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Emerging Science and Technology priorities in public research policies in the EU, the US and Japan

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Emerging Science and Technology priorities in public research policies in the EU, the US and Japan

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2. The future of R&D in services: implications for EU research and innovation policy (PREST)
3. Emerging Science and Technology priorities in public research policies in the EU, the US and Japan (CM International)
4. Perspectives of national and regional research and innovation systems in an enlarged EU 2015: specialisation, complementarities and competition (Logotech)
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Executive summary

The objective of this Platform Foresight project is the analysis of emerging science and technology priorities in public research policies of the European countries, the US and Japan. The present report summarises the main findings of the study. The project began in August 2004 and ended in October 2005[1]. It was carried out by a consortium led by CM International and comprising moreover ICTAF (Israel), VTT (Finland) and Z punkt (Germany). As far as the review and the analysis of foresight studies in the USA and Japan is concerned, the partnership has been able to contract local teams: the Institute for Emerging Issues (North Carolina State University) and the Institute for Industrial Interchange (Tokyo).

Forty emerging technologies selected

By means of a questionnaire sent to more than 300 experts, a list of 104 technologies – established by scanning foresight literature- has been evaluated.

- Four priority fields have been retained: Nanotechnologies and New Materials, Information Society Technologies, Life Sciences and Technologies for Sustainable Development.
- 40 technologies have been selected as the main priorities one for the future.
- Amongst these 40 technologies, the most prior ones belong to the Life-Science scientific field.

Analysis of main socio-economic factors motivating policy support as far as these technologies are concerned and identification of potential areas of leadership for Europe

1. The economic factors provide the most important rationale impacting public R&D support policies in virtually all priority fields (with the partial exception of the field of Sustainable Development) and almost regardless of the geographical area. Even though the relative importance of the economic variable may differ between countries, the related issues of international competitiveness, economic development and, at a smaller level, job creation form an integral part of virtually all countries' public R&D policies.

2. The defining characteristics of the US public R&D policy are a) an even stronger impact of the economic factors than in other geographical areas; b) the enormous influence of defence-related research activities; and c) the importance given to the high potential areas made up of converging technologies.

3. In the Japanese context, in turn, economic issues play an equally dominant role motivating public R&D support policies in virtually the entire range of high priority technology fields. Moreover, the awareness of a number of the country specific conditions (such as the social consequences of prevailing demographic trends and the country's geographic situation) provide additional, at times highly important, but generally inherently partial socio-environmental rationales.

(1) The project had initially been set out for one year, but in accordance with the European Commission services a period of two additional months was decided.

4. Of the three geographical areas in question, Europe is the region that is most strongly influenced by societal – i.e. social and environmental- factors. As a matter of fact, ecological and quality of life issues generally provide a unifying and defining element of European public R&D support policy.

5. Nevertheless, the European research landscape is characterised by important differences between the different countries. A number of factors account for this, such as countries' GDP, their political environment, their scientific position, the relative importance of the defence sector, their industrial fabric, etc.

6. Economic factors that impact public financing of R&D policies are present both in Europe, the US and Japan. However, Europe is faced with policy rigidities that have an important impact on the efficiency of public support, influencing both the form in which support is being administered and the research organisation itself. In the USA, defence-related R&D activities (that are transversal by nature) and the creation of the NNI[2] (a multidisciplinary institution designed to support converging technologies) increase the efficiency of public policies. Europe does not have any such support mechanisms. What is more important, the key role of the environmental factor (precaution principle) and the relative weakness of policy institutions at European level seem to represent further obstacles to the creation of an efficient public support structure. Nevertheless, Europe occupies a significant scientific position on some technologies, such as "Ultra-thin functional coatings", "Bioactive materials and surface" and "Nanocomposite and nanometrical-nanoscale reinforcements in electronics, chemistry, medicine… ".

7. The field of Information Society technologies, in turn, is to a large extent a reflection of present market realities and the corresponding presence of leading enterprises, notably in Europe (particularly visible in mobile communication). This field provides an equally important potential for Europe, particularly as regards the newly emerging health sector applications, which is not least due to the relative importance of the societal factors in Europe.

8. Even though generally considered as an important issue by all governments, Sustainable Development constitutes the field in which country specific differences are most significant. Whereas most of the countries agree on the importance of Sustainable Development issues, there is no consensus about the technologies that are likely to promote this type of development (i.e. in the energy field: nuclear in France, solar in Germany and wind in Spain). While this makes the identification of widely shared (and thus operational) European policy approaches in this field a somewhat difficult task, Europe has a particularly strong interest in giving high priority to at least two technologies that could benefit from the support of the importance of the environmental factors: "Air-water purification" and "Renewable and recyclable materials". And while the significant delay in the "fuel cells" area is likely to constitute a serious hurdle for further growth potential, the present "biofuels" advantage needs to be confirmed and exploited intelligently.

9. The field of Life Sciences constitutes the potentially most important research area. In spite of a slight head start of the USA, the sector remains an area with competitive positions still being largely undefined and in which there are no strong differences on the specific technology level. Public support can thus make a real difference, ideally being targeted at the entire sector. Taking into account the relative importance of social-environmental factors, Europe has the potential of occupying a leading role in the future life-sciences scientific field.

(2) National Nanotechnology Initiative

List of recommendations

10. To prevent a decline of Europe S&T positioning in the eventuality of a failure of the Lisbon strategy combined with the consolidation of the current trend putting the emphasis on economic factors for the support of R&D, the corrective strategies for Europe could include the following recommendations:
    - To develop a new "airbus strategy", based on an important economical issue in which Europe can, by the way of public and private partnerships, take a lead within 30 years;
    - To foster industrial R&D strategies and cooperation on strong industrial based technologies having an existing potential leadership such as "mobile communications", "micro and nano-sensors" or "biofuels";
    - For other technologies in which there are no clear existing leadership potential, to promote "centres of excellence" at regional level that could help in developing clusters at local level. This strategy goes through support policies to incubators and start-ups, to venture capital, to enhance cooperation between regional clusters…
    - To try to attract research centres in Europe and mostly in less developed countries using the opportunities of new Objective 1 ERDF funding (the "Irish model"). At broader level, create conditions to attract foreign researchers in key technologies in which Europe (or a majority of European countries) seems to need competences (e.g. IPV6 or robotic in the IST field).

11. Additional specific actions –funding of transfer activities, "trans-national" research, venture capital…- should be carried out aiming at enhancing the transfer process management from R&D to application/innovation in Europe. Specific technologies that are very dependant on such links could be targeted. This is the case for smart materials, ultra-thin functional coatings, microsensors and nanosensors…

12. To establish a strong industrial European strategy as a basis for a R&D strategic policy linked with economic issues. As long as Europe will not have such strategy, R&D targeting on economic issues will depend on national will and national environment and opportunities.

13. To enhance the participation of SMEs -which constitute the basis of European industrial environment- in R&D projects. A first step could be to simplify public support procedures today often analysed as "too bureaucratic, too formalistic, too rigid" or "complex proposal procedures, slow administrative processes and high administrative expenses", at European level (but also often at national level).

14. Access of small research intensive companies to venture capital should be strongly supported – incentives, organisation, networks, pools,…–, mainly in the field of ICT, Life-Sciences and nanotechnologies. A specific recommendation could be to support at political level the creation of a venture capital line at the European Central Bank.

15. To launch a programme to overcome the significant differences in the views of European countries with regard to technologies that promote sustainable developments.

16. To organise some awareness raising campaigns targeting the public at large in order to promote a better understanding of the potential applications of some key technologies, such as stem cells or protein engineering …

17. Europe should support sustainable development know-how throughout Europe by means of conferences, CD Roms, etc… "We have to list the real know-how in Europe (publications, patents…)"

18. To organise awareness of the scientists of what happen elsewhere in applications' focused R&D.

19. Legal issues to favour the development of R&D on key emerging technologies:
    - To encourage national legislation to facilitate approval procedures for tissue engineering products
    - To strengthen legal protection of the European cultural collections
    - To propose EU regulation for nanotechnology and nanoparticles in therapy
    - To have a clear position at European level on the patenting of human DNA and human stem cells.

20. To organise networking between scientific communities to foster convergence: micro-robotic, virtual reality and computer aided surgery, mobile communications and health services, neurology-nanosensors, neuro-informatics…

21. To use applications' targeted projects to reinforce convergence: nano-computers, applications of multipurpose robots, microbiotic applied to biology…

22. The need to facilitate cooperation between research institutes and very small firms or associations through European Research programs: groups of artists for research in virtual realities, artists and industries, SMEs in FP7…

23. In order to foster the field of sustainable development in the years to come, it seems necessary to underline that external costs are real costs. This needs to be done on permanently, on the basis that externalities do often have a strong local impact. It is thus necessary to involve local companies and industry in an effort to work out solutions on how to internalise social and environmental costs. If this is not done locally (while respecting the optimal cost matrixes), there will be little progress at the international level either. Supporting programs by the EC (DG Research, DG Region, DG enterprises, DG Environment) could thereby play a major role (incentives and financial support of pilot initiatives). At a first step, a strong effort for raising awareness at political level should be undertaken.

24. Facing issues at worldwide level, Europe could foster large dissemination of results. In the area of sustainable development, it could take the form of the support of R&D project in which research activities are carried on in Europe and demonstration activities are carried on in developing countries.

25. A strong focus in the public support should target molecular imaging. The USA has clearly taken the lead on these technologies. It is of high importance to keep companies' imaging research potential within Europe as some dislocating temptations already exist as well as we can observe a beginning of brain drain movement. In addition to financial support, more cooperation in university in this field (towards a European Master degree) is also needed.

26. Beyond the legal issue to encourage national legislators to facilitate approval procedures for tissue engineering products, there is a real need of clinical and economical studies on this technology. These studies should be included in the EU programs.

27. It is necessary to enhance the GEN-AU program mainly to attract researchers back in the human genomes and proteomes field. The same recommendation is also available for protein engineering through a European HUPO project.

28. It is necessary to ensure continuity in the European Union framework programs as biotechnology research needs long-term activities to attract private companies.

Introduction

Objectives of the project

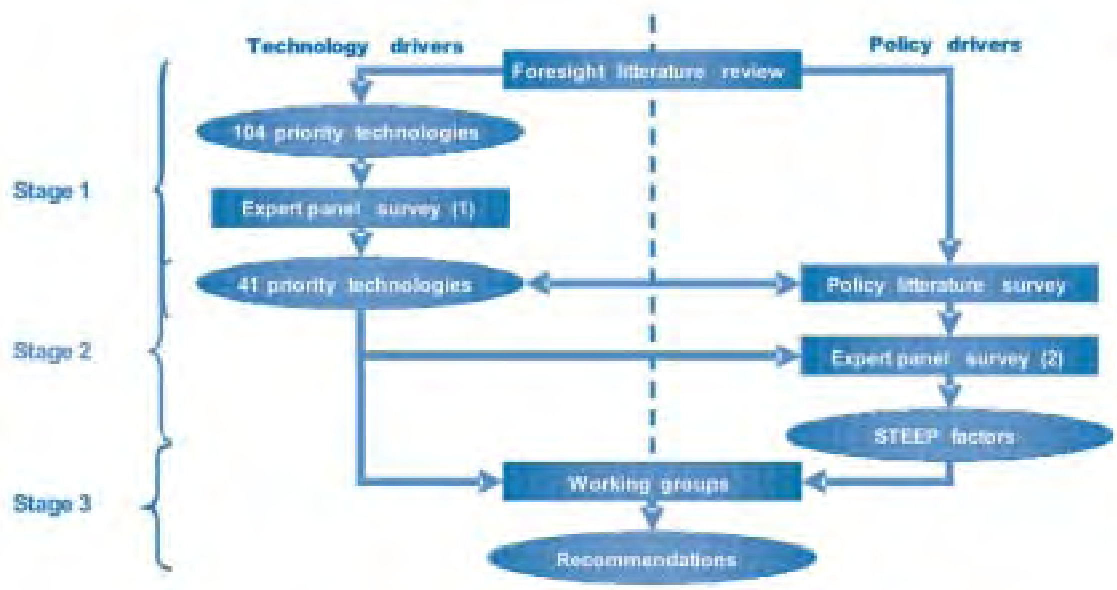
The main objective of the study is to examine the leading world economic areas on emerging science and technology priorities in public research policies and to relate these priorities to emerging science and technology developments and their economic and social rationales. The study identifies scientific and technological developments and research priorities in which Europe could take the lead in the years to come. By providing recommendations for public policy support to emerging science and technology priorities, the study aims at contributing to the development of research and innovation policies of the European Union.

Thus, this study allows to:
- Identify emerging science and technology themes, thereby particularly focusing on potential discrepancies between, on the one hand, emerging science and technology priorities as far as public research policies are concerned and, on the other hand, emerging science and technology priorities effectively being at an early RTD stage
- Assess the European potential for leadership on the most important emerging science and technology priorities
- Recommend policies for emerging priority themes

Methodology and main steps

The global approach of the project comprises 3 major stages. Two main drivers have thereby been used as analytical focusing entry point: technology and public policy. The figure below describes the project process.

Figure 1: Main project steps



The first stage deals with the identification of emerging issues in science and technology developments. Members of the consortium using existing foresight literature carried out this task through desk research.

The second stage consists in identifying potential leadership areas for Europe among the emerging science and technology developments. This stage is based on primary research in the form of an expert panel survey. This survey is thereby divided into two rounds. While the first round aims at identifying science and technology priorities for Europe, the objective of the second round is to analyse potential areas of leadership for Europe on the basis of an assessment of both the continent's strengths and weaknesses in the identified science and technology areas as well as the socio-economic factors for public policy support. The relative position of Europe compared to that of the USA and Japan is of utmost importance in this part.

The third stage aims to define policy recommendations in support of the development of potential leadership areas for Europe. This stage is also based on primary research in the form of experts' interviews as well as collaborative work arrangements favouring multiple interactions and exchanges.

Rationale for the final report content

This kind of project requires at the very outset a clarification of its key elements (Chapter 1). It is thus indispensable to clearly define the meaning of "key emerging technologies". For that purpose, and reflecting a predominantly technical point of view, several criteria are to be used, such as the date of maturity, the relative importance of basic research versus development and application, etc. Other criteria reflect the technologies' potential impact, taking into account both their relative importance and their nature. Thirdly, the point of view of and the assessment made by experts are to be used to define new priority emerging technologies.

On the basis of this definition, it is thus possible to undertake an analysis of existing foresight literature and to make a consolidated selection of technologies. The emerging key technologies are then to be described in terms of a number of different typologies.

The second issue deals with public support to priority emerging technologies (Chapter 2). Two forms of public policy support can thereby be set apart. The first one is what can be called an investment strategy. In fact, the assessment and evaluation of the level of financial investment used in support of any given technology provides a useful indicator for the global policy support to this technology. However, financial support is far from being the only means to support R&D and other forms of support must be taken into account to have a clearer and more appropriate vision of existing public policy support.

This being said, it has to be kept in mind that, no matter how comprehensive the measurement of existing public policy support may be, it is bound to be of only limited value as it merely presents the visible part of the iceberg. As a matter of fact, to be able to make meaningful, i.e. effective, policy recommendations it is indispensable to understand the drivers and the rationales underlying and, at least partially, motivating this support. To this end, the relative impact different socio-economic factors have on the intensity of public support will be evaluated on a geographical basis, using various official public policy documents.

Chapter 3 aims to evaluate the relative scientific positioning of Europe vis-à-vis its main competitors, i.e. the USA and Japan, as far as the selected emerging new technologies are concerned. Particular attention will thereby be paid to the analysis and the description of potential links at geographical level between scientific positioning, public policy support and socio-economic factors. This analysis will be particularly interesting given the fact that the elements of scientific positioning and public policy support provide the framework which helps to account for Europe's present situation vis-à-vis its main competitors, while the element of socio-economic factors at geographical level constitutes the context within which the evolution of public policy support is likely to be shaped in the future. Potential leadership areas for Europe will be analysed.

Chapter 4 finally formulates a series of policy recommendations on the basis of the findings of the present study and of a scenario building approach.

1. Forty key emerging priority technologies for Europe

Our study leads to the identification of 40 emerging priority technologies that are of key importance for Europe in the future[3]. These 40 technologies have been grouped within four main scientific fields:

- Nanotechnologies, knowledge based multifunctional materials, new production processes (11 technologies)
- Information Society Technologies (12 technologies)
- Life-Sciences, genomics and biotechnology for health (8 technologies)
- Sustainable development, global change and ecosystem (9 technologies)

Two different rationales support the selection of these technologies. The first one is directly related to our definition of a key emerging technology (part 1), while the second one is the results of the foresight literature review both in the European and the main competitor countries (part 2). Subsequently (part 3), these technologies will be analysed and an attempt will be made to characterise them.

Methodology:

A questionnaire was sent to a panel of about 1300 experts in all countries of the enlarged Europe. These experts represent the totality of the European countries and the science and technology fields. 2/3 of the experts interviewed are from public research while the remaining 1/3 comes from the private sector. The expert panel survey is focused on high level experts and more than 2/3 of the experts interviewed are directors / heads of department in their organisation.

In parallel, an in-depth analysis of foresight literature has been set up. More than 110 foresight reports have been analysed covering both the enlarged Europe, the USA and Japan.

1.1 Our definition of a key emerging technology

1.1.1 Main criteria to define an emerging technology

At the outset of our study, we have considered that "emerging science and technology developments" include only **issues that are at their early stage of development at a science and technology level**.

The main criteria to define emerging developments are thereby the following:

- preponderance of basic research and invention activities,
- far expected date of maturity (at least 10-15 years).

Even when having a high potential of development, science and technology developments already mature or in growth are thus not considered in this report as "emerging science and technology development".

(3) The 40 selected emerging priorities are Listed in annex of this report

Several elements provide valuable indicators as to whether a particular technology is still in the emergence phase or already more advanced in its development:

- expected date of maturity (at least 10-15 years)
- expected date of commercial application (at least 15 years)
- qualitative comments coming from experts or foresight studies

This criterion of maturity is analysed for the 40 technologies in the table below, where "M" means mature, "G" in growth and "E" expected.

According to the experts consulted, amongst the 40 emerging science and technology priorities five will be mature on 2025 and four have an expected date of maturity posterior to 2030. The majority of them (24) have an expected date of maturity in 2030. None of the emerging science and technology priorities selected are expected to be mature before 2025.

Table 1: Expected date of maturity of the emerging science and technology priorities

Priority emerging technologies	2015	2020	2025	2030	after 2030	Level of uncertainty
Supply chain management	G	G/M	M	M	M	1,31
Software technologies for transport of digital data	E/G	E/G	M	M	M	1,71
More efficient energy consumption	E	G	M	M	M	1,66
Image sensors	E	G	M	M	M	1,88
Mobile communications (4th generation mobile phone)	E	G	M	M	M	1,35
Advanced technologies for virtual reality / augmented reality	E	G	G	M	M	1,68
Advanced data mining technologies and high performance data storage systems	E	G	G	M	M	1,76
Ultra-thin functional coatings	E	G	G	M	M	1,94
Bioactive materials and surfaces	E	E	G	M	M	1,90
Application of stem cells in the treatment of different diseases	E	E/G	G	M	M	2,38
Inherently smart materials	E	E	G	M	M	1,59
Low-cost high-efficiency solar cells	E	G	G	M	M	2,04
New technologies for fuel cells	E	G	G	M	M	1,80
Biofuels	E	G	G	M	M	1,76
New energy storage technologies	E	G	G	M	M	2,14
Capture and storage of CO_2	E	G	G	M	M	1,81
Air/water purification	E	G	G	M	M	2,00
Active packages	E	G	G/M	M	M	1,56
Tissue engineering	E	G	G	M	M	1,71
Individualised health services and drugs	E	G	G	M	M	1,86
Techniques for diagnosis and repairs of structures	E	G	G	M	M	1,81
Bio-genetic materials	E	E	G	M	M	2,33
Human genomes and proteomes	E	E	E/G	M	M	1,78

Priority emerging technologies	2015	2020	2025	2030	after 2030	Level of uncertainty
Embedded single-chip applications	E	E	E/G	M	M	1,77
Broadband network	E	E/G	G/M	M	M	1,70
Computer-aided surgery	E/G	G	G	M	M	1,92
Protein engineering	E	G	G	M	M	1,70
Design of structures with intelligent behaviour and response	E	E/G	G	M	M	2,00
Logistic chaines based thoroughly on RFIDs	E	E	E	M	M	1,56
Renewable and recyclable materials	E	G	G	G	M	1,62
Mutlipurpose intelligent and mobile robots	E	G	G	G	M	2,00
Large-scale DNA analysis	E	E	G	G	M	1,67
New tools for in-vivo diagnostics	E	E	E	G/M	M	1,83
Nanocomposites and nanometrical reinforcements in electronics, chemistry, medecine…	E	E	E	G	M	1,73
Complete modeling for the transfo-rmation of materials and integration in databases – Virtual chemistry	E	E	G	G/M	M	1,77
Cell therapy	E	E	E	G	G/M	2,00
Nanotechnology and nano particles in therapy	E	E	E	E	E	1,71
Microsensors and nanosensors	E	E	E	E	E	1,78
Bio chips	E	E	E	E	E	1,85
Fusion power	E	E	E	E	E	2,21
Intelligent artificial limbs	E	E	E	E	E	1,71

1.1.2 The potential impact of a technology

While the definition presented above focuses on the “emerging” part of the technology, it needs to be complemented by a clarification of the meaning of “key” or “priority”. The evaluation as to whether or not a given technology is a key one is closely related to an assessment of its potential impact. In order to analyse this potential impact, the study suggests to the experts four different main issues, asking them to assess the potential impact of the technology on each of the following issue:

1. Impact on science and technology
    a. Overcome technology barriers
    b. Interactions with other technologies
    c. Return effect on further research activities
    d. Create an EU S&T advantage

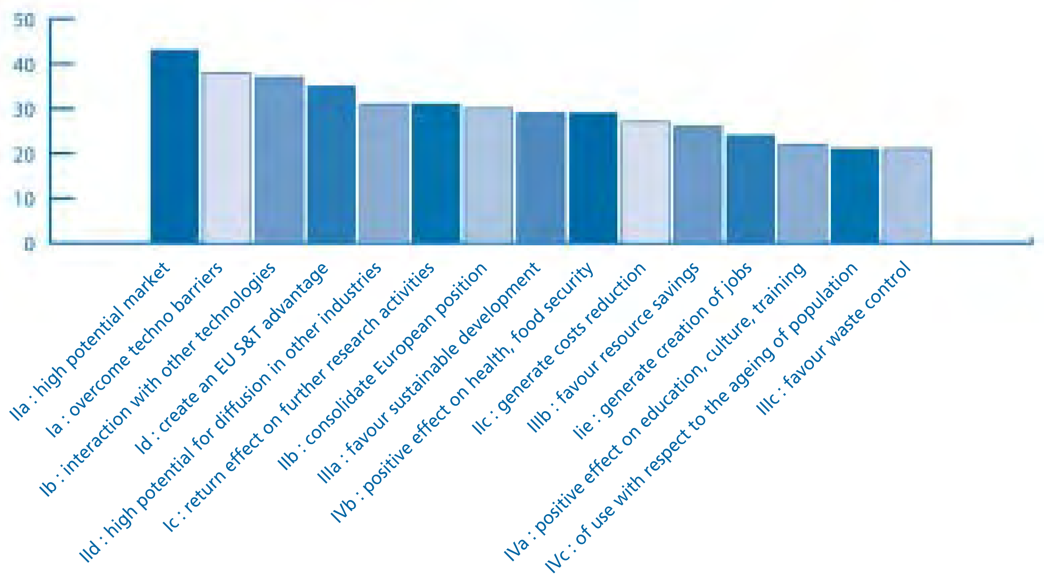
2. Impact on industry and business
    a. High potential market
    b. Consolidate European position
    c. Generate cost reduction
    d. High potential for diffusion in other industries
    e. Generate creation of jobs

3. Impact on environment
    a. Favour sustainable development
    b. Favour resources saving
    c. Favour waste control

4. Impact on quality of life
    a. Positive effect on education, culture and training
    b. Positive effect on health, food security
    c. Targets ageing issue

The detailed importance of each type of impact can be seen in the following figure.

Figure 2: Relative impact of the 40 selected emerging technologies
Global indicator of importance of each proposed criteria



1.1.3 The experts' assessment

Focusing on the emerging technologies with the most important impact, the analyse shows that "more efficient energy consumption (hybrid cars, diode-based lighting technology, new technologies for monitoring and controlling heat and ventilation)" ranks, according to the experts, first in terms of its impact at both economic, scientific, environmental and quality of life level.

In the same way, considering the ten most important technologies in terms of their impact on each of the four criteria, it has to be noted that six of these are "transversal" in the sense that their impact is not restricted to any one particular issue group:

- More efficient energy consumption (hybrid cars, diode-based lighting technology, new technologies for monitoring and controlling heat and ventilation)
- New technologies for fuel cells
- Low-cost high-efficiency solar cells
- Multipurpose intelligent and mobile robots
- Bioactive materials and surfaces (Biopolymers, Biocompatible materials, Bone replacement materials, Nano structured surfaces for implants, Titanium dioxide nano particles for anti-bacterial surfaces, Silver nano particles as antibiotics, Cellulose-based materials)

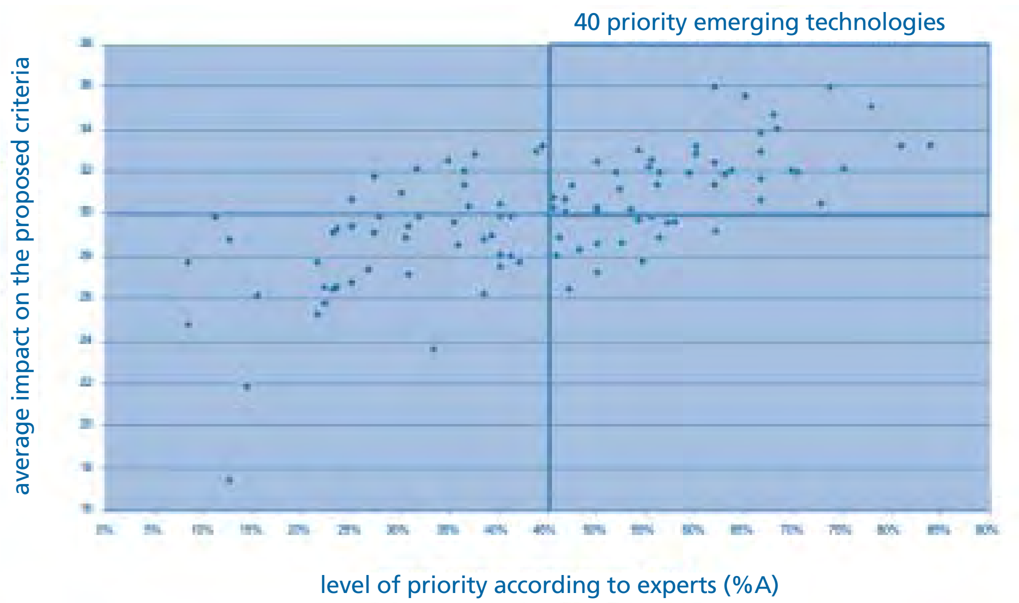
- Advanced data mining technologies and high performance data storage systems (e.g. Intelligent systems for decision-making, Computer modelling and design of systems and processes)

In conclusion of the analysis of the potential impact of the emerging technologies it can be said that at least for most of the technologies having an important impact, this latter one is not sectored on any particular criterion but rather transversal in nature, impacting on all of the four criteria.

Methodology: the selection of 40 emerging technologies

The selection has been made on the basis of both an assessment of the importance of the potential impact of the 104 pre-selected technologies through a foresight literature review and the relative priority level of each technology, arrived at by means of an expert panel survey. The figure hereafter describes the results of the selection process.

Figure 3: Selection of the 40 priority emerging technologies



1.2 Foresight literature review

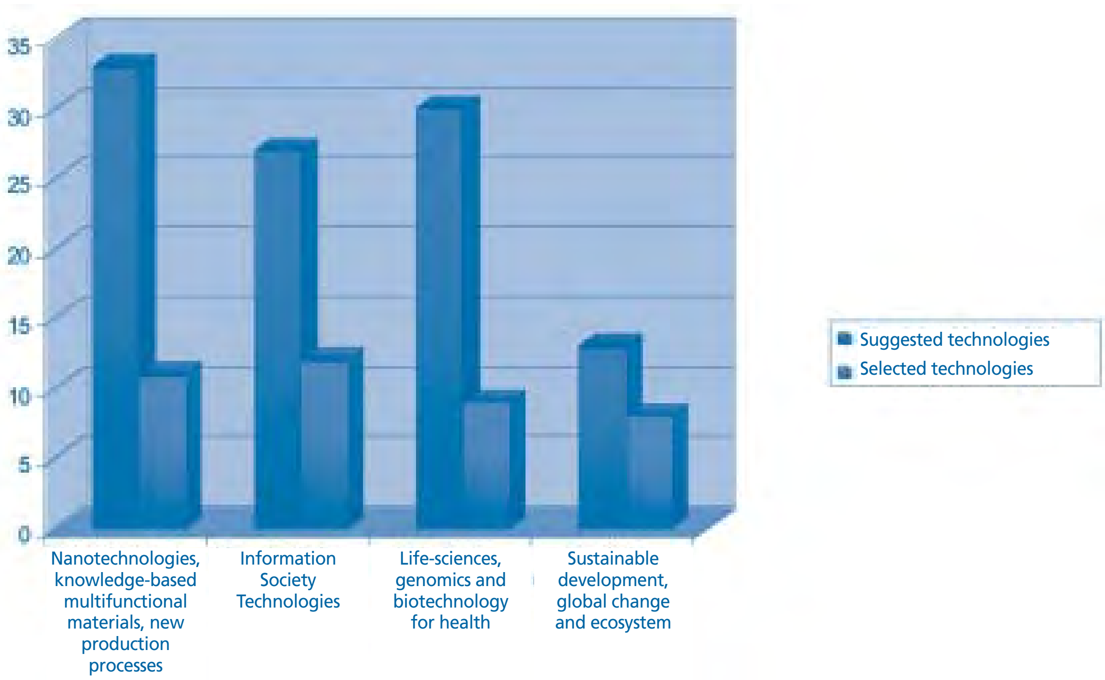
1.2.1 A coherent vision of emerging technologies

The foresight reports that have been analysed in the context of this study deliver a coherent and convergent vision of emerging sciences and technologies. No matter whether the focus was on a specific scientific field or geographic area, no strong divergences have been identified between the visions of the future and the expected progresses in science and technology.

One hundred years after the rupture caused by the publication in 1905 of the two articles by Einstein about relativity, on the one hand, and quantum, on the other hand, no similar breaks are foreseen in the future (even if we know today that the two theories are not compatibles). The evolution of sciences and technologies are assessed on the basis of what we already know, reflecting current paradigms. The main evolution that is visible concerns the influential role of environmental issues as important accelerators to technology developments.

It has therefore been relatively easy to formulate a first list of 104 emerging technologies before selecting the most important ones on the basis of our definition. It needs, however, to be underlined that the number of selected technologies is not related to the number of suggested technologies. As can be seen in the graph below, this distinction is particularly important for the Sustainable Development scientific field. It seems that either few emerging technologies are identified by means of foresight exercises in that fields (indirectly converting a majority of them into key ones) or alternatively that foresight practitioners underestimate the importance of Sustainable Development altogether as a crucially important scientific field for the years to come.

Figure 4: Suggested versus selected technologies by scientific field



1.2.2 The confusion between applications and technologies

Another important point resulting from the analyses of the foresight literature that needs to be underlined refers to the frequent confusion between applications and technologies. In fact, this confusion is mainly due to the different entry points used by different foresight exercises.

Indeed, foresight analyses looking at "emerging technologies" have two main entry points: technology field and application field. However, any one application field does not necessarily refer to any one technology field and a combination of very different technologies will at times correspond to a specific single application. In the same sense, one technology can be used in a variety of different application fields. Table 2 summarises this differentiation Table 3 provides a list the 40 selected technologies in positioning them depending on their application/technology focus.

Table 2: Application versus technology

	1 technology field	More than 1 technology field
1 application field	Technology field with mainly one application field	Application field with very different technologies
More than 1 application field	Technology field (with many possible applications)	(void)

Table 3: Functional list of selected technologies

Technology field (with many possible applications)	Technology field with mainly one application field	Application field with very different technologies
	Bioactive materials and surfaces	
	Complete modelling for the transformation of materials and integration in database	
Bio-genetic materials		
Inherently smart materials		
	Nano technology and nano particles in therapy	
	Nanocomposites and nanometrical-nanoscale reinforcements	
Ultra-thin functional coatings		
	Supply chain management	
	Logistic chains based thoroughly on RFIDs	
Design of structure with intelligent behaviour and response		
Software technologies for transport of digital data		New techniques for diagnosis and repairs of structures
	Broadband network	
	Mobile communication (4^{th} G)	
Advanced technologies for virtual reality/ augmented reality		
	Computer-aided surgery	

Technology field (with many possible applications)	Technology field with mainly one application field	Application field with very different technologies
		Individualised health services and drugs
Advances data-mining technologies and high performance storage systems		
Embedded single-chip applications		
Multipurpose intelligent and mobile robots		
Image sensors		
		Intelligent artificial limbs
Microsensors and nanosensors		
	Capture and storage of CO_2	
	Air-water purification	
	Low-cost high efficiency solar cells	
	New technologies for fuel cells	
Biofuels		
		More efficiency energy consumption
		New energy storage technologies
Renewable and recyclable materials		
Cell therapy		
		New tools for in-vivo diagnosis
Bio-chips		
Tissue engineering		
	Application of stem cells in the treatment of different diseases	
		Active packages
Large-scale DNA analyses		
	Human genomes and proteomes	
Protein engineering		

1.3 Typology and characterisation of the selected technologies

This first typology of the 40 selected technologies in terms of the differentiation between technology field and application field needs to be complemented by an in-depth analysis of these technologies for the purpose of the present study. While a first distinction refers to the scientific field, at a secondary level and using the experts' points of view, it is possible to establish a hierarchy of the priority levels accorded to each technology within the European context.

1.3.1 Four scientific fields

The 40 technologies can be classified within four main scientific fields:

- Nanotechnologies, knowledge based multifunctional materials, new production processes
- Information Society Technologies (IST)
- Life-Sciences, genomics and biotechnology for health
- Sustainable development, global change and ecosystem

The classification of the 40 technologies within these scientific fields is the following:

Bioactive materials and surfaces (biopolymers, biocompatible materials, bone replacement materials, nano structured surfaces for implants, titanium dioxide nano particles for anti-bacterial surfaces Silver nano	**Nanotechnologies, knowledge-based multifonctional materials, new productions processes**
Complete modeling for the transformation of materials and integration in databases - Virtual chemistry	
Bio-genetic materials	
Inherently smart materials	
Nanotechnology and nano particles in therapy (e.g. liposomes, polymeric nano particles, active ingredient nano crystals, drug delivery, polymer therapeutics, fullerene, thermo therapy with nano particles)	
Nanocomposites and nanomaterials-nanoscale reinforcements in electronics, chemistry, medecine… Application among others : "components of next-generation computer"	
Ultra-thin functional coatings	
Supply chain management	
Logistic chains based thoroughly on RFIDs	
Design of structures with intelligent behaviour and response	
New techniques for diagnosis and repairs of structures (sensors, metrology, simulation…)	

Software technologies for transport of digital data	**Information society technologies**
Broadland network (advanced optical communication, Multiprotocol label switching, IP/WDM…)	
Mobile communications (Fourth generation mobile phone)	
Advanced technologies for virtual reality / augmented reality	
Computer-aided surgery	
Individualised health services and drugs	
Advanced data mining technologies and high performance data storage systems (e.g. Intelligent systems for decision making, computer modelling and design of systems and processes	
Embedded single-chip applications	
Multipurpose intelligent and mobile robots	
Image sensors (robot perceptive systems, image processing…)	
Intelligent artificial limbs	
Microsensors and nanosensors	

Capture and storage of CO_2	**Sustainable development, global change and ecosystem**
Air/water purification (Artificial rain, international water, transfer system, advanced wastewater treatment and recycling, quality monitoring, adavanced seawater desalination, sewage purification system)	
Low-cost high-efficiency solar cells	
New technologies for fuel cells	
Biofuels	
More efficient energy consumption (hybrid cars, diode-based lighting technology, new technologies for monitoring and controlling heat and ventilation)	
New energy storage technologies (flywheels, supercaps, supraconducting magneto-electrical storage	
Renewable and recyclable materials	

Cell therapy	Life-sciences, genomics and biotechnology for health
New tools for in-vivo diagnostics (e.g. contrast media for ultrasonics, nuclear visual methods...)	
Bio chips (DNA chips, protein chips, labs-on-a-chip, cell chips, nanotech for the further development of tissue engineering	
Application of stem cells in the treatment of different (e.g. neurodegenerative) diseases	
Active packages (new materials included biodegradable packaging, micro-sensors for food security	
Large-scale DNA analysis	
Human genomes and proteomes	
Protein engineering	

This classification is mainly useful for methodological purposes. It is at this field level that comparisons can be made in terms of public budget, country-level particularities or socio-economic factors motivating particular public policy strategies.

As a matter of fact, each scientific field has its particular characteristics at the socio-economic level. These particularities can cover four main subject areas:

- **Economic:** the existence of strong industrial base, the level of competitiveness, the market potential,…
- **Societal**: the existence of a collective-societal issue, ethical issues, awareness and public/scientific acceptance,…
- **Scientific and technologic:** the history of the field (advantage for the first comer?), resources in R&D and education systems, technology transfer issue,…
- **Politics:** legislation issues, coherence of R&D organisation and funding schemes, fiscal environment,…

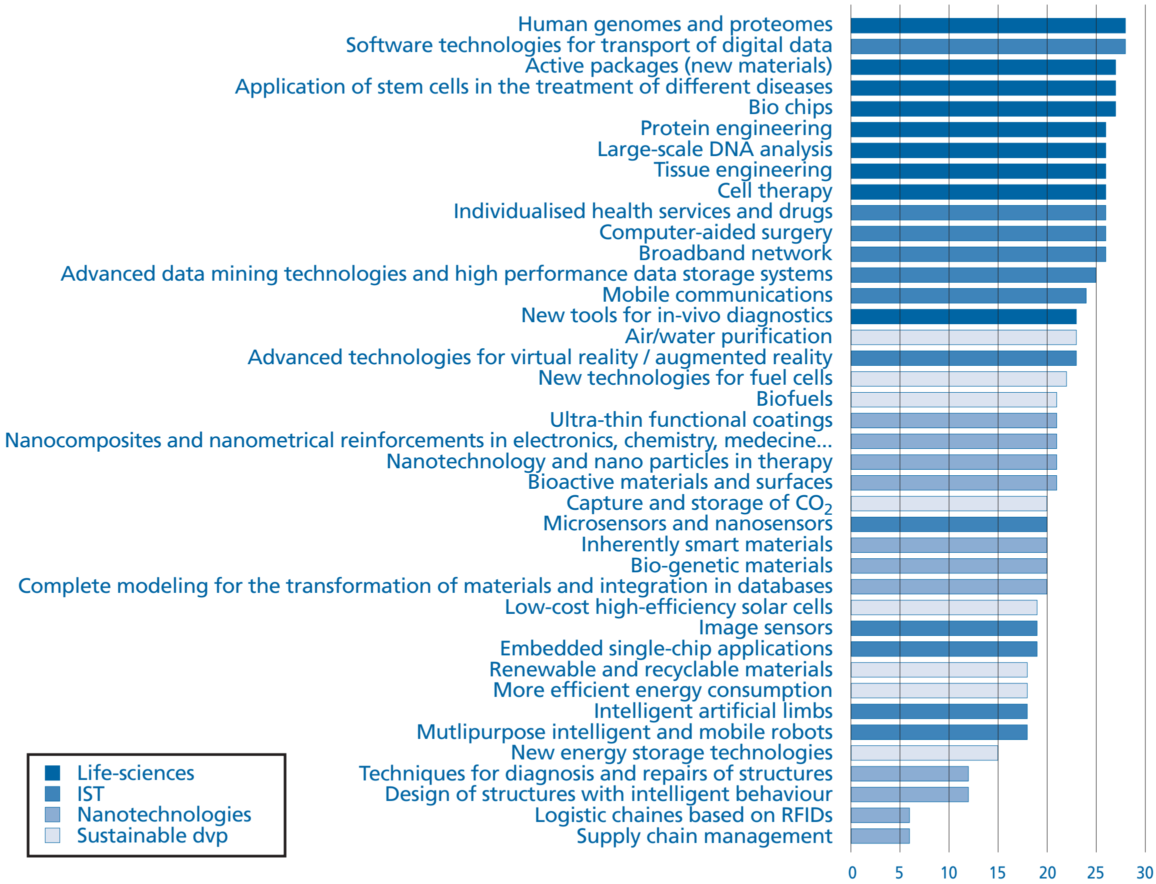
However, this distinction must be considered with caution in a foresight exercise. While it is evident that IST, for example, are by nature horizontal (finding use in a large number of applications covering the totality of the scientific fields), it seems that the issue of convergence at the scientific field level is of utmost importance for current and future R&D performances. As a matter of fact, to successfully exploit the full potential to be realised through the many links between nanotechnologies and computing (nano-computers), between neurology and nanosensors, between mobile communications technologies and technologies for health, between nanotechnologies and photovoltaics… constitutes one of the key challenges facing Europe and its main competitors in the years to come.

There exist various ways to promote potential links between different scientific fields, and public policies have an important role to play. By means of lending support to the creation of multidisciplinary institutes, paying the necessary attention to projects featuring scientific links, targeting project applications requiring scientific cooperation, supporting the setting up of forums for debate and a variety of networking tools, creating specific multidisciplinary budget lines… individual countries and/or Europe can have a major impact in facilitating relationships at least at the level of basic research. This aspect will be further analysed in this report.

1.3.2 Organisation into a hierarchy

One of the questions asked to the expert panel was to classify each technology, in terms of priority for Europe, using a three levels' scale from strong priority, moderate priority and weak or no priority. On the basis of the experts' point of view, this information has been translated into a hierarchy of the 40 selected technologies according to their relative level of priority.

Figure 5: Hierarchy of the 40 priority technologies



As being reflected in the above figure, the experts' view is quite homogeneous in its emphasis on the priority to be accorded to life-sciences technologies. Only one technology belonging to this scientific field is not classified within the ten most prior ones: "New tools for in-vivo diagnosis". While at this stage it is not yet possible to explain this choice, it can be underlined that "in-vivo" technologies frequently provoke public debate on ethical questions. Moreover, it can be pointed out that amongst the IST that are classified as the most prior ones, two relate to health issues ("individualised health services and drugs" and "computer-aided surgery").

At the opposite end of the scale, Nanotechnologies are not seen as the most prior technologies by the experts. However, significant differences between the technologies can be highlighted. The same phenomena can be observed for the scientific fields of Sustainable Development and IST. As far as this last field is concerned, it is interesting to note that while the more prior technology is of key importance for the future, it does not necessarily represent an area in which Europe would be considered a leader in scientific terms ("software technologies for transport of digital data", to be linked with the third prior rank in this field accorded to "broadband network" technologies).

Amongst the 25 most important firms in the European IST sector, none is working in the area of broadband networks. In the USA, by contrast, Cisco and Nortel communication are classified at the 6th and 12th rank of the most important US IST firms respectively, with the annual turnover of each of these two firms being largely superior to the turn over of the most important European IST firm (STMicroelectronics).

Source: http://solutions.journaldunet.com/0509/050901_europe_it.shtml

2. Public policy support and main drivers

This chapter intends to provide a more in-depth understanding of the public policy support in Europe and its main underlying rationales. The focus will thereby be particularly on the importance of the support given to R&D activities in the four major scientific fields that our study has underlined as the ones in which emerging technologies are the most prior ones for Europe.

The first part will look at the major investment strategies in the USA, Japan and Europe, thereby highlighting the main existing differences between Europe and its two main competitors as far as relative importance accorded to specific scientific fields is concerned. Moreover, an attempt will be made to describe the main R&D strategies as part of a more global environment which is politic, economic, legal, cultural, historic, etc. This extended focus will facilitate the identification of key factors explaining R&D public policy and budget allocation in the three geographical areas.

The second part, in turn, will analyse the heterogeneous impact of a number of very diverse key factors on the four scientific fields, potentially acting as the main drivers for policy support. To this end a distinction has been made between four main sets of factors that will be helpful in the context of the ensuing analysis: Political factors, economic factors, social factor and environmental factors. The result of this part of the study will be qualitatively improved and a more in-depth comparison between Europe, the USA and Japan.

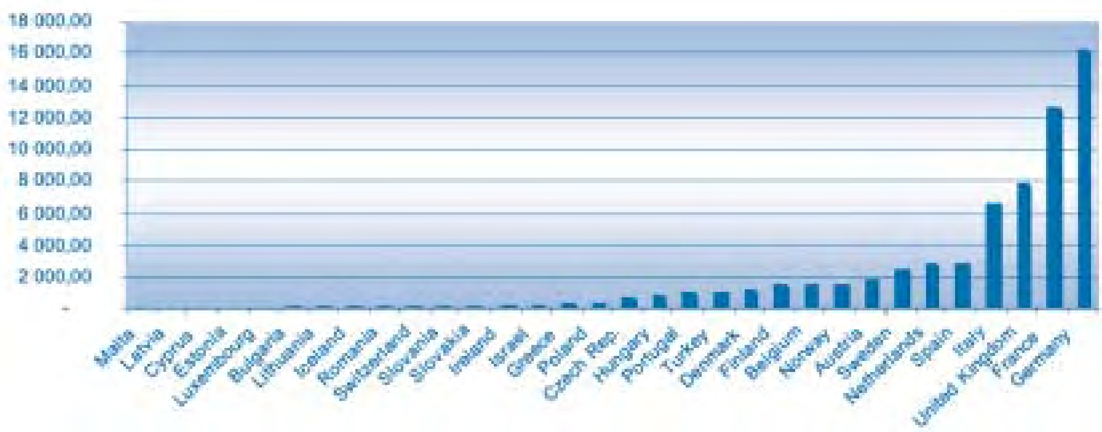
2.1 Investment strategies and main drivers

2.1.1 Investment strategies

Investment strategies are easily measurable, both within Europe at country level and in comparison with the USA and Japan, as long as we stay at scientific field level. At a more detailed level, such as the technology one, however, the largely insufficient access to relevant figures makes a meaningful analysis almost impossible.

A first possible analysis is a very generic one on the public R&D budget at European level. The figure hereafter[4] shows the main variations between the different states included in our study.

Figure 6: Public R&D budget in Europe (in M€[5])

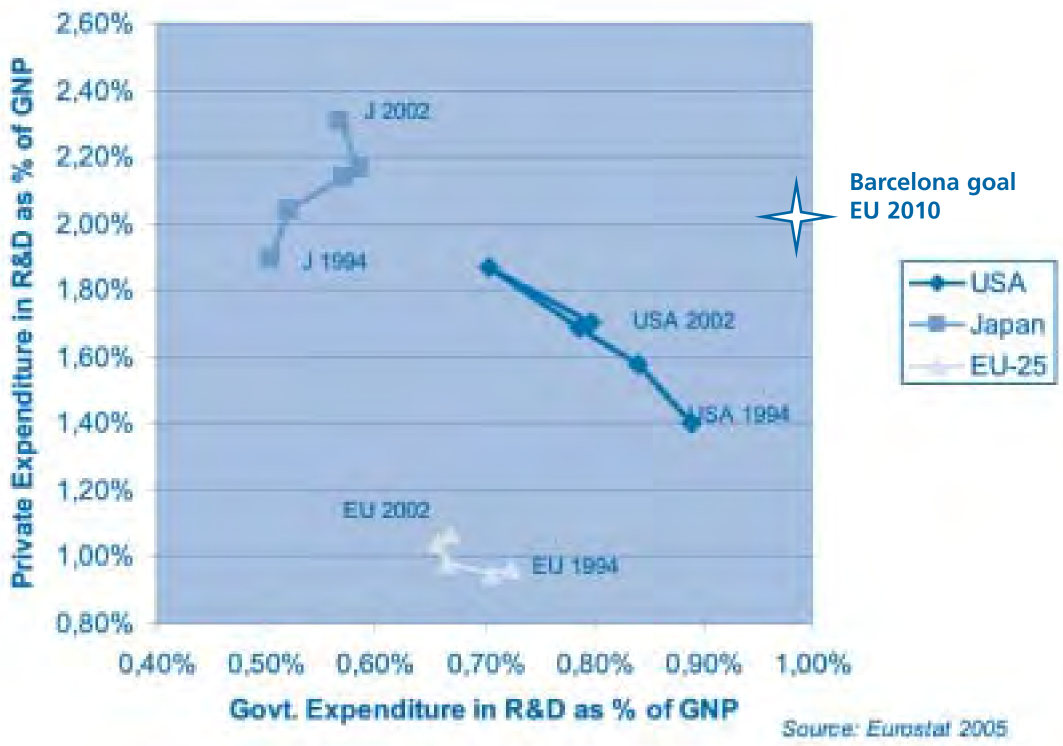


(4) Cf. annex 3 for details and sources
(5) Cf. sources in Annex 7

As can be seen from this graph, four European countries, i.e. Italy, United Kingdom, France and Germany, represent 64% of the global R&D budget in the enlarged Europe. Adding to these countries Spain, Netherlands and Sweden, the sum of the public R&D budget of these 7 countries represents more than 76% of the global European R&D public budget. An analysis which is solely based on an evaluation of budgetary priorities at European level thus reflects much more the particular strategies of the continent's 4 to 7 top-spending countries than a real European strategy shared by all of its members.

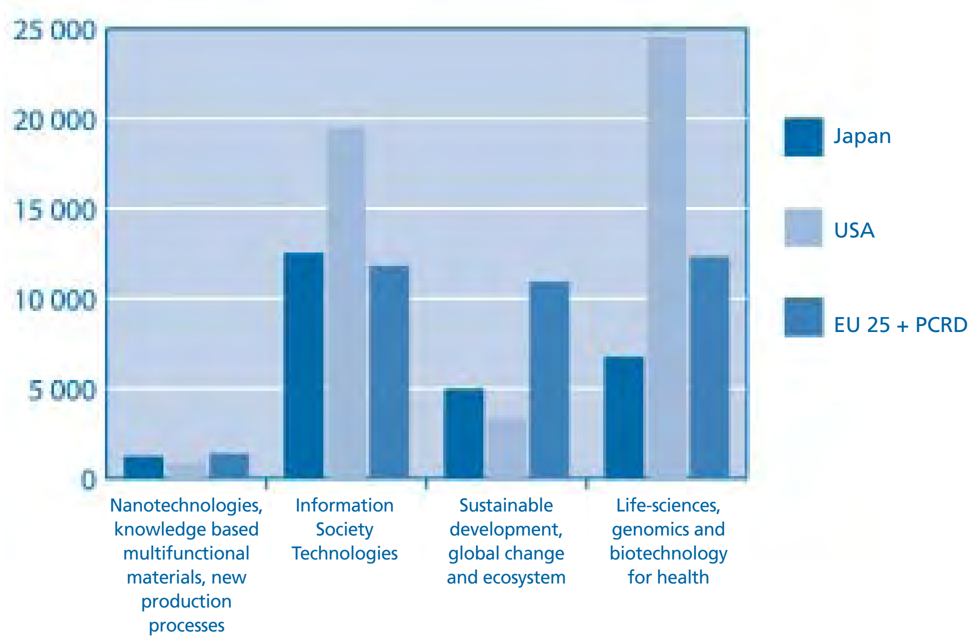
With such a level of disparity, the global average in terms of research intensity is clearly at Europe disadvantage, as shown in the graph below.

Figure 7: Research intensity in Europe, the USA and Japan 1994-2002



However, even when making abstraction of this limitation, the comparison between the public budget strategy in Europe with the ones existing in the USA and Japan is very instructive, as can be seen in the graph below.

Figure 8: Distribution of public budgets by scientific fields in the Japan, the USA and EU[6]

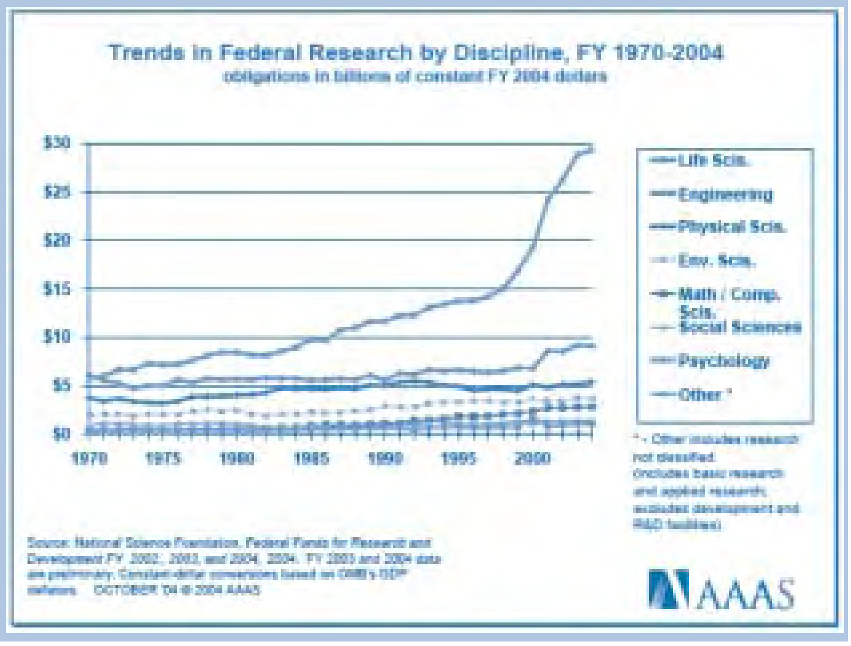


Above all, this graph shows that public budget policies in the USA and Japan are a clear reflection of the relative priority levels attributed to the different scientific and technological fields. Thus, IST and Life Sciences concentrate 77% and 73% of the total public R&D budgets in the USA and Japan respectively.

The strong priority accorded to the life sciences scientific field in the USA

Clearly becoming a priority in the USA, the Life Science field has been progressively growing since the 70s, with a huge increase since 1997.

Figure 9: The growth of life-sciences in the USA



(6) Cf. Annex 7

In the same period, the importance of basic research in this field has been constantly growing (another huge leap in 2000), supported through its main agency: the National Institute of Health (NIH).

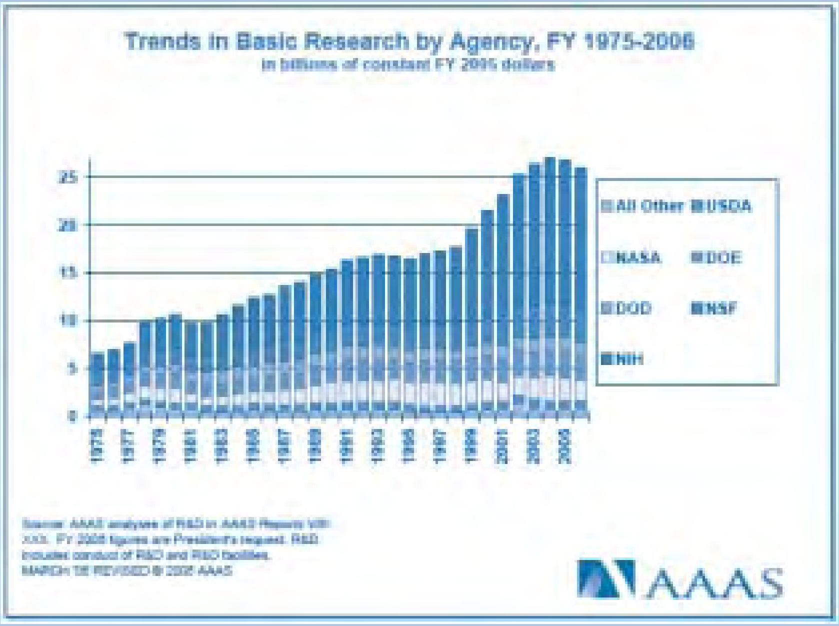


Figure 10: Relative importance of basic research in life-sciences in the USA

At the same time, 80% of European R&D funding is focused on 3 scientific and technological fields: communication and information technologies, biotechnologies, but also the sustainable development, which includes environment and energy. This choice clearly reflects the intention to be in the forefront as far as ICT and life sciences are concerned and not to be outdistanced by the USA and Japan[7]. The relative budgetary importance of the technologies related to sustainable development, in turn, corresponds to Europe's attempt to maintain its international influence in this field and to ensure a world leadership as far as related technologies are concerned. However, the inherent risk is that of a dispersion of efforts which is all the more acute as the policies of the various Member States of the EU are not sufficiently coordinated.

Lastly, this graph points out that the support for research in the nanotechnologies and materials is generally relatively weak, both in Europe, the USA[8] and Japan. This could be one of the reasons why experts have not classified the technologies of this field amongst the most prior ones.

In addition to public funding, other forms of support can be mobilised at national level to support R&D. It is impossible to list all the relevant policies that can be used, as they can focus both on specified issues (legal issues, fiscal incentives…) or large ones designed to impact the general environment al context itself (economic, social, politic…).

(7) The number of patents deposited to the OEB by the US firms is 2,38 times superior to that of EU origin.

(8) The graph only takes into account the efforts made in the field of nanotechnologies. Indeed, the budgets allocated to materials are not clearly distinguished in the programs of public research of the Member States of the European Union. Budgets allocated to materials by the United States and Japan rise to 58 and 95 million € respectively.
Source for the USA: http://www.france-science.org/publications/materiaux/
Source for Japan: www.swiss-japan.org/sts/cours_sts_contexte_actuel.ppt

2.1.2 Strategies' rationales

A) The USA

Key factors for understanding USA policies related to Japan and Europe on emerging technologies

• **Security of the nation: from cold war to September 11th**.Security has always been a top priority, directly impacting the US R&D budget allocation. However, due to the end of cold war and the new threat of terrorism, the funds have shifted from traditional "defence" towards "homeland security". The defence related budget of basic research has thus declined by 13% between 2004 and 2006, while the homeland security budget increased by 32%. The same evolution can be observed in the areas of applied research (-15% vs +15%), development (+2% vs +25%), and facilities and equipment (-68% vs +35%)[9]. More generally, it is important to underline that this new focus on homeland security comes with an increased emphasis on applied technologies rather than fundamental R&D. The main scientific sectors to benefit from this new priority given to homeland security are biology, chemistry, radiology, genetics as well as the nuclear sector.

• **The economic competition is no longer based on technological supremacy, but on scientific convergence capacity**. Until only a few years ago, inter-agencies R&D programs were supported by the Federal government with a particular focus on applications in an attempt to achieve technological leadership (e.g. programs associating the Department Of Defense and NASA). This is still the case in certain fields, such as Defence, Homeland security R&D or Networking and Information Technology R&D *("supercomputing and cyber-infrastructure R&D should be given higher relative priority due to the potential of each in furthering progress across a broad range of scientific and technological applications"[10])*. At the same time, a more recent trend, supported at highest political level, attributes increasing priority to converging scientific fields in an attempt to foster economic development. This is, for example, the case for nanotechnology by means of the National Nanotechnology Initiative *("…key to facilitating breakthroughs and to maintaining US competitiveness"[11])*. Nanotechnology provides thus an important example of R&D being supported for economic reasons and leading to a complete reorganisation of the scientific field by means of a common political initiative. The same trend is also visible in the Life Sciences field. Beyond the attempts to safeguard the technological leadership necessary in the "traditional fields" (and ICT seems to belong to these traditional fields), the USA increasingly focuses on completely new, potentially highly rewarding economic activities that result from scientific convergence which, in turn, becomes a key challenge for economic development in the future.

• **An ageing population and a particular sensitivity to certain diseases** make the improvement of human health a high priority mainly through Life Science R&D support. Even though (or because?) the life expectancy in the EU exceeds that in US, the demand for a healthy and long life is an important social issue in the US context. Complex areas of research, such as on obesity, Alzheimer's, diabetes, or infectious disease are reflecting this priority. Economic factors are thereby not ignored as the US pharmaceutical industry is very important and research on infectious disease targets also plants and animals, and thus both agriculture and agro-food sectors.

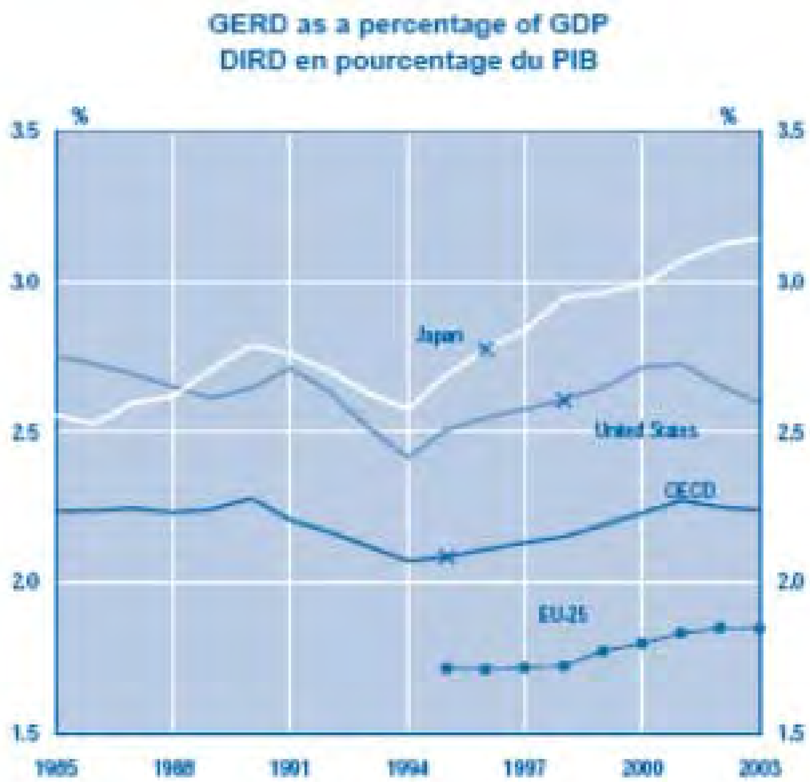
(9) R&D Chapter 2006 – US federal Budget 2006 – www.ostp.gov/htm/budget/2006/FY06RDChapterFinal.pdf
(10) "2006 budget priority memo" OSTP, www.ostp.gov/htm/m04-23.pdf
(11) Idem

• **National energy security appears as a political priority both for economic growth and national independence**. This priority translates itself into support to hydrogen, fuel cells, nuclear and fossil fuels research. But with the climate change threat becoming increasingly urgent, related R&D activities go beyond the energy issue in order to equally address the areas of **water issues** and **earth observation**.

Some additional environmental factors have to be underlined for a better understanding of public policy support to R&D in the USA

1) The real decline of GERD as a percentage of GDP

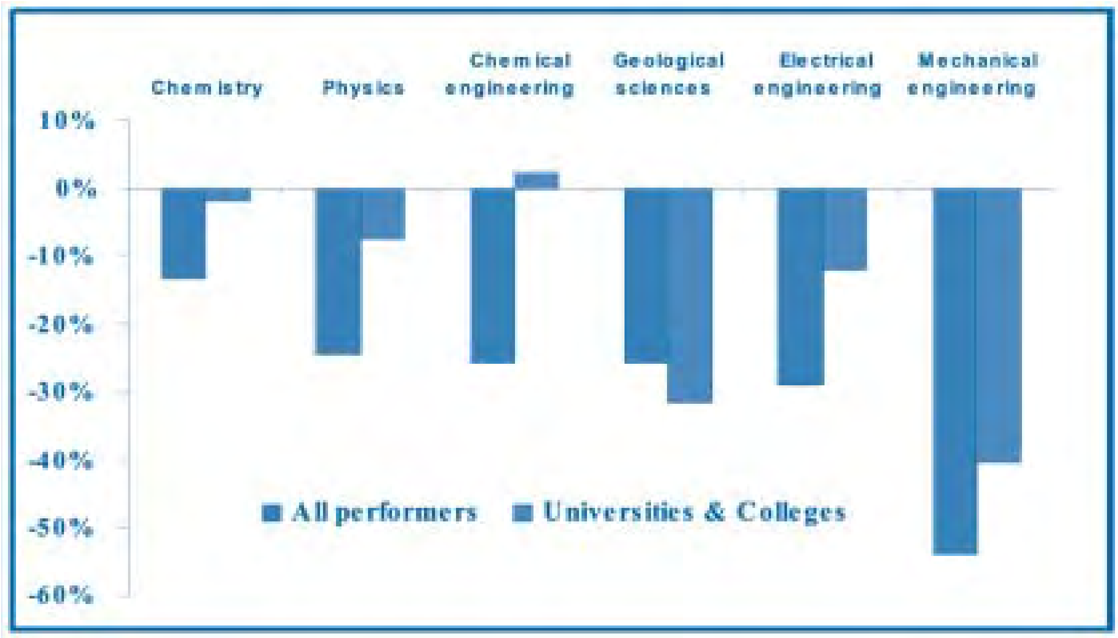
Figure 11: The decline of basic research in the USA



Source: OECD Science an innovation key figures 2005 http://www.oecd.org/dataoecd/49/45/24236156.pdf

The above table shows clearly that the global R&D support in the USA has been declining since the beginning of the new millennium. This decline is particularly pronounced for industry-financed R&D. Federal support seems to be on the rise during the period, but (1) it is not sufficiently strong to balance the global decline, and (2) it is based on somewhat discriminatory priority choices (homeland security, for instance). Charles W. Wessner has, for example, underlined a decline in the involvement of the Federal Obligations for Research in some scientific fields[12]: The Wessner' analysis describes a trend that, if confirmed in the coming years, will have an important impact in terms of engineering capacities in the US (see table hereafter).

Figure 12: The decline of USA R&D funding by sectors



Finally, and taking into account the general evolution of US public R&D budgets, 2006 will be the first time when the country's overall R&D budget will not increase compared to the previous year and will fall behind inflation[13].

2) The end of the Promised Land for foreign researchers

Since decades, the USA has been an attractive country for students and researchers. The capacity of attracting human resources thereby constitutes a highly important factor in support of a dynamic R&D landscape. However, the USA's more restrictive visa policy, adopted in the wake of the September 11th attack, has the negative side effect of preventing the entry of some of the best and most promising student and research potential. While it is too early to assess the negative impact of this policy in terms of human resources for R&D, this potentially important factor (of change) cannot be ignored in the context of foresight scenarios.

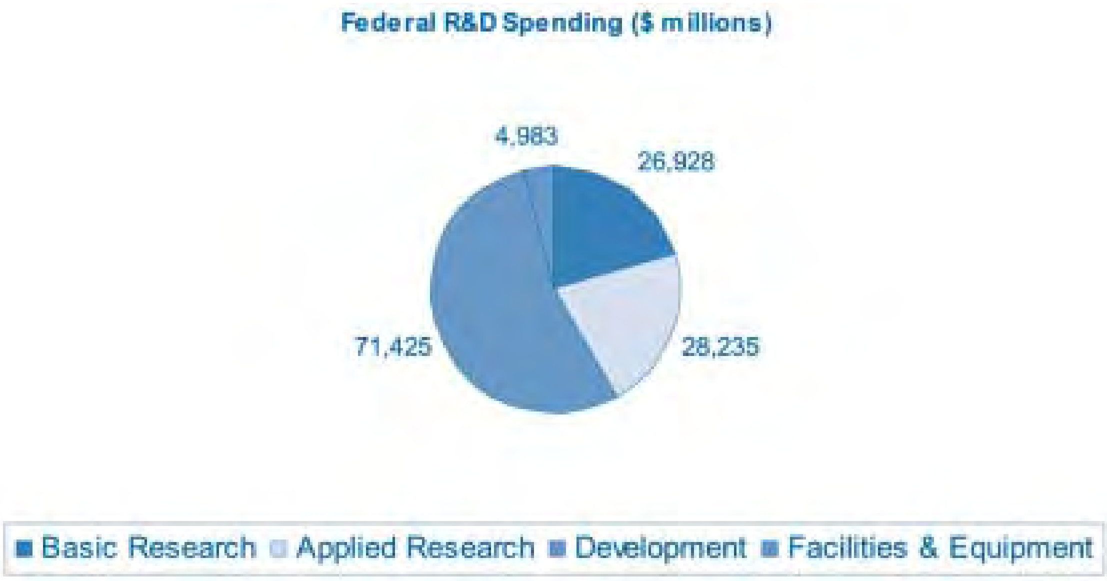
3) The importance of Applied Research and Development

Looking at the Federal spending (table hereafter shows estimated spending in 2005[14]), it appears that basic research in the USA at Federal level is less important in terms of corresponding budget allocation as is commonly thought.

(12) Charles W. Wessner, "Current trends and challenges in the US innovation system" Zagreb, June 5, 2004, power point presentation: http://www.mzos.hr/Download/2004/06/05/Wessner.ppt

(13) Kei Koizumi, Historical Trends in Federal R&D, AAAS Report XXX: Research and Development FY 2006, www.aaas.org/spp/rd/06pch2.htm

Figure 13: The relative importance of applied research and development in the USA



Another way to measure the relative weakness of basic research is to look at the "investment criteria" that have been initiated through the "President's Management Agenda" which are (1) Relevance, (2) Quality and (3) Performance (complemented by a suggested list of indicators).

While the use of such criteria can easily match applied research or development activities, some doubts exist as to their relevance to basic research.

4) The capacity to change R&D priorities according to major evolutions

This last point is certainly essential to the understanding of the factors motivating public policy support in the US. As has been analysed in detail by the AAAS[15], internal or environmental factors have in fact the potential of dramatically modifying the priorities underlying R&D budgets. Space-related R&D activities were thus a crucial priority during the 60's for political reasons and the decision to be the first nation to send a human being on the moon. (While the first rationale was political, K.J.Galbraith has analysed the impact of such a policy in terms of economic development). In the wake of the oil crisis energy became an important priority in the 70s. At the end of the 90s (and due to the decision to double the budget of the National Institute for Health within 5 years) Life Sciences became the focus of increased interest from different social (and economic) factors. Since September 11th, public support has been focused on Homeland Security R&D activities. While this capacity to change priority settings can be seen as an advantage in terms of an increased adaptability to new constraints, it can also be interpreted as a weakness for basic R&D that requires time and constant effort to provide relevant results.

(14) Source: R&D Chapter 2006 – US federal Budget 2006 – www.ostp.gov/htm/budget/2006/FY06RDChapterFinal.pdf
(15) Op.cit. http://www.aaas.org/spp/rd/06pch2.htm

B) Japan

Although Japan is one of the leading countries in the field of S&T, it has experienced a serious depression since the early 1990s due to the intensified economic competition which followed the end of the Cold War. This has led to a decline in R&D investment of private companies which used to account for about 80 percent of R&D investment in Japan[16], and the subsequent deterioration of the competitiveness of Japanese companies.

To overcome this situation and avoid further economic and social crisis, the Japanese government adopted in November 1995 the "Science and Technology Basic Law". According to it, Japan implements every five years a fundamental framework program in order to promote the advancement of science and technology in comprehensive and systematic ways. The first "Science and Technology Basic Plan" (1996-2000) led to the rise of public funds for S&T.

The second plan (2001-2005) aims to continue increasing the public investment in S&T[17] and the effective/efficient resource allocation, and to reinforce the cooperation between industries, universities and government. Thus, Japanese research is often oriented to applied research and development.

In order to *"acquire new markets and give a new impetus to the economy and to secure people's comfortable and safe life"*, the plan has defined four priority areas: Life sciences; Information and telecommunications; Environmental sciences; Nanotechnology and materials. In addition, four other areas of importance have been identified: Energy; Manufacturing technology; Infrastructure; Space and oceans.

Structural reforms have been carried out to improve the S&T environment in Japan and to strengthen the country's R&D capability. Hence in 2003, (1) some universities have been grouped together; (2) evaluation programs of scientific projects have been implemented[18], (3) "intellectual clusters" have been established in the regions to implement S&T policies in the regions and to increase industry-academia collaboration, and (4) public universities have gained independence, with the purpose of enhancing their management.

An additional effort is being carried out concerning the S&T human resources: it is considered as an urgent task to *"attract excellent personnel to the world of science and technology and to prepare an environment that allows them to display their abilities to their utmost"*. For that purpose, Japan aims to build an environment where people engaged in S&T will have the opportunity to acquire the skills required in their fields, to gain practical experience, and where they will be rewarded for their efforts.

(16) [Science and Technology Basic Plan 2001-2005, Government of Japan]. As we pointed out in our last report, the number of Japanese S&T papers (..) is far behind the USA (..) and Europe (..), but the country is first (..) regarding the number of patents. Those facts highlight the importance of private sector in R&D in Japan.

(17) [Science and Technology Basic Plan 2001-2005, Government of Japan]. The objective is to increase the percentage of the national gross domestic product (GDP) to 3.4%, i.e. at the same level as the leading European Countries and the USA. The total amount is estimated about 24 trillion Yens (209 billion €) between 2001 and 2005.

(18) [French Embassy in Tokyo, 2002]. Those evaluation programs permitted to select 113 "centre of excellence", which will receive between 800 k€ and 3.2 M€ each year for 5 years. All selected projects are re-examined after two years.

For FY 2003, the Japanese Diet has voted an S&T budget of 30 billion €. According to a report of the French Embassy in Tokyo ["Le budget pour la science et la technologie, Michel Israël, 2002"], this represents 25% of total public and private R&D investment, which would amount to about 120 billion €.

Key factors for understanding Japanese policies related to the USA and Europe on emerging technologies

1. The economic malaise
This is the main reason. To emerge from this malaise, Japan considers essential the creation of new knowledge and the generation of new industries. It aims to be a "technology-oriented nation".

2. The aging population and the trend towards fewer children
Since creativity is important in the field of science, a decline in the vitality of society is an important concern. The decline in the number of younger people may lead to a decline in the potential in science. The white paper on S&T 2003, highlights that this trend can also present an obstacle to securing successors to technologies and skills in manufacturing.

In addition, an aging population represents an important factor for health related sciences as well as a financial burden for society as a whole.

3. The lack of resources and the geographical position of Japan
Those reasons contribute to explain the Japanese support on food and environmental issues, on research concerning new energies and on earthquake disaster prevention/mitigation.

C) Europe

Key factors for understanding public policies on emerging technologies as being put in place in the European countries in comparison with the USA and Japan

- **Economic factors provide an important factor for the overwhelming majority of the countries**. The promotion of economic development and the strengthening of the competitiveness of specific sectors provide key rationales underlying public policy support. However, **while the link between R&D and economic development is obvious for most of the countries, the link between R&D and job creation (or perhaps between economic development and job creation) is less evident**. As a matter of fact, this link is only really relevant in countries which are large R&D contributors, such as the USA and Japan, and – at European level – France, the UK, Germany, Spain, Sweden Finland, but also Austria, Ireland and Israël.

- **Social factors do not play a preponderant role in most of the countries**. In this context one needs to distinguish between two somewhat different kinds of social factors. On the one hand, the exposure to particular diseases and the challenge of demographic change are very present in the USA and Japan as well as a number of European countries, such as Austria, France, Germany, Spain, Switzerland and – to a much lesser extent

– the Netherlands, Sweden and the UK. On the other hand, the articulation of social demands and the influence of “alternative” consciousness constitute influential factors in more than half of the European countries while they are virtually absent in the USA and Japan.

- **Environmental and quality of life factors are present in most of the countries**. Amongst these factors, the most important ones for both the USA, Japan and the European countries seem to be: the promotion of health and well-being (at the border of social factors) and the awareness of resource depletion with, for most of the countries, a specific focus on energy resources. However, while almost universally classified as “sustainable development”, this field is interpreted in very different ways by the individual countries. **Once again it becomes clear that the concept of “sustainable development” is not understood in the same way by different countries**.

- **The political factor is certainly the most difficult to apprehend in a comprehensive manner**. While the impact of the political factor is rather uneven within different countries, two points can be underlined:

• Countries featuring the most important public R&D support policies in terms of budgets allocated are subjected to a combination of around 90% of the items that compose the political factor. This means that a **strong R&D financial contribution must necessarily be supported by a strong political involvement** at government level and is thus not merely a reflection of specific financial or investment tools. In other words, **public support to R&D is not solely a technical but rather a political matter**.

• The second point is that international cooperation is clearly a common factor for small sized countries with limited financial means or those wanting to make a specific effort to catch up with other countries in terms of R&D competencies. **This serves to underline the debate between “networking R&D” and “pole of excellence”** (provided that we admit that this controversy is a real one – cf the concept of “networks of excellence”-).

By contrast, it appears that “defence and homeland security” is not very important in the European context with the exception of the United Kingdom, Israel, Turkey, France and Germany, i.e. those of the European countries spending most on defence. This constitutes a very important difference as to the USA.

Finally, a rather surprising result is the relatively low importance of the factor “Political parties, pressure groups and lobbying” (which is only present in Austria, Germany and the Netherlands) given the relatively important impact of the social factor “Strong articulation of social demands”. It appears that this last factor is much more a perception of societal demands by governments than a real socially constructed expression of demands through associations, lobbies or political parties.

However, it has to be emphasised once again that the addition of the particular R&D strategies of the individual European countries does by no means automatically translate into an integrated and coherent R&D strategy at European level.

2.2 Contribution of socio-economic factors to public policy support

One frequently used structure to analyse the impact of socio-economic factors in public policies is an analysis by STEEP sectors, with STEEP standing for Society, Technology, Economy, (natural) Environment and Politics. In the context of the present study, the sector of Technology is dropped, since it is the topic of the study itself. The STEEP approach is commonly employed by British researchers from SPRU (Sussex Policy Research Unit at the University of Sussex) and PREST (Policy Research in Engineering, Science and Technology, University of Manchester).[19] It is also used – although not under the same name – in most German corporate foresight exercises.[20] The list hereafter provides the most commonly used explanation of the STEEP factors.

Society
- demographic change (ageing, shrinking of population)
- societal structures (family, generations, networks, gender relations...)
- social factors (incl. income, welfare, poverty...)
- values (perceptions, beliefs, attitudes) and life styles

Economy
- competitiveness of companies
- competitiveness of regions
- labour market
- new models of work organisation

Environment and quality of life
- health and well-being
- ecological sustainability
- resources depletion
- climate change

Politics
- national governance
- international governance
- national (and international) security
- global shifts of power
- pressure groups and lobbying (including NGOs)

In an attempt to assess the relative impact the main STEEP factors have on the formulation of public R&D policy in the different countries, a literature review based on official public policy documents (budget, official reports and evaluation…) has been carried out. Neither press articles nor public speeches have been taken into account in this analysis.

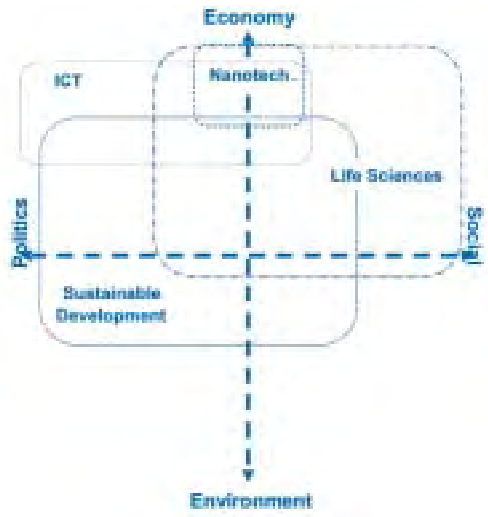
(19) See e. g. Michael Keenan: What is foresight? (2000), available in the internet from http://www.les.man.ac.uk/PREST
(20) See Klaus Burmeister, Andreas Neef, Bert Beyers: Corporate Foresight, Hamburg 2004, p. 40ff

2.2.1 Situation in the USA and Japan

A) The USA

The main factors underlying the public policy rationale regarding R&D support are summarised in the figure below.

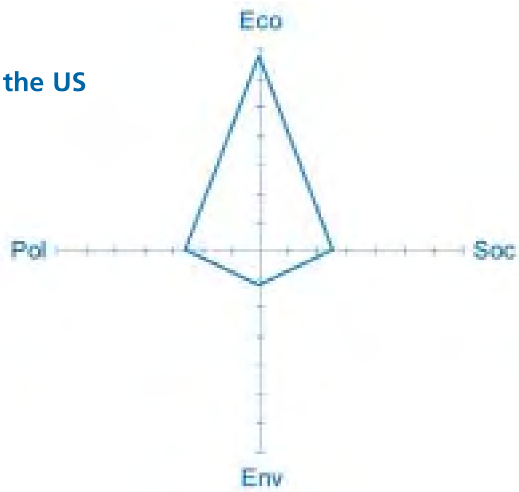
Figure 14: Major factors and forms of R&D support in the USA



The economic rationale undoubtedly provides the main driving factor for public R&D support in the US context. This is particularly true for nanotechnologies and ICT.

Nanotechnology

Figure 15: Nanotechnology field in the US



The nanotechnology scientific field is organised through the National Nanotechnology Initiative (NNI) that regroups 11 Federal agencies such as the DOD (Department of Defence), the DOE (Department of Energy), the DHS (Department of Homeland Security), the NASA, the NIH (National Institutes of Health), the National Science Foundation… and other participating agencies. Nanotechnology is described by the Office of Science and Technology Policy as a key one “to maintaining US competitiveness”. Economic factors are so predominant to explain the support to nanotechnology.

However, the scientific convergence is a real issue recognises by the Federal government. NNI so represents the answer in terms of organisation the government has developed to tackle this issue. The first attempt to have common multidisciplinary approach goes back to 1996 and NNI first appears in the 2001 budget submission to Congress by the Clinton administration[21].

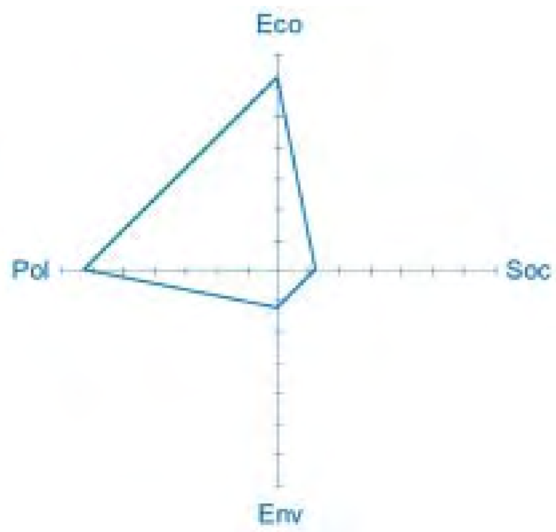
Seven program components areas composed the NNI' framework:

1. Fundamental Nanoscale Phenomena and Processes
2. Nanomaterials
3. Nanoscale devices and systems
4. Instrumentation Research, Metrology, and Standards for nanotechnology
5. Nanomanufacturing
6. Major research facilities and instrumentation acquisition
7. Societal dimension

Comparatively to other scientific fields, nanotechnology R&D activities are mainly focused on basic research. However, with a budget of $ 1.05 billion for NNI out of $ 132.2 billion for the Federal R&D global budget (including defence), the priority for the field has to be put into perspective. In fact, applied research coming from NNI' program are supported as part of the different participating agencies depending on the application field.

Information and communication technology

Figure 16: IST field in the USA



The US government supports Information Communication Technology (ICT) mainly for economic and political reasons.

The NITRD (Networking and Information Technology R&D) program is shared by eight different agencies. Amongst these agencies, one which represents less than the middle of the total budget is the National Science Foundation. All the other ones are "application" agencies. Within these agencies the two most important in terms of budget allocation are the Department of Defence and the Health and Human services (National Institute for Health).

(21) www.nano.gov

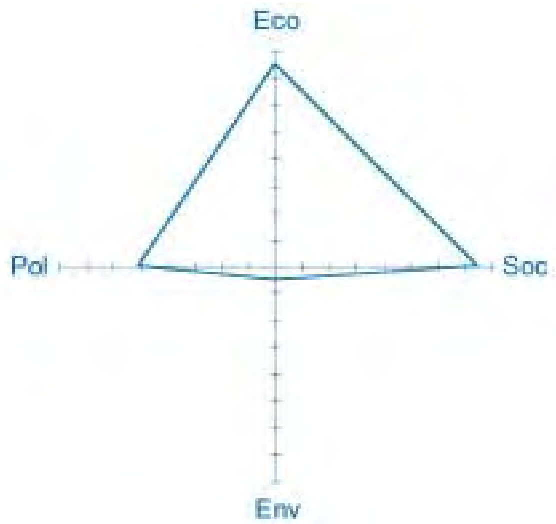
Economic factors are so easy to understand. If NSF has the role of financing university basic research, all the other agencies and departments mainly finance applied research and development programs in their activity areas.

In addition, we mustn't forget that most of the large US ICT companies of today have been created by researchers, and the links between research and economy remains a strong reality.

At political level, the Bush administration emphasises on the horizontal role of ICT and the "cyberinfrastructure" for the whole science and engineering communities. At the same time, ICT appear essential for defence and the actual supremacy of the US army is in large part due to its high level of ICT use.

Life Sciences

Figure 17: Life-sciences field in the US



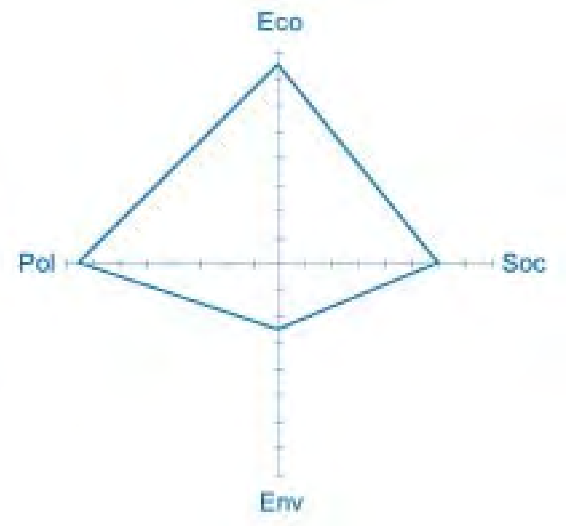
Three factors can explain the public policy support to Life Science. The first one is social. This sector is in front line in order to solve the issue both of an elderly population, with its specific health problems, and of particular diseases such as AIDS, cancer, diabetes,… This research area is very popular in the US, and apart from public support, many public or private foundations contribute to support it.

The second important factor is economic. Life Science sector is an important one in the USA. The US pharmaceutical sector realise half of the world sale in the field. This issue itself can be sufficient to explain the support to Life Science. But Life Sciences applications are also used in other sectors such as agriculture. This sector is clearly strategic for USA as the country is the first agriculture and food exporting country in the world.

The third important reason that can explain Life Science public policy support, and which is certainly more important in the US than in other geographic areas, is the policy factor, mainly in terms of homeland security and research on bioterrorism protection. Several research programs are developed that target on bio-defence against nuclear, radiological or chemical attacks through the National Institute of Allergy and Infectious Diseases (NIAID).

Sustainable development

Figure 18: Sustainable development field in the US



Sustainable development in the USA should be understood as covering three main topics: the climate change issue, the natural resources issue and the specific energy issue. In the reality, these three topics are linked as they answer to the same objective: they *"are critical for achieving sustained economic growth while ensuring national energy security and a healthy environment"*[22]. It means that with sustainable development, we find the compilation of the main factors supporting R&D public policy:

- the political factor in terms of national security (here energy independence and security and natural resources);
- economic growth and prosperity in the long term;
- healthy environment and good life conditions for the population.

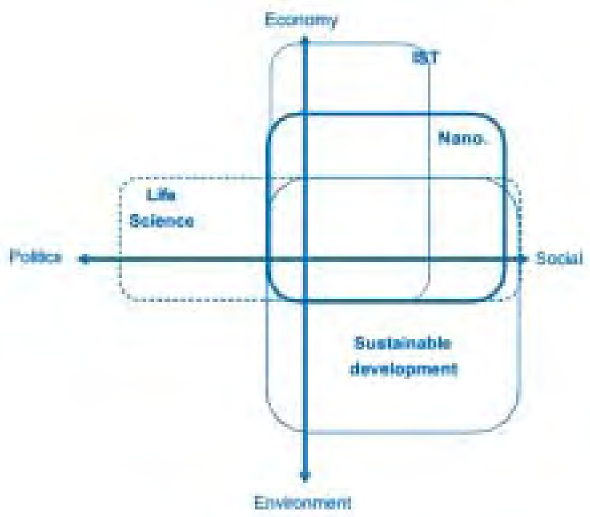
Most of the researches undertaken in this field belong to the National Climate Change Technology Initiative (NCCTI)[23]. The main issues target to climate and global earth observation, water purification, and above all, hydrogen R&D through the President's Hydrogen Fuel Initiative which aims *"to accelerate the worldwide availability and affordability of hydrogen-powered fuel cell vehicles"*[24]. (in our understanding: a political factor of energy independence that could contribute to healthy environment and will increase the economic growth).

B) Japan

The main factors underlying the public policy rationale regarding R&D support are summarised in figure 19.

(22) "2006 budget priority memo" OSTP, www.ostp.gov/htm/m04-23.pdf
(23) See : http://www.climatescience.gov/about/nccti.htm
(24) R&D Chapter 2006 - US federal Budget 2006 - www.ostp.gov/htm/budget/2006/FY06RDChapterFinal.pdf

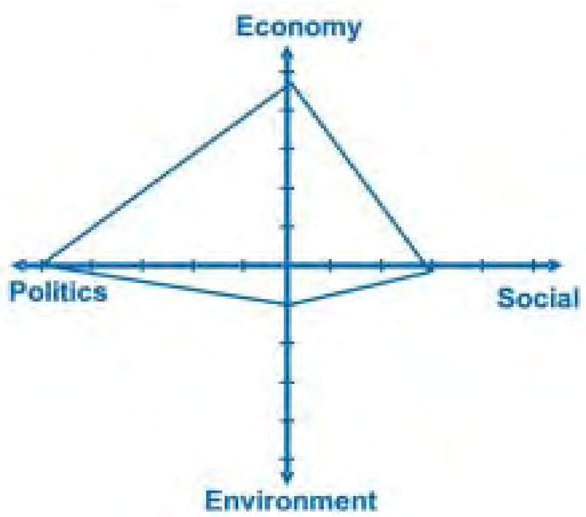
Figure 19: Major factors and forms of R&D support in Japan



While economic factors provide a strong focal point in the Japanese context as well, their role is certainly less preponderant than in the USA, with Japanese public R&D support equally focusing on activities that lack market potential. In contrast with the USA, Japanese R&D support finds an important part of its underlying rationale in social factors.

Nanotechnology and materials

Figure 20: Nanotechnology in Japan



According to the second basic plan, the field of nanotechnologies is one of the four priority areas for Japanese scientific and technologic expansion. Nanotechnologies are considered strategic because they impact many other scientific fields. In particular, nanotechnologies are expected to:

- **strengthen Japanese industrial competitiveness** and to allow a sustained economic growth;
- help to improve the lives of the population by contributing to **respond to socio-environmental problems** (low birth rate, aging of the population, energy saving, safe space-creating materials technologies for assurance of safe living spaces).

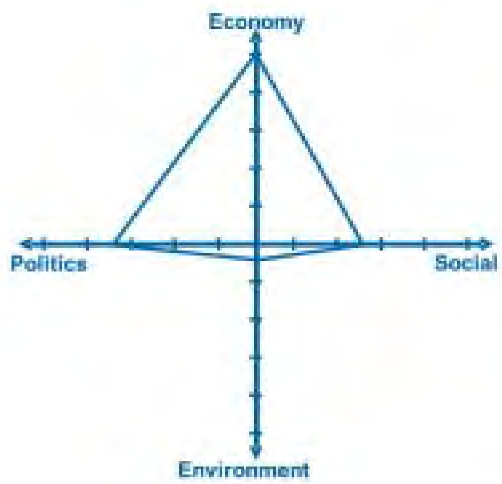
There are high hopes that nanotechnologies and materials will be a kind of industrial revolution of the 21st century, bringing important breakthroughs in the fields ranging from materials, electronics, mechanics, biotechnology, pharmaceutical development, and medical treatment.

The 2nd science and technology basic plan points out that in this field, the R&D level in Japan is *at the same level or slightly higher* than that in European countries and in the USA. Japan Government has been successively increasing its R&D investment in this field in order to take the leading position[25].

The basic plan also indicates that Japan must pay attention to **maintain a good balance between fundamental research and that aimed for industrialization**, which used to be significant because of the importance of private funding.

Information and communication technology

Figure 21: IST in Japan



Japan's support to information and communication technologies is **mainly due to economic factors**. The Ministry of Education, Culture, Sports, Education, Science and Technology highlights that research in this field is essential for *expansion of knowledge gathering industries like IT or high-tech industries, as well as for improving existing technologies which deserve manufacturing technologies*.

(25) In FY 2003, Japan's Ministry of Economy, Trade and Industry has increased its budget for promoting commercialization of nanotechnology by 5.6 percent, from 85.6 Mds Yens M€ to 90.4 Mds Yens M€. [Source: French Embassy in Tokyo, "Le budget pour la science et la technologie, Michel Israël, 2002"].

The Japanese government considers that Information and Communication technologies based on computers and networks are the principal intellectual and creative infrastructure for modern society and the seeds for the development of new industries. Japan aims to become an "advanced *IT network society*".

Furthermore, ICT produces changes in socio-economic activities that extend to the daily lives of the population: electronic commerce, remote medical treatments, distance education programs, home offices, electronic governance, etc. Advances in this field are thus considered as important by Japanese society for improving overall well-being.

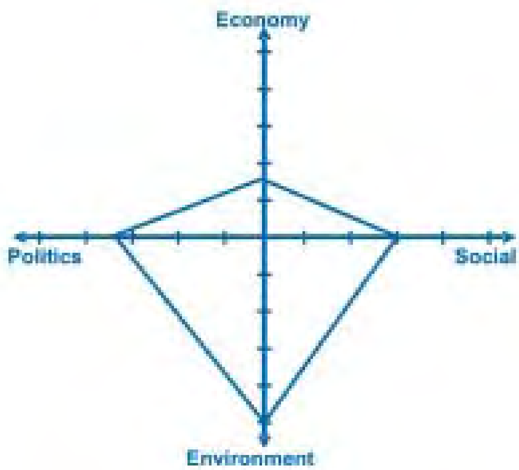
According to the 2nd Basic Plan, the level of Japan is considered to be superior to those of European countries and the USA in mobile-phone systems, optical communications technology and IT terminals. However, the USA is leader in computers technologies and in software sciences.

For ICT, Japanese government aims to stress fundamental and leading R&D fields that are not attainable strategically and effectively only through market-motivated activities.

In FY2003, the public funds for science ICT represent 175,3 Mds Yens.

Sustainable development

Figure 22: Sustainable development in Japan



Environmental sciences public funding represented 108.8 Mds Yens for FY 2003, i.e. an increase of 8.1% in relation to FY 2002[26].

As a country with limited land and natural resources and exposed to natural hazards, Japan is highly aware of environmental issues. Global warming, depletion of the ozone layer, abnormal weather and other phenomena are considered to have a significant impact on Japan's social life and also on its economic development.

The 2nd Basic Plan indicates that Japanese R&D in environmental science is on roughly the same level as the European countries and the USA regarding global warming, in measuring techniques and in management of technology of chemical substances. However, according to the Basic plan, Japan is behind in environmental monitoring.

(26) [Source: French Embassy in Tokyo, "Le budget pour la science et la technologie, Michel Israël, 2002"]

• **Energy and nuclear**

In order to avoid future insecurity in energy supply, Japan seeks to establish a safe and stable demand structure while reducing its reliance on fossil fuel.

In particular, the field of nuclear power is expected to play a central role against global warming.

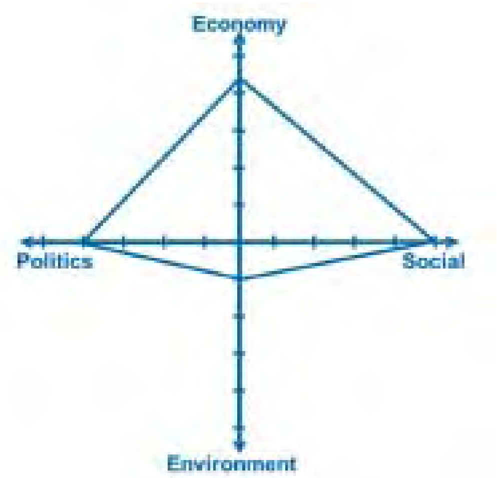
Manufacturing technology

It is important to highlight this topic which is not one of the four priority areas, but is still mentioned in the 2nd Basic Plan. Indeed, Manufacturing technology is fundamental to the Japanese context since it used to constitute the source of its economic power.

Japanese level of manufacturing technology is considered as one of the highest in the world. Hence, the Basic Plan points out the importance to continue developing innovative technologies based on the existing high level techniques. Advances in this field should involve micro-machines, environmental friendly technologies and fine-parts processing.

Life sciences

Figure 23: Life-sciences in Japan



The field of life sciences is essential for Japan. In FY 2003, more than the half of the increase of the S&T budget has been given to life sciences, which represents 406.8 billion of Yens[27].

Life sciences are expected to contribute to rapid progress in medical science. It must be reminded that since 1981, cancer has been a leading cause of death in Japan, and that its incidence is predicted to rise with the aging population. The aging population implies also serious concerns about neurological disorders and psychiatric diseases – like senile dementia. Therefore, biotechnology for health, which contributes to prevent and treat diseases, is central for Japanese society.

The food S&T is also a key topic in the Japanese context, contributing to food security, promoting a healthy diet and securing a sustainable food production.

(27) [Source: French Embassy in Tokyo, "Le budget pour la science et la technologie, Michel Israël, 2002"].

On the one hand, the public has an extreme sensitivity about food security that has risen with the background of health problems such as bovine spongiform encephalopathy or avian influenza. Since it contributes to secure food, technology plays an important role in food concerns.

On the other hand, because of its lack of resources, Japan is highly interested in agricultural biotechnological issues.

Fundamental knowledge on functional genomics is another point of interest concerning life sciences. Because of its impact on the analysis of gene functions and the ensuing creation of new industries in the future, this field is a focus of high attention.

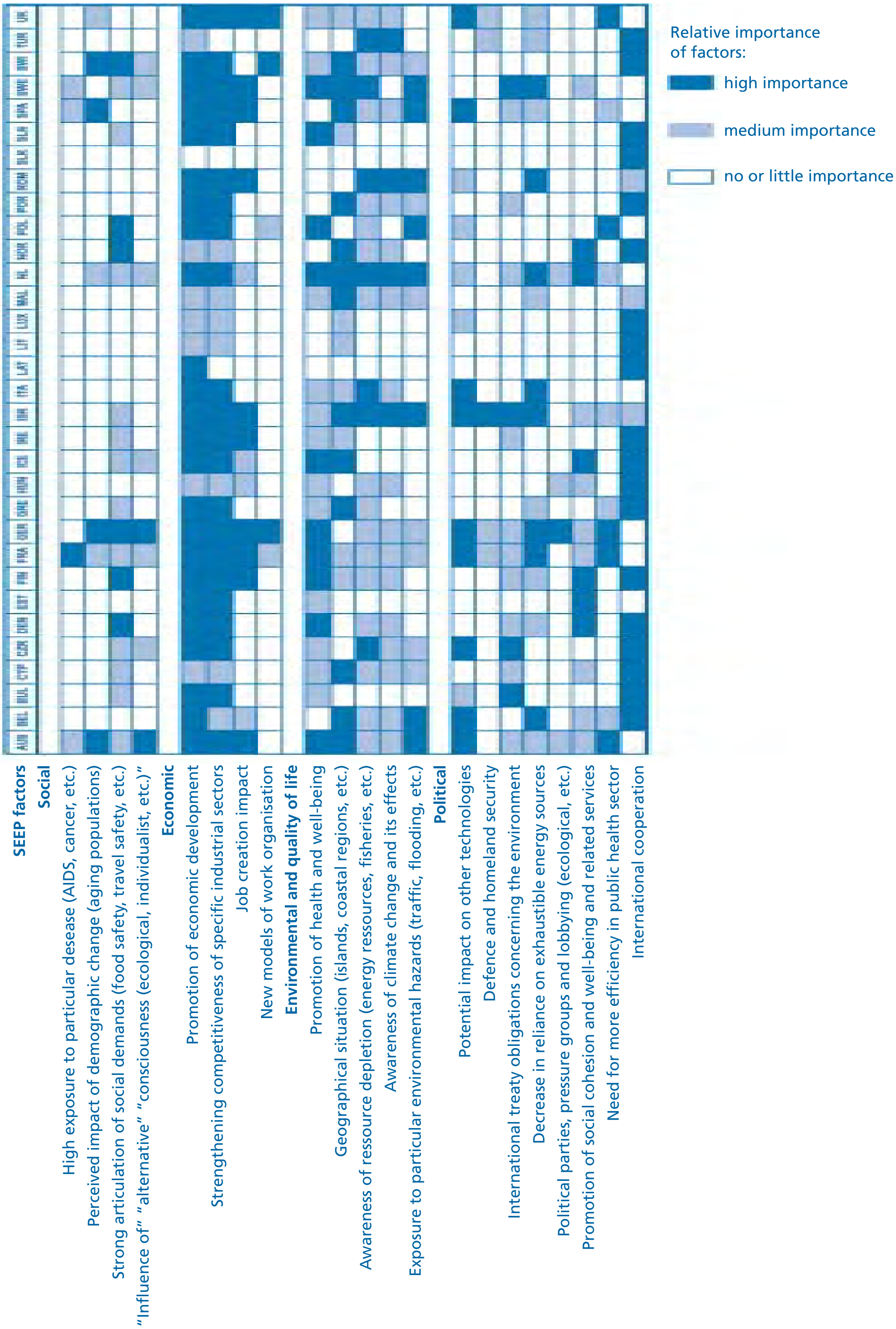
According to the 2nd Basic plan, the level of R&D fields in life sciences has been kept high in some topics such as rice genome, specific microbe genome deciphering and livestock cloning. However, it is still behind Europe and the USA as a whole. Because of the rapid advances of research in the field of life sciences, the 2nd Basic plan lists the strategic areas on which Japanese research must focus its priority efforts[28]. The plan also requests an implementation of basic R&D in life sciences.

2.2.2 Four main models to understand the situation in European countries

Given the heterogeneity of the European R&D landscape that has already been underlined in the previous part of the analysis, it is impossible to summarise the European situation by means of a single graph as was done in the US and Japanese context. As a matter of fact, a hierarchy of the different factors motivating public R&D policy support in Europe translates an intrinsically country-specific situation into a correspondingly heterogeneous table, as can be seen below.

(28) Proteomics, elucidating three-dimension structure of proteins and drug-acting genes and genome science; cellular biology; clinical medicine and medical technology; food S&T; brain science; bioinformatics.

Table 4: Main STEEP factors at country level in Europe

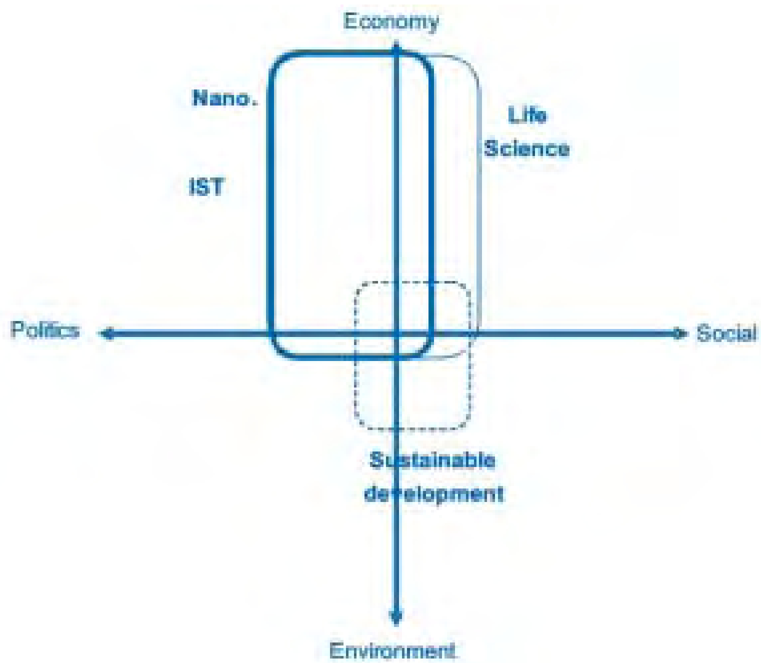


While the table serves to emphasise the overall importance for most of the countries (but not for all) of the different economic factors as well as the political factor related to international cooperation, this picture needs clearly to be refined. Considering the four main contributors to European R&D in terms of public budget allocations, i.e. Germany, France, United Kingdom and Italy, it must be underlined that none of these views international cooperation as a factor likely to influence their R&D policies and strategies (even if being part of many cooperation mechanisms set up at international level in the different scientific fields of R&D).

In order to provide an in-depth analysis of the heterogeneous R&D landscape in Europe and to try to formalise an understanding of the various factors supporting R&D policy at the scientific field level, a detailed, country-by-country analysis has been made[29]. Reflecting the results of this analyse, four main models at European level are being proposed in the following. Quite naturally, these models do not cover all of the different countries' specificities. Nevertheless, they provide a useful means for an overall mapping of both the global situation of the European context and, more specifically, the main socio-economic factors that support public R&D policies in the different scientific fields.

A) The economic driven model

Figure 24: The economic driven model



This model emphasises the economic factor as the key driver motivating public R&D strategies regardless of the scientific field in question. The only field that seems not to be driven by the economic rationale is thereby sustainable development, with the corresponding market potential not being considered as very important in the short term.

Countries like United Kingdom, Ireland, Sweden, Finland or Switzerland can be classified under this model.

(29) Cf. socio-economic report, august 18th 2005

The Finland example[30]

Technology forms an essential part of the Finnish industrial policy and is acknowledged at the highest level of the Finnish government. Key issues concerning technology are regularly discussed at the Science and Technology Policy Council, chaired by the Prime Minister. The Finnish R&D expenditure grew rapidly during the 1990s, mainly owing to an increase in business enterprise input, and totalled 5 billion euros in 2003 which represent 3.5% of the country's GDP. The share of business enterprise R&D expenditure grew from 57 per cent in 1991 to some 70 per cent in 2003. The increase in business enterprise R&D expenditure is mainly due to the electronics industry.

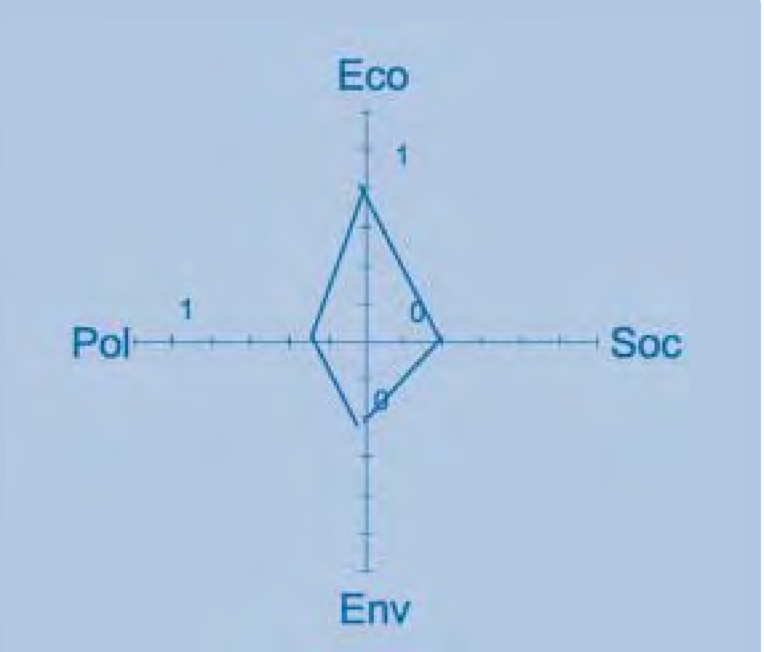
The share of public R&D funding of the gross domestic product was 1.01% in 2003. After a slight decrease in the total R&D expenditure in 2004, the government budget appropriations on research and development was increased by 56 million euros, amounting to 1.6 billion euros for 2005. Universities account for 26% of the R&D expenditure in the state budget, Academy of Finland 14%, The National Technology Agency Tekes 26%, state research institutes 16%, and university central hospitals 2%. Finland has also actively contributed to the formulation of EU science and technology policy. International research cooperation is considered very important for a small country.

The overall aim of the Finnish technology policy is to promote economic growth and competitiveness of industry and commerce, contributing thus to employment and social wellfare. The importance of internationalisation and sustainable developments are underlined in R&D policy documents too. The current technology focus areas of Tekes are ICT, biotechnology, nanotechnology and materials technology, together with business competence and business development. In addition, Tekes has defined six application focus areas driven by market needs: renewing products and business concepts, environment and energy, health and well-being, services, security and safety, and work and leisure. The four research councils of the Academy of Finland are for bioscience and environment, culture and society, health, and natural science and engineering. The Academy's current focus areas include Baltic Sea; environment and law; environmental, societal and health effects of genetically modified organisms; health services; microbes and man; systems biology and bioinformatics; future electronics; proactive computing; information technology in mechanical and automatic engineering; industrial design; and wood material science. Among the planned new focus areas are chemical, physical and biological nanoscience; nutrition, food and health; and five programmes on culture and society. Tekes is funding mainly applied research and the Academy of Finland mainly basic research. The Academy of Finland and Tekes are increasingly cooperating within the framework of various research programmes to strengthen the coherence of Finnish science and technology policy.

(30) Sources: STPC, 2003: "Knowledge, Innovation and Internationalisation"
Tekes, 2005: Building on innovation – Priorities for the future (editions in English and Finnish)
Academy of Finland, Annual Report 2004
www.research.fi
www.tekes.fi/eng/innovation/policy
www.tekes.fi/english/programmes
www.aka.fi
Note about the Academy of Finland documents: Budget figures for the research programmes of the Academy of Finland are not available on the website www.aka.fi . Also, the foresight part of the website is currently being updated, so it would be worth checking the contents after some days. (The most recent foresight paper now available is from year 2000.)

Nanotechnology and materials technology

Figure 25: Nanotechnology in Finland



The aim for Finland is to be a value-adding applier and developer of customised materials. In particular, functionality, intelligence and compatibility of materials, as well as materials life cycles are focused on, with the aim of combining technologies in a value-adding way. For nanotechnology, the focus is on innovative nanostructured materials, new structures for nanoelectronics, and nanosensors and actuators. International co-operation is seen to be important in this field.

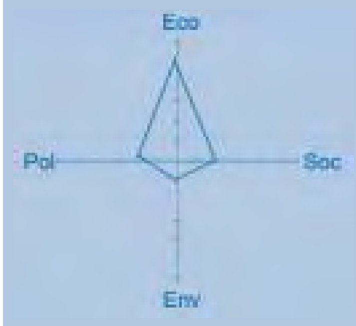
Tekes launched its 5-year FinNano technology programme in January 2005[31]. The total volume of the programme is estimated to be around 70 million euros. As stated in the Tekes programme description, the "programme activity will help nanotechnology to be made available to existing enterprises and ensure that Finland's competitiveness in the domain of nanotechnology is reinforced and grows to become internationally attractive for new business activity". On the other hand, the need for nanotechnology programme is explained by current change factors such as networked activity, efficacy requirements, environmental problems and sustainable development. Similar type of strong economic and business-oriented arguments, together with references to the quality of life and ageing population, can be found in the programme texts for biomedical and multifunctional materials, and clean surfaces.

The Academy of Finland is planning to launch its 'chemical, physical and biological nanoscience research programme' during 2006. (The board of the Academy is expected to allocate funding for the purpose in Fall 2005. Three Research Councils – Research Council for Biosciences and Environment; for Health; and for Natural Sciences and Engineering – are preparing the programme together.) Three preliminary thematic areas have been selected for the Academy's Nanoscience Research Programme: directed self-assembly, functionality in nanoscale, and properties of single nanoscale objects. A close co-operation with the corresponding Tekes programme is planned. This can be seen as an effort to intensify co-operation between basic and applied research in relevant fields. Because of the strong Finnish forest cluster, wood material science is another important cooperation area.

(31) The first three-year nanotechnology programme funded by Tekes was completed in 1999. During the years 2000-2004 funding of nanotechnology research was through diverse Tekes research programmes.

Information and communication technology

Figure 26: IST in Finland

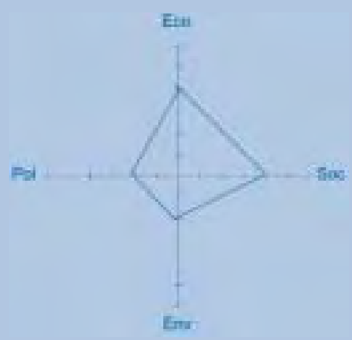


The aim of Finland is to be a world leader in applying and developing ICT technology. Strategic application areas include embedded intelligence and seamless communication, and supporting business innovations through ICT; work in knowledge-based society; and ICT in well-being society and knowledge society services. The strategic development areas are broadband communications with specific reference to mobility, software-intensive products and systems, and management of knowledge and content. The aim is further to use Finland as a test environment for new applications and services.

The main arguments for public R&D support in the area of ICT are economic (business opportunities, competitiveness, cost-efficiency), although social and political factors (user-orientation, equality, democracy) are also taken up when discussing the various application areas. There is also political will to use Finland as a 'test laboratory', combining modern ICT technology and wellfare. Environmental arguments are less prominent.

The on-going Tekes technology programmes in the area of ICT technology focus on interactive computing (total budget 84 million euros), modelling and simulation (total budget 92 million euros), miniaturization of electronics[32] (total budget 125 million euros), and e-business logistics (total budget 25 million euros). Significant development of IT products and systems is included even in the technology programmes focusing on future healthcare (total budget 150 million euros), construction and services (total budget 32 million euros), building services (total budgets 27 million euros), and value networks in construction (total budget 33 million euros). The Tekes programme on intelligent automation systems was completed by 2005 (total budget 45 million euros). The planned new technology programmes focus on 'experience industry', industry software, telecommunications, innovative services, renewed business and management, and networked production control systems. ICT plays an important role in these programmes too.

Tekes currently also co-operates with the Academy of Finland within the framework of the research programmes focusing on the application of information technology in mechanical, civil and automation engineering, and proactive computing. Another area of cooperation is 'life as learning' that also includes the ICT dimension. In addition, the Academy of Finland has an on-going research programme on future electronics.



Life Sciences

Figure 27: Life-sciences in Finland

The aim of Finland is to be a significant developer and utilizer of biotechnology, building on its internationally competitive basic research in the areas of genomics and molecular biology. The strategic application focus areas are health care, safe production of functional food throughout the business chain, and environmental and natural resource

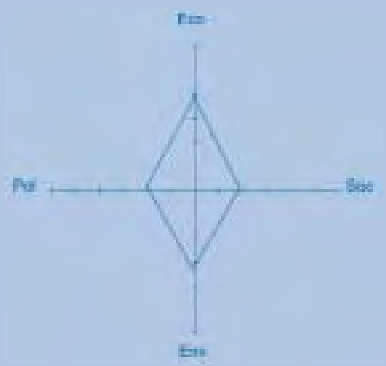
(32) Includes links to the nanotechnology programme as well.

applications of biotechnology. Focus areas for strategic development are systems biology, bioprocess technology, and combining biosciences and ICT. Ageing population, the threat of rapid spread of new contagious diseases, and the global problems related to health, safety and wellbeing are usually first pointed out in arguments for public R&D expenditure in these areas. On the other hand, there is an equally heavy emphasis on the potential economic benefits (lowering costs of public health care with the help of better diagnoses and preventive treatment, new business opportunities, competitive export products). Environmental political factors (international agreements, regulation, etc.) are also mentioned. The reputation of the Nordic welfare states puts its own political pressures for public R&D expenditure.

The on-going Tekes technology programmes in the area of life sciences focus on commercialisation of biomaterials (total budget 26 million euros); biomedicine, drug development and pharmaceutical technology (in cooperation with the Academy of Finland and Sitra, the Finnish National Fund for Research and Development; total budget 20 million euros), future healthcare technology (total budget 150 million euros) and novel biotechnology (Tekes funding around 50 million euros, some additional public funding from The Ministry of Agriculture and Forestry). The focus areas of the Academy of Finland research programmes include environmental, societal and health effects of genetically modified organisms, health services, microbes and man, and systems biology and bioinformatics (in cooperation with Tekes). Among the focus areas of the new research programmes prepared by the Academy of Finland are nutrition, food and health, and substance abuse and addictions.

Sustainable development

Figure 28: Sustainable development in Finland



Environment and energy is one of the application focus areas of Tekes. The theme concentrates on eco-efficient and sustainable solutions in various industry clusters, and makes use of the market potential in mitigating global warming and responding to the challenges of obtaining energy in an acceptable and affordable way. Among the most promising strategic areas for Finland are sustainable processes, wood biomass utilization and future fibre products; renewable and clean energy and climate change mitigation; and development of new sustainable technologies / solutions / processes / services in the environmental industry cluster, making use of the Finnish high-level expertise and demanding home market.

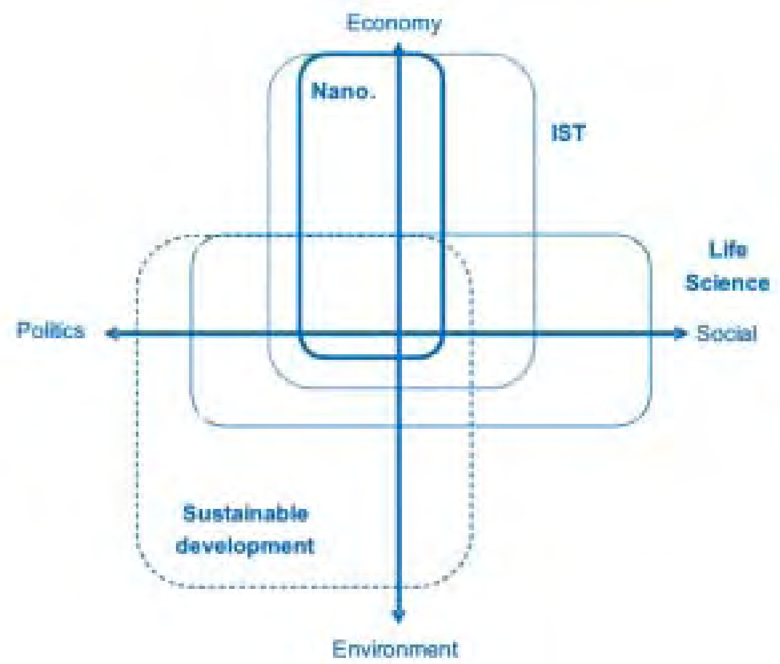
Economic factors (cost benefits of material and energy savings, increasing market for environmentally friendly solutions), environmental factors (global environmental threats, mitigation of climate change), as well as political and social factors (international agreements, regulation, increasing environmental awareness, etc.) are all mentioned as reasons for public R&D expenditure. The main emphasis is in economic factors, followed by the environmental ones.

The focus areas of the ongoing Tekes technology programmes include 'business opportunities in the mitigation of climate change', distributed energy systems (incl. fuel cells), fine particles (technologies for decreasing emissions, impacts in environment and health), and recycling technologies and waste management. Among some additional Tekes focus areas are production and use of wood fuels, and wood material science (related to the developments of the Finnish forest cluster). The relevant research programmes of the Academy of Finland focus on the environmental problems of the Baltic sea, environment and law, and the effects of genetically modified organisms (environmental, societal and health effects).

B) The politic – economic model

The second model put the emphasis, in addition to the economic factor which is still the main driver for Nanotechnologies and IST, on the political factor as a key driver for life-sciences on one hand and sustainable development on the other hand. In this model, Life-sciences and sustainable development are always driven by their own specific issue (social for life-sciences and environment for sustainable development). But rather to emphasis on the potential market or economic development issues these fields could represent, the focus is put on the political at government level to use R&D as a key means to provide significant answers. As an example, "cancer" has been imposed as a national cause in France. This political will can thus be the expression of a strong national interest. But it can also at the opposite be the results of a weak -or not shared- social interest about specific issues. The political factor is in this case the means to impulse R&D in a field where there is no strong social support (sustainable development in some countries as an example).

Figure 29: The politic-economic model



Countries such as France, Germany, Belgium, Austria, Israel, Romania, Denmark… are close to this model.

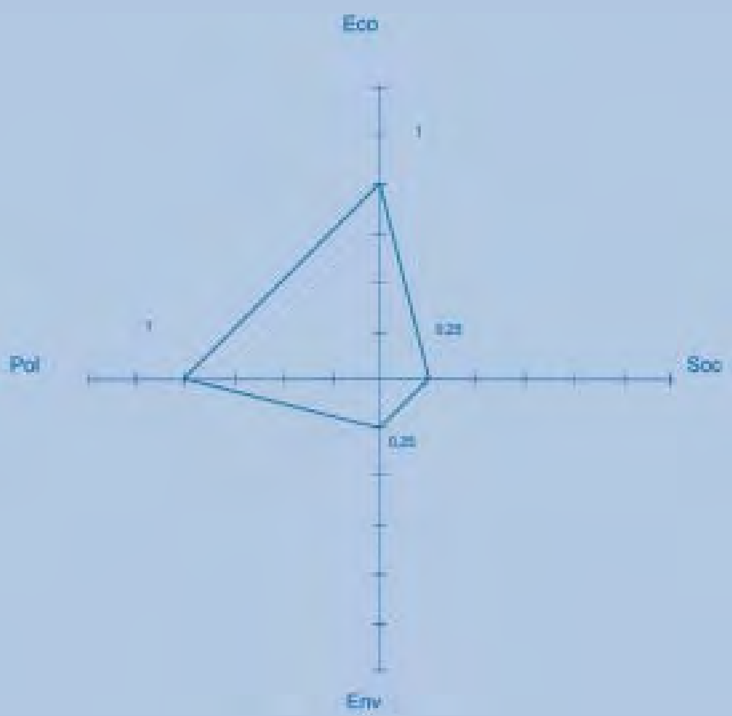
The Austrian example

In 2004, Austria spent 5.346 billion € on R&D which represent 2.27% of the country's GDP. The share of public funding amounts thereby to somewhat more that 1/3 (35% in 2004), industry spending accounts for about 44%, the share of foreign R&D funding is with about 20% comparatively high – which is an indicator for the attractiveness of Austria as R&D location. The Austrian government has put much emphasis on its ambition to attain the Barcelona objective of 3% GERD/GDP by 2010. Budgetary planning is in line with this goal: Austria is about to spend 5.77 billion euros in 2005 for R&D (public: 2.12 billion), representing 2.35% of the GDP and an annual growth rate of 8% – which is to be sustained in the next years. The federal government has increasingly attributed specific supplementary means to R&D within the framework of two "Offensivprogramme" (since 2001). An additional "research billion" for the years till 2010 has been proclaimed on the "Reform Summit for Employment" on May 1, 2005. Tax schemes which are favourable for spending in commissioned research have been put into force. Besides Finland and Sweden, Austria could be the only EU member to attain the Barcelona objective.

One of the disadvantages of the Austrian R&D system is the fragmentation of public funding. Therefore, governmental activities are also directed to bundle and coordinate funding activities.

Nanotechnology

Figure 30: Nanotechnology in Austria



As in other countries, nanotechnology is regarded as an auspicious future technology with enormous potential for developments and applications in different fields of industry relevant for Austria: automotive, information and communication, mechanical engineering, construction, health (medical devices), energy. Thus, the rationale behind public support for nanotechnology is primarily economic (creation of jobs, Austria's position in global competition).

On the whole, the field of material sciences and its physical and chemical fundaments received about 26 mio € in 2004, another 40 mio of public support went into microtechnologies, but funding for nanotechnology is also running through other budgets.

As a case in point, the Federal Ministry of Traffic, Innovation and Technology has launched a specific program "Nano and Microtechnology Initiative" (endowed with about 1 mio Euro per annum) to promote growing interests in interactions between science and economy in the field of nanoscience and nanotechnologies. A precondition for this is to guarantee sufficient supply and a well organised starting and nodal points to connect different disciplines of science. Because of the complexity of the field of nanoscience the activities are divided into 4 different program lines (research and technology development in cooperative projects, networks and development of confidence, measures for further education and accompanying measures).

Information and communication technology

Figure 31: IST in Austria

ICT play a crucial role in Austria's R&D system as enabling technologies from which all industries and society as a whole profit much. Austria has therefore accompanied most ICT developments (hardware, software, services) with own research efforts, concentrated among others in the Austrian Research Centers at Seibersdorf. But the rationale for supporting ICT is not purely economic. ICT are also regarded as a means to promote sustainable development (see paragraph about s. d.) and social cohesion (overcoming the digital divide, access for all).

From the perspective of Austrian budgetary systematics, ICT are combined with traffic. The total budget for this sector amounted to about 63 mio € in 2004. As a country with much transit traffic, as well in the North-South and the East-West directions, Austria puts much emphasis on the economic and environmental efficiency of transportation systems and is investing comparatively large sums in ICT for transportation: intelligent traffic systems and services for effective and efficient logistics and infrastructures. The industrial sector of rail technologies with all its component suppliers is one of Austria's most significant branches of economic activities. ICT for transportation is therefore very important for safeguarding the attractiveness of Austria as a business location.

Life Sciences

Figure 32: Life-sciences in Austria

Life Sciences are a stronghold of Austrian R&D with a total funding budget for the health care sector in 2004 of 341 Mio. €. As a country with an aging population at the one hand and a booming tourist industry at the other hand, Austria puts a strong emphasis on providing health services to its own population and to tourists. Thus a societal rationale combines with an economic one. The same holds true for the agro-food sector, another important industry for Austria – and a main field of innovation for biotechnologies. The rather "green" orientation of Austrian agriculture with a high share of ecological or "biodynamical" farming does not – or at least not generally – hamper innovation, but on the contrary incite it in certain fields. Moreover, it adds an environmental rationale for life sciences R&D.

One example is the interdepartmental research program "LISA - Life Science Austria". Its aim is to strengthen the international position of Austria by the expansion of its already excellent competence and good reputation in this field. Generally, life sciences are regarded as the most seminal and most innovative sector of Austria's research and development. Austria's competence in this discipline is underlined by its ability to rapidly transform research results into economic applications. Jointly responsible for the good international reputation of the country's activities is the existence of a capacious dynamic "life science scene" in Austria.

Sustainable development

Figure 33: Sustainable development in Austria

As in Germany, sustainable development is writ large in Austria. The total funding for the R&D sector environmental protection alone amounted to 49 Mio. € in 2004, but technologies for sustainable development are also financed through other budgets, e. g. agricultural research and forest research – besides agriculture, the wood industry plays an important role for Austria.

Three programs display the scope of activities:

"ProVision" is to produce new knowledge about the consequences of climate change, to advance sustainable life and welfare models and to advance sustainable spatial development.

The program "Sustainable Economics" supports three special program lines: "the house of the future" (innovative concepts for reconstructions of domestic architecture; use of environmentally sounded materials), "the factory of the future" and "energy systems of the future". It is aimed to give innovative impulses for sustainable economy in general, and more specific for an eco-efficient liberalisation of energy markets and the search for intelligent, efficient and flexible energy systems which are based on renewable energy sources and materials. Themed "comprehend, advance and connect" the program "Sustainable economics" connects basic research with concepts, technological developments and applications.

Another point is sustainable transportation. As the website of the Austrian Research Centres at Seibersdorf puts it: "The promotion of innovation in transport and mobility systems plays a prominent role on the technology and innovation policy agendas." Traffic congestion, adverse environmental effects of transport growth, particularly in urban and environmentally sensitive areas (e.g. Alpine transit routes), and safety issues put pressure on policy makers, industry and researchers alike to promote and introduce more sustainable forms of transport and mobility services. New technology, information and communication technology (ICT) in particular, can play a crucial role to improve the efficiency, safety, environmental sustainability and meeting the user needs of the transport sector, but also change the demand patterns for mobility in the world of production as well as in daily life.

The Romanian example

A basic instrument for the implementation of the R&D policy in Romania was the National Plan for Research, Development and Innovation for 1999 – 2005 (1999) of The Romanian Inter-ministerial Council for Science, Technology and Innovation (CISTI). In May 2000, the general framework for innovation policy, the Medium Term 2000-2004 Strategy for Science and Technology (part of the National Economic Development Strategy 2000-2004), was approved. The 2000-2004 Science and Technology Strategy is now the principal innovation policy document. The main objective is to increase the involvement of the science and technology sector in the broader economy. The underlying view is that science and technology are essential elements for economic development and are main instruments for sustainable growth and European integration[33].

The R&D system in Romania is characterised as a predominantly applied research system with strong research potential in the fields of IT (including micro-technologies), communications, biology/biotechnology, chemistry, physics, medicine, environment, engineering (materials and processes, avionics, energy, mechanics, vehicles). The National Plan for R&D and Innovation defined the following development objectives[34]:

- Agriculture and food (AGRAL);
- Life and health (VIASAN);
- Environment, energy, resources (MENER);
- Territory arrangement and transportation (AMTRANS);
- Stimulation of the inventions application (INVENT), oriented towards the achievement of new products and technologies, based on patents own by Romanian inventors;
- Economic re-launching by research and innovation (RELANSIN), targeting the modernisation of the products, technologies and services supplied/used by the economic units;
- Quality and standardisation (CALIST), supporting the increase of the Romanian products and technologies quality, including in order to facilitate the access on the EU United Market;
- Consolidation of the quality infrastructures (INFRAS) supporting the development of the quality infrastructures in accordance with the EU principles and practices;
- Informational society (INFOSOC);
- Biotechnologies (BIOTECH).

According to the National Development Plan, technological priorities in Romania will reflect trends in the world markets and include, among others: biotechnology, new materials, environmentally friendly techniques and products, micro-technologies. In order to diversify the Country's productive basis and foster possible imitation phenomena, a preference will be given to enterprises entering into new sectors. The need to better put into relation R&D institutions with the productive world will be addressed by the usual combination of supply-side and demand-side actions. On the one hand R&D institutions will receive basic support to investment in equipment and human resource formation, on the other hand they will be encouraged to become more market-oriented through the continuation of present efforts of attracting private financing into the national sectoral research programs. Finally, grants for industrial R&D will be given to enterprises for their own research initiatives. This pool of instruments will complement the opportunities

(33) Innovation policy in seven candidate countries: the challenges. Final Report, 2003. http://ica.cordis.lu/search/index.cfm?fuseaction=lib.simpledocument&DOC_ID=6403697&CFID=3269116&CFTOKEN=75035358
(34) Blaz Golob, Enlargement Project S&T Institutions and S&T Policies in the EU Acceding Countries, Feb. 2004, http://enlargement.jrc.es/FuturesEnlargementII/Florence11-03/stprofiles.pdf

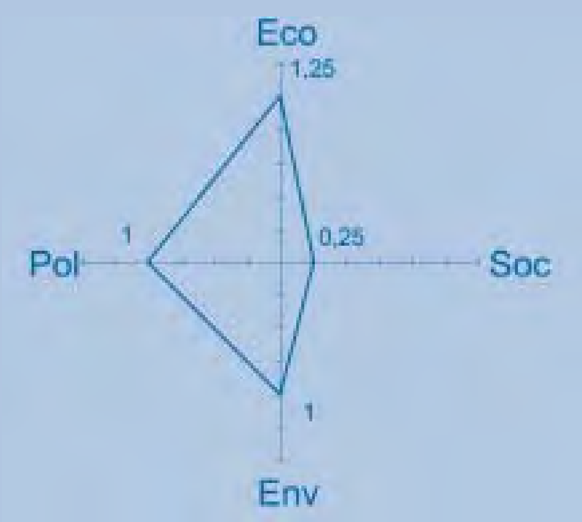
provided by the EU Sixth Framework Program which already represents one of the sources for financing research activities in Romania.

To improve participation to the Sixth framework programme, a reorganisation and extension of the network of national as well as regional contact points has started.

In June 2004 a new law has been issued on good conduct in scientific research, technological development and innovation. It establishes a new institution (the national council of ethics for research, development and innovation) in charge with coordination and monitoring on how norms are applied[35]. The increase in the state budget for research is now included in current legislation, and Romania wants to achieve the target of 1% of GDP for research in 2007 and 3% by 2010.

Nanotechnology

Figure 34: Nanotechnology in Romania



The Romanian programme "New materials, micro and nanotechnologies – MATNANTECH", initiated in 2001, aims to develop and support the research focused on advanced materials, nanomaterials and nanotechnologies. The strategic goals of MATNANTECH programme are[36]:

- Development of scientific knowledge in the field of science and engineering of new materials, micro and nanotechnologies
- Dissemination of results
- Transfer of results to practical applications, innovative and competitive products and technologies
- Development of partnerships between research and end-users
- Innovative application of new materials and technologies for environment and resource protection.

The second and third priority thematic areas of research in FP 6 (*"Information Society Technology"*, and *"Nanotechnologies and nanosciences, knowledge-based multifunctional materials and new production processes and devices"*) have research priorities which are reflected by MATNANTECH thematic directions.

MATNANTECH strategy helps moving ideas from the advanced research stage, through the applied research stage and into the marketplace. MATNANTECH vision can be comprised in several main directions:
- Multi and inter-disciplinary research

(35) 2004 Regular Report on Romania's progress towards accession, http://www.mie.ro/Dialog_structurat/English/2004_regular_report.pdf
(36) NANOTECHNOLOGY IN ROMANIA, The National Institute for Research and Development in Microtechnologies, http://www.mct.ro/web/2/fp6/3/Nanotechnology-Romania.htm

- Synergetic and innovative research results
- Partnership between research institutes, universities, SMEs, in order to extend national and European scientific, technological and innovation patrimony.

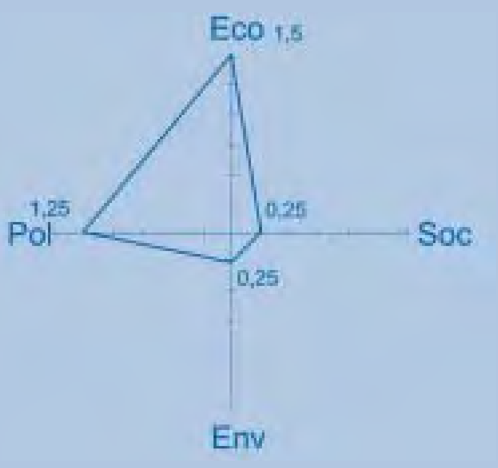
Within the framework of MATNANTECH Programme, a total of 108 collaborative projects, 3 single beneficiary projects and 7 priority projects were approved by August 2001 involving 134 Partners and a funding R&D budget of 6.530 MEuro. About 49% of the beneficiaries are from the institutional sector, 13% from large enterprises and 38% from small and medium-sized enterprises.

MATNANTECH is financing projects in nanotechnologies, such as:

- Bionanotechnology network (BIONANONET) – Biol. Roxana Vasilco, IMT-Bucharest (roxanav@imt.ro)
- Characterization of Materials and Structures for Micro and Nanonengineering MINAMAT-NET) – Dr. Raluca Muller, IMT-Bucharest (ralucam@imt.ro)
- Network of Research Laboratories in Nanotechnologies (NANOTECHNET) – Dr. Marius Bazu, IMT-Bucharest (mbazu@imt.ro)
- Consulting Centre in Nanomaterials, Nanostructured and Nanotechnology (3N) – Dr. Irina Kleps, IMT-Bucharest (irinak@imt.ro)
- Nanostructured silicon matrix for applications in biology and controlled drugs supply – Eng. Anca Angelescu, IMT-Bucharest (ancaa@imt.ro)
- Noise measurements in nanomaterials: a new investigation method – Dr. Mihai Mihaila, IMT-Bucharest (mihaim@imt.ro)
- Centre for Researches in Nanobiotechnologies (CENOBITE) – Dr. Marius Bazu (mbazu@imt.ro)

Information Society Technologies

Figure 35: IST in Romania



The "Brain Bench Global IT IQ Report 2001" placed Romania on the 1^{st} place in Europe, and the 6^{th} worldwide, in the classification of geographical areas with the highest concentration of certified professionals in 30 of the most critical IT skill areas[37].

According to the Romanian Ministry of European Integration Romania has an internationally competitive IT sector, thanks to the following achievements:

- Some 5,000 firms active in the IT sector with an annual growth rate of 20%
- Romania is the first country in Europe regarding concentration of certified professionals in 30 of the most critical information technology skill areas.
- Between 2001 and 2002 the value of ICT market increased by 100%.

(37) Diana Voicu, Information Technology and Communications – A driver for en effective integration Information Society, Ministry of Communications and IT, 2004, http://topics.developmentgateway.org/edevelopment/rc/ItemDetail.do~384905

A strategy of telecommunications development was drawn up by the Ministry of Communication and Information Technologies (MCTI) as a priority field of the country's macroeconomic infrastructure. Based on the survey undertaken by the consultancy company Dofrecom France, a long-term development program with strategic objectives was devised to include: the use of top world technology; expansion and improvement of the quality of services.

The transition to Information Society was defined as one of the strategic objectives of the Romanian Government for the 2001-2004 period and one of the EU pre-adhering conditions[38]. The transition towards the Information Society presumes the development of ICT field, which is of vital importance for the development of Romania. This field experienced a difficult process of adaptation and restructuring that evolved satisfactorily towards those market areas where we are competitive, for example, the software industry. The software industry registered an exponential growth also because big corporations used cheap, high-skilled manpower from Romania to develop offshore software[4]. It is interesting to note that Romania's density of software graduates (per thousand inhabitants) is significantly higher than in USA, five times higher than in Russia and nearly seven times bigger than in India. Romania has a long history of education and research in all fields of engineering and software. There are 116 universities, 36 of which have a computer science related faculty.

Sustainable Development

Figure 36: Sustainable development in Romania

According to the Romanian National Sustainable Development Strategy, for Romania, sustainable development is not one option among many others, but it is the only responsible way to plan development in line with Romania's national interest and the requirement of international collaboration. Therefore, the national strategic study for sustainable development did not simply attempt to follow the most recent trends of the international scientific community. The endeavour to incorporate the philosophy of sustainable development in any national or local development strategy is essential for Romania to cope with the requirements of, and fit into, the current complex world[39].

In the end of the 90's Romania recognised that its economic situation and development are far from meeting the requirements of a sustainable development. During the last ten years of the 90's, the structural crisis and the inherited unbalances, the delay of the economic and institutional reform, the incoherence and incongruities and gaps between the components of the economic reform, between the nominal and real economy, have caused a prolonged decline of the country. The hectic and destructive use of resources has also contributed to this situation. The impact on the environment was most severe: on the

(38) NATIONAL STRATEGY FOR THE NEW ECONOMY AND THE IMPLEMENTATION OF THE INFORMATION SOCIETY, MINISTRY OF COMMUNICATIONS AND INFORMATION TECHNOLOGY, 2002, http://www.mcti.ro/1324.html

(39) National Sustainable Development Strategy, http://www.sdnp.ro/ncdpublications/nssd.pdf

one hand, wasteful use of resources has become chronic, and on the other, the economy, continually impoverished, can hardly cover the costs for the protection of the environment – though they are relatively low, as compared to those in the developed countries. The evolution of the economy is marked by distortions, with a strong note of nonsustainability[10].

It was also observed that the energy sector in Romania was facing very difficult problems: lack of a long-term energy strategy consistent with a sustainable development strategy; scarce and incoherent legislation and regulation; poor institutional framework; virtual exhaustion of known oil and natural gas reserves; inadequate price policy for energy; continuation of various forms of subsidies; obsolescent and inefficient technologies throughout the energy chain; high level of environment pollution, and many more[10].

Life Sciences

Figure 37: Life-sciences in Romania

According to the EU ForeTech project, in order to meet society's needs and increase its competitiveness, Romania should address many of the global needs relating to the health, food and the environment, and to sustainable development, and to find the best ways in attracting the human, industrial and financial resources to develop and apply the agro-bio-industrial technologies

In Romania the cultivated area with genetically modified (GM) crops recorded a significant increase during the last years. Very important challenge is the use of the potential of biotechnology to improve the non-food uses of the crops being known that the biomass could contribute to alternative energy with both liquid and solid biofuels such as biodiesel and bioethanol as well as process such as bio-desulphurization. Plant genomics also contributes to conventional improvements through the use of marker-assisted breeding, biomass could be used also as a renewable resource for chemical industry.

Romania needs to know the new ways to protect and improve the environment using the biotechnology including bioremediation of polluted air, soil, water and waste as well as to develop cleaner industrial products and processes[40].

C) The social – economic model

This model is close to the previous one in its global format. The main difference is the nature of the socio-economic factors that support nanotechnologies on one hand, and sustainable development on the other hand.

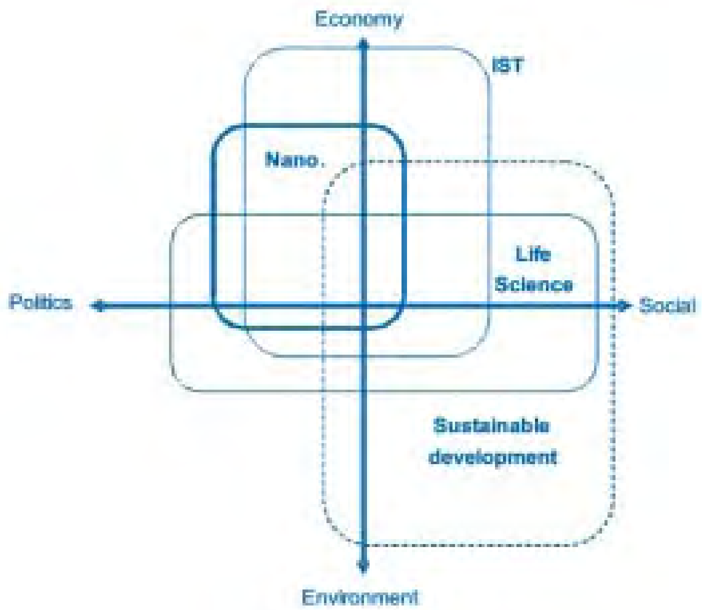
Regarding nanotechnologies, the model shows a shared influence of economic and political factors. A reason that can explain this situation can be the weakness of industries able to benefit of nanotechnology applications – large preponderance of SME based economy like in Italy, or very traditional industrial base as in Bulgaria – . In order to however support R&D in this scientific field, political will so becomes a preponderant relay factor.

(40) http://foretech.online.bg/docs/background_papers_BIO_ro.pdf

At the opposite, socio-economic factors that support sustainable development R&D are clearly based on social and environmental issues. If environmental issues are of course easily understood, the social ones can be explained by the fact that there is a strong awareness of the potential impact of non sustainable development on quality of life and health. This awareness is very often the results of the geographical situation of the countries (Netherlands, Portugal…) or there current level of pollution or industrial risks (Czech Republic, Bulgaria…). But there is also an other factor that can be influent in this model which is the fact that a beginning of market opportunities could be perceived in this field, as it is the case for example in Spain.

So the countries that belong to this model or are close with it are Czech Republic, Bulgaria, Netherlands, Spain, Italy, Portugal…

Figure 38: The social – economic model



The Spanish example

In 2001, Spain spent some 6 billion euros on its various R&D activities which represents slightly less than 1% of the country's GDP. The state finances thereby about half, i.e. slightly less than 3 billion euros, of all research expenditures. Making abstraction of R&D funding coming from foreign companies, the private sector in the UK accounts for only about 48% of overall expenditure, i.e. significantly less than the 2% suggested in the Barcelona accords. The government's objective is to increase the R&D budget by about 9% annually.

Generally speaking, the Spanish R&D landscape is suffering form a series of handicaps, such as an acute lack of resources (which is at least partially due to insufficient private implication: only about 20% of Spanish enterprises realise technological innovation activities), a shortage of a qualified workforce, low number of (creation of) innovative companies, poorly developed links between research institutions and companies, insufficient coordination of the national R&D effort, lack of awareness as to the impact of innovation on business performance (e.g., as regards the field of nanotechnologies).

As regards the influence of the SEEP factors on public R&D policy in Spain, the economic variable seems slightly predominant in the areas of Nanotechnology and ITC, while societal factors (demographic trends, new life styles) play a more important role in the areas of Life Science. While Sustainable Development does not constitute a research program in itself, the theme – in itself rather economically motivated – partly justifies a number of other, more specific programs, such as the Subprogram of Maritime Technologies and the Program on Energy. Environmental considerations are only of most secondary importance.

Nanotechnology

Figure 39: Nanotechnology in Spain

The Spanish situation as far as the nanotechnology area is concerned is contradictory. On the one hand, there exist research groups of international standing, while, on the other hand, national research policy has only in 2004 started to acknowledge nanotechnologies' importance. Moreover, an overwhelming majority of companies making up the industrial fabric only start to slowly discover the enormous implications this technology field is likely to have on their sectors in the not all to distant future.

Spain is thus exposed to some major challenges in the nanotechnological field. While the establishment of a support structure (funding, infrastructure, science parks, education,…) is indispensable for the emergence of competitive national actors, the gap between the existing scientific potential (on the part of both public and private research centres) and the absence of economic interest (on the part of the companies) has to be rapidly overcome. To this end, the government has planed a number of test programs.

Information and communication technology

Figure 40: IST in Spain

Spain will adopt broadband in 2005 which is very likely to result in a massive increase in broadband investment and competition. However, low home PC penetration and low overall online penetration risks to slow down the broadband market development towards the end of the decade. As a matter of fact, Spain has been for many years significantly below the European medium as far as the area of ICT is concerned.

Nevertheless (or therefore), R&D in the field of ICT is seen as crucial for a number of reasons: to secure the future competitiveness of the Spanish economy (also beyond the ICT sector), to create high value-added jobs, to provide new administrative opportunities as well as a series of societal benefits (education, health,…).

Life Sciences

Figure 41: Life-sciences in Spain

Biomedical research is, above all justified by the objective of increasing individual and societal quality of life, by providing the promise of an increase in life expectancy and qualitatively better and more efficient health services. A number of programs are thus, for example, concerned with research on specific illnesses which seem rather prominent in Spain, such as cancer and cardio-vascular diseases.

In general, the medical sciences have developed in the course of the last 15 years into a very promising sector of the Spanish economy and constitute today with almost 15% of the overall national R&D budget the government's funding priority. Nevertheless, the relationship between the pharmaceutical industry and biotechnical research centres has to be further developed in order to improve the commercial output of R&D advances. What is more, in the face of a rather underperforming domestic industry of medical equipment, pharmaceutical companies indirectly create a strong dependence on imported machinery, a situation that needs to be progressively modified in the medium term. Today, only about 20% of medical equipment in domestically produced.

Sustainable development

Figure 42: Sustainable development in Spain

Spain has no R&D area dedicated specifically to Sustainable Development. The theme does, however, appear in the context of a variety of other programs, such as Maritime Technologies and the Program on Energy, almost exclusively motivated by an underlying economic rationale. In fact, there are numerous programs related to maritime sciences: many local economies depend on the sea, such as fisheries and tourism, and the increase in maritime traffic has only served to further highlight the relevance of the subject matter.

As regards the research area of alternative energies, a similar (and mainly economic) rationale applies. Wind power is thus primarily seen as an enormous economic opportunity for the country's companies active in this sector. As a matter of fact, totalling around 25% of overall European production, Spain is already the 2nd most important producer of wind energy in Europe and strongly growing (+27,2% en 2004). As far a solar power is concerned, Spain is the main producer in Europe and third world wide. And while due to changes in Spanish tax laws the growth of the biofuel market is expected to continue, the bioenergy unit of Abengoa, Europe's leading bioethanol firm which last year produced 260 million litres of ethanol in Spain and about 400 million litres in the United States, is due to open a 200 million litre plant in northern Spain at the end of this year.

Sustainable development related R&D is thus primarily motivated by natural geographic conditions (such as the availability of large stretches of unused/agricultural land, windy climate along Atlantic coastline,…) and economic considerations. The government makes thus its support for the ecological agenda dependent on them not becoming a burden for further economic development.

The Czech Republic example

The total of R&D expenditure reached 32 247 million CZK in 2003. In comparison with the previous year, R&D expenditure increased by 9,1% from 29 552 million CZK in 2002. The share of R&D expenditure of the gross domestic product – GDP was 1,34%. The government provided 13 488 million CZK from public budgets to support R&D activities. The government spent on R&D 0,56% of the GDP.

In the last few years we are witnessing a basic transformation of the Czech regime as well as related changes in the science and research domains of the Czech republic. Corresponding organisational changes accompany this transformation.

The system of central planning and management of the science and research has been abolished. Direct governmental interventions into most of research institutions have been eliminated. New structures and forms, complying with principles of democracy, plurality and competition, have been adopted.

New actors in research and development appeared, Freedom of research was introduced through the principle of free individual work and responsibility.

A combination of institutionally and specific (Through grants) financing of R&D was introduced. Market oriented entrepreneurial activities are applied in R&D business sector, mainly due to the influence of privatisation.

International co-operation in the field of R&D was created, including participation in the EU framework–programmes.

The changes are well depicted in the following; in 1990: 68 thousand workers were employed in R&D. In 1991 the number of R&D workers was 44 thousand (about 65% of the previous number) and in 1992 to 31 thousand persons (about 46% compared to that of year 1990). In 1995-98 the number was estimated to be 23 thousand persons.

In 2003: R&D personnel about 25 thousand employees are involved in R&D.

The changes were also accompanied by a privatization drive.

The first wave comprising 58 institutes with 13 000 employees, was completed in 1993.

Additional 51 institutes with 14 000 employees were privatised in the following second wave. The privatised research and development institutes represented about 4% of the total number of enterprises planned to be privatised.

The average size of a privatised organisation was about 260 employees. There were only 11 organisations with more than 5 000 employees. R&D institutions within enterprises employed about 20 000 employees and they were privatised together with the relevant manufacturing enterprises.

Foreign investments, in the Czech economy, are growing. The annual investment activity in the processing industry grew by about 16%, and a positive structural shift is going on in favour of investments into machines and plants by foreign companies. Foreign companies made use of investment incentives provided by the government.

The percentage of export of the high-tech industries products in the total export of the Czech Rep. is growing (from 8,2% in 1998 to 12,4% in 2002), and is approaching the volumes in other European countries.

The Czech Republic authorities recognised that in order to enhance the results of its R&D endeavour they must emphasize the quality and innovativeness of research results through new systems of the research and development evaluation and also reduce the fragmentation of the public support, which is now split into too many research orientations and projects. This will be accompanied with the preparation of new legislative norms for the operation of the R&D organisations. It was recognised that a significant lag behind the EU-15 countries also exists in patent applications and granted patents, it is planned o remedy this situation.

Since foreign companies often use short-time advantages of the inland investment incentives and the present existing low wage level, it cannot be said that the investments into research and development in the industrial sector grow at a sufficient pace. It is expected, however, that R&D expenditures will increase in the long perspective to 3% of GDP as required by the EU Lisbon target for 2010.

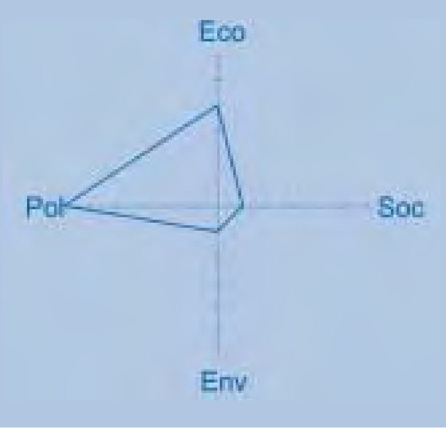
It seems that the main problem regarding R&D and innovation processes in the Czech republic is the very low level of demand for research from indigenous businesses. Domestic companies still see innovation to be excessively risky and do not have sufficient resources to finance R&D.

The reasons may be the low level of capitalization, a lack of track record in financing R&D projects and the shortage of equity finance.

IT is proposed to establish an explicit innovation policy which will aim at an enhanced balanced progress of R&D capability and the establishment of innovation networks, support of spin-offs and engagement of stakeholders from the entrepreneurial sector.

Nanotechnology

Figure 43: Nanotechnology in Czech Republic



Fundamental and oriented research in the Czech Republic is performed in the Institutes of the Czech Academy of Sciences and at the universities. It is funded by the state from public resources, both from the budgets of the academies or universities. These grants are given by the Grant Agency of the Czech Republic, Grant Agency of the Academy of

Sciences of the Czech Republic, University Grant Agencies or Ministerial specialised resources. A certain amount of funding also comes from European research schemes. Until 1989, applied research has been funded by the state, either directly or indirectly through ministries or through state industrial companies. Since then most applied research institutes were (with some exceptions) either privatised or closed down, and the capacity of the applied research has decreased substantially (particularly in the area of electronics and communications). As a result, centres of excellence and sources of new ideas and procedures in the field of micro and nano technologies must be looked for predominantly in the academic and university institutes.

Nanotechnology research networks exist in six countries in Central and Eastern Europe, according to the survey of nanotechnology networks by the European Commission. The Czech Republic is the home of a specialised network of five partners dealing with materials prepared with Metal Organic Vapour Phase Epitaxy. The Technology Centre of the Czech Academy of Sciences is a partner of the European MINATECH network, aiming to assist SME's in participating in EU research projects, handling Nanotechnologies issues.

Information and communication technologies

Figure 44: IST in Czech Republic

The Czech government approved a policy in May 1999 aimed at building a highly developed information society, including the right of direct access to information. It identifies priority areas and sets specific tasks to be achieved for each of these areas. In March 2002, the Czech Government adopted an updated action plan as part of its national information policy so as to bring its objectives closer to those of eEurope 2002. It included a list of information society projects to be implemented by public administration services. The ICT manufacturing production value generated in the Czech Republic is still proportionally small as compared to world or EU15 production. Considering the dramatic effects of the transition period in early 1990's and the consequent transformation of most of the Czech industries, this is a reasonable outcome. Since then, strong foreign direct investments started to flow and the arrival of many major ICT multinationals into the country modernized local industry and increased its competency. Nevertheless, The Czech Republic ICT production today does appear to have little effect on the position of Europe. Mainly since the global ICT production by the candidate countries only accounts for 1.2 percent of the global market and the EU25 expands the EU15 production value by 5.9 percent. The scale of the change that is caused by the Czech Republic is thus of little significance as of now.

A look at the Czech Republic share in the production of ICT will show that it produces 29% of all the office equipment produced in the candidate countries of the EU, 21% of the control and Instrumentation, 22% of medical and industrial equipment, and 18% of both radio communication, radars and components. This fixes the Czech Republic in a relatively good position among the new members of the EU 25.

Life sciences

Figure 45: Life-sciences in Czech Republic

The statistics of life sciences related institutions in the Czech Republic are impressive. 21 life sciences related institutes are in the Czech academy of sciences. The statistics show that over 30,000 students are engaged in biology, Chemical and Pharmaceutical related disciplines. The chemicals and pharmaceuticals sector employ around 120,000 employees.

In the newly created Life science organisation one finds:

- 78 universities and research institutes (faculties, departments, labs, etc.);
- 36 biotech companies (including those established by foreign investors);
- 42 pharmaceutical related companies, 18 environment related companies;
- 20 food related companies and over 100 “other” biotech companies.

The long tradition in R&D support of the Life sciences in the universities is countered by the low innovative activities and by the lack of globally competitive “champions”. Lack of technology transfer experience is also part of the matrix of limited cooperation between universities and industry.

Joining the EU provided better access to markets, partners and foreign investors and helped integration with EU research programs.

The life science sector in Czech Rep. must integrate the life science sector within the country and also promote and “sell” the integrated Czech Life Science competencies to the outside world. Based on the opinion of experts the Czech Republic may become a biotechnology center in Central and Eastern Europe, specializing in stem cell research, hepatitis and AIDS (HIV) treatments, and in leading-edge biotechnology-nanotechnology processes.

Several biotechnology Czech companies can serve as an example.

A company that was spun-off by leading scientists at the Czech-based Research Institute for Pharmacy and Biochemistry develops new drugs for treating cancer and HIV and improves the performance and effectiveness of established drugs. This company experienced a 70 percent year-to-year increase in revenue in 2004.

A second firm specializing in the production and distribution of in vitro research products for molecular and cellular laboratory medicine. The company's team focuses on the development of Kits, which detect and measure antigens or antibodies.

Another company, the first spins-off of the Czech Republic's Academy of Sciences 13 years ago, collaborates with leading Czech-based academic institutions to commercialise key discoveries. Others develop new, targeted therapeutic drugs by producing radiopharmaceuticals for diagnostic and therapeutic purposes.

International Pharmaceutical leaders continue to invest and expand their operation in the Czech Republic. The Czech biotechnology sector is internationally recognised for its world-renowned discoveries and breakthroughs in the sciences, including a new line of human embryonic stem cells, or ESLs. Only three laboratories have accomplished this critical step worldwide. Czech Republic scientists are also doing research resulting in the convergence of biotechnology and nanotechnology.

Sustainable development

Figure 46: Sustainable development in Czech Republic

The Czech industrial policy goal after 1989, was to carry out restructuring of the old planned economy and commence its growth subsequently. This had to be done while respecting inherent social and environmental limits and needs. The Czech industry had also to embark on the path to sustainable development. Since September 1989, practically all of the ecological parameters in the Czech Republic have significantly improved, as a result of huge support on the part of the public at large, which demanded an instant improvement of the environment, which at the time was in a catastrophic state. A new effective system of environmental protection was introduced. This system leaned upon progressive European legislation. Also, a mobilisation of significant funds, both private and public, was very successful. The dramatic decrease in air and water pollution results mostly from installation of end-technologies that do not change basic production techniques and impose an economic burden. It is not possible to achieve further significant improvement through such measures. Instead of costly measures at the end of the technological process, it is necessary to provide solutions based on sustainable development strategies. This approach brings a double benefit: both economic and ecological. The new, ecologically acceptable technologies must respect the economic and the social needs.

The Czech government, Inspired by the European Commission's Fifth Action Plan on the Environment, approved several important activities e.g. The "shared responsibility among the Government, industry and public". The activities have been improving constantly. In 1999 the Agreement on Cooperation among the Czech Ministry of the Environment, Czech Confederation of Industry and Transport and the Czech Business Council for Sustainable Development was signed and in 2000 the Action Plan for Cooperation followed. As a result, the readiness of industry to inform about its impact on the environment increased significantly. A large array of enterprises had fully complied with the Law on Information on the environment even before it was accepted and they published their environmental reports.

In the industry sphere, several voluntary agreements in the field of environment and sustainable development have been signed with various governmental and nongovernmental bodies.

It seems that the Kyoto target on greenhouse-gas emissions could be reached comfortably and emission reduction will be helped by membership of the EU emission trading scheme.

It was proposed that emission trading should be accompanied by an excise duty on household coal to persuade household owners not to use coal-fired heating which is not subject to the permit system. In addition, plans for new brown-coal power plants and relaxation of environmental regulation for mining brown coal should be reconsidered, both for environmental and cost reasons.

Artificially low prices are encouraging energy consumption and the policy of bringing retail energy prices to market levels should be completed.

Although air pollution has been reduced significantly, levels still remain relatively high. More cost-effective instruments need to be used in bringing levels down further. In this regard, the introduction of emission-related taxes on commercial vehicles is welcome and should be extended to all vehicles. The introduction of road pricing in urban areas should also be considered.

The demand for energy, when generating a unit of GDP, decreased by 30% between 1990 and 1999. This decrease can be mainly attributed to the natural restructuring of industry in the 1990's, however, the demand for energy in the Czech economy (expressed as domestic consumption of primary energy resources per one unit of domestic product) is still high. According to the Ministry of the Environment, it was higher by 23% compared with that of the European Union and 4% above the average of the OECD Countries.

The National Strategy aims at an increase in the share of renewable resources in the total material input into the Economy however, from the point of view of sustainability their exploitation should be lower or equal to its natural reproduction.

The goal of the National Strategy with respect to exploitation of renewable resources is prudent, meaning that the exploitation of renewable resources would not damage the basic life supporting environmental functions. Non-renewable resources will be substituted with renewable resources whenever this is possible. The extent of exploitation of renewable resources, has both a significant economic and social impact (employment, public health, rural development) as well as an impact on the environment. Revenues from the exploitation of non-renewable resources should provide funds that if invested should provide a sustained flow of renewable substitutions for gradually exploited non-renewable resources.

Despite a rapid decrease in the 1990's, the consumption of energy in the Czech Republic remains high. Energy consumption per capita is approximately on the level of the EU average. However, in terms of energy intensity of the economy, the Czechs use of energy is more wasteful than the EU. As far as the structure of primary energy Fossil fuels dominate (91% in 1999), the share of natural gas increase. However, the use of renewable resources is still on a very low level (about 1.5%).

The Czech Republic has not so far taken seriously enough the EU recommendation for support of producing electricity from renewable resources in the domestic electricity market. This defines the goal that the use of renewable resources for electricity should amount to 22% by 2010 in the European Union and to reach a share of 12% of use of renewable resources for primary energy consumption.

The basic approach for the sustainability strategy in the area of the decrease in energy demand is a program of energy savings. a suitable economic environment must be created in which it is advantageous to invest in energy saving. This condition applies to both households and factories.

The first step is a move in the direction of energy sources that burn “cleaner” fossil fuels, namely natural gas. The second step is a reduction in heat loss and electricity during transport and distribution. The third step is support for renewable energy sources, an increase in the efficiency of energy production through modern fossil fuel burning technologies (an increase in efficiency by 5-20%), and through co-generation of electricity and heat (an increase of up to 40%).

The long-term government’s energy policy defined by law includes goals and priorities of the government in the area of energy management and the impact on the environment. However, it should be mentioned that during the creation of the energy policy a full social consensus was not achieved. The emission of air pollutants in the Czech Republic indicated a remarkable decrease between 1989 and 1999. This decrease reached 90% with solid particles, 87% with sulphur monoxide, and a somewhat lower decrease (58%) of nitrous oxide, carbon oxide (22%) and volatile organic compounds (39%).

The total amount of surface water pollutants from stationary sources in the Czech Republic significantly decreased between 1989 and 1999. This can be attributed to improvements in the situation in the area of waste water. The total amount of waste water output decreased by 33%. The number of citizens connected to public drainage systems increased from 73 to 75 percent. Waste water treatment, drained by public drainage systems, increased from 71 to 95 percent. Between 1990 and 1999, 333 new waste water plants were finished in the Czech Republic so that their total number in 1999 amounted to 959. Lower use of fertilisers and pesticides in agriculture resulted in a decrease in non-point pollution of surface and underground water. Along with the ongoing decrease of air pollution by stationary sources the relative significance of this non-point sources of pollution grows, namely the pollution by nitrates. Despite a significant decrease in air and water pollution, the Czech Republic is far from a state that could be considered sustainable in the long term. New measures are applied mostly due to adopting the EU legislation.

In 1999 the amount of waste produced in the Czech Republic, was 3.5 tones of waste per capita. On average, the amount of waste per capita in the EU is approximately the same. From this amount, about 1/4 is industrial waste, 20% agriculture and forestry waste, and 14% energy waste (without radioactive waste) and 12% communal waste. A high share of waste, nearly 9%, belongs in the “dangerous waste” category. In 1999, only 3% of waste in the Czech Republic was incinerated. Approximately 26% of waste was used as secondary material, 3% was recycled, 30% was deposited in dumps. The goal of the waste policy is a decrease in waste production and a preference for the safest, most advanced techniques in processing, detoxication, and/or depositing of dangerous waste. An increase in recycling and energy use of waste (burning) is, in respect to its current low level in the Czech Republic, a prime necessity. The adoption of European legislation will significantly improve this situation.

D) The multi-driven model

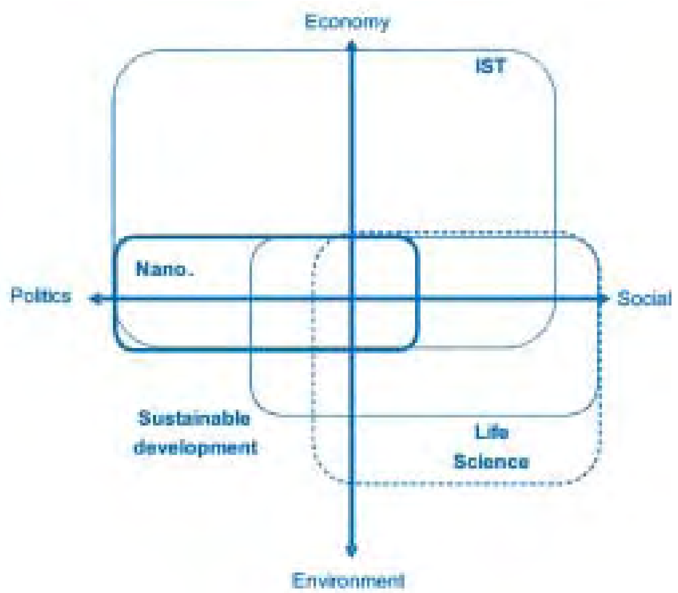
The last model shows a very strong differentiation between IST and the three other scientific fields. In this model the only real impact of economic factor will be on this field. This can be easily understandable if we take into consideration that IST can benefit to every industrial sector and so could easily be linked to competitiveness in general terms. But Social and politics factors are also largely used to support this R&D field. It means that IST are developed in order to reinforce social development at large in many fields such as education, government and public sector, health, etc.

Looking at life sciences and environment fields, the main socio-economic factors to support R&D public policies are both environmental and social. It is a quite similar model than the 3rd one, but without visions of a potential emerging market.

Finally, the nanotechnology field is mainly supported by politic factor. This situation can be analysed as a way to support R&D in the field with the main objective to "remain in the running" at least to benefit for cooperation opportunities at international level.

Not surprisingly, the countries close to this model are relative small ones at European level such as Malta, Estonia, Hungary…

Figure 47: The multi-driven model



The Malta example

Malta[41] tries to overcome the handicap of not having natural resources by incorporating such new developments as alternative energy resources. The estimated budget of Malta for R&D during 2003 was 5.6 Million Euros. Most of the scientific and technological research is done in the University of Malta, which supports competitive research program.

(41) http://www.jrc.es/projects/enlargement/FuturesEnlargementII/Florence11-03/stprofiles.pdf

The Maltese government assigns top priority to the role of science and technology that are on the National Agenda since the 1980s.

The government's goal at that time was to exploit the opportunities offered by the application of science and technology towards securing the country's continued social and economic progress. This was the base of the establishment of the Malta Council for Science and Technology (MCST) in 1988 as an advisory body for creating a scientific national policy. The next step was taken by Malta in 1994, when the Foundation for Science and Technology was established as a public Foundation. The new body was needed for the implementation and coordination of national science and technology policies under the direction of the MCST.

In 1994 the government adopted a National Science and Technology Policy, which outlines the direction of Maltese future activity in R&D policies.

Malta has developed in 2003 a National Research, Technological Development and Innovation (RTDI) program. RTDI Strategy of this program is mainly to change relate to shift in emphasis from S&T per se to STI Policy adding Innovation to the previous S&T policy approach. The preparation of the strategic program was helped by the Maltese Cabinet Ministers' involvement in EU Councils in particular the Competitiveness Council. The RTDI Program as an implementing measure aims to emphasise the economic advantage and achieve mainly two objectives:

a. To provide technical support for Malta in order to be able to implement the Acquis Communautaire and to promote the appropriate environment for the continuation of science and innovation research.

b. To support the synergy of private and public scientific and technological research and developments.

The implementation of RTDI program is carried out by financing all Sub-programs at up to 100% of direct costs. It aims mainly for projects lasting for up to three years. However, a survey carried out on 2003, showed that the Innovation efforts in Malta require a better research community-industry co-operation and improved local and international networking.

Information and communication technology

Figure 48: IST in Malta

Malta spent much effort during the recent years in order to create an appropriate atmosphere for the development of information technologies. The efforts of the Maltese government are based on the recognition that these technologies might be an empowering force to bring about strategic change in the economy. It is not only in terms of improved management systems for cooperative governance, but also to facilitate closer collaboration between governmental and private players and the research centers as well.

The policy aims also to use these new information technologies for increasing the public involvement in policy making in Malta.

This Policy of the Maltese government has started in 1990 by setting up of the Management Systems Unit. Two years later, the government established an interdisciplinary experts team in order to create a one-year study needed for developing a National Strategy for Information Technology. The work of this team was led by a bottom – up approach. In 1995-the results of the team led to adopt a new scientific policy by the government.

In 1999 the Central Information Management Unit (CIMU) was established in the office of the Prime Minister. This unit directed by the Chief Information Management Officer. The aim of this unit is to regulate and to give strategic direction for the establishment of information systems within public services setting. In 2000, the estimation of the central IT budget as a percentage of the national budget was at 1.09%.

Regarding the ICT Awareness among Enterprises, the government commissioned MISCO International and KPMG to carry out a survey between January and February 2002. The survey was directed specifically toward business entities. The study carried out among 250 businesses showed that the annual investment in information technology by Maltese companies ranges from €1,250 to €62,500 according to the firm's size.

The study shows that on average, companies employing up to five workers invest €1,250 a year in IT. The investment rises to €3,750 in the case of firms with a workforce of 6-20 employees and to €8,750 in the 21-50-employee category. Where the workforce is composed of 51 to100 employees this rises to €22,500 and then to €62,500 where the number of workers exceed 100.

Moreover, two out of every three businesses that use the Internet at their workplace carry out IT related training at their place of work".[42]

One of the focuses of the governmental policy was on the development of e-commerce technologies as a mean to deal with the digital economy.

From 2003, two recent developments address the infrastructure gaps in establishing Malta's place in the digital economy: first, *the liberalisation of the telecommunications sector*. Second, *the proposed establishment of a legislative framework for information practices*.

Regarding the *liberalisation of the telecommunications sector* most of the telecommunications services, including cable TV networks, have been liberalised. Regarding the fixed and mobile telephone systems they are still controlled by monopolies. But the new policy tries to break them.

Regarding *legislative framework for information practices* the Government published last year a White Paper proposing a legislative framework for information practices. The policy represented in this white paper, tries to develop technologies of e-commerce legislation. It aims to create the legal basis for the free and safety economic interaction in the electronic commerce. In other worlds, it tries to protect the bill data and the safeguards of the technologies users, such as citizens, owners' rights, valuable data and information systems.

(42) Innovation Policy Profile: Malta in Innovation Policy in seven candidate countries: the challenges. Final Report Volume 2.4. (Islands Consulting Services, March 2003)
ftp://ftp.cordis.lu/pub/innovation-policy/studies/malta_final_report_march_2003.pdf

The Bill draws on a variety of sources, such as the UN Commission on International Trade Law (UNCITRAL), Model Law on E-Commerce of 1996, or the 'Electronic Signatures' and 'Electronic Commerce' directives of the EU.

The government website designs, hosting and maintenance, and generic e-mail accounts use was issued by CIMU on 2001. The upgrading was needed to secure the government's IT. Regarding the enlargement of the MAGNET (Malta Government Network) use and the attainment of e-government, the Maltese government supported related projects such as a technology audit, directed towards the physical network, Network usage and service provision or a new design for Remote Access Service Facilities. It is an exercise aimed at providing MAGNET users with improved remote access via the telephone line. In this sense, modem Speed was increased to 57.6k with the number of modems increased 15-fold[43].

Another scientific direction of MAGNET is to procure a network storage solution, whereby all storage will be securely located centrally.

Sustainable development

Figure 49: Sustainable development in Malta

[44]One of the top priorities of Malta's national policy in relation to science and technology as outlined in the National Science and Technology Policy Document (1994) is Sustainable development.

The policy that has developed upon this priority, was set on the recognition of the important outcome of the 1992 World Summit in Rio de Janeiro and the agreement for the program of Agenda 21. The policy of Malta, regarding this international commitment, was defined by (Malta Council for Science and Technology) MCST. MCST have made a clear commitment to give sustainable development a prime importance in science and technology policies at the national level.

a. Under this policy, Malta initiated scientific activities under Sustech Consulting program. The Activities undertaken by Sustech Consulting aimed to raise awareness of shared responsibilities with respect to water resources use, production and conservation such as setting up of a Water Information Management Network, made up of local and international water networks. The program focused on S&T projects such as the commissioning and servicing of water and wastewater treatment equipment; the design of water and Waste water specification and supply management system for the industrial and agricultural and households sectors; Preparation and coordinate hydrological and geological researches, initiations of Environmental Impact Assessments (EIA); carrying out of water audits for industrial sectors including hospitals, and various of scientific projects which studied the application of innovative technology.

(43) Innovation Policy Profile: Malta in Innovation Policy in seven candidate countries: the challenges. Final Report Volume 2.4. (Islands Consulting Services, March 2003) ftp://ftp.cordis.lu/pub/innovation-policy/studies/malta_final_report_march_2003.pdf

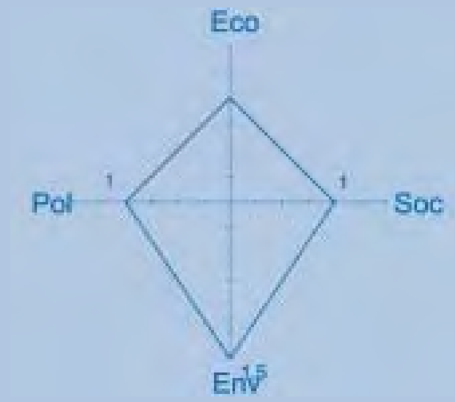
(44) European commission, 2002' "innovation and SME", European trend chart on innovation: analytical report, transfer of innovation policy schemes in candidate countries. (http://trendchart.cordis.lu/Reports/Documents/TCW7PolicyTransferPaper.pdf and http://www.mcst.org.mt/resources/pubs/ST_policy.pdf

b. Another issue under the sustainable development scientific policy of Malta is related to efficient and alternative energies. In this area, Malta supports studies and activities in the areas of Alternative; economically feasible, energy-saving and renewable energy applications. Thus reducing Malta's dependence on foreign fuel supplies as well as negative environmental impacts. The applications in these areas included renewable energies such as direct solar heating, photovoltaic, wind energy and energy-saving buildings.

c. Taking to consideration of the geographic condition of Malta as an Island, the governmental scientific policy has focused also on co -ordination of sea- and land-related activities (ranging from free port and ship repair activities to fishing and aquaculture and recreational activities including tourism). The policy often multiple and competitive between themselves, should lead, in particular to an integrated sustainable coastal management scheme.

Life Sciences[45]

Figure 50: Life-sciences in Malta



One of the main priorities of the Maltese national scientific program is to promote Malta's competitiveness through research and innovation in the area of Biotechnology. It has based on the assumption that Malta has always had a high level of skilled or even highly skilled workers prompting the establishment and growth of Biological industries based IT. The supporting in biotechnology R&D might encourage the development of these industries.

Regarding MCST, the application of biotechnology needs to be developed in the unique areas such as medicinal technologies, human and comparative genomes, and medicinal and aromatic plants. This technology might be developed as well as in the food industry and the production of specialty biochemicals, including biofuels.

As a first step, MCST became a partner institute of the World Economic Forum in February 2003, and participated in the eFORESEE Biotechnology Pilot foresight exercise. This project, aims to increase the biotechnology component of the Maltese marketplace by 2015. The main objective is to produce a plan to develop the fledgling Maltese Biotechnology Industry into a core sector of the Maltese economy by 2015 through a collaborative venture between academia, the public and private sectors and society. The participation of MCST in developing the scientific national biotechnology strategy of Malta might provide the necessary theoretic infrastructure for national investments in this area. In addition, it might help to attract foreign direct investment.

(45) http://www.eforesee.info/malta/biotech-programme.shtml?s=8442C368-7D5626124516-1679

3. Scientific positioning of Europe

3.1 The scientific positioning at field level and its links with socio-economic factors

3.1.1 The main indicators

This part of the report will provide a comparative analysis of the respective positions of Europe, the USA and Japan, both in terms of their public support structure as well as their scientific position.

In order to carry out this analysis, we have used the results of the expert panel. At this stage, the element of "public support" is thus defined as the "public support efficiency" according to the expert point of view.

By "public support efficiency", we mean the feeling that experts could have on the global efficiency of public support to a specific technology. This public support could either be financial or not. We can understand this indicator both as a way of measuring the impact that the public support can have on R&D related to a specific technology, but also as a way of measuring the capability of the R&D system to benefit from public support.

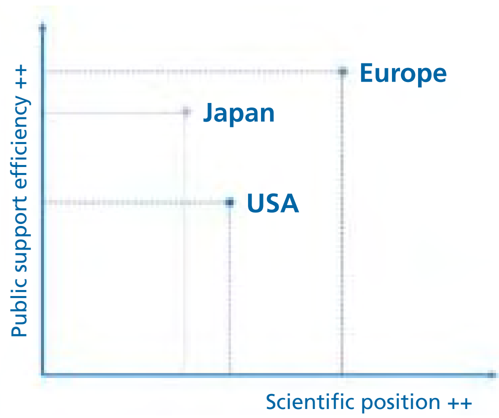
The "scientific position" indicator related to a technology is built in comparing the position of EU, USA and Japan according to the experts' point of view.

As a matter of fact, both the "public support efficiency" and the "scientific position" are based on the experts' opinion. Examining the extent to which the subjective character of the experts' evaluation might limit the very relevance and utility of their contribution to the present study, we compared their input to "objective" variables, such as the distribution of R&D budgets by scientific fields in the three geographical areas on one hand, and the number of patents and the number of publications on the other hand, and didn't find any significant contradiction.

These two indicators allow us to make a specific graph, each indicator representing an axis.

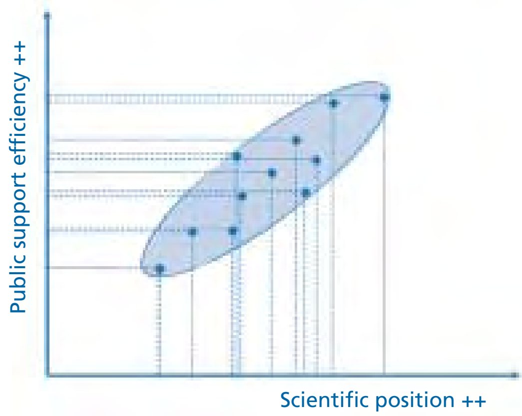
If we take one specific technology, we can place it in the graph with different position that represent the EU positioning, the US positioning and the Japan one.

Figure 51: Relative positioning of a technology



As the experts have answered technology by technology, if we place the average position of each technology that belongs to a specific scientific field into the above graph, we can obtain a group of points that represents the relative positioning of a whole scientific field for a geographic area. This type of representation by group will be the one that we will use in this chapter to facilitate the comparison.

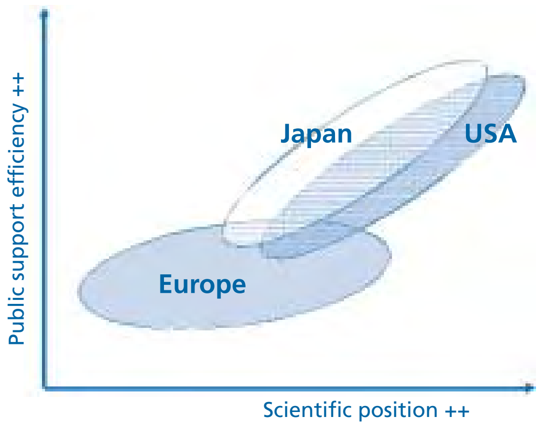
Figure 52: Relative positioning of a scientific field



3.1.2 Scientific field specificities and potential leadership at this level

A) Nanotechnologies, knowledge-based multifunctional materials, new production processes

Figure 53: Scientific positioning of Europe in nanotechnologies



As the graph shows, the relative position of Europe, Japan and the USA in the field of nanotechnologies suggest a strong correlation between public support efficiency, on the one hand, and the corresponding scientific position, on the other hand. While this is particularly evident in the case of Japan and the USA, this link is somewhat weaker for Europe. Different hypotheses can be formulated in an effort to provide possible explanations.

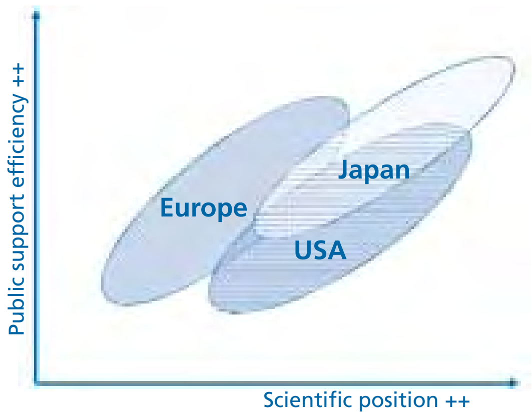
A first possible hypothesis could be based on the difficulty to concretely define this field in terms of scientific competences. Nanotechnologies are by nature convergent technologies, and any effort to precisely define the support provided to this field is quite difficult as it covers different scientific domains[46]. We can thus make the hypothesis that in the field of nanotechnologies, it is not so much the importance of the public support that makes the difference, but the way this support is being delivered. If this hypothesis is true, it means that Europe needs to give higher priority to the issue of convergent technologies in terms of R&D organisation and/or policies:

- A more adapted R&D organisation would mean multidisciplinary laboratories capable of developing their own research programs backed by specific public funding;
- A more adapted R&D policy would imply a new way of financing multidisciplinary research such as specific budget guidelines or relevant incentive programs.

The second hypothesis we could make is that even though Europe as a whole is behind – with nanotechnologies requiring strong scientific competence levels in different technology fields – some European countries make real efforts in terms of public support in this field. Moreover, this implies the existence of a "two speed Europe" made up of countries with hugely diverging R&D potential having an impact on the global European scientific position and public support efficiency.

B) Information society technologies

Figure 54: Scientific positioning of Europe in IST



As far as the area of information society technologies is concerned, the graph above shows the leadership of the USA and Japan in terms of scientific position, while Europe is seen as having a less important scientific position.

As we will see in the next part of this report, this vision is a rather global one and does not necessarily correspond with the realities at the technology level. (Europe has, in fact, a high level of scientific expertise for at least two technologies.)

(46) In 2004, the OECD has published a report indicating that many countries have developed definitions of nanotechnology as a field of science and technology, and explicitly recognise nanotechnology as a multi- or inter-disciplinary field that draws upon work in the physical science, life-sciences and engineering (OECD: *2004 Results of OECD mini-survey on nanotechnology R&D programmes* DSTI/STI/TIP (2004)9).

Equally interesting is the finding that the efficiency of public policy support as being described by the experts seems to be equivalent in the USA and Europe. But if we look on the global public budget spent in this field, the USA spends almost twice as much as Europe does. This last point provides one possible explanation of the leading scientific position of the USA. This, in turn, suggests two possible strategies for Europe to enhance its own scientific position in the field of information society technologies:

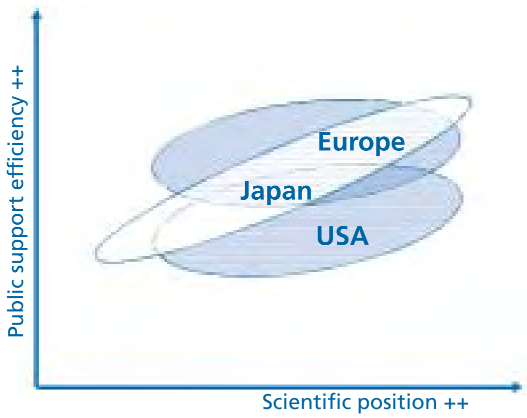
- To increase its public budget in this area;
- To increase the efficiency of its public support structure in the same way as in Japan (the financial support in Japan and Europe being at comparable levels).

But this field is also characterised by a very strong link with economic issues and economic development at large. It is thus interesting to see that while the USA and Japan clearly based their public support on economic factors (and somewhat political ones in the USA case), Europe put a strong emphasis on societal factors. In a caricatured way, we can say that Europe supports IST while the USA and Japan support ICT.

In parallel, it seems obvious to underline the links between IST and the economic environment. The relative weakness of Europe could so be analysed as a weakness of the industrial base in this field (if this is true, it means that there will be a strong link between the industrial competitiveness and the scientific positioning at technology sector), or, as a new evidence of the weakness of the links between basic R&D and application development in Europe.

C) Sustainable development, global change and ecosystem

Figure 55: Scientific positioning of Europe in sustainable development

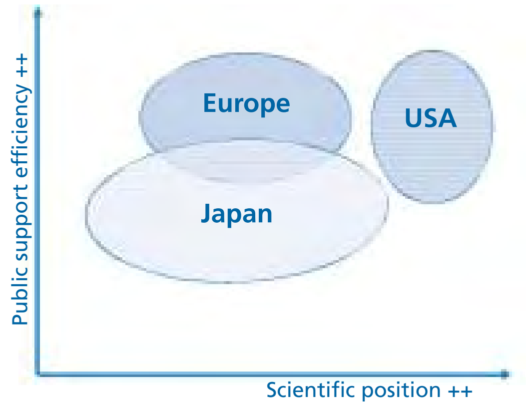


The field of sustainable development constitutes an area in which experts fail to identify strong differences between the three geographical areas in terms of their respective scientific position. The only main specificity that the graph underlines is the somewhat disparate positioning of Japan, being attributed both with strong and weak scientific position. As the scientific position of Japan is linked to the issue of public support efficiency, it will be interesting to analyse public / governmental choices in terms of support to one technology rather to another one (the hypothesis being difficult that the positioning of Japan is primarily a question of “efficiency” of the public support given the fact that this indicator does not seem to play an important role in Europe and the USA).

In addition, the graph reveals the high level of public support efficiency in Europe in this field. This point will have to be understood in terms of underlying socio-economic factors. At the same time, however, the ensuing analysis has to account for the reasons why this high level of efficiency fails to influence more strongly the level of Europe's scientific position vis à vis the USA.

D) Life-sciences, genomics and biotechnology for health

Figure 56: Scientific positioning of Europe in Life-Sciences



In comparison with the three other fields described above, the life-sciences field displays a highly differentiated graph. As far as the regions' scientific position is concerned, the experts' vision is that the USA have a strong advance vis à vis Europe and Japan which are at comparative levels. Looking at the "y" axis, in turn, Europe and the USA are globally positioned at the same level while Japan is positioned at a somewhat lower place. If we take into account the fact that the USA support this scientific field at a more higher level than Europe in terms of public expenditure, a growth of this level at European scale could certainly benefits to the scientific positioning.

What is also interesting is the fact that the position of each geographical area is rather "compact" and well defined. Contrarily to the other fields where the positions were often mixed or confused, in the field of life-sciences we do not see large disparities as far as the regions' positioning is concerned. We are in the situation in which the differences between the technologies in the same geographical areas seem not to make sense.

With its underlying priority technologies being of very recent nature, life-sciences are a new scientific field, and this relatively early stage can be characterised by the absence of any strong differentiations at a geographical area level. As a matter of fact, the differences in terms of the regions' scientific position are mainly due to historical reasons (the USA seem to have embarked on this research field before Europe and Japan[47]), with public support being generally dedicated to the whole field (mainly for basic research) instead of specific technologies.

We can conclude that life-sciences are a field in which the scientific positioning at technology level is not set as yet.

(47) In 1998 for the USA

E) A positioning that reveals different approaches of public support to emerging technologies depending on the R&D fields

The table hereafter attempts to summarise **the main hypothesis we can formulate at this stage from the experts' point of view on the scientific position and public support efficiency in Europe** in the four main scientific fields covered by the priority emerging technologies.

Scientific field	Public support efficiency	Scientific position	Main issues for Europe
Nanotechnologies, knowledge-based multifunctional materials, new production processes	No apparent relation between public support and scientific position	Convergent technologies that need scientific competencies in different technology fields (countries with high R&D potential). A weak position for Europe	Convergent technologies in terms of organisation of R&D and new ways of policy support. The high level of R&D performance in different fields
Information society technologies	Strongly linked with the scientific position	Weak at global average but strong on some specific technologies due to economic strength	More public support or research of more efficient ways of supporting R&D linked to economic issues.
Sustainable development, global change and ecosystem	High position in terms of public support efficiency	Strong (but not leading) scientific position	How to transform the public support efficiency in scientific positioning?
Life-sciences, genomics and biotechnology for health	Public support is of high importance for the future positioning	Scientific positioning not set today at technology level	The main strategic field for the future and a field which relates to major socio-economical issues

3.2 The scientific positioning at technology level

During the previous parts of this report, we have focused our analysis on the scientific fields. In this section, we will now focus on technology level, but always using the scientific field as an entry point. We will use the analyses and results we have obtain at scientific field level to understand how and why a technology belonging to this field is supported or not, if this support is mainly financial or not, if there is a clear link between the policy support and the scientific position, and to compare these different results with USA and Japan.

The aim at this stage of the study is thereby not to draw recommendations as to European policy support to the technologies in question, but rather to concentrate on a number of inputs likely to be of importance. The present section thus aims at presenting Europe's strengths and weaknesses at the technology level. Moreover, it will provide a comparison between the European as well as the US and Japanese realities in terms of technology specific scientific positions, on the one, and public policy efficiency, the importance of financial public support as well as the importance of other public support, on the other hand.

To make this analysis, we have mainly used the results of the expert panel. The questions included in the questionnaire are the following:

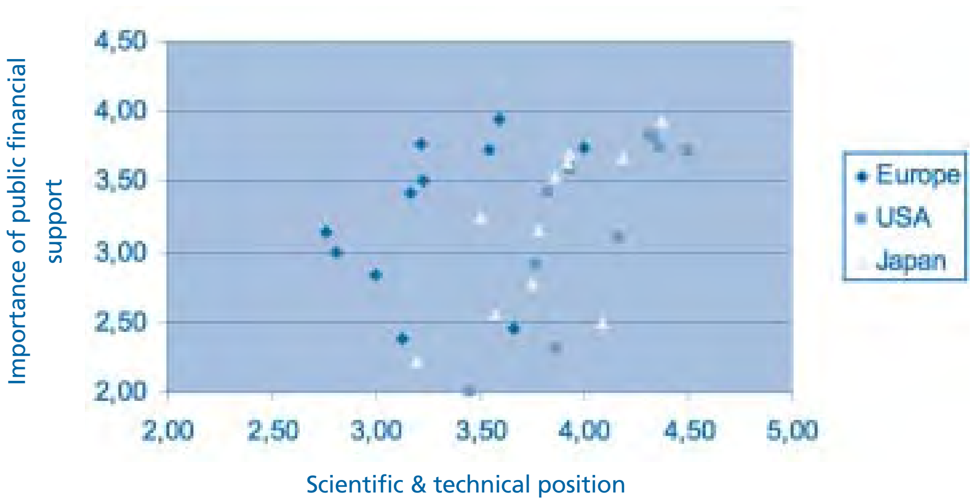
At international level, and for this specific emerging technology, can you specify from your own viewpoint: (from 0 to 5 or n.a. : 0 = insignifiant, 5 = very high)

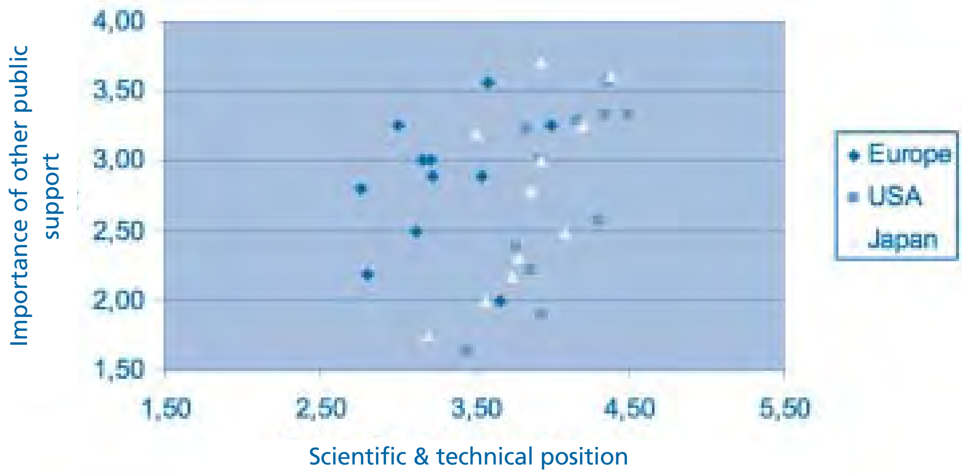
	Europe	USA	Japan
Scientific and technical position	n.a.	n.a.	n.a.
Public support efficiency	n.a.	n.a.	n.a.
Importance of public financial support	n.a.	n.a.	n.a.
Importance of other public support	n.a.	n.a.	n.a.

While the experts answered the questions on a technology-by-technology basis, we have thereby regrouped the technologies into major fields in an effort to make the study's previous outputs operational.

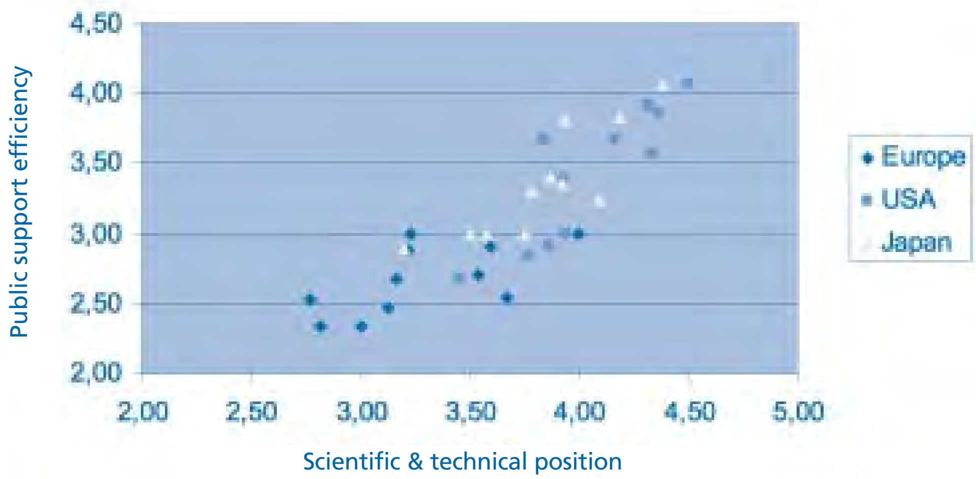
A) Nanotechnologies, knowledge-based multifunctional materials, new production processes

The nanotechnology field is described by the experts as an area in which Europe is not very competitive in terms of its scientific position compared to the USA and, for some technologies, to Japan. However, public support is quite similar in Europe, the USA and Japan both in terms of financial or other types of support. The two tables hereafter clearly recapitulate this situation.





The graphs underline the fact that public support in the nanotechnology field in Europe is not so much insufficient as it is inefficient. Directly relating the issue of support efficiency to the corresponding scientific position, the following graph further confirms this assessment.



The situation of Europe as far as the nanotechnology field is concerned can thus be summarised as follows:

- Strong public support in this field (on an equal footing with support in the USA and in Japan)
- A relatively weak scientific and technological position due to a lack of efficiency of the public support

Public support for nanotechnology is generally channelled through a number of ministries and research councils with responsibility for different fields of applications or fields of science and technology. Some countries have begun to take steps to centralise management of their R&D programs, even if program implementation remains distributed. But very few countries have instituted a real "national institute" as an integrated institute with its own researchers (Canada, USA) or smaller "Nanotechnology research institutes" focusing on some specific technologies or applications (Japan, Denmark). Co-ordination could also entail development of a national strategy for nanotechnology development (Netherlands, Poland, United Kingdom, etc.).

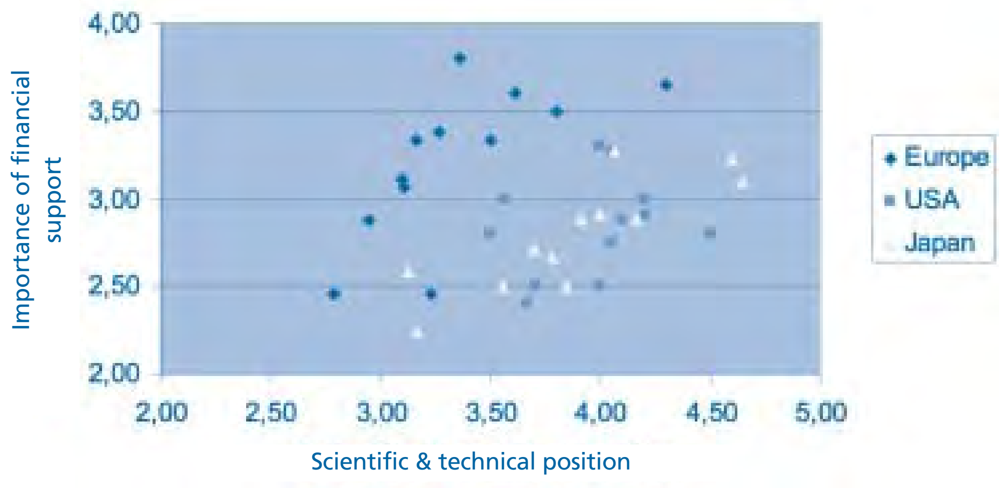
Further focusing at the technology level, the first round of the expert panel has demonstrated that nanotechnologies were not belonging to the future's most important priority technologies. As a matter of fact, of the 40 technologies selected, the first one relating to the field of nanotechnologies, i.e. "ultra-thin functional coatings", is classified at the 20th rank. What is more, it is precisely this technology on which Europe scores best in terms of its scientific position. In fact, enjoying strong public support, Europe is positioned before the USA and Japan on this technology.

The technologies on which Europe obtains almost equally strong scores in terms of its scientific position ("bioactive materials and surface" "nanocomposite and nanometrical-nanoscale reinforcements in electronics, chemistry, medicine…" coming 3rd and 4th respectively) also received strong public support, reflecting the high priority given to them in the field.

The technology coming 2nd in terms of its scientific position ("Supply chain management") is classified last of all the 40 selected priority technologies. However, even though public support for this technology is very weak, Europe is the leader in terms of its relative scientific position.

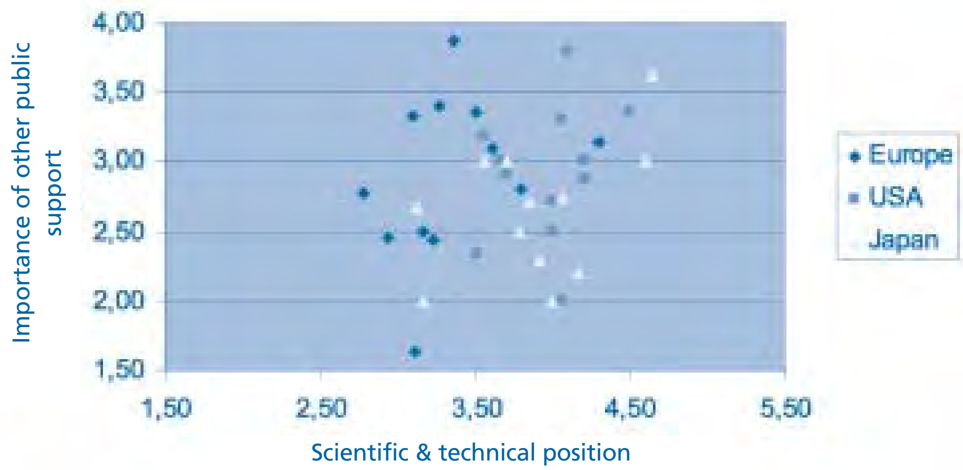
The situation described at technology level puts into perspective the pessimistic view prevailing from an analysis at field level. In fact, Europe is well placed in terms of its scientific position as far as the top priority emerging technologies are concerned and the policy support in both quantitative and qualitative terms is largely equivalent to that of the US and Japan. This, in turn, suggests that the issue of average scientific positions cannot be adequately addressed with the confines of the rather general elements of "more or less support" and "more or less competencies". In fact, it seems that the real issue in terms of potential future recommendations as to public support policies towards new emerging technologies in this field primarily relates to European capacities of effectively addressing the issue of convergent technologies in order to increase efficiency levels for the public support allocated.

B) Information Society Technologies



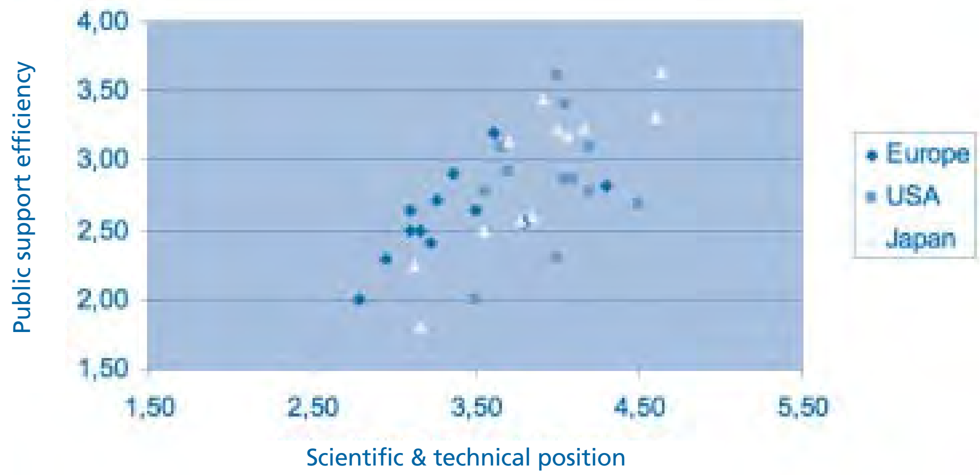
Of considerable interest as far as specific technologies are concerned, the present graph shows that Europe does not occupy any dominant scientific positions in the field of information society technologies, except for one technology: "Mobile communications (4G)". Moreover, the graph shows that for the other technologies where Europe is relatively well positioned ("Embedded single-chip applications", "Microsensors and nanosensors", "Software technologies for the transport of digital data", "Individualised health services and drugs"), the level of public financial support is, according to the expert assessment, disproportionably more important than in the USA or in Japan.

Putting into relation the importance of other public support and the scientific position, in turn, provides us with a somewhat different picture. The graph below thus shows that the support level in Europe is largely comparable with that both in the USA and Japan.



In Europe, one technology receives a particularly high level of public non financial support ("Individualised health services and drugs"). As a matter of fact, it is this same technology that also receives the most important financial support, which is certainly due to the relative importance of the addressed issue in a society in which health is mainly a public service. The technology of "Advanced technologies for virtual/augmented reality", by contrast, stands out for the very weak support it receives.

The third graph, in turn, clearly shows – rather unsurprisingly – that the efficiency of the public support is strongly related to the scientific position.



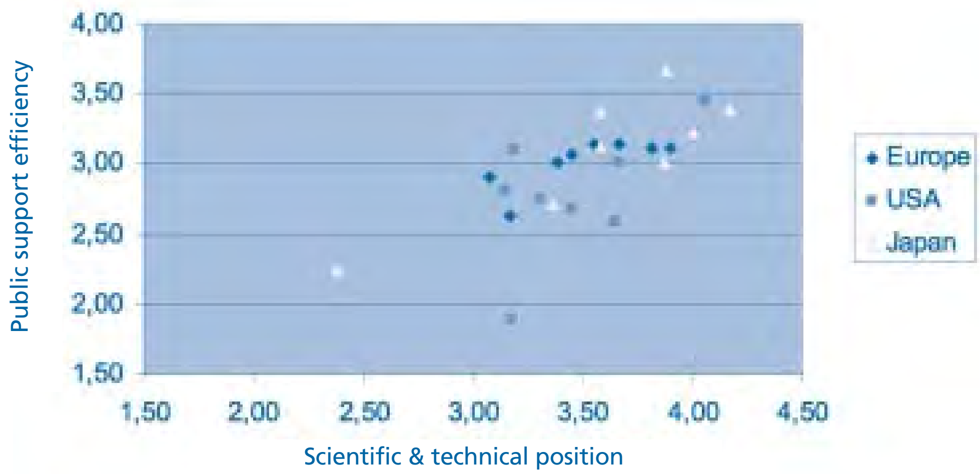
Overall, the different graphs provided fail to provide effective new inputs as far as the IST field is concerned and the geographical areas' relative positioning largely reflects the actual strengths and weaknesses in the field[48]. Japan is thus leading the field in the robot technologies[49] and mobile communications (just before Europe), while the USA have a strong position in terms of telecommunication ("Software technologies for transport of digital data" and "Broadband networks"). In fact, the importance of the economic sectors (existence of competitive companies, etc.) acting as an important driver to support the corresponding scientific positioning (rather than public support) becomes evident once more.

At the same time, however, new emerging technologies open up new areas where the situation is more open to competition. One of these, for examples, is the set of emerging technologies related to future applications in the health sector ("Computer-aided surgery" and "Individualised health services and drugs"). On both of them the USA has already managed to secure, albeit not yet overwhelming, competitive advantages.

As far as other new emerging technologies are concerned ("Microsensors and nanosensors", "Embedded single chip applications", "Intelligent artificial limbs"…), it is impossible to obtain a clear view of any strong relative position. These are technologies for which strong public support can make a difference.

C) Sustainable development, global change and ecosystem

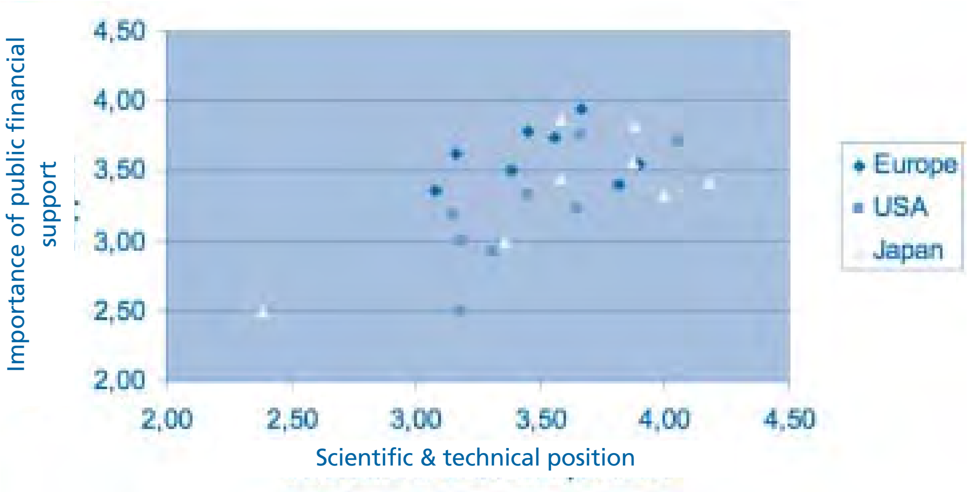
At first view, the field of sustainable development is characterised by a quite homogenous scientific and technical position with no significant differences between Europe, the USA and Japan. The graph below shows this situation. It also demonstrates that there is no major difference in terms of public support efficiency.



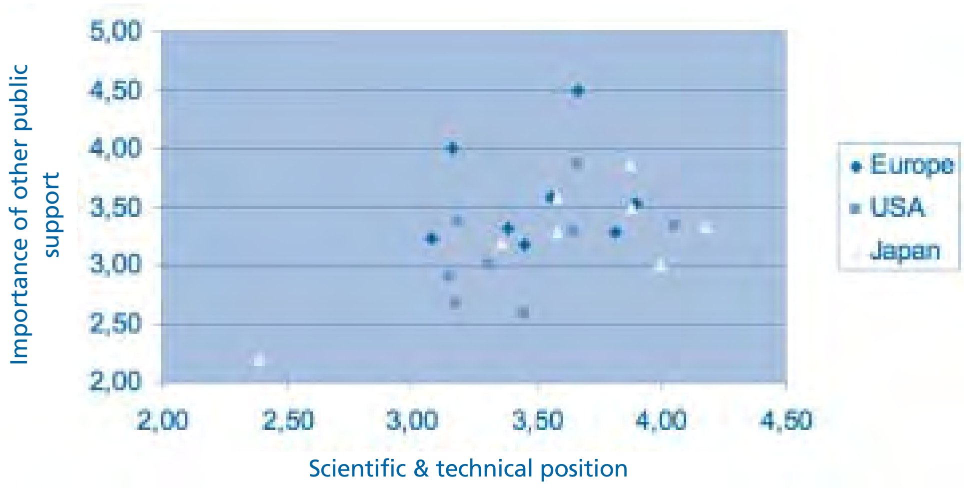
(48) Cf. Fistera "Europe's strengths and weaknesses in Information Society – a patent analysis" IST -2001-37627 – January 2005.

(49) Regarding robots technologies, it seems that the USA, and above all Europe, have give up the competition and just want to keep their respective positions.

The situation is the same in terms of public financial support, with a global average of support comparable between the 3 geographic areas (graph below).



In terms of other public support, two technologies in Europe are clearly above average. These technologies are "Low cost efficiency solar cells" and "New energy storage technology" in spite of a corresponding weak scientific position. (see graph below).



The situation of "Low cost efficiency solar cells" is relatively easy to understand. At European level, this technology, which is being supported only by some countries but not on global level, benefits from a strong policy support which, in turn, is mainly due to the presence of "green" parties at government level and/or a strong awareness of the population as to the importance of energy issues (relayed by some lobbies at national level).

As regards "New energy storage technology", it is difficult to arrive at a consistent hypothesis. On this technology, Europe is behind USA and Japan (1st technology) in terms of its scientific position. It is also the technology for which public support is the least efficient in spite of an average financial support. As to the priority order of this technology, it figures last within the sustainable development field.

In addition and also concerning the field of energy, it is interesting to notice that Europe is not considered by the experts as being competitive in "New technologies for fuel cells" in spite of it being the most competitive geographical area for "biofuels".

Potentially more interesting is an analysis of the relatively strong scientific position of Europe in "Air-water purification", a technology ranking first in the sustainable development field. Once again, the European countries lack a common positioning in terms of public support to this technology. Nevertheless, Europe has certainly an important role to play in this research area.

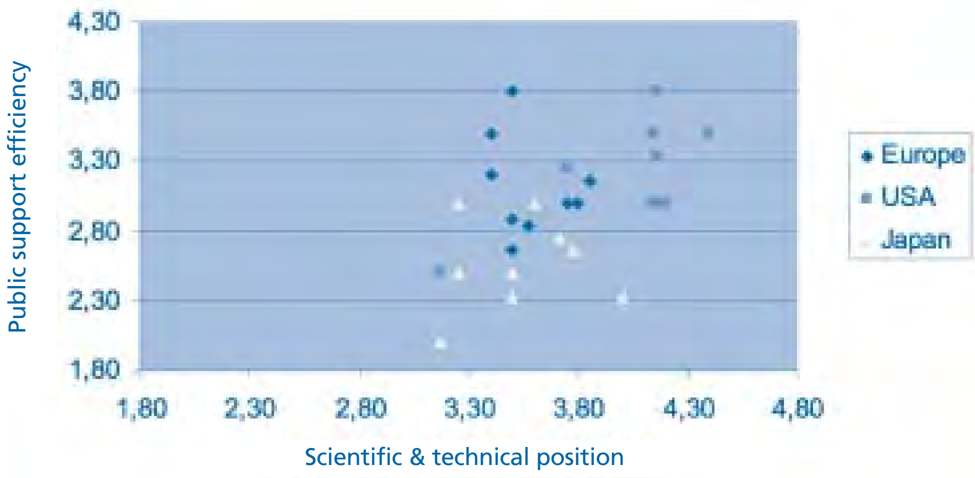
Lastly, it is important to underline that the most important technology in Europe in terms of its relative scientific positioning is "Renewable and recyclable materials". Europe is placed just behind Japan on this technology and largely before the USA. However, this technology does not benefit from an important public policy support, financial or other.

D) Life-sciences, genomics and biotechnology for health

Within the study's parameters, the Life-Sciences is certainly one of the most important one. As a matter of fact, 9 out of the 40 technologies considered as being priorities are classified within the 14 most prior ones (with 8 classified within the 9 most important ones). This field is thus considered as the most important one in terms of new emerging technologies.

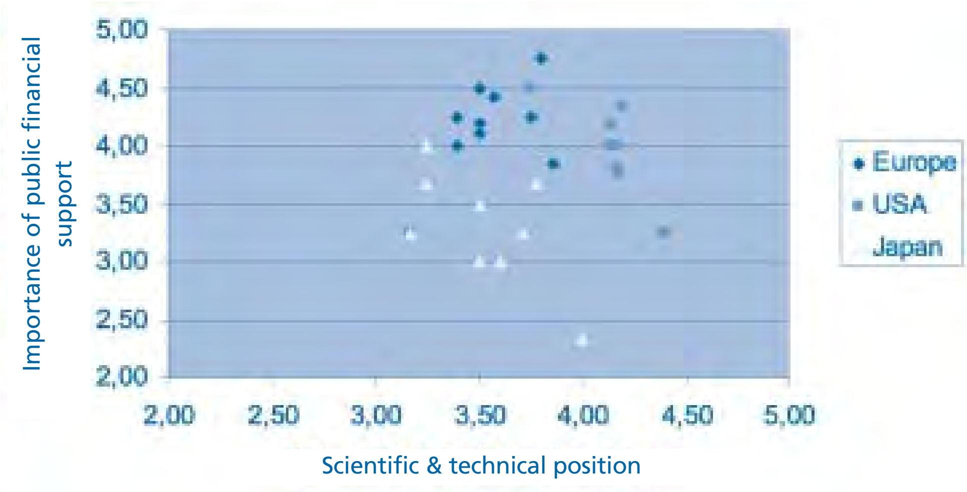
As indicated above, in the US context this field is the centre of the country's most important public support effort in terms of public funding for social, economic and political reasons. In Japan, in turn, this field has been considered as a priority area only for the last few years.

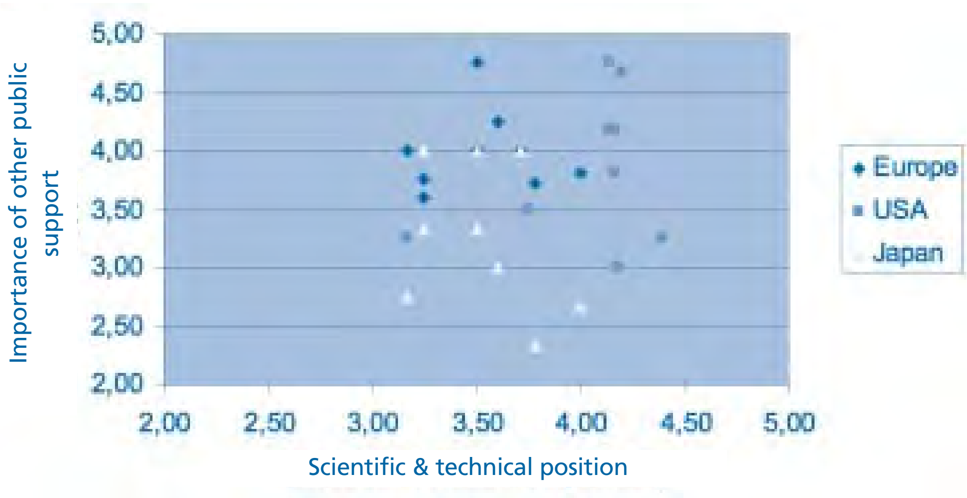
The graph hereafter clearly reflects these differences:



The graph depicts a real three-face picture. The USA are clearly before Japan and Europe in this field in terms of its relative scientific position. Europe and Japan are more or less at the same level of scientific positioning, with Europe benefiting from more efficient public support (equivalent to that of the USA) than the Japan.

This difference in terms of policy support between Japan and Europe can be seen both in terms of financial and other public support (see the 2 graphs below).





The Life sciences field remains an area with competitive positions still being largely undefined and in which public support can thus make a real difference. The differences between the various geographic areas are not visible at a technology level (except for the "Active packages" technology on which the USA is behind Europe and Japan, but which is at the frontier of the sustainable development field in terms of applications). Life Sciences is thus a field in which the scientific positioning at technology level is not strongly defined as yet and where public support to R&D can thus have a beneficial impact on a large range of technologies

4. Recommendations for public policy support in Europe: three scenarios

Suggesting recommendations for public policy support is always a difficult and ambitious task. Making such recommendations needs to address two key challenges.

1) The first challenge tackles with priority issues: Taking into account the limited public resources in budgetary terms, do we have to support technologies in areas of strength? Do we, on the opposite, have to support technologies in areas of specific weaknesses in order to close potential gaps with the USA, Japan and other potential / emerging competitors? Do we have to select technologies which are critical in terms of potential societal impact? Is it necessary to target on specific niches? Is it necessary to target technologies that could lead to potential new markets and economic development new areas? As a first answer to these questions, we have considered that all emerging technologies identified have high potential benefit. Therefore no premature prioritisation in funding should be made. Only specific public policy strategies can provide such prioritisation.

2) The second key challenge focuses on the nature of public support. Always taking into account the limitation of public resources, we can assume that for some technologies, private financial support soon can easily play an important role[50], and that public support can take other forms (e.g. non financial) or even play no role at all. The table hereafter suggests the nature of public support in three different possible situations.

   - In the first case, the fact that a market already exists or that a potential market could exist for applications using a technology, and the existence of European companies in the field that are engaged in basic research (Market and companies).
   - The fact that a market already exists or that a potential market could exist for applications using a technology, but that no large European companies exist in this areas able to undertake basic research.
   - The fact that a technology doesn't rely to a potential market but that the technology could have a major impact on some key societal issues.

Table 5: R&D environment and public support nature

R&D Environment	Market & companies	Market, no companies	No market but collective issue
Public support nature	Support targeted to R&D firms (tax incentives, researchers mobility, …)	100% public support funding and accompanying measures	100% public support funding and accompanying measures

(50) It is already the case for some of the 40 technologies

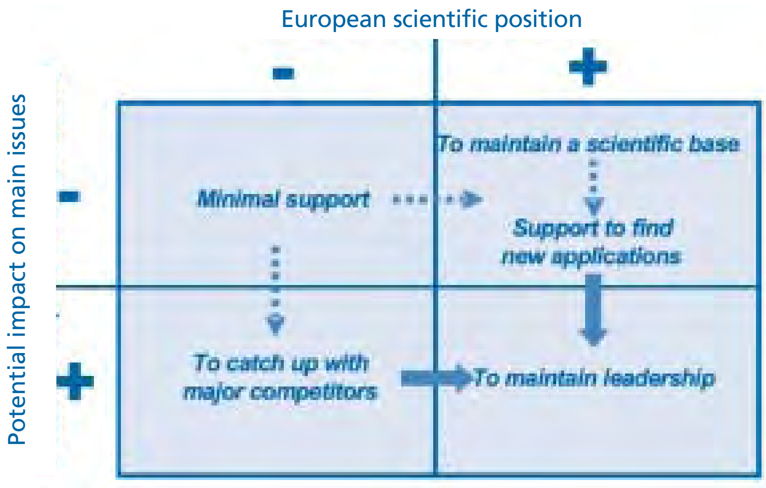
But there is also another way that could provide an interesting definition of the nature of the public policy support to R&D. This approach takes into account:

1) The scientific positioning of Europe *vis à vis* its main competitors (mainly the USA and Japan).

2) The potential impact the technologies could have on the main issues for the years to come (elderly, climate change, energy, metropolisation, growing north-south gap…)

It seems that it is possible, using a simple matrix as below, to characterise European public policy support to R&D and its rationales through its main objectives.

Figure 57: Characterization of public policy support through its objectives



NB: the arrows represent the possible (and desirable) evolution from one situation to another

Keeping these main challenges in mind, we have interviewed experts[51] in the four scientific fields covered by the study. The interviews were based on four main questions:

- Do you think that the European Commission should launch a specific program to support this technology?
- If yes, what are the rationales and what kind of policy recommendations should be made (financial support, support for networking, incentive measures targeting the member states, other promotion facilities…)?
- Do you think that the European Countries should support this technology?
- If yes what kind of public support is needed?

(51) Working groups were first planned for this phase. But in accordance with the European officers in charge of the project, we have opted for this methodology that could more easily address non consensual recommendations. List of participating experts are in Annex.

For each scientific field, a specific “recommendation report” has been drafted and then send to the experts in order they can add comments. Our intention with this interactive phase was either to obtain consensus or to determinate recommendations that could be subject of controversies. Controversies can thus be the pointers of different appreciations of a technology or of different perceptions of geographical situations vis à vis a technology.

In principle, one could draw road maps for each of the emerging technologies with existing problems and obstacles, projections about breakthroughs and possible achievements within a certain time horizon. But these road maps would not add up to a general picture of European research and research policies and the uncertainties about the evolution of European research grows the farther we move into the future. It seems therefore necessary to draft some scenario of European R&D development in the years to come, and to assess the recommendations in the light of these scenarios.

The first part of this chapter will thus describe the main paths for the future. Using these paths, it will be possible to draft possible evolutions (micro-scenarios) of each scientific field based on the results of our analysis (part two). Two scenarios will be then developed and the different recommendations will be suggested in the frame of the one or the other scenario (part three).

4.1 The main paths into the future

Already for some decades, economic development has provided the main rationale underlying public R&D policy support. R&D is thereby interpreted at political level as an important driver towards economic development, the emergence of new activities and the creation of jobs. This trend finds expression in most of the European countries through the relative preponderance of the economic rationale underlying public R&D strategic choices. While some countries (cf. UK, Ireland …) put an almost exclusive emphasis on the economic factor (and thereby neglecting some of the others), only small countries (or those featuring a scientific position that is far below average on the majority of scientific fields) put their main emphasis on alternative socio-economic factors (cf. Malta or Hungary).

In terms of strategy, this high importance related to the economic factors has different results:

- The first one is the opportunity to support more efficiently those technologies which are directly linked to the issue of economic development. In the context of emerging technologies, this means that those technologies which have a potential of leading to successful market applications will be more attractive than those for which the potential market is not visible yet or inexistent.

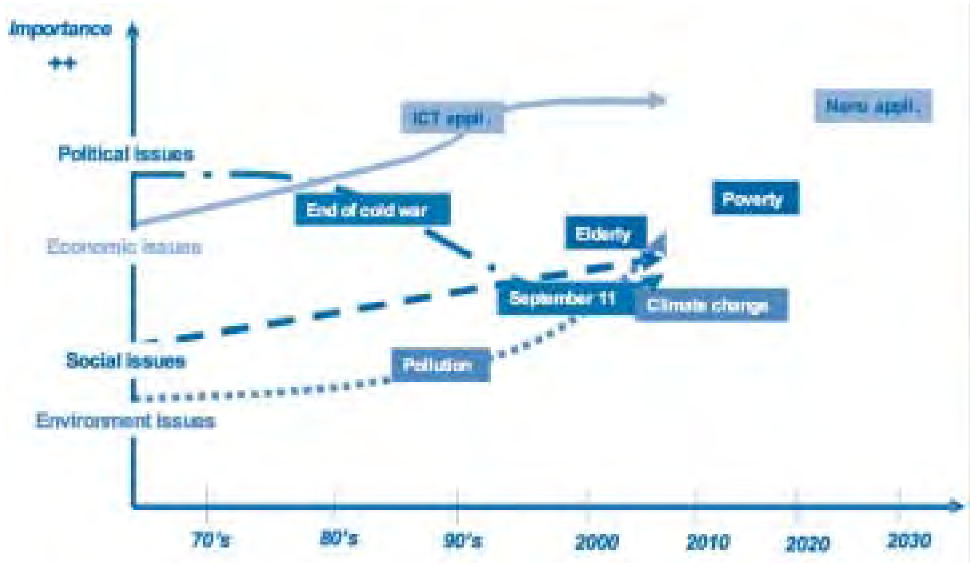
- The second result addresses the issue of the underlying objective of public support. Instead of directly supporting those technologies for which there exists important market potential, public policy measures could rather be used as indirect tools in support of private R&D, while at the same time concentrating financial R&D support on technologies and scientific fields for which such markets opportunities are lacking. This, however, means that alternative rationales need to be identified as an alternative basis for public policy support. Japan provides an interesting example of this constellation.

- The third result is that a major strategic decision in terms of public budget allocation relates to the choice between support to either basic R&D or application/development. The USA provides thereby a good example of this debate, with the progressive decline in basic R&D support in recent years being compensated by new investment priorities and a conservation of overall R&D support. Quite obviously, the current US administration has decided to favour applicative research to the detriment of basic research as far as most scientific fields are concerned, the only exception being the life-sciences. However, similar strategic choices can be observed in most of European countries as well. The current government of France, for example, has thus been accused by researchers for its bias towards innovation to the detriment of research at large.

Relatively stable through time, the high importance of socio-economic factors as an important driver for R&D policies is not easily challenged. It has thus been widely demonstrated that research and innovation are important drivers for economic development and this assessment is largely shared at a global level (cf. the priority level accorded to R&D by India and China in their economic development processes). However, two different scenarios seem possible as to the future evolution of the relative weight of the different issues (economic, social, environmental and political).

The figure below describes in an admittedly somewhat simplistic way the possible main evolutions of the issues facing and influencing R&D in accordance with a number of particular factors or events.

Figure 58: The evolution of the main socio-economic issues facing R&D



- Political issues: the main event that had an impact on the curve describing the importance of the issue for R&D is the end of cold war with the decline of military R&D spending. The curve remained at a relatively low level and only grew as a result of the awareness of some societal-environmental issues at political level (progressive emergence of these issues on the political agenda of the different countries), on the one hand, and the impact of the September 11th attack, on the other. This latter event has reinforced military and homeland security R&D spending, first in the USA, then also in a number of European countries[52]. This curve is, however, quite different in

(52) Specific research programs largely motivated by political factors can also contribute to this growth; however, there seems little indication of the existence of such programs during in the last two decades.

the case of the new member states of the European Union, with the will to catch up with other member states (in terms of participation to European R&D programs, R&D budget, R&D system organisation…) often acting as very influential political factor.

- Economic issues: The importance of economic issues has been constantly growing in the post world war period. Following the era of reconstruction, economic development was boosted by means of new technology innovation, becoming progressively the main driver for R&D and thus supplanting the political (military) one. The advances in the area of ICT applications have represented a significant period to R&D activities in this field. Other technology applications, such as nanotechnologies, are likely to present similar opportunities in the future.

- Social issues: the importance of social issues has been constantly growing in recent decades, mainly driven by various health challenges. However, the elderly are likely to represent the main social issues for the years to come, with implications for a lot of scientific fields (architecture and urbanism, transport and mobility, ICT, health, etc…). In addition to this issue which is likely to present new challenges to Japan, the USA and Europe alike, a second one could possibly emerge in the form of poverty at both global (North/south) and intra-societal level.

- Environmental issues: environmental issues have undoubtedly undergone the most important evolution since the 1960s. The first visible issue that provided a source of a light inflection were the threats of pollution and resource depletion. The environmental issue has since been reinforced by the progressive integration of the ecological challenge in the political agenda (culminating in the Brundtland report in 1987 and the representation of green party members in some of the European parliaments). The challenge presented by the issue of climate change has the potential to produce a significant impact on the curve in the years to come.

On the basis of the evolutions taking place within the R&D environment as well as an understanding of the most important underlying rationales, two trends are so possible for future scenarios:

- The continuation of the actual trend: Economic issues are still the main important ones to elaborate public policy support to R&D strategies at world wide level. The other kind socio-economic support can play a role, but only at border level, for some countries and some specific issues.

- The evolution of the actual trend with a strong emphasis on societal factors. Such an emphasis could be explained by:

  - The elderly issue that becomes a major one in our societies (Europe, the USA, Japan…), with its consequences mainly in terms of health;

  - The climate change issue that appears as a prior one due to the rapid evolution of the situation.

  In this trend evolution, economic factors are progressively supplanted by societal ones, and it can be seen as a greater opportunity for a lot of European countries as the links between scientific position and industrial tissue are becomes weaker.

These two trends will be considered for the micro-scenarios construction process as the main variable, used in parallel with the evolution of the public support at European level. The evolution of the public support could take three different formats:

- Business as usual: the public support accorded to a scientific field keeps the same average level as today.
- The niche evolution: some choices are made to support at higher level some specific technologies within a scientific field.
- The scientific excellence: strong emphasis is put on a scientific field and strong public support is provided in order to foster the Europe average scientific positioning at field level.

4.2 Micro-scenario elaboration

The objective of this part is, using the previous results of our analyse, to build some micro scenarios at scientific field level, talking into account the different possible evolutions of the public support strategy and the evolution of the situation in terms of socio-economic factors.

4.2.1 Nanotechnologies, knowledge-based multifunctional materials, new production processes

If we first consider the possible evolution of the public support to R&D in this field, we can consider that this variable can only takes two relevant values in this field: business as usual or a niche scenario. Actually, we have already underlined the fact that this field was obviously driven by economic factors. Even in the case of the reinforcement of societal factor, we cannot imagine that this kind of factors will be sufficient to support a strong public strategy favouring this field. In addition, we have observed that this field is today obviously supported at the same average level in Europe, the USA and Japan. However, the scientific positions of the three geographic areas are different and we haven't been able to assess that public support can make any change to this average level.

The "business as usual" strategy can be described as the prolongation of the actual trend. Even if the European Commission elaborates a specific strategy on the field, we cannot see strong changes as these ones can mainly be driven by the private sectors/investments based on a solid industrial position. The only benefit it can gives is on a better efficiency of public spending if the strategy tackle the issue of organisation (organisational cooperation between different scientific fields through new running means).

Looking at the "niche strategy", the question will be which key technologies can mainly benefits from a stronger public policy support in terms of positioning Europe as a potential leader at this level?

The main strong points of Europe in terms of emerging technologies are on "ultra-thin functional coatings" and "supply chain management". This last technology has been classified as the less prior one within the 40 selected technologies, and thus strong efforts are certainly not necessary. However specific efforts on "ultra-thin functional coatings" can certainly reinforce the European leadership. Looking at the field as a whole, two other technologies appeared as very important for the experts: "nanotechnology and nanoparticles in therapy" on one hand, and "nanocomposites and nanometrical-nanoscale reinforcements in electronics, chemistry, medicine…" on the other hand. These two technologies are converging ones at application level, focusing other scientific fields (chemistry, electronics…) or application fields (health and medicine). Specific niche strategy of Europe on these technologies can eventually be efficient if the environment is favourable, e.g. if the societal factors becomes preponderant comparatively to the economic factors.

The scenarios in nanotechnology can thus be described as follows:

Table 6: Nanotechnology field micro-scenarios

Business as usual	Niche scenario	
Europe keeps its low scientific position, but could eventually benefits from a more coherent organisational environment on the field	Specific European public support may be helpful to foster its leading position on "ultra-thin functional coatings".	If societal factors becomes more influent, Europe can extend the niche strategy on "nanotechnology and nanoparticles in therapy" and "nanocomposites and nanometrical-nanoscale reinforcements in electronics, chemistry, medicine…" .

4.2.2 Information Society Technologies

With IST, we face the same situation as nanotechnologies but perhaps in a more clear-cut way. It is obvious that the scientific positioning of the three geographical areas -Europe, the USA and Japan- are clearly much more linked with the industrial basis than on public support strategies. Public support strategies can only play a margin role for R&D leading positions. Europe's good position in terms of "mobile communications" is thus mainly the results of the industrial European strength in this area.

As a matter of fact, one can say that the scientific positioning in this field is already stated, and that major evolutions seem unrealistic. A "scientific excellence" scenario at the whole field level appears so impossible, as it was for the nanotechnology field.

Two scenarios are once again possible in this field, the "business as usual" one and the "niche scenario". The first one could however lead to foster the positioning of Europe in the "mobile communication" area. But this evolution will not necessary proceed from direct public support to the related technologies. Support to industries, to industrial R&D and to the reinforcements of the links between public and private R&D in the field could certainly provide a better impact.

With regard to the "niche scenario", potential scientific leadership of Europe on some specific technologies could mainly and easily be developed in an environment in which economic factors loose their predominant role to the benefit of societal factors. Using societal factors such as health and medicine as rationale, Europe could easily developed R&D focused on converging applications such as micro-robotic, virtual reality and computer aided surgery, mobile communications and health services, neurology-nanosensors, neuro-informatics…

Table 7: IST micro-scenarios

Business as usual	Niche scenario
Europe keeps its low average scientific position, but could potentially reinforce its leadership on mobile communications.	With the support of an evolution putting the emphasis on societal issue for R&D, Europe can invest on converging applications, mainly in the health sector, in which IST key technologies can play a major role.

4.2.3 Sustainable development, global change and ecosystem

As we have already shown it, the sustainable development scientific fields has two main characteristics: the first one is the very weak importance of economic factors to explain the public policy support to the field, and the second one is the strong positioning of Europe as compared with the USA and Japan. The continuation of the actual trends thus cannot necessary called into question the European position. The only situation in which the USA and Japan can seriously challenge Europe will be if the economic factors and issues take a strong emphasise in the field. Without wanting to make any predictions, one can say that such evolution can mainly take place on the energy issues. But even in the energy domain, if Japan and the USA are leader in the "fuel cells" area, the strong position of Europe in "Biofuels" can help in maintaining a global positioning.

At the opposite of nanotechnologies and IST, a strategy to strongly support R&D in sustainable development seems possible in Europe and could provide relevant results in terms of leadership position. "Scientific excellence" in sustainable development could thus be a target for a R&D European strategy. However, to be politically acceptable, this strategy needs to be based on societal factors, and so only a context in which societal issues (such as climate change) playing a major role beside economic issues can lead to such strategy.

Finally, a "niche strategy" is also possible for Europe in this area. This strategy could reinforce the main strength of Europe compared with the USA and Japan, notably on "air-water purification", "biofuels" and "renewable and recyclable materials". The role of European networking can certainly be preponderant for such strategy.

Table 8: Sustainable development micro-scenarios

Business as usual	Niche scenario	Scientific excellence
Europe keeps its good scientific positioning as long as economic issues don't take a leading role in this scientific field.	Specific European public support through networking can strengthen the European leadership in technologies such as "air-water purification", "biofuels" and "renewable and recyclable materials".	Scientific excellence in the whole field could be a relevant opportunity for Europe if environmental issues become preponderant at worldwide level.

4.2.4 Life-sciences, genomics and biotechnology for health

Our previous analysis have described this last field as the most important one for potential evolutions in future, as the scientific positioning of the three geographical areas is not set yet. It is thus a field where strong potential public strategies can have an important impact. But the nature of this impact in terms of European scientific positioning could be very different and could lead to opposite situation depending on the strategy and the factors that can support these strategies.

If we first consider that “nothing change”, and so that no strong European strategy to support life-sciences is implemented, it is obvious that the differentiation between Europe and the USA, and perhaps with Japan, will weaken. The differences at public investments level in the field between the USA and its competitors are so important, that one can't imagine that Europe could catch up with the US in terms of scientific positioning without strong investments. So such scenario is possible, but not desirable for Europe.

“Niche strategy” can thus be considered as a relevant one for Europe. But it means that it is possible to identify emerging technologies where Europe can take a leadership. The previous results of our analysis have shown that such identification wasn't possible. The niche strategy have thus to be built on a proactive manner. As we have already stated that Europe's public policy support to R&D was much more multi-targeted than in the USA or Japan, using different socio-economic factors, we can suggest that a niche strategy putting the emphasis on convergent applications will be more easy to support at political level (1), will be coherent with the niche strategies suggested for the nanotechnologies and IST fields (2), and could lead to a strong position in the future as converging applications are one of the main issues for future of sciences (3). Applications such as neuro-informatics, computer aided surgery, mobile communications and health… could support important development at key technology level in life-sciences and help Europe in establishing a scientific leadership on some technological niches.

Finally, scientific excellence could be reach if Europe invests strongly in this field in order to catch up with the USA advance. These strong public investments are possible if Life-Sciences really become a priority at European level. Such priority level could be difficultly reaches if the main socio-economic factor that can support R&D in the field is still economics. But if, in addition to this rationale, societal factors becomes important, mainly by the awareness of the elderly and quality of life challenges (and their consequences both on health sector and on agro food), Europe can easily decide a scientific excellence strategy in this scientific field.

Table 9: Life-sciences micro-scenarios

Business as usual	Niche scenario	Scientific excellence
Europe is getting left behind the USA in this scientific field.	Europe invests on converging applications, targeted mainly on the health sector.	Scientific excellence in the whole field could be a relevant opportunity for Europe if societal issues (elderly and quality of life) become preponderant at European level.

4.2.5 From micro-scenarios to 3 macro-scenarios

If we make a compilation of the different micro-scenarios, we can obtain a large range of macro-scenario. However, using a normative approach, we have decided to reduce this number to 3 coherent, self sustainable and sharply contrasting scenarios.

The main rationales of the 3 scenarios are the following:

1) The continuation of the actual trend in terms of R&D budget in Europe will not be sufficient to reach the 3% objective. The current trend will only allow reaching 2.2%[53]. A major evolution will thus be necessary to increase the R&D intensity in Europe.
2) Due to the financial constraint, it is not realistic to imagine that Europe can develop a "scientific excellence" strategy in more than one scientific field in parallel in the years to come.
3) At the opposite, a "nothing change" scenario is possible in all the scientific fields

The table hereafter provides a first description of the three scenarios based on the micro-scenarios.

Table 10: From micro-scenarios to macro-scenarios

	Public R&D strategies are market driven based	Public R&D strategies are both market driven and societal based	
Nanotechnologies	Europe keeps its low scientific position, but could eventually benefits from a more coherent organisational environment on the field	Specific European public support to foster the leading position on "ultra-thin functional coatings" and to reach a leading position on "nanotechnology and nanoparticles in therapy" and "nanocomposites and nanometrical-nanoscale reinforcements in electronics, chemistry, medicine…" .	NA
IST	Europe keeps its low average scientific position, but could potentially reinforce its leadership on mobile communications.	With the support of an evolution putting the emphasis on societal issue for R&D, Europe can invest on converging applications, mainly in the health sector, in which IST key technologies can play a major role.	NA
Sustainable development	Europe keeps its good scientific positioning as long as economic issues don't take a leading role in this scientific field.	Specific European public support through networking can strengthen the European leadership in technologies such as "air-water purification", "biofuels" and "renewable and recyclable materials".	Scientific excellence in the whole field could be a relevant opportunity for Europe if environmental issues become preponderant at worldwide level. [54]
Life-Sciences	Europe is getting left behind the USA in this scientific field.	Europe invests on converging applications, targeted mainly on the health sector.	Scientific excellence in the whole field could be a relevant opportunity for Europe if societal issues (elderly and quality of life) become preponderant at European level.
	Scenario 1: "Barcelona light"	Scenario 2: "Opportunities for cooperation"	Scenario 3: "Life-Sciences strategy"

(53) Key Figure 2005, www.cordis.lu/indicators

(54) A scenario based on scientific excellence in sustainable development is possible. The rationale is a focus on climate change issues. However, as it will be more or less based on the same model that the one developed in the life-sciences scenario, only this last one has been developed

4.3 Scenario 1: "Barcelona light"

This first scenario is the non-desirable one for Europe. The recommendations included in this scenario will thus aim to either correct the situation or prevent any such evolution from happening in the first place.

4.3.1 Basic assumptions

- Insufficient European GERD

- No coherent European R&D policy (only little coordination of national and EU levels, only first steps towards an ERA). Main R&D actors target worldwide cooperation

- Economic motives as main drivers of European public policy

- Life Sciences potentially becomes a field where economic factors are the main drivers, as well as sustainable development. The strategic choices in terms of R&D are market driven

4.3.2 Scenario description and recommendations

Due to the predominance of economic issues, the public R&D policy in Europe, the USA and Japan will still be mainly driven by economic factors. Earlier on it has been underlined that only few European countries (mainly the United Kingdom, Ireland, Finland and Sweden) have been able to significantly exploit this factor as a basis for their R&D policy. There are no obvious reasons to suggest any change in this situation, with most of the European countries featuring a rather heterogeneous mix of different factors in support of their R&D policy (and using the economic factor as far as they can). It seems therefore reasonable to suggest that in general terms the scientific position of Europe vis-à-vis the USA and Japan will not only fail to progress, but is likely to decrease slowly but progressively[55].

A first implication of this scenario is the relative progress of some European countries in terms of their scientific position and the relative decline of the majority of others, which is likely to create a serious challenge to European cooperation strategies: while the first group of countries will be likely to reinforce their cooperation with the USA and Japan, the second group will network at European level or play a sub-contracting role to US/Japanese cooperation mechanisms.

Such situation is based on the fact that through economic factors, countries can easily make choices in terms of R&D strategy and focus their public policy effort on some very competitive technologies in which they can play a leading role in association with a strong industrial and innovation development process. Their interest is so to participate in centres of excellence at international level that associates R&D institutes and major firms with the objective of developing new activities or market through innovation. In this perspective, Europe doesn't necessary represents the best area for cooperation, especially if the R&D policy of most of the European countries is driven by multiple societal factors and targets many issues without making a clear choice favouring Economic development.

(55) This assumption is based on the European weakness on industrial R&D on one hand and on the generally recognised insufficient links between basic research and application developments on the other hand.

The example of the Institute of Nanotechnology

The IoN works closely with governments, universities, researchers, and companies worldwide on developing and promoting all aspects of nanotechnology. It also serves as a key organiser of international scientific events, conferences, and educational courses designed to encourage nanotechnology takeup by industry, as well as stimulating interest in less developed countries.The institute regroups, as full (corporate) members: 3i Group plc, ABB Corporate Research, Addleshaw Booth & Co., Applied NanoSystems, Australian Wool Innovation, BDP Advanced Technologies, BP International, ETF Group, GlaxoSmithKline, ICI, INASMET, Innovation Group, Institute of Occupational Medicine, London Centre for Nanotechnology, Merck NB-SC UK, Microtechnology Centre Management Ltd, MWG Biotech Ltd, Nanofilm, National Physical Laboratory, Qinetiq, The Scottish Centre for Nanotechnology in Construction Materials (NANOCOM), Qinetiq Nanomaterials Ltd, Raith GmbH, Science and Technology Information Centre, Taiwan, Scottish Enterprise, Sekisui Integrated Research Inc., Syngenta Ltd., Tetronics Ltd, Thomas Swan & Co Ltd, Unilever.

http://www.nano.org.uk/

At the opposite, but for the same reasons, the lack of strategic choices in public R&D could lead to a situation in which most of European countries will try to be generalists. Due to the absence of real political will and resources to generate very high level potentiality for research development in one specific scientific field or a set of technologies, research institutes will try to cooperate through networking at European level in order to reach a mass effect. But we cannot be sure that this mass effect will be sufficient to enable real scientific recognition at worldwide level compared with the USA or Japan. In fact, this networking model will certainly much more represent a way to resist to the rising of India and China.

In order to prevent such evolution, or to benefit from it, the corrective strategies for Europe could be the following one:

- To develop a new “airbus strategy”, based on an important economical issue in which Europe can, by the way of public and private partnerships, take a lead within 30 years;

- To foster industrial R&D strategies and cooperation on strong industrial based technologies having an existing potential leadership such as “mobile communications”, “micro and nano-sensors” or “biofuels;

- For other technologies in which there are no clear existing leadership potential, to promote “centres of excellence” at regional level that could help in developing clusters at local level. This strategy goes through support policies to incubators and start-ups, to venture capital, to enhance cooperation between regional clusters…

- To try to attract research centres in Europe and mostly in less developed countries using the opportunities of new Objective 1 ERDF funding (the “Irish model”). At broader level, create conditions to attract foreign researchers in key technologies in which Europe (or a majority of European countries) seems to need competences (e.g. IPV6 or robotic in the IST field).

In operational terms, some concrete recommendations have thus been suggested by the interviewed experts:

Recommendation 1

Additional specific actions -funding of transfer activities, "trans-national" research, venture capital…- should be carried out aiming at enhancing the transfer process management from R&D to application/innovation in Europe. Specific technologies that are very dependant on such links could be targeted. This is the case for smart materials, ultra-thin functional coatings, microsensors and nanosensors…

Recommendation 2

To establish a strong industrial European strategy as a basis for a R&D strategic policy linked with economic issues. As long as Europe will not have such strategy, R&D targeting on economic issues will depend on national will and national environment and opportunities.

Recommendation 3

To enhance the participation of SMEs -which constitute the basis of European industrial environment- in R&D projects. A first step could be to simplify public support procedures today often analysed as "too bureaucratic, too formalistic, too rigid" or "complex proposal procedures, slow administrative processes and high administrative expenses", at European level (but also often at national level).

Recommendation 4

Access of small research intensive companies to venture capital should be strongly supported -incentives, organisation, networks, pools,…-, mainly in the field of ICT, Life-Sciences and nanotechnologies. A specific recommendation could be to support at political level the creation of a venture capital line at the European Central Bank.

4.3.2 SWOT and situation related to socio-economic factors and players' strategies

Table 11: "Barcelona light" SWOT

Strengths	Weaknesses
• Individual players actions in the R&D field can be taken very fast	• Not enough money to cover all the priorities in all the countries
Opportunities	**Threats**
• Possibility to quickly elaborating niche strategies at country level in Europe	• Decision process on R&D priorities leave Europe • Gap between industrial basis and research basis

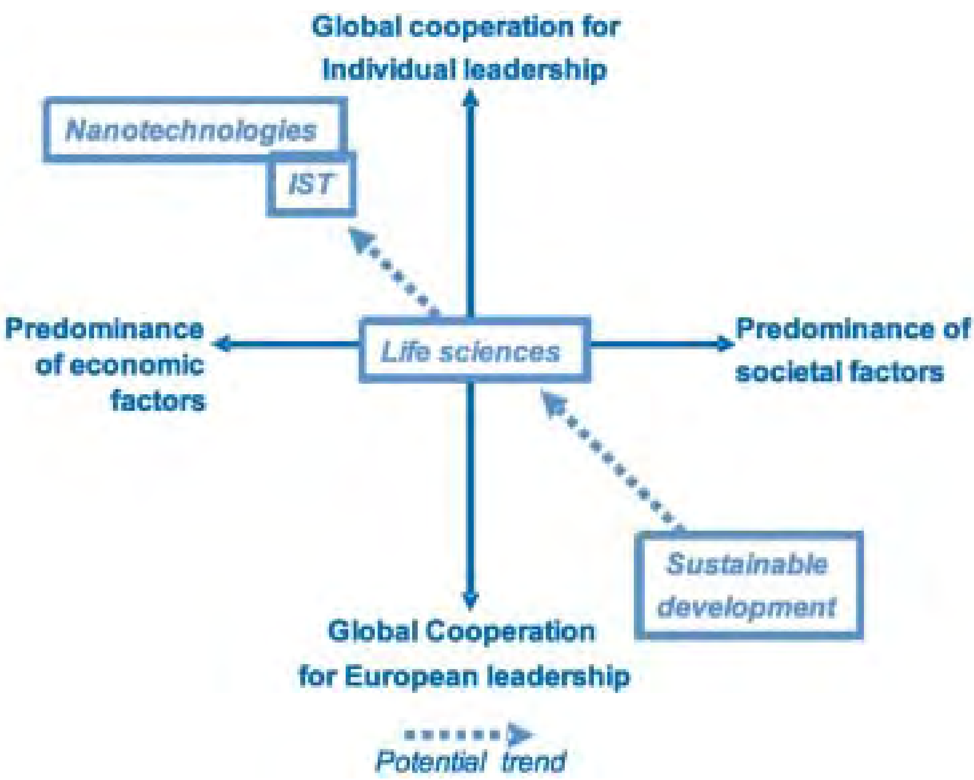
Methodology: the scenario situation

The graph describing the scenario situation describes the positioning of each scientific field with regards to two main dimensions: the socio-economic factors that support the public R&D policy on one hand and the strategies of the R&D actors on the other hand.

The strategy of the R&D actors (research centres) could thus be:

- To cooperate at global level in order to increase their individual leadership
- To cooperate at global level in order to increase European leadership through networking activities

Figure 59: "Barcelona light" situation



4.4 Scenario 2: "Opportunities for cooperation"

"Opportunity for cooperation" describes a wishful image of what can happen, if European actors (at EU and national levels) follow an active R&D policy.

This scenario is based, on the one hand, on the continuity of the dynamic inherent in existing trends and, on the other, the progressive reinforcement of environmental and social issues in the political agenda. The European Commission and the European countries target their R&D policies on "niche strategies". This approach leads to reinforce cooperation between European countries via networking.

4.4.1 Basic assumptions

- Rise of European GERD (close to Barcelona level)
- Societal motives as main drivers for Life-sciences and sustainable development
- Coordination of R&D policies on some potential niches for scientific leadership at European level

4.4.2 Scenario description and recommendations

Reflecting doubts as to the predominant role of the economic factor in the future, this scenario questions the economic development's central place in the future development of our society. New issues are already visible on the political agendas in Europe, the USA and Japan and their relative importance is likely to continue to increase. For instance, the issue of climate change could thus dramatically convert environmental factors (relating, as it does, to major irreversible changes in a very short period of time at planet life scale) into important issues for the support of public R&D policy strategies. The same phenomena can be visible in the life-science field with the growing importance of elderly issues.

Provided that this constellation will come to constitute the global R&D environment and given the fact that public policy support will have to take into account this new situation in its strategic priority choices, these forces could provide a relative opportunity for European countries as well as the continent as a whole.

In addition, European countries seem to widely employ various socio-economic factors simultaneously (3 to 4 factors can thus be employed) in support of a particular scientific field. While the use of economic factors today puts the USA and Japan at an advantage (with the economic issue being considered a priority), this constellation has the potential to become a serious handicap vis-à-vis Europe in the years to come. At a secondary level, China and India risk also to suffer from this situation in the development of their respective R&D activities, depending on their choice between focusing their R&D support on economic development issues or deriving their public policy support from political factors (R&D competitive advantage at national level in a competition with the USA, Japan and Europe).

In such environment the European strategy could be to focus on specific technological niches at scientific field level.

This "niche strategy" can take three different aspects:

1) A niche strategy based on already strong European position to become worldwide leader

In this strategy, the Europe will strongly support technologies such as:

- "ultra-thin functional coatings", ("bioactive materials and surface" and "nanocomposite and nanometrical-nanoscale reinforcements in electronics, chemistry, medicine…" in the nanotechnologies field;

- "mobile communications", and, at a weaker level "Embedded single-chip applications", "Microsensors and nanosensors", "Software technologies for the transport of digital data", "Individualised health services and drugs" in the IST field.

2) A niche strategy on potential key emerging technologies that can easily be supported by societal factors

The aim of this strategy is to benefit from societal factors to support specific key technologies at European level:

- "air-water purification", "biofuels" and "renewable and recyclable materials". in the sustainable development field;

- Technologies having application in the health sector in life-sciences field such as "cell therapy", "application of stem cells in the treatment of different diseases", …

3) A niche strategy based on scientific fields' convergence

This last strategy could be deployed in parallel to the two precedent strategies, and will focus much more on applications than on technologies themselves[56].

- Nano-computers
- Applications of multipurpose robots
- Microbiotic applied to biology
- Micro-robotic
- Virtual reality and computer aided surgery
- Mobile communications and health services
- Neuro-informatics
- Neurology – nanosensors
- …

In order to facilitate the taking off of such strategies, the experts we have interviewed has suggested different range of recommendations for the European Commission and/or for the European countries.

The first range of recommendations aims at enhancing the public and the scientist community about the potential of the different key technologies and the European know-how.

Recommendation 5

To launch a programme to overcome the significant differences in the views of European countries with regard to technologies that promote sustainable developments.

Recommendation 6

To organise some awareness raising campaigns targeting the public at large in order to promote a better understanding of the potential applications of some key technologies, such as stem cells or protein engineering …

(56) The list that followed is not exhaustive, but is based on experts' suggestions expressed during the interviews

Recommendation 7

Europe should support sustainable development know-how throughout Europe by means of conferences, CD Roms, etc… "We have to list the real know-how in Europe (publications, patents…)"

Recommendation 8

To organise awareness of the scientists of what happen elsewhere in applications' focused R&D.

These above "awareness recommendations" should be accompanied by a legal effort in order to solve some specific issues on some key technologies:

Recommendation 9

Legal issues to favour the development of R&D on key emerging technologies:

- To encourage national legislation to facilitate approval procedures for tissue engineering products
- To strengthen legal protection of the European cultural collections
- To propose EU regulation for nanotechnology and nanoparticles in therapy
- To have a clear position at European level on the patenting of human DNA and human stem cells

Specific recommendations also target the issue of convergence, firstly at scientific level, but also at "institutional" level (cooperation with very small entities in some activities' niche.

Recommendation 10

To organise networking between scientific communities to foster convergence: micro-robotic, virtual reality and computer aided surgery, mobile communications and health services, neurology-nanosensors, neuro-informatics…

Recommendation 11

To use applications' targeted projects to reinforce convergence: nano-computers, applications of multipurpose robots, microbiotic applied to biology…

Recommendation 12

The need to facilitate cooperation between research institutes and very small firms or associations through European Research programs: groups of artists for research in virtual realities, artists and industries, SMEs in FP7…

Finally, some recommendations have been suggested focusing on the sustainable development field.

Recommendation 13

In order to foster the field of sustainable development in the years to come, it seems necessary to underline that external costs are real costs. This needs to be done on permanently, on the basis that externalities do often have a strong local impact. It is thus necessary to involve local companies and industry in an effort to work out solutions on how to internalise social and environmental costs. If this is not done locally (while respecting the optimal cost matrixes), there will be little progress at the international level either. Supporting programs by the EC (DG Research, DG Region, DG enterprises, DG Environment) could thereby play a major role (incentives and financial support of pilot initiatives). At a first step, a strong effort for raising awareness at political level should be undertaken.

Recommendation 14

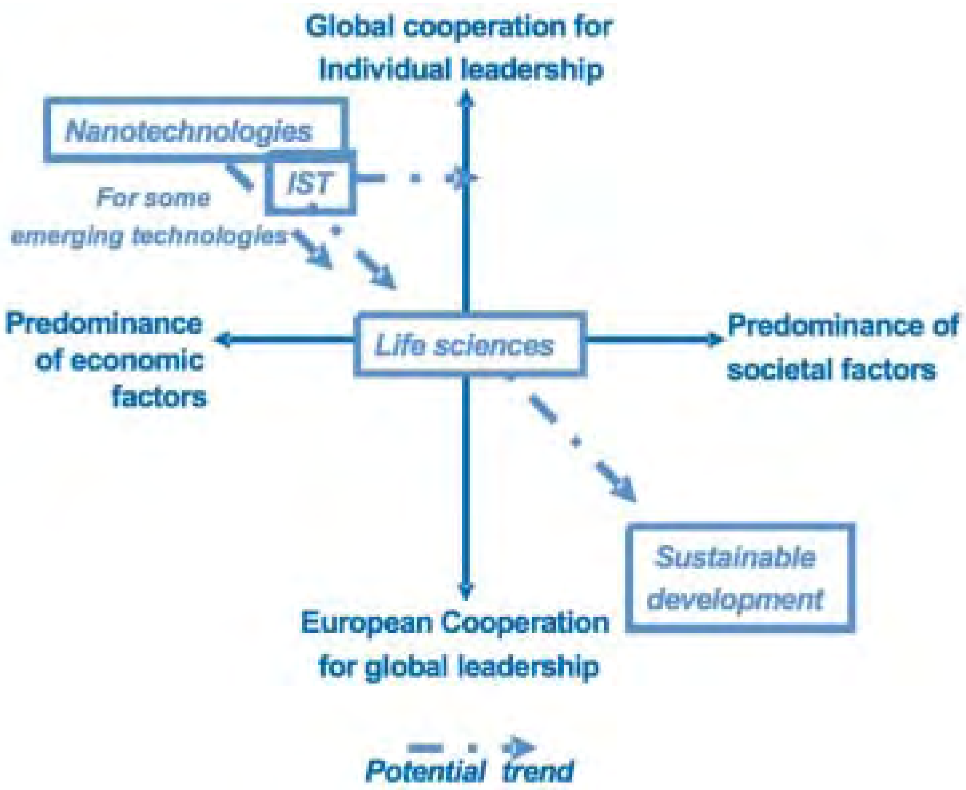
Facing issues at worldwide level, Europe could foster large dissemination of results. In the area of sustainable development, it could take the form of the support of R&D project in which research activities are carried on in Europe and demonstration activities are carried on in developing countries.

4.4.3 SWOT and situation related to socio-economic factors and players' strategies

Table 12: "Opportunities for cooperation" SWOT

Strengths	Weaknesses
• Strategies partly based on existing or potential scientific leadership • Factors motivating R&D public support in sustainable development and convergent applications are potentially strong in Europe as they cover societal issues	• Longer decision processes because of the necessity to assess strategies at European level targeting technology niches
Opportunities	**Threats**
• Europe takes a lead position on convergent technology applications where societal factors can play a major role. Key emerging technologies belonging to Nanotechnology, life-sciences and IST fields are concerned • More budget (close to the Barcelona objectives)	• Gap between industrial basis and research basis

Figure 60: "Opportunities for cooperation" situation



4.5 Scenario 3: "Life-sciences strategy"

The "life-sciences strategy" is based on the main assumptions that the "opportunities for cooperation" scenario in terms of R&D environment situation. In terms of strategy, there is a clear shared objective at European level to become leader in the life-sciences field. Strong investments are made in the field and most of the niche strategies of the previous scenario now only targets on converging technologies in quality of life applications and health sector.

4.5.1 Basic assumptions

- Rise of European GERD (trying to close on Barcelona level)
- Focus new money on life sciences
- Nanotechnologies and IST are still mainly market driven, even on emerging technologies. However, some niche strategies focused on applications target technologies in this field.

4.5.2 Scenario description and recommendations

Compared with Japan and the USA, European countries generally employ social, environmental and political factors in a more harmonised and coherent way alongside the economic factors as it has been showed in chapter 2. In addition, and regardless of the scientific fields in question, these factors are often used in a complementary manner. While Europe seems thus to have a "tradition" in relying non-economic factors to support its political choices for R&D, the populations of Europe are used to consider these factors as potential main drivers underlying political decision-making process in the field of R&D. By contrast, the use of these non-economic factors in the US and Japanese context is usually limited to very specific scientific fields and remains rather appendage to the main economic rationale. The life-sciences sector, both in the USA and Japan, constitutes an appropriate example. The only exception to this pattern is sustainable development which in the Japanese context is supported for exclusively environmental reasons.

As far as the life-sciences field is concerned, the actual predominance of the USA in terms of its scientific position is mainly due to the fact that R&D support in this field started earlier than in Europe (priority accorded to this field is visible since the beginning of the 70's in the US and a dramatically increase of public financial support exists since 1998). This position can obviously be challenged and a high public support to these technologies based on economic, but mainly on social and political factors has the potential to help catch up with the USA and, as far as some technologies are concerned, to transform Europe into a global leader exploiting the already existing potential of European R&D in this field. While there is no major handicap to the ascension of Europe to potential leadership position, it is, as has already been pointed out, not yet possible to predict on which technologies Europe could possibly develop this leading role.

The scenario is thus based on a strong political and societal focus to elderly as a major issue facing our societies. This issue impacts in a fist stage the health scientific field, but also, at a second stage, other scientific field such as social sciences, political sciences, cognitive sciences (with the issue of memory and training processes…). At the frontier of this elderly issue, quality of life also become a major challenge, focus on ageing population but having knock on effects on public at large. Quality of life issue includes environmental researches, but agro-food, urbanism and architecture, transport… are also concerned.

The elderly and quality of life issues thus put a strong emphasis on the life-sciences scientific field as a whole, but also impulse convergence between the four different scientific fields. Having a life-sciences strategy thus leads to develop key technologies in the other scientific fields to develop converging applications in the health or quality of life sectors. The scenario thus doesn't only focus on a strong public support to life-sciences field, but also on a niche strategy to support some potentially "converging technology", mainly in the IST and nanotechnology sectors. We come across the niche strategy based on scientific field convergences again as we have describe it as a part of the previous scenario (scenario 2).

In terms of international cooperation, rather than competing in life-sciences, Europe, the USA and Japan could unite around a new common interest to cooperate through an international excellence centre based on societal issues in an attempt to favour scientific convergence. As is already the case with regard to some major scientific issues, such as nuclear energy or space development, the issues of aging populations and quality of life constitute an obvious example with a potential to lead to international cooperation. As the technologies to be used to address this issue stem from different scientific fields, these issues have the potential to initiate wide scientific cooperation mechanisms on emerging technologies in the years to come.

As regards the role of India and China within this new emerging research world, any cooperation mechanism with Europe, Japan and the USA is not envisaged for the near future due to different levels of scientific expertise. In fact, a "sub-contractor" role appears to be much more plausible and desirable for these countries provided the international community wants to prevent these countries from developing their own particular R&D potential (supported by various political factors related to the will to compete with the main actors).

Lastly, this scenario put the emphasis on the leverage role of public support. Even if pharmaceutical industries can have a major role in the scenario, all the more reason that elderly becomes an important market, both through its number and its solvability. But the health sector is still in most of the countries, and specifically in Europe, mainly a public service working for the general interest. The USA example demonstrate clearly that scientific positioning in the field is for a main part the results of a strong public support. A European public strategy, based on the current and recognised European competences in the health sector could thus have a strong impact in the future.

In addition to a general recommendation to increase national and European public funding in the life-science field, the interviewed experts have provided some more detailed and focuses suggestions:

Recommendation 15

A strong focus in the public support should target molecular imaging. The USA has clearly taken the lead on these technologies. It is of high importance to keep companies' imaging research potential within Europe as some dislocating temptations already exist as well as we can observe a beginning of brain drain movement. In addition to financial support, more cooperation in university in this field (towards an European Master degree) in also be needed.

Recommendation 16

Beyond the legal issue to encourage national legislators to facilitate approval procedures for tissue engineering products, there is a real need of clinical and economical studies on this technology. These studies should be included in the EU programs.

Recommendation 17

It is necessary to enhance the GEN-AU program mainly to attract researchers back in the human genomes and proteomes field. The same recommendation is also available for protein engineering through a European HUPO project.

Recommendation 18

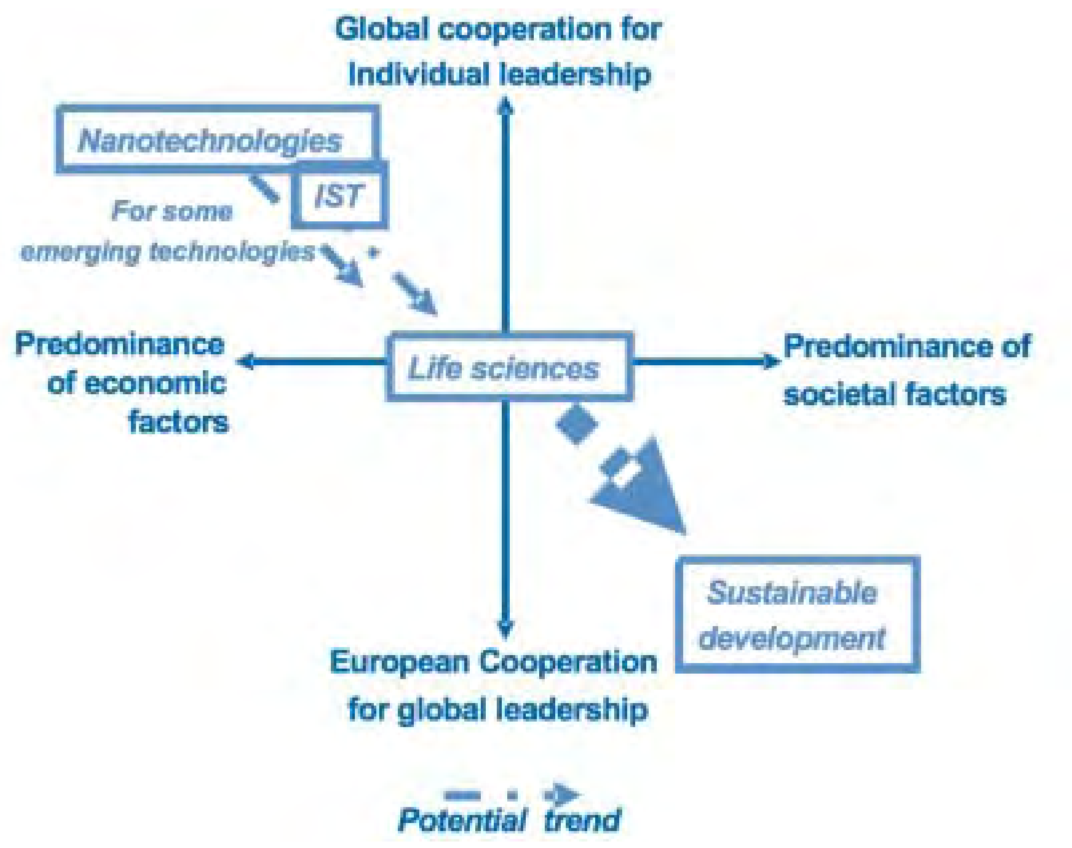
It is necessary to ensure continuity in the European Union framework programs as biotechnology research needs long-term activities to attract private companies.

4.5.3 SWOT and situation related to socio-economic factors and players' strategies

Table 13: "Life-sciences strategy" SWOT

Strengths	Weaknesses
• Budget and manpower increase • Closing the gap with the US in life sciences	• Acceptation of the US and Japan domination on nano & IST (at least for some technologies
Opportunities	**Threats**
• Strong support for convergence on the health and quality of life technology issues • Quality of life issues can partly support the development of the Sustainable development field	• Not to master some emerging technologies needed to enter convergent based application fields not targeting health or quality of life issues

Figure 61: "Life-sciences strategy" situation



5. Conclusion

This report highlights 40 key emerging technologies in Europe, Japan and the USA for the years to come, and describes the actual positioning of public R&D in Europe vis a vis these technologies, compared with Japan and the USA. By the way of scenarios, different recommendations are suggested in order to enhance the positioning of Europe with regard to both the technologies and the role of Europe in terms of competition and cooperation in the R&D fields.

Without coming back to the detailed results of the study which are the subject of the whole report and mainly the chapter 4, we just want to underline here two aspects which are of interest both for R&D public policy decision and foresight works on the subject.

A first one is that the study underlines that there are very strong gaps between the situations in the different scientific fields. The role of public policies could thus be dramatically different depending on the fields. The study has so demonstrated the weak potential role of public support for some scientific fields compared with others. It has also highlight the importance of the "story" and development level of the scientific field as having a crucial role in its future potential development. The current "converging" issue, which is much more a convergence between scientific fields rather than a convergence between technologies, puts a new emphasis on this need to really focus at this level to have a good understanding of the scientific realities and their determinant.

The second one is the importance of socio-economic factors in public R&D policy. It was obvious that these factors could explain public policy decisions. But what has been underlined is that these factors and their evolution can represent major trends that can strongly impact public actors in their decision making abilities and opportunities. These factors, as trends, are not only part of the scenery for foresight practitioners, but could offer important potential for decision that could drastically change the scientific positioning of countries in a scientific field. Without wanting to minimize issues such as budget or potential market, socio-economic factors could strongly support decision making at political level and act as a rationale for choices and prioritisation.

Table of figures

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