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Creative system disruption: towards a research strategy beyond Lisbon

Key Technologies expert group

September 2005

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Foreword

Europe is currently facing the critical challenge of revisiting and re-shaping/re-structuring its whole societal model. The emerging society, ageing and health-conscious is based on a rural economy maladjusted to new realities and an industrial sector changing from labour and capital-intensive to knowledge-intensive mode. The European economic model is built upon old paradigms and a R&D system which is strong in generating knowledge but unable to transmit effectively its results to the economy. The way forward for Europe depends on a creative system disruption based on long-term coherent investments in Key Technologies.

This is the synthesis report of the high level group on Key Technologies set up by DG research of the European Commission in December 2004 and which completed its work in September 2005.

The High Level Group (HLG) mandate included the definition of a permanent system for setting long-term visions for Key Technologies by 2009/2010 when FP8 would be under discussion. The first task was to assess the potential and the emerging scientific and technological research topics in the fifteen selected areas. The second task was to provide a holistic and forward-looking view to develop guidance for new research agendas based on the conjoint analysis of all reports, exploiting the potential synergies across these technologies and including the insights drawn from the overall analysis of all the Key Technologies.

The HLG kick-off meeting was held in Brussels in January 2005, followed by a restricted workshop in May 2005, where the preliminary individual reports were presented to collect comments from all the members of the HLG and from other invited experts. The revised reports were subsequently validated by other experts in the field. The synthesis report and the fifteen sectoral reports were debated at the conference entitled 'Key Technologies for Europe' held in Brussels on 19-20 September 2005, which was inaugurated by Commissioner Potočnik.

The synthesis report draws on the fifteen thematic reports that provide a detailed analysis and forward-looking perspectives for the EU-25 R&D system in fifteen Key Technologies: agriculture, biotechnology, cognitive sciences, communications, complexity, energy, environment, health care, information technology, manufacturing, nanotechnology, security, services, transport and Social Sciences and the Humanities.

The report outlines for the rationale and shape of a long-term beyond Lisbon agenda based on creative system disruption and a more short-term transition research agenda for Europe.

Aknowledgements

We would like to express our gratitude to DG research - Unit K2 'Science and technology foresight' for their support and encouragement throughout the development of the group's work. Special thanks are due to Dr Paraskevas Caracostas and Mr Elie Faroult for their insights and guidance with the work.

We would also like to thank all the experts that contributed with their insights, opinions, effort and time to ensure accomplishment of the group's mission.

Abbreviations

3D	Three Dimensional
AI	Artificial Intelligence
CEN BT/WG 161	Comité Européen de Normalisation Technical Board / Working group 161
CERN	Centre European Recherche Nucléaire (Organisation Européenne pour la Recherche Nucléaire/ European Organisation for Nuclear Research)
CIP	Competitiveness and Innovation Programme
CREST	The Committee for Scientific and Technical Research
DG	Directorate General
EMBO	European Molecular Biology Organization
EPR	European Pressurized Reactor
ERA	European Research Area
ERA-NET	European Research Area Network
UK ESRC	Economic and Social Research Council of the United Kingdom
ESRP	European Security Research Programme
EU	European Union
FP	Framework Programme
GMO	Genetically Modified Organisms
ICT	Information and Communication Technologies
IP	Intellectual Property
IST	Information Society Technology
ISTAG	Information Society Advisory Group
IT	Information Technologies
KT	Key Technologies
NEC	Network Enabling Capabilities
OMC	Open Method of Coordination
PASR	Preparatory Action on Security Research
PFI	Private Finance Initiative
PV	Photovoltaics
RES	Renewable Energy Sources
RTD	Research Technology and Development
R&D	Research and Development
SME	Small and Medium-Sized Enterprises[1]
SS&H	Social Sciences and the Humanities
SWOT	Strengths, Weaknesses, Opportunities and Threats
US	United States
USA	United States of America

(1) The category of micro, Small and Medium-Sized Enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million. OJ L 124 (2003) pages 0036 - 0041 - Commission recommendation of 6 May 2003 concerning the definition of micro, Small and Medium-Sized Enterprises.

Executive summary

The high level Group on Key Technologies was set up by Unit K2 'Science and technology foresight' of the Directorate General Research (DG Research) - European Commission, with the task of providing inputs for the 2006 report on perspectives of European research. The group assessed fifteen Key Technologies (KT): agriculture, biotechnology, cognitive sciences, communications, complexity, energy, environment, health care, Information Technology (IT), manufacturing, nanotechnology, security, services, Social Sciences and the Humanities (SS&H) and transport. A key expected output is a set of recommendations for introducing permanent processes for developing long-term visions and short to medium-term strategies for research in Key Technologies by 2009/2010, when the eight Framework Programme (FP8) would be under discussion.

The **key messages** emerging from this synthesis report are:

1. Europe needs to define and implement a long-term research strategy, hereby referred to as t**he *beyond* Lisbon strategy**, which is supported by a long-term vision (30-50 years) and transition agenda;

2. Europe needs to project a more **optimistic, proactive** approach in its research policy, rather than being deterred by its weaknesses and threats. This policy should be rooted in **a dual strategy** of addressing Europe's short to medium-term needs, whilst maintaining a more long-term global outlook for emerging opportunities in KT;

3. In benchmarking itself with the United States (US) and Japan, Europe needs to adopt a strong **'differentiation'** approach rather than an **'imitation'** approach, where the emphasis is in building on Europe's particular strengths and competencies in current, potential and emerging sectors;

4. Europe needs to complement its current short-term Lisbon agenda with a more **long-term agenda for creative system disruption**. The linkage and coherence between the Lisbon and beyond Lisbon strategies needs to be tackled through a transition agenda driven by ongoing foresight activity;

5. The beyond Lisbon strategy aims to complement the current drive to improve European **competitiveness** with strategies for global **cooperation**, where these are appropriate and efficient. Cooperation may prove more effective in terms of basic research, whilst competition is more viable and efficient on the innovation front;

6. The action plan for the beyond Lisbon strategy should focus EU research on the factors that differentiate the EU from the rest of the world. The plan needs to build on Europe's ability to generate new knowledge and simultaneously tackle the interfaces that hinder competitiveness: society's deficient 'absorptive capacity' for innovation and the deficient knowledge transfer mechanisms of knowledge to the economic tissue. The Research and Development (R&D) system as a vital part of the interfaces must be re-configured in order to take a continuing proactive attitude to ***'Bring society to science'*** and ***'Take science to the economy'***.

Beyond Lisbon: balancing opposing trends and approaches

- Differentiation vs. catching-up strategies building on existing EU research strengths.
- A long-term vision to engineer a *creative system transition/disruption*[2] rather than merely addressing *system failure* and overcoming existing weaknesses.
- Articulating short-term and long-term strategies: support for long-term basic research *opportunities* vs. short-term applied research *priorities*.
- Balancing cooperation approaches for a long-term research vision with the competitive pressures of the Lisbon agenda.

Overview of key findings

The systemic analysis on the fifteen KT and insights from the Strengths, Weaknesses, Opportunities and Threats (SWOT) analyses highlight the fact that **'knowledge creation'** is a key strength of the union. Knowledge creation is also commonly acknowledged as the starting point for a competitive economy, and that if an economy wants to be competitive it must ensure a steady flow of knowledge creation.

The other key messages emerging from the SWOT analysis (see Chapter 2) were:

- The EU R&D systems need to address the **new paradigms** of a society undergoing fundamental change as well as defining its societal role. A strategy for transforming the EU R&D system needs to be based on a systemic approach integrating long-term and short-term strategies and the member states R&D systems to obtain synergies and rationalise efforts. The EU needs to implement adequate mechanisms to bridge the gap between the R&D system, the public sector and the business system;
- The EU needs to introduce **system innovations**, i.e. combinations of radical technological and organisational/social innovations in many areas of economic activity, that allow reconciling economic, social and environmental objectives, values and beliefs;
- Horizontal technologies are critical for tackling the **new societal paradigms** combining the systemic approaches of the complexity and cognitive sciences with the adequate technical expertise.

In meeting the challenge of KT, Europe needs to invest in a two-pronged approach combining a long–term research strategy with a short to medium-term transition agenda, which need to be developed and implemented in parallel. In developing the transition agenda (see Chapter 3); Europe needs to invest its efforts in building on existing strengths, whilst also attacking its major weaknesses. An indicated way forward has been identified focused on:

(2) The magnitude of the change required entails more than incremental improvements to address system failure; it calls for a more proactive approach: a break with current mindsets, practices, policies and structures. This is what is being termed a creative system disruption (Schumpeter). The term disruption is used to emphasize that the transformation is not incremental or easy but rather involves a step-change and the abandonment of some existing ideas and routine.

- **Optimising European society's rich assets** by exploring the potential of multiple roles and opportunities and through investments in the social sciences, cognitive sciences and complexities cluster as drivers of social change and system transformation;

- **Transforming Europe's research system** by addressing system failure and providing an attractive environment for young researchers, especially those working at the interface of KT;

- **Instituting creative systemic disruption approaches** to EU policy based on the use of foresight as a vision-setting and policy coordination device as well as a catalyst for systemic disruption.

Creative systemic disruption

Europe's research strategy beyond Lisbon must be translated into an **EU R&D action plan** with six pillars:

1. Global vision

- To project a global vision for European research beyond Lisbon which is less US and Japan-centred while recognising and responding to other significant players emerging in KT[3] (for example, China and India).
- To re-engineer Europe's role in supporting the long-term research strategies of neighbouring countries and regions, in the light of the emerging global scenario outlined above, taking account of the economic, security, environmental, and social opportunities and threats that are opened up through KT.
- To approach the EU-US research gap with a longer-term perspective focused on domain-specific and sector-specific targeted measures, drawing on a detailed ongoing quantitative and qualitative analyses of the situation with the individual KT and of emerging trends and prospects.

2. Engineering creative system disruption

- To keep a closer focus/watchout on new emerging sectors where as yet no research gap exists and where Europe could take the lead: Europe needs to make a discrete jump towards new sectors where it can start working before its competitors.
- To engineer a shift to a bio-economy, away from processes using non-renewable resources towards those using biological renewable resources, combining greater economic efficiency with a reduced environmental impact.
- To capitalise on the emergence of effective information economies and other virtual structures supporting communities and individual social and professional lives.
- To facilitate the transition to alternative, sustainable lifestyles through investment in new technologies and the accompanying change in policies, structures and mindsets.
- To project and target investments in KT as drivers of structural change.
- To cope with the new context of R&D, by rapidly changing European research strategies, resource allocation patterns, research management systems and evaluation procedures.
- To support member governments in addressing the long-term challenges of investing in KT.

(3) International competition is increasing with new countries making impressive strides. Canada, Israel and Australia, although small, are already strong competitors. China, India and Brazil are emerging biotechnology powers. Unless it improves enough, Europe risks being caught between the present US leadership and other possibly successful imitators

3. Projecting a new long-term research agenda and culture

- To complement the current short-term focus of the European research agenda with a strategy for research supported by a long-term vision (30-50 years), addressing the long-term challenges faced in the development of KT and emerging sectors.
- To reverse the current culture/mood of over-emphasizing the potential for immediately apparent applications by launching a drive for a substantial effort in basic research as the means for sustaining the development of durable applications.
- To develop a world class infrastructure at EU-level by clustering European multidisciplinary research teams (physicists, chemists, biologists and engineers) to enable innovative solutions to intransigent problems. The involvement of social scientists is critical to ensure that new scientific advances take full account of social needs and constraints, also embodying social innovation.
- To close the technology divide, the science and technology divide, the scientists and citizen divide, and produce new knowledge that can be part of a singular discipline but also something new, which is at the intersection or the border of individual disciplines.[4]
- To ensure that a proportion of EU research funding is ring-fenced for the long-term research agenda opening up at the interface of disciplines, in particular cognitive sciences, biomimetics, complexity and social sciences.
- To capitalise on the expertise, interests and enthusiasm of Europe's many (SS&H and other) researchers, by introducing more responsive mode research funding, particularly for KT, alongside initiative or programme mode funding.
- To address the issue of risk, both in terms of (i) the constraint of risk failure when investing in technologies whose potential is only realised over a long period of time, and (ii) the risks and benefits of a pervasive new technology where it is not possible to predict with precision the development path and impacts of a new technology.

4. Foresight approaches

- To address the current vacuum at European level in high level structures and processes for defining long-term vision(s) for European research which go beyond the sum-total of the individual member state visions and strategies, and build on and utilise synergies and scale economies of an integrated system.
- To develop and create a better understanding of the evolutionary paths of these KT and define effective, coherent, long-term research priorities in the next phase of the evolution cycle.
- To provide a critical bridging role (i) from one Framework Programme for research, technological development and demonstration activities to the next, in terms of priority-setting and emerging research themes; and (ii) between FP and other funding instruments (Structural funds, Competitiveness and Innovation Programme - CIP, …), to ensure coherence of efforts and resources.
- To develop more bottom-up approaches to the identification of long-term European research priorities using foresight-based technology platforms.
- To foresight actions that allow Europe to fill the gap at least in specific areas of convergence, with other competing systems like the US, China or Japan by exploiting the peculiarities/specificities of European research and industries.

(4) Priami

5. Exploiting knowledge creation 'Take science to the economy'

- To change the old "linear" or sequential scheme based on the premise that basic research evolves to applied research, which in turn results automatically to technology transfer.
- To rethink the way in which new knowledge produces innovation and identify actions needed to activate the process of exploitation and to ensure protection of Intellectual Property (IP) to defend our industries from potential exploitation of EU knowledge by non-EU industries.
- To promote measures to bring together the R&D system and the business community.
- To target the flexibility and innovative capacity of European small and medium enterprises (SMEs) as a means for overcoming the weak knowledge transfer process.

6. Investing in societal learning 'Bring society to science'

- To address the growing intersection between science and technology and people's beliefs and values, with a particular focus on the new issues around socially sustainable innovation, governance, conceptions of risk and participatory processes.
- To identify appropriate means for engaging the public in what researchers are doing, and why.
- To address the cultural constraints deterring investments in and social acceptance of KT.
- To invest in life long learning programs, to overcome the 'age divide', 'knowledge divide' and 'digital divide' so that all citizens can participate in society.

Although this action plan reflects a long-term vision for research; this report also makes a case for instituting a short-term agenda to help on the path of transition, described in Chapter 3: Optimising European society's assets, transforming Europe's research system and creative systemic disruption - approaches to EU policy.

Introduction

The high level group on Key Technologies was set up in December 2004. Its mission was to assess the potential and emerging scientific and technological research topics in fifteen specific areas, their impact on EU competitiveness and societal fabric, and the potential response of the EU and its members states. The group was responsible for exploring the opportunities for a uniquely European approach in exploiting potential synergies across these technologies, and develop guidelines for new research agendas. The findings of the group are to assist with the identification of possible priorities for the European research policy, but their main objective is to prepare elements for the 2006 report[5] on perspectives of European research.

The seventeen members of the group, chaired by **Teresa de Lemos** and rapporteur **Jennifer Cassingena Harper**, represent a range of disciplines and sectors as well as a variety of EU member states. **Emilio Fontela** contributed to the work of the group, by analysing all reports, and using a vision building approach to propose a new paradigm for the development of the EU societal system.

The sectors and experts are as follows:

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For each sector there was an expert whose task it was to produce a report which was subsequently validated by other experts in the field. The group met twice from December to September 2005 on 17 January and 23-24 May 2005. The latter meeting focused on presentations of the individual reports and group discussions. The work of the group ended with a conference held in Brussels on 19-20 September 2005.

(5) The unit K2 "Science and technology foresight" of DG Research has been attributed since early 2004 the preparation of a report on science and technology policies to replace the former report on indicators.

The mandate and key tasks

There is currently no formal system in place for "foresight-type activity" in preparing systematically for the FP long-term vision and priority-setting (although Information Society Technology (IST) Programme has a system through ISTAG). Thus a key output of this group is to define a permanent system for setting long-term visions in various areas by 2009/2010 when FP8 would be under discussion. The group is thus serving as a proxy for a full foresight exercise. The work of the Key Technologies group takes place within the frame of a particular European/ global policy context and has also to take account of the emerging policy and research scenario in Europe and worldwide.

The group is concerned with providing an input on FP7 and its specific programmes by presenting an overview of key trends of research development in major areas of science and technology. Rather than producing new data, the focus of work is on delivering a good synthesis of existing material, some analysis and a forward look using a systems view to cover the problems and issues.

The work of the group involved a number of tasks including preparation of area reports by the experts. The reports assess where the EU stands in the particular field on a world level as well as providing a forward look. The papers produced were validated by 10-15 experts in the field. The chair and rapporteur were responsible for developing on the basis of these papers, a synthesis report, focusing on the cross-cutting issues or common clusters of issues and lessons to learn.

The individual reports reflect a wealth of know how and insights and essentially converge on a number of common European challenges and themes. Taken as a whole, they make a strong case for heavy long-term investments in KT as the means for engineering a major transition[6] in the EU techno-economic system and European society as a whole.

Chapter 1 presents the main challenges the EU R&D system is facing and proposes a 'cluster approach' for the subsequent analysis and synthesis of the KT.

Chapter 2 presents for all the fifteen KT the main findings and an overall SWOT analysis. It concludes with the main challenges the EU R&D system is facing.

Chapter 3 outlines the short to medium-term priorities and immediate actions which are needed to place Europe on the path of system transition.

Chapter 4 presents the approaches and rationale for the design of long term strategies that need to be implemented for the sustainable development of the EU-25 R&D system.

(6) The present period is defined as one of transition between two distinct technological styles -or techno-economic paradigms- and at the same time as the period of construction of a new mode of growth. Such construction would imply a process of deep, though gradual, change in ideas, behaviours, organizations and institutions, strongly related to the nature of the wave of technical change involved. It is only when the diffusion of the new paradigm has reached a certain critical mass, imposing its new modernizing logic upon the rest of the productive system, that both the painful consequences of the process of "creative destruction" and the obstacles to a full -and beneficial- deployment of the new potential become fully visible. long wave transitions are processes of "creative destruction," not only in the economy, as shown by Schumpeter, but also in the socio-institutional sphere. (Carlota Perez).

Chapter 1: Key questions and rationale

This chapter starts by addressing the main challenges that EU-25 R&D system is facing. These are: prioritisation and targeting of investments, policy coherence for cohesion, solidarity and international cooperation, system transition policies and the research agenda for Europe and finally the beyond Lisbon agenda – How to engineer a creative system disruption.

It ends with a description of the cluster approach used to analyse and synthesize the key findings and recommendations of all of the fifteen KT. The clusters are: socio and systemic approaches including cognitive sciences, complexity and SS&H, transversal technologies that includes biotechnology, communications, IT, nanotechnology and manufacturing and targeting societal challenges which includes agriculture, energy, environment, health care, security, services, and transports.

1.1. Policy context

A number of the reports highlight the disruptive global policy context which is emerging, influenced by and in turn influencing the development of KT. The emerging global context requires strong, unified and coherent policy responses on the part of the European Union and member-State governments.

Facing the challenge of disruptive global change

Today, Europe is faced with the unexpected challenge of addressing potentially dislocating and disruptive global issues. These issues have paradoxically arisen as a result of the success of earlier policies, geared to enhancing industrial growth and competitiveness. Many citizens of the EU, and other countries in the world, are living in a time of unparalleled wealth and consumer power, which is leading to a drain in global resources and serious knock–on effects in terms of the ability of the planet to cope with their demands.

New research strategies are urgently needed to find technologies that are planet friendly and can also provide acceptable lifestyles for its citizens, in an era where resources can no longer continue to be used in a careless or profligate manner. (Saxl)

The recent reviews of the EU and member states' progress in meeting the Lisbon agenda (including the Kok report)[7] highlight the fact that the achievement of the Lisbon research and innovation goals depends, indeed demands, far greater efforts than merely increased investments in research. Whilst Europe needs to address the problem of system failure affecting its research and innovation system, reflected in its poor record on knowledge transfer

(7) The mid-term review of the process concluded that results so far were mixed. After a promising start in 2000, employment growth slowed sharply, while productivity growth has been disappointing throughout, owing partly to the failure to take full advantage of the knowledge economy and Information and Communication Technologies (ICTs). Although the poor economic performance is partly due to the slowdown in the world economy, more needs to be done to raise growth potential and employment in Europe. communication from the Commission on cohesion policy in support of growth and jobs: community strategic guidelines, 2007-2013 Brussels, 05.07.2005 COM(2005) 0299

to industry and the commercialisation of Europe's research strengths, a process of major structural change is required which goes beyond merely addressing systemic failure. Ironically, the process of structural change or system transition/disruption stems from and is driven by advances in basic research in KT[8] and therefore one long-term challenge for the EU is to sustain and improve its key strength which is knowledge creation.

Europe is currently at an important crossroads where strategic decisions need to be taken on future directions for creative system disruption and transition to a *beyond Lisbon research strategy*. The current discussions on the Commission proposals for FP7 indicate the following emerging trends: the broadening of the EU research agenda to meet the global drivers, the deepening of coordination between EU and member state research policies and programmes, coupled with an extension of the range of instruments and dedicated resources.

The linkage between FP7 and the structural funds and the launch of the Competitiveness Innovation Programme in support of the renewed Lisbon strategy drive, highlight the need for achieving consensus on a clear direction and long-term vision for EU research policy. The transition calls for political direction and balanced approaches.

1.2. Key questions

This section focuses on four key sets of questions which have emerged from the analysis presented in the reports. These comprise questions of approach in terms of targeting and prioritisation within the research agenda which need to be addressed on the basis of expert opinion (the scientific and business community) but ultimately require a political decision. The coherence and cohesion issues and the political agenda rest with the politicians and decision-makers.

1. Prioritisation and targeting of investments for Europe's competitiveness

In seeking to improve its competitiveness through research and innovation, Europe faces difficult choices in prioritising and targeting its short, medium and long-term research investments.

• Do we continue to invest in and reinforce existing European areas of strength?

• Do we address areas of weakness with emerging high economic/market potential?

• Do we address areas that are critical for meeting emerging social needs?

• How do we target niches and sub-niche areas within specific priorities?

Key finding: the reports highlight the fact that while in the majority of the KT, Europe is falling behind the US and Japan, in the long-term Europe faces the risk of strong competition in research from China, India and other low cost countries. To meet this challenge, Europe needs to adopt more proactive, smart approaches in targeting its long-term research

(8) pervasive technologies do not develop in a vacuum, but co-evolve with institutions (Nelson, 1994). Thus, even if the early innovations giving rise to a new pervasive technology were to be created without any institutional innovations, the further development of the technology would require the creation of appropriate institutions. An important characteristic of biotechnology is that it is both the result of a process of structural change in science and that it contributes to structural change in industry (Saviotti)

investments in KT. The emphasis should be on identifying emerging opportunities rooted in existing strengths, where Europe is in a strong position and has strong interests to take and maintain the lead.

Mind the gap

- In **biotechnology**, Europe risks being caught between the present United States of America (USA) leadership and other possibly successful imitators.

- Europe, which holds a large part of the responsibility and merit for launching **cognitive sciences** and fuelling it with some of its key insights, has of late been lagging behind the US and Japan, and must make a very resolute effort to catch up and remain in the lead, in the face of the increased level of competition brought about by China.

- It is true that today the EU is lagging behind USA and Japan research systems. Therefore we cannot think of filling the gap by investing less money (both the public bodies and the private companies) than our competitors in the same applicative and research domain. We need a discrete jump towards something new in which we can start working before (or at least together with) our competitors **(complexity).**

2. Policy coherence for cohesion, solidarity and international cooperation

In the emerging globalising learning economy, investments in KT are not solely driven by motivations of economic competitiveness. Rather the key to optimising research investments and value-added lies in a healthy concern with social cohesion and global solidarity. Europe needs to address the growing challenge of coherence of research policy with other community policies, in particular cohesion policy[9] and international cooperation. The re-launch of the Lisbon strategy for growth and jobs highlights the need for cohesion policy to focus to a greater extent on knowledge, research and innovation, and human capital.

- Do we strengthen research capacities throughout Europe in those targeted sectors or is investment to be directed to the existing centres of excellence?

- Does Europe need to invest in new centres of excellence?

- Where should these centres be located?

- How do we balance the competitive drive behind the Lisbon agenda with more cooperative approaches required on the research front?

- How do we address broader solidarity concerns with the rest of the world through a new European global vision for research?

(9) The recently published third interim report on cohesion confirmed that the enlargement of the union to 25 member states, has dramatically increased disparity levels across the EU. This together with further enlargements to 27 or more (Bulgaria and Romania also set to join the union in 2007), presents an unprecedented challenge for the competitiveness and internal cohesion of the union. By mobilising the potential for growth that exists in all regions, cohesion policy improves the geographical balance of economic development and raises the potential rate of growth in the union as a whole. Cohesion policy can help all regions to build up research and innovation capacity, thus contributing to the effective participation of those regions in the European Research Area and research and innovation activities of the union in general.

Key finding: a number of the reports highlight the need to focus on the human and social face of KT and their strong potential for improving cohesion and solidarity through international cooperation.

Europe's value added: cohesion, cooperation, solidarity

Will a policy of raising the average R&D intensity of countries in biotechnology while preserving the present inter-country distribution be more effective than one achieving the same average R&D intensity while reducing the difference between the best and worst performers? (Saviotti)

Does the policy address the "digital divide" among European countries that sustain essential differences in the available communication network and services to citizens, enterprises and public organizations? (Kavassalis)

The desired future would bring about broad and equal access to high-quality healthcare, within financially sustainable healthcare systems around Europe. (Braun)

Prospects for a more equal access to energy resources and for a more equal distribution of energy services: what are the prospects for economic growth in developing countries and how will this affect energy trade, consumption patterns, energy prices and environmental impact? (Joergensen)

The next generation of advanced manufacturing and processing technologies will be expensive to produce, and no one entity has all the resources and expertise needed. Cooperative R&D with sharing of costs, risks, and expertise is necessary. Properly managed international cooperation in advanced manufacturing R&D, through the EU, can help improve manufacturing operations, enhance international competitiveness, and lead to technology breakthroughs via market-driven R&D. (Sá da Costa)

Across the world, there are many research groups and facilities. It is likely there is considerable duplication of research, and lack of communication across national boundaries may be resulting in a slower-than-need-be progress. It is vital that the EU takes a lead through its FP7 and FP8 programmes by focusing on goal-oriented research in relation to these global issues, and actively seeking international partnerships, where possible, to short-circuit the realisation of these goals. (Saxl).

3. System transition policies and research agenda for Europe

In synergy with the Lisbon agenda, Europe needs to drive and coordinate dynamic policies in the short to medium-term which are aimed at putting in place the first steps towards a system transition. These policies need to be supported by a targeted research agenda aimed at optimising the results and opportunities offered by KT.

- Does Europe have an effective enough mechanism, for coordinating individual national action plans and reform programmes on a European level?

- Does Europe have an effective approach for harnessing research efforts across Europe to ensure common goals and targets?

- Does Europe have appropriate instruments for integrating national research agendas into a joint European Lisbon research agenda?

- Does Europe have appropriate instruments to set up and manage a system transition agenda?

Key finding: the main case for a transition agenda in terms of research policy and agenda emerges from the agriculture and environment reports but is also echoed in other reports.

The case for system transition

How to address the real challenges posed by the Lisbon strategy in terms of policy reform and transition and the related implications for research policy and the research agenda? – i.e. the CAP reform and the transition to rural development and the new paradigm for EU research in agri-food, the environment and rural economies?

It also needs to take into account contributions from social sciences, transport, health-care, IT… (Downey)

First, a long-term research agenda is needed to enable system innovations and underpin corresponding long-term transition strategies. Second, a shorter-term agenda is necessary to ensure that the continuous improvement of current and existing technologies, geared towards aims of competitiveness on the one hand, but also guided by the long-term transition agendas on the other. (Weber)

4. The beyond Lisbon agenda: engineering creative system disruption

In parallel with the system transition agenda, Europe needs to develop from now more long-term approaches to its research strategies extending from 30 to 50 year timeframes and encompassing both inward and outward thrusts. Such long-term vision would allow Europe to invest more strongly in KT as drivers of creative system disruption.

- Can Europe afford to continue with its focus on the relatively short-term research agenda up to 2010/13 or should it develop a longer time frame up to 2030 and beyond?

- Should substantial long-term investments in KT, in particular disruptive technologies, form part of a broader agenda to bring about a major transition in the European techno-economic and social system?

- Is Europe willing to acknowledge that heavy investments in KT demand stronger policy efforts than merely addressing system failure?

- Is Europe ready for the new production paradigms which might involve significant disruption?

- Should Europe imitate the strategies followed by its major competitors? Or should it develop a differentiated approach capitalising on its strengths?

Key finding: a number of the reports highlight the need for Europe to embark on a more ambitious process of creative system disruption as the basis for a "differentiation" rather than "imitation" approach in the bid to close the gap with the US and Japan. The switch to new production paradigms and the bio-economy are among the indicated ways forward for long-term strategy.

The case for creative system disruption

European manufacturing industry has been, and continues to be, successful in maintaining its leadership. However, this position is menaced on two fronts. On the one hand, EU industry faces continuing competition from the other developed economies, particularly in the high-technology sector. On the other, low-wage economies are increasingly threatening the more traditional manufacturing sectors. While the pursuit of new production paradigms might involve significant disruption, failure to break the current pattern gives rise to equally serious threats for European industry. (Sá da Costa)

What is needed is a **decoupling** of economic growth from resource consumption, an imperative that would require a significant change in the socio-ecological metabolism. However, as argued by Huber (2004), the objective should be **metabolic consistency** (i.e. an integration of industrial transformations in ecological transformation processes) rather than a simplistic call for a reduction in resource-intensity by a factor of four to ten. …. the main challenge consists of devising ways to translate it into meaningful signals for current markets, into appropriate regulations and into widespread practices of resource consumption, but also into longer-term research strategies. In particular, it would require changes along the entire production-consumption systems, from resource extraction to final consumption of goods and services, and the possibilities to establish closed material loops. (Weber)

To sum up:

In considering the key questions and findings emerging from the analysis of the reports, the key messages for targeting Europe's approach to KT in the short, medium and long term:

1. To adopt more proactive, smart approaches in targeting Europe's long-term research investments in KT with an emphasis on identifying emerging opportunities rooted in existing strengths;

2. To optimise research investments and value-added by focusing on the human and social face of KT and their strong potential for improving cohesion and solidarity through international cooperation;

3. To drive and coordinate dynamic European policies in the short to medium-term and engineer a system transition, supported by a targeted research agenda aimed at optimising the results and opportunities offered by KT in addressing future world issues;

4. To embark on a more ambitious process of creative system disruption, as the basis for a "differentiation" rather than "imitation" approach, for closing the research gap.

1.3. The cluster approach

The organisation of the synthesis report is structured along two main lines: the key questions emerging from the analysis and recommendations of the KT experts, and a (conceptual) model developed to provide a rational framework for all the fifteen KT under analysis. The sectors vary mainly in terms of technological intensity, orientation to theoretical development and societal problem solving. Based on this analysis, the KTs were grouped in clusters of sectors with similar characteristics. Three clusters emerged (see fig. 1.1):

1. **Socio and systemic approaches:** cognitive sciences, complexity and SS&H;

2. **Transversal technologies:** biotechnology, communications, IT, nanotechnology and manufacturing;

3. **Targeting societal challenges:** agriculture, energy, environment, health care, security, services and transports.

The first cluster groups the sciences - SS&H, complexity, and cognitive sciences – that can propose a theoretical framework for the systemic and holistic models required to study the inter-action within its members, the horizontal technologies, the societal challenges as stand alones and also, very importantly all the simultaneous interactions intra and inter clusters, including for example how to utilise the available technologies (second cluster) to solve the societal challenges that the EU-25 face (third cluster).

Key Technologies - cluster approach

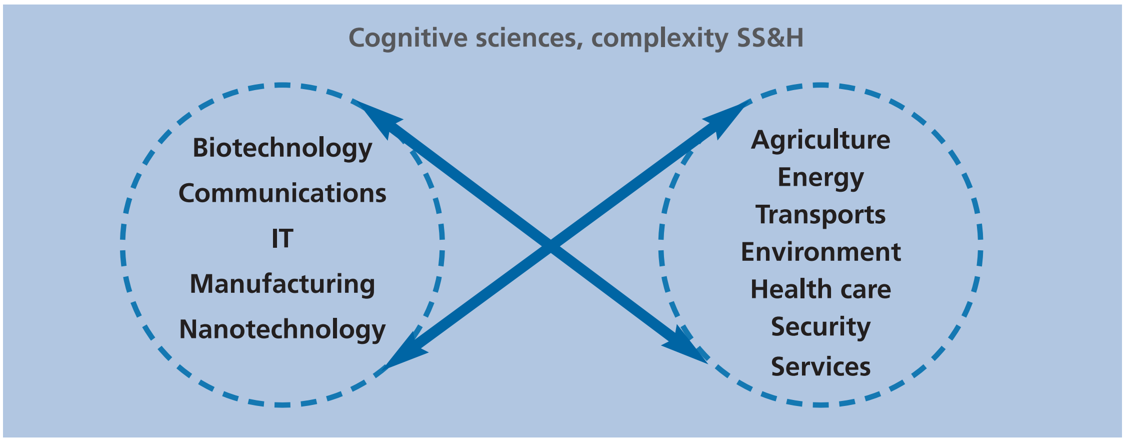

Fig 1.1. **Socio and systemic approaches:** cognitive sciences, complexity and SS&H; **transversal technologies:** biotechnology, communications, IT, nanotechnology and manufacturing; **targeting societal challenges:** agriculture, energy, environment, health care, security, services and transports.

The second cluster groups the technology intensive sectors - Biotechnology, communications, IT, nanotechnology and manufacturing – which per se, in conjunction with other, or converging with others provide the technological base for the sectors that target the Societal challenges (the third cluster).

The third cluster includes the areas that deal with the main socio-economic concerns of EU citizens - agriculture, energy, environment, health care, security, services and transports. These areas need to feed on their specific knowledge, use the potential provided by technology, the systemic and holistic approaches and the social models to address the challenges that each one faces and are detailed in each report.[10]

This model provides a framework for the analysis of the reports and its key findings. It permits also to that the conclusions are put forward with an underlying rationale that takes into account the relations among all the fifteen KT.

Chapter 1 described the key questions the EU R&D system faces and the cluster approach used for the subsequent analysis. Chapter 2 presents the main findings and the synthetic SWOT analysis (the overall SWOT analysis is presented in Annex I).

(10) A summarized approach can be found in the SWOT analysis – Annex I.

Chapter 2: Analysis EU – 25
a 'Knowledge and competitive society'

This chapter presents the main findings and conclusions for all fifteen KTs and for each cluster. It includes a description of the overall SWOT for the EU R&D system.

The key conclusion is that the main challenge facing Europe is the need to draw on inherent strengths, i.e. cultural diversity and societal values, as part of the current drive to become a competitive'knowledge society'.

2.1. Main findings and key issues

This section presents an overview of the main findings and key issues included in each report[11]. The sectors are grouped in three clusters: **socio and systemic approaches, horizontal technologies and targeting societal challenges.**

2.1.1. Socio and systemic approaches: SS&H, complexity, cognitive sciences[12]

The SS&H are a meta-category covering a broad canvas including philosophy and history, social sciences including economics, sociology, political science, anthropology and social psychology, related disciplines such as statistics, demography, socio-legal studies and social policy and a range of trans-disciplinary subject areas such as communication and Information Technologies, health, environment, development, and science and technology studies.

Cognitive sciences is the interdisciplinary study of mind and brain, combining the concepts, methods and insights of large parts of psychology, neuroscience, evolutionary biology, linguistics, philosophy, anthropology and other social sciences, and formal methods from computer science, mathematics and physics. …It is instrumental in:

- Solving specific problems of a diverse, multicultural, complex, and ageing population;
- Developing applications of cognitive sciences (in ICTs, health, education) and reaping the benefits;
- Taking as full a part as possible in the 'cognitive (mind-brain) revolution' and securing Europe position in the scientific elite of tomorrow.

These three areas are closely connected, as Andler indicates: 'Cognitive sciences are a basic framework to handle complexity. Information and communication technology are enabling technologies to render the science of complexity practical, and social sciences are a challenging applicative domain' (adapted from Andler). As noted by Priami, 'the long-run goal of the science of complexity and the convergence of sciences and technologies could be programming the cell'. Of course we first need to completely understand how living matter functions. The result of this achievement would have major impacts on the IT field (new computational

(11) This section relies entirely on the reports and summaries for each KT. Quotations were sometimes adapted to render the synthesis more homogeneous.
(12) Daniel Andler, Cognitive Sciences Report, Georges Gaskell, SS&H Report and Corrado Priami, Complexities Report

paradigms, new primitives for programming, new software development tools, new living hardware) and on the biotechnology, health and pharmaceutical fields (new drugs development, new genetic therapies, new cell repairing tools, predictive, preventive and personalized medicine)'.

The same complexity approach must be (Gaskell) adapted to 'the social dimension and dynamics of societies in a changing world, which requires the study through the perspective of SS&H as a prerequisite for understanding social change and informing policy making in many domains. The European Union can be seen as the evolution of a unique form of society, combining political and cultural integration with a respect for, and an active upholding of national cultures and identities, which may be seen as a new model for social cohesion (Sinne et al).

This cluster can therefore provide the new models and paradigms to a vast number of issues, either technologically driven or societal driven. The convergence of sciences and society call on combined efforts: cognitive sciences to understand how complex systems, such as living organisms function, to tackle the complexity and SS&H to provide the social dimension.

In a significant number of these research areas, or sub-areas, the EU is in a leading position. It is at the forefront of the major developments, nevertheless it is in danger of losing its advantage, as there is a major interest from outside to attract the best brains away from Europe.

2.1.2. Horizontal technologies: biotechnology, communications, IT, manufacturing, nanotechnology

Biotechnology[13]

This technology has a very wide potential impact on society, a potential which is currently realised only in very small part. For instance, it is foreseen that in what is called the 'bio-economy, processes based on fossil fuels and non renewable raw materials will be replaced by biological inputs, energy sources and processes. Up to now, the adoption of biotechnology has been very unevenly distributed, being highly concentrated in the pharmaceutical sector, followed by the agrochemical sector'.

Industrial biotechnology is a technology therefore of immense scope, in which Europe has both considerable strengths and very strong inducements to participate.

Communications[14]

During the last years, digital networks have become a critical component for new business and social functionalities that would be totally impossible to be obtained otherwise. Communication technologies have migrated from the laboratories and the head offices of the telecom operators to a ubiquitous presence in production and exchange processes, delivery channels and, virtually, in any organizational structure that shape modern economic and social life.

In brief, communications infrastructures will become ever more complex and need to be more efficient by incorporating these new branches in a totally seamless way. Innovating through new networking ideas that realize the potential of the "converging technologies" allow also for the emergence of effective information economies and other virtual structures supporting communities and individual social and professional lives.

(13) Paolo Saviotti, Biotechnology report.
(14) Petros Kavasalis, Communications report.

Research in communications technologies has moved out from the specialized laboratories of the old telecom operators and shifted orientations and methods. Meanwhile, long term research has been considerably "downsized" in favour of a more "commercial" R&D strategy aimed at producing nearer-term technologies, product-related innovation and customised network solutions.

IT [15]

Information technology is pervasive in the present and even more so in the future in numerous sectors/areas, as technologies will tend to converge to solve specific socio-economic challenges. It will be pervasive in the inter- and intra-relations in all sectors and clusters of the KT. It has an enormous economic and societal relevance not least for innovation and knowledge transfer. It is estimated that the productivity growth rate of Europe's economy is based on Information and Communication Technologies (ICT) to a degree of 50%.

IT has the potential to support and enhance the transformational process and a widespread embedding of IT in everyday life is envisaged, e.g. ICT-based public transportation systems. The trend to miniaturisation will continue and reality will be associated with virtual reality. The most relevant projects to be developed will be in the following areas:

Knowledge technologies: the development of technologies will permit the construction of knowledge data Bases (Ontology) and the convergence of several sciences and technologies. For example, the data Bases: "Open mind common sense" or "Digital Aristotle".

Artificial Intelligence: technology is being developed in the areas of "capable perception" (including their nano and bio tendencies), reasoning, speech recognition and vision systems, as well as the creation of interfaces for the general public. It can be envisaged the applications to home robots, for agriculture and third age, new materials and bio-structures. The inter-disciplinary research with cognition (or intellect), neuroscience, psychology physiology, philosophy etc will have a major impact in Artificial Intelligence (AI) and the knowledge society. For example, the knowledge of the cognitive processes of knowledge acquisition will be determinant in software conception, particularly educational software.

Virtual reality: technologies as interactive three Dimensions (3D)-TV or free-View point video will integrate all reality in systems of virtual prototypes as AVATARS – a software that humanises robots – with applications as tourist guides, traffic controllers, 3D simulators for oil prospecting. These possibilities are extensive to reconstruction of buildings horizons, molecular structures, weather forecasts, etc.

Human-Computer interaction: the optimisation of interfaces will allow multi-sensorial, multi-modals, multi-linguistic, tele-presence and interfaces brain-brain. It is assumed that the presence of hardware will be diminished and embedded in all sorts of objects, more intelligent and intuitive. "Ambient intelligence will integrate the ability to learn with the user as a way of avoiding interfering with the freedom of the human being (through the areas of cognition and AI). It will also recur to the semantic analysis – This can bring to jurisprudence and politics to the area of IT. Security and privacy are issues to be solved.

The current funding mechanisms for IT are not seen as sufficient and Bibel suggests complementarily a bottom-up award scheme to fight bureaucracy, provide "risk" money also to researchers, award individual ideas, etc.

(15) Wolfgang Bibel, IT report

Manufacturing[16]

European manufacturing industry continues to be successful in maintaining leadership in some sectors. Leading edge research capabilities are available across Europe. However, this position is menaced on two fronts: first, EU industry faces continuing competition from other developed economies, particularly in the high-technology sector; second, low-wage economies are increasingly threatening the more traditional manufacturing sectors.

Although the pursuit of new production paradigms might involve significant disruption, failure to break the current pattern will conduce to equally serious threats for European industry: in the future, manufacturing companies will be even more dependent on flexibility and speed, as well as on localised production. The basis of competitive advantage will be creativity and innovation in all sectors of the manufacturing enterprise. Manufacturing will become increasingly service intensive as new technologies and new business practices will be inseparable.

Many of the areas for manufacturing research are crosscutting areas being applicable to several enabling technologies. Adaptable and reconfigurable manufacturing systems, Information and Communication Technologies, and modelling and simulation are especially important. Two important breakthrough technologies – submicron manufacturing and enterprise simulation and modelling – will accelerate progress in manufacturing.

Nanotechnology[17]

Nanotechnology is about being able to observe, understand and manipulate the entirely different properties that materials exhibit at the nanometre scale (i.e. the scale of atoms and molecules) compared with those they exhibit in the 'bulk' material, and apply this knowledge to the creation of revolutionary new materials, products and processes. A recent EU paper 'Towards a European Strategy for nanotechnology' recognises the important implications nanotechnology has for most, if not all sectors, and particularly highlights medicine, information, energy, materials, manufacturing, instrumentation, food, water, the environment and security as key areas for European research.

The report's analysis of Europe's science and technology base and activities demonstrates that in some areas substantial efforts are needed to succeed in the competition with the US, Japan, etc. in most factors including the number of patents, the spending levels in R&D and in education, the number of researchers, the percentage of corporate research, the net business profits, and many others in today's hydrocarbon-based economy. Unique opportunities exist however for Europe's nanoscience base in meeting the demands on new markets for the sustainable, people and planet-friendly technologies of the future.

All these KT - biotechnology, communications, IT, manufacturing, nanotechnology - are pervasive in a vast number of sectors and other technologies. The main conclusions is that with the convergence of sciences new fields of science will emerge, that the systemic approach will be further developed and finally that these KT will integrate much of the knowledge of the first cluster – cognitive sciences, complexity and SS&H. The applications will target the societal challenges, which themselves are inter-connected.

Last, a word of caution has been forward in several reports, as to the importance of maintaining support for the basic sciences like mathematics, physics and chemistry – in some the EU is at forefront.

(16) José Sá da Costa, Manufacturing report
(17) Ottlia Saxl, Nanotechnology report

2.1.3. Targeting societal challenges: agriculture, energy, environment, health care, security, services, transports

Agriculture[18]

In response to the ongoing reform of the common agricultural policy, EU enlargement and more liberal world trade in agricultural products, allied to increasing society/consumer demands, as well as other policy developments and international drivers of change, Europe's agri-food industries and rural regions will be radically transformed in the coming decade.

Following the fundamental reform of the common agricultural policy (Luxembourg, 2003), the overall policy framework, has shifted towards rural development, involving the

- Development of an internationally competitive multifunctional European agriculture, producing market-required food products and environmental goods and services

- Diversification of the economies of rural regions throughout the enlarged EU

- Protection of Europe's rich heritage of rural landscapes and cultural diversity

As sectors inherently based on the exploitation of natural resources, Europe's agri-food industries are confronted with virtually unique challenges by the two overarching EU goals, c*ompetitiveness and Sustainability*.

Countries that achieve the optimum balance between the economic dictates of profitability in agriculture, and at the same time address environmental and consumer concerns will have internationally competitive agri-food industries in the coming decades. *Knowledge is the key to attaining this crucial balance*.

EU agriculture and rural regions must be repositioned in the knowledge economy, by developing knowledge-based multifunctional agricultural sectors and rural economies.

This will require a new conceptual framework or paradigm for EU research in agri-food, the environment and rural economies that should involve a two-dimensional research strategy, comprising both a *transition* and a *high-Tech research agenda*. The two agendas should be designed so as to support both the competitiveness and sustainability of the EU agri-food industries and rural economies.

The transition research agenda is envisaged as being more concerned with sustainability, in the context of the shift from the volume/output bias of the former common agricultural policy to the more consumer/society multifunctional reformed common agricultural policy.

The high-Tech research agenda should be more concerned with competitiveness in the context of freer world trade in agricultural products, following the ongoing WTO negotiations.

To illustrate the general scope and thrust of the two dimensions of the proposed research strategy, indicative research for the transition research agenda, should involve consumer demands, food for health, new models of farming systems, regulatory framework, rural environment, rural innovation and policy developments; and for the high-Tech research agenda, plant science, animal science, environment, diagnostics, and pharmaceuticals.

(18) Liam Downey, Agriculture report

Environment[19]

Environmental technologies cover a broad spectrum of technological development. In the past, environmental technologies were mainly associated with individual sectors (see also the sectoral reports on energy, transport, agro-regional systems), but increasingly emerging generic technologies are being recognised as crucial (biotechnology, nanotechnology, materials, ICT, see respective reports). In addition, cross-cutting developments like new environmentally oriented product-services (see also services report) and environmental and resource management are likely to grow further in importance. A fundamental change must also be seen in the shift in perspective from environmental impact analysis to the analysis of ecology-society interactions, where system boundaries for assessing environmental impacts are drawn more widely and lead to different conclusions.

Environmental technologies are not only of outstanding importance in Europe, but represent a major and fast growing world market that offers significant export opportunities. Due to regional differences in regulations and practices, however, there are also strong local specialisation effects to be observed in some areas of environmental technologies, implying a need to provide locally or regionally adapted solutions.

Remaining a lead player in environmental technology, both for the sake of reducing environmental impacts in Europe and for the benefit of our export-oriented industries, will require maintaining a leading position in research and technology as well as in terms of optimising system solutions in the context of the European regulatory and market context.

Health care[20]

The beginning of the twenty-first century provided an early preview of the health challenges the EU will confront in the coming decades. The systems and entities that protect and promote the public's health, already challenged by problems like obesity, toxic environments and health disparities, must also face emerging threats, such as antimicrobial resistance and bio terrorism, while the scientific and technological advances, such as genomics and informatics evolve faster than the assessment of potential implications (social, cultural, global, ethical).

Healthcare technologies will globally gain in importance, even though their application will remain quite different from country to country, since the organisation and funding of health care remain matters of national competence. The technical progress within the health care sector will make possible many new or improved, but costly, medical treatments.

There is a determination to maintain general and comprehensive access to health care (even in the face of increasing costs) and there is a need to develop health care services and preventive strategies relating specifically to age-related illnesses, and these should be aimed at enabling older people to live active, healthy and independent lives, remaining in their own homes, further into old age.

The advances arising from S&T in gen- and biotechnologies, information - communication- and medical technologies have been identified as a crucial component of the effective delivery of health care in the future.

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(19) Mathias Weber, Environmental technologies report
(20) Anette Braun, Health care report

Modern healthcare technologies and prevention strategies will have the potential to extend the life expectancy of people, to increase their quality of life, to open up new tools for health prevention, monitoring, diagnosis, treatment and aftercare in an ageing European society. Promising developments over the next few years are expected to include vaccines against infectious diseases; the ability to predict, delay, prevent and even cure cancer, heart disease, and certain neurological diseases; genetic engineering (e.g. the human genome project), continuing developments in biomaterials for prostheses and advances in robotics.

Energy[21]

Availability of energy is a prerequisite for economic growth and welfare. Increasing energy consumption, liberalisation of the energy markets, security of energy supply and the need to take action on climate change and environmental matters are producing new challenges for the energy sector. The strategic goal of EU energy research is to develop sustainable energy systems and services for Europe.

The outlook for the European energy situation considering current trends will imply increasing consumption, increasing use of fossil fuels and a doubling of the import of fossil fuels. The EU response to this situation is diversified combing market pull and technology push measures. Ambitious targets are set for renewables, electricity generated from renewables, biofuel, energy efficiency etc. But event these ambitious targets may not be sufficient to address the serious challenges ahead. Further, there are major implementation problems due to lack of enforcement mechanisms. Another implication is that market pull measures are not coordinated across member States.

Energy R&D funds have decreased at EU and also at member States level over the years. The prioritisation of funds reflects history and over the years, the allocation to nuclear research has declined and more are now used for non-nuclear research. There are major differences across the member States, reflecting energy policies and path dependency in energy R&D. Energy efficiency R&D has high political awareness, but in practice this field is rather diffuse.

There is a strong European base in fundamental science and technology areas of relevance to key energy technologies and in some areas, ambitious experiments and demonstrations are set up, all of which make European stakeholders attractive in international cooperation.

Security[22]

The comité Européen de normalisation, technical board/Working group 161- CEN BT/WG 161 on 'Protection and Security of the citizen' adopted the following definition in January 2005:

> ***Security** is the condition (perceived or confirmed) of an individual, a community, an organization, a societal institution, a state, and their assets (such as goods, infrastructure), to be protected against danger or threats such as criminal activity, terrorism or other deliberate or hostile acts, disasters (natural and man-made).*

The European industrial and research community has excellent skills to support and further develop their contribution to addressing the day-to-day security problems, e.g. world-class sensors of all types, top of the art Network Enabling Capabilities (NEC), etc.

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(21) Birte Joergensen, Energy report
(22) Alois Sieber, Security report

Although advances in individual technologies are very much needed, modern security missions and civil crisis management require urgently a *strong focus on integrated concepts*. It is suggested to follow and develop the concept of NEC which are much more concerned with evolving capability by bringing together decision-makers, sensors and other equipment/systems, and enabling them to pool their information by 'networking' in order to achieve an enhanced capability. In NEC, the key word is interoperability and this at the level of respectively services ***(human interoperability)***, systems ***(technical interoperability)*** and information ***(data interoperability)***. c***onverging technologies*** are a key area to be explored.

The integration of systems has a large impact on the current way of testing, evaluation and certification. ***New test, evaluation and certification tools*** will need to be explored, in particular the use of simulation in the testing, evaluation and also at the (pre-) certification level.

In order to address the risk of capability-based research and an integrated approach to overemphasise systems technologies and thereby not pay sufficient attention to enabling or underpinning technologies and basic research, it is recommended to consider the establishment of ***European basic research programme***, from which the application- and system-oriented research programmes (FP, Preparatory Action on Security Research - PASR, European Security Research Programme - ESRP and defence research) could pull the relevant enabling technologies

Services[23]

Contribution of business related services to the performance EU economy business related services provide an enormous potential of high premium jobs, which has been insufficiently exploited up to now. Empirical studies show that companies which shape their business processes towards a logic of services achieve high competitive advantages and are able to enter new markets. There will be a further increase in the importance of services for the development of the European economy as a whole. Nevertheless, a lasting competitiveness of European services on world markets depends on the ability to improve service production processes and to design continuously innovative service products.

There is little knowledge about how to develop, design and to model service driven innovation processes systematically. A better understanding of the interrelationship of service and innovation processes could lead to sustainable enforcement of international competitiveness.

An important reason for the existing lack of service research: research administrations among other organisations are still dominated by a traditional production model. Therefore, the service economy needs a tailor-made basis for innovation of its own. This basis includes and requires enhancing the valuation of services within society, to increase the willingness of companies to invest in service innovations, and, above all, to strengthen a European service research with an international orientation. So far, there is only a rather fragmented service research structure within the different EU member states.

In Europe technology development, goods production-oriented research and practice are well connected. But to service research, such a statement can be made only on a limited scale. It is necessary to raise the so far limited readiness/tradition of service companies for systematic Research and Development and for participating in collaborative development projects with science. On the other hand, science should also make more efforts to ensure the sustained implementation of its research findings in close cooperation with partners in practice.

(23) Walter Ganz, Services report

Needs for action may be outlined as follows:

- *Reinforce the research profile of services:*
  Reduce deficits in the perception of services as a relevant R&D subject.

- *Strengthen international lead positions:*
  Safeguard the international catch-up capability and set (new) core competencies.

- *Intensify R&D co-operation with the world of practice:*
  Develop knowledge about sustainability and continuity of research results in a joint effort with the world of practice.

- *Create service excellence centres:*
  Bundling resources in subject-specific networks of excellence.

Transport[24]

The leadership acquired by Europe in this domain over the last thirty years – from aeronautics to high speed trains to automobiles and services, would not have been possible, without the dynamic innovation policies: the paradox is that although representing almost a quarter of private sector European research, transport does not appear as a sector of advanced technology – most probably due to the fact that it is more a diffuser and user than a generator of new techniques.

Transport equally represents a major challenge for the integration of the enlarged European area, the improvement of the daily life and the environment – both local and global.

The Key Technologies for the future of transport cannot be envisaged as a simple continuation of past dynamics. They must also take into account the eventuality of discontinuities and shifts in the next 30 years, in particular, linked to the change in mobility spaces, to the massive integration of new Information Technologies into the market and the competition faced from Asia and above all the risks related to climate change and petrol shortage. Faced by the eventuality that in 2030 transport will on its own consume the available petrol sources, it is not sufficient to develop incremental technologies as we did over the previous decades but also to conceive voluntary transition strategies to adopt rupture technologies.

Based on the results of the technology platforms and the prospective analysis of the trends and key challenges of the 2030 horizon, this report proposes within a dual perspective of continuity and rupture, a coherent list of 25 Key Technologies for the future of transport. Due to lack of detailed information, the state of play with regard to Europe's science and technology potential can only focus on a selection of these technologies and on elements of global appreciation. This reflects a situation of contrast: on the one hand a strong innovation dynamic driven by large enterprises (ten out of twenty of the most important private research budgets are based in the transport domain); on the other hand a weak and major fragmentation of the public research or European system and a worrying time lag in Europe's take-up of emerging technologies – like combustibles.

The report concludes with six main recommendations: to elaborate long-term strategies of transition addressing key challenges (energy, global warming, enlargement, vulnerability of transport); to prepare detailed status reports on public and private research programmes in different European countries, to re-orient the European research programmes (FP7) towards emerging (rupture) technologies and the instruments for implementing European

(24) Jacques Theys, Transports report

policies; to assess the impact of emerging technologies (nanotechnologies) on transport; and finally to create a European research and innovation diffusion network comparable to the American transport research board set up in 1925.

The main challenges that the EU is facing are: firstly, the need to redefine its societal model to take into account for example the changing rural economy and ageing society, and secondly concerns over environmental sustainability. These must be coupled with the need to preserve its values and beliefs.

2.2. SWOT analysis

Based on the SWOT analysis included in all the KT reports, an overall SWOT Synthesis for the EU R&D system is presented in Annex I. It is not the sum-total of all the SWOTs but a different analysis whose objective is to analyse the overall R&D system not the individual sectors. As a consequence some issues were moved from its original classification, for example from weaknesses to threats. As such, this matrix builds primarily from the individual SWOTs but incorporates insights drawn from the reports and from the holistic view throughout all the KT. As it is a rather complex and long matrix, this section provides a summary of the most important findings.

It is clear from the SWOT analysis that the EU R&D key strength is its potential for knowledge creation – the cultural diversity and an intellectual challenging environment provide the ingredients for this – but it lacks the ability to transfer and apply this knowledge effectively and efficiently.

But this strength is in danger. The lack of strategy, the fragmentation, the duplication of resources, and the 'brain drain' are putting the EU R&D competitive advantage at risk. This has been aggravated by the tendency to only fund R&D whose results are 'market and end-user oriented', as such fundamental research has been somewhat neglected.

Basic research or fundamental research is a very long-term business with uncertain outcomes but is essential to the future developments of science. This thesis is very clearly stated in the Security report.

> 'The risk of capability-based research and an integrated approach is the over-emphasis of systems technologies and consequently, the lack of focus on enabling or underpinning technologies and basic research. This over-emphasising system technology is not only real for security-related research activities. It also constitutes a very relevant problem in defence-related research activities and even for the last evolutions in civil-related research activities'.

Overall EU R&D SWOT[25] - Summary

Global threats – climate change, depletion of resources, energy shortage and ageing population

Major strengths of EU R&D

- The diversity of cultures, and tolerance –intellectually challenging environment
- EU's R&D system has a long-term vision for excellence in scientific research
- Fundamental knowledge creation is strong
- Internationally recognised, high level research tradition at research institutes, university and academic level - a drive to scientific excellence
- Good track record in natural sciences, engineering – chemical and manufacturing are basic traditional and mature industries that emerged as key to support many other areas - and medical sciences
- High awareness of the importance of services even in the manufacturing sector
- International companies with R&D activities
- Research integrates national R&D networks (FP6, European Research Area - ERA)

Major weaknesses of EU R&D

- Lack of a vision to rationalise and articulate long-term basic research with short-term applied research
- Tendency to abandon long-term / high impact research – lack of focus on enabling or underpinning sector and basic research
- Fragmentation, discontinuity, un-coordination
- Lack of interdisciplinary communication
- The amount of R&D expenditures is decreasing
- Excessive bureaucracy – both within the R&D system and the EU funding schemes
- Some areas of research are under-funded
- The working and living conditions of R&D staff are poor in comparison to the US (and also between some EU countries)
- The research staff is an ageing population
- The management skills of R&D staff are poor
- The investment of the corporate sector in R&D and innovation is low
- The knowledge transfer to the applied sector is weak – no systematic systems in place, no cultural drive, the spin-off activity is low

Major opportunities of EU R&D

- Willingness to promote coordination, cooperation and development of synergies between the member states' initiatives
- The societal awareness of global risks such as climate change, energy depletion and the environment deterioration is leading to the recognition of the need of more research to address these threats
- Definition of the societal role of research
- Increasing demand on the faster spread of results in the field of R&D
- Increasing weight of knowledge intensive sectors
- An expanding service sector

(25) With Anette Braun's co-operation.

- The majority of EU companies are SMEs which have the needed flexibility, skills and intellectual capacity to foster innovations. This induces a more dynamic environment than in the US where large companies dominate

Major threats of EU R&D

- Unfavourable external macroeconomic conditions
- The financial sector is risk averse – It is needed access to public funding for expensive, high-risk, long-term projects but also to additional private-sector risk capital
- Increasing regional disparities - Rural regions falling behind
- An increasing gap of knowledge between sections of society - the haves and the have-nots; the technology and digital divide, the separation between science and technology (knowledge and production), and the scientists-citizens divide
- The EU society has so far shown an apparently limited "absorptive capacity" in regard of innovation, and/or of disruptive transformations, e.g. internet
- The US is leader in the theoretical developments of management theory
- Service research is dominated by the US, and can become permanent and Europe will lose its innovative leadership in many areas

This view is also supported by 'Kavassalis' regarding the recent developments in communications research.

> 'Many researchers and industry observers seem to recognise that in facing this complexity, we absolutely need to turn again into long-term / high impact research and define a more ambitious communications policy in this regard. But, as concludes a recent workshop in this regard hosted by the Columbia University[26], in order *"to justify the support of and the investment, a vision of the accomplishments and rationale for basic research needs to be articulated and promulgated"*. Such a vision, and this is the essential recommendation of this report, might accept that a long-term research, in current days, should of course contribute to define a broader horizon for the innovation but it also needs to be effective in the sense of: i) recognizing priority areas (and selecting key-research problems) with high impact in evolution of the communications technologies and networks, ii) using a mix of different perspectives, ranging from pure to basic & applied research and systems engineering – and maybe call for some interdisciplinary support and, finally, iii) addressing the relevant policy issues which are necessary to stimulate technology transfer from research to application.'

It is interesting to note that often mentioned in several reports, although somewhat subdued, the essential role that the acknowledge strengths in the traditional mature industries of chemistry and manufacturing play in sustaining the development of a wide number of innovative emerging sectors.

As to the other factors undermining the potential for R&D development, **'brain drain'** comes at the top. The EU has the best intellectual potential in the world, be it in terms knowledge creation or socio awareness concerns, but factors related to its socio-cultural heritage – rigidity and bureaucracy thrive - translated into misadjusted policies, regulatory frameworks

(26) See the report from this workshop, entitled "Basic research in telecommunications", at http://www.citi.columbia.edu/CITI_Research_advisorycomm.pdf).

and the still ongoing process of integration fails to transmit its full benefits to society. This is also translated in poor working and living conditions for the most talented people. The most talented people are the most mobile, and their prime motivation is to work in an environment where they find support for their research, better working and living conditions. Not giving the existing brains the dynamic and motivational environment that they need to work leads to the exodus - 'brain drain' - to the US. The EU is loosing its attractiveness both internally and externally (the outside best brains tend also to go Europe hence the 'brain drain' between the EU and the US and between some EU member states). This process is aggravated by the EU's steeply declining birth rate simply there not enough people (especially young people) to sustain the knowledge creation process.

Indeed, the process of knowledge creation needs a meaning critical mass of brains, i.e., only when a sufficient number of different people are in contact, that by means of the interaction between them, is possible to a have true sustainable process of knowledge creation - this can not be imposed it is a consequence as to the human mind works (Andler).

In summary, EU R&D key strength – potential for knowledge creation – is in danger. This needs to be tackled as the most critical issue the R&D system is facing, as intellectual capacity is the key factor in the knowledge economy. To overcome the ongoing downward spiral the EU has the chance now with the allocation of resources in FP7 to promote measures to prevent the exodus and increase the attractiveness of the R&D system to the best brains.

Another key weakness of the EU R&D system is **fragmentation of resources** – human, financial, etc., but it has to be emphasized that the weaknesses are viewed on a European scale not at member state level. As the process of integration within Europe is much more recent than the creation of the US and Japan, it is not surprising that most of the problems are related to lack of a common EU vision and strategy; hence the problems of fragmentation, duplication and lack of co-ordination still remain. This leads to an overall underperformance of the available resources, which also, in many instances are less than those available in the US and Japan. The rationalisation of the EU R&D system is also a critical issue that the EU has to address to attain critical mass in some areas plus efficiency and effectiveness. The role of the EU Commission will be central providing clear guidance.

One key weakness is that the EU R&D System **lacks the ability to transfer and apply the knowledge** that it creates effectively and efficiently. One of the causes is fragmentation of the R&D system, the other relates to the demand side – where the economic tissue is predominantly SMES (more in the EU than the US). It happens that large companies tend to have longer term strategies, being more risk prone, proactive in promoting and adopting innovation, hence more private investments in R&D as in the US. Nevertheless, SMEs have the needed flexibility, skills and intellectual capacity to foster innovations, like for example, the wide adoption of new logistic models. This induces a more dynamic environment than in the US where large companies dominate, but to reap the benefits there are weaknesses that have to be addressed in the research and education agendas such as the improvement of management research and skills (is critical to include basic management skills in higher education curricula).

The **service** sector in the EU is increasing its importance and developments such as the Private Finance Initiative (PFI) in the UK contribute to enhance its relevance. Indeed PFI is a procurement model where the objective is a 'service provision' instead of the classical infrastructure. By giving to the private sector the freedom to innovate on how to supply the service the government induces gains in efficiency.

A threat that the EU can transform in an opportunity is the knowledge that is acquiring about the consequences of an **ageing population**. Its impact in society in the social system, the economic and technological is high. The issues the EU is facing now will be faced in a two or three decades by China, South and Central America and India.

There are **socio-cultural drawbacks**, common to all (or nearly all) member states related to the European cultural characteristic of risk aversion. This translates into the reluctance to approach the solutions within an integrated framework and a resistance to adopt rupture strategies that would conduct to novel ways to solve problems. Instead the EU is more culturally more prone to adopt incremental changes that may not be sufficient to address all the challenges it faces: demographic, economic environmental, etc. Analytical as well as management approaches based on insights from complex systems research will have to be adapted to the requirements of management and policy.

As to the available **resources** the main problem lies with its application. Some areas are underfunded; there is un-coordination, lack of synergies, etc. To overcame this weakness one key opportunity is the correct allocation of resources in FP7, that must be preceded by the definition of the long-term strategic goals for research coherent with the EU strategy as defined in the Lisbon agenda – Social cohesion and competitiveness.

Thus, it is critical that **for a good decision-making process that proper procedural mechanism support decision-making**, e.g. the allocation of funds in the next framework programs. These include the setting-up of procedures within the EU that can monitor the system but more importantly that can provide insight as to the decision making of policy makers, such as regular foresight exercises with scenario building are of the utmost importance. Health, agriculture, and economic decision makers could enhance their activities through the application of the science of complexity. These activities must be carried out together with the study of their ethical and social implications.

With the new framework programs there is the opportunity to reflect on the vision of the EU and its research strategy in the light of global pressures, and adjust it if necessary. There is now the opportunity also to assess the procedures and /or foresight type methodologies to evaluate the strategic fit between the Lisbon strategy, the research agendas and the changing external parameters.

From the analysis of each individual sector, each cluster and the holistic view of all clusters, **it emerges that Europe is a 'knowledge society' but not a 'competitive society'**.

Chapter 2 outlined the key findings in all the reports and presented the main conclusions on the conjoint SWOT analysis. Chapter 3 elaborates on the analysis and presents the short to medium-term priorities and immediate actions for the EU system transition. Foresight emerges as a key enabler of the setting-up and follow-up of the strategic EU R&D path. Chapter 4 follows with the approaches and rationale for the design of long term strategies for the sustainable development of the EU-25 R&D system.

Chapter 3: System transition policies

This chapter outlines the short to medium-term priorities and immediate actions which are needed to place Europe on the path of system transition. The concept of a transition agenda is projected here as a unifying, structuring theme and approach for Europe as a whole, embracing both old and new member states. The transition agenda aims to address the challenge of ensuring the coherence of European policies and strategies, not solely across sectors and key technology domains but also along short, medium and long-term timeframes. Foresight's role in engaging the stakeholders and taking forward this agenda is critical.

Although the report focuses on and projects a long-term vision for research beyond Lisbon, in this chapter we aim to complement this vision by outlining the core elements to be considered in designing the strategy to effect a system transition in the short to medium-term. The rationale for a system transition agenda emerges from a number of the reports. The communications report highlights that we are currently at a turning point between the creative destruction of the old paradigm and the full potential of the new paradigm. Similarly in manufacturing (Fig.3.1.), Europe is facing the challenge of industrial transformation from a resource intensive to a knowledge intensive sector.

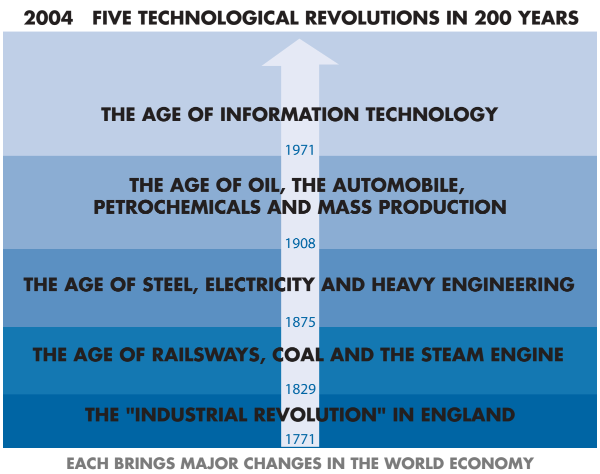
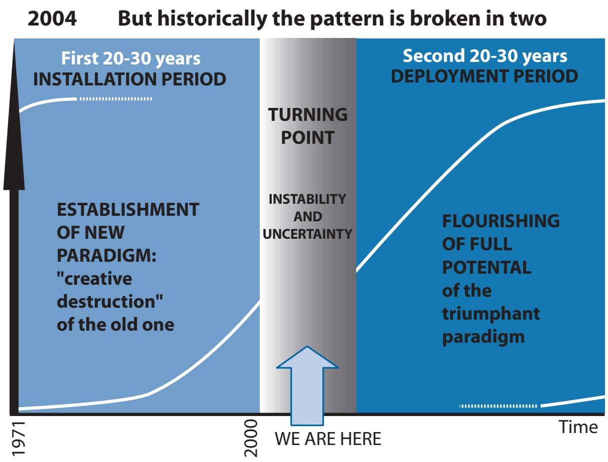


Fig. 3.1. Manufacturing new paradigm.[27]



(27) C Perez (2003 & 2004) referred to by Kavassalis

The rationale for system transition

Industrial transformation is a must. In order to meet the competitive, environmental and social challenges, a concerted effort will be needed to transform European manufacturing from a resource intensive to a knowledge intensive, innovative sector capable of achieving and maintaining technological and production leadership in the global market place.

A new approach to manufacturing is required – innovating production. The traditional structure of manufacturing industries is constructed upon the three pillars of *land, labour* and *capital*. The challenge is to move towards a new structure, which can be described as 'innovating production', founded on *knowledge* and *capital*. The transition will depend on adoption of new attitudes towards the continued acquisition, deployment, protection and funding of new knowledge. (Sá da Costa)

A number of the reports highlight the need for a two-pronged approach, combining a long–term research strategy with a short to medium-term transition agenda, which need to be developed and implemented in parallel. Both the long-term and short to medium-term agendas entail considerable challenges in terms of garnering appropriate political, academic, business and public support at European and member state level, however of the two the transition agenda is likely to prove the more elusive to put into place. It entails major shifts in political, social, business and academic/research mindsets and accompanying changes in the European research system and the general framework conditions. Its success depends on the level of political, public and academic engagement that can be obtained and sustained for this endeavour, and the extent to which the stakeholders can be induced to come together, learn together and decide and work on common goals. Foresight can play a critical role in helping the stakeholders to further define the vision and the actions to take this agenda forward.

Example of a European dual research strategy

Two-Pronged research strategy: to re-position EU-25 agri-food industries and rural economies, a two-dimensional strategic research agenda would be beneficial, involving:

- *A transitional research agenda* geared to re-orienting agriculture away from the production/output driven systems, supported by the former common agricultural policy, to the more consumer/society concerned multifunctional model, envisaged in the reformed policy. (Luxembourg, 2003)

- *A high-Tech research agenda* designed to harness advances in biotechnology and ensure the longer-term competitiveness and sustainability of the EU-25 agri-food industries. (Downey)

First, a long-term research agenda is needed to enable system innovations and underpin corresponding long-term transition strategies. Second, a shorter-term agenda is necessary to ensure the continuous improvement of current and existing technologies, geared towards aims of competitiveness on the one hand, but also guided by the long-term transition agendas on the other. (Weber)

The transition research agenda targets three aspects of transition which Europe needs to take action on to engineer the shift to the knowledge-intensive, bio-economy. Firstly, the elaboration of the transition agenda builds from Europe's position of strength, its rich socio-cultural identity and context and the challenge and opportunities which multi-cultural diversity present for KT. Secondly, in bringing about and supporting this shift, the transition research agenda focuses on the actions needed to induce a major shift in the EU's current research set-up, processes and practices in order to improve the coherence, effectiveness, and competitiveness of the research system. Finally, the required shift in EU research policy strategy and approaches is highlighted as the way forward in terms of activating the transition agenda on all three fronts, socio-cultural, research system and supporting policy. A number of policy recommendations are presented drawing on insights and proposals emerging from the individual reports.

Having justified the need for a transition agenda, there follows the conclusions drawn from the findings of the SWOT analysis. First, this section presents an overview of key findings, highlighting the need to focus on EU R&D assets with an optimistic outlook - **Optimising European society's assets**, followed by recommendations for immediate actions as part of the transition agenda - **Transforming Europe's Research system**. The chapter concludes with a set of policy-related recommendations for systemic disruption - **creative systemic disruption - approaches to EU policy**.

3.1. Optimising European society's assets

This section focuses on one of Europe's under-utilised assets, its rich multi-cultural society and its emerging high potential for creativity and innovation. European society is often considered and presented as a passive player in KT; however there are growing signs of a more proactive role being played by European society as a gatekeeper and shaper of KT.

The findings related to the socio-cultural context highlight the growing significance of the highly diverse, multi-cultural and multi-political/governance dimension of European (25++) society in providing the problematique and creative environment, but also in its more active role as recipient, client/market, sponsor, driver, laboratory/test-bed, gatekeeper and shaper of KT and the related research agenda. As the examples provided below indicate, European society is playing and has the potential of playing a wide variety of roles in relation to KT and their development and take-up. As a highly advanced mode 2[28] society, Europe has to assign particular attention to the impact of society on KT as well as the impact of KT on society. The report therefore contends that society, the social-cultural context and its related strengths and challenges have to be carefully factored into Europe's system transition agenda and research strategy over the short, medium and long-term.

Indeed as noted above in Chapter 1, the capacity to address the human and social face of KT comprises Europe's "value-added" in the emerging global scenario and could constitute the core of Europe's differentiation strategy vis-à-vis the US and Japan. In this section, we consider the potential socio-cultural facets and thrusts of Europe's research strategy in the transition phase as featured in the individual reports. In the main, the reports present a strong case for substantial investments in the SS&H, cognitive sciences and complexities cluster together with the other KT as drivers of social change.

(28) In mode 2 society (Nowotny, Scott and Gibbons, 2001) characterised by the growth of complexity and uncertainty, science is no longer an autonomous space, separate from society, and knowledge is increasingly generated in the context of application.

European society in transition as the problematique for Key Technologies

European society, by its very nature and rich diversity, provides a fascinating model in complexities research for predicting the evolution of modern society. Priami highlights the need for Europe to follow the US lead by investing in interdisciplinary research in social change and systemic transition.

Modelling European society

We must continue pursuing the social cohesion that characterises Europe with respect to the USA. This is a key issue to ensure high standards of quality of life that in turn make easier penetration of innovation into the society. This goal is achieved by investing in social sciences and behavioural economics. These fields are more and more characterised by the use of models that try to predict possible evolution of systems through simulation…

Since complexity arising from interactions and interconnections pervades most of the strategic sectors for the future of the enlarged EU, we must ensure a solid body of research activities in the enabling technologies of the cutting-edge field. (Priami).

European diversity as a laboratory or testbed for Key Technologies

Along the same lines, Andler presents Europe's unique legacy and combination of social and cultural mores as a rich, if currently untapped, laboratory for cognitive sciences experiments.

The experience of variety: an irreplaceable source of insights and experiments for cognitive sciences

Among the advanced regions in the world, Europe is quite unique in presenting a huge collection of cultures, languages, mores, social skills, political systems, etc. which, on the one hand, present endless variations, and on the other, are closely packed together, so that one can often find, for any given dimension, examples which differ along this dimension without differing significantly on all… This repertory of 'subjects' constitutes a unique source of conjectures, experiments (thought experiments, real experiments, experiments set up for non-scientific purposes by the societies themselves as they adopt or try out some particular change), and comparative observations. To our knowledge, outside of linguistics and psycholinguistics, this opportunity has not been tapped. (Andler)

The European knowledge society as the client or market for Key Technologies

As Europe moves closer towards the Lisbon goal of becoming a fledgling knowledge society, it is also transforming into a demanding market /client for a range of knowledge- and learning-related products and services. Andler makes the case for investments in cognitive sciences as the means for addressing the multiple needs of European knowledge society:

> … a multi-lingual, multi-cultural, multi-modal society wants as many tools it can get to enhance information, dialogue, comprehension, fusion, evolution, individual and collective learning, decision making; an ageing society needs every resource to

> understand and enhance the last third of the life-cycle; a leisure society wants a far richer repertory of non-utilitarian activities; a service-oriented society wants to gain control over more of the tools which make services more productive and more user-friendly;… (Andler)

The enlarged Europe as the creative environment for Key Technologies

The enlarged Europe provides a rich source of human and non-human, tangible and intangible cultural resources. This together with investments in KT offers a creative environment for attracting and retaining the best brains worldwide. Ganz makes the case for European investments in multidisciplinary service research to tap opportunities for developing new cultural products and services.

There is little knowledge about the influence and impact of cultural factors on service offerings, the demand for and quality of services. The European cultural diversity provides opportunities to set up intercultural service competencies supporting the design of exportable innovative services by building up multidisciplinary service research on EU level. (Ganz)

The European citizen as sponsor of Key Technologies

In the context of a European ageing society and the drive to reduce national budgetary deficits by cutting back on the welfare state through pension reform and other unpopular measures, the challenge of justifying public investments in KT is considerable. The European citizen, in his/her critical role of sponsor of KT, needs to be convinced of the benefits and the need for this massive shift of resources to the intangible knowledge-based activity. This ultimately depends on the public level of understanding and image of these KT as indicated below.

Justifying increased research investments

It will be important to see whether we can find a balance between the Europe's ambition expressed in Lisbon agenda and the public attitude to science and technology. This means that we should reduce the technology and digital divide as well as the separation between science and technology (knowledge and production). A main force in driving towards the balance is the ability of researchers to communicate the results of their work to the largest audience (reduction of the scientists-citizens divide). If this action succeeds, it could be easier for politicians to justify massive investments in R&D. Otherwise it would be difficult to have growing investments in R&D in a period in which the EU economy is growing slowly. (Priami)

European democracy as gatekeeper and shaper of Key Technologies

Europe's democratic tradition together with the variety of national and regional value systems influences and shapes the acceptance and update of KT with the general result that social acceptance is slow and hinders forward progress. Strong efforts are needed to bridge the science-society divide with a greater emphasis on KT in particular.

Managing Europe's role as gatekeeper

The cultural and socio-economic heritage of the EU makes slow the process of acceptance of radically new technologies. The consequence is that highly innovative EU industries can suffer a resistant market to their product… Public opinion on the convergence of sciences and technologies is a discriminating issue for the future development. The high risk is that common people start looking at this field in the style of a science fiction in which any trouble can be easily solved or any application of this research can produce dangerous side effects. We need to generate an informed consensus in citizens about convergence of science and technologies. (Priami)

The major *threats* are associated with implementation problems in the creation of the ERA, public concerns regarding controversial technologies such as Genetically Modified Organisms (GMOs) and nuclear. (Joergensen)

Biotechnology creates particular ethical and legal dilemmas more difficult than those of most other technologies. However, the general environment in which it evolves can have an important influence on its development. The image and understanding that people have of science could be a crucial factor in this sense. On the one hand a negative image of science is likely to constitute an obstacle to any new technology; on the other hand too limited an understanding of science and technology constitutes an obstacle to a rational dialogue about new technologies …

In a democratic society technologies cannot be imposed upon people, but they can only diffuse and provide all their benefits if they are generally accepted. The future of biotechnology will depend greatly on the ability to create a receptive and supportive socio-economic environment, a task which seems to be more difficult in the EU than in other countries. (Saviotti)

A number of the reports provide recommendations for managing better the science-society interface:

- To promote a broadening of the European science and society remit and to substantiate it through the setting up of a dedicated task force and increased prominence and funding for SS&H research in the FPs. Investing in comparative research is an effective way of gaining European 'added value' - a significant investment in research infrastructures (in the form of training and development of methodologies, analytic approaches and data bases) is recommended. That the EC should set a target of allocating 5% of the overall research budget to the SS&H over the next 10 years or so. Such a public commitment of resources would act as a considerable incentive to mobilise the SS&H community (national funding bodies, academies and researchers) to come work together to frame the SS&H in the ERA;

- To develop a well-designed communications strategy[29] for KT to explain the needs and benefits of research investments to the citizen - People should know why money is invested in research in terms of impact for their future needs. This would make the scientist closer to society in an historical moment in which their role seems to become less and less evident;

(29) A new contract between science and society is being called for, based on greater openness of science. Research activities transcend the immediate context of application and begin to reach out, anticipate and engage reflectively with the impact that science and technology will generate. (Nowotny et al)

- Public opinion on the convergence of sciences and technologies is a discriminating issue for the future development. The high risk is that common people starts looking at this field in the style of a science fiction in which any trouble can be easily solved or any application of this research can produce dangerous side effects. To accomplish this task is necessary to create awareness in the media having in mind that it is not marketing or advertisement of a new research field. The dissemination activities must be carried out by scientists as well as legal and ethical experts, coping also with religious issues as well as human rights;

- To improve the image of science and technology through the pursuit of challenge projects which aim at improving core social needs such as public transport or preventive medical technology (Bibel et al. 2004). Europe has to re-structure its funding policies and mechanisms in such a way that development leads to improvements for groups, societies and individuals within a sustainable environment;

- To provide more targeted EU funding for the establishment of a small number of European centres for advanced research in the Social Sciences and Humanities, akin to CERN, the European Molecular Biology Organization (EMBO) or the Sanger centre for genomics. Such centres would work at the leading edge of research, attract scholars from across Europe, train PhD students and collectively contribute to a distinctively European approach to societal issues.

3.2 Transforming Europe's research system

This section aims to identify and address some key systemic barriers affecting the European research system, undermining its global excellence and competitiveness in the KTs. A number of the reports highlight the challenge of systemic failure, and its many faces, as well as the need to radically transform the general framework conditions for research and the take-up of KTs. The analysis points to the need for a radical re-structuring of Europe's research system to address problems of fragmentation, slow reaction to fast changing research and policy environments and emerging opportunities, together with insufficient scale and flexibility of research funding and related structures.

Improving speed, scale and flexibility

The scenario in which R&D investments are considered is rapidly changing and is more and more global than before. The dissemination of knowledge is cheaper than before due to the rapid growth of internet. Emerging systems like India or China are increasing their percentage of export of high-tech product and are also raising their investments in R&D. To cope with this new context of R&D we need to rapidly change our research strategies, the size of research budget, the research management systems and the evaluation procedures. This is needed to have more flexible tools that can adapt to new emerging situation on the fly and that can tune the R&D activities according to the new global parameters that have to be monitored continuously (Priami).

Europe could be falling behind in generic technologies, simply because other world regions are faster and less restrictive in developing and adopting new generic technologies (in particular nanotechnology and biotechnology). While there may be good reasons for being restrictive, this could have adverse effects not only on Europe's competitive position in general, but also with respect to its performance in the field of Environmental technologies. (Weber)

The speed with which Europe can unleash the full potential of KT depends primarily on EU and member state willingness and efforts to address the challenge of the radical re-structuring of the currently highly fragmented research system. The efforts to increase the scale of investments have to go hand in hand with the setting up of new processes and structures at EU level to re-design the system. EU initiatives such as the Open Method of Coordination (OMC), the ERANET scheme and the European research council are a step in the right direction but more needs to be done to strengthen coordination and coherence of the system. A number of the reports highlight that Europe is lacking world-class structures for research: for example there is no central "engine" for mobilizing R&D innovation potential (like defence R&D in the US) or centres of excellence with world recognition to support and drive KT research. A common recommendation in the reports is the setting up of a number of European centres and networks, aimed at ensuring the continuity, coherence, critical mass and focus, required to support cutting edge research.

Fragmentation deters excellence and competitiveness

The potential for a competitive performance of Europe is enormous. The number of highly educated people with great talents traditionally compares well with any other area in the world. Many fruitful ideas have their origins in Europe. But there is a systemic failure in exploiting this potential to a degree which would allow Europe to excel in competition with the rest of the world in economic terms…

One of the reasons behind the above-mentioned systemic failure is the tendency to hinder activities of motivated individuals or groups (by a host of regulations, rigid structures, etc.) rather than supporting activities in a synergetic cooperation and a friendly competition. This tendency has led to fragmented activities and structures in all sectors. The EU's member states are governed by 25 varying legislative, regulatory, educational, financial and patents systems blocking many attempts for fruitful cooperation. Europeans must learn to pull together. (Bibel)

The main weaknesses of our research system are the limited size of EU industries, the low percentage of people working in the high-tech sector with respect to the whole amount of working people, the difficulty of transferring to industries the knowledge produced in the research activities, low generation of patent or IP protection. All the characteristics highlighted above allow high flexibility and adaptation to rapidly changing environments, but do not allow reasonable investments over a reasonable period of time in highly growing sectors. This threat is accentuated by the reduced time (or higher speed) of exploitation of discoveries into the market. (Priami)

The reports highlight the fact that European research suffers from a number of handicaps as compared to its global competitors. These relate to discontinuity (Priami) in the development of new knowledge and innovation in R&D activities at the info, nano, cogno, bio interface, which undermines the competitive edge of the research system as a whole. European research in KT needs the guarantee of continuity and focused and targeted investments if it is to compete worldwide. The second handicap relates to the fact that as compared especially to their US counterparts, European researchers have to contend with restrictive and unnecessarily burdensome processes of proposal preparation at European level in order to access research funding. This process slows down and de-motivates researchers, in particular young researchers in emerging fields who have the impression that the system is biased against newcomers and outsiders. Europe needs to improve the research climate and conditions, if it is to reverse the 'brain drain' to the US, in particular North America. There is also an insufficient inflow of scientists to Europe, due to European regulatory systems complexities and rigidities and generally sub- competitive work conditions. Efforts are in hand on the part of DG Research to track down European scientists in the US and to gauge the types of incentives necessary to attract them back to Europe. Similarly the recent launch of the European charter for researchers is another important step in the right direction but further efforts are needed to address human resource and skills challenges in KT as outlined below.

Shifting the balance from bureaucracy to creativity

As suggested also in the W. Bibel's report, part of the European funding should be provided as awards, rather than bursaries given to the winners of a call for offer. The reason for this is twofold: first, professionalism in grant-proposal writing does not coincide entirely with scientific excellence and fecundity; there are too many good proposal writers whose scientific output does not deserve privileged treatment, and, much worse, there are outstanding scientific groups which are poor at meeting deadlines, finding the requisite (often contrived) partnerships, and writing up proposals. In addition, giving out awards (large and in small numbers) saves a huge lot of time (and thus money) on the source and on the target sides; it also modifies the spirit of the transaction, favouring honesty and realism over hype and self-aggrandisement. (Andler)

Along side initiative or programme mode funding, there is a need to capitalise on the expertise, interests and enthusiasm of Europe's many SS&H researchers with responsive mode research funding. (Gaskell)

Transition agenda for human resources development

The intellectual capacity and scientific basis in the individual disciplines is excellent. So what is needed is an openness towards 'rupture strategies', a rational management of the necessary means for exploring new ideas, of collaboration without heavy overhead, of direct transfer of novel techniques to industry, business, administration and governance, and of norms, standardizations, and generally a political climate which support the synergy of creativity. (Bibel)

The other key shortfalls undermining the European Research and Development system relate to human resources, in terms of both quantity and quality. There is insufficient targeting of human resource development policies on a European level, both in terms of defining human resource needs in key technology sectors, and in benchmarking and assessing generic research skills and competencies. The research/technology gap between Europe and the US and Japan needs to be further studied to ascertain and pinpoint actual shortfalls in human resource development investments both from quantitative and qualitative perspectives. Important lessons and insights may be drawn from such study and analysis both in terms of good practices and for convincing the policy-makers and public of the need for increased investments. The reports highlight a number of such shortfalls presented in the SWOT[30], including the lack of R&D management skills, the shortage of IST engineers, skilled "knowledge workers" and skilled technicians, and the lack of support for individual genius.

The reports include a number of important recommendations with regard to curricular content and upgrading to address the transition skills agenda, including:

- To improve the quality of PhD training through the development of a new European system of PhD training to meet transition challenge;
- To prepare the future generation of research and innovation stakeholders for a new and pervading "convergence of sciences" paradigm. This will help in establishing peer-to-peer relationships across different disciplines;
- To provide young scientists and researchers with the interdisciplinary/multidisciplinary skills to facilitate their integration into different research communities that to date have only limited interactions (ICT, life, Cogno, nano);
- To engender a higher esteem for all actors involved in the educational, scientific and technological cluster resulting also in appropriate infrastructures and salaries;[31]
- To re-explore educational system design and skills, particularly in relation to the future of engineering education and vocational education systems, which need to undergo a considerable mind shift in terms of curricular content and learning models;
- To develop national capacities (including research infrastructure) required for the further development of crop and livestock production systems.;
- To promote lifelong learning programmes as a key to ensuring that new graduates keep up with the fast changing knowledge-economy – it is estimated that recent graduates will need to revamp their competencies five years after graduation;
- To promote complementary measures for upgrading the knowledge and competence base for environmental design and product development in Europe. Teaching and education curricula have a major role to play here.

3.3. Creative systemic disruption – approaches to EU policy

Building on the findings, insights and recommendations elaborated in the previous sections (3.1 and 3.2), the policy agenda for engineering creative systemic disruption emerges around the following broad thrusts:

- Policy orientation and vision-setting
- Transition policy management and coordination
- Foresight as a catalyst for creative system disruption

3.3.1. Policy orientation and vision-setting

The difficulty in building long-term coherent European research strategies and the risk of fall-back on national programmes which do not have sufficient critical mass (Theys).

(30) Annex I: SWOT
(31) Successful scientists must become heroes before they leave the country or die (as it happened to Einstein and Zuse in their homeland and to too many others).Bibel

The majority of the reports highlight the key deficiency in EU research policy as the lack of an overarching, coherent future vision for EU R&D. The Lisbon agenda does comprise a broader overarching strategy, encompassing a number of pillars and priority areas, within which, however research is one element, albeit a key element. The main emphasis is on increasing the scale of research investments in the short to medium-term but there is no clearly elaborated vision for research and the more long-term dimension beyond 2010 is not addressed by the Lisbon strategy. This report makes the case for the launch from now of a dual strategy combining both a long-term research agenda extending beyond Lisbon and a transition short- to medium-term agenda. The transition agenda needs to address a number of challenges in terms of orientation:

- Steering the shift from the resource-intensive to the knowledge-driven bio-economy.

- Shifting mindsets from concern with increasing the quality of life through economic competitiveness to more sustainable, globally responsible lifestyles.

- Developing a global vision which addresses emerging social, economic, and political issues and research challenges facing Europe and its relations with the rest of the world. (Gaskell)

- Inducing a rapid change in research strategies, resource allocation, management and evaluation procedures to address the new R&D context.

- Targeting emerging sectors where Europe can take the lead and providing the appropriate research support infrastructure.

- Spearheading an extensive transformation of Europe's research system, focusing on urgent priorities and windows of opportunity for immediate action.

- Optimising on Europe's socio-cultural assets by investing in the SS&H, cognitive sciences and complexities cluster as drivers of social change.

3.3.2. Transition policy management and coordination

To implement the transition policy agenda in its long-term as well as in its short- to medium-term dimensions, Europe contends with a number of constraints which have emerged from the EU's experience in keeping the Lisbon strategy on track. The recent Kok review[32] attributes the poor progress and delivery of the Lisbon process to "an overloaded agenda, poor co-ordination and conflicting priorities" and mainly a lack of political will. The policy transition and coordination theme is common to a number of the reports and relevant actions are outlined below:

- To overcome major systemic barriers and path-dependencies through organisational change.

- To promote policies which master the whole innovation chain (basic, applied research, innovation and diffusion) and addressing innovation policy and management in a holistic, knowledge-driven and participative way.

- To work towards more rigorous policy coordination of strategies, methods and approaches, i.e. the coherence of policy initiatives taken in different realms, ranging from RTD-policy and regulation, standardisation, assessment and market creation to competition policy and infrastructure development. Coordinated policy strategies are particularly important for system innovations in order to create stable long-term perspectives for innovating firms.

(32) http://europa.eu.int/growthandjobs/pdf/kok_report_en.pdf

As a consequence, a better coordination between policies is now increasingly sought, departing from a focus on individual instruments towards well-tuned strategies to embed adaptive combinations of instruments (Rennings et al. 2003). (Weber)

- To encourage more intense policy coordination across different instruments and funding mechanisms, ranging from research to innovation, technology transfer and commercialisation and to ensure that the synergetic effects between different policy instruments are to be exploited in order to promote Key Technologies effectively. (Weber)

Defining the right frameworks and incentives is crucial - A long-term change or transition to sustainable production-consumption systems is needed, relying on what has been called system innovations. Ground-laying research on system innovations and transitions is the key to give better orientation to policy and corporate decision-making. (Weber)

Some sector-specific recommendations:

- To ensure compatibility of data measurements (most relevant in health care) to support policy coordination and to address over strict data protection and certification. (Braun)

- To design and implement the knowledge and innovation infrastructure to support the future needs of rural economies, including the natural resource based sectors: this raises public sector governance issues, including strategic directions, capacities, and organisational/ delivery structures, are widespread concerns. Also, the need for new funding mechanisms designed to ensure that the knowledge and innovation needs of rural economies are adequately provided for and in a timely manner. (Downey)

- To apply ICT to improve the optimisation of structures and removal of system failures hindering innovation. (Kavassalis)

- To remove organisational and institutional barriers for the uptake of environmental technologies innovations. It needs changes in mindsets in industry as well as in policy, to raise awareness of the potential benefits that could be reaped if environmental technologies are introduced and used in an intelligent way. The main output should be a well-designed framework of incentives, regulations, and market-based instruments. (Weber)

The individual reports propose a number of tangible actions for overcoming system inertia and improving transition management and coordination by learning from and working through existing mechanisms:

- Capitalising on relevant insights and policy learning generated through the OMC and the work of the CREST OMC Working groups, in order to identify good practices in transition management.

The most advanced approaches at member states level try to integrate policy strategies in support of environmental technologies within broader and long-term strategies towards sustainable development. Most notable among these are the dutch initiatives under the headline of transition management (see Box 3), although other countries (Denmark, Austria) have also started to employ similar strategies.

Transition management in The Netherlands

Transition management is a policy approach aiming to develop and implement long-term strategies towards sustainable development in key problem areas of Dutch society. Strategic research agendas are developed as part of a broad consultative process aiming to develop long-term (30-50 years) visions for these problem areas (e.g. water management, mobility, energy supply, etc.). In parallel, concrete experimental action are implemented and support networks created to ensure a continuous learning and adjustment process between the strategic and the operational level. (Kemp/Rotmans, 2005)

The OMC aims at enhancing mutual learning between member states about good practices in environmental policy as well, thereby also contributing to a greater coherence between them. (Weber)

- Engineering policy transition in government by working through the ERA-NET (an FP6 coordination mechanism to benchmark and coordinate national research programmes) structures and analysing and building on their results. A number of the reports make reference to the important role being played by ERA-NETs (Transport, environment, energy, agriculture), while others highlight the need for setting up ERA-NETs to address particular KT (SS&H).

- Building on the experience and structures generated through the FP6 technology platforms to extend the policy transition process to the business community.

The potential of ERA-NETs for policy coordination

Established in 2003, ERA-NET "Transport" encompasses 16 European countries coordinating their efforts in terms of research on transport. In order to identify the priorities regarding European co-operation, a "DELPHI" survey has been launched by the end of 2004. The latter clearly illustrates the different countries' preoccupations, more specifically on the issue of the contribution of research to *public policies.* (Theys)

As an industry inherently based on the exploitation of natural resources, the overarching EU goals of competitiveness and sustainability present virtually unique challenges for agriculture and forestry, and also the marine sector. Countries that achieve the optimum balance between the economic dictates of profitability in agriculture and at the same time address environmental and consumer concerns will have internationally competitive agri-food industries in the coming decades. *Knowledge is the key to attaining this crucial balance*. This brings into sharp focus the particular relevance to the agri-food industries of the Lisbon strategy… It also highlights the importance of ensuring, within the context of ongoing ERA-NET actions, closer alignment of national research programmes and the EU Framework Programmes with the development of multifunctional models of EU agriculture. (Downey)

Well-established, well-functioning ERA-NET in fusion is taking a lead in international R&D. (Joergensen)

3.3.3. Foresight as a catalyst for creative system disruption

The discussion on policy orientation and vision-setting and transition policy management and coordination points to the critical role of foresight in preparing the ground for a system disruption. A number of the reports highlight foresight's multi-dimensional role in achieving policy transition and system innovation:

- Foresight provides a new arena/space "where policy and investment decisions are discussed and in which "futures" are contested…". (Braun) Foresight has the potential of quantifying and qualifying the future potential of a key technology.

- Foresight's outreach role in bringing about broader stakeholder participation, engagement and learning in the communication of longer term issues and the building of consensus on the most promising areas.

- Foresight plays an important role as "coordination device" of collective strategy development for realising system innovations in society, by aligning "the individual strategies of the variety of industrial, research, policy and societal actors… when they are geared towards long-term objectives that cannot easily be achieved through market mechanisms". (Weber)

- Foresight provides the tools (scenario-building, road mapping) for tackling key problems and issues by developing different plausible scenarios against which R&D actions and roadmaps are tested. In the UK and Swedish energy foresight exercises, the scenarios approach helped participants to explore different plausible futures (with the time perspective of 2040) and to gain insight in implications of different scenarios and to see beyond present concerns. (Joergensen)

- Foresight provides insights into decisions related to strategic funding of Research and Development in relation to emerging opportunities and niche areas.

- Foresight helps to identify the major trends and drivers (technical, political, societal and economic) shaping the future and influencing the medium to long-term environment of KT and this helps guide current investments in research. For example, in the health report, it was noted that "six of the foresight studies analysed assign great importance to individualised medicine (the German Delphi' 98, the German futur, the Danish and Swedish foresight studies, the British foresight programme and the RAND study). The studies largely agree that by 2020 healthcare will become more personalised and tailored to the individual". (Braun)

Why foresight?

To overcome the ongoing downward spiral the EU has to set-up procedures, methodologies, that allow not only the monitoring of the R&D system but more importantly that can provide insight and support to the policy makers in their decision-making process. Thus, it is critical that for a good decision-making process that proper procedural mechanism be set up. Of the tools available, regular foresight exercises based on scenario building are of the utmost importance.

Health, agriculture, and economic decision makers could enhance their activities through the application of the science of complexity. These activities must be carried out together with the study of their ethical and social implications. The two most pervasive weaknesses are the reluctance to approach the problems within a systemic and holistic framework and a resistance to adopt rupture strategies that would conduct to novel ways to solve problems. Instead the EU is culturally more prone to adopt incremental changes that may not sufficient to address all the challenges it faces: demographic, economic environmental, etc. To overcome these weaknesses, analytical as well as management approaches based on insights from complex systems research will have to be adapted to the requirements of management and policy.

One key opportunity is the proper allocation of funds in the next framework programs. It can not be overlooked that the correct allocation of resources must be preceded by the definition of the vision for the future EU R&D system and its strategic goals. Within the new framework programs lies the opportunity to reflect on the EU vision and its research strategies – long term and short term - in the light of global pressures, and adjust them if necessary. There is now the opportunity also to assess the procedures and /or methodologies like foresight – to evaluate the strategic fit between the Lisbon strategy, the long term and short term research agendas with the changing external parameters. (Lemos)

In summary

In meeting the challenge of KTs, Europe needs to invest its efforts by building on existing strengths, whilst also attacking the major weaknesses. An indicated way forward has been identified focused on:

- Optimising European society's rich assets by exploring the potential of multiple roles and opportunities and through investments in the social sciences, cognitive sciences and complexities cluster as drivers of social change and system transformation.

- Transforming Europe's research system by addressing system failure and providing an attractive environment for young researchers, especially those working at the interface of KTs.

- Creative systemic disruption approaches to EU policy based on the use of foresight as a vision-setting and policy coordination device as well as a catalyst for system disruption.

The next chapter outlines the framework and rationale for the setting-up of a long-term strategy coherent with the short term measures outlined in Chapter 3.

Chapter 4: The way forward

Creative system disruption
towards a research strategy beyond Lisbon

This chapter presents the approaches and rationale for the design of long-term strategies that need to be implemented for the sustainable development of the EU-25 R&D system. The rationale was developed from the conjoint analysis of all the fifteen reports. The main conclusion is that Europe is facing the critical challenge of revisiting its societal model. The new society, ageing, with an industrial sector which is changing from labour and capital intensive to knowledge intensive, an economic model built on old paradigms and an R&D system which is knowledge intensive but not always agile in reaping commercial benefits depends on the integrated efforts of all sectors. The contribution of cognitive sciences, SS&H and complexity to the areas where technology is developed – IT, nanotechnology, biotechnology, manufacturing, to the societal concerns – agriculture, health care, environment, energy... will be key, together with developments in the converging technologies.

The next section presents the systemic framework and rationale for the strategies, followed by a presentation of the main issues that need to be addressed in embarking on a 'European strategy beyond Lisbon'.

4.1 Overview of systemic framework and rationale

4.1.1. Strategic and systemic approaches

The decisive action that Europe has to engage in is the building of a future vision for an integrated EU R&D system, based on a harmonious balance between market-driven and long term research. The elaboration of a clear and coherent strategy should provide the answer to the 'why' and 'how' to invest in long term research. It is important to note that the market benefits of investments in basic research very often can only be reaped after a period of 10-20 years and the Lisbon agenda ends in 2010. It will prove very difficult to address this agenda by promoting basic research – it needs to be tackled with a short term strategy essentially promoting mechanisms to transfer existing knowledge to market.

The establishment of a long-term research agenda must be built on a long-term vision for excellence in scientific research, as the EU seeks new ways of tapping into science, technology and innovation, eventually opting for 'rupture strategies.' It will then be possible to take decisions related to new energy sources which require long-term investments. The alternative is that the EU-25 will be too slow or ill-prepared in addressing the challenges related to the growing dependence on imports of fossil fuels, climate change, environmental problems and economic growth.

The systemic and holistic approach that is needed is depicted in complexity theories.

So if we are in the shape of converging these sciences and these technologies, we should close the science and technology gap, similar to the technology gap that divides different people acquainted or not with technologies. These issues are related to complexity in terms of the size of the systems that we can manipulate and to scalability of our current techniques and methodologies. All of this should be done in order to enhance the quality of life, the health systems and the health possibilities for people, to protect the environment, to grow the innovation and the competitiveness of the industries and to ensure social and economic development. (Priami)

and illustrated in fig. 4.1.

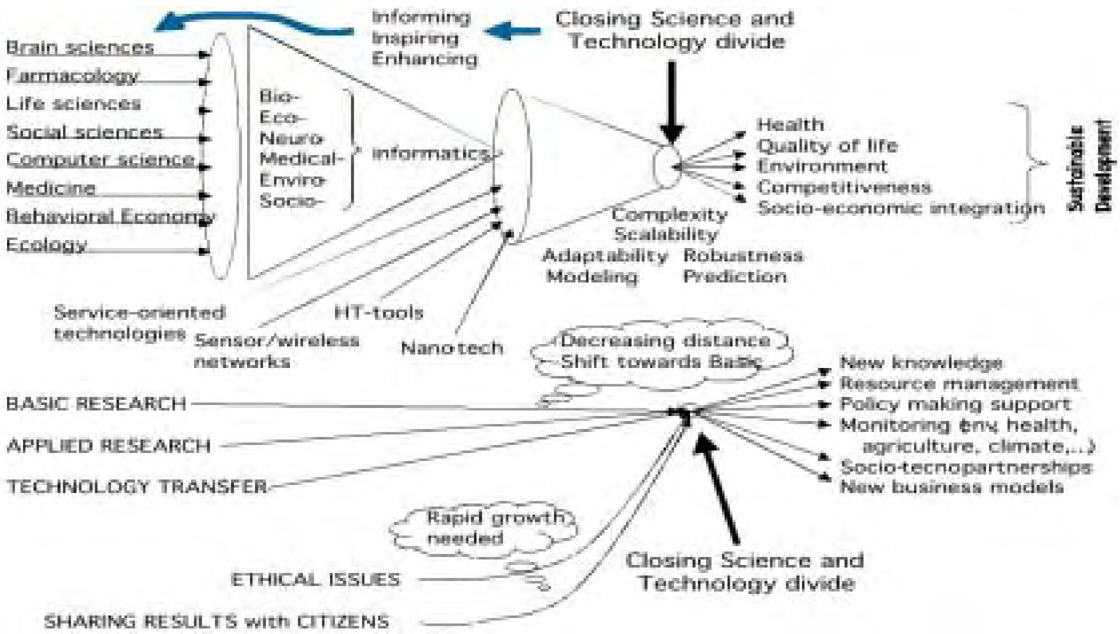


Figure 4.1. Research scenario in the convergence of sciences and technologies (Priami)

It is also important to take advantage of the willingness on of member states to improve coordination, cooperation and development of national efforts and initiatives, and the motivation and commitment of new member states.

4.1.2. Socio-cultural/socio-economic context

The need to foster innovation and competitiveness coupled with a EU sensitivity about social well-being, like adequate health care, and environmental sustainability, sustainable energy sources - offers a major opportunity to capitalise in the knowledge available in research areas such as: complex systems, IT, biotechnology, nanotechnology, etc. where the EU has a leading edge. To accomplish this, efforts need to focus on cross-border communication and benchmarking, capitalising on other cultures and styles, synergising without uniformising, establishing coherence and consistency, and mutual learning.

Europe's legacy of risk aversion and the welfare state model underpins the subdued interest from the private sector for R&D investments, and the poor working and living conditions for talented people. It is of vital importance that Europe addresses this issue, as intellectual capacity is the key driver of the knowledge economy. The most talented people are the most mobile, and their prime motivation is to work in an environment where they find better working and living conditions, and support for their research. Hence the 'brain drain' between the EU and the US and between some EU member states.

A weakness that the EU can transform into an opportunity is its know-how on the implications and impacts of the ageing population. The impact in society, on the social system, and the economic and technological implications are huge. The issues which the EU is facing now will be faced in two or three decades by China, South and Central America and India.

The EU R&D systems need to address the new paradigms of a society in mutation. SS&H will be a key area to build new models of a society that is ageing – hence the need to study the adjustment of the socio-economic development model that was built in the assumption of a different age pyramid. This has obvious implications in the welfare state, the labour market, the health care system not forgetting urbanism and rural development. All the horizontal technologies will be key to address this issue using the systemic approaches that complexity and cognitive sciences can provide.

Agriculture is a sector that is in urgent need of addressing the issue of its own sustainability. It must make full use of the available knowledge and competencies within the EU and use a holistic and systemic approach to define its own research agenda towards new models of sustainable rural economies and agri-food industries.

4.1.3. Bottlenecks to be overcome

Overall, the EU is strong in the area of fundamental research – There is a high potential for development but doesn't have the ability to transfer this knowledge effectively and efficiently. This is caused essentially by factors related to the supply side where the prevalent culture in the research sector which is weighted against commercialization, (bureaucracy); excessive fragmentation and to the demand side – vis-à-vis SMEs (more predominantly in EU than US) large companies tend to have longer term strategies, being more risk prone, proactive in promoting and adopting innovation, hence more investments in R&D like in the US.

It is clear that one of the key weaknesses is fragmentation, be it of resources – human, financial, etc., nevertheless it has to be emphasized that the weaknesses are viewed on a European scale not at member state level. As the process of integration within Europe is much more recent than the creation of US and Japan, it is not surprising that most of the problems are related to lack of a common EU vision and strategy; hence the problems of fragmentation, duplication and lack of co-ordination still remain. This leads to an overall underperformance of the available resources, which also, in many instances are less than those available in the US and Japan. For example, the investment level of private R&D in these countries. The rationalisation of the EU R&D system is critical issue that EU has to address to attain critical mass in some areas, efficiency and effectiveness overall. It is also an issue that has to be dealt with centrally, i.e., the role of the EU Commission will be a key one in providing clear guidance.

It is interesting to note that often mentioned, although very discretely, was that the acknowledge strengths in the traditional mature industries of chemistry and manufacturing are essential to sustain the development of a wide number of innovative emerging sectors. Clearly this is an iterative process where these industries must also to incorporate new knowledge, mainly IT.

Lastly, it is widely recognised that the EU has to improve the communication between citizens and scientists and to generate an informed consensus about (convergence of) new science and technology.

4.1.4. Policy implementation issues

As to resources the main problem lies with policy implementation.

4.1.5. Shortfall in competencies and skills

The great challenge that lies ahead for Europe goes deeply into the roots of society. It is not only a question of losing competitiveness, it is more deeply rooted and dangerous. The main challenge ahead is the danger of losing the existing potential for knowledge creation - the critical issue the R&D system is facing.

Indeed two key major weaknesses that came across in all the sectors as evident symptoms are fragmentation and lack of critical mass. The process of knowledge creation relates essentially to a critical mass of brains, i.e. only when a sufficient number of different people are in contact, through their interaction, it is possible to generate a truly sustainable process of knowledge creation. This can not be imposed it is a consequence of how the human mind works. Management research and skills are major weaknesses that have to be addressed in the research agenda and education (it is critical to include basic management skills in higher education curricula).

Due to its steeply declining birth rate, Europe simply does not producing enough researchers (especially young people) to sustain the knowledge creation process. This is aggravated by the fact that the EU is not providing researchers with a dynamic and motivational environment that they need to work in - hence the 'brain drain' to the US. Europe is losing its attractiveness both internally and externally. In summary, the EU has an impressive intellectual potential on a world class, be it in terms of knowledge creation or societal awareness concerns, but factors related to its socio-cultural heritage cause rigidity and bureaucracy to thrive and are translated into misadjusted policies and regulatory frameworks, whilst the ongoing process of integration fails to transmit the full benefits to society.

(33) According to the economist, much of the myth is caused by incomparable data, for instance on differences in labour productivity and return on capital. And in how far can the EU-US gap be explained by differences in the industrial structure, e.g. that the US has a strong and R&D intensive ICT sector? If a comparison is made on the R&D /sales ratio, Europe is leading in sectors such as automobiles & parts and aerospace & defence.2 A further issue is whether these advantages of the US, are a characteristic of only a limited number of 'excellent' areas (California, East Coast, Texas,...) or present across all states? The benchmark picture will be quite different if we compare particularly well performing regions within Europe with individual states within the US. The workshop aims to address these issues with the ultimate objective to better understand the drivers of the innovation gap between the EU and the US. *Mirror, mirror on the wall, Europe vs. America, June 19th, 2004.*

4.2. Concluding remarks

The rationale outlined above highlights the need for the EU to pursue a smart differentiation approach (building on its inherent strengths) rather than a catching-up strategy which merely seeks to emulate US or Japan-specific success stories.

The EU R&D systems need to address the new paradigm of a society in mutation as well as the definition of societal role. SS&H is a key area for building new models of an ageing society – hence the need to study the adjustment of the socio-economic development model that was built in the assumption of a different age pyramid. This has obvious implications for the welfare state, the labour market, the health care system not forgetting urbanism and rural development. All the horizontal technologies will prove critical in tackling the new societal paradigms by combining the systemic approaches that complexity and cognitive sciences can provide with their own technical expertise.

> *Agriculture is a sector that is in urgent need of addressing the issue of its own sustainability. It must make full use of the available knowledge and competencies within the EU and use a holistic and systemic approach to define its own research agenda towards new models of sustainable rural economies and agri-food industries. (Downey)*

From the analysis of each individual sector, each cluster and the holistic view of all clusters, it emerges that Europe is a 'Knowledge society' but not a 'Competitive society'.

> *The key long-term challenge is therefore to transform the EU into a 'Knowledge **and** competitive society'.*

It is thus apparent that Europe needs to introduce system innovations, i.e. combinations of radical technological and organisational/social innovations in many areas of economic activity, that allow reconciling economic, social and environmental objectives, values and beliefs. (Weber). 'The socio-cultural heritage if properly harnessed with its diversification, creativity and freedom of thought is a key 'European strength (Gaskell)' upon which the EU must focus in its future strategic options.

> *Karen Siune and colleagues argue that the European Union can be seen as the evolution of a unique form of society, combining political and cultural integration with a respect for, and an active upholding of national cultures and identities, which may be seen as a new model for social cohesion. (Gaskell)*

It is generally agreed, that 'knowledge creation' is the starting point for a competitive economy. So if an economy wants to be competitive it must ensure a good flow of knowledge creation. The EU performance is lagging behind in the competitiveness of the economy, which is closely related to the capacity to innovate. It is widely recognised that in Europe there is a widespread deficiency in the transfer of the knowledge created to the business environment slowing the innovation process.[33]

The need to foster innovation and competitiveness coupled with a EU sensitivity about social wellbeing, e.g. adequate health care; and environmental sustainability – e.g. sustainable energy sources - offers a major opportunity to capitalise on the knowledge available in research areas such as: complex systems, IT, biotechnology, nanotechnology, etc., where the EU has a leading edge. To accomplish this it needs border-crossing, communication, comparison, capitalising on other cultures and styles, synergising without uniformising, establishing coherence and consistency, legibility, learnability.

In conclusion, the leadership of the EU, supported by the appropriate decision making tools, has to propose a unified strategy spanning social, welfare and financial policies. It must utilise the synergies and scale economies of an integrated socio-cultural-economic system to harmonise the strategies of the R&D system, the innovation system and the business system, as well as the dynamics between them.

The recommended way forward is:

- To define a strategy for the EU R&D system – **The beyond Lisbon strategy** – using a systemic approach integrating the long-term and short-term strategies and incorporating member states' R&D systems to obtain synergies and rationalise efforts. Coordinated policy measures to address the deeper qualitative gap (rooted in outdated EU mindsets and structures) underpinning the quantitative gap (in research investments) with the US, Japan and other world, and capitalising on its potential for knowledge creation, and defining appropriate frameworks and incentives for research and technological development.

- To set up an **action plan for the beyond Lisbon strategy** which includes two types of measures: first to exploit the factors that differentiate the EU from the rest of the world: its ability to generate new knowledge, and secondly, to address in parallel the deficiencies evident at the interfaces of the R&D system encompassing society and business, which are hindering competitiveness:

Per definition the R&D system is part of the interfaces and must adopt a proactive attitude and promote two types of actions:

- *'Take science to the economy'* and implement the adequate mechanisms to bridge the gap between the R&D system and the business system improving the deficient knowledge transfer mechanisms to the economic tissue.

- *'Bring society to science'* and remove the barriers to system innovation adoptions, like the society's deficient 'absorptive capacity' of innovation. It would also help to improve the communication between the citizens and scientists and generate an informed consensus about (convergence of) new science and technology.

The next section presents the key recommendations, which draw on the combined key findings of all the reports and outlines the proposed framework for the way forward.

4.3. Key recommendations

The current situation calls for drastic action - **a creative systemic disruption** is proposed: **Europe's research strategy beyond Lisbon** must be translated into an **EU R&D action plan** with six pillars:

1. Global vision
2. Engineering creative system disruption
3. Projecting a new long-term research agenda and culture
4. Foresight approaches
5. Exploiting knowledge creation *'Bring society to science'*
6. Investing in societal learning *''Take science to the economy"*

4.3.1. Global vision

- To project a global vision for European research beyond Lisbon which is less US and Japan-centred while recognising and responding to other significant players emerging in KT (for example, China and India). In terms of global competitiveness, Europe needs to be prepared for the potential squeeze between high-end technology players and low-cost producers as well as agile players that are positioning themselves to combine both attributes.

International competition is increasing with new countries making impressive strides. Canada, Israel and Australia, although small, are already strong competitors. China, India and Brazil are emerging biotechnology powers. Unless it improves enough, Europe risks being caught between the present USA leadership and other possibly successful imitators. (Saviotti)

- To re-engineer Europe's role in supporting the long-term research strategies of neighbouring countries and regions, in the light of the emerging global scenario outlined above, taking account of the economic, security, environmental, and social opportunities and threats that are opened up through KT.

Key SS&H theme identified by the Economic Social Research Council of the United Kingdom (UK ESRC): understanding European identity and the processes of europeanisation. This is especially important in the context of enlargement. This also refers to Europe's world vision and roles, and a re-appraisal of its positioning vis-à-vis historical engagements (e.g. Mediterranean, Africa, Latin America, etc.). How should the identity of Europe in the world be built? It will be important to understand the new Europe and its place in the world - for economic development and for quality of life in the light of social and demographic changes. Issues of cultural identity and understanding diversity are also important in this regard. (Gaskell)

- To approach the EU-US research gap with a longer-term perspective focused on domain-specific and sector-specific targeted measures, drawing on a detailed ongoing quantitative and qualitative analyses of the situation with the individual KT and of emerging trends and prospects.

For example the EU research system is performing relatively well in terms of life science publications but the relative quality of the publications is less clear. Quite apart from the relative levels of funding, one could have doubts about the health of the EU research system. A study of the contributions of the EU research system to biotechnology would certainly improve our understanding of the situation. (Saviotti).

4.3.2. Engineering creative system disruption

- To keep a closer focus/watchout on new emerging sectors where as yet no research gap exists and where Europe could take the lead: Europe needs to make a discrete jump towards new sectors where it can start working before its competitors, for example future society needs at the end of the hydrocarbon economy, the generation of new waves of techniques and frameworks in highly competitive fields such as pharmaceuticals, biotechnology, and IT or more significantly the convergence between them.[34]

- To engineer a shift to a bio-economy, away from processes using non-renewable resources towards those using biological renewable resources, combining greater economic efficiency with a reduced environmental impact.

- To capitalise on the emergence of effective information economies and other virtual structures supporting communities and individual social and professional lives.

Many researchers and industry observers seem to recognise that in facing this complexity, we absolutely need to turn again into long-term / high impact research and define a more ambitious communications policy in this regard. But, as concludes a recent workshop in this regard hosted by the Columbia University, in order "to justify the support of and the investment, a vision of the accomplishments and rationale for basic research needs to be articulated and promulgated". (Kavassalis)

- To facilitate the transition to alternative, more sustainable lifestyles through investment in new technologies and the accompanying change in policies, structures and mindsets.

We need to radically rethink what constitutes a successful society in world terms, and must expect, as a result, the reduction or even demise of some industries that are highly energy, water or mineral resource intensive. These may be as disparate as the aviation and aerospace industries, paper and bottle making industries, out-of-season food exporters and importers, exotic flowers producers and the fast food industry. (Saxl)

- To project and target investments in KT as drivers of structural change. For example biotechnology both results from a process of structural change in science through the dynamics of new knowledge creation and itself contributes to structural change in industry by redefining industrial sectors.

(34) Converging technologies report

- To cope with the new context of R&D, Europe needs to rapidly change its research strategies, resource allocation, research management systems and evaluation procedures.

- To support governments in addressing the long-term challenges of investing in KT. Governments are often faced with two competing constraints of adapting to the evolution of the world economic system by learning a new technology invented elsewhere and of fitting the necessary new institutions within their existing institutional structure. (Saviotti)

4.3.3. Projecting a new long-term research agenda and culture

- To complement the current short-term focus of the European research agenda with a research strategy[35] supported by a long-term vision (30-50 years) which addresses the long-term challenges facing KT, emerging sectors and societal concerns.

- To reverse the current culture/mood of over-emphasising the potential for immediately apparent applications (what's in it for the economy and society), by launching a drive to re-affirm the need for a tremendous effort in basic research as the means for sustaining the development of durable applications.

- To develop a world class infrastructure at EU-level to cluster European multidisciplinary research teams (physicists, chemists, biologists and engineers) to work together to find innovative solutions to intransigent problems. The involvement of social scientists[36] is critical to ensure that new scientific advances take full account of social needs and constraints, also embodying social innovation.

The UK biotechnology & biological sciences research council launched in 2004 the initiative of centres for integrative & systems biology. These centres are to possess the vision, breadth of intellectual leadership and research resources to integrate traditionally separate disciplines such as biology, chemistry, computer science, engineering, mathematics and physics in a programme of international quality research in quantitative and predictive systems biology. (Priami)

- To close the technology divide, the science and technology divide, the scientists and citizen divide, and produce new knowledge that can be part of the singular discipline but also something new, which is in the intersection or in the border of the initial disciplines. Potential major results in scientific and technological achievements at the intersection of classical disciplines and Information and Communication Technologies (for instance, ICT-bio, ICT-cogno, ICT-nano). (Priami)

- To ensure that a proportion of EU research funding is ring-fenced for the long-term research agenda opening up at the interface of disciplines, in particular cognitive sciences, biomimetics, complexity and social sciences.

The two main factors which prevented cognitive sciences in Europe from gaining the sort of dynamics which it was acquiring elsewhere, are first the reluctance of funding sources to divert serious amounts of money away from the established disciplines, and more generally the lack of mobility of the national scientific communities; and second, the specific

(35) In some sectors it is needed a very long-term research strategy translated in a research agenda with definite goal setting such as the case of transports (Theys) and energy (Joergensen)

(36) "SS&H researchers are best placed to formulate a fuller range of topics, scientific models and approaches" EURAB

resistance put up by the establishments within each discipline against the cognitive turn which some in the discipline wanted to take. Europe… seldom succeeded in creating world class centres large enough to reach critical mass, to attract a high enough proportion of the very best students, and to federate all the relevant disciplines and paradigms. (Andler)

- To capitalise on the expertise, interests and enthusiasm of Europe's many (SS&H and other) researchers, by introducing more responsive mode research funding, particularly for KT, alongside initiative or programme mode funding.

- To address the issue of risk, both in terms of (i) the constraint of risk failure when investing in technologies whose potential is only realised over a long period of time. (ii) the risks and benefits of a pervasive new technology where it is not possible to predict with precision the development path and impacts of a new technology.

4.3.4. Foresight approaches

- To address the current vacuum at European level in high level structures and processes for defining long-term vision(s) for European research which go beyond the sum-total of the individual member state visions and strategies, but build on and utilise synergies and scale economies of an integrated system.[37]

- To develop and create a better understanding of the evolutionary paths of these KT and define effective coherent long-term research priorities in the next phase of the evolution cycle.

- To provide a critical bridging role (i) from one Framework Programme for research, technological development and demonstration activities to the next in terms of priority-setting and emerging research themes; and (ii) between FPs and other funding instruments (Structural funds, CIP, …), to ensure coherence of efforts and resources.

- To develop more bottom-up approaches to the identification of long-term European research priorities using foresight-based technology platforms.

- To foresight actions that allow Europe to fill the gap at least in specific areas of the convergence, with other competing systems like the US, China or Japan by exploiting the peculiarities/specificities of European research and industries.

4.3.5. Exploiting knowledge creation - 'Take science to the economy'

- To change the old "linear" or sequential scheme that basic research evolves to applied research that will produce in turn technology transfer. Targeted and communicative research includes in a non linear and homogeneous line all the above aspects. Usually there are three issues that must be thought of when we try to develop a research project: the first is the basic research, then the applied research and finally the technology transfer. In this new arena of converging sciences there is a decreasing distance between these three items. There is also a shift towards basic research because the cycle between the basic research, the scientific discovery hunting and the technological implementation as well as economic exploitation of the discovery is exponentially faster than it was even a decade ago.

(37) Insights from Teresa de Lemos

- To rethink the way in which new knowledge produces innovation - the process is not absolutely easy and automatic; on the contrary a large amount of (public) investment is needed to activate the process of exploitation and to ensure protection of IP in order to defend our industries from potential exploitation of EU knowledge by non-EU industries.

- To promote measures to bring together the R&D system and the business community.

- To target the flexibility and innovative capacity of European SMEs and contribute to overcome the deficient knowledge transfer.

4.3.6. Investing in societal learning - 'Bring society to science'

- To address the increasing intersection between science and technology and people's beliefs and values and new issues around socially sustainable innovation, governance, conceptions of risk and participatory processes.

As science and technology moves into increasingly value laden topics, the public wants its voice to be heard in decisions shaping research agendas, in regulation and in choices about the options that science and technology offers for the future of societies. (Gaskell)

Examples include developments in fields such as cognitive neurosciences and nanotechnology; international debates over issues such as genetically modified crops, energy management, and human embryo technologies; debates between business- and consumer-led perspectives in the developed world; and the needs of developing countries in agriculture, food, health care, IP and trade. New insights into the roots of these various controversies could be offered to improve communication among the relevant constituencies.

- To identify appropriate means for engaging the public in what researchers are doing, and why. This is a double issue: it can help politicians to justify why they want to invest more money in research and also help in creating an awareness that researchers work for people rather than being in their labs writing their own theories that no one will ever use. (Andler)

- To address the cultural constraints deterring investments in and social acceptance of KT. National cultures and existing institutions can be powerful determinants of the development of a new technology as scientific and technological progress, e.g. the EU refusal to allow the cultivation of genetically modified plants and to heavily discourage their use in food production.

- To invest in life long learning programmes. All age groups and backgrounds must keep up-to-date with the new developments to improve their competencies and skills and overcome the 'age divide', 'knowledge divide' and 'digital divide' so that all citizens can participate in society.

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An expert group has been set up to assess the potential and the emerging scientific and technological research topics in fifteen specific areas, their impact on the EU competitiveness and societal fabric, and the potential response of EU and its members states, while examining what possibilities exist for a uniquely European approach to exploiting the potential synergies across these technologies, and develop guidance for new research agendas. These issues should feed the identification of possible priorities for the European research policy.

The group, via a series of working papers and of the present synthesis report has tried: to identify which key socio-economic challenges Europe is facing in relation each of the research fields; to provide for each field an overview of EU policy responses in the last 5-10 years; to establish an overall comparison of Europe's position in research in each field, to measure levels of R&D spending for the EU as a whole, the member states, other competitors/partners; to identify strengths and weaknesses of Europe's sectors and companies and related industries from the specific areas in a global perspective; to identify and analyse policies and programmes of member states and international organisations; to define a forward look: long-term challenges, visions, and finally to present an overview of recent foresight work highlighting the future challenges for Europe in this research field.

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