

The very rapid progress of the sciences and technologies, their distinctive characteristics and the highly varied uses to which they can be put demand from us more than ever an effort of vigilance, foresight and evaluation. In recent years in France that effort – covered by the generic term ‘Technology Foresight’ – has given rise to a number of exercises relating to the French system of research and innovation (*FutuRIS*), to *Key Technologies 2010*, to the future of the strategy of the National Agricultural Research Institute (*INRA 2020*), and to the contribution that could be made to the challenges of sustainable development and the improvement of everyday life by various services and technologies (*Agora 2020*).

There was previously no summary in English of these four projects. This publication fills that gap and aims to provide an account, for the benefit of the international community, of some major projects carried out in France on the basis of different – and particularly innovative and promising – approaches.

# Science and Technology Foresight: Four French Case Studies

Collected Essays by  
Hugues de Jouvenel, Jacques Theys and Sébastien Maujean

*With a Foreword from Paraskevas Caracostas*

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# Foreword

HUGUES DE JOUVENEL, JACQUES THEYS AND SÉBASTIEN MAUJEAN <sup>1</sup>

Our age is one of very rapid progress in the sciences and technologies, fields displaying distinctive characteristics on account of their generic combinative character (as emblemized in the convergence between information and communication technologies, biology, nanotechnologies and the cognitive sciences – the NBICs). For this very reason, these are, potentially, very much ‘enabling technologies’ and can be put to many and varied uses, from the noblest to the most perverse.

Hence, the steering of research and, *a fortiori*, the control of the uses of these new technologies have become major issues, requiring an unprecedented effort of monitoring, anticipation and evaluation. This has led to a great many technological foresight exercises being conducted in most of the industrialized countries.

France could not remain aloof from these concerns and many exercises of this kind have been undertaken within the country. Not being content to focus merely on the predictable advances of the sciences and technologies, and their potential applications, these studies have endeavoured to identify collective issues and needs (sustainable development, demographic ageing, the rise of the knowledge economy etc.) and, on the basis of these social issues, to explore what respective priorities should be accorded to research, development and innovation.

The present work covers four of the main technological foresight exercises carried out in France in recent decades: *FutuRIS*, the *Key Technologies 2010* study, *INRA 2020* and *Agora 2020*. Each of these projects, which have prompted significant intellectual production and spawned many publications in French, is briefly summarized here in English to serve as a contribution to the thinking done by our anglophone colleagues working in Europe and the rest of the world on similar areas of research.

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# Preface

PARASKEVAS CARACOSTAS <sup>I</sup>

The increasing rate of progress in science and technology, together with globalization, makes economic and social trends more difficult to predict. Interrelationships between science, technology and society are becoming more complex. In the face of major challenges, such as climate change, resource scarcity or ageing, global governance is still embryonic. The current financial and economic crisis compounds these structural uncertainties. It may have negative social and political effects. But *krisis* in ancient Greek also means the moment of decision. Either mankind will be unable to address the challenges lying ahead and may suffer more poverty, more instability and environmental disasters, or it will seize the opportunity to initiate the transition to a new socio-ecological model of production and consumption.

Therefore, thinking, debating and shaping the future (a rough definition of “foresight”) is even more essential today. In Europe, foresight activities emerged first at the national level. To mention just a few, Germany, France, the UK and the Netherlands have been undertaking a range of “futures research” activities since the early 1990s. Austria, Ireland, Portugal, the Czech Republic, Sweden and Greece followed suit. Recently it was the turn of Finland and Denmark to launch wide-ranging technology foresight initiatives. At the end of 2007 the German Federal Ministry for Education and Research (BMBF) launched a new foresight process in order sustainably to safeguard Germany’s status as a location for research and education.

These initiatives range from technology-focussed and expert-driven activities to more socially oriented ones with a broader stakeholder participation. They have also varied in their objectives, from identifying strategically important technologies for the companies implanted in their countries to more general questions about the role of public authorities and the institutional and societal conditions for socio-economic change.

Since March 2000, when the member states of the European Union defined the “Lisbon Strategy” to make the European Union “the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion”, the creation of a European Research Area (ERA) has been seen as an essen-

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1. Advisor in the “Science, Economy and Society” Directorate, Directorate General for Research, European Commission, Brussels. The views expressed hereafter are personal and cannot be considered as official views of the European Commission.

tial dimension of this ambitious strategy. This is because scientific research and technological development have for many decades been key to economic competitiveness, as well as to addressing major societal or environmental problems. Eight years later, in December 2008, research ministers of the EU agreed on a “2020 Vision for the European Research Area”, stressing the importance of research for addressing the needs of citizens.

Political decision-making is based more and more on a large number of players and a variety of levels (European, Community, national and regional) where choices can be made and action taken. The complexity of policy-shaping and policy-making is increasing. Joint strategic visions to choose the priorities for technological and scientific objectives centred on society's economic, social and industrial problems are becoming essential.

At European level, after the initial role of catalyst played by the FAST (Forecasting and Assessment in Science and Technology) Programme from 1978 to 1993 and the establishment of the Institute for Prospective Technological Studies in Seville in 1994, a new wave of cooperation activities was launched in the years 2001-2005. These activities achieved the following:

- They created and developed transnational networks between sponsors and practitioners of foresight;
- They initiated mutual learning processes between (old and new) member states and regions;
- They produced forward-looking ideas and visions for EU research policy (for example, expert groups on the future of universities or on the nano-bio-info-cogno convergence process);
- They supported the development of tools (in particular for regions and new member states wishing to launch foresight initiatives);
- They supported the setting up of a monitoring system on foresight in Europe.

In addition, some thematic programmes under the fifth and sixth EU Research Framework Programmes have supported foresight projects in their domain (e.g. Information and Communication Technologies, manufacturing, transport, energy, etc).

Now, consensus is growing that a more coherent development of research and innovation policies in Europe implies an urgent need to co-operate more systematically and efficiently to share the knowledge base on which European, national and sub-national policy decisions are made. This would make it possible to:

- address many problems and challenges jointly, providing specific solutions, where necessary, for different socio-economic contexts;
- improve the quality and impact of national and regional foresight exercises, by comparing findings and methods and, consequently,
- contribute to improved policy design and implementation at European, national and regional level.

It is even more urgent, now that the idea that a number of EU countries may combine their efforts at “joint programming” in the field of research has been endorsed at a high political level (EU “Competitiveness Council”) in December 2008.

Against this very dynamic European background, the four experiences described in this book clearly show that a revival of foresight is under way in France. It should not be forgotten that, together with the United States, France has a long tradition in futures and forward-looking activities, going back to the institutionalization of the Commissariat Général du Plan in 1946 and to the famous pioneering work of Gaston Berger in the 1960s.

In the 1990s, in the context of the market-oriented political shift observed in most Anglo-Saxon countries, it seems paradoxical that a new generation of foresight activities emerged. It is as if, where the government sees its role diminishing in the economy, foresight, a kind of long term planning activity, flourishes. The paradox may be resolved if one thinks of the features of these new processes. They are initiated by public authorities, but they differ from traditional forecasting and planning. They aim at offering a space to a varied set of actors (the government being one of them), so that they can confront their visions of the future and hopefully coordinate their action.

French “*prospective*” has been part of this new type of foresight. *FutuRIS*, *Agora 2020*, *INRA 2020* and *Key Technologies 2010* are illustrations of such an evolution, corresponding to the various different types of foresight:

— *FutuRIS* was systemic and national in scope; it concerned the research and innovation system and combined scenario work and quantification of outcomes;

— *Key Technologies 2010* was, similarly, national but it focused on industry and had a shorter time horizon; it coupled an analysis of socio-economic issues, including at world and European levels, with a review of sectoral dynamics;

— *INRA 2020* centred on a research organization; it produced scenarios in respect of the societal environment of agro-industrial research and drew the implications for the organization;

— finally, *Agora 2020* addressed a wide range of issues related to daily life (quality of life in cities, safety, risks, spatial planning, coastal areas and the sea, resources, etc); it involved a wide variety of stakeholders, actors and, for the first time, the public itself and combined many methods; the international and European contexts were taken into account; it challenged researchers to translate “questions to research” raised by users into “research questions”.

The initiators, operators, sponsors, participants and clients of these projects have contributed to strengthening the French component of the emerging “European Foresight Area”. This book will significantly help to disseminate the results of these activities to a wider European and international public. It will certainly attract the interest of practitioners and policy-users elsewhere in Europe and may, therefore, stimulate further networking and cooperation.



# FutuRIS

## A FORESIGHT PROJECT FOCUSING ON THE FRENCH RESEARCH AND INNOVATION SYSTEM

VINCENT CHARLET <sup>1</sup>

### Overview of the Exercise

FutuRIS (Research, Innovation, Society) is an initiative launched in 2003 by the French Association for Technical Research (*Association nationale de la recherche technique*, ANRT) to bring together leading players from the public and private sectors with the aim of taking a foresight approach to the French Research and Innovation System (FRIS). Since early 2006, when substantial reforms and significant institutional changes were introduced by law, FutuRIS has turned to a collaborative platform, supported by public and private sectors, capable of permanent expertise and monitoring activity on RTD (Research, Technology and Development) strategies.

In concrete terms, FutuRIS is a systemic foresight operation, which, since its beginning in early 2003, has used a number of exploratory scenarios to simulate potential changes from which key issues could be identified. Its remit also encompasses publishing sound, evidence-based recommendations and participating in change management when deemed necessary.

The purpose of this paper is to describe the context, method and main results of FutuRIS.

This paper deliberately focuses on the launch of FutuRIS, i.e. on the initial assumptions and findings that justified the resort to scenario-based foresight analyses; and on the construction of scenarios itself and the most evident findings those scenarios produced. FutuRIS led to the construction of five scenarios that present possible changes in the FRIS over the next 20 years. These attempt to explore the possible consequences of a certain number of events and public policy options.

The reader should bear in mind that a public debate on public research funding flared up in France in early 2004, after President Chirac announced a new parliamentary bill on research. FutuRIS had been in existence since

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2002 and had not anticipated that research policy would become such a hotly debated issue (though it had obviously taken the view, from the outset, that it was a topical one). This unexpectedly high media profile presented a great opportunity for FutuRIS and its findings to receive some publicity and win a hearing at the higher political level.

The bill passed into law in early 2006. Most of the institutional changes it entails, directly or indirectly, are still on-going, but FutuRIS can claim to have had some impact on certain governmental decisions and, above all, to have provided the parties to the debate with solid, evidence-based material for discussion.

As a result, a number of recent decisions are in line with FutuRIS recommendations. In other words, they can be seen as possible answers to challenges FutuRIS identified in 2003 and 2004. This may retrospectively explain why FutuRIS seems at times to emphasize certain issues that are not as pressing in 2006 as they might have been in 2002, or why it urges the government to take certain decisions that have in the interim been taken. Nonetheless, research and innovation require long-term policies and not all FutuRIS's recommendations have been implemented. Most of its fundamental points are therefore still valid in 2006.

## ***Procedure***

### ***Context***

The French Research and Innovation System (FRIS) was established after the Second World War. At that time, the technologies required for heavy industry were a key priority; state-run companies played a key role in technical research; there was sustained economic growth; exchanges with the outside world were limited; there was strong support for technical progress in public opinion; and the research sector offered solid career possibilities.

Today, the field of knowledge has widened, with life sciences becoming increasingly important; society's attitude is more ambivalent; the French economy operates as part of the European and global economies; multinational companies (MNCs) now play a key role; and many feel that state institutions — those in the research sector in particular — have grown too rigid with age and are in danger of becoming ineffective.

The current system has made it possible for France to stake a claim in several major markets, including aeronautics, space, nuclear power, the automotive sector, railways, public works, and defence. By the same token, France has also managed to maintain a respectable position in the area of fundamental research.

However, with the exception of microelectronics, the existing system has produced far less satisfactory results in the information technology field, not to mention biotechnology.

One explanation for the increasing doubts surrounding the ability of the current Research and Innovation System to meet the future needs of French society relates to the changes that have occurred in the political, economic, social and technological environment over the past 50 years. Some have even suggested that the French Research and Innovation System is in a critical situation.

This explains FutuRIS's decision to examine the system as a whole rather than focusing on any of its individual elements.

There are many links between the components that make up the system. Research and innovation have brought about a wide range of changes in society. Some have been marginal but steady, such as the reduction in the consumption of certain products or services, or changes in the work place; others have been more radical, such as the appearance of new techniques for power generation. New branches of industry have been created (for instance, the plastics industry in the 20th century); technical paradigm shifts have occurred (such as the omnipresence of information and communication technologies today). It is evident that research and innovation has a great variety of technical, economic, and social implications.

Rather than limiting its ambition to a critical review of the current situation of the French Research and Innovation System, FutuRIS decided to conduct a foresight analysis targeting the challenges that this system is likely to face between 2000 and 2020, thereby looking at a relatively wide range of possibilities.

Once these challenges were collectively agreed upon and analysed, FutuRIS could base its subsequent work — and recommendations — on a sound basis. Unsurprisingly, the platform proved to be a useful resource when a new programmatic Law for Research and Innovation was placed high on the political agenda. FutuRIS also provided sharp insights into several key issues, such as human resource management or the development of high-tech companies.

## *Underlying Assumptions and First Observations*

Like any other investment, research and innovation entail spending in the short-term. However, their output contributes to meeting social needs that can be broken down into three main categories: increased human knowledge, improved social well-being, and a contribution to national defence and security, both internal and external.

1. While each country is responsible, at the national and European levels, for defining the resources it wishes to allocate to the global pursuit of scientific knowledge, the reality is that, below a certain level of funding, the national

research and innovation system might be marginalised, and the beneficial interaction between basic research and innovation might also be jeopardised.

2. In European societies with low levels of population growth and high levels of fixed capital, the increase in revenues will primarily come from intangible investment in research, innovation, education and training. It is this investment that will also make it possible to combat certain negative external implications of economic development.

Intensity of innovation will have a definite impact on standards of living and the quality of employment. In addition to the impact of economic growth on the number of jobs available, innovation can contribute to reducing unemployment, if the job market is sufficiently flexible.

3. Current geopolitical analyses show the wide range of threats our societies are likely to face in the future. These challenges will require a diversified defence system, the construction of which will entail a significant volume of research and innovation.

4. Investment in research and innovation has major long-term effects and any delays are virtually irreversible. Some of the main strengths of French industry today are the product of decisions taken in the 1960s. Europe has never recovered from its failure in the IT sector in the 1970s. If Europe were to lose ground over the next decade, the fallout would still be significant in 2030.

Against this backdrop, all countries must determine their research and innovation strategies and decide how to allocate resources. The situation varies considerably from one country to the next.

— The United States has, at least for the moment, the weakest constraints. It is able to cover a wide range of social requirements and remain a major player in all fields of fundamental and applied research.

— The smaller European countries can confine themselves to providing excellent education and training for their engineers and either take advantage of innovations introduced by multinational firms or focus their efforts on one highly developed field in their economy.

— The mid-size countries (such as France, Germany, and the UK) are faced with a twofold dilemma: they must select the fields to which they intend to give priority and avoid both geographical and sectoral fragmentation.

It is also important not to overlook the ambiguity of the term ‘country’ in Europe today. National governments are just one of many players when it comes to striking agreements at the European level, and local authorities are beginning to have real power. Whether they are multinational or not, firms see development and survival as their top priorities; they do not receive orders from the public authorities, but they are influenced by the prevailing political, economic and social environment, and the attractiveness of public research facilities to their business.



Where business is concerned, studies show that the profitability of investment in R&D is, on average, relatively high by comparison with other investments. However, by weakening earnings in the short-term, too high an R&D rate can increase the risk of takeover bids, even for large firms.

Although it is preferable in terms of economic structures to see the creation of numerous innovative small and medium-sized businesses, with a sufficient number reaching the level of medium to large companies, the average rate of failure must still be kept within limits. In order for this to occur, it is necessary that these companies cover an area of activity that is broad enough and that they have access to pan-European and international markets.

Finally, it is important to remember that, in a research and innovation system, researchers and innovators are also a scarce resource. Faced with low levels of reward and compensation or poor working conditions, these researchers and innovators may choose to move abroad or, if they have come from other countries initially, to return home or go elsewhere.

For decision-makers in French society, which is significantly open to Europe and the world, reforming the French Research and Innovation System and managing it with an eye to its social value is a difficult task and one that requires in-depth consideration. This must go beyond the question of how short-term difficulties are to be resolved, when these are symptoms of long-term problems. As the resources available to French actors, particularly the state, are modest, the targeting and efficiency of spending are key issues.

## *Initial Perspective on the FRIS*

While relatively well known for its R&D figures, which are subject to international statistical standards, the FRIS is much more difficult to position in terms of innovation.

To begin with, it is important to stress the complexity of the FRIS. The bodies responsible for the public section of the system vary considerably in terms of status and resources, and the businesses behind the private section range from large multinational groups to fledgling companies that have often been in operation for only a short period of time.

Where innovation is concerned, advances often occur in fits and starts, with constant interplay between imitation and invention.

As a system, the FRIS is not a straightforward sum of independent parts. Any changes to a given element or link may influence the rest of the system.

## *The Funding of Research and Innovation*

From 1990 to 2000, the French GERD (Gross Domestic Expenditure on Research and Development) increased from 27.9 billion to 31.65 billion euros (adjusted for inflation), and decreased from 2.41% to 2.22% of GDP.

At the same time, the percentage of public funding fell from 53% to 45%, with private funding covering the remainder. However, the execution structure has not changed significantly, with around 39% being public and 61% private.

The sharp fall in GERD as a percentage of GDP between 1990 and 2000 is largely due to the reduction in defence R&D spending. Since then, it has been much steadier and may possibly be rising again today.

To give an international perspective:

— France's GERD represented only 13.6% of the US GERD in 2003, and this percentage has declined continuously over the last 20 years.

— China's GERD is already higher than that of France.

— The GERD of the Europe of 25 comes to only 75.4% of the US GERD, whereas these two regions have very similar GDPs.

The indicators, which do not measure GERD spending but rather the results of this spending (number of patents, theses, publications, etc.), are open to criticism on account of the heterogeneous nature of research and development systems in different countries. Nevertheless, the fact that France is almost always ranked poorly within the European Union is a further cause for concern.

In terms of public funding, the percentage of state funding had gone down 6 points by 2000, while regional funding has always been very low. However, funding from Europe (various types of Commissions, ad hoc collaborative and intergovernmental financing) has risen from 5% to 10% in 10 years.

The percentage of funding provided by civil society (via non-profit-making organizations) remains marginal. Nevertheless, this source of funding is of particular importance to laboratories, because it can be used much more freely.

Where private funding is concerned, the percentage provided by the financial markets is increasing, but still accounts for only 1.8%. Subsidiaries of foreign firms carry out around 20% of private R&D in France, whereas a little over 20% of French R&D is carried out by French firms abroad. R&D is 50% more internationalized than it was 10 years ago. The balance is slightly negative, though the deficit remained more or less constant through to 2000.

In 2003, the national funding of research amounted to 34.4 billion euros and could be broken down as follows:

Public funding: 15.7 billion (45.5%), of which:

- military and major technological programmes: 5.8 billion
- public laboratories: 9.1 billion
- innovation policy: 0.7 billion

Private funding: 18.7 billion (54.5%), of which:

- outsourcing to public laboratories: 0.7 billion
- intra-firm RTD projects: 18.0 billion.

It is clear from these figures that the scope of the field in which France is expected to compete is not compatible with the resources allocated to research and development.

It will only be possible to reduce the gap between objectives and resources by using the available resources more effectively, increasing these resources or scaling down the objectives.

## Human Resources in Public Research

In full-time equivalents, France has 127,500 researchers (at end 2000), with 41.2% in public research and 58.8% in private. The public sector includes higher education (45.7% of the public workforce), the *Centre National de la Recherche Scientifique* (21.9%), the other *établissements publics à caractère scientifique et technologique* (EPST: Public Scientific and Technological Institutions) (9.5%) and the *établissements publics à caractère industriel et commercial* (EPIC, Public Industrial and Commercial Institutions) (22.9%).

Higher-education professionals are supposed to devote half of their time to research duties but, in reality, the time devoted to research, research skills, and preferences varies considerably from one individual to another. Furthermore, such differences are heightened by the fact that recruitment is primarily driven by teaching needs.

While the age pyramid for researchers in the private sector is satisfactory (mode on the 26-35 age-bracket with a significant decrease thereafter), EPST's researchers are more heavily weighted toward the 50-60 age-group, and the distribution of EPIC researchers, though slightly better, has a mode of 40-45 years. This situation obviously creates a number of problems.

## Private Research and Innovation

The data on company R&D is relatively accurate:

- The number of companies concerned is around 5,300: 4,000 in industry, which account for 80% of research, and 1,300 in services, which represent 15%. In industry, the key sectors are electronics, pharmaceuticals, land transport, chemicals and aerospace.
- French groups employ 55.5% of researchers in the private sector, of which nearly 90% are employed in companies with over 500 employees. The 13 largest alone account for half of research spending in companies.
- French companies that are subsidiaries of foreign groups employ 16.6% of researchers in the private sector, 80% of whom work in companies with over 500 employees.

— Independent French companies, although representing 80% of companies involved in research, employ only 28% of researchers, 19% of whom work in companies with fewer than 500 employees.

However, these figures mask a key phenomenon. France's success in energy, telecommunications, aerospace, and microelectronics would not have been possible without state-of-the-art technological research centres. Nevertheless, some of these centres have been seriously disrupted by privatisation or projected privatisation. This important work has not always been successfully transferred to private businesses.

As far as innovation is concerned, a survey of industrial companies shows that 41% of them claim to have innovative products or processes. This rate rises to between 55% and 60% for companies in the electronics, chemical, and pharmaceutical sectors.

However, innovation may also relate to a company's means of financing, marketing methods, human resources training, or organisational management. It also concerns market and non-market services, whose relative weighting in the French economy is on the rise.

## Public Policies and the Legal Framework with Regard to Research and Innovation

Public policies on research and innovation cover a wide range of actions, including:

— Orientation of public research bodies and university research (four-year contracts, scientific jobs, PhD training, relations between industry and Higher Education institutions), mostly by the Ministry of Research;

— Incentives to promote fundamental and applied research, as well as linkages between public and private research. Note that neither the National Research Agency (ANR, the Agence Nationale de la Recherche) nor the competitiveness clusters (*pôles de compétitivité*) existed in 2003, when FutuRIS was initiated; the responsibility for these public policies was shared by the Ministry and public research organisations;

— Incentives to enable ambitious innovative industrial projects (radically low-emission car engines, mobile television etc.). This is now the remit of the Industrial Innovation Agency (AII, Agence de l'innovation industrielle), which also did not exist before 2003. Most observers agree that France had given up this kind of innovation policy before the AII was created;

— Support for the creation of innovative companies (tax incentives, reduced payroll contributions) and financial incentives to promote innovation (ANVAR, the Agence nationale de valorisation de la recherche);

— Support for other public policies;

— Assistance with the dissemination of scientific and technical knowledge.

As regards public policy, the main characteristics of the FRIS in its present form depend on the 1982 law on public research. It established institutional frameworks for public research organisations (the so-called EPSTs and EPICs, such as CNRS, Centre national de la recherche scientifique, and CEA, Commissariat à l'énergie atomique, respectively) defined a new civil-servant status for public research staff, set up a Higher Council for Research and Technology (CSRT, Conseil supérieur de la recherche et de la technologie), paved the way for regional research policies and, last but not least, created a new budgetary tool, the civil R&D budget (BCRD, *budget civil de recherche et du développement*), intended to promote the coordination of the various ministerial policies dedicated to research, technological development and innovation.

In 1999, another significant milestone was reached with the “Innovation Law”, which created a more favourable legal framework for cooperation between public and private research and for the creation of start-ups by researchers.

Lastly, as already explained, the government set up a range of new mechanisms in 2005 and 2006, some of which are briefly mentioned above: competitiveness clusters, National Research Agency, Industrial Innovation Agency... The aim of this paper is to describe the context in which FutuRIS was launched, and it is therefore not deemed necessary to describe these extensively.

## Conclusion

Even before any foresight analysis, such a review of the current state of the FRIS raised a series of important challenges and questions in 2003.

### In Terms of Information

— It was obviously necessary to strengthen the international benchmarking effort, in order to separate out the effects resulting from the specific features of the French system from “real” worldwide issues.

— It appeared — and still is — necessary to make an effort to identify the reality of research in Higher Education, moving beyond the simple use of agreed calculations. The same also applies to clinical research.

— A number of issues relating to the activity of companies in research and innovation remained unclear:

— Should an effort not be made to produce a better description of innovation in industry, public and private market services, and in non-market services?

— Should we not review the influence of major firms on the research and innovation activities of their suppliers?

— Should we not review the scope of the life-cycle and growth of SMEs (small and medium enterprises) founded by researchers from public laboratories?

— For laboratories bound by the public accounting system (i.e. an accounting system designed to monitor the legality of spending), creating an accounting system based on full costs, including personnel, facilities, and other spending, while separating funds received from public bodies and those from other sources, was and still is a critical issue.

### **In Terms of Public Policy**

— What policies should be adopted with regard to public research staff?

— Should we examine the misappropriation of public resources? Will spreading resources too thinly among many programmes marginalise some of these programmes, forcing them to cope with high operating costs disproportionate to their results?

— In support of innovation, what balance should be struck between direct support and indirect measures to promote innovative businesses and, in particular, SMEs?

### **International Perspective**

In light of this synopsis of the state of the FRIS, what do the main international data demonstrate?

### **Research and Development in Businesses**

This section <sup>2</sup> focuses on research in companies around the world and the situation of a few chosen countries. The aim is to shed new light on traditional viewpoints deeply anchored in France and the French system.

Businesses represent around two-thirds of R&D spending around the world. Where R&D investment is concerned, the top 700 businesses account for a total of 330 billion euros — nearly half of global R&D spending.

A review of the data on this sample brings out five key characteristics:

1. The ratio of R&D to sales is fairly consistent within a given sector. For example,

— In the automotive industry, the average rate is 4.2% (Ford: 4.7%, Renault: 4.9%, PSA: 3.9%)

— In the pharmaceutical sector, the average rate is 13.7% (Pfizer: 16%, Sanofi: 16.4%)

The GERD for the leading French groups will only increase in the future, proportionate to growth and the percentage of R&D activities located in France.

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2. See DTI (British Department of Trade and Industry). *The 2003 R&D Scoreboard*. Edinburgh: DTI, 32 pp.

2. However, the ratio of R&D to sales varies considerably from one sector to another:

- 13.7% for pharmaceuticals
- 10.8% for software and IT services
- 10.0% for microelectronics and IT hardware
- 6.0% for electronics and electrical engineering
- 4.3% for aeronautics and space (this figure is additional to the percentage of government contracts)
- 4.3% for chemicals
- 4.2% for automotive
- Only 1.1% for construction, 1.3% for electricity, 1.8% for agro-industry, and 0.5% for oil

3. The growth rate in R&D spending also varies from one sector to another. Between 1996 and 2000 it rose by 43%. The leaders in achieving this growth were:

- IT services and software
- Pharmaceuticals
- Health
- Microelectronics and IT hardware
- Aerospace and defence
- Automotive

However, the telecommunications sector has seen no growth; growth has been low in the chemical industry and merely average in the electronics and electrical engineering sectors.<sup>3</sup>

4. For the 700 companies with the highest level of R&D investment, total spending on R&D can be broken down as follows for the main sectors:

1. Microelectronics and IT hardware	72.1 billion euros	21.6%
2. Automotive	59.9 billion euros	18.0%
3. Pharmaceuticals	58.2 billion euros	17.5%
4. Electronics and electrical engineering	34.4 billion euros	10.3%
5. Software and IT services*	21.0 billion euros	6.3%
* The aerospace-defence sector, which recorded 12.9 giga-euros (3.9%) in private funding alone, could well be the fifth-placed sector, factoring in public contracts.		

3. DTI. *The 2001 R&D Scoreboard*. Edinburgh: DTI, 44 pp.

5. The positions of countries in each area of activity vary considerably. The United States, which has very good levels in all fields, has a true monopoly only in software and IT services (1/15 of R&D for businesses). 45% of R&D in the main UK companies is generated by Glaxo and Astra. Canada is dominated by Nortel, Italy by Fiat, the Netherlands by Philips Electronics, Finland by Nokia, and Sweden by Ericsson. France and Germany have a more diversified portfolio, with R&D in German businesses in the sample running at twice the level of French R&D by volume, with heavyweights such as Daimler, Siemens, and Volkswagen featuring in the list.

The countries where GERD is high tend to be those that have historically a number of big businesses in innovative industries.

### **Spotlight on the Situation in Selected Countries**

We must not lose sight of the fact that the regional innovation systems (RIS) in the different countries do not have the same structures and often operate in specific political and economic contexts.

For the United States, we would like to highlight a few well-known characteristics.

— That country is responsible for more than one third of global expenditure on R&D, a percentage far higher than its contribution to World Gross Product.

— Public-private interplay is very strong, on account of the links between businesses and universities.

— The system is Darwinian (based on the dual notions of competition and trust), although government spending can vary significantly and rapidly (the Department of Defence budget increased from \$45 billion to 60 billion between 2001 and 2003, the National Institutes of Health budget rose from \$15 billion to 27 billion between 1998 and 2003, while the National Aeronautics and Space Administration (NASA) saw its budget cut from \$10 billion to 4 billion between 1981 and 1983, and then returned to the original levels over the following seven years).<sup>4</sup>

— The system of governance, which is simple in principle yet complex in detail, respects the principle of separation: strategy and allocation of budgets (government and Congress), allocation of funding for projects (agencies), management of people (organisations).

— The US invests aggressively in the sectors it regards as representing high potential: in 2003, ICT (Information and Communication Technologies) investments were \$42 billion higher than in the Europe of 15 (+150%), and \$13 billion higher in biotechnologies (+500%).

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4. AAAS (American Association for the Advancement of Science). 2003 *Annual Review*. Washington, D.C.: AAAS, 2003, 28 pp.



The Department of Defence (DoD) budget (\$54.8 billion in 2003) can be broken down as follows: \$45 billion for industry development, \$5.2 billion for research (primarily 1.7 billion for the DoD's own laboratories, 1.7 billion for industry and 1.4 billion for universities), and \$4.8 billion for advanced development. The DoD remains the main source of funding for ICT. Since the NIH (2003 budget: \$27.3 billion) does not fund development, it is far and away the leading federal investor in research, providing over one third of funding for university research, and covering all aspects of health, restricting itself to neither medicine nor biology.

As far as the other countries are concerned, almost all those with high levels of R&D spending are currently reforming their public research system, targeting two main aspects: competition and collaboration with business. Fixed budgetary contributions are being scaled down in favour of a funding structure based on competitive tendering; organisations are being given more autonomy and responsibility for their own management, and provisions such as the Bayh-Dole Act are militating in favour of a patent-based evaluation policy.

This is particularly the case in Japan, where the level of R&D is high, but public research has played only a minor role to date.

In Germany, public research and industry used to complement each other well, due primarily to the Fraunhofer Institutes. However, the major fundamental research institutions — Helmholtz (23,000 staff), Leibnitz (12,000), and Max Planck (around 15,000) — were independent from the rest of the system, as were many universities. It is this group that is being reorganised.

The UK is a particularly interesting case, given that it reformed its system about 20 years ago and we can therefore see the outcome to some extent. Although the results are not as favourable as originally expected (impoverishment of many universities, weakening of non-university public laboratories), this is obviously due to the fact that the government sought both to improve the efficiency of the system and to generate savings.

## *Construction of Foresight Scenarios*

### **Foreseeable Context for the Next Twenty Years**

Before presenting the Foresight work generated by the FutuRIS project, it is worth noting a few general trends that are expected to occur over the next 20 years.

1. The development of Eastern and Southern Asia will produce major changes to the global geopolitical and economic map, which will modify the balance of power in the area of research and innovation. If Europe does not devote sufficient resources to this area, growth, which is already at risk of slowing, will be compromised. This will leave Europe uncomfortably placed between Asia, with its dynamic growth, and the USA, which is expected to continue to commit considerable resources to research and innovation.

To provide a rough overview, world GERD is expected to rise from €629 to €1,320 billion over the next 20 years (allowing for inflation), with the percentage claimed by the United States down slightly from 36.6% to 33.0%, while the Europe of 15 will see its share fall from 22.3% to 17.5%. China will rise to 14.9% and industrialised Asia to 24.1% (Japan, Korea, Taiwan, Indonesia, Thailand, Singapore, and Malaysia). France, which currently accounts for 4.9% of world GERD, is expected to come in at between 2.6% and 5.3%, depending on the various possible scenarios.

At the same time, the globalisation of economic activities will accelerate, while global problems such as climate change will continue to emerge.

This change may be accompanied by heightened tensions and latent or open conflicts, which will result in greater importance for security and defence issues.

With the exception of the domestic market, the future of the construction of Europe remains uncertain. There may be a renewed trend toward state sovereignty (and certainly a fatal stagnation of the European project) or the creation of a federal Europe made up of a small number of countries.

However, regardless of the configuration, it appears that:

— no European country (with the possible exception of the UK) is capable of maintaining an adequate security and defence system on its own.

— in terms of R&D, strong European partnerships are essential for the creation of global centres of excellence.

2. Changes to democracy will continue to transform the relationships between science, technology, and society. It will no longer simply be a question of keeping citizens informed of developments in science and technology. Instead, it will be necessary to incorporate research and innovation into the interaction between scientific, political, economic, and social trends. Even with the assumption that there will be a basic consensus on values, behaviour may result in differences of opinion as to what is at stake, which would create major tensions. As such, FutuRIS expert panel 3, working on the interaction of research and innovation with society, concluded that, “reviving ambitious innovation policies requires an open and informed debate, looking at the innovation process both in terms of its goals and the methods employed”.

3. France’s productive structure will continue to change over the long-term, with jobs tending to be concentrated upstream, downstream, or alongside actual production units. There will be increasingly closer ties between services and industry. This explains why it is dangerous to describe the economy and society of the future on the basis of yesterday’s concepts. For example, growth in intangible investments will continue to outpace the formation of fixed capital.

4. The tension that exists in France over the amount and distribution of mandatory levies is likely to intensify. In an ageing society, pressure for

increased “social spending” could lead to future cuts. This situation can be illustrated by numerous decisions taken over the last decade.

It is entirely possible that the problem of unemployment — compounded by the rising number of pensioners (2010-2020) — may lead to an explosion in social spending that would result in the breakdown of the current system, assuming that economic and social systems remain unchanged and that the economy does not return to sustained growth.

Therefore, at the state level, the possibility that future difficulties in reducing the budgetary deficit will entail a more conservative allocation of public spending is a realistic concern.

5. The management of public affairs will now be split between European, national, and regional levels. If not carefully managed, this development will increase the complexity of the situation. Managed correctly, however, this new dynamic could make a positive contribution by involving a greater number of players.

6. As regards technologies, France and Europe missed out on the IT revolution in the 1960s and have only partially recovered, due to the telecommunications boom. The next two technological revolutions are likely to concern:

— the field of health and life sciences, which are linked but not identical (biology is already lagging behind the US; is this irreversible or can it be brought up to speed?)

— closer connections between biology and ICT, in which Europe runs the risk of being sidelined if current trends persist.

In this respect, specific attention should be paid to sectors that are at the crossroads between fields, such as hardware, nanotechnologies, and certain biotechnologies.

These predicted trends should be kept in mind when considering FutuRIS’s analysis of scenarios.

The analysis given in this document will be as brief as possible, while at the same time providing enough detail to facilitate understanding.

## *Methodology*

### **Building Support**

Several choices were made to position FutuRIS in the French context.

1) The programme was not launched or managed by the national government, because it was important for scientific, economic and social actors to be more involved in co-building research and innovation projects and activities. Nevertheless, public support was important where legitimacy and access to

some information and resources were concerned. The aim was to involve both public and private players, representing all sides of demand and supply of research and innovation.

2) France needs to build a strategic capacity (including foresight, a global vision of the FRIS, social debate, governance, methodological and technical tools for public choice etc.) for confronting the future and determining how to face it on the best possible terms.

FutuRIS was divided into 3 phases:

— Phase 1: February 2003 to April 2004. Trends and context (international, European and national) + exploratory work of scenario-building on the research and innovation issues (Excellence in R&I, Competitiveness, Science and Society Relationships). The themes were defined by the project team during the feasibility study.

— Phase 2: May-December 2004. Strategic governance of the FRIS; Synergies between higher education, research and innovation; Attractivity; Institutional organization + work in progress on inter-sectoral issues.

— Phase 3: January-June 2005. Employment prospects and careers for PhD graduates outside the public research system; Development of innovative firms; Inter-sectoral issues.

The main methodologies used were: scenario workshops, polling techniques, stakeholder consultation procedures, mixed panels (with experts and other participants), SWOT matrix analysis.

The scenarios were designed to enable a systematic review of possible changes in the FRIS over the next 20 years, with the goal of shedding light on a number of key issues. It was possible, as a result, to assess the consequences of a certain number of events and public policy options.

## **Identifying and Selecting Participants**

In the first — most open and participative — phase, four working groups were selected by the management team and the chairmen of the four groups. The people were selected according to the complementarities and diversity of their professional experiences. The idea was that a balance should be struck in each group between the main categories targeted (experts/stakeholders; research and higher education/business/government/society) and according to the selected criteria (sex, age, sector, professional profile and position, geographical area of origin...). The participants came from research institutes (and, to a certain extent, higher education), private companies (large firms and SMEs), government bodies (ministries and agencies), and non-profit organizations.

The persons selected were then asked to nominate someone they thought interested in/interesting to FutuRIS (“snowball sampling”). Beyond the four working groups, a group of virtual participants was estab-

lished, and interactions by collaborative virtual tools were organized with them (to react to papers, fill in questionnaires etc.).

The fact that the ANRT (Association nationale de la recherche technique) ran the programme made it possible to achieve a good balance between firms and public research organizations. But higher education, and especially the universities (part of a dual system in France with the *grandes écoles*), whose position in France is quite weak by comparison with the arrangement in most countries, were insufficiently represented at the beginning.

There was subsequently an attempt to correct this. The main weakness in terms of participation related to the “society” component: the programme intended to focus on the research-innovation-society system, but, for various reasons, the third element was not taken into account as much of as the other two.

FutuRIS was also an open process in terms of information and communication – and, as far as possible, participation (intranets for virtual participants, website, events, media etc.).

## The Scenario-Building

The scenarios proposed were not intended to represent the most likely or most preferable changes. Their objective was — and still is — to explore a relatively broad scope of possible changes by providing a consistent framework. To a great extent, these scenarios incorporated the research carried out by four FutuRIS expert panels.

The value of the scenarios lies in the interpretations and discussions to which they give rise, including any criticism.

The scenarios were developed in three stages.

1. A preliminary stage, during which the foundations were developed, with a view to answering the initial question: “What are the main areas in which changes will influence the future of the FRIS?” Fifty parameters were identified among the various working groups.

2. A stage during which the actual scenarios were built up, focusing on a second question: “What are the plausible combinations of changes in the various areas that we can use to define plausible outlooks, also relevant for the next 20 years? (The aim at this stage is also to select and calculate figures characterising these outlooks.)

3. An exploratory stage, during which a third question was examined: “What lessons can be learnt from these analyses?”

The range of scenarios was drawn up on these strong foundations. It was also necessary to pin down a plausible, global setting, resorting to few hypotheses.

First, we should note that between 1990 and 2002 French GDP increased by 1.7% *per annum* in volume. The scenarios therefore explore a range of figures from 1.2% to 2.5% on average over the period from 2000 to 2020.

The GERD, which stood at 2.2% of GDP in 2000, was less than 2% at the beginning of the 1980s and 2.4% in 1990.

The European objective is to increase it to 3.0% in the future. The scenarios were pitched within a range from 1.7% to 3.0%. Although there is a positive correlation between the volume of the GERD and the rate of GDP growth in the long run, this link is not always true over the medium-term.

These figures were hypotheses used for subsequent calculations. They were not produced by a model, but correspond to reasonable hypotheses, given the state of the six components.

## ***Results and Presentation of the Scenarios***

Below is a brief summary of each scenario examined.

### ***Scenario Ia: Defensive Decline***

In a context of US leadership, China and India are gradually emerging on to the world scene, while Europe is struggling to become organized. The state is changing through limited, uncoordinated ad hoc adjustments. With regard to science and technology, the social context is one of conflict and deadlock. Public research is losing its relevance due to funding cutbacks. Industrial R&D remains at modest levels. France is forced to abandon part of its current RDI (research, development and innovation) objectives.

### ***Scenario Ib: Opportunistic Passivity***

In the same international and European context as above, international economic growth is nevertheless stronger, leading to a slight increase in the volume of public research focusing on high-potential fields for the future. Private R&D increases slightly. The satisfactory level of funding associated with innovation policies does not make up for the fall in public R&D contracts for businesses.

### ***Scenario II: Opting for National and Regional Dynamics***

In a world characterized by conflictual relationships and relatively low growth levels, with China and India playing a significant but destabilising role, the European Research Area is unable to progress due to a lack of agreement between member states. However, the relatively positive pragmatism towards innovation expressed in public opinion, as well as state modernisation and decentralisation enable structural changes to be made in public research and RDI to develop in SMEs nationwide. However, as these trends are restricted to the national level, their sustainability and impact are limited.

### *Scenario III: Ambition for France and Europe*

In a world characterized to some extent by conflict, but enjoying comparatively favourable growth, the European Research, Higher Education and Innovation Area is set up, with major programmes, including defence/security R&D. Public confidence in innovation, together with open and transparent debate processes, as well as the modernisation of the state, enable structural changes to be made in public research, which in turn makes possible the growth of industrial RDI nationwide.

### *Scenario IV: Pragmatism in a Europe of Regions*

In a context of US leadership and relatively strong economic growth, China and India are emerging relatively smoothly, with the result that geopolitical balances are being called into question. The European Research, Higher Education and Innovation Area is set up, with major programmes, but excluding defence/security R&D. The regulation of innovation by the market in a society with few conflicts facilitates a dynamic growth of innovation. State reform and decentralisation are accompanied by structural changes in public research, which is organized around regional centres, and this in turn facilitates the development of R&D and innovation, although primarily in SMEs.

In time, negotiations over access to scarce resources on both sides of the Atlantic are a source of serious tensions; the impact of some major technological accidents may also contribute to these tensions.

With this scenario, there is a risk of Europe becoming too fragmented, both between and within regions. Such conflict could cancel out the expected benefits of this scenario.

### *Scenario V: France, a Player in a Powerful Europe*

In a multipolar, regulated world, based on the United States, China, India and Europe, with relatively strong levels of growth, an ambitious European Research, Higher Education and Innovation Area is set up, ranging from basic research to major programmes and defence/security R&D; public confidence in innovation, based on open and transparent debate processes, the reform and decentralisation of the state, are accompanied by structural changes in public research, which is organised around regional centres, and this in turn facilitates a boom in private RDI.

### *Quantitative Implications of Each Scenario*

The above overview of the FutuRIS scenarios becomes even more meaningful in light of the synoptic indicators characterizing them, as shown in Tables 1 and 2. Rather than studying these directly, readers should refer to them as and when necessary, as the lessons learnt are presented for the different scenarios.

**Table 1. Synoptic Table of R&D Indicators – relative values (by 2020)**

Scenario	2000	Ia	Ib	II	III	IV	V
GDP Growth	1.2	1.8	1.5	2.2	2.0	2.5	
GERD/GDP	2.2	1.7	1.7	2.2	2.8	2.4	3.0
GERD financing % public <sup>a</sup>	45.5	45.0	45.0	37.8	42.0	40.5	42.0
% private	54.5	55.0	55.0	62.2	58.0	59.5	58.0
GERD performance % public	38.9	41.7	41.7	32.4	35.0	35.2	34.8
% private	61.1	58.3	58.3	67.6	65.0	64.8	65.2
% private R&D on public contracts	16.0	11.5	11.4	16.5	20.8	18.6	21.8
% foreign subsidiaries in private R&D	19.2	20.0	20.0	22.0	26.0	26.0	30.0
% French subsidiaries abroad	21.8	35.0	35.0	25.0	20.0	22.0	22.0
% Europe <sup>b</sup> in public funding	10.4	8.0	8.0	8.0	25.0	25.0	25.0
% Regions in public funding	1.4	3.0	3.0	12.0	2.0	12.0	12.0
% knowledge production objective in public funding	61.1	72.0	71.9	52.4	55.9	66.5	57.6
% industrial innovation support objective in public funding	2.1	3.3	3.3	10.0	4.9	10.3	10.3
% defence/security in public funding	36.8	24.7	24.7	37.6	39.2	23.3	32.0
% budgetary fund in public research performance	84.6	84.1	84.1	63.4	57.0	47.9	51.7
% public contract objective in public research performance	4.9	6.6	6.7	16.1	17.3	22.1	21.7
% industrial contract objective in public research performance	5.7	5.6	5.6	12.4	13.1	14.8	14.3
% non-profit private in public research performance	2.4	2.4	2.4	4.7	5.7	4.3	5.8
% state budget in GERD	42.2	42.5	42.5	32.4	36.5	31.1	32.3
a: national, regional, European (EU budget) levels b: EU budget and European intergovernmental funding Note: Public research includes the research activities of universities and public research organisations. Source: FutuRIS.							



**Table 2. Synoptic Table of R&D indicators  
absolute values in billions of euros (by 2020)**

Scenario	2000	Ia	Ib	II	III	IV	V
GERD	31.7	30.21	34.00	41.10	60.59	49.93	68.84
GERD financing public <sup>a</sup>	14.4	13.89	15.64	15.52	25.45	20.22	28.91
private	17.3	16.31	18.36	25.58	35.14	29.71	39.93
GERD performance public	12.3	12.59	14.18	13.32	21.23	17.57	23.93
private	19.4	17.62	19.83	27.80	39.35	32.37	44.91
Private R&D on public contracts	3.10	2.02	2.26	4.58	8.20	6.01	9.79
Foreign subsidiaries R&D	3.25	3.26	3.67	5.47	8.82	7.53	11.57
French subsidiaries abroad	3.70	5.71	6.43	6.22	6.79	6.37	8.48
Europe <sup>b</sup>	1.50	1.09	1.22	1.25	6.36	5.06	7.23
Regions	0.20	0.41	0.46	1.87	0.51	2.43	3.47
Knowledge production objective	8.80	9.79	11.00	8.20	14.23	13.44	16.65
Industrial innovation support objective	0.30	0.45	0.50	1.56	1.24	2.09	2.99
Defence/security objective	5.30	3.36	3.78	5.88	9.97	4.71	9.26
Public research budgetary funding	10.40	10.59	11.92	8.45	12.10	8.42	12.37
Public contracts for public research	0.60	0.83	0.95	2.15	3.67	3.89	5.20
Industrial contracts for public research	0.70	0.71	0.79	1.65	2.78	2.60	3.44
Non-profit private funding for public research	0.30	0.30	0.34	0.62	1.21	0.75	1.38
State R&D budget	13.36	12.81	14.42	13.32	22.07	15.52	22.18

a: includes funding from non-profit private organisations

b EU budget and European intergovernmental funding

Source: FutuRIS.

## Lessons Learnt from the Scenarios

Designed during the 2003-2004 research crisis, but with a deliberate long-term focus, the scenarios highlighted two non-contradictory features:

- the future of the FRIS remains to a great extent open;
- nevertheless, the FRIS was seen to occupy a dangerous position: in an economic context which would not necessarily be favourable, establishing a French and European strategy involving major reforms seemed essential.

## Objectives and Resources

In euros, adjusted for inflation, based on a GERD of €31.65 billion in 2000, the scenarios envisage volumes between €30.21 and €68.84 billion in 2020.

The review of GERD financing for each scenario shows that:

- in all the scenarios, government and business enterprises fund 85% to 90% of GERD;
- it does not appear that the regions (1.4% of public GERD in 2000) will be able to exceed 12% in 2020, but they may, however, play a key role in regional stimulation and support;
- Europe (10.4% of public GERD in 2000) could reach a maximum of about 25% in 2020;
- voluntary organizations, even though their contribution has the advantage of being highly symbolic and quickly channelled into laboratories, will only represent a marginal proportion of the GERD;
- accounting for the wide range of French objectives, total public funding is not expected to fall much below 40% of the GERD (a higher percentage than in other countries, but these countries do not have the same structure).

The two most satisfactory scenarios (III and V) provide a percentage of GDP ranging from 1.18–1.26 for public funding and 1.62–1.74 for private funding. The frequently stated assumption of 1% public and 2% private — as laid down in the Lisbon Strategy — does not appear credible.

Furthermore, if economic growth remains low (Scenarios Ia, Ib, II), public objectives will need to be aligned with the available resources, for example, where military R&D or large-scale civil technological programmes are concerned. If we do not want this to occur, promoting R&D in the state budget is essential.

## **European R&D Policy**

In three of the scenarios reviewed, the EU R&D budget stagnates or even falls slightly. In the other three, the general EU budget sees a sharp increase between now and 2020, rising from 5% to 25% of public R&D, a significant increase in relation to the 2000 budget. In this context, the FP (Framework Programme), which will also grow, is supplemented by the ERC (European Research Council) with an annual budget of €2.5–3.5 billion (i.e. €0.3 billion to €0.4 billion for France) and MITPs (Market and Innovation Technological Programmes) with a volume of €10 billion to €15 billion per year (i.e. €1.3 billion to €1.8 billion for France).

In the scenarios that are explored, contrasting hypotheses are made about the European intergovernmental R&D budget, which is targeted at knowledge-creation (in particular CERN, the European Organization for Nuclear Research) and at defence/security spending (in particular, ESA, the European Space Agency).

However, this spending will need to be funded, and Europe will also face tough choices. As structural funds cannot be reduced, on account of the

needs of new member states, increases in R&D funding would require both a larger European Union budget and budget cuts directed at programmes such as the Common Agricultural Policy (CAP).

## Human Resources in the Research Field

With respect to public research, we need to put the issue of the shortage of young researchers in perspective, at least in quantitative terms (the issue may be considered in qualitative terms if the perceived interest in public research careers declines; it may also be raised in certain specific disciplines).

The level of recruitment depends on four parameters:

- public research spending, which varies scenario by scenario;
- departure rates, linked to the demographics of the current researcher population: in the period from 2000 to 2010, the annual departure rate (retirements plus other departures) will be 4.2% of the population, compared with less than 3% over the previous decade;

**Table 3. Recruitment and Staffing Levels in Public Research in each Scenario (2010)**

Scenario: annual growth rate (in %)	1995 2000	2000-2010					
		Ia	Ib	II	III	IV	V
(a) Public R&D spending	3.0	0.1	0.7	0.4	3.2	2.0	3.9
(b) Total departures <sup>1</sup>	2.9	4.2	4.2	4.2	4.2	4.2	4.2
(c) Expenditure per researcher <sup>2</sup>	1.0	1.2	1.8	1.5	2.2	2.0	2.5
(cc) Additional expenditure <sup>3</sup> per researcher	0.0	0.0	0.0	1.0	1.5	1.5	1.5
(d) Recruitment <sup>4</sup>	4.9	3.1	3.1	2.1	3.7	2.7	4.1
(e) 2000-2010 Workforce Change	2.0	-1.1	-1.1	-2.1	-0.5	-1.5	-0.1
<b>Absolute numbers – expressed as a ‘head count’</b>							
Public Research Workforce 2010	76,500 <sup>5</sup>	68,500	68,500	62,000	73,000	66,000	76,000
Annual number of recruitments	3,700	2,400	2,400	1,600	2,800	2,100	3,100
<b>Absolute numbers – expressed in full-time equivalents for research<sup>6</sup></b>							
Public Research workforce 2010	52,500	47,000	47,000	42,500	50,000	45,000	52,150
Annual number recruitments	2,200	1,650	1,650	1,100	1,900	14,500	2,100

1 Retirements and other departures of researchers.

2 Increase in spending per researcher (remuneration, equipment, technical and administrative support, etc.), assumed to be equal to the rate of economic growth.

3 Additional rate of growth in spending linked to an improvement in the researcher environment, for Scenarios II to V.

4 (a) + (b) - (c) - (cc) .

5 For 2000.

6 Assuming a constant ratio of researchers to teacher-researchers; teaching faculty counted as equivalent to 50% of full-time researcher.

Source: FutuRIS.

— change in the total payroll cost per researcher: our simulations are based on a constant cost, i.e. costs increasing proportionately with per capita GDP in France, thus keeping pace with the change in income for the rest of the population;

— overhead costs (equipment, technical support, infrastructure): we carried out a simulation in which this cost changed at the same rate as GDP and, for Scenarios II to V, a simulation in which this cost increased by an extra 1% or 1.5% per year.

To move from full-time equivalent research time calculations to head counts, we must put forward a hypothesis about the percentage of university faculty members in the total public research workforce. It was assumed that this percentage would remain constant.

The results are presented in table 3.

We can see that, with the hypotheses selected, public research staffing levels would stabilize from 2000 to 2010 in all the scenarios, with the amount of annual recruitment always lower than 1995-2000 levels.

A similar calculation model was used for private research, the main difference being that the age pyramid is not the same and, on average, researchers in industry remain in the research field for only a few years. The results are presented in Table 4.

Scenarios III and V correspond to a slight increase in staffing levels between 2000 and 2010 for researchers in industry. However, these calculations do not provide any indication of the backgrounds of these researchers (engineers or PhDs).

**Table 4. Research Recruitment and Staffing Levels for Businesses in each Scenario (2010)**

Scenario	1995 2000	2000-2010					
		Ia	Ib	II	III	IV	V
a. Industrial R&D spending*	2.0	-0.5	0.1	2.0	4.3	2.9	5.2
b. Total departures* <sup>1</sup>	8	10	10	10	10	10	10
c. Expenditure per researcher* <sup>2</sup>	1.5	1.2	1.8	1.5	2.2	2.0	2.5
d. Recruitments*	8.5	8.3	8.3	10.5	12.1	10.9	12.7
e. Annual number of recruitments	6,400	6,200	6,200	7,900	9,100	8,200	9,500
f. 2000-2010 workforce change*	0.5	-1.7	-1.7	0.5	2.1	0.9	2.7
Private research workforce	75,000 <sup>3</sup>	74,000	74,000	79,000	92,000	82,000	98,000

\* annual growth rate in %

1 Assuming that, in the period 1995-2000, a researcher remains in this type of position in a company for an average of 12.5 years, which means a departure rate of 8% a year, including staff retirements. Between 2000 and 2010, the same hypothesis was used, but the rate of retirement was 2% higher.

2 Increase in expenditure per researcher (remuneration, equipment, technical and administrative support, etc.), which is also assumed to be equal to the rate of economic growth.

3 For 2000.

Source: FutuRIS.

## Public Research Funding Methods

In 2000, nearly 86% of public research resources were allocated as a core funding budget to institutions (including faculty members' salaries). The remaining amount, i.e. 14%, corresponded to contractual resources:

- around 5 % from public incentive funding (ministry research budgets, “national science fund”, etc.),
- slightly more (5.7 %) from contracts with industry,
- the remainder (just under 5%) being split between funding from non-profit organisations (Pasteur, charity funds, etc.) and public procurement contracts (mainly defence and space).

The scenarios explore hypotheses regarding budgetary (core) funding for public research, ranging from 84% (status quo) to 47.9% in Scenario IV, with situations intermediate between these two.

In our investigations, the percentage of incentive-type funding has taken over most significantly from budgetary funding. This is in line with the hypothesis of the emergence of research funding agencies.

The other item on the increase is industrial contracts, the relative percentage of which is multiplied by three in the scenarios most affected by this development (Scenarios IV and V).

Public procurement contracts and non-profit funding, despite increasing twofold or more, remain at a more modest – yet still significant – level (8% to 12% in Scenarios II, III, IV and V).

It should be noted that our scenarios maintain the predominance of budgetary (core) funding of research, which means that we have in fact analysed various mixed situations in which tenured researchers and public research organisations continue to play a key role. However, this is set against a backdrop in which contractual incentive funding is no longer marginal and industrial relations develop.

## Methods for a European Strategy

The European level is an increasingly important dimension in research and innovation activities and policy. However, given the current state of affairs, it is necessary to differentiate between four funding methods:

- funding from the European R&D budget (Framework Programme)
- state funding targeting knowledge creation and managed within the framework of intergovernmental European institutions (e.g. CERN or EMBO, the European Molecular Biology Organization)
- state funding focused on defence/security and managed within the framework of intergovernmental European institutions (e.g. ESA, the European Space Agency)

— state funding with a pre-competitive target and managed as a set of integrated programmes (e.g. EUREKA).

Naturally, these distinctions may evolve over the next two decades.

The calculations provided in the technical document make it possible to estimate the total amount of funding per year managed in a European context for French R&D in the various scenarios.

### **Range of Funding Structures for R&D Implementation in Businesses**

In 2000, public resources for R&D in businesses amounted to about 16% of total R&D activities, with three quarters of this linked to defence-/security-related public procurement contracts (space, aeronautics, nuclear technologies, weapons systems). We carried out simulations, varying the rate of business R&D activities financed by public resources from 13% to 26%. This last figure shows public resources doubling in 20 years (in absolute values).

In our explorations through the scenarios, national and European incentive funds for industrial R&D and innovation, as well as funds obtained from the financial markets, are, in half of them, multiplied by a factor of three. However, due to the low volumes initially involved, these major relative changes do not have a significant impact on the funding structure.

The highest-volume item, public procurement contracts, is at most barely above 2000 levels on a relative basis. This assumption certainly bears critical review.

However, the outsourcing of R&D by businesses to public research bodies increases sharply in three scenarios, rising from 3.6% of total resources of public R&D in 2000 to over 7% in 2020.

### **The Challenges of Territorial Attractiveness for Anchoring the R&D Activities of Multinational firms.**

Based on the hypotheses used for the scenarios, it is possible to calculate plausible rough estimates for the location of foreign R&D activities in France and the location of French R&D activities abroad.

Scenarios Ia and Ib result in high deficits.

Scenarios III to V result in positive balances.

### **The Public Drivers of Innovation**

In this case, the term “public drivers” refers to the MITPs (Market and Innovation Technological Programmes, designed to develop innovations in the area of collective goods and infrastructures, from the upstream stages through to the marketplace) and to the major defence and security pro-

grammes in fields such as space, aeronautics, nuclear technologies, and weapons systems, also known as TDPs or Technological Development Programmes.

These public drivers accounted for almost half of public R&D funding in 1990 and just over one-third in 2000. A key issue with regard to prospects for the FRIS concerns the future volume of these programmes.

The scenarios examine cases in which the funding for these drivers drops to levels below 25% of public funding in 2020, together with cases in which the trends are reversed to 1990 levels.

Another key point for the future concerns the relative weight of defence-TDPs in relation to MITPs, civil programmes concerning collective goods and infrastructures.

## *Use and Dissemination of the Results*

The first dissemination tools were used to create a live debate around the outputs of the operation:

- the organization of public events: press conferences, seminars, “Journées FutuRIS” with 350 participants in April 2004, conferences and round tables, presentations during the annual ANRT meeting (400 persons attending) and during the AGM of ANRT;
- Presentation of the outputs to a number of regional, national and European organizations;
- Participation of team members in a number of R&I-oriented events.

A second important line of action was involvement in the public debates around the 2004 legislative reform of the French public research system. Several meetings were held in ministries, académies (regional educational administrations), public research bodies, and there was also a hearing in the French Senate.

Finally, several documents were published:

- 20 reports (paper and web-based publications);
- Six “newsletters”, with a print run of 1000 for the first and 4500 for the last;
- 10 press articles on the operation in 2003, followed by 65 between January 2004 and May 2005;
- Interviews with around 20 team members;
- 2 websites (27,875 hits between March 2004 and May 2005, between 800 and 1900 downloads of main documents).

## ***Gains from — and Limitations of — the Exercise***

Even though they account for only a part of the analyses of the FutuRIS project, there are three key benefits to be derived from the scenarios as a result of their quantitative characterization:

- they illustrate the main trends, which are unlikely to undergo major changes even over the long-term;
- they show that, despite these trends, there can be considerable room for manoeuvre and that a number of decisive choices will be required in the short-term;
- they highlight some of the key issues that will be developed further toward the end of the document.

## ***Conclusion***

This paper has focused deliberately on the launch of FutuRIS. That is to say, it has focused:

- on the initial assumptions and findings that justified the recourse to scenario-based foresight analyses;
- on the construction of the scenarios themselves and on the most noteworthy findings they produced.

However, based on this sound analytical framework, FutuRIS developed many other activities, hosting nearly a dozen expert groups on more accurate, in-depth issues between 2004 and 2005, including the employment potential of young PhDs, sectoral dynamics of innovation, challenges faced by human resources management in public research etc.

At the end of 2005, FutuRIS also mandated an international review panel to assess the relevance of the work done so far and make suggestions about the best way for FutuRIS's institutional sponsors to support the important changes the FRIS is currently undergoing.

On the basis of their recommendations, a set of public and private actors – roughly the same as FutuRIS's sponsors from 2002 to 2005 – decided to launch FutuRIS as a permanent platform, with a trial phase from 2006 to 2008.

Now that a Law for research has come into force, policy and strategic advice needs have changed. Though a 'foresight' attitude is still of high added-value, there is no longer quite so much point to constructing new foresight scenarios on the FRIS every three years.

On the contrary, public and private actors have expressed a demand for analytical tools, together with open discussions which could help them shape their own research and innovation strategies. This is the mission of the new FutuRIS platform, which has committed itself to issuing an annual work of reference analysing the state of the FRIS in its international environment.



## **Appendix:** ***FutuRIS Steering Committee (2003-2006)***

### **Chairman:**

Jean-François Dehecq (CEO, SANOFI-Synthélabo)

### **Members:**

André-Jacques Auberton-Hervé (CEO, SOITEC), Étienne-Émile Baulieu (President, Science Academy), Christian Brechot (Director General, INSERM), Thierry Breton (CEO, FRANCE TELECOM), Alain Bugat (Director General, CEA), Pierre Castillon (Founder, Applied Science & Engineering Academy), Martine Clement (CEO, SGI), Laurence Danon (CEO, FRANCE PRINTEMPS), Jean-Jacques Duby (Director General, SUPELEC), Alain Etchegoyen (State Planning Commissioner), Jean-Pierre Falque-Pierrotin (Director General, CT & Post, Department of Industry), Jean-Jacques Gagnepain (Director, Technology, Research Department – Louis Gallois (President, SNCF), Marc Giget (Professor, CNAM), Jean-Paul Gillyboeuf (Inspector General, Defence Department), Marion Guillou (Director General, INRA), Pierre Haren (CEO, ILOG), Philippe Jurgensen (CEO, ANVAR), Axel Kahn (Director, Institut COCHIN), Bernard Larroudurou (Director General, CNRS), Michel Laurent (Executive Vice President, Universities Association), Jacques Lesourne (President, Futuribles International), Gérard Megie (President, CNRS), Alain Merieux (CEO, BIOMERIEUX), Philippe Pouletty (CEO, FRANCE BIOTECH), Denis Ranque (CEO, THALES), Jean-Pierre Rodier (CEO, PECHINEY), Jean-François Trogrlic (National Secretary, CFDT).

## ***FutuRIS Steering Committee (2006-2009)***

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### **Members:**

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# Key Technologies 2010

PHILIPPE BOURGEOIS <sup>1</sup>

## Overview of the Exercise

The French Ministry of Industry periodically launches a technological foresight study that aims to identify what the most important technologies for French industry will be in five or ten years' time. After the first two studies in 1995 and 2000, *Key Technologies 2010* is the third technological foresight exercise of this kind.

It brought together more than a hundred experts from the worlds of business and public research, who were divided into eight study groups: basic services; daily needs; travel; communications; semi-finished products; production plant, processes and methods; support functions, and thinking tools. A dedicated website both facilitated contact with the experts outside the group sessions and enabled interested persons to make contributions.

The study attempted to find an answer to two key questions:

- What are the technologies that will give France a competitive edge and enhance its attractiveness to investors in the world in the period to 2010-2015?
- What technological orientations should the public actors adopt to respond to these imperatives?

Identification of the key technologies was made in two phases:

- First, an analysis of the major societal challenges of the next 10 to 15 years enabled the most important relevant technologies to be identified;
- subsequently, an examination of France's advantages in respect of these technologies enabled the key technologies to be selected.

The key technologies identified represent applications that can be brought to market by 2010-15. Nevertheless, the frame of analysis often went beyond this time-horizon to observe more structural trends that may emerge some considerable time after 2020.

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1. Member of the Steering Committee of *Key Technologies 2010*.

The geographical field of the study had three dimensions:

- an international and, in particular, European dimension, making it possible to take account of criteria of positioning, mobility and localization of activities, together with potential cooperation with other European countries;
- a national dimension, since the framework for this study is predominantly France, which provides the frame of reference for the key technologies identified;
- and lastly, a regional dimension, the regions being both instrumental in economic development and prospective future users of the study. The territorial dimension also shows up in the competitiveness clusters, which are identified in each file.

The outcome of the study *Key Technologies 2010* took the form of a report encompassing files on the 83 key technologies for 2010 and eight sectoral monographs describing the technological dynamics of these sectors.

## Procedure

### Motivations

Since 1995, the ministry with responsibility for industry has launched a technological foresight exercise every five years. The study entitled *Key Technologies 2010* is the product of the third exercise.

There were at least four reasons for the Industry Minister's decision to proceed in this way:

— Globalization is a reality. It has created profound upheavals within economies and mentalities. The economic environment of industries has undergone profound transformation. Markets are becoming global, as is competition between firms. The shortening of the time span involved in bringing an innovation to market is one of the noteworthy consequences of these upheavals. Speed of adaptation to these changes affords undeniable competitive advantage. Anticipation becomes a key element in companies' strategies. It is essential that they think about the future of the technologies they need to master to remain competitive.

— Over the last five years, technology has continued to evolve. New technologies have emerged, while others have disappeared. These developments offer many opportunities for those able to prepare for them, but also represent a threat for those unable to foresee them. The aim of studies in technological foresight is to provide economic and industrial actors, among others, with insights that enable them to anticipate and react to developments in ways essential for building their future success.

— Companies are faced with currently ongoing economic change. Among these, the largest have the human and financial resources to prepare them-

selves for such change, but the same does not always apply in the case of SMEs (small and medium-sized enterprises). Caught up in the day-to-day business of increasingly demanding management tasks, their directors have little available time and resources to devote to forward thinking. They need access to an analysis that can enable them to situate themselves in this continual process of evolution.

— Lastly, local and regional authorities feel an increasing concern for the future of the companies that make up the economic fabric of their areas. They need a frame of reference that can enable them to act — and be seen to be acting — in respect of technological development.

The aim of *Key Technologies 2010*, which starts out from this diagnosis, can be summed up in the question: what are the technologies that will guarantee France and its various territories competitive edge and attractiveness to investors over the coming five to ten years?

The foresight approach implemented in the *Key Technologies 2010* study was concerned to incorporate socio-economic issues into an overall technological aim. It sought to identify the technologies with a positive impact on the industrial and service activities carried out in France on the basis of possible responses to the societal challenges facing contemporary economies, and the dynamics currently existing in the major technological fields.

## *The Organization of the Exercise*

After an invitation to tender was published by the Directorate-General for Enterprise and Industry (DGE), the implementation of the study was entrusted to a consortium of five companies, led by the innovation consultancy Erdyn. The consortium was made up of Futuribles, Cybion, Virtuoze and Biotics. The project team was led by Patrick Haouat, CEO of Erdyn.

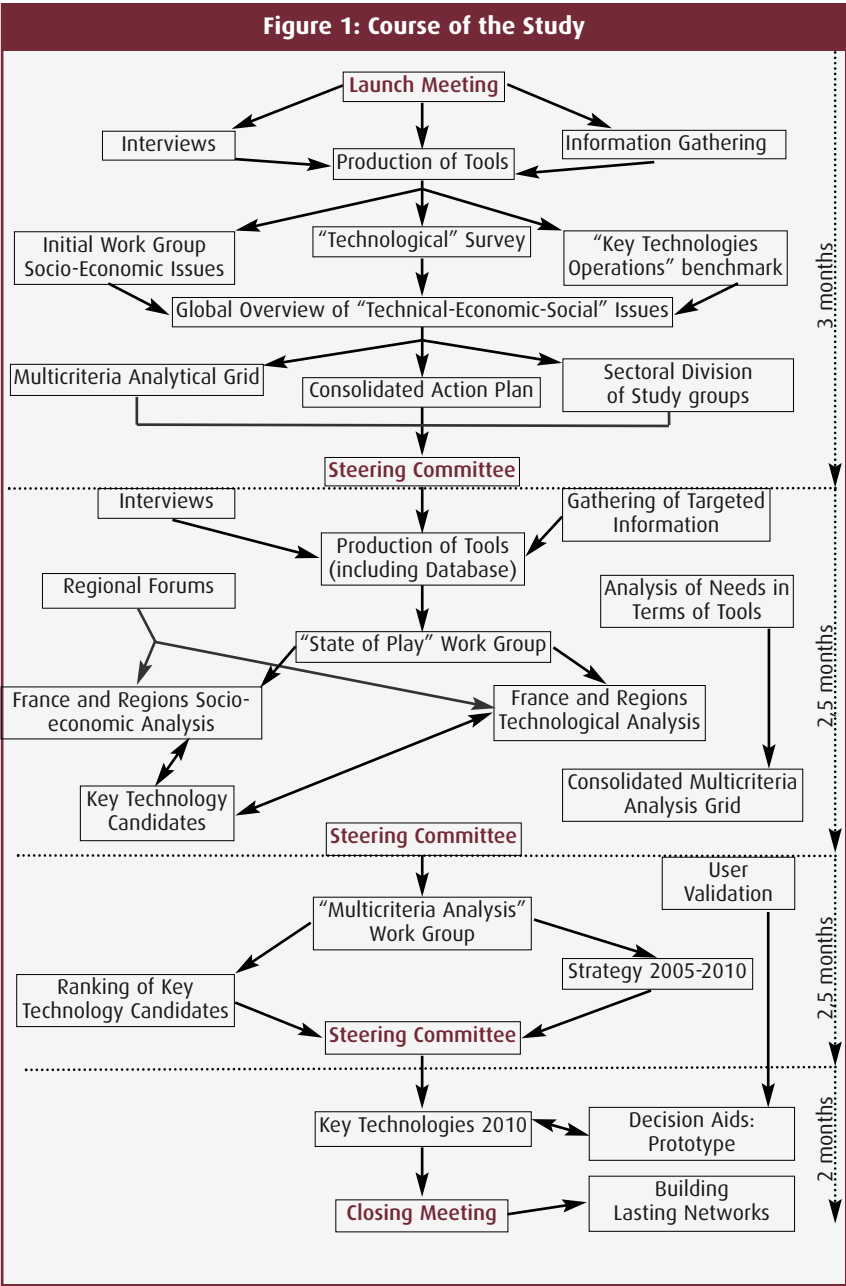
The study was monitored by a steering committee chaired by André Lebeau, former chairman of the French National Space Studies Centre (CNES) and former CEO of the French meteorological service (Météo France). There were more than thirty people on this committee, drawn from various civil service departments and business and public research bodies. Philippe Bourgeois was project head of the study within the DGE.

## *A Study in Three Phases*

The study was carried out as shown in Figure 1. It was structured around the three following phases:

### **Phase 1: Preparation and Main Orientations**

This first phase enabled the frame of the study to be carefully delineated and the tools and methods subsequently used to be designed and developed. During this phase, the following actions were carried out:



— a series of interviews with the sectoral heads of the DGE enabled us to build up an initial overview of French industry, all sectors of activity included, and to identify the priority issues and themes;

- the information gathered in these interviews was complemented by an exercise in documentary analysis. The documents assembled were indexed and archived on the study's website;
- as a complement to this technico-economic approach, the main socio-economic issues were analysed (at the global, European and French levels);
- based on direct personal approaches and messages put out in the press, a wide call for candidates was made, in order to “recruit” the experts who were to contribute to the study. These experts were divided into eight study groups;
- a dedicated website was created ([www.tc-2010.fr](http://www.tc-2010.fr)). This site, which had private and public areas, enabled the experts — and also interested others — to suggest technologies that could be regarded as “key”. It also gave them access to a huge quantity of documentation.

## Phase 2: The Work of the Expert Groups

The leadership of the exercise by the expert groups was at the heart of the study. A division of tasks along the lines of “needs and applications” rather than technologies, was chosen for the eight study groups, which each met four times:

1. **Basic Services:** energy production and distribution, supply and treatment of water, re-cycling, building and buildings services, domestic appliances, furniture;
2. **Daily Needs:** agriculture, the agrifood business, pharmaceuticals, toiletries and detergents, textiles and clothing;
3. **Travel:** transport facilities, transport services, automotive services, hotels and catering, and travel agencies;
4. **Communication:** IT and office facilities, radio facilities, television and communications, media and information and communication services, advertising and marketing, publishing;
5. **Semi-finished Products:** non-energy mining, basic materials (metal, paper, wood and minerals), plastics and (non-pharmaceutical) chemicals, metals and metal products;
6. **Production Plant, Processes and Methods:** instrumentation, industrial machines and installations, electrical machines and installations, methods for improving productivity;
7. **Support Functions:** banking and insurance, R & D and consultancy, engineering and architectural activities, security services, recruitment and temporary work services, legal services, accounting and management services, wholesale and retail commerce, miscellaneous services;

**8. Thinking Tools:** a cross-disciplinary group made up of regional actors in economic development and figures from the chambers of industry and commerce.

The first seven groups worked on the basis of “sectoral monographs” composed during phase 1. These documents were progressively enhanced with the contributions of the experts.

### **Phase 3: The Writing, Validation and Finalizing of the Study**

After the expert group meetings, the lists of key technologies proposed by each of the seven groups were consolidated by the project team. The 83 key technologies ultimately selected were each assigned a file, validated by the sector specialists from the DGE and the Directorate-General for Energy and Raw Materials (DGEMP) and by the steering committee members.

Summarized versions of the sectoral monographs were drafted, for incorporation into the report.

In parallel with this work, various actors in technological development were consulted:

- a plenary meeting, bringing together all the experts from the different study groups, took place at the Ministry of Economy, Finances and Industry;
- four meetings with the local actors were organized in the regions (at Lyon in the Rhône-Alpes region, Douai in Nord-Pas-de-Calais, Orleans in the Centre region and Strasbourg in Alsace).

## **The Selection Method for Key Technologies**

A technology (or set of technologies) was deemed to have “key” status if it was capable of exerting structural effects on the competitiveness or attractiveness of activities in France. The technologies ultimately selected are both existing technologies with a high potential for development and impact, and emergent technologies that can be introduced into — and deployed in — industry over the next ten years.

The mode of selection of key technologies was structured around three lines of analysis:

- the major issues of the next twenty years and the possible technological responses;
- the technological dynamic at work in the major technological fields;
- France’s advantages in the technologies identified, both for responding to the challenges of tomorrow and to those challenges at the heart of the sectoral dynamics.



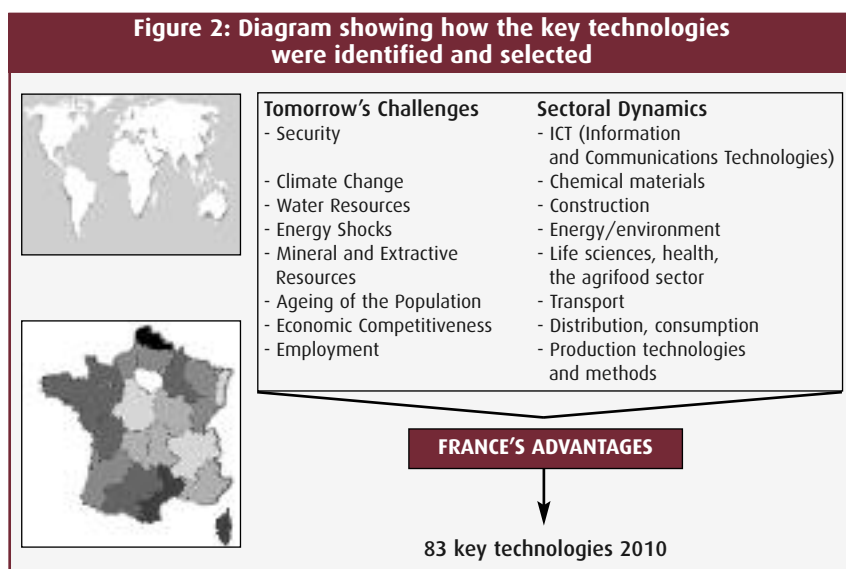


Figure 2 gives a schematic view of the method used in selecting the key technologies 2010.

## Results

The results of the Key Technologies 2010 project take two forms: a list of 83 key technologies (See list at Annex 1) and eight sector monographs.

Each technology is described in a file with the following fields:

- general title of the technology;
- description of the technology, which states the main principles on which it is based, gives examples of the “technological building blocks” that make it up, identifies possible obstacles to development, and specifies the level of maturity of the technology;
- an area for comment.

Each technology is described according to a model file pattern structured in the following way: description of the technology; issues and impacts (how the technology makes a response to certain issues possible and the foreseeable impact of that technology); market (what will the technology be used for); actors (characterizing the ecosystem in which the technology will potentially develop). See Annex 2 for an example of a key technology file.

For their part, the sector monographs present the economic significance of the sector, followed by the dynamics of technological development within it. In order to maintain coherence with the two preceding foresight exercises, the report does not include the titles of the study groups as presented in page 5.

Since these monographs are particularly “dense”, we shall confine ourselves in this section to presenting the results of *Key Technologies 2010* through the prism of “tomorrow’s challenges”. The key technologies identified by the experts are situated within a context bristling with challenges. These technologies are responses to the issues that will structure tomorrow’s world.

The challenges selected in the study are eight in number: problems of security relating to the geopolitical context; climate change; water resources; energy challenges (energy production and the control of consumption); availability of raw materials; an ageing population; employment; and economic competitiveness.

For greater clarity of exposition, we shall group these into three broad families: geostrategic, ecological and socio-economic issues.

## The Geostrategic Issues

### The Security Challenge: An Increasingly Unstable World

With the disappearance of the Soviet Empire, the world seemed for a time potentially safer. But the rise of terrorism has upset the world order. Very rudimentary, if not indeed archaic, devices may now constitute weapons of mass destruction and endanger modern Western societies. The mastery of technologies enabling the preventive countering of such devices or the attenuation of their consequences is a major issue for those societies that are potential targets. This development has two consequences:

— the fields of defence and internal security are brought into closer proximity;

— control capacities become the central element in power: the key thing is to guarantee the capacity to control flows (flows of information, and financial and human flows).

#### KEY TECHNOLOGIES CONCERNED WITH THE SECURITY CHALLENGE

8. Infrastructures and Technologies for “Diffuse” Communication Networks
10. Protection of Electronic Transactions and Contents
12. Management and Broadcasting of Digital Content
58. Intelligent Road Infrastructures
59. Active Vehicle Safety
61. Passive Vehicle Safety
68. Vehicle-Infrastructure Data Links
69. Automated Aerial Vehicle Systems
72. Authentication Technologies
73. Traceability
74. Process Control by Image Analysis
75. Intelligent Sensors and Signal Processing
82. Complex Systems Engineering

In such an environment, the safety of infrastructures and public places will become a significant element in the specifications for new technology.

The issues here are not merely economic, since, if new technologies enabling security (of data, places and persons) to be preserved are to be socially acceptable, the challenge will also be that they simultaneously preserve a private sphere, so as to avoid an Orwellian “Big Brother” syndrome.

## The Pursuit of Energy Independence

The oil shocks of 1973 and 1979 revealed the vulnerability of modern economies with regard to energy supply. A quarter of a century later, our economic systems and lifestyles continue to be based on a massive consumption of energy in a context in which the emerging countries are coming to the fore as enduring new centres of consumption. Despite the diversity of the primary sources of energy, fossil fuels (oil, gas and coal) still represent 80% of global energy demand.

### Increased Energy Demand

An increase in global energy demand seems inevitable over the next twenty years, given population growth, the industrialization of the developing countries, and the inertia of production systems. The exact level of that increase is, however, in question. If the growth trends currently observed persist, particularly those of China, it is the consumption of the developing countries that may increase most rapidly.

We should, however, keep in mind that these forecasts are, above all, projections of present trends and do not represent differentiated consumption scenarios based on alternative hypotheses (lesser or greater economic growth, energy saving measures, technological progress etc.).

### Preponderance of Fossil Fuels and Energy Dependence

Global energy consumption today is of the order of 10 Gtoe (gigatonne oil equivalent), 8 Gtoe of which is fossil fuel (oil, gas and coal). In the developed countries, gas and nuclear have, over the last thirty years, gradually

#### KEY TECHNOLOGIES CONCERNED WITH THE ENERGY CHALLENGE

1. Micro-energy management
26. Building-Envelope Systems
30. Renewable Energy Incorporation Technologies in Building
31. Photovoltaic Systems with Integrated Storage
32. Wind-power Systems with Integrated Storage
33. Artificial Fuels produced from Biomass
34. Third-Generation Nuclear Reactors
35. Low-temperature Heat Exploitation and Distribution by Heat Pump
36. High-Performance Lighting Systems and Components
38. Command and Control of Networks and Power
42. Accelerated Composting of Fermentable Waste and its Energy Conversion
62. Piston Engines
63. Turbine Engines
71. Vehicle Flow Management

come to replace coal and oil in the generation of electricity. Oil is used mainly in the transport field. Economic dependence on fossil fuels seems likely to continue and probably to increase.

### **Technical Issues around Energy**

Prospects with regard to energy involve some particularly important issues:

- the energy security and independence of France and Europe;
- the progressive exhaustion of hydrocarbons (and, primarily, conventional oil reserves) on which the transport sector very largely depends;
- global warming, which could have dramatic consequences over the next century.

The alternatives to fossil energies are many and varied. Modes of energy generation with a reduced CO<sub>2</sub> content are nuclear, biomass (including bio-fuels), geothermal, solar, wind and water power. However, the potential of most renewable energies is limited in the medium term by the quantity of investment required, the variation of exploitable potential between various regions, and the inadequacies of electricity storage technologies.

The carbon-dioxide-free production of hydrogen would make available a new fuel for energy needs that is both effective and produces no emissions other than water. However, apart from the problem of storage, the technologies for producing “clean” hydrogen are at a very early stage of research (nuclear thermolysis and photolysis) or produce insufficient yields (electrolysis). Its widespread use by 2020 is therefore improbable.

Apart from the improvement of yields or of the efficiency of energy-consuming appliances, the control of energy consumption also involves improved management of energy flows at the level of an individual device (e.g. an automobile), an electrical network, a building or an industrial zone (industrial ecology) by the use of intelligent energy-consumption-regulating appliances.

### **Access to Mineral and Extractive Resources**

Unlike energy resources, the supply of mineral raw materials receives little attention. However, according to Jacques Blamont,<sup>2</sup> if consumption continues at present rates, known reserves will largely be exhausted by the end of the twenty-first century. By 2020, only the extraction of zinc and lead should reach these physical — and also commercial — limits (a fall in consumption due, in part, to stricter environmental and health legislation, and to more recycling).

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2. BLAMONT Jacques. *Introduction au siècle des menaces* (Paris: Odile Jacob, 2004).

### KEY TECHNOLOGIES CONCERNED WITH THE MINERAL AND EXTRACTIVE RESOURCES CHALLENGE

18. Nanostructured Materials and Nanocomposites
19. Materials for Electronics and Measurement
23. Special Materials Recycling
27. Composite Building Materials based on Recycled or Biomass Materials
41. Automated Waste Sorting
42. Accelerated Composting of Fermentable Waste (made of biodegradable organic matter) and its Energy Conversion
76. Multi-materials Assembly
77. Micro- and Nano-components
79. New Surface Treatment Processes
80. Shaping Processes for Innovative Materials

### Unequal Distribution: the Rise of Economic/Strategic Risks

Mineral resources are distributed unequally across the globe. This geological phenomenon is accentuated by the logics of profitability (the fixed costs of extraction are very high and require long-term amortization) and industrial concentration specific to the sector.

The supply of some minerals is totally or almost totally dependent on one or two dominant producers. The case of China is, in this connection, doubly emblematic of the rise of economic/strategic risks on a world scale:

— thanks to a commercial strategy of “boom and bust” market manipulation, it has a quasi-monopoly in the antimony, tungsten and rare earths markets;

— the increase in Chinese demand led to an increase in prices, because the lack of productive investment and the self-limiting of production capacity in the 1990s left the sector unable to cope with rapid variations in demand.

### Prices: Sudden Sharp Variations

Given the limited market reactivity of producers, the concentration of certain resources and the non-substitutable character of some metals, the metals markets are subject to sudden, sharp price variations. These can be explained by a scarcity of supply, for example as a result of conflict in the production zones (e.g. the quadrupling of the price of cobalt in 1978 following conflict in Zaire) or an “act of state” (the suspension of Soviet titanium exports in 1978-9 or Russian exports of palladium in 2001).

We must take cognizance, also, of an issue peculiar to the “high-tech” metals, i.e. those metals which present a specific risk of crisis as a consequence of “explosive” demand arising out of a newly discovered application (as in the case of rhodium and palladium used in catalytic converters), or a fast-growing market, such as ICT, which has seen a high level of demand for metals like tantalum (for condensers), gallium and germanium (high frequency

electronic components) or indium (flat LCD screens), the price of this latter having risen from 70 to 700 dollars per kilogram in one year.

**Demand from China and the Other Emerging Economies**

The 1990s were characterized by China coming to the fore as a major producer and exporter of mineral raw materials (zinc, copper, coke and tungsten) on the global market. This situation turned around sharply in the early 2000s with China becoming a net importer and one of the leading global consumers of non-ferrous metals (copper, aluminium, zinc, nickel etc.) and steel.

**Technological Issues around Raw Materials**

Prospects for change in the levels of demand for — and the prices of — metals depend in part on new outlets. However, where certain metals, such as zinc or platinum, are concerned, there are serious risks associated with the resources. For example, unless a viable substitute emerges, the platinum market could see an appreciable increase in demand. Between now and 2010, this should be due mainly to an increased demand for classical (catalysis and jewellery) or new uses (fuel cells). The search for substitutes seems all the more pressing for the fact that most deposits are situated in politically unstable areas.

Recycling is becoming a priority here. Though the recovery (recycling) of expensive metals (used in electronics, for example) poses no great problems, it is essential that economically efficient recycling industries are established for cheaper metals.

*The Ecological Issues*

**The Challenge of Climate Change**

Since the early 1970s we have seen a marked rise in the concentration of certain greenhouse gases in the atmosphere, together with the beginnings of global warming. The reality of this phenomenon and its origin are now to all practical purposes beyond debate, even if some of the phenomena controlling the climate still lie beyond the comprehension of scientists. The temperature rise could foster the development of infectious diseases, their expansion into

**KEY TECHNOLOGIES  
CONCERNED WITH THE  
CLIMATE CHANGE CHALLENGE**

- 15. Modelling, Simulation and Calculation
- 21. Industrial Biotechnologies
- 22. Microtechnologies for Process Intensification
- 26. Building Envelope Systems
- 37. CO<sub>2</sub> Capture and Geological Storage with New Design for Coal-fired Power Stations
- 60. Architecture and Materials for Lighter Vehicle Construction
- 62. Piston Engines
- 63. Turbine Engines
- 71. Vehicle Flow Management

the temperate zones, and global epidemics. Moreover, by 2020, summer heat waves or extreme climate events such as cyclones will represent a more significant risk.

### **The Reduction of Greenhouse Gas Emissions: an Imperative Necessity**

Greenhouse gas emissions arise out of the whole range of human activities. However, the energy sector in the broad sense (transport, electricity generation, industrial and domestic combustion) contributes to around 80% of greenhouse gases. The largest part of these emissions is due to the use of fossil fuels.

### **Lines of Response to Climate Change**

There are three lines of response to the issues posed by climate change:

1. the first is to prevent it by using energy sources containing less carbon and by controlling energy needs;
2. the second is to capture and store greenhouse gas emissions (CO<sub>2</sub> storage);
3. the third is to prevent the consequences produced by climate change; to forestall:

- the risks associated with flooding (landslides; pollution of watercourses, porous road surfaces enabling better run-off of water);

- the risks associated with heat waves (water-saving technologies; reversible solar air conditioning systems);

- the risks associated with violent storms (more weather-resistant building methods);

- the risks associated with the development of infectious diseases such as malaria or dengue fever by appropriate medical treatment.

### **The Issue of Fresh Water Resources**

Between now and 2020, climate change will accentuate the problem of access to drinkable water. It will amplify this phenomenon in regions like Central Asia, the Middle East, the Mediterranean region and

#### **KEY TECHNOLOGIES CONCERNED WITH THE WATER RESOURCE CHALLENGE**

- 29. Water Management in Building
- 39. Measurement of Priority or Emergent Water Pollutants
- 40. Membrane Filtration Technologies (Water Treatment)
- 73. Traceability
- 74. Process Control by Image Analysis
- 75. Intelligent Sensors and Signal Processing
- 79. New Surface Treatment Processes
- 80. Shaping Processes for Innovative Materials

Australia. In coastal regions, we can envisage an increased salination of the estuaries and ground water.

### **Increasing and Unequally Distributed Consumption**

The available studies show that extraction is growing twice as fast as the population:

- in the last 50 years world-wide water extraction has increased fourfold;
- though the inhabitants of the developed countries consume more water than those of the developing ones, their consumption has diminished overall by 11% since 1980;
- globally, agriculture is the main consumer (70% of water extracted) and should remain so on account of the growth of surface-areas under irrigation;
- in the next 20 years, it is the industrial and energy demands of the emerging countries that should most increase the need for water.

### **Deterioration in the Quality of Water**

Agriculture is one of the most polluting sectors. Surface runoff results in diffuse pollution through fertilizers and pesticides. This problem can be expected to worsen between now and 2020, given the lifespan of these chemical compounds.

Industry emits the most dangerous pollutants (heavy metals, persistent organic pollutants) and the most multiform (liquid, atmospheric and solid). Its worldwide impact could be increased fourfold by 2025. Lastly, those households not attached to a wastewater treatment system contribute to chemical and organic pollution.

### **Risks of Shortage**

The over-exploitation of ground water, which makes up 90% of directly useable global freshwater resources, means that it is restored only very slowly (0.1 to 0.3% per year), which is a problem. On the basis of United Nations mean demographic projections, 2.8 billion individuals will be suffering from water stress or shortage in 2025.

### **Technological Issues Associated with Water Resources**

The technological issues associated with water resources mean that more water can be saved for human needs (mainly agriculture), the quality of water can be preserved by reducing pollution or the available water resources can be increased.



In agriculture, there is a possibility of developing hybrid or GM (genetically modified) plants that either have better drought resistance or tolerate irrigation with brackish water. More efficient irrigation techniques exist already (drip-feed systems), but the costs of these remain high, which is also an issue. Research should also be devoted to limiting the use of fertilizers or pesticides by precise and economical manuring or spraying technologies and by developing “natural” fertilizers or pesticides.

The efforts already begun in industry should continue. There is particular uncertainty about the extension of resource-efficient techniques to the industrializing nations.

In terms of infrastructure, significant investment will be necessary to limit leaks in distribution and irrigation networks, which is a major issue in terms of materials and network design.

Where water quality is concerned, it is necessary to improve water treatment and purification techniques.

## *The Socio-economic Issues*

### **The Ageing of the Population**

United Nations demographic projections show that the world population could be around 7.5 billion by 2020, most of the growth occurring in the so-called Southern countries.

All countries in the world are going through a phenomenon of demographic transition, characterized by a shift from high to low birth and death rates. Though this process has been going on in Europe at a relatively slow pace over the last two centuries, it is now moving at a much swifter rate in developing countries such as China or the countries of the Maghreb. One of the chief consequences of this demographic transition is the ageing of the population which, though particularly marked today in the industrialized countries — particularly in Europe — is now also affecting, and will increasingly affect, the rapidly developing countries such as China and the countries of the southern shore of the Mediterranean.

#### **Technological Issues Associated with Ageing**

In any event, the ageing of the population will raise very important questions and affect

#### **KEY TECHNOLOGIES CONCERNED WITH THE CHALLENGE OF AN AGEING POPULATION**

- 45. Cell Therapy
- 46. Proteomics
- 47. Gene Therapy
- 48. Large-Scale Functional Genomics
- 50. Vectorization
- 52. Recombinant Vaccines
- 53. Foods for Health and Well-being

individuals' expectations in the coming years in Europe. From the standpoint of innovation and technology, growing old in good health and retaining one's independence and capacities is certainly a major expectation. The increase in the number of older people will not be without its impact on:

— health issues, both in the field of health costs and in terms of specific needs connected with age-related conditions, such as neurodegenerative illnesses;

— communication needs, with ergonomically simplified devices adapted to sight- or hearing-related disabilities;

— needs for remote diagnosis or alerting (self-diagnosis systems, automatic alerts in case of accident etc.), given the growing number of older people living alone;

— mobility needs, in order to enable the oldest individuals to retain independent mobility for as long as possible;

— needs for personal services, both in respect of household services (cleaning) and emotional needs for human contact and communication.

The issues around the ageing of the economically active population and the employment of the over-50s are equally important, particularly where the general question of employment is concerned.

## The Employment Challenge

France has lived with a high level of unemployment for twenty years (around 10% of the population of working age) and, even more troublingly, with endemic under-employment. Nonetheless, the theme of labour shortages periodically comes to the fore. With the baby-boomers retiring and an expected fall in the working population from 2007 onwards, demographic trends are reawakening these fears — or hopes, for some see in them a promise of an end to joblessness and a return to full employment.

### The Consequences of the Ageing of the Working-Age Population

The median age of the French population is rising and, with it, the median age of the economically active population. This ageing of the working-age population that is actually in work poses several problems, which will become increasingly acute. These include:

— the development of skills for the different age-groups, this

#### KEY TECHNOLOGIES CONCERNED WITH THE EMPLOYMENT CHALLENGE

5. Tools and Methods for the Development of Information Systems
13. Semantic Web Technologies
14. Human-Machine Interfaces
81. Co-design Methods and Tools
83. Technology Transfer

development being a function of the training that will be directed towards workers in their forties, with a view to keeping them economically active, and of the improvement of their working conditions;

— wage costs which, so long as they remain directly linked to seniority, are in danger of increasing correlatively;

— the even more acute problem of how retirees are to be replaced. On average, around 40% of the French working population, including the managing directors of SMEs, should leave their employment in the next ten years if retirement ages remain unchanged.

### **Technological Issues Associated with Employment**

The question of employment will certainly remain a major issue for European societies and for France in the next ten years in particular. This need to create jobs and impart dynamism to the labour market will have an impact on:

— the need for life-long learning, not only to enable the oldest section of the working population to remain economically active, but also to enable all the working population to change their type of employment during their careers and adapt themselves more easily to restructurings of the productive apparatus;

— the ergonomics of workstations and man-machine interfaces, so that productivity may benefit from the experience of older workers, without being diminished by what may well be less efficient physical aptitudes than those of a twenty-year-old;

— the tools for collaborative working required for the emergence of innovations that require skills which cannot, in many cases, be possessed by one person or company alone;

— risk-taking and entrepreneurship, which may be a product of training and information tools, but are more a function of socio-organizational and political innovations.

### **The Issue of Economic Competitiveness**

The long-term development of modern economies is characterized by a general phenomenon of tertiarization (or increasing “weightlessness”).

The boundary line between industry and services is becoming increasingly hazy. Two trends are actually at work here:

— on the one hand, in their pursuit of efficiency, industrial enterprises are refocusing on their core business and increasingly externalizing production-related activities;

— on the other hand, industrial enterprises are being encouraged by the way demand is developing to build a growing service element into their

### KEY TECHNOLOGIES CONCERNED WITH THE COMPE- TITIVENESS CHALLENGE

5. Tools and Methods for the Development of Information Systems
6. Engineering of Onboard Systems
7. Software Components
15. Modelling, Simulation, Calculation
20. Catalytic Processes
21. Industrial Biotechnologies
22. Microtechnologies for Process Intensification
48. Large-Scale Functional Genomics
49. Combinatorial Chemistry and High Throughput Screening
55. Imaging and Instrumentation for the Life Sciences
69. Automated Aerial Vehicle Systems
70. Ultraprecise Positioning Systems
71. Vehicle Flow Management
74. Process Control by Image Analysis
81. Co-design Methods and Tools
82. Complex Systems Engineering
83. Technology Transfer

industrial products. Given this increasing “weightlessness” of productive activities, we are seeing the emergence of a “new economy” that has nothing to do with the Net Economy of the early years of this century.

### A New Technico-Economic Paradigm

This “new economy” is assuming a number of peculiar characteristics. We shall mention only three here, all of which represent significant long-term trends:

— The first relates to the increasing disconnection between economic growth and the consumption of (energy-related and non-energy-related) mineral and extractive raw materials. This is a phenomenon linked principally to the progress of science and technology;

— The second characteristic of this “new economy” is the disconnection between the real sphere (the production of goods

and services) and the financial sphere. This is so great that global financial flows are estimated to exceed real commercial transactions by a factor of a hundred, and these have no rational connection to the actual dynamism of the real economy.

— The third characteristic is clearly the globalization of the economy. We are moving into an economy that is increasingly organized on a networked basis, the networks having less and less of a connection to the territorial dimension that underpins the principle of national sovereignty.

By dint of this globalization of the economy, competition is increasing ineluctably and competitiveness is becoming an absolute imperative.

### Four Strategies for Competitiveness

The pursuit of competitiveness, in which all companies now have to engage, largely involves four kinds of strategy which, though not entirely new, are becoming more and more surely the norm:

— through the tertiarization of productive activities, which finds expression in an increase in the number of inputs that are “weightless” in nature and in the transition from mass production to bespoke production of goods, increasingly delivered “service included”. This tertiarization forces an ever greater degree of cooperation on companies, even though they are in competition in other respects.

— through a phenomenon of the industrialization of services that is not completely new, as is attested, for example, by the automation of many tertiary-type functions.

— through the extension of competition, reaching now to whole nations and territories. Hence the challenge for territories of having to improve their attractiveness to investors. This now represents a major issue.

— And, lastly, through a race to global competitiveness, which involves a redeployment of activities between the market, non-market and domestic sectors. Traditionally, it has been those activities where productivity was stagnant that have been transferred from the market to the non-market sector. Since the market and non-market sectors are now both equally confronted with global competition, they tend to transfer activities where productivity is stagnant or in decline to the domestic sector (e.g. home-banking, in which the activity formerly performed by the bank clerk is now performed by customers in their own free time, or voluntary organizations, which now complement the public sector). Will telemedicine supplant the country doctor and surveillance cameras replace the neighbourhood policeman?

## *Conclusions and Impacts of the Exercise*

### *Lessons of the Exercise*

Key Technologies 2010 has now become a recurrent exercise. It is a response to a high level of demand from the public authorities for insight into technological development in the medium term, both in order to guide their technological development policies and also to provide a broad overview of technical change to the SMEs.

From the experience gained in the three *Key Technologies* exercises that have been carried out since 1995 we can identify the following lessons:

— The question asked at the beginning of the exercise is crucial in orienting the work of analysis. On that question depend, quite clearly, both the form of the results obtained and also the methodology that will be chosen.

— The choice of experts is key. The quality of the results will, in part, be down to them. Experts who are trying to make a case for their own technologies must be avoided as far as possible.

— Smaller units make for greater efficiency in the study groups. Fifteen assiduous participants seems the right size, since everyone must be able to express him/herself. The quality of the group leader is also a key factor in the success of the exercise.

— It is essential to have a website to extend the legitimacy of the exercise beyond the experts directly used. For that site to operate properly, however, it is crucial that it is updated and kept fresh.

— Lastly, it seems vital to have wide communication about the exercise, well beyond the inner circle of initiates.

## *Use and Dissemination of the Results*

The results of the three *Key Technologies* exercises have been used differently, each use corresponding, in fact, to a particular context.

The results of the first exercise, which were published in 1995 under the title *The 100 Key Technologies in the Period to 2000*, were used to guide the technological development policy of the Industry Ministry around 50 key technologies by way of a specific tendering process.

The results of the second exercise, published in 2000 under the title *Key Technologies 2005*, were used largely by local actors in technological development to guide their action and better target their priorities in attracting international investment.

The results of the third exercise, *Key Technologies 2010*, will be used to guide the work of the competitiveness clusters and help local authorities to put in place a technological development policy. Moreover, this report will be a particularly important “thinking tool” in analysing the impact of technological development in terms of economic change.

## *Gains from — and Limitations of — the Exercise*

Apart from the insight gained into technological development, the various *Key Technologies* exercises have enabled us to create a community of experts, bringing together people from many different horizons: companies, public research institutes and other public institutions. The fact of collaborating has made it possible to build up a shared view among the experts. Moreover, thinking within the study groups has made for rich, varied exchanges of opinion. It has been an opportunity for relationships to form and projects to be concretized.

These positive contributions made by the *Key Technologies* project also bring into focus the limitations of this kind of exercise:

— If the vision shared by the experts is to be disseminated more widely, it is essential that all the actors take on board the results of the study. This requires favourable conditions, particularly a will on the part of the actors to play a part.

— This type of exercise also requires that the various parties involved collaborate on the project. This isn't always easy. The sociology of organizations shows how hard it is to get bodies to work together when they possibly feel in competition with one another.

— One of the conditions for such an exercise to be successful lies in the legitimacy of the body that is the “vehicle” for the project. This legitimacy plays its part in getting actors to commit to the project and in having the results disseminated. It depends, among other things, on the support of the public authorities in being willing to use the results of the exercise.

## ***Annex 1 — List of Key Technologies 2010***

1. Micro-Energy Management
2. Digital Information Storage
3. Processors and Systems
4. RFID (Radio Frequency IDentification) and contactless cards
5. Tools and Methods for the Development of Information Systems
6. Engineering of Onboard Systems
7. Software Components
8. Infrastructures and Technologies for “Diffuse” Communication Networks
9. Network Virtualization
10. Protection of Electronic Transactions and Contents
11. Data Acquisition and Processing
12. Management and Broadcasting of Digital Content
13. Semantic Web Technologies
14. Human/Machine Interfaces
15. Modelling, Simulation and Calculation
16. Virtual Reality, Augmented Reality, 3D
17. Mobile Display Advertising
18. Nanostructured Materials and Nanocomposites
19. Materials for Electronics and Measurement
20. Catalytic Processes
21. Industrial Biotechnologies
22. Microtechnologies for Process Intensification
23. Special Materials Recycling
24. Materials Functionalization
25. Technical and Functional Textiles
26. Building Envelope Systems
27. Composite Building Materials based on Recycled or Biomass Materials
28. Air Management in Building
29. Water Management in Building
30. Renewable Energy Incorporation Technologies in Building
31. Photovoltaic Systems with Integrated Storage
32. Wind-power Systems with Integrated Storage
33. Artificial Fuels Produced from Biomass
34. Third-Generation Nuclear Reactors
35. Low-Temperature Heat Exploitation and Distribution by Heat Pump
36. High-Performance Lighting Systems and Components
37. CO<sub>2</sub> Capture and Geological Storage with New Design for Coal-fired Power Stations
38. Command and Control of Networks and Power
39. Measurement of Priority or Emergent Water Pollutants
40. Membrane Filtration Technologies (Water Treatment)
41. Automated Waste Sorting



42. Accelerated Composting of Fermentable Waste and its Energy Conversion
43. Treatment of Unconfined Odours
44. Transgenesis
45. Cell Therapy
46. Proteomics
47. Gene Therapy
48. Large-Scale Functional Genomics
49. Combinatorial Chemistry and High Throughput Screening
50. Vectorization
51. Monoclonal Antibody Engineering
52. Recombinant Vaccines
53. Foods for Health and Well-being
54. Food Allergy Control
55. Imaging and Instrumentation for the Life Sciences
56. Architecture and Materials For Land Transport Infrastructures
57. Minimum-Disturbance Infrastructure Work
58. Intelligent Road Infrastructures
59. Active Vehicle Safety
60. Architecture and Materials for Lighter Vehicle Construction
61. Passive Vehicle Security
62. Piston Engines
63. Turbine Engines
64. Vehicle Acoustics
65. Electrical Architecture of Vehicles
66. Electronic Architecture of Vehicles
67. Vehicle Energy Management
68. Vehicle-Infrastructure Data Links
69. Automated Aerial Vehicle Systems
70. Ultraprecise Positioning Systems
71. Vehicle Flow Management
72. Authentication Technologies
73. Traceability
74. Process Control by Image Analysis
75. Intelligent Sensors and Signal Processing
76. Multi-Materials Assembly
77. Micro- and Nano-components
78. Photonic Processes and Systems
79. New Surface Treatment Processes
80. Shaping Processes for Innovative Materials
81. Co-design Methods and Tools
82. Complex Systems Engineering
83. Technology Transfer

## Annex 2 — File 39. Measurement of Priority or Emergent Water Pollutants

### Description

As an indispensable tool for diagnosis, forecasting and assessment, metrology has an increasingly important place in the field of water management.

From a technological standpoint, current aims include the development of new detection systems dedicated to specified single pollutants, together with improved instrumentation by achieving greater precision, reliability, measuring speed, automation and miniaturization. More generally, the aim is to find alternatives to the traditional approach, based on taking samples on site and analysing them in a laboratory thereafter.

Ultimately, the objective is to have a complete toolkit which would include, alongside the already available instrumentation and methods, such devices as:

- automated systems for on-line, real-time measurement;
- low-cost, miniaturized systems (for example, biosensors);
- portable analysers for use in the field;
- automatic periodic sampling systems;
- passive sensors for measurement *in situ*.

One of the priorities is the development of new tools for the measurement of anthropogenic sources of pollution and, more particularly, of the “new” or “emergent” pollutants. This concerns, for example, the pharmaceutical products whose presence in water, in the form of residues, has been pointed up in various studies.

Other pollutants, such as pesticides, dioxins, phthalates, heavy metals etc. have been monitored for longer and now have “priority” classification. Particular attention is being paid to products likely to affect the endocrine system, on account of their potential health impact. The need to keep these “endocrine disruptors” under scrutiny may also involve the development of new detection and measurement tools.

**Degree of Development:** emergence - **growth** - maturity

### Issues, Impact

Framework directive 2000/60 on Community Action in the Field of Water Policy (complemented by directive 2003/210 on groundwater) is aimed at protecting and improving the quality of the European Union's

water resources. It involves the establishment of monitoring networks, requiring improved measurement tools. The list of priority pollutants, updated every four years, currently includes 33 substances.

In late 1999, the European Commission also put in place a community strategy on endocrine disruptors. The actions planned include identification of the substances concerned and assessment of the associated risks, together with the development of methods of measurement.

## *Market*

The water metrology market remains very closely linked to the development of regulation: with regulation tightening, there is a growing need for improved instrumentation. However, the USA, Germany and Japan are in a dominant position in this market.

**Degree of Dissemination of the Technology:** emergence - **dissemination** - widespread use

**Fields of Application:** electrical and electronics industries; water abstraction, treatment and distribution; sanitation, highways and waste management.

## *Actors*

**Scientific Disciplines:** biochemistry, biology of organisms, physical chemistry, analytic chemistry, electronics.

**Technological Competences:** analysis, measurement and control, organic chemistry, biotechnology, environment - pollution

**Links with (technologies):** improved physical upstream water treatment technologies, water management in building, data acquisition and processing, intelligent sensors and signal processing, materials for electronics and measurement.

## *Main French Actors*

**Skills Centres:** Ifos (Institut de formation, CNRS<sup>3</sup>-École centrale Lyon), LAAS (Laboratoire d'architecture et d'analyse des systèmes, CNRS Toulouse), LEOPR (Laboratoire d'électrochimie organique et photochimie redox, CNRS-University of Grenoble), LNE (Laboratoire national de métrologie et d'essais), Nancie (Centre international de l'eau de Nancy), OIEAU (International Office for Water).

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3. Centre national de la recherche scientifique, the main French national scientific research institution.

**Industrial Actors:** Anjou Recherche, Bamo Mesures, Datalink Instruments, Degremont, Environnement SA, Iris Instruments, Neosens, Nereides, Secomam etc.

Research work is carried out mainly within the framework of the Riteau network ([www.riteau.org](http://www.riteau.org)).

**Example of Actors worldwide:** Aqualyse (Netherlands), Bran+Luebbe (Germany), Endress+Hauser (Germany), Kobold (Germany), Honeywell (United States), Horiba (Japan), the European SWIFT-WFD project ([www.swift-wfd.com](http://www.swift-wfd.com)).

## ***Comments***

The “French School of Water Management” is recognized internationally. It is, however, more concerned with the management and use of the resource than with the corresponding applied metrology. With water resources becoming scarcer (relative to increased need) and the costs of water rising, we shall see a marked development of related support activities, particularly of monitoring and profiling. By their nature, these markets will reflect levels of consumption and they will generate service jobs through many SMEs and SMIs (small and medium enterprises, small and medium industries).

# INRA 2020

## A FORESIGHT STUDY ON FRENCH AGRICULTURAL RESEARCH

NICOLAS DURAND <sup>1</sup>

### *Overview of the Exercise*

INRA 2020 is a foresight exercise carried out by the French National Institute for Agricultural Research (Institut national de la recherche agronomique, INRA) between 2001 and 2003, in order to explore the possible courses of development of that body in the period to 2020. Above and beyond its contribution to the thinking and planning of the Institute, INRA 2020 sought to contribute to the debate on the future of French agricultural research in general.

The exercise as a whole, which was preceded by a great deal of debate (involving 2,000 people, both within and outside INRA), was divided into three phases: first, the staff of INRA and its main partners were consulted; this was complemented by a more formal foresight exercise based on the scenarios methodology; lastly, thanks to the lessons learned from these two phases, the President of INRA led an exercise in strategic thinking, in order to outline the Institute's aims in the period to 2020.

The exercise produced several scenarios:

— Six context scenarios describing the possible development of the environment of INRA in the period to 2020 (international balances, social demand, scientific dynamic, organization of research etc.). The usefulness of these scenarios is linked to the fact that, even if the development of INRA is not dictated by the way its environment develops, it seems that certain configurations may be particularly favourable to some scenarios for the development of INRA.

— Five internal scenarios outlining the possible development of INRA in the years to 2020 (goals and missions, resources, organization etc.), entitled: “The Pre-eminence of Generic Knowledge in the Life Sciences”; “The

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1. Nicolas Durand is an agricultural engineer with a degree in political sciences. From 2002 to 2003, he was adviser to Bertrand Hervieu (then President of INRA) and, as such, coordinated the INRA 2020 exercise.

Tripod Asserts itself in Europe”; “Priority to Food”; “Refocusing on French Agriculture” and “Towards Sustainable Development”.

Based on a cross-comparison of these context scenarios and the internal scenarios, INRA 2020 proposes a strategy for the Institute in the years to 2020 — a “Wager on the Future”, in which a number of proposals and convictions each have their place. The success of INRA 2020 can be attributed to the complementarity of its three strands (debates, foresight, strategy), despite an incomplete translation of these into reality. Though conceived primarily as an exercise to stimulate debate and reflection internally, the study made a welcome contribution to the debate on the future of research. Three questions in particular benefited from the light cast on them by the scenarios discussed in the report: the place of Europe in the world, the role of science, and the organization of public research (agencies).

Furthermore, the study has enabled INRA to face up to the new context and challenges of the period to 2020. The institute already has a certain number of key assets for doing so, though it will, nevertheless, have to reinforce these by changing scale and modifying its paradigm.

## **Procedure**

For almost half a century, agricultural research was guided by the (undisputed) principle that science contributes naturally to development, and that development takes only one form and is inevitable.

The debates in France and Europe on the manipulation of living organisms, pollution caused by agriculture, the deterioration of the countryside, health scares and the quality of food have put an abrupt end to this accepted view. The persistence, the world over, of great poverty among peasant farmers and of recurrent malnutrition in the countries of the South has finally thrown science’s capacities to meet the challenges of development definitively into doubt.

Agricultural research thus found itself faced, as the last century ended, with the question of its legitimacy and its future. This process of self-examination found a particular echo in France where agricultural research has a particularly significant place. It was a particularly serious issue for the INRA which, with its 10,000 employees, is not simply the premier agricultural research organization in Europe, but one of the foremost in the world.

Launched in Autumn 2001, INRA 2020 emerged out of these doubts and questions. For those managing the institute, particularly its president who led the entire operation, the plan was to conduct a foresight exercise on how the institute was to develop in the years to 2020, then to derive a strategy from that exercise for its 2006-2009 four-year plan. The operation was, then, subject to internal logics and time scales (in terms of science policy, recruitment, equipment etc.). It also aimed to contribute to more general debates on the reform of the system of research and innovation and, in particular, on the role assigned to public research.

## *The Method*

A three-pronged approach was adopted:

1) Debates organized within the framework of the 22 regional centres of the INRA, bringing together the institute's staff and its principal partners — debates in which almost 2,000 people took part and which enabled us to bring out hopes and fears, strengths and weaknesses, and the major questions to which the institution had to find answers.

2) A simultaneous exercise in exploratory foresight, carried out by a working group using the scenarios method, which consisted in:

- exploring how the external environment of the institute might develop;
- exploring how INRA itself was going to develop, given its internal dynamic;
- and, lastly, making a cross-comparison of the possible futures of the INRA and the possible futures of its external context, in order to highlight the major issues with which the institute was likely to be confronted and explore the various strategic options.

3) The presentation and debating of the conclusions of this process among the governing bodies of the institute, and the commitment of its president to a project running to the year 2020.

All this material was carefully recorded and has been set down in various reports.

The exploratory foresight exercise itself was carried out by breaking down:

- the elements of the external context into four essential “components”: the global environment, the social demand with regard to the life sciences, environmental sciences and corresponding social sciences, the general scientific and technological dynamic, and the organization and management of public research in France and Europe;
- the elements relating to the internal dynamics of INRA also into four “components”: the strategic aims and objectives of the institution, its human resources, its partnerships and finance, its organization and management.

For each of these components the most crucial variables were identified and their past evolution described, together with possible future trends, these latter being defined with the aid of contrasting hypotheses.

Then, component by component, the combinations of hypotheses were examined, which would make it possible to define microscenarios for each of them. And also, by an identical procedure, the possible combinations between these microscenarios were examined, so as ultimately to define general scenarios regarding, on the one hand, the possible developments within the external context of INRA and, on the other, the possible developments within the institution itself. By cross-comparison of these two families of scenarios, it was possible to test how the possible futures of INRA might prosper more or less well when confronted with the possible developments of the operating context and, conversely, how these latter might influence INRA's own dynamic.

## The External Context <sup>2</sup>

Combining hypotheses on the possible development of the components of the external context, the group constructed six macroscenarios (see figure 1), with titles borrowed from the vocabulary of meteorology. These scenarios, deliberately chosen to present fairly distinct alternatives, are markers of the range of possibilities. They describe conceivable paths of development to the year 2020, with potential transitions from one scenario to the other.

### 1. Gulf Stream: a Unipolar World Driven by Faith in Progress

In this scenario, the United States imposes its vision of a unipolar world. Its domination is exerted in all fields, including the economic, where the internationalization of capital flows reaches great heights. Inequalities also increase between countries, as they do within national systems. In spite of frequent climatic events, the international community neglects the environment. The uniformity and standardization of food make European agriculture increasingly dependent on industry.

European public opinion recovers faith in progress, and major scientific and technological advances give the illusion that man is becoming the master of the workings of living matter. The relations between chromosomal architecture and genetic expression are progressively elucidated. The use of stem cells increases substantially, opening up the possibility of effective repair technologies.

These successes fuel the scientific dynamic: science is regarded as an inexhaustible source of innovations and all that can possibly be done is permitted. Some voices, however, are raised in alarm, denouncing the dangers of technology running out of control, the multinationals' increasing monopoly over biotechnological inventions and the growth of inequalities between North and South. These caveats lead the authorities to maintain a system of vigilance and expert evaluation.

To take advantage of the general enthusiasm, French public research bodies increasingly enter into contracts and partnerships with private research institutions; joint public-private laboratories become common. Public-sector research workers become private contract workers. There is a rapprochement between research bodies and higher-education establishments to the point where their laboratories are amalgamated as "research and higher education clusters". Public-sector research, directed towards innovation for purposes of enhancing competitiveness, is steered by funding and assessment agencies.

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2. This presentation of the context scenarios, internal scenarios and strategic cross-comparison is taken from Bertrand HERVIEU and Hugues de JOUVENEL. *Prospective de la recherche. Agriculture, alimentation, environnement/Research Foresight. Agriculture, Food and the Environment* (Paris: Futuribles, 2005).



## 2. Changeable Skies: Innovation for the Security and Well-Being of Regional Blocs

Planetary tensions are aggravated by repeated (economic, political and natural) crises. In the decade 2000-2010, in the absence of satisfactory global governance, regional groupings form to protect themselves from the turmoil. Governments resort to voluntaristic policies in an attempt to cope with the consequences of instability. In the environmental sphere, each bloc attempts to remedy its natural accidents in isolation. Security becomes the absolute priority, often to the detriment of individual and collective freedom.

In Europe research is at the heart of the strategy of autonomy and security that is put in place. The dangers of general shortages relegate ethical questions to the second rank.

There is no great breakthrough in the science and mastery of the finer mechanisms of living matter, but there is progress in the understanding and management of ecosystems, and also of social systems and behaviour. Mobilization of all the players in the agrifood sector enables research to contribute to recreating a situation of relative plenty in spite of the constraints of international instability.

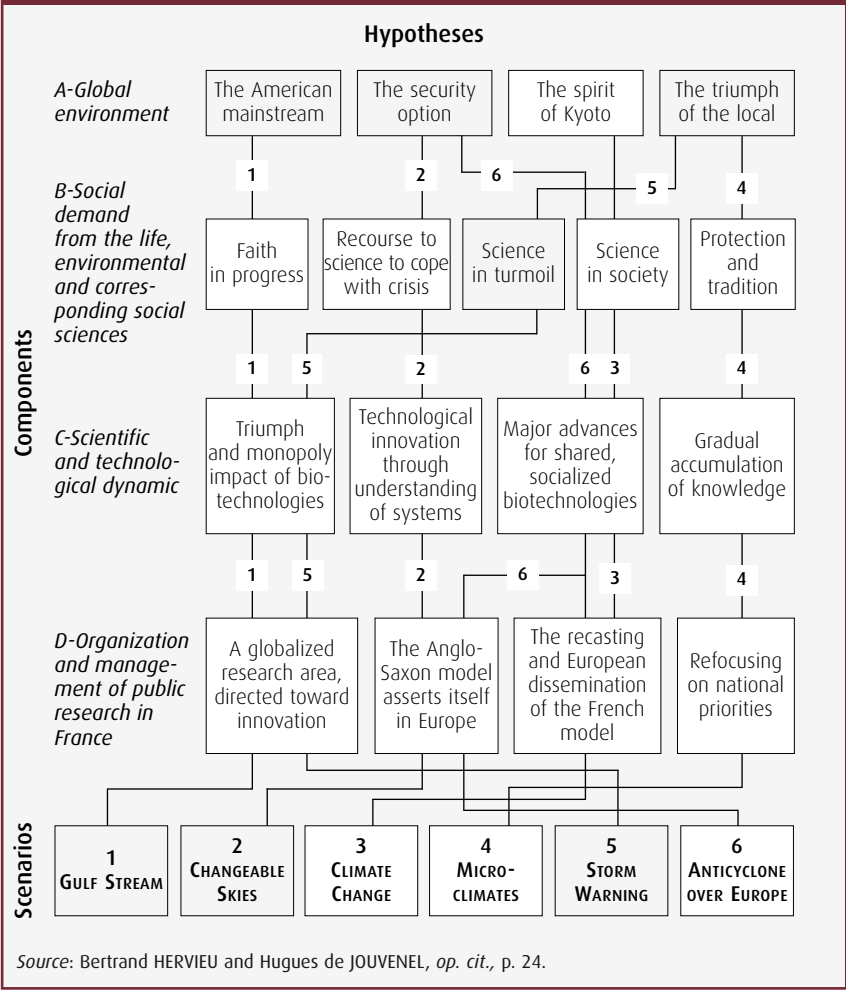
Europe increases the speed of its integration and implements its plan for a European Research Area (ERA),<sup>3</sup> in order to steer research toward what seem to be urgent objectives. The national and regional levels are relegated to a subsidiary role. Research institutes, universities and higher-education institutions combine into research and higher-education clusters in intense competition with each other. Civil-servant status is now reserved for a small number of established research scientists. The other operatives, private contract workers, have diversified careers within the ERA. The orientation and evaluation of programmes is entrusted to European funding and assessment agencies.

## 3. Climate Change: Global Governance for Sustainable Development

Under the impact of major climatic and health events and worsening North-South inequalities, global governance is established during the decade 2000-2010. The concept of sustainable development becomes the paradigm of international order, particularly in its environmental dimension (combating the greenhouse effect, maintaining biodiversity). The social dimension of this is taken into account only in certain regional blocs, particularly in Europe, which, externally, increases its development aid and attempts, internally, to reconcile economic growth, social equality and res-

3. The European Research Area brings together all the available Community resources for the better coordination of research activities and the convergence of research and innovation policies, at national and EU levels. See Communication of the European Commission. *The European Research Area: Providing New Momentum*. Luxembourg: Office for Official Publications of the European Communities, 2002.

Figure 1 — Construction of the Context Scenarios



pect for the environment. The Common Agricultural Policy (CAP) now steers agriculture towards the production of environmental goods and services.

In the life sciences, the social demand is predominantly for advances in the field of health and for linkages between development and environment. It is fuelled by an unprecedented scientific and technical dynamic in genetics and microbiology, making it possible to intervene on living matter at all levels. Breakthroughs take place in the understanding of individual and collective behaviour, but particularly in insight into ecosystems. This broad scientific progress is based, at the international level, on an open system for the circulation and pooling of knowledge.

In France, the state creates the conditions for close cooperation between the private sector and public research, but, in close collaboration with the Commission, its European partners and the regions, preserves the latter's public interest missions. The management rules for research bodies are simplified and the management and decision-making scope of the universities is widened. Public research improves in efficiency and clarity: the research bodies, grouped around ten or so major clusters, acquire total responsibility for the funds allotted to them. But a large proportion of the finance for programmes, managed through national or European funds, lies outside their control. For staff in public-sector research, mobility becomes the rule. The "French R&D model", recast in this way, influences the formation of an ERA, leaving a considerable role to the national level.

#### **4. Microclimates: a Fragmented World, Oriented toward Local Development**

In an ever more uncertain world, uncoordinated national strategies develop over the decade 2000-2010 in pursuit of great economic, social and political autonomy. Autarky is not the goal: there continue to be exchanges, including in the scientific field. The principles of solidarity and proximity fuel local dynamics oriented towards a development more respectful of social and environmental equilibrium. Quality of the human environment, conviviality, health and food security are the priorities expressed by society. French agriculture reconnects with local produce and adopts more environmentally-friendly production systems.

These trends are reinforced by crises undermining the credibility of a research that would prioritize performance over respect for the human person. Hence a disenchantment with research and a rigid conception of life, held to be sacrosanct, which co-exists with a preoccupation with scientific advances in health care in the context of an ageing population.

These pressures and the financial orientations to which they give rise lead to the scientific dynamic losing momentum. Advances in biotechnology run up against the complexity of life on its various different scales. Similarly, the human sciences make no significant advances in the understanding of social phenomena.

This leads to a thoroughgoing re-structuring of French public research. The state accords priority to research that is goal-oriented (by objectives), refocused around a number of themes of economic interest or serving to promote security. The universities take on the major part of fundamental research, doing so with greatly reduced budgets. Staffing levels in public research are drastically reduced: only one retiree in four is replaced. The private sector becomes, then, a treasured ally. Many partnerships are formed at the local level with a fabric of innovative SMEs (small and medium enterprises) and SMIs (small and medium industries) and with participation from local authorities, leading to a marked decentralization of research institutes. Lastly, French public research is refocused on national objectives, pursued at the local level, with a handful of institutes pursuing goal-oriented research.

## 5. Storm Warning: a Wayward Science Plunges the World into Turmoil

In this transitional scenario, an intense circulation of knowledge at the global level, combined with major advances in genetics, leads, at the end of the 2000s, to uncontrolled development of biotechnological innovations and major accidents in the fields of agriculture, food, health and the environment. Society then takes control of the orientations of research, which leads to the existing agricultural and food models — and, more generally, models of development based on growth and mass consumption — being brought into question. Society calls for “traditional” food, combining quality with food security and the protection of ecosystems. These expectations give rise to a strong ethical dimension in the orientations of the life sciences and a rise in local development based on the principles of solidarity and proximity.

## 6. Anticyclone over Europe: Europe Defends its Model

In a unipolar world, in which the dominance of the American model is distinctly felt and natural accidents occur repeatedly, Europe decides around the middle of the 2010s to defend its social, political and economic model by giving renewed impetus to European construction, which had been left in abeyance. Other regions of the world, South-East Asia in particular, also decide to speed up the move to more structured relations.

This fresh impetus finds expression in the construction of an ERA which, without being cut off from the international community, enables Europe to bolster its own system of research. Faith in scientific progress having given way to a more critical attitude, civil society involves itself in research decisions, steering the life sciences towards a focus on health and the links between development and environment.

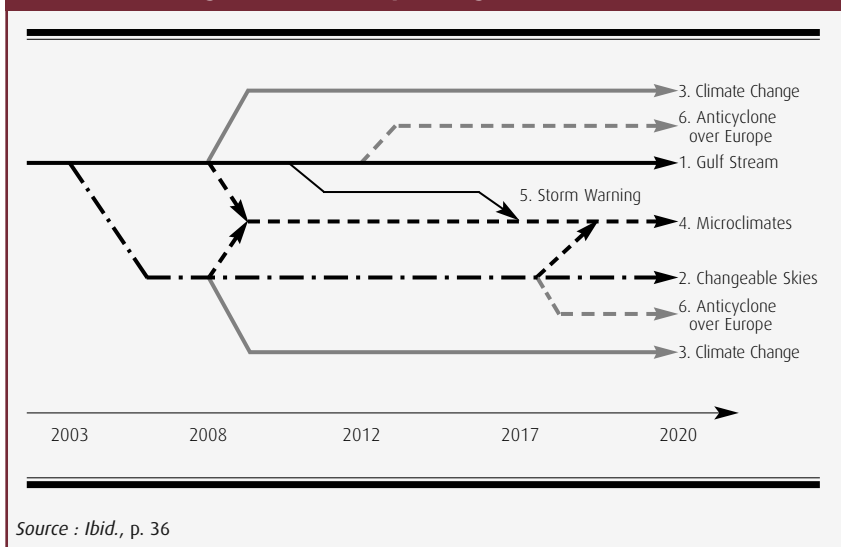
Supporting this social demand, French and European researchers achieve important advances in the understanding of ecosystems. The construction of the ERA borrows from the French and Anglo-Saxon models. In 2020 it is far from being complete, but is already creating strong synergies between research and higher-education establishments.

## The Sequencing of the Scenarios

Not all these scenarios are equally probable today, nor *a fortiori* between now and 2020 (see figure 2). They derive, more or less directly, from a scenario of global governance dominated by the American model. It may be that that scenario, *Gulf Stream*, will go on unfolding until 2020. It is probable, however, that it will lead on to other configurations.

The first of these would be the establishment of an unregulated multipolar world in which, in order to cope with instability, the international community attempts to protect itself in regional blocs (*Changeable Skies*). The second possible bifurcation occurs around 2010: under pressure of climatic or economic events, the unipolar world, like the unregulated multipolar world, may give way to a system based on local development and national autonomy

Figure 2 — The Sequencing of the Scenarios



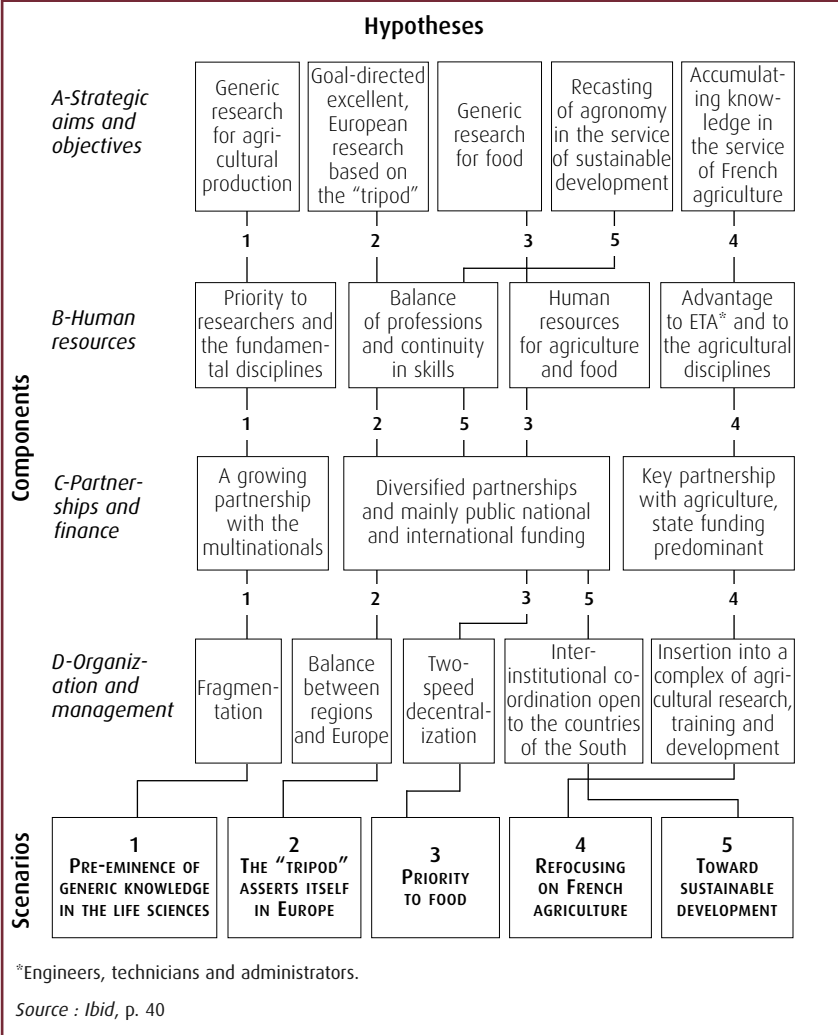
(*Microclimates*) or, by contrast, to genuine world governance in respect of the environment (*Climate Change*). Other paths may lead to the *Microclimates* scenario, the first of these being a major crisis, largely science-induced, that would occur around 2010 (*Storm Warning*); another being a fragmentation of the *Changeable Skies* system after a failure of the strategy of regional bloc formation in the mid-2010s. Lastly, *Anticyclone over Europe* is a possible development from *Gulf Stream*, in which Europe would decide to break free of America's sway during the 2010s. It may also be an eventual outcome of the *Changeable Skies* scenario, if we suppose that regional blocs are successfully formed only in some parts of the world, particularly in Europe.

## Results

### *The Different Scenarios for INRA's Internal Dynamics to 2020*

Every organization is influenced by changes in the context in which it operates, changes we examined in the previous chapter, but its future also depends largely on the forces of change or inertia at work within it. Let us see what the consequences of these forces may be in INRA's case. INRA's internal dynamic may be described in terms of the development of four components: its strategic aims and objectives, its human resources, its partnerships and funding, its organization and management. We have selected five scenarios for consideration (see figure 3).

Figure 3 — Construction of the Scenarios for INRA's Internal Dynamics



## 1. The Pre-eminence of Generic Knowledge in the Life Sciences

INRA focuses its research on generic knowledge in the life sciences and forms scientific partnerships with comparable laboratories in the developed countries in order to meet the imperative of academic excellence. Agricultural production for food, pharmaceuticals and energy becomes the main priority, as an indirect goal of more fundamental research.

INRA works in close synergy with the private sector through partnerships around very large facilities. These partnerships have flexible legal structures.

## KEY FIGURES ON INRA

INRA is Europe's premier agricultural research institute, the third-ranking research establishment in the world in the fields of agriculture, food and the environment and the second-largest French public research institute. It is made up of:

### 13,000 men and women:

- 8,600 operatives in 2003, of whom 1,850 are scientists, 2,270 engineers and 4,470 technicians and administrative staff (from the brochure of the institute, 2004).
- 2,880 trainees taken on in 2003.
- 1,450 post-graduate diploma students, PhD students and foreign pre- and postdoctoral students.

### 14 scientific departments:

- 21 centres spread over more than 200 research and experimentation sites throughout France.
- 257 research units (2003), including 141 "joint" research units (INRA in association with other bodies), 50 experimental units, 33 contract units (in receipt of financial assistance), 33 federative research units, 2 joint experimentation units.

### Budget: 596 million euros (2004) Output:

- 2,475 publications in 2003, including 2,249 articles, according to figures from the Institute for Scientific Information.
- 184 basic patents in France (3,500 with extensions to international patents), 19 of them for 2003.
- 400 active plant variety certificates for various species, including 59 new certificates in 2003.
- 1,700 operating licences.
- 13 companies supported as part of a programme for the creation of new innovative companies between 2001 and 2003.
- 52 projects financed as part of the sixth European FRDP (Framework Research and Development Programme).

### Strategy:

For the period 2001-2004, six strategic headings have been defined:

- improving the living environment, preserving the natural environment and producing sustainably (23% of researchers and engineers in 1999);
- improving human food, preserving the health of consumers and understanding their behaviour (7% of researchers and engineers in 1999);
- diversifying products and their uses, improving their competitiveness (21% of researchers and engineers in 1999);
- developing generic strategies for the life sciences (24% of researchers and engineers in 1999).

Source: *Ibid*, pp. 42 and 44.

The public authorities retain an important guiding role, but share it with multinationals, which profit from the competition between national R & D (Research and Development) systems.

Around 2010, INRA is behind some major advances in certain fields of the life sciences and the agricultural, food and pharmaceutical sectors are driven by a high level of innovation. But voices are raised demanding expert evaluation of these innovations. INRA, whose job it is to provide that evaluation, finds itself facing conflicts of interest (contribution to innovation vs. expert evaluation of that innovation).

Private laboratories and the laboratories of INRA, of higher-education institutions and other bodies come together in research clusters (which strengthens the bonds between research and teaching). Given the cost of the facilities and the imperative of excellence, these are few in number and distributed unevenly throughout the country. Regional authorities attract them by making significant contributions to their costs.

INRA concentrates on the fundamental disciplines, particularly those required for integrative biology. It recruits actively in the private sector and abroad, in particular, thanks to an upgrading of pay scales, but its overall personnel levels fall, which is partly offset by partnerships. There is a high level of mobility among staff. Public funding, which is marginally the greater source of income, pays for a decreasing number of tenured staff. Other needs are covered by European and regional subsidies, mainly by private finance.

These orientations lead to research teams gaining their autonomy and, in the middle of the 2010s, to a split between the central departments of INRA (which are transformed into a financing and evaluation agency) and the laboratories (which are incorporated at the administrative level into autonomous “clusters”).

## **2. The “Tripod” Asserts Itself in Europe**

INRA operates in its three historic fields of intervention: agriculture, food and the environment. But the high level of connectedness between these fields necessitates a reorganization of research practices: the formation of scientific communities of a critical size, interdisciplinary work, academic and economic partnerships.

INRA becomes further integrated into the ERA. The institute takes advantage of European programmes that cover three quarters of its contractual funding — which itself represents 25% of INRA’s budget. State funding, which makes up 70% of the institute’s budget, is in decline.

Recasting its scientific paradigms, INRA now gives precedence to the in-depth understanding of mechanisms and interactions in complex systems — technical, biological and human. The institute maintains a balance between competences in basic and applied research. But the range of skills is



narrowed in order to create scientific communities that have an international “profile”. Retirements from the organization are offset by an active recruitment policy. Its rapprochement with higher education establishments and other bodies brings 2,000 researchers into participation with INRA.

Among the researchers, as many of the recruits are veterinarians and engineers with doctorates as are university-qualified scientists. There are more and more foreign researchers and high staff mobility becomes the norm.

The mid-2010s sees the arrival on the market of the first transgenic varieties resistant to water stress,<sup>4</sup> eagerly awaited on account of global warming. Biofuels derived from lignocellulose material open up new prospects for energy self-sufficiency within the European Union. The citizens’ level of scientific and technical understanding has risen. These successes in innovation and social dialogue provide a greater audience for INRA’s model of organization and research.

### 3. Priority to Food

INRA focuses its strategy on food and on its links with agriculture. A policy of intense communication makes it possible to overcome opposition from medical circles, which are reluctant to see INRA devoting itself mainly to food. The legitimacy of the institute is reinforced by a partnership with medical research and by coming additionally under the auspices of the Ministry of Health.

These changes lead to researchers leaving, but the range of skills is not radically affected (except for a recruitment drive from medical circles). Thanks to a policy of active recruitment, staffing numbers stabilize at the level of the early 2000s. Partnerships with higher education, other research bodies and the teaching hospitals bring more than 2,000 researchers into participation with INRA. An adjustment to civil servants’ employment status increases the mobility of INRA’s employees and makes personalized career-management possible.

To meet the fluctuating demand of consumers, there is emphasis on generic research relating to in-depth knowledge of foodstuffs, the impact of varieties, modes of cultivation and technologies on their structure and properties, and also on respect for the environment. The institute’s cross-disciplinary skills enable it to make a contribution to the question of water quality.

The social sciences are drawn on substantially to provide insight into consumer behaviour, the cultural construction of food regimes and the economic viability of production systems.

INRA, supported by the regions, mounts an effective partnership with agricultural organizations and consumers. As for the major food companies,

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4. Water stress is a state in which there is insufficient water of adequate quality to meet human and environmental needs.

they form closer relations with the institute in order to cope with a diversity of demand hostile to product standardization. In spite of this partnership, INRA plays its part in providing public scientific expertise.

INRA, whose central departments retain a strategic orientation role, is increasingly decentralized; it bases itself on two types of structure:

- A network of regional research centres, reorganized into a more rational distribution. Financed in very large part by the regions, they are focused on local development and staffed essentially by engineers.

- Clusters of thematic excellence, which group (mostly university) laboratories around large facilities, and receive industry, national and European funding.

State funding is reduced, but remains the main source of finance. Research contracts from the major European programmes represent 50% of contractual resources.

#### **4. Refocusing on French Agriculture**

Whereas it had been INRA's objective in the early 2000s to establish its excellence in the areas defined by the "tripod", at the end of the decade it has to refocus on agricultural production. This for two reasons:

- its plan to mobilize the life, social and engineering sciences runs up against the effects of disciplinary boundaries, institutional rivalries and budgetary restrictions;

- the civil R&D budget is broken up between different ministries: INRA is placed entirely under the aegis of the Ministry of Agriculture with a diminished budget and a single mission: to contribute to the competitiveness of French agriculture.

For lack of sufficient resources, staff leaving for reasons of age and restructuring are seldom replaced. By 2020, the bulk of researchers are working on agricultural production. INRA partly offsets its reductions in staffing levels by the joint laboratories it has created with CEMAGREF (The French Public Research Institute for Agricultural and Environmental Engineering Research) and the agricultural and veterinary colleges. The agricultural institutes and technical centres are incorporated into INRA. At the end of the 2010s, the institute's national network extends to more than 200 sites.

Recruitment policy remains active where engineers, technicians and administrators are concerned. INRA staff, almost all of whom are French, are granted tenure early and there is relatively little mobility among them.

Though public funding remains the largest source of finance for the institute, it is now exceeded by around 25% by finance from the agricultural profession, the agricultural supplies sector and the regional authorities. Lastly, though INRA remains a research body with a relatively centralized management, its status is evolving towards that of an EPIC (French acronym for "public establishment of an industrial or commercial character").

## 5. Toward Sustainable Development

Under pressure from repeated incidents of an environmental and public health nature and as the charges mount against intensive agriculture, the Ministry of the Environment becomes the third control administration of the INRA.

INRA is resolved to grasp the opportunity presented by sustainable development by activating its skills capital and its network of relations to provide interfaces between agricultural production, food, and the management of land and natural resources. The paradigms of agricultural research are challenged: by wider considerations of space and longer time-scales, approaches based on cross-disciplinary research, and closer links between the biotechnical and social sciences. The reorganization of the departments into communities of critical size facilitates closer relations with the universities and the CNRS (The French National Centre for Scientific Research). At the same time, INRA moves closer to bodies like CIRAD (French Agricultural Research Centre for International Development) and IRD (French Agricultural Research Centre for International Development) in order to develop an overall strategy.

INRA finds partners, especially financial partners, among European industrialists who have been sensitized to the need for sustainable development, and receives support from the regions where its centres with Europe-wide reputations are based. The institute is at the centre of a system of international agricultural development, training the scientific elites of the countries of the South.

INRA remains mostly dependent on the state, but the greater part of its operating resources come from European and international funding.

The contents and methods of the agronomy practised at INRA are updated. The understanding of biodiversity makes for some original genetic constructions, such as plants with specific forms of resistance for areas with endemic pests. INRA contributes greatly to ecological engineering to produce tools for the sustainable management of ecosystems.

The institute maintains a balance between basic cognitive and applied research. But the range of competence is narrowed in order to create scientific communities that have a European and international “profile” — a narrowing that is offset by its scientific alliances.

Retirements from the organization are offset with the aid of government support. The balance between researchers, on the one hand, and engineers, technicians and administrators on the other is maintained. Among the researchers, priority is given to the recruitment of engineers with doctorates and foreign researchers. A high degree of mobility among employees becomes normal, particularly to posts abroad. There is increasing personalized management of career paths, improving the attractiveness and performance of the institute.

The researchers now involve themselves in a dialogue with the users of the research, who take part in defining its objectives.

## Cross-Comparison of Scenarios to Identify Scope for Manoeuvre

By cross-comparison of the potential developments within its operating context and the developments toward which its internal dynamic is leading it, an organization can discover its scope for manoeuvre: the scenarios arrived at on the basis of internal forces are not all compatible with certain contextual macroscenarios. The strategic plans of an organization like INRA must therefore fit into a field of both internal and contextual possibilities.

### The Dangers of Excessive Dependence on the Private Sector

A strategy centred on the “pre-eminence of generic knowledge in the life sciences” has clear affinities with the *Gulf Stream* hypothesis, the most probable evolution of the context over the period to 2020, since, in contributing to innovation, INRA would participate effectively in economic wealth-creation. Thanks to its partnerships with the multinationals, it would attract capital that would otherwise have been invested elsewhere and contribute to increasing France’s scientific capacities. Even from the standpoint of public expert evaluation, INRA’s contribution could be positive, among other things in responding to concerns over the possibility of “innovation running out of control” — on condition, however, that expert evaluation undergoes thorough change so as to take on board the reality of partisan interests and weigh these against each other to arrive at a more objective opinion. Where training is concerned, such an orientation would enable INRA to sink its laboratories into “bioindustrial clusters” built on to higher education establishments.

There is a danger of the *Gulf Stream* scenario leading to *Storm Warning*, in which innovation is regulated in too exclusively commercial a manner and certain scientific advances are denatured as a result. An INRA with such an orientation toward the development of innovations for the benefit of industry would come under serious challenge. If accidents were to occur, it would be criticized for not having shouldered its “traditional” public service role, in spite of being financed largely from public funds.

In the *Changeable Skies* context, a strategy based on public-private synergy and international co-operation so as to promote innovation would find little favour with public opinion. It would be the same within the framework of *Climate Change*, in which the mastery of complex systems counts for more than fragmentary advances made on mere segments of living matter.

Moreover, with that strategy, INRA would cease to be a goal-oriented research body: its scientific strategy would be defined in relation to disciplines and not any longer by objectives, which would now be set by its private partners. With its laboratories becoming autonomous and its central departments being transformed into a funding and evaluation agency, the INRA would be in danger of disappearing. Furthermore, in the name of competitiveness, INRA would have to abandon whole swathes of research activity. With these social and institutional upheavals and radical changes of identity, a quite different form of “French agricultural research” would emerge.

Figure 4 — Recapitulative Table

	Gulf Stream	Changeable Skies	Climate Change	Micro-climates
The pre-eminence of generic knowledge in the life sciences	++	–	–	--
The “tripod” asserts itself in Europe	–	++	++	--
Priority to food	+	+	+	+
Refocusing on French agriculture	+/-	–	--	++
Toward sustainable development	–	+/-	++	--
++ Very high degree of robustness, pertinence, coherence and legitimacy both external and internal. + Good degree of robustness, pertinence, coherence and legitimacy both external and internal. +/- Random level of robustness, pertinence, coherence and legitimacy both external and internal. – Low degree of robustness, pertinence, coherence and legitimacy both external and internal. -- Very low degree of robustness, pertinence, coherence and legitimacy both external and internal.				
Source : <i>Ibid</i> , p. 60				

## European Public Goods: a Difficult Goal

In adopting the “European Tripod” strategy, INRA is in a good position to contribute to the general interest in the case of the *Changeable Skies* or *Climate Change* scenarios, in which public research is expected to produce public goods. These are at the heart of the “tripod” strategy, since they are the product of confronting the three prongs of that strategy with each other: agriculture/food for the quality of the food system, food/environment for food security, and environment/agriculture for land planning, the management of natural resources and the production of energy and materials. INRA would work to boost the science-society dialogue. It would also make a contribution to the need for reassurance by providing objective expertise. Lastly, INRA’s contribution to training would be appreciable, particularly in creating the skills Europe needs.

On the other hand, in the context of a weak Europe, the “tripod” strategy would be out of step with a world where only commercial innovations count. With the arrival of *Microclimates*, the goals of the INRA would be at odds not only with society’s expectations, but also the resources it requires.

For INRA, which has from the outset devoted itself to producing public goods, the “tripod” strategy presents the advantage of a continuity of aims and missions, but it also has some major disadvantages. First, a lack of clarity — with the notion of tripod and of the exploration of its interfaces requiring explanation. Second, a lack of dynamism, if the tripod merely remains a statement or accumulation of aims: first, agriculture, then food, then environment. Last of all, a risk of being spread too thin, when science requires increasing human and financial resources. To reduce this danger, INRA

could narrow its spectrum of disciplines and offset these losses by scientific alliances with other actors. It could also commission research like a funding agency, abandoning some of its scientific autonomy.

## Food and Water: Two Unifying Missions

Whatever the context scenario, food will remain a major issue, though one of differing significance: depending on the particular case, it might be a question of helping the agrifood industries to win markets (*Gulf Stream* context), ensuring the safety of foodstuffs and self-sufficiency (*Changeable Skies*), developing sustainable food systems (*Climate Change*) or contributing to the development of local produce and healthy food products (*Microclimates*).

From the general interest standpoint, it makes sense to take food as a strategic objective and there may even be further economic and social utility in this if we add in drinking water. The management of water, both qualitatively and quantitatively, is a major issue in the period to 2020, while in France research into water has so far lacked co-ordination.

By giving priority to food and water, INRA would increase its social and economic legitimacy. There would also be a scientific coherence to this, as these two aims require inter-disciplinary approaches and a systems approach to the processes of fallback and traceability. Both call on soil science, which could become a strategic linchpin of the institute's activities. Adding the field of water to that of food would make it possible to revamp relations between INRA and the farming profession around a new project. In this way INRA would be setting itself goals that can be understood by the general public, which would mean that the "tripod" would be the goal at which it arrived, not the starting point from which it attempted to legitimate its activities.

However, the institute would have to make good its skills shortages in soil science and deal with problems of legitimacy, particularly for the food/health area. And we must not leave out of account the reservations of the farming world: there is a danger that this strategy will increase the dependence of that sector on the agrifood industry and, besides, it regards water primarily as an input and only secondarily as a public good.

## Agriculture: an Over-Restricted Field

A refocusing of INRA's efforts on French agriculture would make it possible to integrate all the institutions involved in research, training and development for the agricultural sector. This rapprochement would be seen as evidence of increased effectiveness for a system that is regarded as too dispersed. Though isolated from the rest of the scientific community, French agricultural research would then be in a good position to form strategic partnerships with its European counterparts.

In the *Microclimates* context, this refocusing on French agriculture would guarantee that farming served the purposes of national autonomy and local

development. But in any other scenario there is a danger of this strategic option being inappropriate. This would be the case, for example, in a context of *Changeable Skies* or, even more, in that of *Climate Change*, where agricultural research is expected to yield supra-national public goods. In the *Gulf Stream* framework, INRA would help French agriculture to gain globalized markets, but the advantage would be short-lived. To give up generic research in favour of strict support for agriculture might lead to a loss of scientific autonomy for France and a drying-up of the well-springs of innovation.

The “return to agriculture”, like any strategy of refocusing on the historic core activity, appears attractive, but there would be an exorbitant price to pay for it. It would bring about a narrowing of the aims of INRA, a contraction of its staff and budget which might foreshadow its disappearance. To make a return to agriculture would be tantamount to intellectual isolationism. Where the dialogue between science and society is concerned, it would be to limit the contribution of INRA to the agricultural partnership and hence to restrict its audience and legitimacy.

## The Heavy Demands of Sustainable Development

Sustainable development is a “mobilizing utopian goal” that is capable of carrying the whole of INRA through to 2020. It is a logical extension of the “tripod”, particularly in its European dimension. INRA is very well placed to move into the fields of activity implied by sustainable development, as these latter require integrative research, its particular field of excellence.

And yet the context must be favourable. To move toward sustainable development would be appropriate in *Climate Change*, which is based on a model of development that shows concern for social and natural equilibria. INRA would produce global public goods in essential fields: animal and plant diseases, global food balance etc. For French agricultural research, a strategy of sustainable development is a major opportunity for reform. With such a strategy, CIRAD, INRA and CEMAGREF would find ways in which their scientific policies could converge.

There are, then, many advantages to this strategy in a world won over to the project outlined in *Climate Change*. But, in another context, including that of an enduring *Gulf Stream*, it is not a very tenable strategy: in a world driven solely by the creation of commercial goods, the producers of public goods are marginalized. If countries move toward isolationism (*Microclimates*), such a strategy would even be doomed to fail. And in a *Changeable Skies*-type context, it would provide only a partial response to the demands of a society seeking reassurance.

A strategy centred on sustainable development loses out, then, in any other eventuality than *Climate Change*, a scenario that can only eventuate in the medium term and presupposes an exceptional mobilization of the international community. While waiting for that eventuality, on what public support could one draw to put that strategy in place right now, when a major wave of recruitment is scheduled?

Moreover, in spite of the quality of research around sustainable development carried out at INRA, its culture and practices have remained largely French. In spite of the desire to contribute to the development of the countries of the South and to the global food balance, it is not certain the institute could manage to effect such a change in the short term.

## **INRA, 50 YEARS OF CHANGE AND TRANSFORMATION**

### **The 1950s and 1960s: the Modernization of Agriculture**

French agriculture lagged markedly behind the major developed countries. The mission assigned to INRA when it was created in 1946 was to mobilize science in the service of agricultural development to ensure food autonomy. Agriculture became increasingly productive, but also more specialized and regionalized.

### **The 1970s: the “Agrifood” Turn**

Having largely achieved its quantitative objectives, INRA shifted the emphasis on to the transformation of agricultural “raw materials” (development of microbiology and engineering sciences, close partnership with industry) and product quality. France gradually moved into the agrifood market to the point where it reached the first rank of exporting nations. At the same time, the institute showed an increasing interest in environmental and local development issues.

### **The 1980s: Academic Excellence**

INRA, transformed into a public scientific and technological establishment, was removed from the exclusive control of the Ministry of Agriculture and placed under the joint aegis of that ministry and the Ministry of Research. Characterized by bursts of over-production, this period saw an end to the pursuit of increased yields that had established the institute’s reputation. With ecological catastrophes worldwide and a growing awareness of pollution caused by agricultural activities, some urgent questions arose in the fields of the environment and product quality. Furthermore, the fall of the Berlin Wall had great repercussions for European construction and the perception of the role of science in a world that was no longer bipolar. Scientific excellence became the rule for the researchers. The basic sciences — including molecular biology — were to the fore.

### **The 1990s: Expansion of the Area of Competence**

The third transformation was characterized, among other things, by the extension of the INRA’s areas of intervention. First, the environment became part of its concerns, from the angle of agricultural activities and their impact on ecosystems and from that of the conservation of natural resources. Human nutrition and food supply also came within the institute’s purview. Increased uncertainties, the emergence of long-term concerns, shifts in the balance between various disciplines and the difficulty of the choices with which it was faced led INRA to reassess its activities, and, among other things, this generated various projects in the field of scientific foresight.

*Source: Ibid, p. 16.*



## ***A Successful Internal Discussion and a Welcome Contribution to the Debate on the Future of Research***

What overall assessment of INRA 2020 can we make three years after its completion? Such a question is tricky, particularly for someone involved in the operation. Moreover, the effects of a foresight exercise are often difficult to quantify, insofar as they are largely indirect and diffuse.

Nevertheless, it is possible to draw a certain number of lessons from this foresight study, both regarding the way it unfolded and its (internal and external) impact.

## ***A Balanced and Relatively Successful Exercise, Despite not being fully Translated into Practice***

INRA 2020 was launched to help INRA overcome the doubts and questions raised around its future, both within and outside the institute. The aim was not to decide what INRA would be over the next twenty years with the aid of a “development plan”, containing precise dates and figures. It was more a question of setting in train a dynamic of debate that would enable the organization to be a force in the future.

From this point of view, INRA 2020 turned out to stimulate thought and debate in an extremely useful way. The number of participants bears witness to this: almost 2,000 people (INRA employees and partners) took part in the 32 debates that were organized as part of the exercise, both in Paris and in the provinces. And this level of activity was not limited to INRA employees, since 600 (agricultural, scientific, voluntary-sector, economic and political) partners expressed their opinions in these debates on the current and future development of the institute.

The success of INRA 2020 is also due to the complementarity of its three strands — debates, scenarios and strategy. Debate was, in fact, crucial to gaining the commitment of all concerned to the exercise. However, this type of procedure is, by nature, not very future-oriented: INRA’s employees and partners primarily expressed their fears and expectations, and, to a far lesser extent, their visions of the future. The foresight exercise we have described here thus formed a useful complement to the debates by expanding the field of possibilities to contain more than is merely suggested by current trends. Lastly, the “strategy” strand of INRA 2020 brought the whole process to a useful conclusion, as doing foresight research is not just a way of cultivating a “pedagogy of uncertainty”: foresight, through the scope for manoeuvre it identifies, must also be a tool in the service of strategy.

Debates, foresight, strategy — thanks to their complementary nature, these three strands ensured the balance and success of INRA 2020. Yet the connection and coordination of these strands presented a number of difficulties.

For example, the debates were staged before the foresight study was launched and they fed into it in only a marginal way. It would no doubt have been more effective to elaborate scenarios first, and then submit these for debate, in order, on the one hand, to improve them and, on the other, to give a more future-oriented direction to the debates.

The transition from debates and foresight study to strategy is often a tricky stage. The project of a major organization like INRA has to contend with many constraints and sources of inertia, human, scientific or institutional. There is, then, a great danger that the strategic conclusions will make little use of the questions and possibilities opened up by the debates and scenarios.

The strategic project of INRA 2020 (see box) is not entirely immune to this rule: the perspectives outlined, while basing themselves on the two preceding strands, can be seen as extensions of existing orientations. It is more a case of INRA's current strategy being inflected and enhanced, than of any real break with that strategy. Even though some scenarios were tempting on paper (particularly the one centring on food production), their implementation would have been too complicated, if not indeed dangerous, from the institutional standpoint.

Nevertheless, despite there being no “visionary radical change”, the strategic strand of INRA 2020 has the virtue of rendering the institute's current path of development coherent with the potential evolution of its environment. In this way, the INRA project has found itself legitimated and reinforced, both internally and externally.

It is one thing to move from the debate and the foresight study to mid/long-term strategy. To translate that strategy concretely into scientific priorities and a programming of resources is quite another. It is also a tricky phase, in which the achievement of desirable goals is hindered by short-term constraints, such as human and financial resources.

From this standpoint, INRA 2020 has not had the impact which those who promoted it — beginning with the President of INRA — wanted it to have. For example, the Institute's orientations for 2006-2009 refer little to INRA 2020 and, though there are no major contradictions between the two documents, this is mainly because each represents a continuation of previous orientations.

The incomplete character of this translation into practice is due, in large part, to the timing of mandates: the President of INRA, who conceived and promoted INRA 2020, completed his mandate at the end of the exercise and was not able to supervise its concrete implementation. The transition from strategy to short-term orientations has not, therefore, been able to benefit from the same continuity as the previous developmental stages, in which the author of the strategic project (the President of INRA) had led the debates and taken part in elaborating the scenarios.

## INRA 2020: A STRATEGY FOR FRENCH AGRICULTURAL RESEARCH

The future is not an area in which certainties are possible (INRA 2020). On the other hand, it is possible, in the light of the scenarios considered and issues debated, to identify some long-term trends.

In the period to 2020, five major questions are going to arise increasingly at the local and global levels:

- global food security, given population growth and the increasing scarcity of natural resources;
- food safety and the links between food and health which, with trade globalization and the ageing of the population, are increasingly going to become major concerns;
- the location of agricultural activities and, more generally, of productive activities as a result of the growing globalization of the world economy;
- the management of natural resources and territories on account of the (often very long-term) detrimental effects of growth on their equilibria;
- the model of economic and social development, against the backdrop of the emergence of the concept of sustainable development.

Responding to these questions requires additional knowledge:

- integrated knowledge to confront the complexity of the problems and provide an “overall understanding” rather than partial insights;
- shared knowledge to ensure a pooling of advances among all the actors in the scientific community (including the teams in the South) and a “democratization of science” or, in other words, a concerted choice of scientific aims and methods with the whole of society.

To respond to these questions and meet these challenges, INRA has at its disposal, right now, a certain number of key assets: first, its scientific strategy, which combines disciplinary excellence with the integration of different bodies of knowledge; second, its field of competence (agriculture, food and the environment), which covers a large range of the questions now posed on a global scale; third, its organization, which enables it to manage its human and material resources (resource-based agency) and its research orientations (objectives-based agency) in an open and integrated way. Lastly, its dense and diversified network of partnerships (with the world of agriculture, industry, local communities etc.), which ensures that its research has relevance to social, economic and scientific dynamics.

To reinforce its relevance and legitimacy in the period to 2020, INRA must develop its internal scientific debate and make an increased effort at integration, in order openly to construct and explore research objects that are both complex and multi-disciplinary. Among other things, it is a matter of deepening our intimate knowledge of living organisms by developing an expert understanding of the interactions between living organisms and their bio-physical milieu, so that we may subsequently act on those interactions.

Above and beyond INRA, it is now necessary to bring all the components of French agricultural research closer together (the research institutes and also the agricultural and veterinary colleges), in order to increase its effectiveness and give it a higher profile at both European and international levels. If that greater closeness is not to lead to isolation, openness to other — national, European or international — scientific communities must be systematically pursued through a policy of regional clusters (or campuses) with a strong scientific and European identity, on the one hand, and the launching of major programmes that are scientifically, economically and socially relevant, on the other.

*Bertrand Hervieu, President of INRA, September 2003*

## ***A Welcome Contribution to the Debate on the Future of Research***

INRA 2020 was launched at a point when a thoroughgoing debate on research (its aims, organization, financing etc.) was beginning to emerge in France.

The accusations levelled by some against public research, and particularly against research institutes — which included charges of bureaucracy, corporatist sclerosis and even “wastefulness” — gained ground throughout the time INRA 2020 was going forward. These criticisms are not, of course, of recent origin. They do, however, assume a particular emphasis, given the speed with which the political and economic context is developing, with the construction of the European Research Space, the restructuring of public and private research bodies at the international level, the globalization of scientific knowledge and enquiry, and the substantial intrusion of the economic sphere into the field of the life sciences etc.

The findings of INRA 2020, most particularly the scenarios it contained, came at just the right time to fuel this debate. The context scenarios cast light on three questions in particular.

The first concerns Europe’s place in the world. Between a unipolar world dominated by American power (*Gulf Stream*) and a world fragmented by a host of strategies of withdrawal behind national borders (*Microclimates*), there is, in fact, a whole range of international systems in which Europe is more or less present. This palette of scenarios shows up the indispensable role of European construction for the future of French agricultural research.

If Europe is strong enough to make its voice heard among the nations, we may in fact hope to see emerge a global approach — respectful of North-South balances and local identities — to the questions relating to agriculture, food-production and the environment, and also to the mode of production and exploitation of the knowledge that underlies them. If, unfortunately, Europe does not manage to make its influence felt on the world stage, we may fear that conflicts and crises will proliferate in the fields of science, food and the environment: either because a system based solely on the growth of commodities will have triumphed or, conversely, because of a fragmentation of the international system.

The second question concerns the place of science in economic and social development. The scenarios in fact reflect different approaches to research and innovation, from *Gulf Stream*, in which the role of science is limited to the creation of commodity goods, to *Climate Change*, which makes sustainable development the new scientific, economic and social touchstone.

These scenarios thus enable us to gain some perspective on what, at first sight, seems like a deep, underlying trend of our developed, market-based societies: research in the service of a flow of innovations, from transistors to nano-technology. Is this situation a permanent characteristic of our societies, or does it merely express one moment in the history of the relations between

science and economic/social development? Even if these scenarios do not answer this question, they have the virtue of raising it and prompting a salutary caution.

The third question on which the INRA 2020 scenarios cast light relates to the organization of public research — particularly the transposition, which some have called for, of the “Anglo-Saxon model” to French research, by way of the creation of two categories of agency: “resource-based agencies”, on the one hand, in order to manage the human and material resources, and on the other hand, “objectives-based agencies”, whose role would be to define the research programmes put out to tender.

The INRA 2020 scenarios show that this model is not as simple as its advocates claim. The *Changeable Skies* scenario, in which the Anglo-Saxon model wins out in Europe, hints very clearly at this complexity: running alongside “regional clusters for research and higher education”, it has “non-university research institutes” that are both resources-based and objectives-based agencies.

In the event, what is found in the foresight study is echoed in reality, since, when it comes to agricultural research, neither the United States nor the United Kingdom actually apply the “dichotomy” advocated by the French campaigners for Anglo-Saxon models. The American ARS (Agricultural Research Service) and the British BBSRC (Biotechnical Biological Science Research Council) are public research bodies, both of which are, at one and the same time, resource-based and objectives-based agencies: they develop programmes and, in effect, put out tenders to the other players in public or private research, but they also have a certain number of laboratories that ensure their scientific autonomy.

By way of the scenarios, and the strategy deriving from them, INRA 2020 reminds us that, where agencies are concerned, reality is more complex than some may claim. To ask the right scientific questions, we have to play a part in the advance of knowledge, to be attentive to economic and social issues and also, if we are to be able to evaluate and optimize our capacities for action, to manage resources and maintain, renew and build competences. Distinguishing between different functions is a salutary exercise for improving the effectiveness of research organizations. On the other hand, separating them physically would be deleterious from the point of view of research programming.

The future of Europe, the place of science in economic and social development, and the organization of research — on all these subjects (and many others), INRA 2020 has made contributions to the debate on the future of research, a debate that grew and grew until it reached a paroxysm in 2004 (strike of the laboratory directors; national conference on research). In reality, the impact of the exercise was probably more significant outside INRA than inside. Though not intended, this represents a great success for the Institute’s image.

## Conclusion

Despite its limitations, INRA 2020 is a relatively successful example of a scientific foresight study.

In particular, the exercise benefits from the effective combination of debate, foresight studies and strategy. It also has the merit of going beyond the specific case of INRA to shed light on major debates, such as the role of science, Europe's place in the world, and the future of agricultural research.

Far from being merely a topic of concern to researchers, the development of agricultural research has, in fact, substantial consequences for the future of our planet in the period to 2020 and, indeed, beyond that date.

The continuous increase in the world population,<sup>5</sup> the problem of global food security,<sup>6</sup> the urbanization and massive concentration of populations in coastal areas, the open, but highly uncertain future of the peasants/farmers who still represent one half of the inhabitants of the planet, the industrialization of food production, the fact that natural resources are deteriorating and becoming scarcer, the intrusion of technology into all fields of the life sciences, the territorial upheavals due to the increasing globalization of the world economy — all these phenomena make inevitably for a thoroughgoing reorganization of agricultural and food systems in all parts of the world.

Facing these challenges is a long-term task that foresight studies alone can bring to fruition. If INRA 2020 can make even a modest contribution to that task, it will have achieved — and even surpassed — its original ambitions.

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5. A population of nine billion in 2050 according to UN projections. See UNPF (United Nations Population Fund), *State of World Population 2004* (New York: United Nations, 2004).

6. See FAO (Food and Agriculture Organization). *The State of Food Insecurity in the World 2004* (New York: United Nations, 2004).

# Agora 2020

## A NEW FORM OF SCIENCE-SOCIETY DIALOGUE

SÉBASTIEN MAUJEAN AND JACQUES THEYS <sup>1</sup>

### Overview of the Exercise

Agora 2020 is one of the most ambitious recent exercises in public foresight studies in Europe. The operation was launched in late 2003 by the Directorate for Research and Scientific and Technical Activities of what was to become the Ministry of Ecology, Development and Sustainable Planning. It ended in 2007 with the publication of a book-length report.

Agora 2020 is a foresight consultation for the period to 2020 on research in the fields of transport, housing, construction, urbanism, territorial administration, risk and the environment. Its aim was to co-construct more efficient, better adapted research priorities and strategies by drawing on a reasoned analysis of needs, expectations and issues in the period 2020-2030.

The exercise introduces three methodological shifts: instead of focusing on the participants in research, it questions the general public; instead of confining itself to expert opinion, it incorporates the views of those responsible for carrying out sectoral policies; instead of questioning science only through the programming agencies, it has attempted to involve the researchers themselves.

Four specific characteristics distinguish Agora 2020 from comparable exercises in Europe: the concern to take account of the expectations and preoccupations of the most diverse range of actors; the desire to give symmetrical treatment to the demand for, and provision of, research, to the questions raised by society and the answers the scientific community can bring to them; the effort to base the exploration of future scientific and technical issues on a structured, co-constructed sectoral foresight study for the period of the next 20-30 years; and the sheer range of fields covered.

Methodologically, the study was structured around two very distinct main strands: a first consultation phase with regard to the “demand” and a second

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1. Co-authors, with Pascal BAIN, of the report *Agora 2020. Vivre, habiter, se déplacer en 2020 : quelles priorités de recherche ?* (Paris : ministère de l'Écologie, du Développement et de l'Aménagement durables, 2007). Jacques Theys is the initiator and moderator of the Agora 2020 project.

phase of strategically evaluating the “response potential” where research provision is concerned.

The work gave rise, ultimately, to the definition of four families of axes of research: the “obvious choices”, which received the backing of the various actors, this being an area in which research provision is already highly structured; the “nuggets”, in which it would be appropriate to make greater investment; the “no pressure”, which correspond to a relatively low level of demand and an equally moderate level of provision, which are in search of takers; and lastly, the “dilemmas”, a heterogeneous family, a space for budgetary and strategic negotiation and arbitration between actors.

Each of these axes of research has a key message associated with it: invest in the “nuggets” as a priority; reinforce the existing dynamics where the “obvious choices” are concerned (by making the relevant programmes domains of excellence at the European or international level); in the case of the “no pressure” group, keep a watching brief on the development of research demand and the conditions for the development of provision (by anticipating the emergence of new providers or new opportunities); and, for some of the “dilemma” programmes, assess the concrete conditions for the removal of the scientific or technical obstacles to development. Where the others are concerned, it is a question of enquiring more deeply into the ecological, economic or societal benefits to be expected concretely from each programme, with other criteria to be taken into account than those applied in this chapter, and considerable latitude given for deciding between programmes.

Science and technology have probably never occupied such a place in everyone’s daily life, where access to employment, culture, housing, health and the environment is concerned. And yet the idea that society can legitimately express its constructive expectations in respect of scientific research is not taken for granted. The science-society dialogue still largely takes place in the register of distrust. Distrust on the part of the scientists of the intrusion of any non-scientific external logics; distrust of the users towards the “black boxes” of research, which are too far removed from the world of everyday life and real issues. And there is, lastly, a tendency to see the public only through the — initially negative — prism of the “social acceptability” of innovation. In these conditions, building balanced, productive relations between scientific research and “social demand” remains a difficult challenge.

However, reciprocal suspicion does not exclude a shared parallel expectation of openness and new forms of cooperation and communication – as covered by the oft-used formula: “a new social contract between science and society”.<sup>2</sup> We find, in fact, that institutional and methodological innovations have burgeoned everywhere in Europe, the general aim being to arrive at a “more open science”.<sup>3</sup> parliamentary technological assessment offices, asso-

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2. The expression was popularized by Michael Gibbons, former specialist adviser, in the mid-1990s, to the UK parliamentary science and technology committee.

3. We may employ here the phrase coined by Michael CALLON, Pierre LASCOUMES and Yannick BARTHE, “a science out in the open air”. See *Agir dans un monde incertain. Essai sur la démocratie technique* (Paris: Seuil, 2001).



ciations or foundations of concerned users,<sup>4</sup> “consensus conferences”, scientific and technical culture networks, not to mention foresight consultations and exercises, which have shown themselves over time to be remarkable forums for dialogue. Through these convergent initiatives, not only have the issues of technical democracy and the intervention of the public in the adaptation of new technologies been progressively incorporated into the debate, but also the idea that research — by its results, its methods and the expertise involved — has to be able to respond better to the demands and concerns that are those of society in all its diversity, from businesses to the most vulnerable residents or social groups, along with consumers, local communities or those responsible for national public policies.

Agora 2020 is very solidly a part of this dynamic of openness and dialogue. As a foresight consultation on research priorities in the fields of urbanism, the environment, territorial administration, transport and risks, this exercise, involving almost 700 people over three years (from late 2003 to late 2006), attempted, for the first time, to give a voice to absolutely all the parties concerned: companies, voluntary organizations, public authorities, researchers — and also “the general public” itself. Since it was themes relating to daily life that were at issue, it seemed that the opportunity to express needs should be as widely open as possible, particularly to those most directly concerned!

The attempt to co-construct research priorities with the general public is one of the challenges that distinguishes Agora 2020 from all the other foresight exercises conducted recently throughout the world, including Great Britain and Scandinavia. But its main original feature — and, for this reason too, it is a first in Europe — is its attempt to take account, in equal measure, of both the demand for, and supply of, scientific research; the expectations and concerns of society and the demands or logics of the scientists. And to do so with the single aim of ranking research priorities. It was not, then, merely a foresight consultation, but also an attempt to translate the expectations or questions expressed by society into scientific issues and research programmes, which, as we shall now see, is a challenge of a quite other order!

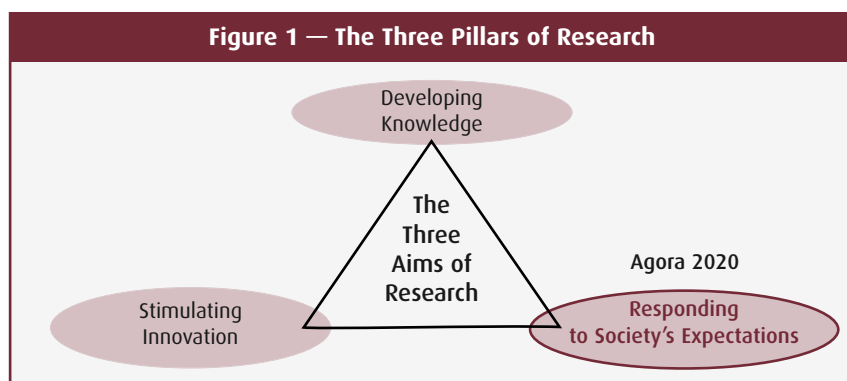
## *Going Beyond Traditional Foresight Exercises*

Agora 2020 was launched in late 2003 by the Research Directorate of the then Ministry of Infrastructures and by the research bodies and programming structures associated with that ministry.<sup>5</sup> A common feature of all these ins-

4. Such as the AFM (Association française de lutte contre la myopathie).

5. More precisely, the following bodies: l'Institut géographique national (IGN), l'Institut français de recherche pour l'exploitation de la mer (IFREMER), l'Institut national de recherche sur les transports et leur sécurité (INRETS), le Centre scientifique et technique du bâtiment (CSTB), le Laboratoire central des ponts et chaussées (LCPC), le Centre d'études et de recherche sur les transports et l'urbanisme (CERTU), l'École nationale des travaux publics de l'État (ENTPE), l'École nationale des ponts et chaussées (ENPC), le Centre d'études maritimes et fluviales (CETMEF), le Programme national de recherche et d'innovation dans les transports terrestres (PREDITT), and le Plan urbanisme, construction et architecture (PUCA).

tutions is that they play a mediating role, a role as interface between scientific research, social demand and public policy. Naturally, it was on the basis of a diagnosis of the operation of these mediating mechanisms that the exercise was undertaken. The aim was never to define priorities for the whole of French research – which is beyond the powers of a ministry for one single sector – but rather to attempt to give somewhat greater consistency to what is traditionally known as “the third pillar of research”, namely the dimension concerned with responding to society’s expectations (see figure 1).



### *“Social Demand”: the Disputed Third Pillar of Research*

There is, in theory, agreement within the scientific community that research must be able to meet three major objectives: “the improvement of knowledge”, “industrial innovation” and “responding to the concerns or expectations expressed by society”. Moreover, these three objectives are solemnly restated in the framework law on research promulgated in 2006. But the legitimacy that derives from this “third pillar” is fragile and disputed, as in the closely related question of “targeted research”. As mentioned in our introductory remarks, researchers are generally uneasy with the idea of research being — even partially — guided by external considerations, and they contest the very notion of “social demand”. For their part, many economic actors tend to the view that this “social demand” equates solely with the needs of the market, and this, once again, downplays the usefulness of a third function of research to a minimum. Most importantly, however, the mediating structures in charge of targeted research themselves have great difficulty giving clear, future-oriented expression to societal expectations and concerns, and translating them into research terms.

It is Paul Caseau, a member of the Academy of Technologies, who has provided the best analysis of this internal difficulty, writing, in an article, of the “failings of targeted research”.<sup>6</sup> One of the most important such fai-

6. CASEAU Paul. *Maîtrise d'ouvrage, maîtrise d'œuvre, tutelles. Réflexion sur les différents rôles nécessaires pour une bonne gouvernance de la recherche* (Paris: Académie des technologies, 2007).

lings, in his view, “relates to the fact that research targets can only ever be stipulated collectively or transversally, whereas those responsible for them operate in terms of vertical schemas or in ‘silos’.” To this major reproach, we may add more classical criticisms commonly made of the processes of programming or orienting research:

- because they are too closed, it is not always possible to take account of the diversity of social demands;

- because they are reactive rather than proactive, they only partially anticipate long-term or very-long-term issues, and the radical discontinuities with which research ought, in theory, to be able to deal.

These identified weaknesses or criticisms define *a contrario* the general aim and specific objectives of Agora 2020:

- first, to attempt to give the clearest, most faithful and most forward-looking expression to the diversity of expectations and future needs;

- second, to transform this expression into research priorities that are both solidly argued from the standpoint of “social demand” and credible and legitimate in the eyes of the scientific community.

As we shall see, this assumes we can move from “questions to research” to research questions.

### *Three Methodological Wagers*

To quite a large extent, this two-phase approach, consisting of an open foresight consultation (phase 1), followed by a ranking of priorities (phase 2), is the procedure adopted by most scientific and technological foresight studies undertaken recently in Europe and throughout the world. And, in many respects, Agora 2020 simply forms part of what is already a longstanding international tradition.<sup>7</sup>

The consultation did, however, introduce a number of major innovations with regard to this tradition, which make it, as we have already mentioned, an exercise without parallel in Europe today.

Normally, scientific and technological foresight studies are structured around a dialogue between research programming agencies, experts who are supposed to articulate what is at stake, and “stakeholders”, which may be companies, NGOs, users, communities or, in some cases, trade unions.

Agora 2020 introduces three important departures from this pattern, which are also three methodological wagers (see figure 2).

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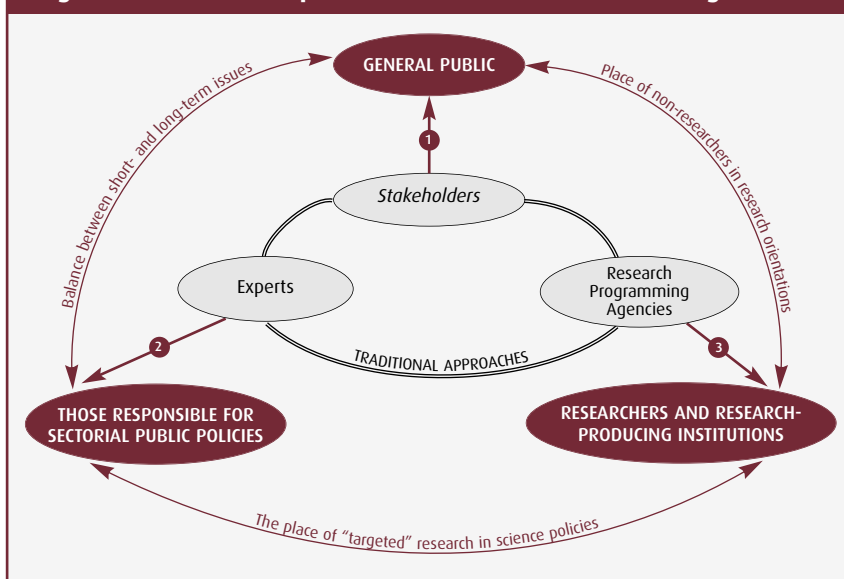
7. The first national scientific and technological foresight exercises were launched in the mid-1990s. For more on these, see BAIN Pascal, MAUJEAN Sébastien, THEYS Jacques. *Agora 2020*, *op. cit.*, pp. 35-40.

1) The “general public” is seen as a fully-fledged actor and becomes an additional stakeholder, alongside those usually considered. Above all, however — and this an even more crucial difference — all the stakeholders are consulted separately, through homogeneous workshops, which makes the Agora 2020 process somewhat akin to that implemented in the French Grenelle Environmental Summit.<sup>8</sup> At least in the first phase of the consultation, the aim was not to arrive at a consensus within “hybrid forums”, but rather to bring out the diversity of “worldviews” held by the different actors.

2) Much greater emphasis than in other comparable studies is put on collective functions and demands linked to public policies, which are no longer conflated with the functions and demands of the experts. To this end, bridges are built here between scientific-technical foresight studies and sectoral foresight linked to public policies, this being facilitated by the particular positioning of the bodies that initiated Agora 2020.

3) Lastly, at an early stage, and throughout the process, the approach brings in the laboratories and institutions which themselves carry out the research and, in the end, these play a major role in the co-construction of the priority programmes. More broadly, Agora 2020 differs from all other foresight exercises in its desire to maintain a continuum between the provision of, and demand for, research and to deal symmetrically with the two.

**Figure 2 – The Three Departures from the Usual Pattern in Agora 2020**



8. In the so-called “Grenelle process” of the Environmental Summit, this is termed “five-handed governance”.

These special features, which naturally make this a little more cumbersome than traditional foresight exercises,<sup>9</sup> explain why the study is divided into five major phases that are differentiated to a considerable extent both in aim and methodological approach:

— in a first stage, in which actors and residents are consulted, the aim is to make visible the diversity of expectations, needs and “worldviews” expressed by these various publics, in all their complexity and, possibly, contradictoriness;

— the second stage, organized around themed workshops (the city, transport, residents etc.) aims, rather, to bring out consensus over priority issues in the period to 2020 or even 2030.

— the third stage, central to the whole process, seeks to translate the major expectations and questions asked of research into research questions and programme proposals. This is, par excellence, the stage of confrontation and dialogue between spokespersons for social demand and researchers;

— the fourth stage initiates strategic thinking on the programme axes previously proposed. It enables a reasoned choice to be arrived at concerning the research that is to be undertaken as a priority over the next ten years;

— lastly, a fifth stage, which should not be forgotten, is devoted to exploiting and concretely implementing the results of the consultation.<sup>10</sup>

Completing each of these stages meant finding a solution to the various “methodological challenges” just mentioned, while respecting the major features of the approach: the challenge of aggregating the various fragmented “worldviews”, that of “translation”, that of multi-criteria ranking (incorporating the perspectives of research provision and demand on an equal footing) and, lastly, that of exploitation of the results — in a context that was now completely different from the one that pertained at the beginning of the exercise. To what extent were these challenges met? This is what will be discussed in the following sections, as we describe the terms — beginning with the notion of “social demand” — modalities (participation, translation) and main results of the Agora 2020 process.

## ***“Social Demand” as a Site Intermediate between Research and Society***

The notion of “social demand” is a convenient one, as it enables us concisely to encompass all the — material or symbolic — interactions that link scientific and technical activities to the rest of society. This is, no doubt, one

9. Hence the length of the exercise (almost three years) and the complexity of the arrangement (more than 30 workshops or panel discussions).

10. Begun in 2007, this phase is currently on-going in co-ordination with the continuing work of the Grenelle Environmental Summit.

of the reasons for the enduring nature of this expression which, though often put in inverted commas, is rarely rejected in the multiplicity of discourses directed at measuring, criticizing or, by contrast, promoting the importance assumed by research and innovation in the contemporary period. But the strength of such a notion — the fact that it is context-dependent — is also its weakness. If we are to use it, then, rather than simply discussing its greater or lesser justification — at the political level (legitimacy), the economic level (“effective demand”) or the scientific level (objectivity) — we must make clear the role we intend to make it play.

In the specific context of Agora 2020, that role is an intermediate one. To opt to lend it such a role means, first, breaking with the simplificatory idea of a linear trajectory running from a (more or less latent) social demand to “social problems”, then on to expertise or technology and, lastly, through to public decision-making. Secondly, choosing not to subordinate social demand either to the viewpoint of the researchers or to that of their institutional, economic or social environment is also a way of taking account, without any pre-constituted hierarchy, of a genuine plurality of points of view. With this initial choice behind us, the approach presented here consists, so to speak, in a twofold detour: a detour through research from the standpoint of citizens, practitioners and experts, and a detour through society from the standpoint of scientific researchers. At the point where these two “journeys into alien territory” meet — journeys made possible, if not indeed prompted by their future-oriented character — are to be found both the formalization of a social demand and also its translation into research questions.

In its first phase, then, Agora 2020 bases itself on the diversity of expectations and anticipations that make up the social world, and thence makes its incursion on to the terrain of research and technology. In order to do this, three series of workshops and a questionnaire-based survey explore, in the most differentiated way possible, the respective viewpoints of the “general public”, “actors”, “experts” and “foresighters”.

### ***The “Expectations of the General Public”: Convergence and Declared Ambivalence***

The views of the “general public” are normally acquired through opinion surveys, behavioural analysis or market research. Most often, this leads either to the construction and abstract representation of an average public opinion or to a division into as many “audiences” (and, in the event, consumers or users) as there are “specific provisions” of goods or services.

To avoid these two pitfalls, Agora 2020 turned to the “focus group” technique, which makes it possible to create a dialogue between specialized concerns and the broadest possible expression of collective expectations relating to daily life in urban or suburban areas.

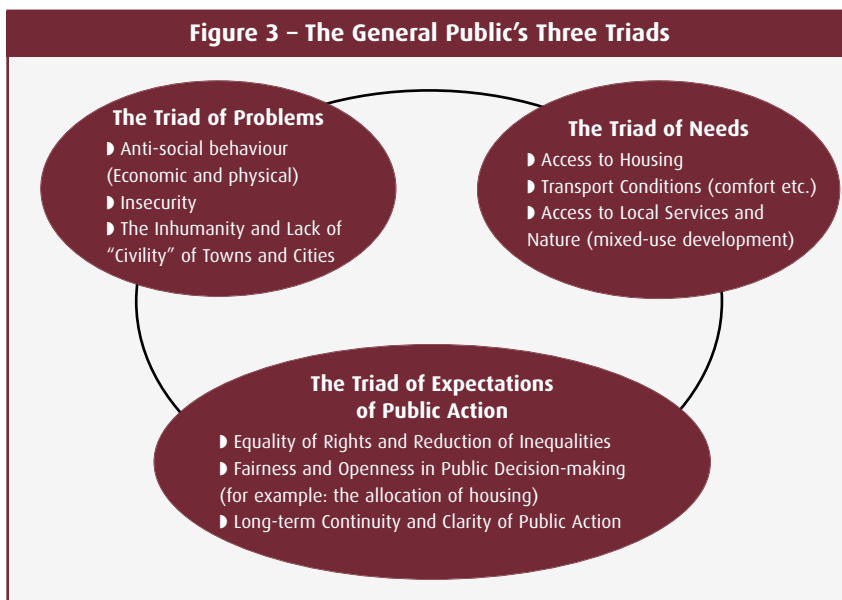
Whether in regard to matters relating to living conditions, the environment and pollution / nuisance, the cityscape and urban planning or mobi-

lity and transport, the view of the general public is remarkable, initially, for its general character. As a “total social fact”, the urban phenomenon in particular engages the whole of individual and collective life; it puts values and social preferences to the test, not to mention private interests, and it constantly mingles present preoccupations with visions of the future.

Despite a form of sampling specific to each of the groups (young city-dwellers in Paris; working-class and immigrant groups in the outer suburbs of Lyon; average, middle-class families in the centre and outskirts of Orléans) and despite the diversity of situations and experiences discussed, analysis of the sessions shows up a surprisingly high degree of convergence between them. The perception of problems and the perception of issues and expectations of public action are drawing manifestly from a common core. Without sinking into caricature, we may even say that the standpoint of the general public seems to be structured by three surprisingly linked triads: the triad of dissatisfactions or problems; the triad of priority needs or issues; and, lastly, the triad of expectations of public action (see figure 3).

It may well be said that there is nothing very new or foresight-related in this collection of residents’ views. Ultimately, however, it is from this domain of daily life that the most imaginative formulations with regard to the future of territories, domestic spaces or technologies have come. Reading the scenarios drawn up by the workshop participants to illustrate their ideal — or most dreaded — views of the distant future, we find narratives much more complex and ambivalent than might be expected from a mere perusal of their grievances. Paradoxically, it is probably from these “fictions of reality” that research will draw the greatest range of stimulating reflections, on

**Figure 3 – The General Public’s Three Triads**



account of their visions of technical progress, the place occupied by nature or the fragility of social institutions. Science and technology here assume a character that is both liberatory and alienating, invasive and transparent, subservient and autonomous. There is not such a simple opposition between Nature, on the one hand, and artifice and planning, on the other. Society “tolerates”, “accepts” or “appropriates” public intervention, but on condition that those interventions are grounded — *de jure, de facto* and in value terms — in the social order.

Though it is true that the general public’s concerns adumbrate a series of “commonplaces”, they do so neither to the detriment of the imagination, to which their future visions attest (much more than the visions of the experts), nor to the detriment of the complexity we can see in their expectations, once we view them as a whole. Proof of this can be seen in the deeply ambivalent character of a certain number of concerns that may be said to tend towards both equilibrium and movement. The desire for individual advancement is counterbalanced by a wish for social stability; criticism of the uniformity of towns and cities is accompanied by a concern that things should last; hopes vested in the increasing versatility of technologies imply that maintenance back-up can be constantly in place. The change fundamentally hoped for in the fields of housing, environment and transport assumes that standards of justice or quality can be established that are sufficiently solid to be guaranteed.

And perhaps it is this — almost wilful — ambivalence that explains a certain difficulty research has in taking on board these expectations, which are, nonetheless, remarkable for their extraordinary stability.

## *The Needs of the “Actors”: A Radical Heterogeneity*

A second strand relates to the needs of “actors”, by which we mean companies, voluntary organizations, local communities and civil administrations, since it is another of the features of *Agora 2020* that it looks at these needs not in a general way (through hybrid working groups), but using four distinct “colleges”, with the explicit intention of bringing out what in their respective preoccupations or visions, unites and divides them. Taking a relatively classical approach (diagnosis and trends, long-term priority issues, and expectations of future action), these four “colleges” are expected, furthermore, to come up with a first list of needs directly addressed to the world of research.

Whereas, somewhat surprisingly, the general public displays relatively homogeneous concerns and expectations, this consultation process brings out very marked divergences. Having neither the same objectives, nor the same perceptions of the available scope for manoeuvre, the voluntary organizations, companies, communities and administrations move, in fact, from relative agreement on future trends to much more divergent positions, as soon as it comes to naming priority issues for action.

Where local communities are concerned, primacy is given to the success of institutional reforms, as an essential pre-condition for any other kind of



action, particularly in the fields of economic development or urban renewal. Though also stressing institutional aspects, the administrations are concerned primarily with the issues of security and land planning, and they formulate their main preoccupations in reference to sectoral policies (“transport regulation”, “control of urban sprawl”, “adaptation of public expertise” etc.). For voluntary organizations, the three main watchwords of collective action are participatory democracy, international solidarity and, first and foremost, social action (“mobility for all”; “access to essential goods and services”; “rebuilding social relations” etc.). Lastly, the companies see their expectations in terms of two quite distinct timescales: in a long-term perspective (“greenhouse effect”, “growing scarcity of resources” and “an ageing population”) and in a much more immediate economic context (“European standards”, “removing barriers to innovation”, “research policies”, “skills formation”, “the productivity of the transport systems” etc.)

Though a consensus exists on some types of dissatisfaction with scientific production, the themes specifically raised for research also reflect greatly divergent points of view (see figure 4 next page). If we leave aside a consensus — noteworthy but limited by differences of interpretation — on the need to develop energy technologies and technologies for “sustainable development”, we have to admit that there is, for example, almost no overlap between the themes raised by the voluntary organizations and those proposed by the companies. The most striking thing is that this by no means reflects an opposition between technological development and social sciences, but a divergence resulting more from the fact that the companies and the voluntary organizations have manifestly different views of what is at stake in research. For the companies, it is a question of acquiring tools capable of improving the operation of systems, whereas for the voluntary organizations, the important thing is to “highlight” the situation of specific groups or populations (the non-mobile, adolescents, families, those in poor housing, users of public transport etc.). We can say something similar about the respective viewpoints of the administrations and the local communities, who also share no common priorities. This radical heterogeneity in fact reinforces the main question Agora 2020 is aiming to answer in its foresight-oriented way: how are we to take account of these different viewpoints in a balanced manner and, on the basis of such diversity, construct a programming framework that can respond fairly to the expectations of all the groups concerned?

### *The Issues for the “Experts”: Coping with External Shocks*

After the general public and the actors, a third strand of the consultation gave a voice to the “experts”. Contrary to the previous phases, what is involved here is not bringing out contrasting “world views”, but rather arriving at a shared consensus on the major long-term issues to be accorded priority within the thematic fields covered by Agora 2020: transport and mobility, towns and cities, housing and construction, territorial administration, and also risk assessment and the knowledge and observation of the land and living

**Figure 4 – The Diversity of Research Themes Proposed by the Actors**

### Voluntary Organizations

- ▶ The reproduction of ghettos and insecurity in outlying urban districts.
- ▶ The mobility of the “non-mobile” (older people, the disabled, residents of “enclaved” districts) and the impacts of automobile dependency.
- ▶ Housing conditions and services in a multicultural society.
- ▶ Development of “social capital” and dynamics of social innovation in civil society.
- ▶ Anthropology and ethology of daily travel.
- ▶ Flexible housing (adaptation of housing to the development of family structures).
- ▶ Development of security and surveillance technologies, individual behaviour and autonomy.
- ▶ Cities and mobility in the post-oil era: what innovations?
- ▶ Place of adolescents and older people in the city.
- ▶ The development of public strategies of assistance to the homeless or those in poor housing conditions.
- ▶ The notion of “urbanity”: concepts, criteria and policies.
- ▶ Sustainable development and North-South trade.

### Administrations

- ▶ Vulnerability and adaptation to the risk of global warming.
- ▶ Impacts and acceptability of energy price rises or a “carbon tax”.
- ▶ Risk governance, insurance and “cyndinics”.
- ▶ New techniques and concepts in safety/security policies.
- ▶ Consequences of an ageing population, and other demographic trends, on value systems, modes of life, mobility and housing conditions.
- ▶ The attractiveness of France as a location in 2020.
- ▶ Obstacles to innovation and marketing of new automobile technologies (fuel cells, biofuels etc.)
- ▶ Territorial equity: criteria, measures and policies.
- ▶ Social dialogue, user services and productivity in public transport: what conception and what strategy for “French-style” public services?
- ▶ Radical innovations in long-distance transport and interoperability of European networks: prospects and obstacles.
- ▶ The new information technologies (mobile, Galileo, RFID etc.) and road management and road pricing policies: revolution or mere adjustments?
- ▶ Conditions and prospects for road transport innovation.

### Companies

- ▶ Precautionary principle and innovation.
- ▶ Development of the concept of public utility.
- ▶ Impact of new ICT on travel and commerce.
- ▶ “Positive energy” buildings.
- ▶ Nanotechnologies and construction materials.
- ▶ Technical trials and “virtual” construction sites.
- ▶ Towards high speed freight trains? Obstacles to innovation in rail transport.
- ▶ Construction of credible scenarios of interaction between urban dynamics, transport, energy and sustainable development.
- ▶ Rationalization tools and techniques for decisions on scarce resources (critical resources, airway slots, materials etc.)
- ▶ Political and social conditions for development of shared or “on demand” vehicles.
- ▶ Air transport, energy and the greenhouse effect: what new technologies?
- ▶ Age-related technologies and services to the elderly.

### Local Communities

- ▶ Dynamics of globalization and the transformation of factors of attractiveness.
- ▶ Engineering of complex urban systems.
- ▶ Real and perceived life territories: what identity for territories?
- ▶ Change management and the construction of “local common goods” (example of sustainable development).
- ▶ Institutional complexity, the cost and coherence of territorial policies.
- ▶ Local development impacts and redistributive effects of infrastructures.
- ▶ Mechanisms of, issues in, and limits to a transition to “residential” or “presential” economies.
- ▶ Energy, ecological, budgetary “footprints” etc. and in terms of the mobility of different urban forms: how to manage the transition to large urban regions?
- ▶ Age and housing policy (services to care-dependent persons, multi-generational housing...)
- ▶ E-government or e-administration: what impacts on services, local democracy and mobility?
- ▶ Multi-flow networks and urban planning: how should public transport, cars, pedestrians and bicycles share a space?
- ▶ What scope for manoeuvre exists in response to urban fragmentation: effectiveness of the various conceivable tools (real estate, fiscal measures, urban and transport policies, location of public services etc.)?

Figure 5a – Issues for Action Prioritized by the Expert Workshops				
Rank	Transport	Score	Land Use Planning	Score
1	Limitation of CO <sub>2</sub> and greenhouse gases EE	29	Adaptation to ageing (and to the demographic differentiation of areas) LV	31
2	Reduction of vulnerability to oil EE	27	Entering the knowledge economy: local dynamics of innovation and training, competitiveness clusters etc. NICT	24
3	Reorganization of trade associated with the emergence of India and China and with the transformations of the “Global Factory”. Adaptation of transport to the new international division of labour EG	23	Territorialization of public services SI	22
4	Global and European competitiveness of constructors, component manufacturers and logistical services EG	19	Attractiveness of “France as a location” and of the major metropolises EG	22
5	Capacity of Europe to regulate the “European Transport Space” effectively EG	18	Anticipation of the consequences of globalization (increased spatial inequalities, transfer of production abroad, vulnerability of areas of mono-activity) EG	22
6	Financing and pricing of local or regional public transport (urban tolls, regional express trains etc.) EFI	17	Sustainable mobility policies: development of alternatives to road transport, limiting the use of polluting forms of transport, anticipating increased transport costs EE	21
7	Relations between the urban centre and periphery. Design of transport systems at the large-territory level SI	17	Adaptation areas to climate change, to the risks of oil shortage and to the new energies EE	17
8	Development and control of motorized transport in the emerging countries EG	16	The structuring of the European “greater regions” (and of trans-European networks) EG	17
9	Regard for the needs of ageing, vulnerable and disabled groups LV	16	Emergence of genuine regional powers IG	16
10	Prevention of the risks of social exclusion and inequalities linked to future decisions RHS	14	Protection of the most desirable spaces in the face of “de-structuring” pressures on transport (pricing, carbon tax etc.) (e.g. coastal areas) EE	16
<b>Legend</b> Sectoral Issues: SI      Europe and Globalization: EG      Demography: D Economic and Financial Issues: EFI      Energy/environment: EE      Institutions, governance : IG Risks, Health, Security: RHS      Lifestyles and values: LV Technology, Research, NICT (new information and communication technologies): NICT				

environments, coastal areas and, lastly, the sea and maritime transport. In this case, the privileged access is sectoral. Eight thematic workshops, made up of “specialists” were tasked with identifying, field by field, the broad trends or possible developments in the period to 2020-2030, together with the uncertainties or radical breaks that may be envisaged, in such a way as to be able to formulate priority issues for action (see figures 5a and 5b), in order to address a series of questions to scientific research. Not being able to analyse the results of each of these workshops in detail, we shall confine ourselves here to presenting a description that cuts across the various different areas and is, as a result, somewhat reductive.

**Figure 5b – Issues for Action Prioritized by the Expert Workshops**

Rank	Housing and Construction	Score	Cities and Urbanism	Score
1	Control of energy consumption and development of renewable energies EE	35	Organization of metropolitan power (and of the relations between “communes” [the smallest French administrative division] and their peripheries) IG	26
2	Poverty and access to housing for the most deprived (right to housing) S	29	Prevention of the risk of “suburban banishment” S	24
3	Maintenance, management and renovation of the existing housing stock SI	26	Combating urban segregation (and inequalities between districts) S	24
4	The Economy of Housing and Land Policy. Access to housing for the middle classes EFI	26	Structuring urban regions and conurbation tions with a view to sustainable development (control of sprawl, creation of secondary centres, mixed-use development) EE	23
5	Sustainable building and housing (high environmental quality [HEQ], ecodistricts, semi-dense housing, materials recycling etc.) EE	25	Capacity of the cities to attract the “new creative classes” and become . major hubs of innovation EG	23
6	Linking of housing policy to transport and urban planning policy IG	24	Local Provision for the excluded the poor and the insecure (access to essential services) S	20
7	Adapting housing supply to the ageing of the population LV	20	Anticipation of the ageing of the population (and old-age policies) LV	18
8	Fresh impetus for innovation in future materials and in building and civil engineering techniques NICT	18	New paradigm for the organization of cities in respect of climate risks of oil shortages (and local energy policies...) EE	18
9	A social mix in housing and combating urban segregation S	18	Promotion of the “European model of excellence” for medium-sized and intermediate towns, combining innovation, knowledge economy and quality of life SI	17
10	Housing policy and the future of social housing S	17	Local policies of “sustainable mobility” reconciling the reduction of pollution, the development of “ways to” and equal access to mobility EE	17
<b>Legend</b> Sectoral Issues: <b>SI</b> Europe and Globalization: <b>EG</b> Demography: <b>D</b> Economic and Financial Issues: <b>EFI</b> Energy/environment: <b>EE</b> Institutions, governance: <b>IG</b> Risks, Health, Security: <b>RHS</b> Lifestyles and values: <b>LV</b> Technology, Research, <b>NICT</b> (new information and communication technologies): <b>NICT</b>				

From the analysis of the approx. 300 trends suggested in these thematic workshops, whether common or specific to the various fields, a rather paradoxical view of the last thirty years ultimately emerges.

On the one hand, the experts hypothesize a certain slow-down of the dynamics seen in France in the last half century, be it in demographics, the rate of economic growth, the size of cities or the development of mobility. It is entirely as though, on a multiplicity of different levels — pace of growth, male and female activity rates, level of urbanization, importance of the Île-de-France among the regions, level of household car ownership — the dominant trend was a plateauing-out. Even in the field of ICT (Information and Communication Technologies), mention is made of the idea of the “beginnings of saturation” or, rather, a “coming to maturity” from 2015 onwards. Hence

the importance granted to the idea of “existing stocks”: the management of the “existing housing stock” and the heritage, problems of maintenance and upkeep, the rebuilding of towns and cities on their own sites, the recovery of brown-field sites, the “intelligent exploitation of infrastructures”, the memory of technical skills etc. Hence also the frequently advanced argument of an “increase in complexity” or “the vulnerability of increasingly interconnected technical systems”, lines of reasoning which are often accompanied by another that stresses the need for a more efficient management of “interfaces”.

In another perspective, however, and despite these conservative hypotheses, the same experts take the view (this was in 2004) that the next thirty years will see a radical discontinuity from the preceding decades. The radical changes mentioned, in understandably varying proportions, may be grouped schematically around eight major developments:

1. the accelerated transition to a “post-industrial” economy in which production is de-coupled from design and bringing to market;
2. a shift in the centre of gravity of the global economy to Asia and the probable emergence, in what is now a multipolar globalization, of a major economic bloc including the United States, India and China;
3. the extension of ICT and virtual technologies to all areas of work and daily life;
4. the return of the question of resources as the central issue in economic development — after a period in which it had “dropped out” of collective concerns;
5. climate transition;
6. an ageing population and generational conflict;
7. institutional transition;
8. an aggravation of social segmentation and the transition to a society based on the individual and on “association with one’s own kind”.

These elements are confirmed generally by foresighters,<sup>11</sup> who see the combination of globalization, North-South demographic disequilibria, the information society, the crisis of the state, and territorial break-up — not to mention climate and energy change — as already indicating that the coming decades will represent a radical break with the past. The dominant feeling is that the main radical changes we shall be confronted with over the next twenty years are, in essence, already present. But agreement gives way to controversy as soon as it comes to saying which scenario of change will prevail.

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11. Of the 300 potential radical breaks mentioned in the various workshops, some 50 items — selected for their cross-disciplinary character and apparently significant impact — were submitted, in questionnaire form, to a hundred foresight specialists for their assessment. A specific treatment of the results of this survey (the distribution of degrees of probability and levels of impact ascribed to each radical discontinuity) is available in the published report, *Agora 2020*, *op. cit.*

And when questioned on the development of the economic system, the institutional architecture, territorial dynamics or social preferences, foresight specialists ultimately turn out to be much more cautious than the participants in the thematic workshops.

In these circumstances, it is understandable that the priorities for action at which the expert workshops arrive are essentially expressions of dynamics that are in the ascendant globally. In most fields of activity, the increasing impact of external determinations finds expression in a shift in the traditional scope for manoeuvre towards wider ranges of intervention, less characterized than before by sectoral logics. Beyond their clear diversity, the questions for research produced in these workshops demonstrate, in particular, the need to introduce discontinuity into the research programmes and embark on a thoroughgoing study of perspectives for radical change and development that branches off in new directions.

## *Translating Divergences into Complementarities: 12 Key Messages*

How are these different viewpoints to be reconciled? One of the main ideas of Agora 2020 is, as we have said, to identify social demand at an intermediate site, in a space of dialogue between the world of research and the full range of society's constitutive elements. But the fragmentation of expectations coming out of the consultation is such that a supplementary stage seems necessary, in which we move from grasping divergences to apprehending complementarities. And to do so, we have to begin by seeing in what respects the respective expectations and experience of the "experts", the "actors" and the "general public" differ so markedly.

Where the experts are concerned, at stake principally are "dysfunctions". Their main reference is to what they regard as situations, phenomena or factors of "disequilibrium". Whether looking at one particular component, the overall plan or some particular (urban, institutional, productive, ecological etc.) "machinery", most of them are concerned with "systems", the current operation or long-term viability of which have to be evaluated, improved or modified. It is for analysis to show up their anomalies, effect their improvement or propose their replacement. In a sense, the experts' vision teaches us primarily what threatens — or, alternatively, is likely to promote — the internal coherence and effectiveness of the specialist forms of expertise. Expressing logically distinct (technical, legal, organizational, budgetary or scientific) needs, their concerns are stated as so many *découpages*, attentive to the independence of the different bodies of knowledge: the financial equilibrium of a particular sector of activity; matching the aims of a particular policy to its outcomes; harmonizing a particular technical system; stabilizing a particular physical situation (the climate, ecosystems etc.).

What emerge from the needs expressed by the established actors (local authorities, public administrations, companies, voluntary organizations) are

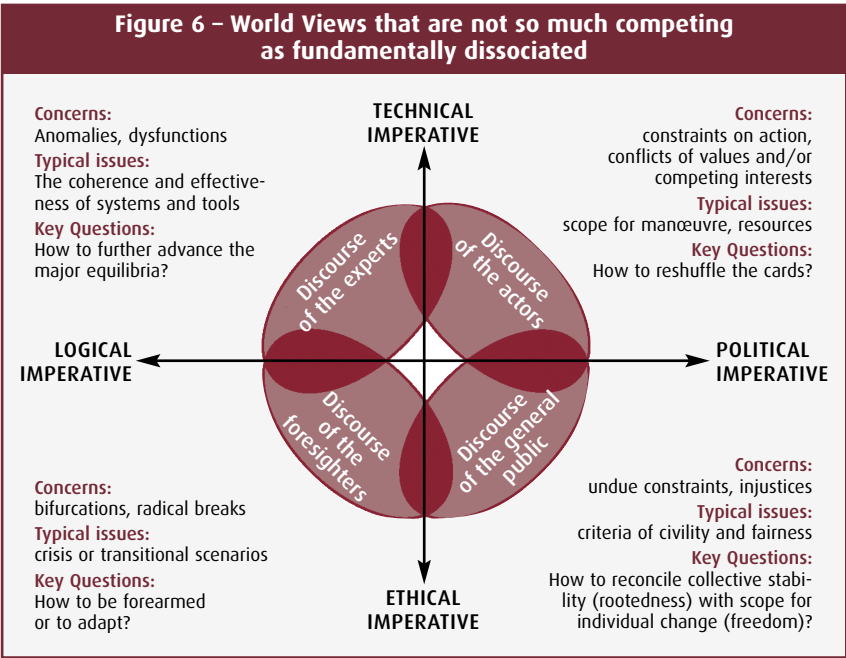
other necessities. Not that they deny the pertinence of the scientific models whose vocabulary they sometimes borrow, but they use these as interchangeable resources that are not designed to constitute autonomous issues. Despite their heterogeneity, the imperatives of the elected politician, the company or voluntary organization manager and the higher civil servant converge, in that they are, most often, defined in relation to each other. This “play of cross-reference” itself fits into a view of action characterized by the urgency with which acceptable solutions have to be found to problems that are already identified or short-term in nature.<sup>12</sup> In terms of research, this translates either into very specific demands that are closely linked to some particular activity or into “generic” needs, associated with short-term management or innovation: general assessments, models, evaluation or management tools, market research into existing technologies, impact analyses etc. This is a position almost symmetrical with that of the experts.

In contrast to the previous two groups, the sample questioned as the “general public” does not see the future as the sum of independent or competing variables. What seem, at first sight, to be antinomic expectations (e.g. “more oversight and fewer constraints”) arise out of practical or moral necessities, which daily experience often prevents them from dissociating. By the standards of the categories of logical modelling or organized action, the expectations expressed by the social world are striking for their cross-disciplinary character. We have in mind particularly the theme of security, which is irreducible to institutional or statistical compartmentalization. The term “security” simultaneously covers the demand for physical protection, for economic stability and for social insurance, together with the need to root in a common core, identities that aspire to a state of multiple belonging. The discourse of the general public, which is naturally more marked than the others by the practical necessities of daily life, is distinct also from that of the “actors” or “experts” in its generalizing, “moral” and temporally diffuse character. The paradox is that the general public’s vision shows itself, ultimately, to be less fragmented than that of all the other groups consulted.

Each of these three viewpoints commands authority in its field: the legitimacy of knowledge and functional pertinence lie with the experts; residents have the legitimacy of hands-on experience and the pertinence of the lived space; the legitimation of action (or of markets) and the pertinence of the institutional or productive territory lie with the “actors” and the professionals. Beyond a form of routine competition, the general public, the experts and the actors are unaware of each other, whether or not their views are opposed or in agreement. For example, none of the themes suggested by the general public appears on the experts’ list and vice versa. To acknowledge this is to

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12. For example, “public support for the competitiveness of economic actors” versus “social and environmental responsibility of companies”; “recognition of the role of the voluntary sector” versus “institutionalization of their modes of action”; “independence of local authorities” versus “funding guarantees (criteria of financial means, criteria of objectives)”; “reform of the state” versus “effective application of the new regulatory mechanisms” etc.



leave aside a whole series of oppositions in which the “scientist” is set against the “layman” or the “entrepreneur” against the “consumer”. Where the debate is usually about the various types of hierarchy to be established between particular points of view, we shall stress, rather, the autonomous nature of viewpoints and the possibility of granting each vision expressed its proper

**Figure 7 – Building Complementarities: the Example of the Oil Crisis and the Greenhouse Effect**

<p><b>DISCOURSE OF THE EXPERTS</b></p> <ul style="list-style-type: none"><li>▶ Prepare for extreme events</li><li>▶ Study more fully the role of the oceans in climate change</li><li>▶ Get ready for the transition to non-oil-based cities and transport</li><li>▶ Lower energy consumption in old housing</li></ul>	<p><b>DISCOURSE OF THE ACTORS</b></p> <ul style="list-style-type: none"><li>▶ Develop viable, acceptable political strategies in a context of major climate and energy uncertainty</li><li>▶ Find preventive and adaptive scenarios, on the basis of technological (environment, energy) and also socio-economic (urbanism, behaviour) innovations</li><li>▶ Have the French economy specialize in the “sustainability industries”</li></ul>
<p><b>DISCOURSE OF THE “FORESIGHTERS”</b></p> <ul style="list-style-type: none"><li>▶ Anticipate the highly probably radical changes and crises related to the acceleration of climate change and the rapid exhaustion of oil and non-oil resources (raw materials...)</li><li>▶ Think through the relationship between oil crisis and climate change</li></ul>	<p><b>DISCOURSE OF THE GENERAL PUBLIC</b></p> <ul style="list-style-type: none"><li>▶ Wider use of clean, renewable energies</li><li>▶ Build housing that adapts to climate change</li><li>▶ Create convergence between domestic ICT and innovation in the “biotechnology” and “biomaterials” fields</li></ul>

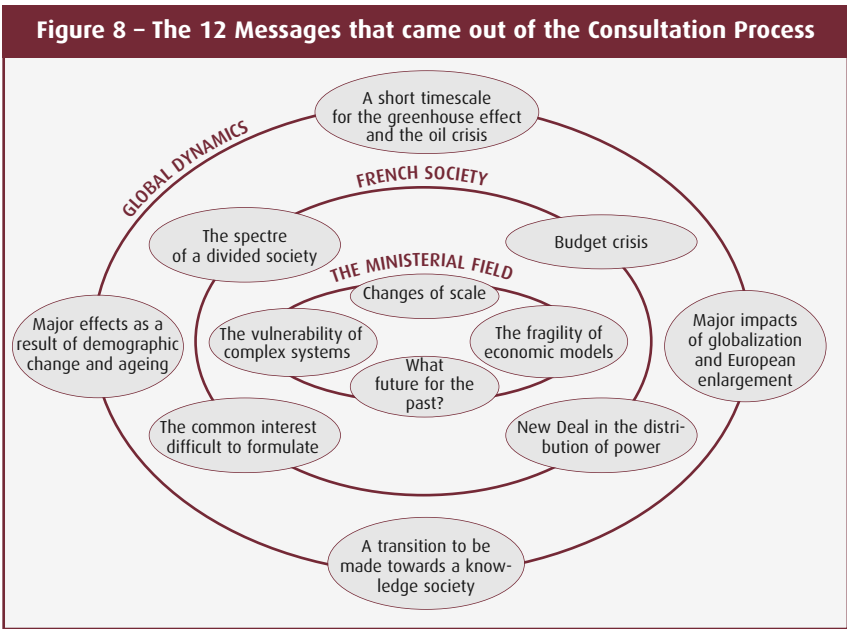


degree of independence. This desire to dissociate so as the better to combine is illustrated diagrammatically in figure 6.

The advantage of this representation in four distinct quadrants is also that it shows that the “centre” of all these discourses does not lie at their intersection and that the – partly empty – area of greatest consensus is not a clear given. Hence the construction of complementarities consists in effecting translations between dissociated spheres. And it was precisely this work of transition from one world view to another (see, for example, figure 7) that enabled us to arrive at the dozen key messages (figure 8) which, in the end, characterize the intermediate platform, or common core, of social expectations formulated throughout the consultation and available in the form of more than a thousand “questions for research”. This result, which emerges directly from the consultation, is summarized very schematically in three overlapping circles, whose respective circumferences cover the main external determinations, the fragilities peculiar to French society and the problems specific to the field of the consultation.

## From Questions for Research to Research Questions

Given all this, how is this intermediate set of key messages and questions addressed to the world of research to be transformed into a series of programmes and lines of research? How — and this is our second detour — is the scientific community to be mobilized, and how are its activities to be



confronted not only with the common core of questions, but also with the content of the thousands of questions garnered in the course of the consultation? Agora 2020's approach was to proceed in two phases. In a first stage, the aim was to structure this confrontation around 15 cross-disciplinary research themes. Then, in as many participative workshops, in a second stage the researchers themselves were invited to take on board the "questions for research", mapped out for the occasion, and translate them into a small number of "preliminary guidelines for programmes".

## ***An Original Contribution to the Traditional Disciplinary Sectoral Approach***

It is not an obvious approach to take a series of questions for research as a starting point. Most comparable exercises — particularly foresight studies or their equivalents<sup>13</sup> — develop most of their thinking from the accepted scientific and technical facts. Though, from the standpoint of research activities, beginning with questions directly originating in the social world may seem some sort of constraint, it also represents an original contribution to the traditionally disciplinary and/or sectoral organization of knowledge.

Responding to a social expectation almost always requires a simultaneous contribution from several disciplines, ranging from the basic sciences to engineering, by way of law, economics or geography (to mention only the commonest). It is difficult, for example, to provide an adequate response to the question "What transition to a hydrogen economy?" (figure 9), without taking a simultaneous interest in the technological potentials or obstacles, the organization of supply networks, market conditions, security norms, mobility, public policies etc.

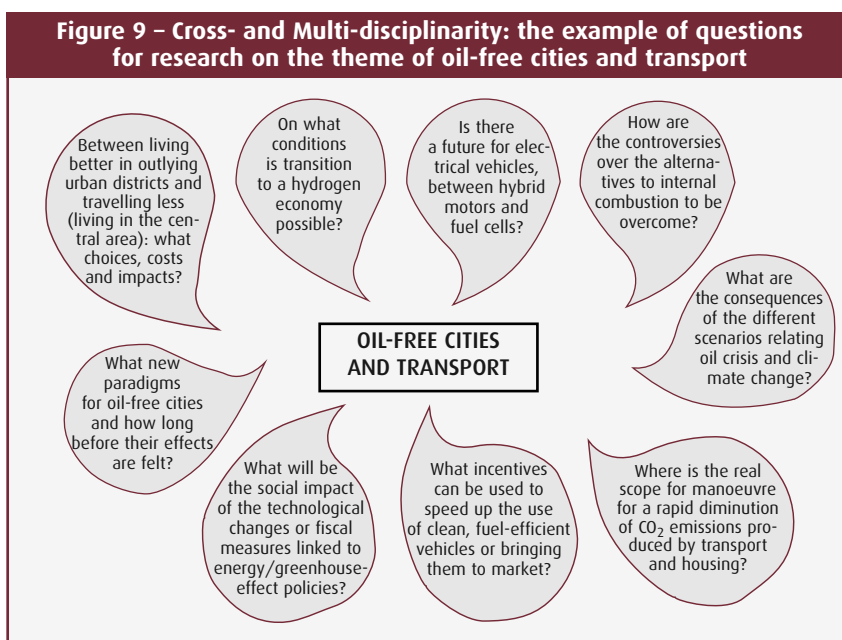
It is difficult, also, particularly because of the importance of "exogenous" issues, not to be interested in a wide range of sectors (the impact of globalization, the use of generic technologies etc.), in the interfaces between research fields (the relations between urbanism, transport and the greenhouse effect), or in scientific developments that have cross-disciplinarity as their trademark (integrated modelling).

## ***A Cross-Comparison Structured by 15 Priority Themes***

The use of a prior structuring into 15 broad cross-disciplinary themes is justified on practical as well as theoretical grounds. It is a division that enables us, first, to keep the basic corpus within reasonable limits: fewer than a hundred or so questions per workshop. More fundamentally, it introduces a framework of multi-disciplinary dialogue. Not all questions for research are appropriate for translation into research questions. But those that find

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13. See, for France, the *Key Technologies* study, sponsored by the Ministry of Industry.



a scientific or technological echo call, as we have just seen, for a combination — if not indeed a displacement — of traditional research approaches.

Running closely in parallel with the key messages, the 15 priority themes are not derived mechanically from these questions. They are to a greater or lesser extent, attached to particular disciplines and vary in their relationships to technological innovation or expertise. The work of consolidation involved can be seen from three examples.

The first is the simplest: this is where a theme flows directly from one of the major messages emerging from the consultation. It brings together a series of prior areas of work, necessitating, more than in other cases, a multi-disciplinary, multi-sectoral cross-fertilizing of the available approaches. Four themes fall into this group:

- “territories and flows in the expanded Europe and globalization”
- “ageing, health, disability”
- “towards a knowledge society”
- “What future for the past?”

The second case covers issues that are very much “all-encompassing”, but so heterogeneous that a division into two distinct themes seems desirable. Despite that division, each of the priorities obtained in this way continues, nonetheless, to call for the full range of possible approaches. This is, as a

result, the privileged site of the interface between the human, physical and engineering sciences. Considerable scope is thus given to experimentation: as a meeting ground between designers and users, or between fundamental and applied science or knowledge. From four initial messages we came to the following eight themes:

- “adapting to climate change”;
- “oil-free cities and transport”;
- “living together in a segmented, multicultural society”;
- “poverty, insecurity, marginality: access to ‘essential goods and services’”;
- “the vulnerable society”;
- “the viability of territorial systems: ‘models and complexity’”;
- “technologies, time, speed and accessibility in 2050”;
- “the metapolis: ‘city living outside cities’”.

The third case is the opposite of the previous one. Here, the grouping of messages corresponds to the disciplinary filter with, on the one hand, an approach in terms of political sciences and, on the other, an economic input. This construction rests, nonetheless, on the hypothesis of a twofold knowledge-transfer: between different sectors of application (the city, housing, transport etc.) on the one hand, and from the academic world to concrete action systems (research-action) on the other. Two themes emerge from this:

- “the ‘production of the common good’”;
- “the viability of sectoral economic models”.

Finally, complementary to these priorities, which all emerged from the common platform of expectations expressed by the range of actors surveyed as a whole, a last theme has been added, in order to cover a more specific concern, but one that is crucial for the general public. This exception gives rise to the fifteenth and last theme:

- “Better daily life in the city”.

## ***A Translation into 75 Preliminary Research Axes***

Lent structure by these 15 themes, the whole range of questions for research have, then, to make the journey from the social world to the scientific. There follows a process of translation that is begun as a long work of mapping and continues in participatory workshops open to the leading figures from the world of research — the scientific directors of the major industrial groups, officials from the public research bodies or objectives-based agencies, leaders of incentive programmes, regional correspondents, laboratory directors, researchers etc.

This long process of translation into preliminary research axes, which is more repetitive than it is transparent, can be summed up very schematically in the form of two questions:

- For each of the themes under consideration, what are the emerging research fronts and to what extent do they correspond to the questions coming out of the Agora 2020 consultation?
- From the standpoint of the scientific community, are the lines of research drawn from the mapping exercises meaningful and, if not, how could they be reformulated or supplemented?

Given the number of people involved in such a process, it is unfortunately impossible to form a precise idea of the transactions successively carried out to arrive at the final result. But we may, nevertheless, observe that more than three-quarters of the lines of enquiry that emerge from the mapping phase — and hence from the consultation — receive validation. Here again, the future-oriented character of the exercise seems to militate in its favour, since an adjustment can be made in the medium term between research “supply” and “demand”, without denying the gap that exists between current research provision and the detailed form of these 75 lines of enquiry (see figure 10).

## ***From Foresight to Research Strategies: The Limits and Scope of Agora 2020***

It was clear from the beginning that Agora 2020 should not limit itself to being a listening exercise, but that the proper aim was to build a strategic tool that would produce precise thematic priorities and recommendations applicable to the organization of research.

In these conditions, the exercise could not end with a list of 75 programme proposals, even augmented with explicit research questions, and this is why much time and energy have, subsequently, been spent on producing a strategic analysis of these programme orientations and extracting from them a shortlist of themes to be addressed as priorities.

Even if the “messages” issuing from this last stage are, as we shall see, relatively explicit, the reception of those messages is not, of course, independent of the context and time of their publication. Launched in 2004 by the then Ministry of Infrastructure, Housing, Territorial Administration, Transport and Tourism, the Agora 2020 exercise was presented to the public in a completely changed context, characterized both by a total upheaval within the landscape of research and by the “Grenelle Environmental Summit” (accompanied by the creation of a new ministerial structure that united Energy, Environment, Territorial Administration and Infrastructure under the banner of Sustainable Development).

**Figure 10 – The 75 Preliminary Research Axes arising out of Agora 2020**

<b>1 - Oil-free Cities and Transport</b>		
1	1A	Society's vulnerabilities to a major oil crisis
2	1B	New paradigms for the organization of activities, towns and cities, and mobility
3	1C	Energy-efficient housing
4	1D	Development of new carbonaceous fuels (including biofuels)
5	1E	Towards a hydrogen-based society: removal of the technical/socio-economic obstacles
6	1F	Electric propulsion: batteries, multi-motorization and distribution networks
7	1G	The heavy-goods vehicle of the future (including the lorry)
<b>2 - Adapting to Climate Change</b>		
8	2A	Assessment of vulnerabilities to catastrophic events
9	2B	Territorialization of the impacts of climate change and strategies for the local actors
10	2C	Adaptation of the built environment and urban areas to climate change
11	2D	Impacts of climate change on river systems and water management
12	2E	Vulnerability of coasts to climate change
13	2F	Vulnerability of the southern countries to climate change and the impact on North-South relations
<b>3 – What Future for the Past?</b>		
14	3A	Deciding between the claims of past, present and future, and strategies of heritage designation
15	3B	Issues, economy and technologies of maintenance and monitoring
16	3C	From urban renewal to the management of housing stocks
17	3D	Buildings life-cycles: from design to recycling
18	3E	Memories of the present: conserving and exploiting the non-material heritage
<b>4 – Living Together in a Segmented, Multicultural Society</b>		
19	4A	Immigration policies and local development
20	4B	Mechanisms of urban segregation
21	4C	Integration, the right to difference or community ascription?
22	4D	Issues in, and forms and sites of, urban socialization
23	4E	Insecurity, incivility and prevention policy
<b>5 – The Production of the Common Good</b>		
24	5A	The public space as a space of interests: towards new forms of mediation?
25	5B	Multi-level government
26	5C	Rationality and clarity of public decision-making
27	5D	Principles and norms of the common good
<b>6 – Territories and Flows in the Expanded Europe and Globalization</b>		
28	6A	Economic and geopolitical dynamics of globalization
29	6B	Logistics and transport systems and their relation to the new geography of European and global flows
30	6C	Attractiveness and competitiveness of territories and inequalities between them
31	6D	The territorial challenges of European integration
32	6E	Dynamics and impacts of global tourism
<b>7 – Towards a Knowledge Society</b>		
33	7A	Knowledge engineering, design tools and professions
34	7B	Interactive democracy, new technologies to aid in consultation
35	7C	Integration, management and use of geolocalized data
36	7D	Geographical information markets, satellite applications and innovative services
37	7E	The digital city
38	7F	The cognitive divide, employment and inequalities

<b>8 – The Vulnerable Society</b>		
39	8A	Vulnerability of territorial systems: what overall approach?
40	8B	Dependability and failsafe operation of major socio-technical systems
41	8C	Assessment, negotiation and ranking of risks and vulnerabilities
42	8D	Surveillance and/or punishment? From security systems to security policies
43	8E	The insurance paradigm: between responsibility and “welfare”
<b>9 – Ageing, Health, Disability</b>		
44	9A	New urban forms of the demand for autonomy
45	9B	Scales and territorial range of ageing
46	9C	Ageing and life-cycle policy
47	9D	The healthy city: from public health to quality of life
48	9E	Road safety for the vulnerable
<b>10 – The Metapolis: “City Living outside Cities”</b>		
49	10A	From metropolises to metapolises: demographic and economic dynamics
50	10B	City living outside cities: housing, lifestyles, mobility
51	10C	Designing and organizing transport systems on the scale of the urban region
52	10D	Structuring the metapolises with a view to sustainable development
<b>11 – Poverty, Insecurity, Marginality: Access to Essential Goods and Services</b>		
53	11A	Governing through the margins? Logics of social support and inclusion
54	11B	Access to essential services for the underprivileged: universal services, individual users
55	11C	The “exclusion system”
56	11D	Crisis mechanisms in access to housing
57	11E	The new frontiers of insecurity
<b>12 – Technologies, Time, Speed and Mobility in 2050</b>		
58	12A	Mobility, uses and value of time, speed
59	12B	New concepts of intelligent, fluid and seamless mobility?
60	12C	The future of very high speed transport
61	12D	Automatic transport and guided systems: the only way to combine speed, safety and energy efficiency?
62	12E	Control of speed and the future of “slow modes” of travel
<b>13 – The Viability of Territorial Systems: “Models and Complexity”</b>		
63	13A	Steering and engineering complex projects
64	13B	Multiscale governance of sustainable development: from the global to the local
65	13C	Modelling and viability of urban systems
66	13D	Design of eco-districts
67	13E	Integrated management of coasts and coastal zones
68	13F	Dynamics of local development and urban economy
<b>14 – Better Daily Life in the City</b>		
69	14A	Accessible, attractive, liveable cities: quality of life criteria and innovation dynamics
70	14B	Comfort, quality and safety of urban travel
71	14C	Future of the housing stock and access to housing
72	14D	Quality of the urban environment (noise etc.): issues, standards and policies
<b>15 – Economic Models</b>		
73	15A	Economic models for information and public data
74	15B	New industrial, economic and financial models for sustainable transport
75	15C	Foresight assessment of “critical” resources for the construction, civil engineering and transport sectors in conditions of globalization

The purport of the document found itself very clearly changed by this: more than a strategic work of reference, what we have today is a resource that can be drawn upon for multiple uses, ranging from the management of targeted research bodies to the design of highly circumscribed programmes.

## *Unambiguous Strategic Conclusions*

The consultation gave rise to 75 programme proposals, which had necessarily to be ranked. Each was characterized as precisely as possible in terms of disciplinary and technological content, intensity of demand, and the potential capacity of the “supply” of research to respond to that demand.<sup>14</sup>

From this analysis, a hierarchy of four families of programmes with clearly differentiated profiles was identified:

- the “obvious choices”, which received the backing of the various actors, for which research provision is already highly structured;
- the “no pressure” group, which correspond to a relatively low level of demand and an equally moderate level of provision, and which are in search of possible takers;
- the “dilemmas”, characterized by contradictory criteria, which, as a result, call for negotiations and trade-offs between actors (the example of hydrogen);
- the “nuggets”, which combine a high level of demand, a low level of research provision and sufficient scientific or technical feasibility.

The major recommendation of *Agora 2020* is, of course, to invest as a priority in the fifteen programmes that correspond to this “nugget” category (see figure 13). But the thematic recommendations that conclude the exercise relate also to all the other “families” of research axes:

— in the case of the “obvious choices”, the point is to reinforce the existing dynamics by making the relevant programmes into domains of excellence at the international level (possibly in association with other European countries);

— in the case of the “no pressure” group, the aim is rather to ensure a monitoring of demand, while anticipating the emergence of new take-up or new opportunities;

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14. It is on this basis, and on the basis of a SWAT analysis carried out with the scientific community, that it has been possible to effect a classification combining six criteria: the intensity of overall demand (socio-economic benefits); demand from the general public; market prospects (and the existence of a national economic base); current research provision in France; the match between that provision and the questions raised by *Agora 2020*; and, lastly, the scientific and technical feasibility of the programmes proposed.



**Figure 13 – The Nuggets. 15 Themes for Priority Investment**

Four Environmental Axes	
2A	Assessment of vulnerabilities to catastrophic events
2C	Adaptation of the built environment and urban areas to climate change
10D	Structuring the metropolises with a view to sustainable development
13D	Design of eco-districts
Three Economic Competitiveness Axes	
6B	Logistics and transport systems and their relation to the new geography of European and global flows
8B	Dependability and failsafe operation of major socio-technical systems
15B	New industrial, economic and financial models for sustainable transport
Six Social or Societal Axes	
9A	New urban forms of the demand for autonomy
10B	City living outside cities
11B	Access to essential services for the underprivileged: universal services, individual users
8D	Surveillance and/or punishment? From security systems to security policies
11D	Crisis mechanisms in access to housing
14B	Comfort, quality and safety of urban travel
Two Cross-Disciplinary Axes	
7E	The Digital City
10C	Designing and organizing transport systems on the scale of the urban region

— lastly, in the case of the “dilemmas”, supplementary assessments are suggested, either to analyse the scientific or technical obstacles that exist in these cases and the conditions for overcoming them, or to produce a more thorough study of the costs and benefits of each programme.

The strategic recommendations have been clearly spelled out, then, for all the research “axes” that emerged out of the consultation.

## *A Need for In-depth Adaptation of French Research*

Thoroughgoing adaptations of the way research is currently carried out will be needed if these conclusions are to be implemented. This applies both to the structuring of research provision and to the operation of incentive programmes and of the processes for mediating demand. The analyses contained in the last part of *Agora 2020* show up substantial discrepancies between the expectations arising out of the consultation process and current research provision – at least as organized in France.

This discrepancy is, in the first instance, “quantitative”: only a third of the programme axes mentioned above are actually properly covered by research. And almost twenty or so of them may be regarded as completely neglected (see figure 14).

**Figure 14 – 19 Neglected Themes**

1B	New paradigms for the organization of activities, towns and cities, and mobility
6E	Dynamics and impacts of global tourism
10C	Designing and organizing transport systems on the scale of the urban region
15A	Economic models for information and public data
1A	Society's vulnerabilities to a major oil crisis
1G	The heavy-goods vehicle of the future
2A	Assessment of vulnerabilities to catastrophic events
2B	Territorialization of the impacts of climate change and strategies for the local actors
4A	Immigration policies and local development
4D	Issues in, and forms and sites of, urban socialization
5C	Rationality and clarity of public decision-making
6D	The territorial challenges of European integration
8A	Vulnerability of territorial systems: what overall approach?
9B	Scales and territorial range of ageing
11A	Governing through the margins? Logics of social support and inclusion
12C	The future of very high speed transport
13C	Modelling and viability of urban systems
14A	Accessible, attractive, liveable cities: quality of life criteria and innovation dynamics
14B	Comfort, quality and safety of urban travel

However, the discrepancy is also — and perhaps primarily — qualitative. Whereas the great majority of programme axes presuppose cross- or multi-disciplinarity, risk-taking, interfacing between technology and the social sciences, or an international perspective, the trends at work in the structuring of research favour disciplinary narrowing, separation between technological research and research in the human sciences, a vertical structuring of programmes and low levels of risk-taking – and observation and demonstration activities are still awaiting recognized scientific status. Quite clearly, these constitute major obstacles to engagement with the questions for research expressed through *Agora 2020*.

If we add to this the maladjustments, mentioned at the beginning of this article, in the programming processes themselves, it is no surprise that the consultation led, ultimately, to a very great number of recommendations concerning the organization and structuring of the research institutions. As examples, we shall cite the following:

— establish “quotas” for high-risk research within every targeted programme (on the themes assuming radical discontinuity);

— within the domain of *Agora 2020*, create explicitly multidisciplinary institutes on, for example, the territorial applications of the sciences of complexity (viability and vulnerability of territorial systems);

— give a recognized scientific status to observation and to the researchers working in that field;

— create “thematic portals” enabling the researchers and laboratories involved in *Agora*’s 15 main themes to be networked;

- extend strategic scientific monitoring to strategic societal monitoring and organize the connections between the two better;
- give a specific place to “users” in the steering bodies of the incentive programmes or targeted research bodies, and create the possibility within these structures for a “governance” in separate colleges (in the manner of the “five-handed” governance in the Grenelle Environmental Summit);
- draw on the “Swiss model” for managing targeted research programmes (putting emphasis on both the co-construction of questions for research and on the ex-post assessment of the answers provided by the researchers);
- develop research programmes centred on discontinuities and the anticipation of such radical breaks;
- and, lastly, move from the exploitation of research to the establishment of genuine “knowledge markets”, making it possible, through effective, on-going forms of mediation, for collaboration between those with responsibility for collective goals, groups of innovators, expertise and training resources, research laboratories and research providers sharing a similar concern to find innovative solutions to regional or societal challenges.<sup>15</sup>

## *A Resource rather than a Strategic Reference*

As with any foresight study, and all the more with an exercise as substantial as Agora 2020, the central question is how it is — or might be — followed up. If the socio-economic developments we have seen in the last three years (crisis in the *banlieues*, a fourfold increase in the oil price) have merely confirmed the urgency of the concerns expressed in the consultation, the institutional context has, for its part, changed totally since the project was launched. This upheaval is clearly a major determinant of how the results of the exercise will be used.

With the establishment of both the new Ministry of Sustainable Development and the Grenelle Environmental Summit, Agora 2020 can no longer be a strategic reference, even if the study had very largely anticipated this structural change, and if the priorities proposed, in the end, very much complement those of the “Summit”.<sup>16</sup> On the other hand, the consultation remains an irreplaceable resource for the laboratories, bodies or programmes that are active in, or developing activities in, all the fields it aspired to cover. Moreover, this resource has already been used concretely in the design or restructuring of certain incentive programmes: the Urbanism, Construction Architecture Programme (PUCA), the Programme for Transport Research (Predit 4), the National Research Agency’s “Sustainable City” Programme,

15. Such as we have seen in the city of Gothenburg.

16. Of the 75 programme axes proposed, almost 60% cover the priorities defined in the “Research” component of the Grenelle Environmental Summit.

the Marne-La-Vallée research cluster etc. And many other development are currently envisaged, extending beyond the fields or geographical limits currently covered — in the field of health, for example, or at the European level.

Agora 2020 was based on three uncertain propositions: that a detour through “social demand” could produce interesting questions for research and innovation; that an exercise in scientific and technical foresight could be successfully connected to sectoral issues; and that a genuine dialogue could be built up between social actors and the scientific community around the co-production of common questions. Retrospectively, we may say that all these propositions have been shown to hold good. The future will tell whether the message of trust in research and its future, expressed by all the actors consulted, including the “general public”, will or will not be heard.