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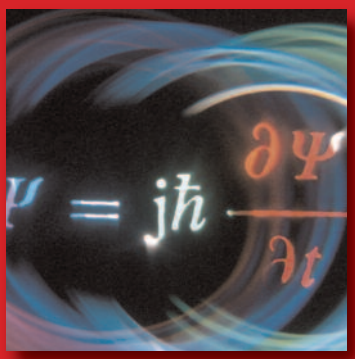
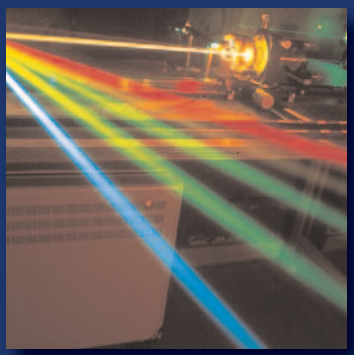
National Research and Innovation Strategy





2010

MINISTRY FOR HIGHER EDUCATION AND RESEARCH

MINISTÈRE
DE L'ENSEIGNEMENT SUPÉRIEUR
ET DE LA RECHERCHE

National Research and Innovation Strategy

2009

General Report

Foreword

At the dawn of the 21st century, our society faces new and urgent challenges. Research and innovation represent the first steps to be undertaken to come out of the current economic downturn. Tougher competition and the arrival of new world players leave us with no other alternative but to invest in the future through the development of research and innovation.

The "green" revolution is no longer just a burning obligation: environmental urgency is on our doorstep and the effects of climate change are now visible. Our growth model has to be reinvented and we will only achieve this by investing in green technologies and clean energy sources. This implies that we must commit ourselves on changing of our life styles completely. We can imagine today what tomorrow's world will be like: where the incessant noise of our cities will have stopped, where pollution will be controlled and biodiversity restored, where products will be followed throughout their lifecycle from the drawing board to the recycling plant, where the weak dependence on non-renewable raw materials for growth and employment will have alleviated the geopolitical tensions that currently exist over their control.

The "Information technology" revolution has become a reality. It has already transformed our daily lives. Tomorrow, digital technology will be the source of our growth: everywhere in the world the race to innovate under way. We are already in permanent contact with our friends and family and in touch with current issues through our mobile phones. Tomorrow, our fridges will automatically provide us with our shopping lists, alarm systems will inform us that an elderly parent has fallen in the living room, and even diabetics will be able to monitor their blood sugar levels in real time. Tomorrow, nanotechnology will play a major part in the added value of those industrialised countries who knew when to seize the opportunity. Tomorrow, like today, the intelligent adoption of information and communication technologies by companies of all sizes, operating in networks, will condition their competitiveness and therefore lead to the creation of long-term high added value jobs. In this technological race, we have to stay at the head of the pack. We must also stand up for our vision about the responsible use of these technologies: from the first Data Protection Law of 1978 to the promotion of an international well balanced regulation of the Internet, which is currently necessary to guarantee everybody's freedom and whose report in July 2009 on the digital economy by 2025 is leading the way.

The ageing of the population in France, in OECD countries and world population growth are important trends. The ageing of the population represents major progress for every individual - thanks to medicine, pharmacology, nutrition, risk prevention, sound economics policies - as long as the quality of life is not affected negatively by a longer life. For medicine and biotechnology, this phenomenon is a massive challenge: new pathologies shall appear, just like neurodegenerative diseases have appeared. We need to know them better in order to improve their treatment. There is every reason to be optimistic: biotechnology is at the dawn of a new revolution. It will enable us to detect cancers before tumours become visible and develop a form of agriculture which respects the environment and is capable of meeting the nutritional needs of a world population set to rise by almost 2.5 bn by 2050, of which one billion will be aged over 60.

These are massive challenges but their existence is no longer doubted. **The time has come to face them up through Research and Innovation**. These will provide solutions to the urgent environmental situation by implementing the "green" growth that all citizens want. Also, they will enable us to keep up with digital technology developments while reconsidering the relationship between hardware and software. Moreover, they will help an ageing population by studying Alzheimer's disease and by developing new solutions to maintain or to improve their physical independence.

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My belief, shared by the entire government, is therefore simple: **research and innovation are not like any other solutions for the future**. They are the main - and sometimes the only - tools available to build tomorrow's world: we must therefore create the necessary conditions and incentives to generate enthusiasm across our nation.

To ensure that scientific progress goes along with social progress, discoveries from fundamental research must be transformed into applications or technological innovations. But this is not enough: society must also be ready to welcome scientific and technical progress and a permanent dialogue between citizens and scientists must take place. Society must also contribute to these innovations, of which many, and among the most important, represent more than just technological innovations.

It is for this reason that I want our country to adopt a **National Research and Innovation Strategy** based on four essential pillars:

- it is a **strategy** based on the analysis of tomorrow's major challenges, which also are our research priorities;

- it is a truly **National** strategy: its priorities will therefore be defined on the basis of the country's most pressing needs in order to reassert the social value of research and innovation and re-establish dialogue between science and society;

- it focuses on **research**: the strategy's priorities will therefore be fully integrated in the planning of our research institutions whose role will be to bring this strategy to life;

- it must enable research to be transformed into **innovation**, by strengthening the interactive *continuum* between research and market and societal needs, leading to a permanent and dynamic process between the discoveries from fundamental research and their technological applications, as well as their dissemination within our universities and elite schools ("grandes écoles").

Innovations do not spontaneously, or necessarily, arise from the progress of fundamental research. However, they depend on the expertise of researchers. While maintaining their role as producers of knowledge, researchers must be trained and encouraged (including financial incentives) to contribute to establishing the necessary link between their work, the response to society's expectations and needs, and the enhancement of the economy's competitiveness. The mutual intermeshing and cross-fertilisation of knowledge and innovation (technological, social and cultural) is the key to the performance of the economic system: the aim of the National Research and Innovation Strategy is to establish the general framework for these exchanges over the next four years while incorporating long-term perspectives.

At the core of the National Research and Innovation Strategy there is an ambition: **to put back research and innovation at the heart of French society and economy.**

The creation itself of this strategy sets the tone. It is the result of a **widespread consultation** with public and private research institutions, associations, members of parliament and representatives from each of the ministries concerned. It is therefore the entire Nation which has designed the government's research and innovation roadmap, which will both guide the future actions of public researchers and clarify the work of private researchers.

We now have a **shared diagnosis** of the place of French research in the world, its strengths and weaknesses and the needs and expectations of our entire society. **Thanks to this common outlook, we will be able to coordinate our actions to respond to the challenges of our time.**

Following the 2006 Pact on Research and the 2007 Law on University's areas of Freedom and Responsibility, all of the conditions are now in place for the emergence in France of a knowledge-based society that all Europeans have been pinning their hopes on since the European Council in Lisbon in March 2000.

Our gaze, full of trust, now falls on our researchers and their teams, engineers and technicians. Through the National Research and Innovation Strategy, it is the whole of French society which sends them a clear message: **we know that our future depends on you and we will be at your side to build the France of tomorrow**.

Valérie Pécresse
Ministre de l'Enseignement supérieur et de la Recherche
Minister of Higher Education and Research

Content

Summary

During six months, more than 600 participants from the academic research sector, small and medium size companies, large firms and associations have contributed to identify France's main priorities in the area of research and innovation. These priorities were defined in light of the scientific challenges raised by the researchers themselves, taking into account society's concerns and the opportunities for the economic development of our country.

This forum resulted in the definition of five guiding principles and three priority areas of research. An integral part of a **global system** of competition and cooperation, French research must respond, **within a European framework**, to the following principles:

- **fundamental research** is essential for all knowledge-based societies. It must be supported in all its dimensions, especially in regards to large research infrastructures;

- **a research strategy opened to society and to the economy** will stimulate growth and employment. To develop its competitiveness, France must rejuvenate, through greater trust and cooperation, the link between public research institutions and companies on the basis of specific medium and long-term goals. This global vision implies the promotion of a **creative society** in which innovation is not only accepted but generated and borne by citizens;

- **better risk management and increased security** are particularly important in our society; they must be strongly considered in social, cultural and technological innovation;

- **human and social sciences** must play a major role in all the priority areas by contributing to the elaboration of interdisciplinary interfaces in all key domains;

- **multidisciplinarity** is essential to pave the way for the most innovative approaches and to be better prepared to meet our society's challenges.

Research institutions and universities must also work more closely with companies (SMEs and large firms) both in regional clusters and at a national level in order to create **an environment which stimulates innovation** and develops competitiveness at the European and international level.

The stakes around the acceptability of new technologies must include the environmental and ethical impact. In this regard, cooperation between researchers and society's representatives must be strengthened in order to develop efficient **communication, training and knowledge dissemination** towards all citizens.

The National Research and Innovation Strategy has three priority areas that are in line with the socio-economic needs and the scientific disciplines where France has a leadership position. They respond to society's challenges, they correspond to new economic opportunities with strong innovation potential and they require interdisciplinary research for which France can mobilise top researchers.

Priority area N° 1: health, care, nutrition and biotechnology

There is a growing social need for health and medical research, which also offers a wide range of opportunities of economic development for French companies both in the pharmaceutical sector and in innovative health technology. This area of research is therefore a main priority and addresses the following main objectives:

- **to characterise living matter,** from the genome to the ecosystems, to develop especially our knowledge of their complexity, in particular:
  - to develop large scale **cohorts** enabling long term observational studies of the general population for a better understanding of the determinants of public health;
  - to develop **models for the living matter** to foster simulation and prediction;
- to focus on the most important areas for public health:
  - to understand the mechanisms and discover therapies for **neurodegenerative diseases**, particularly Alzheimer's disease;
  - to characterise the causes of **emerging and re-emerging infectious diseases,** and to develop appropriate **medicines**;
  - to foster **the autonomy of dependent persons**, elderly and disabled, particularly through assisted living and health technology (robotics, telemedicine, e-health technology, etc.);
- to prevent diseases through **better nutrition** and increase the traceability of food to ensure that its safety; nutrition also covers other areas of care and quality of life: protection of the environment, organoleptic aspects, and cultural identity;
- to bridge the gap between **the outcome of fundamental research and the development of medical applications**. This is achieved trough *translational research* which will be strengthened to establish an effective and lasting link between academic and industrial research and medical investigators:
  - to develop **key technologies for personalised medicine and for cheaper and less invasive health interventions, at least equivalent in efficiency and safety**: rapid diagnosis, medical imaging, telemedicine, etc.;
  - to launch a "biotechnology plan" to boost the growth of very promising **biotechnology and synthetic biology** companies.

Priority area N° 2: Environmental urgency and eco-technology

While the impact of human activity on the planet's global equilibrium is now becoming apparent, there is an urgent need to innovate to ensure a more sustainable development of humankind. Aside from the global nature of this challenge, the growth opportunities for our companies are significant and France must consider eco-technology as a national priority:

- to better understand and model **changes in the climate and biodiversity**, particularly through high performance measurement tools (especially **satellites**) and simulators (high performance computing);
  - to understand how living organisms respond to external attacks (**toxicology and eco-toxicology**) linked to human activities and provide living organisms with enhanced protection;
- to develop **eco-technology and ecodesign** in order to create products and competitive services that have little or no environmental impact throughout their lifecycle;
- to guarantee a **future with carbon-free energy solutions** with a balance between nuclear research and renewable energy research to preserve the environment**:**
  - to apply a sustainable development approach to future **nuclear energy** technologies: fourth generation reactors, fuel cycle, radioactive waste management;
  - to improve the performance of existing **photovoltaic cells** and develop future breakthrough technologies: thin films and organic materials;

o to consider the whole plant, and not only the edible part, in the new **bio-fue**l production processes to avoid harmful competition over the use of agricultural land;

o to endow France with **marine energy** technologies (wave, tide and current energy, ocean thermal energy and off-shore wind farms), which are attainable through the exploitation of its exceptional maritime potential;

- to develop the services and technologies of **sustainable cities and modes of transport:**

o to improve thermal **vehicle** engines and prepare the migration towards low CO_2 emitting and even carbon-free vehicles (electric, hybrid);

o to reduce the greenhouse gas and noise emissions from **air transport** by developing better performance aircraft and optimising air space management;

o to invent models of **sustainable buildings and cities** by reconsidering architecture and urban planning and developing energy storage technologies.

Priority area N^{o} 3: Information, communication and nanotechnology

While information and communication technologies gave rise to a third industrial revolution which has transformed our daily lives, some people are already proclaiming a fourth industrial revolution with the arrival of nanotechnology in all manufactured goods. It is essential that our companies play a successful part in this revolution which furthermore represents major opportunities to fight against exclusion and develop carbon-free technologies. To guarantee everybody's security and freedom, the use of these technologies must also be the subject of research and of suitable regulations. The main challenges are:

- to develop new technical choices for **the Internet of the future or the Internet of things**, in order to influence international standards, a key factor behind the competitiveness of our companies;

- to develop high performance architectures that incorporate all **hardware and software** aspects to increase functionality, availability and reliability;

- to foster the competitiveness of services (banking, media, education and continuing education, etc.) and high tech industries (automotive, aviation, etc.) through enhanced **software edition capacity**;

- to **strengthen our position from software creation to commercialisation. Software security** is a major socio-economic issue due to the dematerialisation of transactions and the use of digital mobile technologies;

- to demonstrate the potentialities of **nanotechnology** for smart materials, electronics, e-health technologies and new energy sources.

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These five general principles and these three priority areas constitute the basis from which the State will allocate resources and plan its research activities. The objective is to simplify the coordination of all research partners in order to increase efficiency ant to reinforce French competitiveness. It will stimulate cooperation between the public and the private sectors, so that research can better feed the economy.

Introduction

Research and innovation, a national priority

While knowledge is the primary goal of research, research also aims to respond to society's needs and expectations. Through the innovations that it generates and the public policies that it enlightens, research contributes to technological development, economic growth, health, care and quality of life as well as human and cultural enrichment. For these reasons, issuing a National Research and Innovation Strategy constitutes one of the State's main responsibilities.

An evolving situation

In France, research and innovation have played an essential role since the end of the Second World War and the reconstruction of the country through large projects (aeronautical, nuclear, space, transport, etc.). These projects have made France a technological power recognised as one of the world's leaders. Major changes have characterised the end of the twentieth and the beginning of the twenty-first centuries. In order to remain competitive, France has to reconsider its science policy, and particularly its design, organisation and resources.

An increasingly dominant European and international dimension

The shake-up caused by the emergence of new scientific and technological powers increases the global resources allocated to science and accelerates the change in research and innovation, thereby leading to a transformation in practices and organisation.

It is in this context of greater globalisation of research and innovation activities that the European Research Area (ERA) is taking shape. The ERA should be the melting pot of "the most competitive and dynamic knowledge-based economy in the world", as stated by the European Council in Lisbon in March 2000. Today, no European country has the means to stand alone in all areas of research. It is by bringing together multidisciplinary teams from different cultures, intellectual and scientific traditions and nationalities that the research and innovation potential of each country will be increased.

A more complex relationship between science and society

Environmental, industrial, economic and social disasters, broadcast by the media to an international audience, evoke fears which sometimes give a negative image to science and technology. Meanwhile, there is still high demand for innovations, particularly technological innovations, as shown by the success of, for example, laser eye surgery or other non invasive surgery, the Internet, home automation and the mobile phone.

The complexity of today's world which is widely dependent on technology and its interconnections, interdependence and multipolar character raises new questions. Security issues, of every kind, are of particular importance: network security, data flow and exchange security, information and product security.

The National Research and Innovation Strategy must take into account these requirements and concerns by reviewing its intervention mode. It is important to encourage a more active participation by society, and particularly the private sector and local authorities, to strengthen opinion channels and to make the most of the development of the European Union. Furthermore, the State must look at improving the conditions of community life through the reasonable use of the precautionary principle.

A contrasted situation

France is the 20th largest country in demographic terms but the 5th scientific power with over 210,000 public and private researchers and, in total, almost 800,000 engineers and scientists. With slightly over 2% of its gross domestic product (GDP) allocated to research, France excels in several areas (mathematics, physics, nuclear, space, agronomy, archaeology, etc.), in which the country has globally-acclaimed scientific clusters.

Nevertheless, France's share of European industry has been on the decline over the past ten years due, in particular, to a lack of innovation. Part of the explanation is the fact that France has not intensified its investment in Research and Development (R&D) for a decade. In the meantime, certain emerging countries, China especially, have significantly increased their potential and their activity in R&D.

Our country's innovation capacity tends to be concentrated in sectors which are not always the most dynamic or the strongest drivers of growth for a high income country like France. Apart from its traditional sectors of excellence (chemicals, telecommunications, energy production and distribution, capital goods, transport, space) and low technology sectors (luxury goods), French economic growth is below what it should be.

France is not sufficiently specialised in the scientific and technological fields which are underpinning the emerging sectors involved in biotechnology and nanotechnology. In these sectors, and more generally for breakthrough innovations, innovation requires the combination of first class scientific capacities and the ability to build quickly from these capacities. Despite the fact that France has managed to create a number of young innovative companies, it has failed in stimulating the emergence of large ones capable to stand out in global markets.

In 2006, France had a global ranking of fourth in the European patents system with 5.5% of applications and is specialised in Machinery - Mechanics - Transport. In the US patent system, France had a global ranking of seventh with 2% of the patents awarded and is specialised in Pharmaceuticals - Biotechnology and Chemicals - Materials. In both systems, France's global share has dropped since 1994.

A field of French excellence: space research and technology

Space is a strategic area both for France and Europe not only in terms of its importance regarding defence and security but also due to its different applications, whether the environment, telecommunications or even satellite location, navigation and satellite data. Research and innovation in the field of space concern generic technologies and systems such as launch systems, satellite platforms and dedicated instruments.

Space research feeds several scientific and industrial sectors. Satellites and probes are formidable observation tools for Universe and Earth sciences and fundamental physics. Space missions very often use pioneer technologies under extreme conditions. Thus they promote the development of advanced technological sectors and the cross-fertilisation of research and industry.

The breadth of the space programmes and the nature of the needs that they fulfil require a European response through intergovernmental cooperation agreements (for example: the European Space Agency) and EU programmes such as Galileo for navigation or Global Monitoring for Environment and Security to observe the Earth.

While France has undeniable assets to attract young scientists from around the world (France is the fourth country for hosting foreign scientists), exchanges with certain countries, including emerging ones, are still insufficient. Furthermore, even if the proportion of French researchers moving abroad is low, it affects very good researchers who are often difficult to entice back. In view of this, the government has undertaken to modernise the management of human resources and offer more rewarding careers in order to make them more attractive and competitive.

France has a leading role in the construction of the European Research Area. Even though there is still room for progress in certain areas, the rates of participation and coordination in European projects are among the best (ranked third and second within the EU, respectively). The French presidency of the European Union also gave a decisive boost to the launch of joint programming in essential socio-economic challenges such as energy and the fight against Alzheimer's disease.

In terms of attractiveness, France has a median position in comparison with its European partners. There is a notable discrepancy between the academic achievements of French research and their tangible benefits for society in terms of innovation and economic development. The fragmentation of the research system, the lack of investment from the private sector in Research and Development (R&D), a modest presence in R&D-intensive or emerging areas such as biotechnology and nanotechnology, and the poor link between the training of public research managers and company managers (dual system of universities and the elite schools or "grandes écoles") are the main factors explaining this situation.

Strengths and weaknesses of the French research and innovation system

Strengths	Weaknesses
• 5th world power in science et technology, both in fundamental and applied research;	• the French research and higher education system is difficult to understand and insufficiently coordinated in its structures and geographic organisation;
• areas of excellence (agronomy, nuclear, space, mathematics, archaeology, etc.) supported by strong research institutions and a very high quality university community;	• poor relationship between public research institutions, universities and companies;
• global industrial leaders, particularly in the aeronautical, transport and energy sectors, environmental services and the agro-food industry and a few world class competitiveness clusters which structure R&D;	• insufficient private investment in R&D and weak presence in emerging sectors;
• a leading role in international scientific programmes and infrastructures and in research for industrial development;	• relationships and partnerships with emerging Asian countries are less dynamic compared with other countries of similar size;
• significant public support for R&D trough direct measures and a strong tax credit scheme.	• excessively rigid management of human resources in a large number of public institutions with an impact on the attractiveness of careers, the mobility of researchers and the hosting of foreign researchers.

The creation of the National Research and Innovation Strategy

Since 2005, France's approach to research and innovation has undergone significant change: we have seen the creation of competitiveness clusters, the National Research Agency, the National Agency for the Evaluation of Research and Higher Education, the strengthening of the autonomy of universities and the support of public-private partnerships particularly through the research tax credit scheme and the Carnot institutes. The aim is to enhance the performance, visibility, international influence and promotion of French research.

Two founding laws have been voted by parliament. On the one hand, the programme law of April 18, 2006 on research embodies the "Pact for Research" between the State and the citizens. On the other, the August 10, 2007 law on Universities' Freedom and Responsibility strengthens their capacity to take initiatives and is likely to improve their visibility on the European and international scene. Since 2008, new measures have been taken to improve a system, which is still too complex and fragmented, and to strengthen France's research and innovation capacities.

The socio-economic and urgent environmental situation demands the continuation of actions to support research, encourage innovation, increase private investment in research and development, and strengthen the public-private partnerships which are propitious to the creation of new companies and the development of SMEs.

The guidelines of the government's policy in research and innovation must now be clearly displayed. National research priorities must be identified and shared by all public and private research bodies, as well as by all citizens. This is the purpose of this National Research and Innovation Strategy document.

Supporting public policy decisions

A key part of the reform of the French research and innovation system, the national strategy represents the chance to shape an environment which is favourable to creativity and innovation, to mobilise human potential, and to confirm the European Research Area as the natural forum for action.

It is the shaping of the French self-image to the benefit of knowledge, society, attractiveness and competitiveness. All scientific partners, without interrupting their own strategies, will thereby benefit from a common tool to direct their choices and practices in relation to major societal and economic stakes. It is also the opportunity to tackle, explicitly and thoroughly, the issue linked to the transformation of the research and innovation production methods and to place them and at the heart of public debates.

On September 3, 2008, the Council of Ministers clearly voiced its desire to provide France with the framework and means to respond to the challenges and stakes of the 21st century. The priorities will have to guide the State's financial decisions, particularly in relation to the projects sponsored by the programme "investments for the Future".

Broad consultation

The drafting of a single strategic document which lays down the direction of research and innovation at a National level is a new experience in France. This original work required a drafting and consultation process which drew on the different views of researchers, socio-economic partners and other stakeholders. In total, around 300 researchers and as many representatives from companies of all sizes and associations took part in the experience through a steering committee, work groups and an Internet-based consultation process which was open to the general public.

The analysis was carried out by working on large subject areas and by integrating, in each case, the socio-economic issues, whether these concerned the expectations of citizens, the needs of companies or the support of public policies. The outcome relied on a shared diagnosis of the strengths and weaknesses of public and private research and the opportunities created, particularly by European and international networks[1].

[1] See the composition and reports of the work groups at: http://www.enseignementsup-recherche.gouv.fr/pid20797/la-strategie-nationale-de-recherche-et-d-innovation.html

The first milestone in an evolving process

This document provides an overview of the challenges at hand in the field of research and innovation and lays down a reference framework for research priorities over the next four years. The purpose of the framework is to guide the State's annual budget, the planning of the National Research Agency's work and the action of research institutions and universities through their multi-annual contracts with the State.

Nevertheless, it does not constitute an outcome set in stone following a one-off strategic study but the first milestone in a continuous process which shall result in the drafting of a new document every four years. These regular reviews will serve to assess the situation and consider changes in regards to new knowledge and challenges.

The National Research and Innovation Strategy's five guiding principles

Fundamental research as a political choice

The history of major discoveries shows us that they rely on high quality fundamental research. It is a guiding principle of the National Research and Innovation Strategy to reaffirm and to guarantee the central place of fundamental research and academic freedom in the French research system.

This is already noticeable in the strengthening of the National Research Agency "Blanc" programme (non-thematic calls for proposals) and France's support of the European Research Council, two bodies whose role is to fund scientific projects on the basis of excellence regardless of their end purpose. The reforms in progress take a similar approach. On the one hand, the autonomy of universities strengthens the link between education and research to the benefit of free thinking within science. On the other, the role of the new institutes of the National Centre for Scientific Research is to energise, organise and develop the scientific communities over the long term.

While supporting many scientific fields, research infrastructures play a key role. They are essential to understand, reproduce and simulate natural phenomena. They provide high quality data and contribute to the development of competencies. Instruments at the cutting edge of scientific development, they also drive technological research and innovation. Through their size and complexity, they represent a significant market for the companies who build them and are a source of job creation. With regard to infrastructure policy, the drafting of a regularly updated roadmap represents the appropriate tool.

Fundamental research also benefits from being in close contact with applied and technological research. It is important to keep the interactive continuum from fundamental research to applied research and innovation. Although technologies are sometimes born without any theoretical bases, such bases are essential for their development. The exchanges between these different areas of science have given rise to numerous theories. The research system must favour this proximity. It can do so by maintaining and strengthening the policy to encourage the creation, in French regions, of education, research and innovation clusters based on strong public-private partnerships.

Research geared towards society and the economy

A major purpose of National Strategy for Research and Innovation is to respond, under the best possible conditions, to the need for the economic and competitive development of French companies.

Such competitiveness is essential to growth and employment. It means renewing - in terms of greater trust and cooperation - the link between public research institutions and companies on the basis of specific medium- and long-term goals.

In this area, France must lift a certain number of barriers which hinder its ability to play a positive role in European and international competition. This is a cultural challenge that the National Research and Innovation Strategy must help to face. The creation of relevant public policies can play a key role. For example, the tripling of the research tax credit made France the world's most attractive country for research from a tax perspective.

This is in fact an anti-relocation measure and also a determinant factor in the location of new research centres and, therefore, a source of growth and employment.

Furthermore, the funding granted by the National Research Agency reflects a balance between, on the one hand, the total freedom to create (50% are non-thematic programmes) and, on the other, the country's priorities proposing an incentive to develop innovation (50% are thematic-based programmes). All of the Agency's funding promotes research based on public-private partnerships.

Furthermore, the economic success of companies requires the innovation to become a product or a service which meets customer's expectations. Unfortunately, the analysis of the need for the development of a product is often neglected due to a lack of information, training or support among French researchers who are likely to create such products. Mixed public-private careers paths, which would guarantee the professional perspectives of each individual, could facilitate these exchanges.

Better consideration of the risks and the need for security

Today people, ideas and goods circulate on a international level. The inherent hazards related to climate change, energy supply needs and the issue of food production for a global population set to reach around 9 billion by 2050 are interrelated challenges which require an adaptation in the management of risks and uncertainties.

In this context, national and continental equilibriums quickly change. Dissemination phenomena (regarding ideas and innovations, as well as viruses) are taking on an unprecedented scale. In all areas, the imperative of change gives rise to rapid rearrangements which permanently destabilise social, political and cultural equilibriums and tend to make individuals, groups and societies live in situations which are structurally uncertain. Inversely, these changes are also sources of progress and represent opportunities to be seized.

Risk is one of the National Research and Innovation Strategy's main transversal thematic and a guiding principle. It implies that support is given to multidisciplinary approaches to situations of risk, in their many guises and dimensions. In this context, special attention must be given to fundamental research in order to analyse and to model these situations and to create, in all subject areas, tools to understand the complexity of the situations. Inseparably, *security*, considered as a major requirement of both collective and private life, must be promoted as an important part of research and as a preferred goal of social, cultural and technological innovation.

Defence and security

Presented in the 2008 White Paper on defence and security, the major strategic directions of public research and development efforts in these areas consist of maintaining critical competencies (e.g.: ballistic systems, submarine resources), developing intelligence capacities, whether technological (e.g.: satellites) or not (e.g.: geopolitical), and competencies in the fight against cybercrime and the proliferation of nuclear, radiological, biological and chemical weapons/agents.

The national research policy must encourage a multidisciplinary and transversal approach which brings together partners from the public and private sectors and which is based on the expression of needs of end users. In order to control costs, dual programmes between the civil sector and defence must be sought. As purely National solutions are ineffective, France has committed itself to cooperation programmes at a European level through the European Defence Agency and the European Security Research Programme and, at international level, through bilateral agreements.

It is important to create new approaches to the issue of security which are easier to use and more efficient for citizens, such as the inspection of luggage without any specific handling requirements. Urban security will also have to be an end goal of specific research, in terms, for example, of crowd control, dissuasive tools and technologies to detect and identify people and risks. France will be able to take up these challenges thanks to the competencies of its industrial fabric in the field of security which will be strengthened by the implementation of the National Research and Innovation Strategy's priorities. An additional step will have to be taken by reinforcing the research coordination system by simplifying it and giving it more visibility among researchers, companies, citizens and public decision makers.

Importance of human and social sciences within the strategy

One of the strategy's strong points is the full recognition given to the decisive place of human and social sciences (HSS) in all of the leading areas of research and innovation.

Too often, this place is only considered on the basis of the contribution that these sciences are likely to bring to the social acceptance of the scientific and technological innovation: analysis of social expectations, exploration of cultural and social changes that the innovation brings about, study of the resistance to the innovation, etc. The other frequent error of appreciation is to confine human and social sciences to the consideration of moral or philosophical questions faced by researchers.

In both cases, the risk of confining HSS in an ancillary role is keenly felt by the communities of researchers concerned. Such a bias would continue if HSS were allocated to a specific subject area within this document. They would become isolated from all the other subject areas with human, social, political and cultural stakes.

The correct positioning of HSS in the National Research and Innovation Strategy consists of stressing the major role that they must play within the priority areas and how they shall contribute to the building of interdisciplinary interfaces in all of the key areas, whether in relation to the ageing population, climate change, energy management, the Internet of the future, sustainable development or the use of nanotechnology.

It is up to HSS to consider the new scales of time and space which reshape simultaneously social practices, the economy and scientific practices and to enrich the public debates.

Multidisciplinarity - an essential part of modern research

The aforementioned guiding principles converge on a single requirement: to allow a multidisciplinary research that contributes to the advance of knowledge. The new scientific instruments and the way in which R&D projects are led require a multidisciplinary approach which can involve several research teams or institutions. Dialogue between subject areas is a condition for success.

In 2000, the Academy of Science said[2]: 'the interpretation of biology, life sciences and applied mathematics, the consideration of the improvement and preservation of the environment, the acceleration of all forms of communication and the necessary development of energy and materials are some of the questions at the heart of the concerns of humankind and at the heart of the development of society worldwide, and in France in particular. '

It must be recognised that while certain areas are more suited to a multidisciplinary approach than others like nanotechnology, biotechnology and information science, breaking down barriers between subject areas and the gradual rapprochement between teams and institutions are essential to ensure a competitive research.

[2]Summary of the biennial report on science and technology in France, 1998-2000, Academy of Science, November 2000

For a competitive research and innovation system

A new system organisation

All the analyses performed on the French research and innovation system over the past few years reach the same conclusion and, on the whole, give the same recommendations with the aim of strengthening the autonomy of its various organisations and the role of universities.

The three functions of a research and innovation system

"Policy making": elaboration and implementation of the national policy, definition of main directions for the system's evolution and allocation of resources over large-scale goals. This area is the responsibility of the government.

"Programming": translation of the large-scale goals defined at the policy level into scientific priorities and research programmes as well as the allocation of resources to research operators and units. The partners are funding agencies, research institutions and some ministries.

"Research and innovation": the production, distribution and exploitation of knowledge. This is the role of higher education institutions, research institutes and companies.

For historical reasons, the French research and innovation system developed into a framework in which the three functions described above were integrated.

Until recently, some ministries and large research institutions accumulated several functions. This organisational model, which was quite widespread in the world until the 1980s, was particularly effective to develop France's technological sectors of excellence.

Its weaknesses have since been revealed. The rapid changes in science and technology, the wide range of competencies to be mobilised for emerging areas and the growing internationalisation of research and development activities require a simpler system which clarifies the roles and autonomy of partners and provides greater national and European coordination. Recent legislative changes reflect this shift and are paving the way for an organisational framework based on "mostly separated functions".

The creation of the National Research Agency and the National Agency for the Evaluation of Research and Higher Education as well as universities' autonomy enable the Ministry for Higher Education and Research to centre its role on strategic policy. The signing of contracts with public research organisations gives them greater autonomy, while State control takes place afterwards. It also sets a clearer boundary between planning and research functions. These changes and the instruments contained in the latest laws must enable universities to define and implement their own strategy more freely.

European and global dimensions

Research and innovation are major levers to deal with the challenges faced by humankind and to enable Europe and France to develop a level of competitiveness which underpins their economic and social model. The efficiency of these levers depends on the quality of our involvement in the new international division of the knowledge-based economy.

Adopting a European framework

The construction of the European Research Area is a major issue. France intends to influence Europe's science policy, particularly under the "2020 vision for the European Research Area" which was adopted on France's initiative during its presidency of the European Union. This particularly applies to the priorities of the Framework Programme for Research and Technological Development, the strategy put together by the "Strategic European forum for International Cooperation in Science and Technology", the joint programming between States, and also the definition of rules governing the exploitation of research, technical standards or the mobility of scientists.

The issue of the coordination of National and European policies is particularly sensitive for certain subjects such as research infrastructures and scientific programming. The objective is to achieve significant scale-based gains but also to improve France's position in the European dynamic through better participation of public and private research and innovation operators in European Research Area programmes.

These ideas have driven the involvement of France in favour of "joint programming" during its presidency of the European Union, reflecting a balance between intergovernmental and Community action.

Joint programming

"Joint programming" consists in coordinating national research programmes in order to tackle, at a European level, challenges for which the urgency, the taking risk and the needs, in terms of human and material resources, are too large not to be shared.

This decision by Member States to commit themselves to large inclusive projects which encourage innovations and pave the way for future markets was taken at the Council of the European Union of December 2, 2008. Six main societal challenges have already been identified: climate change, ageing population, energy supplies, water and food supplies, finance, and security.

Developing our international partnerships

Free flow of knowledge, networking and international cooperation are a basic condition for success in science and technology.

France has a long and recognised tradition of international cooperation in the area of research. The growing globalisation of research activities therefore offers an opportunity but it forces us to review our international scientific policy in relation to development, cooperation and hosting measures, which has not sufficiently evolved over recent decades.

Actions will aim to step up cooperation and exchanges, particularly with China, India, Japan, South Korea, Brazil and Russia. These are countries with strong scientific potential and an increase in scientific relations will result in greater economic exchanges and closer diplomatic relations in light of major global matters. Finally, France shall play a bigger role in international forums which define the research agendas and the regulations related to global challenges and global public goods[3]. This will be done efficiently by coordinating French actions with other EU States, particularly within the "Strategic Forum for International Scientific and Technical Cooperation".

A pro-active policy will enhance the attractiveness and accessibility of France's scientific and technological assets. This policy will be based on specific forms of assistance like those offered by the National Research Agency (the "Chaire d'excellence" and the "post-doctoral return" programmes) and the European Union (for example, the Marie Curie grants), as well as the development of Master's degrees taught in English. The reduction of administrative and accounting hurdles for research institutions, the extension of science visas to companies and the support to the creation of the Community patent should also be achieved.

3 Global public goods are concerns which are of common interest to humankind (the environment, climate change, energy, etc.)

French research at the service of economic and social development

With its dense network of expatriate researchers who fulfil public service missions in Southern countries, France is in a particularly good position in term of research to contribute to development through cooperation with these countries. It must now put this research policy in line with new perspective:

- the countries involved in this type of research cooperation that contribute to their development intend to preserve their identity and heritage. They intend to remain in control of their development and of their research priorities and want to affirm their "scientific sovereignty";

- the awareness among developed nations of their responsibilities in the promotion of research for development leads to North/North partnerships, particularly within the European Union.

Today's diverse levels and types of development have made the classification between developed and developing nations, or between Northern and Southern countries, less effective. The emergence of countries like Brazil and South Africa has led to South/South partnerships. Numerous research issues, and some of uttermost importance to today's world (climate change, emerging diseases, food safety, biodiversity, migration, governance, etc.) can only be adequately dealt with if the local partners, stakeholders and societies in all countries are being considered. Henceforth, the instruments of these partnerships will have to be assessed on the basis of this context as well as their own efficiency.

Common key ideas

An analysis of the directions proposed by the groups that worked in the National Strategy for Research and Innovation shows a convergence of opinions on a few essential goals[4].

More motivating scientific careers paths

The efficiency of the public research system fundamentally relies on its personnel, research professors, researchers, engineers, technicians and managers. However, the appeal of a career in research has on the whole dropped over recent decades, leading to a risk of weakening French research in certain subject areas.

For two years, the government has significantly increased the resources invested in higher education and research and will continue to do so. Through several reforms, including the August 10, 2007 Law on University's Freedom and Responsibility, it has improved human resource management and implemented a plan to enhance the value of careers. It is now time to implement an even more pro-active policy to develop practices. This requires the creation of new instruments (mixed chairs, bonuses, travel assistance, etc.), the development of a managerial culture specific to the employees in higher education and research and better use of existing tools such as continuing education.

The assessment system must also change. A career as a research professor is multi-faceted. The assessment of this occupation still focuses still too much on scientific production, which is measured in a quantitative manner. Innovation, teaching, expertise, management and risk taking are still widely undervalued. Young talents, in order to be attracted to research, must find an environment which favours personal excellence and ambitious goals as well as attractive economic perspectives. Furthermore, an evaluation of the measures which allow the researchers who innovate to receive some reward (material and non-material) must be carried out.

Finally, a rapprochement between the public universities and the elite schools (grandes écoles), while breaking down the cultural barriers which separate scientists, engineers and managers, will allow greater mobility between the academic and industrial environments and thereby offer more career opportunities. It will also help to stimulate creativity and innovation and develop research in the private sector.

[4] Work group reports may be seen at: http://www.enseignementsup-recherche.gouv.fr/pid20797/la-strategie-nationale-de-recherche-et-d-innovation.html

A more attractive innovation environment

Our innovation environment must become more attractive and noticeable within the world's innovation networks, particularly in emerging subject areas and sectors: eco-technology, information and communication technology, biotechnology, nanotechnology (including nano-electronics).

Since the adoption of the Lisbon Strategy by EU countries, France has instigated change within its innovation environment in order to encourage companies' research and development (R&D) activities and technology transfer. The task at hand is to complete this change and, in particular, to reinforce the growth capacity of new innovative companies and to develop new sectors. Growth in non-technological innovation capacity (design and creation, organisational innovation) and a better dissemination of information and communication technologies must also, and particularly among SMEs, contribute to the strengthening of France's approach.

Four areas of action shall enable to complete the public policies implemented over the past ten years.

First, the economic downturn has given rise to very rapid changes in the resources allocated by large countries to various technological, scientific and industrial ambitions, as well as to economic and industrial stakes and to political goals like those which could arise from the Copenhagen meeting at the end of 2009. The effective steering of the National Research and Innovation Strategy requires the systematic monitoring of these changes, both quantitative and qualitative, in partnership with the main ministries concerned, leading to regular overviews of the situation. The improvement of the French innovation environment will therefore be based on more systematic assessments measuring the impact of the public policies.

Secondly, the strengthening of R&D support measures introduced in 2004 (Young innovative company policy, overhaul of the research tax credit, OSEO support, competitiveness clusters, etc.) must be implemented on a long term basis and completed. Under the Framework Programme for Research and Technological Development (FPRTD), we shall also seek to support young innovative companies, particularly during the design and development stages of innovative projects. Start ups must benefit from better access to partnership programmes (funding, business management, legal advice, etc.) and the channels providing capital risk funding must be strengthened, especially during the launching phase.

The third area of action involves stimulating cooperation between different partners while developing the organisational structures to “open” innovation. The effort to pool various entities and to improve efficiency which enhances the value of public research must be significantly increased to reach about 15 “structures” included within the Research and Higher Education Clusters (PRES). These pooled structures will have to come under a more general framework of a simplified research and innovation territorial system with university campuses and competitiveness clusters forming local innovation environments which facilitate public-private partnerships. The organisational structure of the "Thematic Networks for Advanced Research" is meant to resemble that of the envisaged pooled structures. Building such an environment will contribute to the development of companies “open” innovation practices, from innovative SMEs to multinationals, and will strengthen technological research and prototyping capacities. Furthermore, such co-operations lead to a drop in the cost of protecting industrial property, which shall be achieved in particular with the implementation of the Community patent.

Finally, the demand for innovations must be stimulated by strengthening the access for innovative SMEs' to public contracts, by better integrating innovation into public procurement policies and by simplifying the corresponding procedures. On a European level, the importance of innovative companies' access to a large market is one of the pillars of the Lisbon Strategy. It is important that this policy and the promotion of pilot markets on this scale are supported.

Making the most of interdependence

Globalisation has gradually claimed centre stage to become a factor that impacts the way most people live and work. Human interaction is becoming more diverse, widespread and international. Understanding current changes is essential as the analysis of cultural dynamics and economic globalisation phenomena (new markets, economic/financial hazards, social weaknesses, standards and regulations within international law, quality standards, etc.) shall enable us to foresee new opportunities and to anticipate the consequences of large environmental, demographic (North-South dynamic, immigration, etc.), cultural and social changes on individual and collective behaviour.

A multidisciplinary approach is therefore required to bring together "hard" sciences (such as climatology, geophysics, mathematics and life sciences) and human and social sciences in order to place events in a historical and cultural context and to ensure the continuity of the entire innovation chain (research - companies - consumption) as part of a renewed dialogue between science and the world's different societies.

Science and society

A society which is open and active is a creative society that creates, that produces opportunities and that questions its former norms. The dynamics in place lead to a complex rearrangement of the social ties, drawing on the new and the old. They require individual, collective and structural dimensions to be taken into consideration and risks to be controlled.

This new state of affairs means a suitable environment must be created to establish mutual trust: involving stakeholders in the definition of national and local research strategies and their programming; guaranteeing transparency; developing public debates on professional behaviour and ethical issues; reinforcing the use of public expertise; developing an interest in sciences and scientific culture throughout a person's life; facilitating debate on the controversies about science and technology; encouraging research on the relationship between science and society.

The ways in which knowledge and learning are disseminated must also be reviewed. Over recent decades, the volume of knowledge has considerably increased and technical know-how has risen. International exchanges and digital media have led to an increase in the number of sources and channels of information. In such a context, the updating of knowledge appears to be as vital as the acquisition of basic know-how in order to understand, decide and act. The importance of lifelong learning only grows stronger and it must be accompanied by a specific research effort on the learning process, on the conditions of the production and the organisation of know-how and on the cultural diversity of learning processes. It will also be an opportunity to develop exchanges between researchers and citizens and to strengthen the communication of research institutions and universities to the general public about their results.

The priority areas

Research provides an environment that is constantly evolving where positions are not fixed. Breakthroughs regularly mark the development of scientific theories or lead to new key technologies. Subjects which had been once cast aside regain the limelight. In this context, defining a national strategy is a difficult exercise. It is therefore essential to support our areas of excellence and to allow for the development of certain emerging areas or areas which are currently evolving or not clearly established yet, while retaining and capitalising on existing knowledge and know-how.

The National Research and Innovation Strategy proposes **three priority areas**. Their common purpose is to respond to social challenges that were clearly identified, to correspond to emerging economic areas with strong innovation potential, and to require multidisciplinary research on which France can mobilise a large number of leading researchers.

- **Health, care, nutrition and biotechnology** in a context of longer life duration, new infectious diseases and life styles' evolution;

- **Environmental urgency and eco-technology**, to respond to the triple challenge posed by the depletion of natural resources and the functional sharing of land, by the climate change, and by the need for relative energy independence. These issues are interlinked and require a common response.

- **Information, communication and nanotechnology,** now omnipresent in daily life due to the Internet revolution. The multiple challenges found in this area particularly concern security, ambient intelligence, complex systems, parallel and distributed computing, etc.

Challenges

A major challenge for society

The growing expectations of citizens regarding health research and healthcare professionals result from various factors: a longer lifespan and the increase in prevalence of age-related diseases, a sustained aspiration for a healthier lifestyle, a change in living and consumption habits, the emergence of infectious diseases, and the persistence of chronic diseases affecting an ageing population.

Annual healthcare expenditures represent €1,408 bn in Europe and €140 bn in France, about 10% GDP. With one European in four aged over 60 in 2010, the growth of this age category, which already stands at 7% per year, is a real challenge.

Creating knowledge and developing innovative solutions to improve health and nutrition should therefore be promoted as national priorities.

If scientific progress in this area often meets the expectations of society, it also raises legal, ethical, anthropological and philosophical issues. For instance, research conducted on embryos and stem cells, the use of genetic testing, behavioural studies based on medical imaging and medically assisted procreation all raise major questions.

A significant potential for economic development

Many economic sectors are directly concerned by health and nutrition and the French industry in these areas holds different positions ranging from European leadership to poor performance when compared to other industrialised countries.

French agro-food companies are leaders on the European market and second at the international level after the US. The French pharmaceutical industry also holds an interesting position, composed of a few medium-sized and large companies, particularly the French leader resulting from the merger of Aventis and Sanofi-Synthelabo.

On the other hand, the French position on the innovative health technology market is weaker, in spite of active research in this area. While academic research is already strongly involved in this activity, the solutions proposed are rarely adopted by industry; and their dissemination and exploitation therefore remain difficult. Companies are too slow in investing in R&D projects and in committing to the development of innovative products and services. Many obstacles hamper the development of e-health, particularly the lack of cooperation between the academic, the medical and the industrial sectors, and the paucity of projects with local authorities.

Health technology contributes significantly to progress in the prevention, diagnosis and treatment of diseases and disabilities, and citizens' expectations are rapidly growing in these areas. Health technology results from the conjunction between technological skills, usually developed in a area unrelated to medicine, and the competence of biologists and medical investigators, while requiring a thorough assessment in a hospital environment. It concerns imaging, biotechnology and bio-engineering, technologies supporting the development of medicines, surgery and other interventional techniques including patient care. Today in France this activity is mostly carried-out by SMEs, lacking a dominant position.

The home health care sector, which represented 40,000 jobs in 2006, is quickly expanding: over the next five years it could grow by 20 to 30%. It provides French companies with new markets due to the increasing use of new information and communication technology.

Priorities

To develop our knowledge of the living world

Life sciences look at how living organisms function, at every level from genes to the ecosystem. They concern mankind, animal, plant and microbial species as well as their association within ecosystems and their interaction with one another. The diversity and complexity of the mechanisms which govern the relationships within ecosystems, from a molecular to a territorial and a planetary level, still remain poorly known. These unanswered questions on living organisms require the firm support of fundamental and exploratory research.

At the interface of several academic fields, the mathematical and digital modelling of biological processes opens new perspectives on the representation and understanding of living organisms. Based on experimental data produced by fundamental research, **the modelling of living organisms** will provide quantitative and qualitative predictive answers for applied research, particularly in regards to the development of models of pathologies and new treatments as well as the simulation of the dispersion of a product in an ecosystem or in the food chain.

This research is very much multidisciplinary in nature. It requires pro-active and targeted actions in the fields of education (greater interdisciplinarity, creation of multivalent curricula) and geographic organisation (creation of campuses incorporated into existing structures such as research and higher education clusters, competitiveness clusters, thematic research and healthcare networks, etc.). There are a number of pilot sites located in Saclay, Lyon, Marseille, Strasbourg and Montpellier. At the European level, France's presence will have to be stepped up in systems biology and synthetic biology programmes.

Access to **large cohorts** and biological resource banks as well as large infrastructures (with specific interest in bio-computing needs) is essential. It will have to be accompanied by measures at the national level and the networking of these structures at the European level.

To address major public health issues

Political commitments, particularly those contained in the Law on Public Health of August 9, 2004, resulted in the implementation of national public healthcare strategic plans focusing on priority areas. Most of these strategic plans include a research component, creating a momentum in the concerned area. Examples include the Alzheimer plan (2008-2011) and the cancer plan which was recently renewed.

Considering the challenges, healthcare research must be better coordinated in several sectors:
Neurodegenerative diseases, whose prevalence increases with the expanded lifespan and for which, on France's initiative, European joint programming is currently ongoing.

Emerging and re-emerging infectious diseases, for which there is a need to identify the agents and the causative mechanisms to develop diagnoses, vaccines and adapted treatment. Achieving these objectives requires cooperation between veterinary, environmental and human health research.

Development of the autonomy of dependent people. Either related to age or to disability, dependency raises the question of how it can be delayed and mitigated. Research in this area must rely on a multidisciplinary approach, involving technological, medical, economic, social and organisational research. Despite the fact that France has leading research teams in most of these areas, their convergence has yet to be achieved, like in other countries.

Apart from the need for education and for a regional implementation plan, one of the major challenges here is to make sure that France's strategy is coherent and clear in a growing number of essential areas. This strategic planning must include, at the upper management level, consultation between the scientific institutions and the relevant stakeholders. The creation in April 2009 of the National Alliance for Life and Health Sciences, bringing together the main institutional players in this area, should meet this expectation. In particular, this alliance will enable a better visibility and coherence of the French biomedical research capacity in Europe in the implementation of joint programming.

To develop nutrition products adapted to the diversity of citizens and to their expectations

The prevention of some of the most frequent disorders (obesity, cancer, cardio-vascular diseases, diabetes) can be achieved by improving nutritional habits, requiring appropriate use of information and education channels. Epidemiological and interventional studies, as well as studies of consumers' behaviour are therefore crucial.

A healthy and safe diet also requires the strengthening of food safety through traceability, the understanding of the development of toxic and infectious agents, and on the detection and prevention of these agents.

In addition to provinding health, nutrition also covers other aspects of quality of life: protecting the environment, organoleptic aspects, cultural identity, etc. France is famous for its food worldwide, and should therefore build on this reputation by combining all of these aspects.

To increase companies' capacity to innovate

Biological systems engineering, biotechnology and synthetic biology represent considerable industrial development opportunities that French biotech companies are finding difficult to seize. The strengthening of public-private partnerships as well as the entrepreneurial culture of researchers and the funding opportunities for young companies in the sector represent part of the solution.

The development of biotechnologies takes place at a crossroads between the academic and industrial sectors, particularly within the health-focused competitiveness clusters which bring universities, public research centres and biotech companies together into "bioclusters". Biotech firms receive support from project-based funding programmes (such as the National Research Agency and European programmes). These clusters must be strengthened to pool and improve the measures devoted to the promotion of public research, to simplify the creation of public-private partnerships and to support the dynamics of innovation.

A support programme will have to be drawn up on the basis of an in-depth assessment of the 2003 Biotech programme in order to identify the most efficient measures to support innovation in biotechnologies. A specific aim of this new programme will be to help SMEs grow, thanks to a more favourable general environment and also to initiatives such as the provision of public-private investment funds like the one found in the strategic investment fund. Stimulating demand from large companies and the public authorities is an additional channel wich could be particularly useful in the development of environmental biotechnologies.

Furthermore, in the medical field, translational research which creates the link between academic or industrial researchers and medical-investigators is vital and must be reinforced through dedicated infrastructures. At the European level, the introduction of such infrastructures is currently taking place under the European Strategy Forum on Research Infrastructures (ESFRI): France's greater participation in the European Advanced Translational Research Infrastructure (EATRIS) project should resolve the paucity that exists in this area at a national level while serving as a pilot scheme.

Environmental urgency and eco-technology

Challenges

Survival at stake

The impact of human activity on the world's global equilibrium is now apparent as shown by climate change, the depletion of resources and the erosion of biodiversity. The effects of the world's demography on our planet, combined with the current methods of development can lead to a risk of irreversible change to the environmental conditions on which populations, societies and economic progress depend. Sir Nicholas Stern, in his October 2006 report, put the cost of climate change in 2050 at between 5% and 20% of global GDP whereas an investment of only 1% of global GDP per year in the reduction of greenhouse gas emissions would prevent this economic loss. Even though these figures may change according to knowledge acquisition and hypotheses about sustainable growth in the world, they show the scale of the challenges at hand.

These threats force us to reconsider the way we lead our lives and to promote a suitable form of management of the world's public goods. In front of such an emergency, Europe has set itself ambitious goals to be met by 2020: cut greenhouse gas emissions by 20%, increase the share of renewable energy sources to 20% and improve energy efficiency by 20%. Fossil fuels, which account for 80% of the world's current energy needs, are not a sustainable solution either in terms of climate change or in terms of economic growth.

Food production is also a major issue for the decades to come. The world's population is set to rise from 6.5 bn today to around 9 bn by 2050. Combined with changes in eating habits, this demographic development will significantly increase the demand for agricultural products while tensions are currently taking place both on the use of land between natural and cultivated areas and on the allocation of land for food-producing and non-food-producing purposes. The question is not therefore to produce more but to produce better. The situation is critical: in mid June 2009, the Food and Agriculture Organization of the United Nations highlighted that the number of undernourished people in the world based on the WHO recommendations had just exceeded one billion.

In light of this, research plays an essential role in reversing environmental trends, preserving biodiversity and environments, designing new energy solutions and cutting greenhouse gas emissions. The National Research and Innovation Strategy therefore adopts the recommendations made by the "Research" operational committee of the environmental roundtable (*Grenelle de l'environnement*) launched in 2007; and fits into the European Strategic Energy Technology Plan (SET Plan).

Strong economic potential

If France is successful in its "environmental transformation", around 600,000 jobs could be created over the next ten years mainly in the building, infrastructure and renewable energy sectors. It is also €450 bn of trade which will be generated over the same period. And it will also mean a reduction in France's energy bill of around 25% and therefore an improvement in its trade balance.

France is a world leader in traditional energy sources (electro-nuclear, hydrocarbons) with industrial organisations and public research institutions which are leaders in their fields and who have a long tradition as partners. Nevertheless, in the area of new energy technologies, France is behind other European countries like Germany despite an active research in nanotechnology.

On a global level, France is the second biggest agri-food exporter after the US. More than ever activities linked to food and to the management of environments and resources are essential for our country. They affect regional development, play a major economic role and are strategic in terms of the environment, food safety and resource accessibility. The main challenge is to improve the environment by developing production and processing systems while remaining competitive.

The implementation of a new environmental economy requires new financial tools (carbon exchange system, funding of new sectors and of industrial restructuring projects) and new insurance tools (environmental risks, responsible investments). This is an opportunity for sectors of excellence like banking and insurance to rely on solid academic research.

A better understanding of climate and ecosystem change

France's research efforts must continue at the highest level within the IPCC (Intergovernmental Panel on Climate Change) whose work enables climate change to be predicted over the medium and long term in accordance with different hypotheses on greenhouse gas emissions.

There is considerable room for progress in the modelling of the climate and how it will change. There are many challenges to be faced from the spatial and temporal densification of data to the regionalisation of climate change models as well as achieving a better understanding of the role of the various compartments and how they fit together. This field of research must be able to mobilise intensively, often at an international level, large research infrastructures such as computing resources and a wide range of spatial and *in situ* instruments.

In a similar way modelling the change in ecosystems over the long run will be a major step forward. This requires an understanding of the dynamics of biological resources, the evolution of ecosystems and their components and being in a position to measure the impact of socio-economic activities. The scientific fields concerned by this work would encompass life and environmental sciences as well as human and social sciences.

Producing an integrated model of the various types of resources and services provided by the environment and ecosystems (water, soil, subsoil, terrestrial, aquatic, marine and coastal environments) will enable us to assess the impact on demand, to put needs into perspective and thereby to set goals over the long term.
The emerging environmental economy will have to accurately consider all of these elements which particularly concern the industrial, agricultural, and water and waste processing management sectors.

Regarding environmental risks, **research on ecotoxicology and environmental ecology** enables us to understand and to forecast the processes by which contaminants are transferred and their effects on the environment and human health. It calls for greater dialogue between researchers themselves as well as between researchers, companies and public authorities. France's support to the Foundation for Research on biodiversity and the project of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) forms part of this objective.

To control energy in four key areas

By opting for nuclear energy France is less exposed than other economic powers to unexpected events in the energy sector. A leader in the nuclear industry, France intends to reinforce its position while developing clean energy sources, particularly photovoltaic solar energy, second generation bio-fuels and sea-based energy sources. For every euro spent by the State on nuclear research, one euro will be spent on research on clean energy sources and the preservation of the environment.

Nuclear: basic and technological research must respond to the rise in world energy demand by placing nuclear energy within a sustainable development framework through, for example, the development of fourth generation reactors. This requires the anticipation of technological leaps (gas or metallic coolants, resistance of materials subject to irradiation and high temperatures) and the continuous upgrading of our research tools (research reactors, fuel cycle installations). In parallel, it is essential to study the best solutions for the management of radioactive waste, particularly in light of the 2006 law on radioactive materials and waste.

Photovoltaic solar energy: the National Institute for Solar Energy (INES) network supports the creation of an industrial photovoltaic sector while drawing, in particular, on the PV Alliance project which brings together CEA, EDF Energies nouvelles and Photowatt. Thin film technologies, which represent the emergence of a breakthrough technology, and research on organic materials should enable photovoltaic solar energy to become more competitive especially if sufficient industrial capacity is retained in France.

Second generation bio-fuels: two types of processes, thermal and biological, mean that the utilisation of the whole plant can be envisaged. Nevertheless, the organisation of the sources of supply remains a significant concern which justifies the joint action of the State and the private sector.

Sea-based energy sources: France has real potential in this field as it is the world's second maritime power due to its exclusive economic zone and overseas territories. Nevertheless, there are only a few technologies that can claim to be at the industrialisation stage, the marine environment making it difficult to install and maintain infrastructures.

All of these technologies require the development of "systems" based methodologies within complex and transversal projects which can integrate the latest developments from fundamental research and receive information on scientific problems. For these reasons, at a global level and between United States/Japan as well as China/India, "technology integration centres" are emerging which bring together resources and competencies to create an essential size and an international dimension. The optimal use of these integration centres requires upstream input from knowledge-based communities spread throughout France which are also capable of providing essential renewal through the provision of appropriate support. The integration centres must also be closely tied to downstream companies in this field to ensure both that technological innovations are fully utilised and that feedbacks to the knowledge based communities are taking place.

France intends to develop integration centres for each of the technological channels retained by strengthening existing sites or sites in the process of being created (as is the case for photovoltaic energy with INES or for the storage of energy). The aim of these centres is to become leading players at the international level and to form alliances with their European counterparts. In parallel, work must be done on the development of CO2 storage, energy conversion, particularly with fuel cell technology, and the lower use of hydrogen, which also will contribute to limiting the effects of climate change.

To promote sustainable cities and modes of transport

The fulfilment of sustainable development goals under conditions acceptable to citizens requires a significant change in the design and in the running of urban systems and their networks, a gradual but significant modification of the way in which we lead our lives and the development of services which underpin all parts of our social and economic life. The globalisation and development of a knowledge-based society are leading to a great rise in global urbanisation and the mobility of people and goods. Furthermore, a very large share of greenhouse gas emissions concerns the housing and service sectors as well as the transport sector.

From a global perspective, subjects such as urban planning, economics, sociology of organisations, information sciences and operational research are certainly important contributors alongside "hard" sciences and engineering.

Energy moderation in transport, construction, industrial and agricultural processes is the first step in separating economic growth and energy consumption. In sectors where energy is a major concern, innovative optimisation techniques are one of the solutions to reduce energy consumption:

- **in the transport sector:** there is still significant room for progress with current engines but we must prepare ourselves for a shift towards the use of hybrid vehicles and eventually electrical vehicles. Public forms of transport must also pursue their transition towards innovative technologies. Air transport, particularly within a European framework, must cut down its greenhouse gas effect and noise emissions at their sources through the use of satellite navigation technologies and by the defragmentation of air space. All of these modes of transport must use lighter materials that perform better and are more recyclable;

- **in the building sector:** the aim is to reduce the energy consumption of new and existing buildings. Energy equipment and systems must shrink in size and must store energy. In around 2050, the aim is to have buildings with surplus energy, thanks, in particular, to the contribution of solar energy.

In both cases, **the use of nanotechnologies and the design of intelligent materials will be a crucial factor** to meet global objectives regarding the protection of the environment and sustainable development. Furthermore, the availability of breakthrough technologies for the fulfilment of these goals and the technologies' dissemination within the fleets (of housing, vehicles, processes) require both the validation of a number of options and the anticipation of the appropriate use by citizens before market accessibility. Some of these options will only find a market around 2020 or beyond. In terms of company strategy, this horizon is remote and experiments must be carried out as from now. It will be necessary to develop research through several stages and to demonstrate the proof of concepts.

To develop eco-technology and ecodesign

The development of **eco-technology** enables the design of competitive products and services that have a law or even no environmental impact throughout their lifecycle. The applications vary greatly and concern the subjects areas mentioned above as well as the whole economy.

"Green" chemistry is a specific field in which France, thanks to its assets and industrial framework, must position itself. It contributes to the development of new solutions to reduce and eliminate over time the use and production of polluting substances through innovative chemical processes and new applications offered by synthetic biology.

By definition, **ecodesign** draws on several areas of science as well as industrial and architectural design. The wide range of applications to be developed is only possible through multidisciplinary contact and a close partnership with companies, designers and architects. The environmental impact of a product or service throughout its lifecycle is an essential factor to educate consumers, guide industrial R&D, encourage new research and enlighten public policies.

Information, communication and nanotechnology

Challenges

Unprecedented acceleration of technological progress

Information and communication sciences and technologies are at the source of a "third industrial revolution". The socio-economic changes which occur alongside them are comparable to those brought about by the appearance of the steam engine and electricity. Ubiquitous and distributed on a wide scale, they are the cause of radical changes in our modern societies on a collective, individual, professional and a domestic level in the areas of communication, media and transport.

Current tools such as "web 2.0", very high speed networks, "ambient intelligence" solutions, and the increasingly need to model, simulate, store and process large amounts of data will become major challenges for researchers in the future. The manufacturing of electronic circuits will be drastically revised with the new processes involving nanotechnology thus creating innovative architectures that will shake up the digital world and its uses.

Furthermore, the emergence of the digital world has made mathematics a key discipline to create numerous scientific breakthroughs with innovative applications like cryptology and bank security, financial mathematics, modelling, and the compression of images.

The last few years have also shown that the development of technological solutions must include cultural, sociological, ethical and legal changes. This is not only to offer solutions which are better suited to the various uses and users but also to prevent induced problems: illegal content and downloading, security of online commerce and the fight against cybercrime.

A major economic issue

Information and communication sciences and technologies are significantly modifying the creation, production and distribution processes, thus placing them at the heart of economic and technological progress in all sectors of activity. Over the past ten years, they have represented over 25% of the economy's growth and 40% of the gain in productivity due to the diffusion of the innovations to the entire economy. It is therefore important to reconsider the place of digital technology not only as an outcome of technological change but as one of its key drivers.

Information and communication sciences and technologies contribute furthermore to major societal challenges like the ageing population with the use of e-health technology, the fight against climate change with eco-technology, the prevention of the risks of terrorism and natural risks, with the ongoing improvement of information monitoring and processing systems; the improvement in the productivity of public services and the quality of these services for the users.

In particular, information and communication sciences and technologies contribute to the competitiveness of strategic companies for which France is occupying a leadership position in areas such as aeronautics, defence, healthcare and energy. The existence of large companies in the areas of telecommunications and multimedia (France Telecom, Alcatel Lucent, etc.), components for embedded systems (ST Microelectronic, Thales, etc.) and calculators (Bull) as well as important IT service companies (Cap Gemini, Atos Origin) proves that France is present in this industrial sector. However, our position is less favourable in the area of software edition with a small number of companies among the leaders (mainly Dassault Systèmes after the acquisition of Business Objects and Ilog by foreign companies).

Nevertheless, the software industry remains an area in which small firms can quickly become international champions if the innovation process is quick and efficient. France is well positioned in terms of the creation of startups[5], and, therefore, the utilisation of research work. However, unlike the US, the lack of support measures and environments which encourage their growth shows that there is a problem with the economic environment: researchers and innovative companies find it harder to attract capital for the industrialisation of their work. There are also other negative factors like the difficulty in accessing EU market because of its high level of fragmentation.

[5] *France numérique 2012. Plan de développement de l'économie numérique*, (Digital France 2012. Digital economy development plan, October 2008.)

To prepare the Internet of the future and strengthen IT security

New information technologies rely on key e-infrastructures and more precisely on the Internet. This network will face massive changes with the arrival of new infrastructures resulting in an unprecedented number of web services and mobile applications which can be used on a mobile phone. Initial technological choices are sometimes unsuited to the needs of current applications and users, who are demanding with regard to mobility, speed and portability. The Internet's architecture must therefore be adapted to even higher and more heterogenous flows as well as new access methods. This new structure is seen as "The Future of the Internet" and it represents an important economic and sovereign challenge for France and its European partners. The fact that most of the large digital communication infrastructures (Internet network, GPS, search engines, digital memory, etc.) are being developed almost exclusively outside of the EU is worrying and should encourage France and Euroe to react and develop strategic e-infrastructures.

With the growing use of information technologies and the increasing complexity of systems (heterogeneity of transmission flows), the security of digital systems has become a social, economic and also political issue. The mobility of users, the demand for access to data and the dematerialisation of procedures (for example, civil status records are obtained online) as well as the pervasive use of digital technologies mean that the vulnerability of every layer of the IT system (networks, protocols, operating systems, applications, data) is growing. The progress made in this area could allow France to strengthen its market position in the security economy, a market in rapid expansion which is still mainly dominated by the US.

To face up to these challenges, efforts should be focused on a small number of multidisciplinary pilot laboratories structured around competitiveness clusters which are capable of attracting the best players in the field and which can rely on a range of ad hoc platforms and systems for experiments: research grids, ambient intelligence, etc. The European Institute of Innovation and Technology (EIT) could strengthen this measure by giving it a European dimension.

To reconsider the integration of hardware and software

The traditional distinction between hardware and software has to be revised due to the technological offer associated with nanosciences and the ever growing demand for embedded systems.

Miniaturisation means more and more complex systems can be made on smaller and smaller circuits. The applications are numerous and concern both the high density circuits of advanced computer architectures and the new integrated sensors used in new environmental technologies.

The **development of smart systems** needed by all areas of industry (automotive, aeronautics, space, telecommunications, etc.) requires the diversification of the functions integrated on chips, such as ultra-low power communication. As an example, in the area of defence, these new chips are essential elements in the design of unmanned aerial vehicles or new soldier embarking electronics to be more efficient and more secure.

The growing complexity of systems leads to a need for high performance architectures which are jointly designed by researchers having competences in computer sciences and materials sciences to integrate functionalities at the physical, medium access, protocol and applications layers. The co-design is aiming to develop architecture featuring enhanced performance in terms of functionalities, availability and reliability taking into account more and more demanding requirements in terms of speed and power consumption.

For durable and sustainable development of nanotechnologies in France

Nanosciences and nanotechnologies are always associated for the development of future materials. France has significant strengths and there are opportunities both in the field of basic research and in the field of technology to reinforce cooperation and interaction between physicists, chemists and biologists as well as designers, manufacturers and users to create a unique critical mass capable of competing on a global scale.
Three main areas have been identified:

- **nanoelectronics** offer new scientific perspectives through the exploitation of physical effects (quantum electronics, molecular electronics, spintronics, nanophotonics, etc.). This will turn into the development of new technological opportunities (low consumption electronics) and new applications (Systems on Chip, wireless systems);

- **nanomaterials** and materials structured at a nanometric scale exhibit new properties, thanks to their size and organisation (carbon nanotubes, fullerenes, etc.);

- **nanobiotechnologies**, resulting from the convergence between nanotechnologies and biology stimulate numerous applications in biology, medicine and agro-food.

These three areas are driven by three transverse domains: nanofabrication and nanocharacterisation; multi-scale and multi-physics modelling and **the security and management of risks surrounding nanomaterials**.

In order to spur innovation a project called "NanoInnov" has been launched involving the Saclay and Grenoble clusters. It is likely that this project will carry a European dimension through the European Institute of Technology.

To develop the software industry

A strong capacity to create and edit original software is an essential factor for the competitiveness of service companies (banks, insurance, logistics) and high- and medium-tech companies which integrate embedded intelligence (automotive, aeronautics).

The software industry is an industry which relies on a highly qualified workforce and in which emerging countries such as India and China are becoming very competitive. The weaknesses of French industry, here and in other areas, are related to the culture of risk and entrepreneurship between research, industry and risk capital companies. There are other causes which are more specific to the software sector in France:

- There is often a lack of digital culture among decision makers and entrepreneurs and, more generally, a significant digital divide within society. It is important that the foundations of IT and the new stakes posed by digital technology are given a prominent position within education, from primary school to higher education and life-long training.

- The coexistence of two national research organisations in the fields of science and information technologies (CNRS and INRIA) does not enable the considerable potential of public research to be efficiently exploited. These research organisations must coordinate their actions and build a clear strategy while closely involving other leading institutes in these fields which have the key competencies and recognised experience in creating value. This coordination must, in particular, associate research carried out in universities and elite schools ("grandes écoles"). It will also enhance the efficiency of mechanisms and measures which favour innovation and technological transfer.