledge tend to be towards the application areas. However, in the case of ICTs the reverse flow from Life Sciences may be more balanced as new sources of computing devices emerge from a cellular/molecular base.

The relationships and inter-dependencies between the Environment sector, the Energy sector and the Transport sector suggest a more networked flow pattern.

Finally, the significance of technology interactions heightens the awareness of the dangers posed to Europe by areas of weakness in emerging technologies.

Fig. ANN2.1

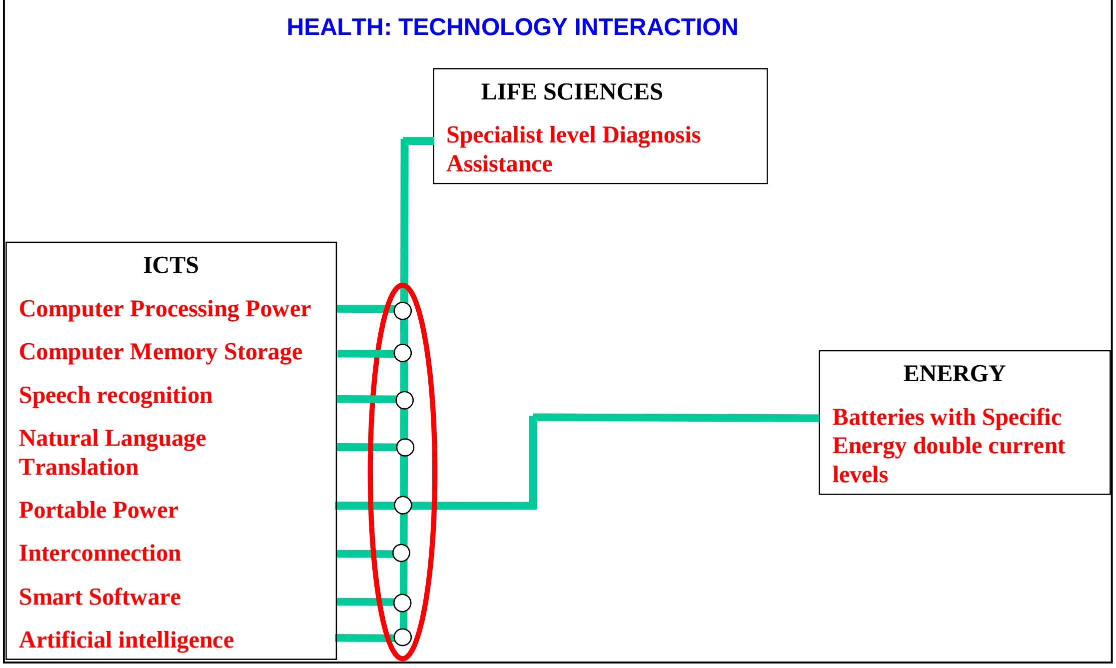


Fig. ANN2.2

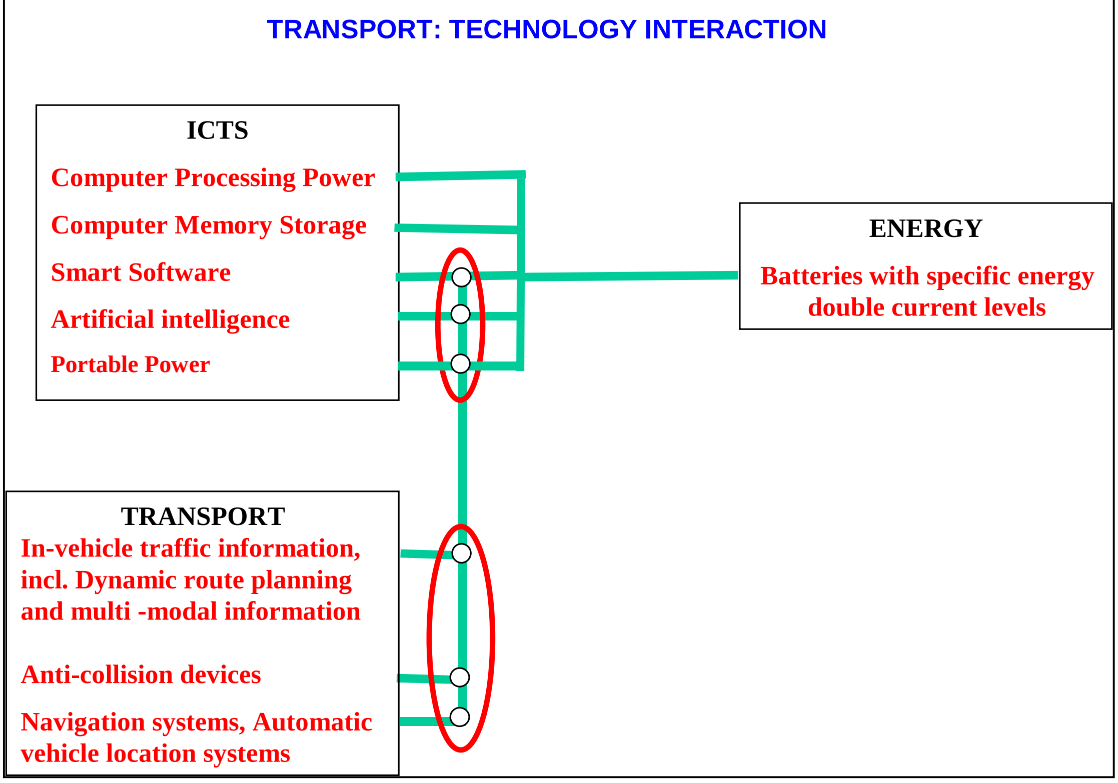


Fig. ANN2.3