National Observatory for the Impacts of Global Warming

Climate change: costs of impacts and lines of adaptation

Report to the Prime Minister and Parliament

2009

Contents

A word from the President

The conclusions of the Intergovernmental Panel on Climate Change (IPCC) set out in its last report for 2007 are final: man is indeed responsible for the climate change that is affecting Earth. Despite this observation, the acknowledgement has yet to be transformed into concrete actions: greenhouse gas emissions have soared since 1990, and even in the period of global economic crisis which we have been experiencing since 2008, the trend in the levels of CO_2 concentration in the atmosphere has not shown any change.

Taking into account climate system inertia, global warming will increase during the coming decades, even if emissions drop sharply. The continued increase in emissions at the current rate could lead us to a catastrophic climatic disturbance. At a meeting in Copenhagen in March 2009, several researchers observed that the emissions of the last few years and certain aspects of the climate were approaching the worst case scenario considered by the IPCC.

Our societies must react in order to keep global warming within limits that enable the effects of climatic change and the resulting catastrophic consequences for the world's populations to be avoided. The effort to be made is essential and vast, so as to limit our greenhouse gas emissions considerably. This requires radical transformations of our economic, industrial and agricultural systems, our way of life and our behaviour.

The awarding of the Nobel Peace Prize to IPCC researchers and to Al Gore has great symbolic value, because the ravages that could accompany a radical change in our climate are comparable to those of a war. It is time to move into action and at the next meeting, in Copenhagen, of the conference of the parties to the United Nations Framework Convention on climate change must lead to an ambitious agreement between all countries in order to meet this challenge.

This is not the first time that humanity has been confronted by the need to adapt to new living conditions, and several societies have been able to overcome considerable difficulties thanks to a change in their practices. This is how man has been able to colonise particularly inhospitable lands, such as the arctic regions or certain tropical deserts. Yet conversely to these examples given to us by history, modern man has the chance to be able to anticipate the changes and to organise his adaptation thereto. We must seize this chance and plan right now the changes to be made in our behaviour.

Since its creation in 2001, ONERC has been an essential tool for bringing public authorities and elected officials the necessary bases for strategic choices and for steering political decisions. After having suggested a national strategy for adaptation to climate change for France, ONERC, together with the Ministry for Ecology, Energy, Sustainable Development and the Sea, responsible for Green Technologies and climate Negotiations, steered an interministerial working group on the impacts of climate change, adaptation and associated costs.

Unlike the works carried out over the last few years, for example those by the World Bank, the United Nations Framework Convention on Climate Change or the Stern Review, the aim was not to obtain a global estimate of cost, but to create the most exhaustive description possible of impacts and to give the basic costs of these impacts by sector, as well as some adaptation measures. The exercise proved to be innovative, particularly for the large numbers of players mobilised, but it came up against a lack of data and references, which proves how far we still have to go. There is great uncertainty over climate projections, and even more so when we try to quantify the impacts that climate change will have, but it does not justify a wait-and-see attitude or lack of decision.

Within the alliance of developed nations, France is amongst those that are the most advanced in the field of combating climate change and adapting to its consequences. We should make the most of

the knowledge gathered by this interministerial panel now, in order to draw up an ambitious national adaptation plan, as heralded by the Planning Law on the Grenelle Environment Forum, adopted on 3 August 2009. The Minister of State, minister for Ecology, Energy, Sustainable Development and the Sea, responsible for Green Technologies and climate Negotiations, wants the preparation of this plan to be the subject of a wide national consultation. This consultation, which will take place throughout 2010, will allow opinions on a field about which we still know too little to be collected from civil society, communities and our citizens.

This ONERC report presents the main results set out by the interministerial panel. The work was spread over two and a half years and more than 200 people were involved. In the name of the ONERC Streaming Committee, I would like to thank all the participants in these works, which are proving to be essential in enlightening decision makers and helping them to make the best choices for the adaptation measures to shape our common future.

Paul Vergès

Summary for decision makers

Climate change is today a reality, and its consequences will have a significant medium-term impact on our environment and our ways of life. The Grenelle Environment Forum recommended anticipating these as of now, in order to minimise the resulting socio-economic impacts and reduce the vulnerability of the players concerned. Defining and evaluating the impacts of climate change that players will have to confront allows the most suitable adaptation measures to be planned.
In March 2007, the Ministry for Ecology, Energy, Sustainable Development and the Sea (MEEDDM) formed an interministerial group under the name "Impacts of climate change, adaptation and associated costs in France", thus undertaking a project to evaluate the damage and the measures that will allow the cost of impacts to be limited.
One of the characteristics of this task resides in the fact that it is, for the most part, carried out by the services concerned, with research organisation and private player collaboration. It must be considered as a stage in an ambitious public action gauging process: **it leads to temporary results that remain open to discussion, for development in later stages.**

Methodological frameworks

The decision has produced **sectoral evaluations** at Horizons **2030, 2050 and 2100, without wanting to aggregate the results.** At this stage, the thematic works have not been designed to be exhaustive: only certain impacts have been assessed in a quantitative fashion.
The group chose to work from the **IPCC A2 and B2 scenarios,** in accordance with the simulations created by CNRM/Météo-France using the Arpège-Climate model. A2 is a rather pessimistic scenario, B2 an optimistic scenario: these two scenarios are generally those adopted in climate change impact analysis.
In the absence of a long-term socio-economic outlook for France per region and per sector, it was decided to work using the current French socio-economic situation (scenario known as "constant economy"). This choice allows the impact of climate change to be isolated from that of other developments and does not add macroeconomic uncertainties to uncertainties relating to climatic aspects. Nevertheless, this choice remains restrictive and limiting for some sectors, for which a socioeconomic change is already anticipated or for which these changes constitute a determining factor in the vulnerability to climate change.

Scope and results of thematic works

Only a limited number of sectors have been studied and within these the analysis only concerned a selection of climate change impacts. The estimated costs must be considered as **rough estimates,** due to the limits of the methodologies used and the non-exhaustive nature of the evaluations carried out. The detail of the quantitative evaluations is recorded in the general report.

Water resources

If we consider demand as being stable, a deficit of **2 billion m^3 per year** in meeting the current needs of industry, agriculture (irrigation) and drinking water supply will be seen at **Horizon 2050.** The projections indicate that the zones most affected will be those already concerned by structural deficits. Estimating the compensation for the potential deficit in water resources at Horizon 2050 only represents a "visible" part of the adaptations needed and an extremely partial evaluation of the need to adapt water-related activities. All sectors will be affected by this change, which will mean an increase in conflicts of use, a decrease in water quality and therefore a disturbance to aquatic ecosystems or part of the water resources. The adaptation of each sector to climate change will include better management of water consumption: adaptation of water demands and requirements is a priority theme. As to the adaptation of the offer, this will have to come within a planned adaptation, in order to study the impacts in advance. The evaluation of the potential cost of these adaptation

measures can only be made via local enquiries. They may represent very high operating investments and expenditures.

Natural hazards and insurances

The analysis concerned four specific types of hazard: floods, coastal hazards, clay shrinkage and swelling and gravitational hazards (avalanches, mudslides, rockfalls, etc.). For example, at a constant rate of urbanisation, the average annual damage to dwellings generated by the risk of **clay shrinkage and swelling** could exceed **EUR one billion in 2100.** This cost could be multiplied by a factor of 4 to 5 if we take into account urbanisation in risk zones. In the absence of adaptation, the impacts of **coastal hazards** (erosion and submersion), will eventually concern several hundred thousand people and the destruction of housing will cost, **for the Languedoc-Roussillon region alone, several tens of billion euro over a century.** The **cost of damages linked to floods caused by rivers breaking their banks** could also be significant with, in this case, major uncertainties remaining as to the expected impact and the difficulty in distinguishing the costs resulting from climate change alone. As to the cost relating to **gravitational hazards,** this has not been assessed, because of a need for more information. However, the heavy **impact on society** of catastrophes arising from these hazards should be underlined, as these can lead to the loss of human life and very high localised costs.

Biodiversity

Even though it is sometimes difficult to isolate the impacts of climate change from other pressures suffered by ecosystems, and even though the problems are very different depending on the ecosystem and the species concerned, **signs of changes in biodiversity attributable to the gradual modifications caused by climate change can already be seen.** Biodiversity is directly affected by the changes in temperature and rainfall amounts in particular, but the **indirect effects** could be at least as high. It is therefore essential to know more about the cross effects of climate change impacts on one hand, and spontaneous or planned adaptations on the other, in order to prevent negative consequences for biodiversity. Furthermore, the **preservation of natural ecosystems and their resilience may also constitute an adaptation action** (combating flooding, for example). The economic assessment of biodiversity losses is based on the concept of ecosystem services. This approach, applied to coral ecosystems and non-goods services provided by forests shows clearly negative impacts. On a more global scale, **significant economic losses related to the reduction, and even disappearance of regulation services** are to be expected, in particular in the second half of the 21st century. Giving priority to territorial governance may enable the better integration of biodiversity protection and the various challenges to be met, on relevant spatial scales.

Health

The economic assessment task concerned the impact of two major extreme events (heatwave in 2003 and flooding of Gard in 2002). The measurement of the impact of the heatwave took into account the real costs and the costs saved for health insurance, the indirect costs (loss of human life, non-productive time) and the intangible costs (estimated value of the loss of quality of life and suffering linked to a decline in health). If the impact for health insurance does not seem significant, the global cost for society as a whole is nevertheless considerable. We estimate the value lost by our society because of the **2003 heatwave** as being a little **more than EUR 500 million** on the basis of an average loss of one year of lifespan[1]. During the floods, three major danger to health phases were noted: an immediate danger phase (injury and death), a short-term danger phase (risks of infection), and a danger phase regarding the psychological problems relating to post-traumatic stress. The group's evaluation task concentrated on this last phase. With regard to the **Gard floods,** the cost of taking care of people presenting psychological disorders has been estimated at

[1] Calculated in accordance with the recommendations of the Boiteux report (2001)

approximately **EUR 234,000 (for 953 people).** This is a low estimate, since it only concerns the cost of treatment (the indirect and intangible costs not having been calculated).

Agricultural Sector

The growth models for the field crops used show an increase in yield in response to climate change (notably for wheat up to horizon 2100). This increase does not take into account inter-annual variability and the drop in water availability. The inclusion of these variability factors, which are still badly integrated into the growth models, could enable the results to be refined and the anticipated increase in yield to be moderated. For example, increased events like the **2003 heatwave** could, in 2100, represent a cost of up to more than **EUR 300 million per year for a crop such as wheat** in the absence of any adaptation measure. **Viticulture** will also be affected by climate change, with high territorial differences and effects on the quality of the wines. In the case of **meadows,** the exercise carried out for the **peri-Mediterranean area** gives a loss-compensation cost of **EUR 200 million per year** over the second half of the 21st century. It is therefore necessary to adapt to these forecast changes as of now.

Forest sector

An increase in productivity (volume of wood) is expected in the short and medium terms because of the increase in temperatures and rates of CO_2 in the atmosphere. Therefore, the additional annual gross production will reach almost 30 million m^3 in 2050. Nevertheless, over this same period, the **expected gains in productivity are on the same scale as possible losses** through wilting, fire, drought, etc. After 2050, the trend will be unfavourable because of water stress, particularly in the south of France, with an increased risk of drought and fire; suggesting **clearly negative impacts in the long term.** In order to compensate for these effects, adaptation by the forest sector will have to make all parties in the field play their part. With regard to **forest fires,** a study led by the interministerial Mission on the risk climate change-related fires is currently underway. According to the initial results, the expected climate change will be accompanied by an **increased hazard in areas that are already at risk** (where systems protecting forests from fires are in place), as well as by a **regional spread (towards the North and at altitude)** of the “forest fire” hazard.

Energy

Climate change will have consequences on demand, with a drop in energy consumption in winter, but an increase in summer because of the need for air conditioning in housing and vehicles. The economic assessment of these impacts reveals **an energy saving trend of around 3%** in the constant economy scenario, i.e. 1.8 to 5.9 Mtoe/year according to the scenarios and horizons, but the spontaneous development of residential and automotive air conditioning will cut global warming-related energy savings by half. In terms of electricity production, because of the restrictions relating to water resources, we must expect a **drop in production of around 15% from hydroelectric plants,** for which water is the “raw material”, and **yield losses** for production and energy transport infrastructures.

Tourism

The results provided by a study carried out by the *Centre International de Recherche sur l'Environnement et le Développement* (CIRED – International Research Centre on Environment and Development) and Sogreah, based on the summer tourist comfort index (ICT), highlight **a drop in summer climate comfort** throughout mainland France, with maximum temperatures reached becoming too high to afford tourists maximum comfort. This deterioration is less marked in the Northern half of France (Northwest Coast specifically), as well as in certain mountainous departments (particularly in the Alps). **In 2100, a significant impact on summer turnover** is to be expected, because of a drop in attractiveness to tourists, except in the north of France and certain departments in the Alps. On the other hand, an improvement in conditions will be seen in the inter-seasons. With regard to winter sports, an OECD study in 2006 indicated that, in the Alps, **the**

reduction in snow cover will reduce the reliability of the depth of snow. In the French Alps, 143 skiable resorts currently have a low snow depth. In the event of warming by +1°C, this will be the case for only 123 resorts; for 96 resorts if warming reaches 2°C and for only 55 resorts in the event of warming by 4°C. In a general fashion, this work indicated that, in all geographical areas of mainland France, the tourism sector must adapt to future indications of climate change in order to limit the negative impacts and seize the potential opportunities.

Transport infrastructures

The predicted climate change could mean adaptations are required at road infrastructure level. If the 2003 heatwave did not seem to cause generalised disorders that call into question the permanence of the roadway or civil engineering structures, the effects of **repetitive periods of heatwave** are not known at this time. As far as the risk of **permanent marine submersion** linked to an overall rise in sea levels by one metre is concerned, this would represent a property cost, for the mainland A-roads (excluding motorways and other roads), excluding loss of use and outside of the "network" effect (for example the submersion of a limited length of road could cause an entire section to be unavailable but only the property value for the submerged length has been calculated) that falls in a range between **EUR 500 million and 1.2 billion.** It could reach EUR 2 billion if the current protections prove to be insufficient. For reasons of data availability, infrastructures outside the public national network and port, rail and river infrastructures have not been studied.

Territories

The words specifically concerned the question of the pertinent scale of analysis, sectoral interaction on a territorial scale, and the concept of **transition towards change.** The importance of the time interval needed for what we could call **"the vulnerability apprenticeship"** was highlighted. This conversion will last as long as the publics likely to be affected by the impacts of climate change are not, on the face of it, uniform. For these reasons, the informing, awareness raising and mobilising of players and populations in relation to climate change and adaptation constitute fundamental aspects. In addition, it has been proved that adaptation will above all include a better knowledge of climate change and its challenges, with **organisation of skills** also playing a major role. In view of these observations, it is necessary to take the measure of **social rhythms** useful for making concrete the common objective of a non-fractured development towards new lifestyles.

Analysis elements

The works carried out highlight the costs, but also the benefits linked to climate change in mainland France, depending on the sector considered, climate scenarios and time horizon. For some sectors, we will see both costs and opportunities depending on the impact studied, so much so that it is sometimes difficult to determine the sign of the "net" impact of climate change. Nevertheless, in view of the qualitative and quantitative analyses carried out by the study groups, we can expect a negative global impact from climate change; the **costs could reach several hundreds of millions of euro per year for various sectors if no adaptation is undertaken.**

Seen as an additional policy to mitigation, **adaptation will allow the costs of climate change impacts to be limited significantly,** and even transformed into opportunities in some cases. If **spontaneous adaptation** can already enable the negative impacts of climate change to be limited, we should note that unorganised adaptation could also cause these to be increased or the benefits to be limited: this is the case with energy, with the spontaneous development of air conditioning, which plays a part in significantly increasing energy consumption in summer, and therefore greenhouse gas emissions; or for agriculture, where a spontaneous increase in irrigation cannot be compatible with the reduction in water availability. This **highlights the importance of coordinating and organising adaptation** in order to avoid these pitfalls.

The impacts of climate change will not be spread evenly or fairly across the territory:

- from a **geographical** point of view, some regions could find themselves severely affected by the changes, whereas others will be less so and may even turn this to good account, these

differences being due as much to climatic hazards as to territorial geographical and socioeconomic characteristics likely to influence the vulnerability of systems;
- from an **individual** point of view, players will not be equally subject to climate change. Depending on the sector of economic activity and the social vulnerability of households, the effects will not be redistributed in the same way. **The most disadvantaged individuals will probably be the most and the quickest affected** by the impacts of climate change.

Adaptation to climate change must therefore be contextualised and make sure **inequalities in view of risk are reduced.**
Several uncertainties remain over what the consequences of climate change will be: it is therefore necessary to plan governance methods that **can be both planned for the long term and progressive** over the short term.

Identified lines of adaptation

While the works were mainly focussed on the impacts of climate change, some lines of adaptation were listed or suggested. These options **do not, at this stage, constitute recommendations, but rather lines to be considered within the framework of adaptation planning studies.** Their relevance, efficiency and feasibility must be studied in an integrated fashion, in particular by taking into account local context.
There follows some non-exhaustive examples of lines identified :

- general: organise availability of climate model results – in particular the collapses on a local level - and impact studies;
- water: implement alternative agricultural systems that are more robust and less demanding on water resources (already included in Objective Earth 2020);
- natural hazards : take into account climate change in planning and development documents;
- biodiversity: enhance protected spaces as preferred areas for observing the impacts of climate change and monitoring adaptation strategies;
- health: integrate health risks of climatic origin in basic and ongoing training for healthcare professionals;
- agriculture: diversify the crop systems, allowing “evasion”, “avoidance” and “tolerance” to be combined;
- energy: ease the development of a building and urbanism framework that reduces the demands on energy, particularly that of air conditioning;
- tourism: develop “four-season tourism”, in order to reduce the dependence on snow.

Perspectives

For reasons of feasibility and data availability, some points could not be tackled. These choices do not prejudge the importance of the impacts of climate change on these sectors, which merit being treated in future stages.
The fields that were not handled in this study and that must form the subject of specific attention in future stages were as follows :

- **“urbanism”**, as well as the **air, port, river and rail** sectors;
- the **maritime, fishing and aquaculture** sector;
- **tertiary sector** activities (other than the tourism sector);
- **industrial sector** activities (other than the energy sector);
- the impacts of climate change on **cultural heritage.**

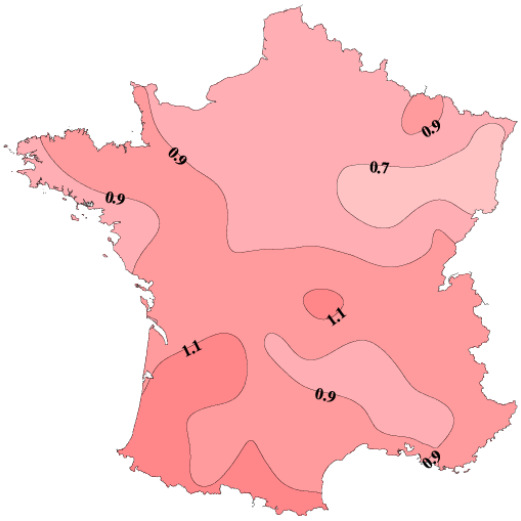
The integration of **Overseas territories** in the quantitative evaluation of impacts and adaptation measures constitutes a major priority. The problems of climate change in the Overseas Departments and Collectivities and in New Caledonia are different from those affecting mainland France. This involves, as of now, works resulting in particular in a better knowledge of the development of climatic parameters and their consequences in these areas.
The **crossover knowledge and observation requirements** have been identified in order to advance understanding of the economic impacts of climate change:

- **improving knowledge** about climate changes, in particular for the hazards that remain subject to major uncertainty :
  + the change in rainfall patterns;
  + the rise in sea levels;
  + the consequences of climate change on the hydrological regime;
  + highly localised climatic hazards, i.e. gravitational hazards;
  + changes to sun and wind patterns;
  + changes to the physico-chemical characteristics of marine habitats.
- improve the characterisation of certain hazards – droughts or heatwaves for example – in terms of intensity or even territorialisation;
- produce **territorialised data,** whether this is for hazards, models, climate scenarios or socio-economic development scenarios;
- improve the **characterisation and quantification of non-goods impacts;**
- **integrate the problems of adaptation and mitigation,** via research aimed at better identifying their synergy and conflicts;
- improve understanding of the **spontaneous adaptation** behaviour of the various players;
- lead a discussion on the feasibility and acceptability of implementing **planned adaptation** measures;
- continue works on **adaptation costs,** little touched on here, on the junction between **the economics of uncertainty** and **long-term economics,** and involving the availability of economic analysis tools for adaptation;
- improve the **inclusion of sectoral interactions:** the impacts of climate change on one given sector will in fact be largely influenced by the impacts affecting other sectors;
- launch a global discussion and a planning effort with regard to **the questions of water availability and use** within the context of climate change;
- continue a **multi-risk and multi-sector discussion** on adaptation.

Finally, in general, the steps must be **produced on other scales,** in particular for local collectivities.

Introduction

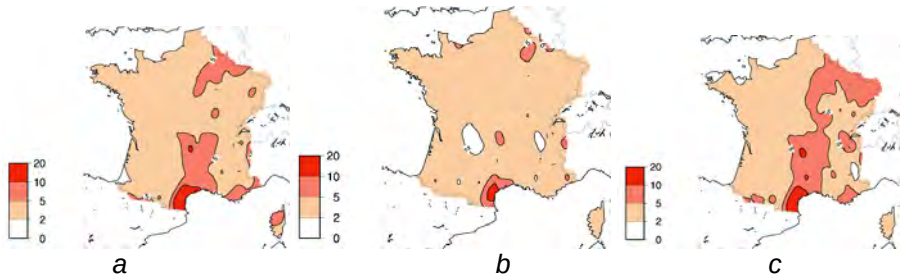
Since the 4th IPCC report, published in 2007, doubt is no longer permitted as to whether global warming is now a reality. Climate models all state that this warming must continue over the coming decades. The global warming recorded in mainland France during the 20th century is about 30% greater than the average warming throughout the globe. The average annual temperature has risen by 0.95°C in mainland France, compared to 0.74°C globally. These values are even higher if we only concern ourselves with the second half of the 20th century: increase of 1.1 to 1.5°C over the period 1950-2000. This average warming is accompanied with an increase in autumn and winter rainfall (between 5 and 35%) and a drop in summer rainfall.



Map 1: Increase in the average annual temperature in mainland France over the period 1901-2000

(source: Météo France)

If this trend must continue in the same proportions, this means that global warming of 2°C will mean warming of almost 3°C for France, or in the most pessimistic scenario, global warming of 6°C will mean we will see warming of 8°C. **Furthermore, in France, summer warming will be clearly more marked than winter warming. This confirms in particular that episodes of heatwave similar to or more intense than that of 2003 will inevitably occur much more frequently.**



a *b* *c*

Map 2: Relationship between the number of days of summer heatwave predicted for the period 2021 and 2050 and that observed during the reference period 1961-1990. Using IPCC scenarios A1B (a), A2 (b) and B1 (c) (source: Météo France)

The exact scale of climate change is still uncertain because it is linked to complex phenomena and to the political and technical choices that will be made.

Numerous researchers, who met in Copenhagen in March 2009[2] on the initiative of the International Alliance of Research Universities, highlighted that the analysis of the latest observations showed that **greenhouse gas emissions were nearing the most extreme scenarios predicted by the IPCC.** The climate's response is also **in the upper limit of the prediction range.**
The speed at which the arctic ice caps are melting has accelerated and during 2007 and 2008 the size of the ice cap at the end of summer has seen an extreme reduction in comparison to the average for the previous years. The speed at which the sea is rising is increasing, from 1993 to date, caused in large part by the increasing contribution from the melting Greenland and Antarctic ice caps. The prediction models for rising sea levels have trouble taking into account the behaviour of these polar icecaps and their results are very uncertain. New estimates based on the relationship between the average global increase in temperature and the rise in sea level over the last 120 years, presuming that this relationship will stay the same in the future, suggests an increase in sea level close to or greater than 1 metre by 2100.
It would appear that, in the current context, greenhouse gas (GHG) emissions cannot be sufficiently adjusted in the short term to stabilise the world's climate: consequently it has become necessary to take into account adaptation, in addition to mitigation actions (i.e. reduction in GHG emissions). **Adaptation** to climate change is defined as "the adjustment of natural or human systems in response to present or future climatic stimuli or their effects, in order to reduce harmful effects or to exploit beneficial opportunities". To this end, we can distinguish adaptation measures by (i) their **spontaneous or planned** nature and (ii) their **private or public** initiative.

The economic challenges of adaptation have in particular been put under the spotlight with the publication of the Stern Review in 2006: the major impacts of climate change will cost up to **20% of the world GNP** (around USD 6,000 billion per year, according to the review), whereas the measures enabling them to be avoided will only cost **1 to 2%** (i.e. between USD 300 and 600 billion per year). A recent report (Parry et al. 2009), co-authored by the President of the impact evaluation group for the last IPCC report, gives similar estimates.

Table 1: Annual costs of global impacts in the WORLD (billions of US dollars)

	Optimistic scenario	Pessimistic scenario	Horizon
Parry et al. report (2009)	1,900	2,400	2060 without adaptation
	1,200	1,500	2060 with adaptation
Stern Review (2006)	1,500	6,000	current and future

In addition to the economic sector, adaptation also concerns biodiversity, water resource management, territorial governance, etc.
Due to the inertia of climatic systems, adaptation actions will only have concrete effects in the medium or long term, but **need to be taken as of today** for maximum efficiency and a reduction in the scale of the impacts. Short-term mobilisation and reaction to counter a medium- or long-term impact is the greatest challenge posed by adaptation.
The first ONERC report in 2005 set out the basis of the climate change adaptation strategy, which was developed in 2006 and adopted by the interministerial committee on sustainable development on 13 November 2006. The second ONERC report in 2007 presented the health risks caused by climate change. This third report is devoted to the results of the interministerial working group on the impacts of climate change, adaptation and associated costs. It sets out to present estimates of the cost of inaction and adaptation implemented in a non-exhaustive fashion, for the key sectors.

The full report by this interministerial group is available on the ONERC website: www.onerc.gouv.fr. It details the estimates made and the reader may refer to it for further information.

[2] http://climatecongress.ku.dk/pdf/Synthesis_Report_-_French_-_ISBN.pdf/

Five appendices complete this report :

- the first presents France's policy in terms of adaptation;
- the second handles adaptation in international negotiations, adaptation policies in Europe and certain developed countries;
- the third presents ONERC's activities since 2007;
- the fourth presents the climate change indicators gathered by ONERC since its last report;
- the last presents the status of research on climate change and adaptation in France.

Cost analysis: general context

The interministerial "Impacts of climate change, adaptation and associated costs" Group was created in March 2007. The aim was to provide a basic sectoral evaluation of the costs of impacts and adaptation at horizons 2030, 2050 and 2100[3].

The works by this interministerial Group were carried out in two phases:

the first phase, in June 2008, aimed at a qualitative characterisation of the impacts of climate change per sector and the definition of a common methodological framework;

the second phase, forming the subject of this report, aims at the quantified assessment of the cost of the impacts of climate change and associated adaptation measures. These works may contribute to the drawing up of a national adaptation plan provided for, at horizon 2011, by the Planning Law of 3 August 2009 on implementing the Grenelle Environment Forum.

Ten thematic groups – health, agriculture, forest, water, transport infrastructures and buildings, tourism, natural hazards and insurances, biodiversity, and territories – were therefore created and entrusted with these evaluations. The Ministry of Food, Agriculture and Fisheries, the Minister for Health and Sports, the Interministerial Department for Development and Territorial Competitiveness, the General Department for Industrial Competitiveness and Departments from the Ministry of Economy, Industry and Employment have taken part in the running of this, alongside the Ministry for Ecology, Energy, Sustainable Development and the Sea, responsible for Green technologies and Climate Negotiations. These groups combined experts and specialists from research, administration, civil society and the private sector.

All parties have been very involved throughout the works, concerning nearly 200 people who attended more than 80 meetings over a little more than two years. In parallel to these works, the Ministry of Agriculture, Fisheries and Food began discussions for the preparation of an adaptation plan and the High-level Committee for Health received a request for an opinion on the health risks linked to the qualitative impacts of climate change.

The framework for the works was created thanks to the methodological support of the International Research Centre on Environment and Development (CIRED), who ensured the uniform nature of the evaluations. In order to guarantee the works were taken over in full by the Ministries concerned, the option was taken to not externalise the creation of the sectoral reports, but to entrust to each administrative department involved at the forefront the control of a sub-group dedicated to evaluating its sector. Each of the sectoral groups thus drew up its own report, in consultation with the departments and partners concerned from the economic and industrial world (EDF, GDF, MRN, Veolia) or research laboratories (CSTB, INRA), all the while following the methodological guidelines and common map.

In view of the knowledge available and the difficulty of the exercise, this is considered as being a first step towards a more complete evaluation of the cost of the impacts of climate change and adaptation.

Common methodological base

From the start of the study, the section undertaken has produced **evaluations per sector, without wanting to aggregate the results.** In terms of feasibility and also operational capability, the aim was not to end up with a global result for France. To ensure coherence across the work of the ten

[3] Interministerial working group "Impacts of climate change, adaptation and associated costs in France" (2008), Interim document, Paris, June 2008. Full report available on the ONERC website: http://www.onerc.gouv.fr .

sectoral groups, a common methodological framework was proposed in the first phase of the works. The main methodological choices are set out in table 2.

Table 2 – Methodological framework

	Methodological choice
Geographical scope	Mainland France, excluding impacts spreading across borders
Horizons	2030, 2050, 2100
Climate scenarios	IPCC scenarios A2 and B2[4]
Climate model	Arpège-Climate model (Météo-France)
Socioeconomic scenario	Evaluation at current economy
Adaptation taken into account	Two adaptation scenarios studied: - Spontaneous adaptation - Planned adaptation

Evaluation at current economy?

In the absence of a long-term socio-economic outlook for France per region and per sector, the group decided to work keeping the current French socio-economic situation (scenario known as "constant economy"): for all the socioeconomic parameters (such as demographics, technology or division of wealth), no development was considered.
This choice allows the impact of climate change to be isolated from that of other developments, does not add macroeconomic uncertainties to uncertainties relating to climatic aspects, and brushes aside the question of discount factors. Nevertheless, this remains problematic for some sectors, for which a socioeconomic change is already anticipated or for which socioeconomic changes constitute a determining factor in vulnerability to climate change.

At this stage, the thematic works have not been designed to be exhaustive: only certain impacts have been evaluated in a quantitative fashion.

Analysis

The works carried out, presented in the most detailed fashion per theme in the following sections, highlight the costs and also the benefits linked to climate change in mainland France. For some sectors, we will see both costs and opportunities, depending on the impact studied, so much so that it is sometimes difficult to determine the sign of the "net" impact of climate change. Nevertheless, in view of the qualitative and quantitative analyses carried out by the study groups, we can expect a negative global impact from climate change; the **costs could reach several hundreds of millions of euro per year for various sectors if no adaptation is undertaken.**

When only the gradual climate changes are considered, the impacts thereof may remain relatively moderated in the short or medium term. On the other hand, **taking extreme events into account** leads to a clearly negative impact of climate change. For example, without adaptation, heatwaves could lead to costs that may reach several hundreds of millions of euros per year for the energy, forest and even agriculture sectors. The cumulative effect on several sectors and the effect of repetitions of these extreme events could also increase the severity of the impacts.

An additional policy to mitigation, **adaptation will allow the costs of climate change impacts to be limited significantly**, and even transformed into opportunities in some cases. If **spontaneous**

[4] Scenario A2 corresponds to economic and demographic development that is little-controlled, leading to major greenhouse gas emissions, whereas scenario B2 presumes controlled development and emissions.

adaptation can limit some negative impacts of climate change, we should note that unorganised adaptation could also cause the damage linked to global warming to be increased or the benefits to be limited: this is the case with energy, with the spontaneous development of air conditioning, which plays a part in significantly increasing energy consumption in summer, and therefore greenhouse gas emissions; or for agriculture, where a spontaneous increase in irrigation cannot be compatible with the reduction in water availability. This highlights the importance of coordinating and organising adaptation in order to avoid these pitfalls.

The impacts of climate change will not be spread evenly or fairly over the territory. The analysis presented here comes within a global national perspective. A differentiated analysis of the impacts must be carried out in the future :

- from a geographical point of view, some regions could find themselves highly affected by the changes, whereas others will be less so and may even benefit;
- from an individual point of view, players will not be equally subject to climate change. The most disadvantaged individuals will probably be the most affected and the inequalities could therefore increase even more.

It is therefore essential to ensure **the inequalities in view of risk are reduced.** This basic concept of inequality in view of climatic hazard has also been highlighted in the National Adaptation Strategy[5] and in the conclusions of the Stern Review.

The weight of the **socioeconomic scenarios** in vulnerability to climate change has been highlighted, even though the mandate was to evaluate the impacts of these changes using a constant economy hypothesis. For all the sectors studied, the development of coherent medium- and long-term socioeconomic scenarios across France seems to constitute a priority, in order to define efficient adaptation measures for these time horizons.

The **time scale** considered is an important variable to be taken into account in adaptation management, in particular in terms of governance. In fact, most of the current decision methods – in particular decisions by private players – are based on relatively short-term approaches. However, the restrictions that climate change will cause require long-term approaches that are voluntarist and anticipatory. Accompanying players during the **"transition" phase** that will prepare societies for adaptation to climate change involves identifying as of now the restrictions to change and adapting certain aspects such as employment and skills, so that these do not become a hindrance to the required economic and societal transformations.

Still in relation to the timescale, the works carried out indicate that several uncertainties remain over what the consequences of climate change will be: it is therefore necessary to plan governance methods that can be both planned for the long term and progressive over the short term.

While the works were mainly focussed on the impacts of climate change, some lines of adaptation were listed or suggested by the various groups and these are set out in the thematic summaries.

[5] ONERC (2007), "Stratégie d'adaptation au changement climatique (Climate change adaptation strategy)", French Documentation, p.25-26.

Table 3 – Costs (in monetary terms, or "physical" impacts) applied to various identified basic impacts (NB: because of several limits and uncertainties, it is essential to refer to the corresponding chapters prior to any interpretation of the elements set out in this table). ***A minus sign may therefore mean either a saving or a loss, depending on the impact considered)***

Sector/impact	Adaptation	2100 / Long term	
		A2	B2
Agriculture			
Impacts on Maize (excluding water restriction, inter-annual variation and extreme events)	Spontaneous	EUR -439 to +65M/year	EUR -68 to 30M/year
Impacts on Wheat (excluding water restriction, inter-annual variation and extreme events)	Spontaneous	EUR -13 to +147M/year	EUR +70 to +111M/year
Impacts of heatwaves on Maize	Without adaptation	EUR -120 to -192M/year	EUR -68 to -94M/year
Impacts of heatwaves on Wheat	Without adaptation	EUR -209 to -334M/year	EUR -118 to -163M/year
Impacts on viticulture in Languedoc	Without adaptation	-26 to -12% yd[6]/year	-18 to -6% yd/year
Impacts on viticulture in Languedoc	Spontaneous	-3 to +30% yd/year	+11 to +46% yd/year
Impacts on viticulture in Burgundy	Without adaptation	+35.2% yd/year	+41.7% yd/year
Impacts on viticulture in Burgundy	Spontaneous	+53.7% yd/year	+41.7% yd/year
Impact on the meadows in the peri-Mediterranean arc.	Spontaneous	EUR -250 to -200M/year	

[6] Yd = yield. The change to yield has no direct cost/monetary gains ratio for viticulture, mainly because of the effects on quality and the price/yield ratio.

Sector/impact	Adaptation	2100 / Long term	
		A2	B2
Health			
Cost of the 2003 heatwave for health insurance	N/A	EUR -280M to +10M	
"Human" cost of the heatwave (years of life lost)		EUR -500 M in 2003	
Cost of the 2002 Gard flood – taken into account psychologically in the liberal sector, excluding long-term	N/A	EUR - 234K in 2002 for 953 people	
Forest			
Impact on the growth of forests (and therefore productivity) (volumes) – without taking into account the risk of fire	Without adaptation	Clearly negative impact, but not calculated at this stage.	
Impact of extremes on the health of forests (and therefore productivity): wilting, etc. – without taking into account the risk of fire	Without adaptation	Negative, but not calculated	
Energy			
Impact on electricity consumption[7]	Without adaptation	-1.5Mtoe/year	-1.2Mtoe/year
Impact on electricity consumption[7]	Spontaneous (air conditioning)	+1Mtoe/year	+1Mtoe/year
Impact on natural gas consumption[7]	Without adaptation	-5 to -3.9 Mtoe/year	-3.9 to -2.5Mtoe/year
Impact on fuel oil consumption[7]	Without adaptation	-1.5Mtoe/year	-0.8Mtoe/year
Impact on petrol consumption in private	Without adaptation	+0.8Mtoe/year	+0.6Mtoe/year

[7] For heating and cooling, in the residential tertiary sector

Sector/impact	Adaptation	2100 / Long term	
		A2	B2
cars Impact on petrol consumption in private cars	Spontaneous (air conditioning)	+1.2Mtoe/year	+1Mtoe/year
Impact of the changes to water resources on electricity production - heatwave	Without adaptation	-0.2Mtoe/year	-0.4 to -0.3Mtoe/year
Impact of the changes to water resources on electricity production - flows	Without adaptation	-0.9Mtoe/year	-0.9Mtoe/year
Tourism Summer turnover subject to a significant reduction in climatic attractiveness	Without adaptation	EUR 15 to 19 B/year	**(A1B)** EUR 10 to 18 B/year
Infrastructures Mainland public A-road network Impact of heatwaves like that of 2003 Impacts of marine submersions (global rise	 Without adaptation Without adaptation	 EUR -70 to +9M/year[8] EUR -2B[9]	

8 Flat rate appreciation of excess cost, obtained by referring to the average annual maintenance budget for the property considered, not taking into account (uncalculated) indirect impacts, in particular those that could be caused to foundations by drought and a fall in groundwater, by geological problems affecting cliffs and subsoils and not taking into account (uncalculated) losses of use, impacts on the operation of road networks, road safety, the use of tunnels, etc.

9 Calculation obtained by flat-rate appreciation of the linear property value of the roads considered in the initial approaches as being exposed, excluding singular structures, loss of use and impacts on the operation of road networks (uncalculated).

Sector/impact	Adaptation	2100 / Long term	
		A2	B2
in sea level of 1 metre) Impacts of climate change on the infrastructures and transport systems for rail, river, port, other transport networks and urban public transport		Impacts not studied during this phase	
Natural hazards Impacts of flooding on 5 catchment basins	Without adaptation	See group's report.	
Impact of heatwaves on farm animal genetic resources	Without adaptation	EUR -1080M/year	EUR -480M/year
Impact of coastal hazards in Languedoc	Without adaptation	EUR -15 to 35 B (cumulated)	
Biodiversity Cost of the disappearance of coral ecosystems (regulation functions)	Without adaptation	USD -6.5 B	
Cost of the loss of forest services: carbon fixation	Without adaptation	EUR -589M/year	EUR -304M/year
Water Deficit in Water to satisfy the current needs for drinking water, industry and irrigation	Without adaptation	Negative, but not calculated	

Water resources

Key messages

- The impacts of climate change on water resources will be multiple, both in terms of the offer (quantity and quality) and demand.
- One of the main challenges of the future will be to merge a decreasing offer with a demand that, in places, is already unsatisfied and that will increase with the impacts of climate change.
- At horizon 2050, we can estimate the deficit in water to satisfy current uses, without adaptation, at some 2 billion m^3.
- These changes will generate restrictions on users: agriculture, drinking water supply, waste water treatment, energy production, and rainwater drainage.
- In order to prepare adaptation, it is necessary to improve knowledge of impacts and environments, and the modelling of systems in interaction with water, and organise monitoring of water (surface and underground) and environments (humid and coastal zones).

Scope of study

Several economic sectors will be impacted by a change to the water cycle: agriculture; the production of energy for cooling production units or operating flow volumes; drinking water supply; supplying canals, etc.
The estimate of the deficit for water users at horizon 2050 has been made on the basis of an extrapolation of the results of a Boe study (2007), relating to a change in flows. The impacts of climate change on the resources will not be limited to this quantitative aspect, as *Table 4* indicates.

Table 4 – Impacts identified and studied: Water

	Quantified	Non-quantified
Increase in demand (rise in temperatures)		X
Change to the available resources	X	
Reduction in water quality		X
Increase in the vulnerability of certain ecosystems		X
Increase in cost for access to water, restrictions on use, treatment, etc.		X

Quantitative impacts: deficit in available resources

The impacts of climate change on flows will be multiple. **At horizon 2050,** Boe (2007) highlights :

- in winter, a moderated reduction, as an overall average, in flows, except for the south-east of the country and the Alps, where they will increase. In spring, slight changes in general;
- in summer and autumn, a major reduction in flows;
- a high increase in the number of low-water level days;
- a reduction in flood flows well below average, but an increase in some cases;
- a reduction in soil humidity regardless of the season, except in mountain areas in winter and/or spring;
- a sharp decrease in snow precipitation and maximum height of accumulated snow at low altitude, which lessens the higher you go.

If we presume that the water resources are today fully exploited in water division zones (ZRE) during the spring and summer and that everywhere else the resources allow drawing to be doubled, it is estimated that **the deficit in water to satisfy the current requirements for drinking water, industry and irrigation will be in the order of 2 billion cubic metres in 2050.**
The territories will not be affected in a uniform fashion: the most vulnerable zones will be the zones already concerned by structural deficits. The cost of the deficit will reach **EUR 5 to 10 billion** if the

volumes of water must be fully compensated and additional treatments implemented. Other scenarios include adapting economic activities are foreseeable and may prove to be less costly.

Limits of the exercise

One of the main limits is due to the constant economy hypothesis, which does not allow changes in use to be taken into account when calculating the deficit. However, **the role of socioeconomic developments** is essential: depending on the population dynamics, for example, without adaptation, the deficit would be much greater than the result shown.

Restrictions on use

Such a deficit will have an impact on all sectors dependant on the resources.

Agricultural restrictions

The agricultural sector, the main user of water resources, with 48% of total consumption, will be particularly affected by the impact of climate change on resources. The initial results of the INRA Climator programme (Brisson & Itier, 2009) on wheat and maize show that the greatest part of the drop in rainfall will mainly lead to a hydrological drought and in part to a soil drought in both rainfed (wheat) and irrigated (maize) crops. Hydrological comfort during the production period will fall in general, with an **increased need for water support** in order to keep current production conditions. However, the **reduction in** water **availability** will cause stricter drawing restrictions. Several crop alternatives with cereal-based one-crop systems are possible and may be favourable for adapting to these changes.

Drinking water restrictions

The drinking water supply (AEP) represents almost 18% of water drawn. While there are currently no major AEP problems, the basins will be faced with more frequent water shortages because of climate change, even in the absence of increased demand. **The reduction in the quality of the resources, accentuated by climate change, will again reduce the amount of fresh water available for domestic purposes.** These developments may lead to an increase in water prices (difficulties in distribution, treatment costs).

Waste water treatment restrictions

In the event of a drop in the watercourse regime, maintaining environmental standards will mean **more intense treatment of waste water and therefore greater treatment costs.** Some impacts of climate change on the water treatment networks will be positive (faster biological reactions), others negative (additional energy consumption, problems relating to odours, increased corrosion phenomena). Crisis management policies will have to be organised to tackle the increased risks – particularly sanitary ones.

Rainwater treatment restrictions

Faced with an increased risk of urban run-off (violent rain, swollen evacuation networks), it will be necessary and without regret to **review the rules on sizing spillways and rainwater recuperation.**

Industry and energy production restrictions

While the quantitative impact of the energy production sector on water resources is currently relatively moderated, **its qualitative impact is not insignificant** (water temperature, contamination by biocides). The impacts of climate change on water will affect energy production in two ways :

- reduction in cooling yield in the case of a combined increase in air and water temperatures associated with a weak flow;
- repercussion from conflicts of use on managing hydroelectric plants.

Civil engineering work management restrictions

The modification of run-offs and external flows is likely to affect the **management of major dams.** This will require a specific outlook.

Significant impacts on quality

Water quality and quantity are interdependent. Ducharne *et al.* (2004) studied the impact of climate change on soil nitrogen mineralization in the form of nitrates, modulated by the changes in rainfall and by agricultural activity. According to their results, in average for the free groundwater, the concentration of nitrates will increase at horizon 2100 by 0-33% in relation to the current concentration. In the water courses, the impact of climate change means an increase in nitrate concentration, but this is less severe than in the aquifers.

Adaptation

Adaptation measures will be local and will affect ecosystems, agriculture, drinking water, flood management, demographics, energy, etc., and they will be based on a complex alchemy between the adaptation of needs and the adaptation of the offer. The adaptation measures identified are set out in *Table 5.*

Table 5 – Recommended adaptation measures

Adaptation of demand	**By savings, modification of activities or substitution of another resource** Reduce domestic consumption : - Active and passive savings (modification of technologies and manufacturing standards) Reduce agricultural consumption : - Reduce irrigation water requirements by accepting a loss in yield less than proportional to the reduction in volume produced - Reduction in irrigation volume - Diversification of watering calendars - Optimise efficiency of water supplied when watering is justified - Implement agricultural systems that are more robust and less demanding on water resources - Nitrogen input reduction policy
	By town planning - Promote efficient town planning at the appropriate levels
	By adapting energy demands - Improve production station yields - Set up management per chain of hydroelectric plant - Limit the installation of new thermal or nuclear power stations in coastal areas
Adaptation of offer	**By developing new infrastructures** - Set up additional water supply infrastructures in order to relieve severe droughts
	By intervening on target flows - Review the flow targets in low-water level and crisis periods by respecting the DCE provisions

Perspectives and recommendations

The research perspectives for improving **understanding of the impacts of climate change** on water are numerous. They are set out in the following table:

Table 6 – Research, follow-up and observation requirements

Research requirements	**Improve knowledge** of the impacts observed and predicted for water quality, past hydrology, environmental operation, and water use
	Better characterise **droughts**
	Improve hydrometeorological **models,** take into account transfers to underground waters and the variations in soil occupation and condition of the vegetation.
	Improve **low-flow planning,** and regionalisation of studies
	Characterise the territory in uniform **hydro-eco-regions**
	On a basin-wide scale, carry out **cost-benefit analyses**
	Carry out research into **technologies for water saving,** treating or recycling
Follow-up and observation requirements	Improve the **monitoring network** for surface and underground waters
	Map humid zones (inventory, characterisation and monitoring)
	Map resource pressures (drawing, river traffic, etc.)

Natural hazards and insurances

Key messages

- Climate change has a definite impact on natural hazards, and must **affect specific territories** (coastal, clay zones, etc) **more** than the mainland territory as a whole.
- The cost of damage to housing in relation to the risk of clay soil **shrinkage and swelling** could be **multiplied by a factor of between 3 and 6 by 2100,** depending on the scenario, without taking into account changes to urbanisation.
- With reference to **floods caused by rivers bursting their banks,** there are no clear strong signals of average annual damage in the examples adopted for illustration purposes, even if, for certain basins (Orb, Meuse), a significant increase can be predicted.
- An essential question is posed for **coastal hazards,** which without adaptation, for the Languedoc Roussillon region alone, could cost almost **EUR 15 billion by 2100** in terms of housing destroyed.
- Lastly, with regard to **gravitational hazards,** the impacts of climate change remain uncertain.

Scope of study

Four hazards have been studied in detail: **the risk of flooding** in 5 catchment basins, **the coastal risk** in Languedoc-Roussillon (submersion and erosion), the risk linked to the **shrinkage and swelling of clay soils** (RGA) due to drought and **gravitational hazards** (torrential floods, avalanches, landslides, subsidence, rockfalls).
Only the damage to housing and buildings has been evaluated[10]: the direct impacts on infrastructures, in terms of health or even biodiversity have not been evaluated.

[10] The impacts of RGA and submersions on transport infrastructures were studied by the Transport Infrastructure and Building Framework group. The impacts of floods on health were studied by the Health group. The Forest Fire theme was tackled by the Forest group.

Table 4 – Impacts identified and studied: natural hazards

	Quantified	Non-quantified
Hazards studied		
River floods	X (partially, with certain basins only)	
Floods from increasing groundwater		X
Coastal hazards	X (partially, only for Languedoc-Roussillon and without taking erosion into account)	
Clay shrinkage and swelling	X	
Forest fires		X
Storms		X
Impacts studied		
Direct costs for housing	X	
Direct costs for companies		X
Health impacts		X
Indirect impacts		X

The consequences of the temporal development of hazards have not been taken into account, in quantitative terms, with the exception of one comparative study of the impacts of climate change and the development of hazards on the risk of RGA at horizon 2030. However, it should be pointed out that, in many cases, it is expected that **this hazard development will have a greater impact on the development of risks than will climate change;** this is what we have seen over the last few years.

Clay soil shrinkage and swelling

Summer droughts are responsible for the majority of claims linked to RGA. Almost all departments are concerned to various degrees, and almost 400,000 single-family dwellings are located in high risk areas. The increase in climate change-related drought frequency and intensity must increase the risk of RGA. In the absence of new urbanisation, the analysis carried out **cites an annual damage cost going from approximately EUR 220 million (reference to the period 1989-2003) to EUR 700 million (scenario B2) or EUR 1,300 million (scenario A2) in 2100; it is therefore multiplied by a factor of between 3 and 6.**
If we take into account increased challenges by 2030 (urbanisation), despite adaptation efforts, the costs increase significantly. **The cost increases by approximately 17% for the period 2010-2030 when the number of individual houses increased by 0.925%.**
When posing the hypothesis that, for new single-family dwellings, the extra cost of adaptation increases to 15% (**adaptation of foundations),** climate change increases the scope of zones for which this is profitable.

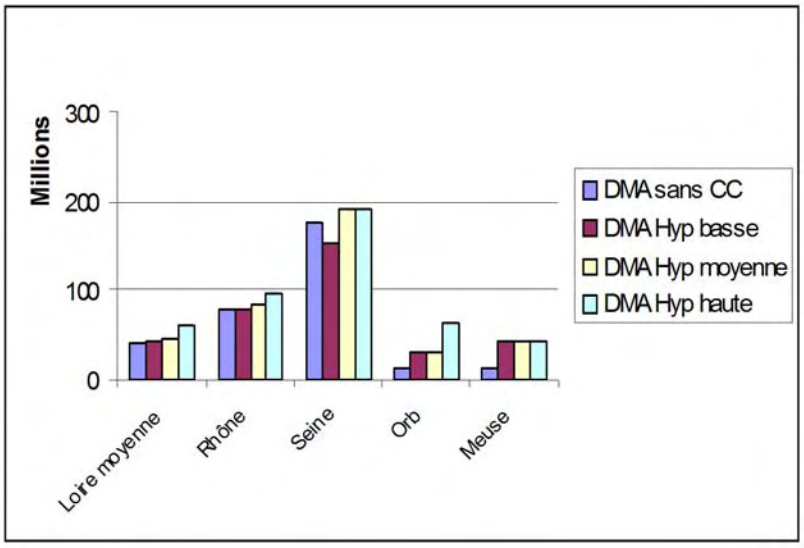
Floods

The impact of climate change on extreme precipitation and thus on flooding is **difficult to evaluate** from climate model simulations. A quantified evaluation exercise has nevertheless been carried out on a selection of catchment basins for which there is data relating to damage observed: **the Seine in Ile-de-France, the Meuse in the Ardennes, the mid-Loire between Nevers and Angers, the Rhône and the Orb.** On the basis of expert opinions and in view of current knowledge, reasonable scenarios for the impacts of climate change on hydrology have been defined for these catchment basins.

Table 8 – variation of flow peak : low, average and high hypotheses adopted for the illustration catchment basins

	Low hypothesis	Average hypothesis	High hypothesis
Loire	+ 5%	+ 10%	+ 20%
Seine	- 10% (from Q100[11])	+ 10% (from Q100)	
Rhône	5% (from Q100)	10% (from Q100)	20% (from Q100)
Meuse	10%		
Orb	10%	25%	50%

Under these hypotheses, we can conclude that damage development **is not significant for the Seine, the Rhône and the mid-Loire; and is very severe for the Meuse and the Orb.** These estimates must, however, by **interpreted with caution.**



Graph 1 – average annual damage to the seven catchment basins (millions euro 2007)

Key:
DMA sans CC =*Average annual damage without climate change*
DMA Hyp basse = *Average annual damage – Low hypothesis*
DMA Hyp moyenne = *Average annual damage – Average hypothesis*
DMA Hyp haute =*Average annual damage – High hypothesis*
Loire moyenne = *Mid-Loire*

Coastal hazard

Based on the hypothesis of an increase in sea level of 1 metre, coastal hazards increase significantly, especially for sandy coasts and soft rock cliffs. Low coasts will suffer erosion or permanent submersion and new zones will be subject to temporary submersions. **140,000 homes and 80,000 people** (as against 15,000 homes today) and 10,000 businesses (employing 26,000 workers) are located in a zone affected by a risk of permanent submersion or erosion by 2100 **in the Languedoc-Roussillon region.** In the absence of a coastline management policy, the cost of

[11] Q10 = current return period of 10 years, Q100 = return period of 100 years

damage linked to “permanent submersion” and erosion hazards is evaluated between **EUR 15 and 35 billion for the Languedoc-Roussillon region alone.**

Gravitational hazards

The impact of climate change on gravitational hazards is **difficult to assess,** because of the very nature of the phenomena in play, the complexity of the links between the hazards considered and the various predisposition and trigger factors. At this stage, it is not proposed that a calculated evaluation be carried out for this hazard. As an initial approximation, we could, however, consider **the possible increase in** superficial and/or frequent **events that are most directly related to winter precipitation** and the major financial consequences in the event of communication routes becoming blocked in the mountains and in winter. We can also note the potential impact of climate change on glaciers and permafrost, on the intensity of torrential floods and lava flows and on the stability of rock walls.

Limits of the exercise

The proposed evaluation limits are mainly due to :

- the restricted scope of costs studied;
- the uncertainty over risk development and the hypotheses put forward;
- the constant economy scenario;
- the various timescales preventing any aggregation;
- the knowledge about the sometimes rough timescales in relation to the phenomena involved.

Adaptation

Adaptation to climate change must enable preventative action to be continued, and even strengthened by implementing “no regrets" strategies. The following table presents the recommended lines of adaptation:

Table 9 – Recommended adaptation measures

Adapting the current catastrophe risk management policy to a changed climatic situation	Improve knowledge, measurement and monitoring networks, multirisk approaches, increasing detection and warning systems, reinforcing current policies with “no regrets” measures, global and coordinated management over the basins at risk
Clay shrinkage and swelling	Adapting the foundations of single-family dwellings
	Implementing more global provisions, such as those recommended in the PPRN regulations
Coastal hazards	Take into account climate change in planning and development documents;
	Development of detection and warning systems
	Analysis of the effects of strategic withdrawal/natural operation restoration/coastline maintenance-type measures
Floods	Formulate suitable responses in accordance with each catchment basin (within the framework of plans such as flood prevention action programmes and management plans for major rivers)
	Adaptation of actions to situations encountered (preparation of crisis management, prevision, awareness, protection devices, adaptation of the soil use regulations)
	Study responses to the risk of urban run-off

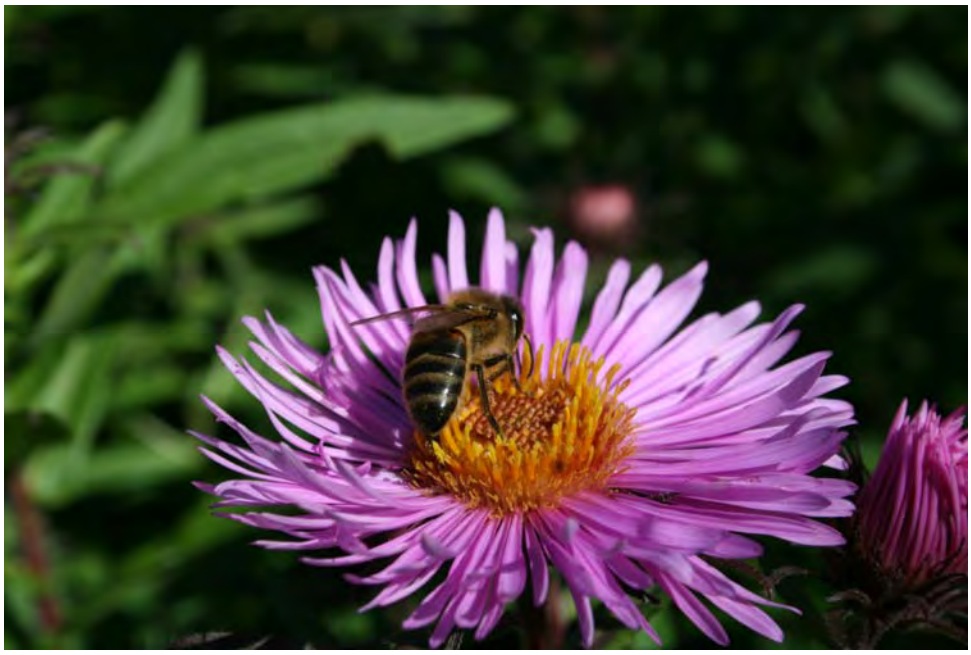
Perspectives and recommendations

The works carried out have revealed the following needs and lines for continuing the analysis of the impacts of climate change on natural hazards:

Table 10 – Research, follow-up and observation requirements

Research requirements	Improve knowledge of climatic variability over the coming decades Improve knowledge about urban run-off, soil reactions and gravitational hazards
	Analyse the **"network"** aspect and intangible impacts
	Characterise the escalation of damage resulting from a **"generalised" event**
	Carry out an exhaustive analysis of the impact on **hydrological regimes**
	Carry out an exhaustive analysis on **coastline disappearance**
	Lead studies into the **role of insurance**
Follow-up and observation requirements	Carry out an inventory/**full mapping of the hazards**
	Implement monitoring and national **databases** of the damage; map current damage
	Improve **observation of the economic cost** of run-off
	Improve the precision of **altimetric data**

Biodiversity



Key messages

- We are already seeing **signs of biodiversity modification** attributable to the **gradual changes** caused by climate change.
- **Extreme events** also have effects on biodiversity, of a nature likely to disturb the mechanisms for biodiversity's adaptation to gradual change.
- In spite of great uncertainty, the various models **focus on the directions of future changes:** alteration to the limits of the large biogeographical zones and changes to the spheres of distribution for species, disassembly of communities of animal and vegetable species and their reconstruction, and even the total disappearance of some ecotypes.
- The economic assessment of these developments concentrates on the loss of **ecosystem services** (regulation services) and does not at this stage consider the multiple values associated to the appearance and disappearance of species or other components of remarkable biodiversity.
- **Significant economic losses** related to the reduction, and even disappearance of regulation services are to be expected, in particular in the second half of the 21st century.

Adaptation to climate change will include improved knowledge of the impacts of climate change, in particular cross effects and **interactions with other sectors.**

Impacts which are already observable

Even though it is sometimes difficult to isolate the impacts of climate change from other pressures suffered by ecosystems (urbanisation, pollution, change in soil use, etc.) and even though the problems are very varied depending on the ecosystem and the species concerned, **signs of biodiversity modification attributable to gradual changes caused by climate change are already observable,** at all organisation levels (genetic, specific, ecosystemic, etc.), and in all environments (terrestrial, aquatic, marine). Consequently, the limits between climatic zones are currently moving in the mainland territory and causing corteges of species dependent thereon to be displaced.

Extreme events, the frequency and intensity of which are likely to be increased, also have effects on biodiversity, which are likely to disturb the mechanisms for biodiversity's adaptation to gradual change.

Future impacts to be anticipated

In spite of the great uncertainty over the modelling results, the various models focus on the directions of future changes. In view of the forecast changes, we not only anticipate a simple **alteration to the limits of the large biogeographical zones and changes to the spheres of distribution for species,** but also a **disassembly of communities of** animal and vegetable **species** and their reconstruction.

The **renewal rate** for the different species groups will probably be high throughout France, including in protected areas.

In a given location, due to the differences in species colonisation capacity, we can expect a latency between the disappearance of current corteges and the arrival of new ones.

Some isolated populations will be more affected.

Typology of the various impacts of climate change on biodiversity

1. Direct effects (type I) come under the action of climate changes on the characteristics of species, ecosystems and ecological functions. They concern:

- the physiology of individuals,
- their behaviour,
- the diversity and abundance of species in a given location,
- their geographical distribution,
- the structure of communities,
- the phenology,

- the area occupied by natural environments.
2. Type II indirect effects are the effects of climate change on the main pressures causing the erosion of biodiversity:
- overuse of soils,
- pollution, fragmentation of environments,
- invasive species and pathogenic agents,
- fires.
3. Type III indirect effects are the consequences on biodiversity of the reaction of various sectors of activity, whether this is mitigation or spontaneous or planned adaptation.
4. Type IV effects are, by retroaction, the impacts of biodiversity on climate change, both in relation to mitigation and adaptation.

Major costs related to the loss of ecosystem services

One of the consequences of the loss of biodiversity will be the possible reduction in ecosystem services and, in correlation, of human well-being. Various categories of ecosystem services (Millenium Ecosystem Assessment France) may be distinguished :

- **supply services** (production of goods) such as : agricultural production support, wood production, aquaculture, drawing water for domestic use, etc;
- **regulation services** (production of services) such as: flood prevention, control of erosion and mudslides, of invasive species, climate control, etc;
- **services of a social nature** (production of services) such as : landscaping, biodiversity and property value, hunting, etc.

The economic assessment step chosen is based on the **direct effects of climate change (type I impacts)** and on **the ecosystem services of general biodiversity** applied to the **regulation services** rendered by the coral and forest ecosystems.

Coral reefs

Coral reefs are suffering from more and more frequent bleaching due to the increase in water temperatures. In addition, their capacity to calcify may diminish because of water acidification. These phenomena place these fragile ecosystems, and the services they provide, in peril.
The regulation services (coastal protection, carbon fixation, water purification) were assessed on the basis of an extrapolation for Polynesia, then for all the French-constructed coral reefs, of the values from a study relating to the island of Moorea[12].
From to this data, we can estimate the value of the services rendered by the reefs at **USD 6.3 billion per year for coastal protection and USD 140 million per year for water purification** (depletion of organic matter and filtration of materials in suspension). An extreme case, which would see the total disappearance of coral reefs, would thus lead to a **net monetary loss of *at least* approximately USD 6.5 billion per year just for the regulation services** studied here.

Mainland forests

The increase in value of these services has been studied, in particular within the framework of the Strategic Analysis Centre (CAS) report[13]. **Regulation services represent a major economic value:** almost 8 times the average value of wood production alone if we limit this to just the carbon fixing and storage services and the production of drinking water.
An economic assessment of the loss of carbon storage services has been carried out, based on the **difference in annual productivity between the Mediterranean forests and those in the rest of France.** By estimating that these Mediterranean-type forests, which currently occupy 9.1% of the mainland territory, will occupy between 19% (according to B2) and 37% (according to A2) in 2100,

[12] Charles, 2006
[13] « L'approche économique de la biodiversité et des services liés aux éco systèmes " 28 avril 2009 http://www.strategie.gouv.fr/IMG/pdf/04Rapport_biodiversite_28avril2009_.pdf

the loss of productivity would be placed between 6 and 16%, i.e. **an economic loss, in terms of stored carbon flows, of between EUR 304 and 589 million.** These values are perhaps optimistic because it is possible that in the transition phase the forests that are newly subjected to a Mediterranean-type climate regime will be even less productive than the Mediterranean forests.

Adaptation

Several categories planned adaptation measurements for biodiversity have been identified, each thriving on the others:

Table 11 – Recommended adaptation measures

Improve scientific and operational knowledge	Improve knowledge, measurement and monitoring networks, multirisk approaches, improving detection and warning systems, reinforcing current policies with "no regrets" measures, global and coordinated management over the basins at risk
Integrate the challenges of climate change into existing biodiversity conservation and management policies	Reinforce the efforts to reduce the pressures on biodiversity other than climate change, in order to increase the resilience of ecosystems
	Ensure the integration of biodiversity-related problems into all general and sectoral policies on mitigation and adaptation to climate change in order to maximise the co-benefits. **Species, protected spaces (including Regional Natural Parks), land projects, ecological and connectivity networks**
Integrate new principles and tools into these same public policies	**Promote adaptive management**
	Reconcile the conservation of a maximum of species with a functional approach in order to ensure the properties of ecosystems and the dependent services are maintained.
	Draw up a decision tree enabling the most suitable intervention or non-intervention methods to be defined
Promote integrated governance	**Propose a general governance scheme** organising existing steering and presentation devices to manage all dimensions of biodiversity and ecosystem services over suitable space and time scales.
Inform and mobilise all players	**Promote the strategies/measures that involve local users and players**
	Develop social science research into accepting adaptation measures

A necessary discussion on cross effects and interactions

The indirect effects of climate change on biodiversity could be at least as serious as the direct effects. It is consequently essential **to study the cross effects between biodiversity and the different sectors of activity,** themselves affected by climate change, in order to specify in particular to what extent the **adaptation strategies of these sectors may have consequences on biodiversity.**

The analysis of the effects of climate change therefore involve *at least* the better identification of these indirect effects and doing everything possible to rapidly minimise all the current and future pressures, in order to enable biodiversity to confront climate change "without handicap".

Perspectives and recommendations

Improved knowledge is essential in order to suggest efficient adaptation measures.

Table 12 – Research, follow-up and observation requirements

Research requirements	Intensify interdisciplinary and intersectoral collaborations
	Study the responses of species and populations to climate change and their potential to adapt
	Develop knowledge on new habitats and species
	Better characterise climatic micro-adjustments
	Study ecotones, refuge zones and gradients
	Study the change processes on multiple scales
	Strengthen knowledge on urban zone biodiversity
	Develop more complete and better performing prediction models
	Resolve the scale compatibility problems
	Develop models suited for overseas lands
	Develop crisis management simulation tools to help with decisions and test crisis response scenarios
Follow-up and observation requirements	Maintain, improve or implement biodiversity monitoring programmes and tools
	Use the protected spaces as observation bases and reference territories for studying the effects of climate change
	Observe and measure the impact of climate change and adaptation measures on carbon and methane stocks and storage by ecosystems

Health

Key messages

- Work concentrated on two lessons learned from extreme events: **the 2003 heatwave** (financial cost and human lives lost) and the **2002 Gard flood** (cost for health insurance for treating psychological disorders).
- In terms of strictly financial costs (health insurance), **the 2003 heatwave does not seem to have led to significant expenditure,** because of a neutralisation between the additional costs (treating pathologies) and the costs avoided (premature deaths of healthcare consumers).
- However, **taking into account certain "indirect" costs (value of lives lost),** this leads to a **cost** for society **exceeding EUR 500 million.**
- **The 2002 Gard flood** caused a net increase in the consumption of psychotropic drugs, with a **cost for health insurance in excess of EUR 230,000** in the affected municipalities.
- Due to the lack of usable data, the data advanced must be interpreted with caution. In order to improve this type of assessment, a collective discussion involving the various parties intervening in the different catastrophes must be undertaken to identify **common parameters and indicators for catastrophes of the same type on the one hand and for all catastrophe situations on the other.**

Scope of study

The analysis concentrates on two historic events, which are not related *a priori* to climate change, but for which we can believe that the latter has increased frequency and intensity during the 21st century :

- the 2003 heatwave, which had major health consequences in terms of premature death and increased morbidity, and could become the norm by the end of the century;
- the cost of the 2002 Gard flood during which many people were victims.

The impacts of climate change on health are not necessarily limited to the impacts of extreme events, as indicated in Table 13:

Table 13 – Impacts identified and studied: Health

	Quantified	Non-quantified
Health risks related to vectors, microbiological, cyanobacteria and micro-algae reservoirs		X
Increased exposure to solar radiation		X
Drop in winter mortality		X
Decrease in the chemical quality of air, increase in pollens		X
Heatwaves	X*	
Floods	X*	
Health impacts from other natural hazards (forest fires, earthquakes, etc.)		X
Reduction in water quality		X
Indirect costs	X*	
Intangible costs		X

** partially assessed*

The 2003 heatwave: a high cost in terms of human lives lost

The 2003 heatwave in France caused an abnormally high death rate, seen at **14,800 people** between 1 and 20 August, mainly the elderly: in total, 82% of deaths attributable to the heatwave were people aged 75 or over.
The assessment of the financial impact of the heatwave on health was based in large part on the InVS publications in 2003 (mortality) as well as on a detailed epidemiological study carried out by this same organisation in 2006, in relation to two groups representing nearly 2,300 people (morbidity). In strictly financial terms, a 2003-type event means:

- additional costs caused by the care of patients whose health was affected by the heatwave;
- costs avoided due to the death of elderly people who are healthcare consumers.

Whether in town or in hospital, there did not appear to be any obvious surge in expenses for the year 2003, or even a sudden drop. This leads us to believe that, for the budgetary balance of health insurance, the different effects of costs created and costs avoided ended up in the mid-term by balancing themselves out.
Taking the value that the years of life lost may represent (indirect costs) **into account noticeably changes the conclusions of the analysis.** By estimating the value, for society, of the years of life lost as being EUR 37,500 per year, on the basis of the Boiteux[14] report, **we estimate the value lost by our society due to the 2003 heatwave as being a little more than EUR 500 million on the basis of an average loss of one year of lifespan per deceased person.** The value of the loss of quality of life for the elderly is added to these costs, having seen their health conditions deteriorate (more than 13,000 people aged 70 or over); this could not be calculated.

The cost of the National Heatwave Plan

Since 2004, the Ministry of Health has set up a national heatwave plan (PNC) enabling management measures to be deployed in the case of heatwaves that are hazardous to health. The alert is triggered on the basis of temperature thresholds being broken, in accordance with criteria defined by a heatwave and health alert system (SACS). The PNC was implemented during the 2006 heatwave and it proved efficient.

[14] Boiteux, M. (2001), op. cit.

For information purposes, an estimate of the cost of SACS was made in 2005. The cost of preparing the alert system was calculated at EUR 286,933. The operating cost between 1 June and 31 August was calculated at EUR 454,006, i.e. a global cost of **EUR 740,939.** This mainly concerns the human cost, counting the InVS human resources, inter-regional epidemiology cells (CIREs), Météo-France and the DGS, for data collection and its interpretation.

The 2002 Gard flood: an increased consumption of psychotropic drugs

The analysis carried out here presents an assessment of the financial impact for health insurance of the psychological consequences following the Gard flood, which occurred from 8 to 10 September 2002. It is based on the south CIRE study, which uses data from the agricultural social mutual fund (MSA)[15].

The study thus compares the 3-week period following the flood to two 3-week reference periods, one in June 2002 and the second in September 2003.

The analysis detailed a significant increase in the rate of issuing new psychotropic drug treatments in the three weeks following the flood in the municipalities affected. The consumption of anti-depressants was then observed for the 6 months following the flood. The report shows a more frequent consumption, compared to the June 2002 reference period.

In relation to the Gard population data from the 1999 INSEE census, the increase in the number of prescriptions equals an **increase of 953 people taking psychotropic drugs** over and above the number usually observed. Amongst these, **141 also took anti-depressants in addition to this treatment.** The total cost for care has been estimated at **approximately EUR 233,000** for 953 people, which is equivalent to an average cost of EUR 245 per person.

This cost may seem relatively modest in regard to the risks considered. However, it must be interpreted as a **minimum cost,** under the hypothesis that the afflictions treated did not reveal serious pathologies. From the literature, it would also appear that people may be affected several months to several years after a flood-type catastrophe.

Finally, it should be noted that **these estimates are limited to the direct costs incurred by the collective solidarity provisions.** They do not take into account either the direct costs borne by the people concerned and their families, or the indirect costs linked to the impact on activity of pathologies, or the intangible costs of the impact of illness on quality of life.

Limits of the exercise

The limits of the exercise carried out relate mainly to the **restrictive character of the scope of assessment:** the difficulty here resides in the lack of sufficient data, both on an economic level (limited here to health insurance expenditure) and in relation to the epidemiological data required for this type of study. As a result, **numerous hypotheses** had to be put forward, leading to the results being interpreted with extreme caution.

Adaptation

Adaptation within the health sector will take multiple forms, such as those outlined in *Table 14* (source: HCSP “transmissible illnesses” commission recommendations), depending on the timescale for which the measures may be implemented.

[15] South CIRE, DRASS PACA and Gard DDASS, “psychological consequences of the floods, from the Health Insurance databases, for the Gard department September 2002”.

Table 14 – Recommended adaptation measures

Short term	Heatwave plan (already implemented)
	Implement an interministerial structure responsible for coordinating national competences in relation to studying the health consequences of climate changes
	• Implement or strengthen monitoring of health and environmental factors that can be modified by climate change • Monitoring of vectorial populations and reservoir hosts; • Monitoring the quality of continental, coastal and estuary air and water and of soils; • Monitoring natural radiation; • Monitoring of resistance and adaptation to pathogenic agents • Monitoring of pneumallergens.
	Implementing and generalising response plans to extreme meteorological phenomena including the systematic study of health effects (somatic and psychological) of these phenomena
	Assess existing plans
	Organise responsibility for populations that are fragile and at risk of fragility when faced with extreme climatic phenomena
	Integrate health risks of climatic origin in training for healthcare professionals
	Integrate health risks of climatic origin into the information messages and campaigns destined for the public and media, in particular aimed at adolescents
Medium term	Monitor the health impact of changes to biological diversity (flora and fauna)
	Observe the change events of infectious agents and their hosts, in particular in relation to natural radiation

Perspectives and recommendations

Several lines have been identified, in order to refine this type of analysis. They concern both the need for additional research and the need for monitoring and observation.

Table 15 – Research, follow-up and observation requirements

Research requirements	Better characterise the **intangible costs** (quality of life)
	Clarify the **methodological difficulties** raised by the economic assessments
	For natural catastrophe, improve the qualification of the definition **of exposure indicators** and exposed zones
Follow-up and observation requirements	Carry out **feedback from experiences** and systematic and uniform assessments across the country
	Lead a collective discussion on the **common parameters and indicators** of catastrophes of the same type on the one hand and of all catastrophe situations on the other, thus enabling short-, medium- and long-term cost evaluations to be suggested.

HCSP "transmissible illnesses" commission recommendations in research matters

The terms of the suggestions made below relate to obtaining results and not to the timescale for implementation. Intermediate results could be useful in public health decisions

Table 16 - HCSP commission research requirements

For the short term	Promote research into man's capacity to adapt to climate changes This development must be multidisciplinary and relate to both: • Public health and the economic impact, especially in times of crisis; • Clinical medicine, and in particular the physiopathology and treatment of thermic shocks due to heatstroke; • Physiology of thermolysis, particularly in elderly patients; • Molecular biology and genetics, integrating the mitochondrial genome.
	Lead research into the perception of the health consequences of climate change in the population and subsequent behaviours.
	Develop experimental research into the capacity of infectious agents and their hosts to adapt to climate change, and on the mutagenic effects of natural radiation on infectious agents.
For the medium term	Evaluate the impact of global warming: on the air and water quality across the territory, particularly in the Overseas Collectivities and Regions and the area surrounding the Mediterranean.
For the long term	Develop or continue research into the mitigation and/or adaptation capacities of the health effects from climate change, by adopting a proactive position (links between the health of ecosystems and the health of populations).

Agriculture

Key messages

- If only the gradual changes (temperatures, precipitation) are considered, the effects of climate change on maize and wheat crops remain **moderated up to a certain threshold, above which they become clearly negative. The reduction in water availability** and **the multiplication of heatwaves** will themselves have **a highly negative impact on yields.**
- In viticulture, strong **territorial differences** will be observed: the analysis carried out cites, for example, an increase in Burgundy yield, but a sharp drop in Languedoc-Roussillon. The **quality and typical features** of wines could find themselves negatively **affected.**
- With regard to meadows, the southern half, and especially the peri-Mediterranean arc will see its **vulnerability increase** due to more frequent droughts in summer, with strong consequences on the profitability of livestock farming.
- The **limits of the exercise** carried out here are **major** and are due to both the hypotheses put forward and the uncertainties present throughout the chain of evaluation. The analysis of these uncertainties and discussions with experts reveals a certain number of requirements to improve knowledge and encourage adaptation in the agriculture sector.
- **The ADAGE Outlook Discussion Workshop** aims to identify and mutually insure the needs for studies and research on this topic. The results will be available in 2010.

Scope of study

For reasons of representativeness and feasibility, the works related to the study of three specific crops: field crops (wheat and maize in mainland France), viticulture (Burgundy and Languedoc-Roussillon) and meadows (South of the Massif-Central). The analysis carried out was not exhaustive: the impacts studied remain partial.

Table 17 – Impacts identified and studied: Agriculture

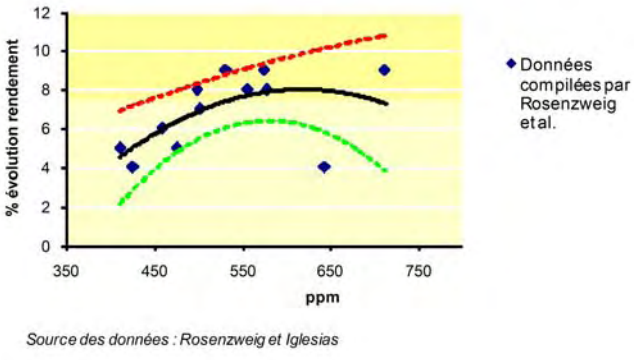
	Quantified	Non-quantified
Increased yield linked to CO_2 concentration	X	
Changes to plant phenology		X
Effects on production of the increase in temperature and the change to precipitation	X	
Effects of the reduction in water availability on yield and production techniques		X
Impacts of heatwaves on crops	X*	
Impacts on bioagressors		X
Loss of yield linked to extreme events and the rise in sea levels		X

** for maize and wheat only.*

Moderated positive impacts on field crops, up to a certain threshold

The analysis carried out for field crops (Rosenzweig and Iglesias, no dated) recorded an increase in yield for **wheat** up to a certain temperature threshold, which, under scenario A2, will be reached between 2050 and 2100. Above this threshold, **yields diminish, but the impact remains moderated.** The results are more contrasted for maize: yields increase slightly until 2030, then begin to drop between 2030 and 2050 regardless of the scenario considered, the impact of climate change tending largely towards the negative in 2100. In terms of costs, this corresponds for **maize in 2100 to a loss that could reach almost EUR 113 million per year.** This development only concerns gradual changes (changes to temperature and precipitation) and does not take into account the reduction in water availability or droughts. However, the multiplication of events such as

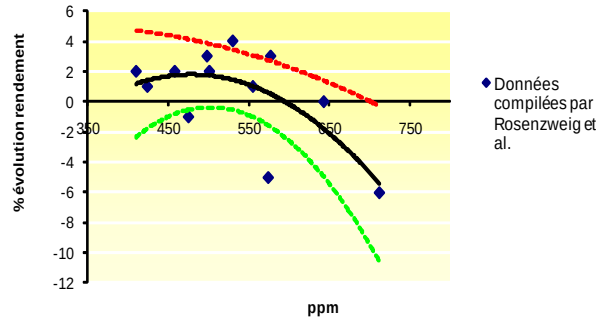
2003 heatwave could represent, in 2100, a cost reaching more than **EUR 300 million per year for a crop such as wheat** under scenario A2, if no adaptation is made, **calling into question some of the optimistic results set out above.**



Graph 2 – Effect of gradual climate changes on wheat yields

Key:

% évolution rendement	*= yield change %*
Données compilées par Rosenzweig et al.	*= Date compiled be Rosenzweig et al.*
Source des données : Rosenzweig et Iglesias	*= Data source: Rosenzweig & Iglesias*



Graph 3 – Effect of gradual climate changes on maize yields

A strong territorial effect on viticulture

Viticulture will also be impacted by climate change[16]. We may see an increased yield in **Burgundy** (+35.2% additional yield according to scenario A2 in 2080 and +41.7% according to B2, without adaptation). These results must, however, be qualified: **it will not be possible under these conditions to produce as many high quality wines as today. Languedoc-Roussillon** may in its turn suffer **considerable reductions in yield without adaptation (up to -26%).**
Technical lines, including irrigation, may, however, change the data (transform a situation from a loss in yield of -18% to an increase of 11% over the period 2070-2099 compared to the reference period, for the useful "grande reserve" land). In this study, the **main limit rests in the fact that the reduction in water resource availability is not taken into account.**

[16] According to the works of Inaki Garcia de Cortazar-Atauri (2006) http://www.inra.fr/ea/fichier_these/These_Inaki_GarciadeCortazar.pdf

A possible increase in yield for meadows in the Northern area; increased vulnerability in the peri-Mediterranean arc.

In the departments of the peri-Mediterranean arc, from 1980 to a date between 2050 and 2090, the changes underway will lead to a **very steep drop (approximately -70%) in yield from meadows in the summer period** – droughts such as those in 2003, 2005 and 2006 having become the norm; **and an increase in yield of 10 to 20% in the winter period** because of more favourable temperatures and CO_2 concentration levels. In total, a drop in annual fodder production of **between -20 and -25%** may be seen. The cost of compensating for these drops in yield (by purchasing fodder) could reach some **EUR 200 million per year** in the second half of the 21st century.

Limits of the exercise

The quantification work presented here comprises a certain number of limits.
These are due to:

- the hypotheses put forward (in particular, constant economy);
- the uncertainties over climate changes and the response of agricultural production to these changes;
- the not taking into account of the water parameter in the quantified assessments;
- the very partial nature of the assessment.

These uncertainties affect **not only the values, but also the sense of variation of the results** by interaction, especially with the regional variability of the impacts of climate change.

Adaptation

The following table sets out the planned adaptation lines suggested.

Table 18 – Recommended adaptation measures

Field crops	- Diversify the crop systems, enabling "evasion", "avoidance" and "tolerance" to be combined - Increase the duration of vegetation in order to enable the succession of summer-winter crops - Lead a discussion on the relevance of implanting new crops, by adopting a "field" approach
Viticulture	- Carry out genetic research for new grape varieties suited to the lands - Lead a discussion on the changes to AOCs - Perfect new irrigation technologies
Meadows	- Extend use to adjustment areas if these exist (summer at altitude) or create these areas - Reanalyse the long-term water management policies in order to improve the irrigation of small areas - Help implement adaptation actions within the framework of collective contracts - Anticipate the consequences of climate change on livestock and adapt, in particular, farm buildings in order to limit the impacts of heatwave on animal performance.

Perspectives and recommendations

Research lines and follow-up and observation requirements have also been identified.

Table 15 – Research, follow-up and observation requirements

Research requirements	Lead/continue research to increase knowledge of: - integrating the water factor into the crop models - bioagressors - the nitrogen aspect and the use of mineral inputs - CO_2 provision - the impact on product quality - erosion of arable lands - pollinators
	Draw up refined forecasting approaches per region and per type of agricultural system
	Take into account the degree of farmers' aversion to risk
Follow-up and observation requirements	Encourage relationships and interconnection between research, development and the professional world in order to ensure knowledge sharing
	Collaborate with other countries facing the same adaptation problems
	Have network monitoring and alert systems developed for pathogenic agents
	Have management methods developed in the fight against the emergence and implantation of pathogenic agents and exotic diseases
	Know and monitor the changes to known vector implantation areas
	Encourage collaboration between the monitoring systems for animal diseases and those dedicated to human illnesses

The ADAGE (*Agriculture Durable par l'Autonomie, la Gestion et l'Environnement* = Sustainable Agriculture through Autonomy, Management and the Environment) **Prospective Discussion Workshop (ARP),** launched on the initiative of the national research agency and for which the results should be available by 2010, aims to identify and mutually insure the needs for studies and research on this topic. Its conclusions will enable this initial list to be completed.

Forest

Key messages

- The impact of climate change on **forest productivity** will occur over two timescales.
- In the short term (up to 2030 or 2050, depending on the scenario), the impact of **gradual climate changes** on wood production will be more or less positive, with economic gains that could reach EUR 150 million per year. These gains will be significant from the Massif Central to the north-east quarter of France, where the number of freezing days will decrease sharply, parallel to an increase in average temperature. Nevertheless, **extreme events** such as droughts, heatwaves and fires could strongly mitigate the positive effects on a national level.
- In the long term (up to 2100), because of more frequent extreme events and the spread of the Mediterranean forest, **the effects will be clearly negative.**
- Quantification concerned one impact (productivity) and one unique dimension: wood volumes. **Non-goods aspects** could not be considered. The restrictive scope of the study constitutes one of the main limits.
- Current and future works both in **pure and applied research** will enable the impacts and adaptation measures that could be taken into account in economic assessments to be widened and go beyond the exercise proposed here.

Scope of study

The quantification and the scenarios proposed are based on the **forest productivity criteria** in accordance with two time horizons: medium term (2030 for A2, 2050 for B2) and long term (up to 2100). *Table 20* indicates that the economic impact of the change in forest productivity on merchandise, the only impact quantified, does not constitute the only identified impact of climate change.

Table 20 – Impacts identified and studied: Forest

	Quantified	Non-quantified
Economic impacts on saleable goods and services from the change to forest productivity	X	
Economic impacts on non-saleable goods and services from the change to forest productivity		X
Insect proliferation		X
Impacts on species migration and ecosystems		X
Impacts of extreme events		X

The task was based on the results from literature and reports from experts who met during a working seminar in March 2009. According to the analysis carried out, the biological and, as a result, economic consequences of climate change for the French forests and the industry dependent thereon, **will occur over two timescales:**

- Medium term: climate change => faster growth rate in the forests
- Long term: climate change => slower growth rate in the forests

From the medium term, more intense and more frequent extreme events (heatwaves, fires) will challenge certain positive impacts of climate change on forests.

In the medium term: a more or less positive impact on wood production from the gradual climate changes

During **an initial period lasting up to 2030 or 2050,** depending on the scenario adopted (A2 or B2), the effects of gradual climate changes (temperatures and CO_2 concentration) will be more or less positive in relation to the total annual gross production. This increase could generate economic profits. By keeping the 2008 wood harvesting rate and presuming that the distribution of forested

areas and the prices remain constant, we can estimate that as an annual average, the **potential** additional revenue compared to the current situation will be around **EUR 150 million per year.** These gains will be real **provided** the commitments undertaken within the framework of the Grenelle Environment Forum for revitalizing the field and the CRE2 (*Comité de Régulation énergie 2* = Energy Regulation Committee 2) programme **are respected,** and **in accordance with the forest sector's capacity to mobilise resources.**
However, over this same period, the **anticipated gains in productivity are equal in amount to the possible losses** through wilting, fire, drought, etc. The impact of the dry spell and heatwave in France in 2003 gives a good indication of the vulnerability of forests to these hazards: greater wood mortality by a reduction in growth in the remaining trees, less truffle production and an environmental loss in terms of carbon, i.e. a total loss of around EUR 1.2 billion (Birot & peyron, 2006). Furthermore, summer 2003 was characterised by fires that were four times more serious than usual (EUR 0.2 billion).
We estimate that, in the case of scenario A2, we could see up to 3 heatwave episodes by 2030. For scenario B2, by 2050 the number of heatwaves will be between 0 and 4. The heatwaves could also lead to **losses of several billion euro over the medium term,** whether we consider all the resulting costs or just those relating to losses in production.

In the long term: a clear change to forest regions and more frequent extreme events, to the detriment of productivity

The main changes foreseeable at horizon 2100 seem unfavourable to the annual gross production, for several reasons:

- Appearance of limiting factors that influence the individual productivity of a species;
- Progressive replacement of one forest type (north) by another (Mediterranean) that is less productive;
- Repetition of unfavourable events such as droughts and heatwaves;
- Greater risk of fires and geographical widening of the risk zone;
- Development of pathogens.

The predicted climate changes therefore suggest **clearly negative impacts in the long term, which are not possible to quantify at this time given the degree of uncertainty.** In order to compensate for these effects, the adaptation of the forest sector must involve the contribution of all players in the field and territories.

Limits of the exercise

The main limits of the study are listed below:

- The evaluation only concerns a limited part of the impacts of climate change on forests; aspects other than goods do not enter into the scope of the costs set out here.
- The scenarios used are deliberately simplistic. They do not allow for the sufficient inclusion of the complexity of the impacts of climate change on forests, in relation to the combination or confrontation of opposite effects and to the different reactions depending on the species under consideration.
- The constant economy hypothesis used does not allow the changes to wood prices and its uses to be taken into account.

Adaptation

Several forest adaptation measures have also been noted and are set out in Table 21.

Table 21 – Recommended adaptation measures

Forestry management	Harvest more: measures for harvesting more and keeping a "reasonable" forest stock
	Lower the age of use/rotation
	Choose suitable species
	Diversify populations
	Encourage species migration by regeneration management in synergy with the migration corridors
	Manage additional volumes resulting from hazards
	Develop new forest management methods to protect against natural hazards in order to ensure the permanence of afforestation and its production.
	Strengthen the measures aimed at reducing other aggressions towards weakened forest ecosystems.
Research, observation	Work on species robustness/resistance
	Develop a system for monitoring the impacts of climate change
Land use planning	Shape the management of protected forest areas
	Have the territories specialise
Industry, outlets	Adapt the industry to wood that can be produced by the forests of tomorrow
	Develop standards and apply measures aimed at encouraging the use of wood (particularly in construction)
Forest fires	Improve forecasting in the zonal systems
	Optimise the means of combating forest fires in terms of cost/efficiency

Perspectives and recommendations

The study carried out has enabled us to highlight a certain number of research lines to prioritise, in order to continue the analysis of the impacts of climate change on forests.

Table 22 – Research, follow-up and observation requirements

Research requirements	Understand the impacts of climate change on forests, particularly on a **local scale** (and per site, which includes analysing long-term soil behaviour) and in relation to forest species.
	List the forest's genetic resources and understand the forest's genetic resources' capacity for **natural adaptation** (especially in terms of the possibilities of species migration)
	Re-define **territory zoning** with forest areas advised and encouraged in accordance with the hazards
	Better assess the **services provided by the forest**
	Integrate the concept of **financial risk** into cost analyses
	Study the development and cost of fire prevention policies (see box)
	Define the strategic options for players in the field, integrating risk and uncertainty.
Follow-up and observation requirements	Carry out an **inventory of current practices** and adaptation measures on a regional/local scale
	Implement a **community strategy** and international scientific co-operation for research on the impacts of climate change on forests

The impact of fires – Extract from the Intermediate Report by the Interministerial Task Force on the spread of forest fires

"Today, 89 departments are temporarily listed by the task force as being at risk of forest fires, of which 14 have a high risk across their entire territory, 8 have a high risk across part of their territory, 6 have an average risk across their entire territory, and 61 have a low risk, of which 4 have an average risk across just part of their territory.
From this observation, the interministerial task force responsible for studying the future spread of zones at an increased risk of forest fires fixed as its objective, in its final report, the proposal of an estimate of this spread towards the North for the periods ending 2010, 2030 and 2050, in relation to climate change as predicted today.
Two approaches have already been explored in order to succeed in estimating this spread of sensitive zones:
a) the characterisation of the sensitivity of the forest populations of tomorrow (…) to fire (…) which may be supported, from the types of populations listed in the national forestry inventory (…)
b) the development of the IFM (*Indice Forêt Météo* = Forest Weather Index, which gives an estimate of the risk of a forest fire occurring, as calculated by Météo France, and which only depends on weather parameters and day length, which allows comparisons to be made between regions with very different climates independently of the species present)"

The final report by the Interministerial Task Force will be available in 2010.

Energy

Key messages

- The climate change measured by the increase in temperatures has two contradictory effects on energy consumption: it leads to a drop in heating requirements on the one hand, and on the other, it leads to an increase in demand linked to air conditioning. Within the framework of the hypotheses put forward and the climate scenarios adopted, the increase in temperatures could, at horizon 2100, lead to a **drop of over 3% in** national energy **consumption** compared to the current situation. The increase in air conditioning devices will cause an increase in demand peaks in the summer period, which will complicate electricity network management.
- At **regional level, situations will be contrasting:** hot regions could see their annual consumption increase, while cooler regions will see it reduce.
- Even though the current models do not enable very precise modelling, **hydroelectric power production could drop by at least 15% at horizon 2050;**
- The energy production and transport infrastructures must see **drops in return related to the increase in temperatures:** the models and data available did not allow this impact to be quantified. Within the framework of the rise in sea level hypotheses, a major sensitivity has not been identified for current nuclear power stations at horizon 2050.
- The strengthening of research and development on **cooling technologies and on towns and habitats that are resistant to heat** will be no regrets adaptation measures.
- These analyses are partial and do not take in account **extreme phenomena that could cut the network or production** (more frequent forest fires, storms, etc.).

Scope and assessment method

The daily temperature data for scenarios A2 and B2 have been used at horizons 2030, 2050 and 2100. On the basis of this data, energy engineers' **temperature-dependent consumption models** have allowed the corresponding energy demand to be simulated using a constant economy hypothesis. Taking into account the data and models available, the quantitative assessment was not exhaustive. In addition, other impacts have not been quantified for reasons linked to the high level of uncertainty over the climate projection models or the low weight of some energies in the current energy bundle. The details of the impacts quantified are set out in *Table 23.* The impacts have been translated into millions of toe (tonne of oil equivalent) per year. Toe has not been converted into monetary terms because of the high level of uncertainty over prices. Amongst the adaptation measures identified, only the impact from a spontaneous development of air conditioning has been quantified.

Table 23 – Impacts identified and studied: energy

	Quantified	Non-quantified
Variation in residential and tertiary gas and fuel oil consumption	*X*	
Variation in electrical consumption for heating and cooling	X	
Variation in consumption by private vehicles	X	
Variation in industrial sector consumption		X
Impact on hydroelectric productivity	X	
Impact on renewable energies, excluding hydroelectric power		X
Impact on electrical production during periods of heatwave	X	
Loss of network capacity because of heat		X
Network break in case of extreme climatic event		X
Excess investment costs for adaptation of future electrical power stations		X
Change to the population division over the national territory		X

A drop in annual consumption

On the basis of the climatic data for scenarios A2 and B2, with a constant economy hypothesis and the inherent uncertainty regarding the models, the modelled impact on energy consumption by the sectors studied is as follows:

Table 24 - Quantitative impacts and adaptation effects

	B2			A2		
Impacts (Mtoe)	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
Residential, tertiary natural gas	-[1,8; 2,4]	[-1,6; -2,1]	- [2,5; 3,9]	- [1,3; 1,7]	- [1,9; 2,5]	- [3,9; 5,0]
Residential and tertiary fuel oil	-0,6	-0,7	-0,8	-0,5	-0,7	-1,5
Heating and air conditioning electrical consumption	-0,8	-0,7	-1,2	- 0,6	-0,8	-1,5
Vehicle air conditioning 45%	0	0,3	0,6	0,1	0,3	0,8
Nuclear power stations and 2003-type heatwaves	0	[0,0; 0,1]	0,2	[0,0; 0,1]	[0,0; 0,1]	[0,3; 0,4]
Loss in hydro electric power productivity	-	0,9	0,9		0,9	0,9
Assessment without adaptation (Mtoe)	***-[3,8; 3,2]***	***-[2,2; 1,8]***	***-[4,2; 2,8]***	***-[2,6; 2,3]***	***-[2.7; 2,2]***	***-[5,9; 4,9]***
Spontaneous adaptation (Mtoe)						
Spontaneous residential air conditioning		0,5	1,0		0,5	1,0
Vehicle air conditioning 90%	0,4	0,7	1,0	0,5	0,7	1,2
Assessment with spontaneous adaptation (Mtoe)	***-[3,4; 2,8]***	***-[1,0; 0,6]***	***-[2,2; 0,8]***	***-[2,1; 1,8]***	***-[1,5; 1,0]***	***-[3,7; 2,7]***

With a constant rate of air conditioning equipment, climate change could lead to a **fall in annual consumption for the sectors studied of around 2% at horizon 2030 and over 3% at horizon 2100.** The spontaneous development of **air conditioning would reduce this gain by half.** We note that while the global impact indicates a drop in consumption, some **sectors will be negatively impacted** and must be compensated (hydroelectric power, air conditioning)

Territorial differences

The combined results on a national level must be interpreted with caution. In fact, on a territorial level, a simulation carried out on a typical group of buildings for the towns of Agen, Lille and Strasbourg showed that **annual consumption will effectively be reduced in the regions with a cooler climate** (major savings in heating), but in contrast **increased in southern areas** (high dependency on air conditioning).

The air conditioning factor

The major part of the “spontaneous” savings modelled comes from the reduction in the demand for heating. However, the increase in air conditioning modifies this observation, in particular if we have to follow the trends of countries such as the United States.
This additional demand for **air conditioning bolsters the pressure on electricity supply: peaks in demand** for air conditioning units in very hot period will require much of the electricity to be supplied exactly **when it is most difficult to produce.** In fact, during really hot periods, the power stations and network lose return and it is necessary to call on additional thermal energy, which is costly, especially in greenhouse gases. The **spontaneous increase in air conditioning units therefore poses major constraints** on the French network.

A drop in hydroelectric power productivity

The drop in precipitation modelled in the main catchment basins equipped with hydroelectric power plants causes us to foresee an **average drop of around 15% of production potential.** Even though the current models do not allow very precise modelling, this trend will highly complicate hydroelectric power management. In very hot periods, these resources are nevertheless of basic value because they enable the rapid cushioning of the demand during peaks in consumption.

Extreme events that are difficult to model

The study carried out does not take into account two potentially major phenomena :

- the increase in intensity and frequency of **storms** is not yet well documented for France. If climate change had an influence on these storms, the impact on the energy sector could be significant (network, storage terminals and production plant);
- the impact of climate change on **forest fires** is still badly modelled. The probable increase in these events will lead to more frequent breaks in the network (necessary for interventions and for safety), which could have major consequences if this occurs at key points in the network.

Limits of the exercise

The constant economy hypothesis and the failure to take into account extreme events other than heatwaves are objective limits to this analysis. Nevertheless, with regard to the uncertainty over the change in energy prices and the occurrence of extreme phenomena, few alternatives are possible by way of exploration. The exercise was also dependent on the data and models available: due to the strategic and commercial interest in some data, they were not always available in full.

Adaptation

Climate change must have the effect of **reducing** annual energy **demand.** Nevertheless, the **change to consumption during the summer months** requires a discussion on the **adaptation of the network and the management of the energy stock,** in particular with regard to crisis management in hot periods or following extreme events. The frequency and increasing intensity of extreme events must be taken into account regularly with a view to advancing knowledge in this area.

Table 25 – Recommended planned adaptation measures

Demand	Research and development into more energy-efficient cooling processes
	Development of more energy-efficient town planning and buildings, particularly in terms of cooling
Offer	Offer: Improve energy plant cooling processes
	Make energy plants more resistant to climatic extremes
	Generalise the group management systems
	Refine the crisis management procedures
	Identify the structures sensitive to a rise in sea level
Crossover	Reinforce the tools for modelling the offer and the demand in relation to the climate

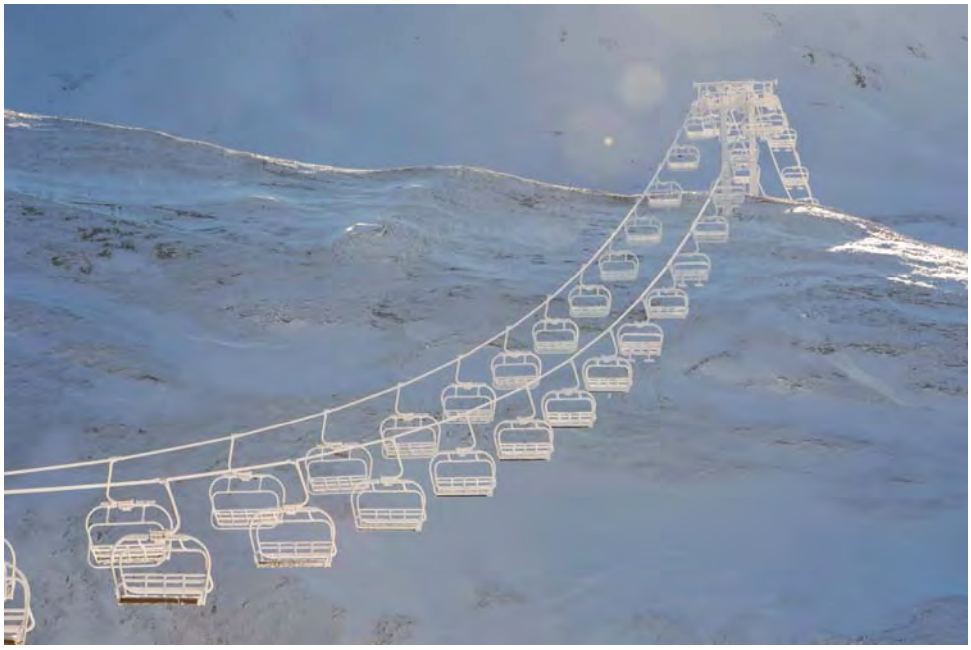
Perspectives and recommendations

The following table shows the identified needs in terms of knowledge, follow-up and observation.

Table 26 – Research, follow-up and observation requirements

Research requirements	Calculate the impacts on the basis of the annualised data from a model pool and combine them for the various horizons in order to quantify the cumulated quantitative and economic impact
	Widen the territorial dimension of the impact models (break down)
	Develop more energy-efficient cooling systems
	Develop technical options for heat resistance for building frameworks and town planning
	Widen the storm and forest fire forecast models
Follow-up and observation requirements	Obtain observation data on consumption and household equipment: for example, on the real rates of air conditioning equipment
	Strengthen consultation with energy operators
	Improve the consumption forecast models in accordance with climate change and carry out a national and regionalised follow-up on trends

Tourism



Key messages

- The impacts of climate change on the tourism sector are multiple
- At horizon 2100, the analysis of the **climatic-tourist comfort index** for the territory indicates a change to a **drop in summer climate attractiveness** across the territory as a whole, but mainly in the south and east of France.
- On the other hand, in the **inter-seasons,** and especially in the months of May and June, the climate attractiveness in 2100 will equal current summer climate attractiveness.
- The result of this change in terms of tourist visits is not immediate: if the climate plays a major role in the choice of destination, **sensitivity to high heats** and the perception itself of what equals excessive heat differs depending on parameters such as the departure period, accommodation method and trip environment.
- With regard to winter sports, an OECD study in 2006 indicated that, in the Alps, **the reduction in snow cover will reduce the reliability of the depth of snow**. In the French Alps, 143 skiable resorts currently have a low snow depth. In the event of warming by +1°C, this will be the case for only 123 resorts: for 96 resorts if warming reaches 2°C and for only 55 resorts in the event of warming by 4°C.
- Future research work must enable these elements to be specified and relate to the "tourist offer" aspects.

Scope of study

Even though the impacts of climate change on tourism are not limited to these aspects, the task focussed on two main points :

- the calculation of a climatic-touristic index (ICT) across the French departments, based on the Mieczkowski method (1985);
- a study into the climatic preferences of French tourists and their perception of climate change.

The main impacts identified during the tasks are set out in *Table 27.*

Table 27 – Impacts identified and studied: Tourism

	Quantified	Non-quantified
Reduction of snow caps, with an impact on winter sports activities		X
Drop in water reserves and restrictions, pressures and even conflicts of use between tou rist activities and other uses		X
Impacts from the rise in sea levels and erosion of the coastline on tourist infrastructures		X
Change in tourist climatic comfort and the climatic attractiveness of destinations	X	
Impacts of health and natural hazards and extreme events on the safety and attractiveness of destinations		X
Erosion of biodiversity and impacts on the attractiveness of destinations		X
Redistribution of tourist flows as a result of the above-mentioned impacts		X

Reduction in summer climatic comfort

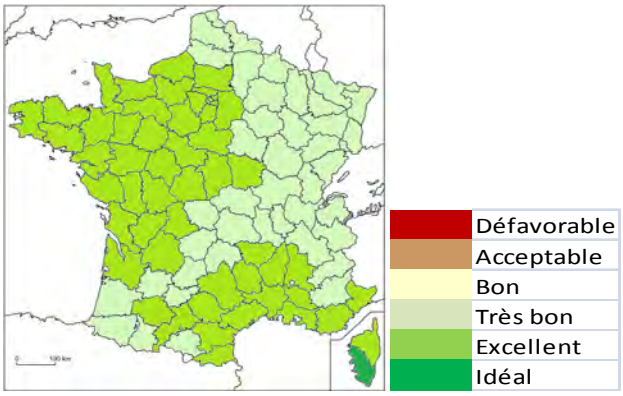
The impact of climate change on the comfort of tourists was tackled thanks to the analysis of the Mieczkowski index.

The Miecskowsi ICT

The ICT comprises six monthly climatic variables (maximum and average temperatures, relative humidity, rainfall, hours of sunshine, wind speed) from which sub-indices are drawn up, each subject to a rating.

The ICT index, varying from -30 to 100, allows you to define whether a climate is favourable to tourism or not, depending on the following grading system: > 90: Ideal; > 80: Excellent; 70 –79: Very good; 60 – 69: Good; 40 – 59: Acceptable; < 40: Unfavourable

In an initial step, for each department, the "climate attractiveness" for the **months of July-August** were analysed on the basis of the ICT, using the average of the reference period 1980-2000.



Map 3 – ICT for the months of July and August for the period 1980-2000

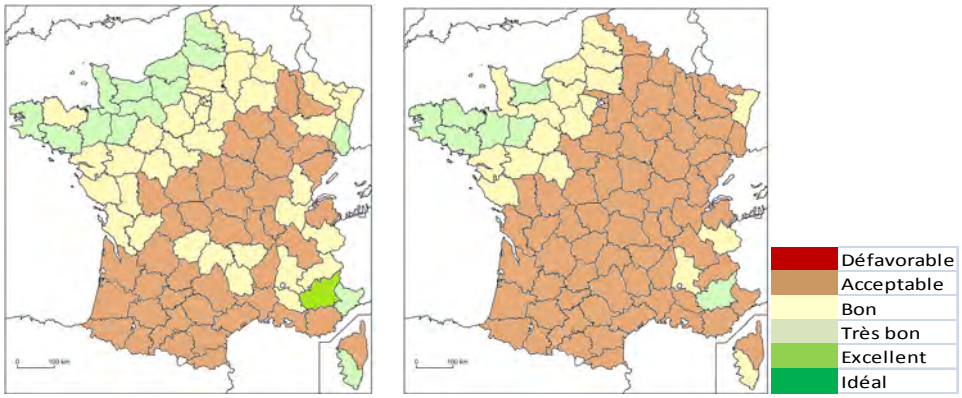
Key:

Défavorable = *Unfavourable*
Bon = *Good*
Très bon = *Very good*
Idéal = *Ideal*

This first map indicates the current climatic conditions favourable to summer tourism across the whole country.

The analysis of the change in climatic data at horizon 2100 has allowed us to estimate for which departments the ICT will be particularly impacted and to compare the expected changes depending on the department, as rough estimates (without, however, drawing conclusions on tourist visits).

Scenario A1B Scenario A2



Map 4a and 4b: ICT for the months of July and August for the period 2080-2100

Key:

Défavorable = Unfavourable
Bon = Good
Très bon = Very good
Idéal = Ideal

In summer, climate change will mean a reduction in the climatic conditions favourable to tourism. This reduction is less marked in the northern half of France (Northwest Coast in particular), and in certain Alpine departments. At a first glance, these conclusions could contradict the widely expounded hypothesis according to which there will be "big winners" from climate change. The analysis shows us here than even in the north, in the scenarios adopted, **the maximum temperatures reached in summer could become too high to allow maximum tourist comfort.** Only horizon 2100 was studied in detail here. It is important to note that **these reductions will begin from 2030-2050.**

Under **A1B,** the departments where the summer ICT reduces by more than 25% currently represents more than EUR 10 billion in turnover for the months of July-August; those where the drop in ICT is between 10 and 25%, more than EUR 18 billion.
If we observe a reduction in summer tourism conditions in 2100, this will not be the case at other periods of the year. **For May and June, we will see an increase in the ICT value** for the large majority of departments, with a climate close to current summer conditions.

Index limits

The main climate index limits relate to:

- The choice and weighting of climatic parameters, leaving a great deal to the arbitrary;
- The failure to take the changing nature of the concept of climate comfort into account;
- The failure to take adaptation into account.

Finally, we note that the **climate only constitutes one of many decision factors** in the tourist demand. Parameters such as the presence of suitable infrastructures, price, and various cultural contexts have not been considered. **The TEC-Credoc study,** the principle results of which are set out below, informs us of the place of climate in the choice of French tourists.

The climatic preferences expressed by tourists

While the climate is not the first factor of choice (Dubois and Ceron, 2006), **43% of responses** nevertheless stated that the climate was one of the most important elements in making a decision, when they had the option of choosing from several destinations in France. The climate is important

for planned trips where the main accommodation is **camping,** and the same goes for **outdoor activities** and **trips of over 8 nights in length.**

Heat and drought raise little apprehension: only 13% of responses stated a temperature that was too high and drought is feared by less than one tourist in ten. Apprehension about drought is nevertheless higher for trips in the country.
For their holidays in 2009, **the temperature above which tourists considered it would be too hot is an average of 32°C.** Age, the area of residence and above all the type of trip planned affect this threshold. Also, the temperature believed to be "too hot" varied between:

- 34°C for camping trips and bathing activities
- 30°C for mountain trips.

A large majority of responses stated that they would decide not to change their planned trip **if there was to be a heatwave.**

It is mainly climatic variability, as well as cold and rainy weather that have a clear influence on tourist trips.

Adaptation

Due to the high reactivity to changes by players in the sector, the expected adaptations are mainly spontaneous, both on the part of tourists and tour operators. These are measures such as artificial snow, the protection of infrastructures, air conditioning in accommodation units and even water resource sharing policies. The main planned adaptation options are listed in the following table.

Table 28 – Recommended adaptation measures

Encourage policies for diversifying the tourist offer, particularly for sites and activities that are highly climate-dependent	Diversification of activities and revenue sources in winter (excluding skiing)
	Development of four-season tourism, in order to reduce dependency on snow
	Diversification of activities in seaside resorts

Perspectives and recommendations

The research requirements highlighted by the study are set out in the following table.

Table 29 – Research, follow-up and observation requirements

Research requirements	Continue the study into tourist perceptions
	Refine the climatic comfort index methodology by adapting it to the characteristics of tourists in France
Follow-up and observation requirements	Widen the consultation to national tour operators in order to: - assess their degree of sensitivity to climate change - know their current position in terms of adaptation

Transport infrastructures

Key messages

- For reasons of data availability, we are only interested here in the impacts of **"heatwave"** and **"marine submersion"** hazards on **State-controlled A-roads.**
- The French road network behaved well overall in the face of the 2003 heatwave, despite localised problems being observed and this being an isolated event. However, in extrapolating "*ex abrupto"* the results of foreign studies to the French case, we can estimate an excess cost **for the maintenance of A-roads in relation to climate change of between EUR -9 and +70 million per year**
- With regard to marine submersions, the **overall rise in sea level of 1 metre** would represent a property cost, for the mainland A-roads (excluding motorways) that could reach **EUR 2 billion.**
- For these two hazards, additional work must be carried out with the operators on the departmental and municipal network and on the motorway network, and on minor roads, as well as in the field of operation and rolling stock
- Additional work on the other transport infrastructures (river transport, port installations, rail network, etc.) is needed.

Scope of study

With regard to the "transport infrastructures" theme, the study only addressed two specific risks:

- Damage linked to submersion (permanent and temporary) due to the rise in sea level
- Damage linked to heatwaves

Table 30 – Impacts identified and studied: infrastructures

	Quantified	Non-quantified
Impacts		
Damage to transport routes (gravitational hazards, fire, flood – urban run-off)		X
Damage to transport routes – marine submersion	X	
Damage to transport routes – heatwave	X	
Ground instability due to drought (clay shrinkage-swelling)		X
Change to pressures exerted on infrastructures by the environment		X
Gains linked to shorter or less intense freeze periods		X
Infrastructure type		
Road	X	
Air		X
Rail		X
Maritime and river		X

The discussion was centred on the **large national mainland infrastructure networks managed directly by the State** (A-roads) for reasons of statistical data availability. It would be useful and opportune to plan to also anticipate the cost of the deterioration of departmental and municipal networks, without forgetting the rail networks, etc. The impact on real road use has not been taken into account either: loss of use (loss of socioeconomic value because of the unavailability of a transport infrastructure) and network effects have not been tackled. Bearing in mind their support function for numerous activities, the **"buildings"** topic has been tackled by several other groups. However, a summary of knowledge and research requirements is suggested at the end of this summary.

Heatwaves

Three additional approaches have been led in order to assess the impact of the increase in heatwave occurrence, each corresponding to 3 different information sources.
The first two approaches, the first based on a **ground survey,** carried out among decentralised services, led jointly by the *Laboratoire Central des Ponts et Chaussées* (LCPC = Central Laboratory for Bridges and Roadways) and the *Service d'Etude sur les Transports, les Routes et leurs Amenagements* (SETRA = Research Service for Transport, Roads and their Improvements), in connection with the *Centres d'Etudes Techniques de l'Equipement* (CETE = Equipment Technical Research Centres), after the heatwave period in 2003, and the other on **the examination of budgetary data and the A-Road and Civil Engineering Structure Quality Index database** for the evaluation and monitoring system for the surfaces of the public A-road network, cited the generally good performance of the roads and road surfaces in the face of the single period of heatwave that occurred in 2003. Nevertheless, a certain number of **localized problems** were observed, caused by clay soil shrinkage-swelling.
The third approach was a benchmark assessment using a foreign bibliography, based on more advanced evaluations than those available in France. A British study (DEFRA, 2006) noted that, for the heatwave years, a budget representing 15% of their annual maintenance budget was consecrated to repairing damage. The Australians (Austroads, 2004) predict variations in overall maintenance costs of -2 to +4% per year due to climate change.
In France, the annual maintenance costs for the public national network were EUR 426M and 456M respectively for 2007 and 2008. If we apply the British percentage, **the cost of a heatwave in France for the year under consideration would represent a sum varying between EUR 64M and 70M.** If we use the Australian percentages, the **annual excess cost of climate change in France for the year considered would be a sum varying between EUR -9M and +18M.** The indirect impacts at foundation and bedding level were not assessed (geographical hazard, drought, variation in groundwater level), nor were the impacts on operating the road networks, road safety or operating tunnels. **In addition, the costs caused by repeated periods of heatwave (climate fatigue) or by an increase in thermal intensity (existence of threshold effects) remain unknown as of this date.**

Marine submersions

A hypothesis where the sea level rises by 1m at horizon 2100 was adopted. For a permanent submersion, we consider that the works under threat are those located at a height below the coastline +1m. The cost could equal the loss of property value.
From information relating to transport infrastructures located at a height below the 100-year submersion height + 1m, taken from the BD Topo Pays® database and by basing the estimate of average linear property cost at EUR 10M per kilometre of road surface and the cost of repair at around EUR 250k/km, **the overall rise in sea level of 1m will represent a property cost, for mainland A-roads (excluding motorways), excluding loss of use, that could reach up to EUR 2 billion.**

Limits of the exercise

In the first instance, **additional work must be carried out on the departmental** and municipal **network** and on the motorway network. A similar task must be undertaken, with the operators, for rail, port and river infrastructures as well as in the field of operations and rolling stock.

Drought and heatwaves :

1. the assessments were drawn up in a climate setting more or less removed from our own with technical frames of reference that were non-comparable and with different operating conditions;
2. the monetary assessments were approximate and very simplistic;
3. the assessment hides local differences.

Marine submersion :

4. we see correspondence problems between the 100-year submersion heights and the heights of the coastline +1m, implying approximations;
5. the protection heights were not identified;
6. the analysis was carried out in relation to a static sea level, without taking into account swell breach phenomena; we have not considered the kinetic impacts of submersion (slow or sudden) on coastal risk.

Adaptation

Adaptation was tackled briefly in this phase of the study.

Table 31 – Recommended adaptation measures

Network management	- Undertake an approach with the managers of port, rail and river infrastructure networks and of roads that do not come within the public national road network - Develop risk analyses per network, per itinerary and for major civil engineering structures - Select the strategic routes and sensitive points that must benefit from priority improvement - Develop communication tools, adapt traffic management tools
Frames of reference	- Revise the frames of reference for the construction and use of transport networks, for roadway maintenance and improve knowledge on the behaviour of materials and structures and on the development of innovative constructive solutions
Coastal hazard and flood risk	- Study the strategies of inland "withdrawal"/staying on site with suitable protection improvements/staying on site and accepting temporary submersions - Update monitoring, alarm and crisis management devices - Establish substitute itineraries and transport methods
Water management for waterways	- Develop support structures - Look into alternative solutions for some uses

Perspectives and recommendations

The lines identified are set out in the following table.

Table 32 – Research, follow-up and observation requirements

Research requirements	Widen the analysis to departmental and municipal road networks, rail, river and port networks and to urban public transport (TCU).
	Heatwaves Launch works on the **effects of heatwave** on road surfaces, and in particular on: - network maintenance policy strategy - road surface "climate fatigue" from repeated demands from high temperature ranges

	Submersions - Continue the assessment, taking into account the **characteristics of the protection structures** - Draw up a method for assessing the costs linked to loss of use
Follow-up and observation requirements	**Heatwaves** **Observation** and tests in order to verify the behaviour of roads and civil engineering structures in repeated periods of heatwave.

Additional spotlight: Buildings

Along with the transport infrastructures, buildings share the characteristic of being **directly subject to climatic hazards.** According to the experts, the main hazards affecting the buildings sector and that could lead to adaptation will be:

- flood episodes (slow and flash floods, urban run-off);
- effects of wind;
- effects of clay shrinkage/swelling;
- urban heat phenomena and remedial methods.

The adaptation of buildings has been especially examined by the other sub-groups:

- Energy: actions aimed at reducing energy consumption from heating and air conditioning on a building-to-building scale;
- Health: adaptation of buildings in order to limit the vulnerability of occupants to the impacts of a period of heatwave or indeed following a flood;
- Natural hazards and insurances: adaptation to the risk of shrinkage/swelling, anticipation of the impacts of floods and wind;
- Territories: putting into perspective the inclusion of the impacts on buildings depending on the region.

New knowledge must be acquired. **For the heatwave hazard,** the **radiative characteristics** of the surfaces of items from the urban fabric play a determining role in the energy use of an urban area. The extent of the impacts expected from a change to these characteristics is still to be validated. It will be necessary to study **the social acceptability of measures** and the definition of practical conditions for implementation and maintenance.
As for the risk of clay soil shrinkage and swelling, knowledge needs to be acquired on **the development on ground water content.**
As the change in frequency and intensity of floods is extremely uncertain, discussions on reducing the vulnerability of exposed buildings feed works underway on **assessing constructive measures** (including amphibious buildings) and **town planning regulations.**

Territories

Key messages

- Territories will not be affected by climate change in the same way: some territories, their economic activities, demographic density or even their biodiversity will be especially impacted. Work concentrated on four types of territory: **the coast, urban areas, the forest and the mountains.**
- Beyond the sectoral aspects analysed by the subject groups, an analysis from the territorial angle must include factors such as **demographic dynamics** – which will modify the distribution of impacts and the type of responses to be made thereto; as well as **different levels of scale** – in order to identify incompatibilities in the recommended measures and avoid conflicts.
- The question of **competence and use** is fundamental and must be considered from the definition of strategies, in order to accompany the transition to change.
- The creation of an adaptation policy on a territorial scale must take into account **all the players** that it must accompany throughout the transition, in the form of an apprenticeship based both on a levelling of the knowledge about the development of phenomena and on favouring local governance; a combination necessary to the social appropriation of climate change.
- Beyond the global aspects, it is necessary to adapt **lifestyles:** to do this, the clear involvement of policy is indispensable, relayed and pushed by the players in economic and community life.

Objectives and scope of study

Crossover by definition, the Territories group focussed its work on **sectoral interactions on a territorial scale** and the **concept of transition to change.** One of the main preoccupations in the procedure has been to **strive for the production of operational tools aimed at the territories** and to consider the instruments that will enable the players, in addition to understanding the challenges, to adapt their governance, their communication and their awareness raising and mobilisation tools.

Analysis from a territorial angle: territories facing challenges

Territories will not be affected by climate change in the same way. It is suggested that the challenges relating to territories likely to be strongly impacted, by virtue of their economic activity, population density or biodiversity, be “cleared”.

The coast

The parcelling out of decision-making on coastal territories, urban pressure and conflicts of use in economic terms may create vulnerabilities to the hazards of climate change. The questions of shoreline submersion, cliff erosion and coastline erosion are just so many factors that will cause the typology of territories to change and have an impact on the activities based there.
A study carried out on the Languedoc-Roussillon coast (EDATER) showed that, in the face of the multiple hazards present in the territory, the climate input was simplistic with regard to economic, social and political complexity and to the aims of land development players. Considered at local level for a field or territory, the integration of the impacts of climate change must be thought of as **one of the development scenario variables.** In order to encourage adaptation, it is a basic pre-requisite that the players acquire knowledge on future climatic phenomena and the actions to be implemented in accordance with their socioeconomic development aims.

Urban areas

Urban areas comprise very challenging territories in terms of the analysis of the impacts of climate change :

- on one hand, the analysis of adaptation in urban areas suffers from a major lack of references;

- on the other, this type of territory (widened to peri-urban areas) concentrates 75% of the population.

This observation pushed the ADEME to initiate a study into the vulnerability of urban areas to climate change, the specifications for which were partly supplied by the examination of the Greater Lyons community. In answer to the challenges revealed by this examination, the ADEME study will aim at producing a **prioritised list of recommendations regarding the inclusion of adaptation in urban environment policies.** This means reacting to the question of restraints on the transition to an adaptation policy in urban zones.

The mountains

An examination by the *Comité du massif des Alpes* (Committee for the Alps Mountain range), in which the scientific committee produced a report on the locations and the proposals on the future of activities in the face of climate change, shed light on the problem of adaptation in this highly challenging territory. The examination revealed that :

- most of the public players are concentrating their efforts on mitigation actions: few adaptation measures are planned to have the alpine system change;
- the long term is not favourable to a constructive posture by private players.

This double observation begs for climate change to be placed at the heart of the mountain range committee's priorities. These initial works already enable us to identify dynamic indicators for adaptation, fields of action for which costs will be measurable, and organisation methods favourable to adaptation to seamless change. The entire focus of the transition phase to change will consist in **defining the new functions of the mountains of tomorrow.**

The forest

Modelling carried out in order to imagine the territorial change to the division of species and the resulting means of production indicates a significant territorial difference concerning the development of production potential: the climatic potential for production is reduced in the southern half and the western side of the country, while the climatic impact is neutral or beneficial in the central part and in the northeast. It is necessary to fully include this **territorial dimension** in discussions on forest adaptation, involving the availability of tools allowing this direction to be pursued.

Analysis crossover elements: demographics and scales

Demographics: risk dispersion factor?

The territorial watchdog, within the framework of its report published in 2009, highlighted by way of statistics the major characteristics of French demographics over the last few years. From this observation, we note the following characteristics of particular importance :

- general dynamics: heliotropism, beyond usual heliotropism, and, to a lesser extent, the attractiveness of major rivers;
- specific dynamics: attractiveness of major urban centres for young populations and for an older population, in the less important urban territories.

The analysis from a territorial angle calls for specific inclusion of these factors, which play a part in **modifying challenges and require suitable responses to be defined** (inclusion of the changes to the density of the zone at risk in the policies for adaptation to natural hazards; management of the elderly in periods of heatwave, suited to their distribution in zones that are difficult to access, whether urban or rural).

Scales: complementary nature of approaches?

We must insist on the need to take into account **all scale levels** at each stage of the analysis and to draw up a strategy. The capacity for an inter-territorial and inter-sectoral summary of knowledge and ensuring the consistency of the strategies of the various players consequently appears to be a major challenge. Inaction or action in the form of refusing to take context into account will have a notable effect in the form of increased vulnerability of territories or certain sectors (economic, natural, social, etc.) and may cause the following impacts:

- Incompatibility of adaptation strategies for a given space;
- Economic risk (insufficient finance for investments made by communities);
- Conflicts of use leading to difficulties in the governance of territories and delays in decision making.

The question of employment

A study initiated by the European Commission and the trade unions in 2003 indicated that while the global benefit for employment from preventing global warming has already been demonstrated, this could mask significant employment movements within sectors or regions. **If the questions of employment and skills are not further integrated in climate policies, we could expect these to become a significant restriction to the economic** and social **changes** required to manage the transition. More in-depth territorial and sectoral analyses are now necessary in order to identify the type and number of jobs that are particularly vulnerable to the impacts of climate change and to the mitigation policies, as well as the jobs that must be created by opportunity, and to help create suitable policies.

Transition management

The creation of an adaptation policy on a territory-wide scale must take into account all the players for which the challenges, territorial scales of competence and level of consciousness are very varied. The Territory group has enquired with each of the sectoral groups in order to identify the players, the lines of discussion on a territorial level, and the tools for analysing impacts and/or the accompanying measures likely to be applicable at territory-wide level, and/or for which a territorial variation will be necessary. This step has revealed a certain number of ways to manage the transition to change phase:

Identify the parties, the territorial competence scales

- Take into account the existing, analyse the lack or absence of subsidiarity between territories.
- Implement relevant structures with private players .

Support and develop local players' capacities to adapt

- Consult the players before defining the strategies.
- Improve knowledge of local impacts, test proposals with a sample group from the players involved.
- Take into account specific contexts (for example, the territory's commitment to agriculture).
- Connect skills and expertise capacities.

Make analysis and accompaniment tools available

- Work on the need for input data to characterise the challenges, an action structuring tool and a communication procedure around these challenges.
- Structure observation, including impact analysis, but also the support for works on territorial differences in climate models and observation of activity migration.

- Plan and organise the territorial procedure.
- Accompany the players by training in the tools.

The MEEDDM SOeS has integrated its project to create a diagnostic and evaluation matrix for the impacts of climate change on economic activities into the challenges for the Territories group. The aim is to propose to the local decision-makers an analysis and forecast guide to the possible hazards encountered.

Perception and development of behaviour in the face of climate change

The Pierre Radanne analysis (2007) of the **restrictions and potential delaying elements** to pushing all of society into action in terms of combating climate change highlighted a **low perception of climate change,** which remains ambiguous and must be supplemented by suitable means (training younger generations in particular). The question of modifying individual behaviour is still taking a back seat, the difficulty being that it means taking on a restrictive step without the foreseeable gains being perceptible in the short term. Nevertheless, beyond global policies, **lifestyle behaviours** may change easily, provided the adoption of a new lifestyle discipline goes from adaptation of one's way of life to a radical change. In order to engage a virtuous dynamic, it will be necessary to have identified the following elements :

- in order to change attitudes, we ought to have concrete arguments that correspond to the reality of the message recipients and to a vision of the future that they can share;
- anxiety could lead to flight behaviour or to avoiding facing reality;
- change on an individual level feeds and builds in parallel a chronicle, a collective history of this change. Intellectuals have a role in the construction and identification of reference groups, a powerful prism for change for the general public.

Define a coherent framework and order internal priorities for the implementation of international undertakings assuming a **clear policy involvement,** relayed and supported by the **major players in economic and community life.**

Conclusion and recommendations

The last few years have seen a growing consciousness develop with regard to the reality of climate change, following the catastrophic meteorological events that have occurred: the exceptional storms of December 1999, several periods of flooding and the drama of the 2003 heatwave. The Stern review and IPCC report in 2006 and 2007 and the awarding of the Nobel peace prize have also been contributing factors. The awareness of the French on this subject must be raised even more noticeably, in order to trigger a significant change in behaviour and the acceptance of the measures necessary for mitigation of or adaptation to climate change. The awareness raising of elected officials remains unequal as far as the reality of changes is concerned, and especially over the possibility of having an influence on these.

The evaluation of the costs of the impacts of climate change and adaptation on a national scale today represents a **true challenge** bearing in mind the uncertainty that affects climate projections and the quasi absence of evaluation methods. The lack or unavailability of data is also a restriction on quantifying impacts and adaptation. In this context, simplistic hypotheses have had to be used and some fields of study abandoned.

As, at this stage, the work carried out was not aimed at being exhaustive, some fields have not been tackled and must be the subject of special attention in future work. We would mention the following aspects in the first instance :

- town planning, port, river and rail sectors and industry;
- maritime sector, fishing and aquaculture;
- tertiary sector activities other than tourism;
- industrial sector activities other than energy;
- secondary effects of direct impacts (for example, the secondary effects of the loss of tourist income in regions for which this represents a major part of the activity);
- the distributional implication of climate change, as territories and social groups are not equal in the face of the impacts of climate change;
- propagation effects (migratory flows in particular): future works must come within a much wider framework than that of a France that is “isolated from the rest of the world”.

Overseas areas are particularly vulnerable to climate change because of their geographical locations, great biodiversity and socioeconomic systems with a population concentration in coastal areas in particular. The approach to climate change, its consequences and adaptation are different from those on the mainland. The quantitative assessment of impacts, vulnerabilities and adaptation measures is therefore a priority that involves improving knowledge of the changes to climatic parameters and their consequences in these areas.

The need for better knowledge is one of the main objectives for the next few years. This means :

1. Improving knowledge on climate changes, in particular for the hazards and parameters subject to major uncertainty, such as :

- the change in rainfall patterns;
- the rise in sea levels;
- highly localised climatic hazards, i.e. gravitational hazards;
- changes to sun and wind patterns;
- the consequences of climate change on the hydrological regime;
- changes to the main physico-chemical characteristics of marine habitats

2. Improve the characterisation of certain hazards – droughts or heatwaves for example – in terms of intensity and duration or even territorialisation.

3. Produce territorialised data, whether this is for hazards, models, climate scenarios or socio-economic development scenarios.

4. Improve the characterisation of uncertainty over the changes to the climate and the responses of natural and human systems to these changes.

5. Reposition climate change in the context of global changes.

6. Develop long-term socioeconomic scenarios on a French and territorialised **scale,** common to all sectors.

7. Improve the characterisation and quantification of non-goods impacts, especially for sectors such as biodiversity, health or forests that, by definition, mainly handle non-goods "items" and services.

8. Integrate the problems of adaptation and mitigation, by initiating research work aimed at better identifying the synergy and conflicts between these two approaches.

9. Improve understanding of the spontaneous adaptation behaviour of the different players: these partially govern the extent of the impacts of climate change for the sectors studied.

10. Start a discussion on the **feasibility and acceptability** of planned adaptation measures.

11. Carry out works on **adaptation costs,** little touched on here, on the junction between **the economic of uncertainty** and **long-term economics,** involving the availability of economic analysis tools for adaptation.

12. Work on the **inclusion of sectoral interactions:** precise characterisation, even modelling of these interactions; in order to take into account any transfer of vulnerability between sectors.

13. Continue a **multi-risk and multi-sector discussion** on adaptation.

14. Work on the "**distributional"** implications of climate change.

15. Work on the effects of **cross-border propagation.**

16. Produce the step on other scales, and in particular on that for local communities.

In general, it should be highlighted that the action levers in terms of adaptation are principally in the possession of local communities.

Without minimising the methodological-type difficulties encountered and the limits set out throughout this report, the message is clear: **climate change in mainland France will have a significant cost, which organised and considered adaptation may allow to be limited** and even, in certain cases, transformed into **opportunity.** The works presented in this report have produced concrete elements which enable the discussion on climate change, its impacts and the resulting costs to be set out. Despite the considerable uncertainties that remain, the results presented must serve to define public policies in terms of adaptation.

APPENDICES

APPENDIX I: French policy in terms of adaptation

The national adaptation strategy

The initial ONERC report to the Prime Minister and Parliament in June 2005 presented the main consequences of global warming in France and contained recommendations in terms of adaptation. This report enabled the definition of the national adaptation strategy, which was validated by the Interministerial Committee for the Sustainable Development on 13 November 2006. It is available on the ONERC website.

The national adaptation strategy, which aims at reducing our vulnerability to the consequences of climate change, considered the following principles for implementing adaptation:

- the concern about equity, which requires bringing together all communities and social and occupational categories likely to suffer the consequences of climate change;
- anticipating crisis situations, in as much as this will be possible;
- the fact that recourse to private or public insurance systems will not allow all situations to be responded to and may even delay required adaptation decisions;
- the fact that aid and subsidies must not end up causing situations with no solution to continue, but rather encourage change and economic diversification from a sustainable development perspective:
- concern over a link with mitigation;
- research for actions offering other advantages, outside of climate change.

Adaptation must be taken into account within all trades. Due to their crossover nature and the relationships they maintain with the economic, social and environmental sectors, we will firstly examine the following crossover approaches: water, hazards, health and biodiversity. Light will then be shed on the following economic activities: agriculture, energy and industry, transport, building and housing, and tourism.

Finally, adaptation must also be thought about in an integrated fashion, this time considering not only activity sectors taken individually, but the most relevant combination possible of sectoral policies within the “environments” selected because of their specific vulnerability: towns, the coast and the sea, the mountains, and the forests.

The national adaptation plan

The Minister of State, minister for Ecology, Energy, Sustainable Development and the Sea, responsible for Green Technologies and Climate Negotiations, presented a paper on climate change adaptation strategy on 13 February 2009 during the Council of Ministers. This paper insisted on the fact that it is necessary to prepare as of now our adaptation to the climate changes that will occur.

Planning Law 2009-967 of 3 August 2009 on implementing the Grenelle Environment Forum, provides, in Article 42 thereof, that a national adaptation plan for the various sectors of activity must be prepared by 2011. It will group together ambitious directions on subjects as varied as combating flooding and adapting coastal zones, changes to forests, the question of water and adapting the economy. The creation of this plan will form the object of a wide consultation that will be launched in the last quarter of 2009.

This plan will find its territorial variation in the “climate energy plans” that must be drawn up by departments, urban communities, conurbation committees, municipalities and municipality committees with more than 50,000 inhabitants before 2012, and in the future regional “energy air climate” plans proposed by the Bill on a national commitment for the environment, before parliament from September 2009.

The Law of 3 August also recommends, for the Overseas departments, regions and collectivities, the implementation of a local strategy for adapting to the impacts of climate change.

Community action

A national adaptation policy cannot be defined without the active participation of the territorial collectivities in addition to the State and the European Union, in accordance with a principle of subsidiarity. In fact, the actual impacts of climate change on a territory will be very strongly linked to local, socioeconomic, institutional and cultural characteristics, and its capacity to adapt even more so.

The 2004 climate plan recommended creating territorial climate plans. A certain number of collectivities have committed to creating these plans, especially at a regional level. The analysis of some fifteen regional and departmental climate plans shows that adaptation is barely tackled in these documents. In the main, proposals relate to strengthening knowledge and launching studies. Then follows communication actions. Only 3 plans have concrete measures aimed at the fields of water and forests. Adaptation remains a little acknowledged field and an effort in training and information must be strengthened.

The City of Paris[17] tackles the question of heatwaves in its White Paper, noting that "the behaviour of a building during a heatwave is today believed to be the main challenge in relation to adaptation, not only in terms of comfort, but above all for public health objectives". The responses suggested are of the nature: to protect glazing from direct solar radiation, insulate from the exterior and cool without encouraging air conditioning. This document urges the building professions to unite and coordinate themselves in order to propose suitable solutions. The Regions of Ile-de-France, Reunion, Provence, Alpes-Côte d'Azur and the Department of Martinique have in particular organised major conferences on the question of impacts and adaptation. Exhaustive studies have been carried out or are underway for several regions or collectivities: the Greater Southeast, the Loire, Rhône-Alpes, Lorraine, the North, Brittany, Basse Normandie, etc.
The MEDCIE study in the greater Southeast or the Lorraine study brings very interesting contributions in terms of methodology. Both suggest an approach per sector after having defined the framework of climate change in their territory and evaluated its impacts. These studies could serve as a model for other regions.

The various players brought together by the Grenelle Environment Forum focussed on the need to set up climate plans for the whole country. In addition, the planning law on implementing the Grenelle Environment Forum stipulates:

> *"The role of public authorities in the creation and implementation of sustainable improvement programmes must be strengthened. To this end, the State will encourage regions, departments and municipalities and their bodies with more than 50,000 inhabitants to establish, consistent with town planning documents, and after consultation with other competent authorities in terms of energy, transport and waste, territorial climate-energy plans before 2012"* (chapter II, article 7).

The bill on a national undertaking for the environment gives a compulsory nature to the drafting of territorial energy climate plans (PCET) by keeping the same completion date.

The PCET steps intend to create, depending on the challenges and local specifics, continuity between mitigation and adaptation. In fact, it is useless to reduce emissions if the parameters of an environment in complete upheaval are not integrated into territorial development strategies. This will mean connecting the adaptation and mitigation strategy with :

[17] City of Paris, 2007: White Paper - Contributions by Parisians to combating climate disturbances.

- the report on the impacts of climate change already observed in the territory, with their social consequences in particular;
- the analysis of the territory's vulnerability to future climatic events and its need to adapt.

In addition, the Grenelle 2 bill imposes regional diagrams for climate, air and energy, created jointly by the regions' Prefect and the President of the Regional Council. This co-drafting must be done within a very short period of one year from the publication of the Law.

In this provision, the principle of regional climate, air and energy diagrams is to strengthen the coherence of territorial action by giving territorial collectivities, responsible for the operational dimension, directions and a regional framework. In this respect, the diagrams will henceforth integrate in a single document the directions for combating the greenhouse effect and atmospheric pollution, for developing renewable energies, for promoting energy efficiency and for adapting to climate change. They incorporate the old provisions of the regional plans for air quality and regional wind-energy diagrams. They serve as a framework for the new territorial climate energy plans, which must be compatible with the regional climate, air and energy diagrams.

Within the framework of adaptation to climate change, the regional diagram may recommend coherent development with regard to the impacts on the water cycle: controlling flood risks, improving water quality, controlling draughts, preserving and restoring environments.

The creation of the diagram will also require mobilising territorial collectivities and all economic players in order to prepare suggestions for the adaptation strategy on a regional territory-wide scale.

Action at corporate level

Major businesses are also concerned by adaptation. The VEOLIA group has therefore set up a greenhouse gas watchdog, an informal structure that serves to feed discussion by various branches of the group and that closely follows progress in terms of adaptation. Within the energy field, EDF, GDF-Suez and RTE have participated in the work of the interministerial group on impacts and costs of climate change. The ViTeCC (Towns, Territories and Climate Change) club, created by the Loans Fund, Météo-France and ONERC, intends to be a place of mobilisation and exchange between institutions, the world of research, collectivities and companies, around combating climate change and adaptation.

APPENDIX II: Adaptation throughout the world

Adaptation within the United Nations Negotiations Framework

Initial measures

The United Nations Framework Convention on Climate Change (UNFCCC) constitutes the framework for international action to mitigate climate change and adapt to its impacts. The UNFCCC, adopted in 1992 in Rio, came into force in 1994 and currently counts 191 Parties (Member states). By signing this Convention, the Parties undertake to launch national strategies for adaptation to the impacts of climate change, and, for developed countries, to provide financial and technical support to developing countries.

The Convention makes reference to adaptation in several of its articles and in particular Article 4, which stipulates that States implement "measures aimed at easing suitable adaptation to climate change".

The first meetings of the Conference of the Parties (COP) were devoted above all to reducing greenhouse gas emissions in industrialised countries, with the aim of limiting climate change and minimising its effects. The capacity for adaptation was considered as being inherent to ecosystems and society and, therefore, not requiring explicit or voluntarist policies. Furthermore, adaptation was then considered as a defeatist recourse that reflected an inability to overcome the challenges of mitigation.

Over the years, the Supreme Authority of the Convention, namely the Conference of the Parties (COP), took several decisions in relation to adaptation. These decisions concerned the support and financing of developing countries by developed countries, in order to help them in terms of impact assessment, training, education and awareness raising, implementing concrete adaptation activities, promoting the transfer of technologies and sharing experiences through regional workshops.

The first significant progress on adaptation was recorded during the 7th Conference of the Parties in 2001. The COP acknowledged that developing countries would often be the most affected by the impacts of climate change and that they needed financial and technical support in order to assess their vulnerabilities and develop plans to adapt to these impacts. In particular, the COP created two special funds for supporting adaptation: the fund for less advanced countries and the special fund for climate change. These funds are aimed at financing the implementation of national adaptation programmes of action (NAPA) and projects linked to adaptation, the transfer of technology, energy management, agriculture and projects linked to economic diversification.

The parties also created the Kyoto protocol adaptation fund to finance concrete adaptation projects in developing countries. It is financed by a contribution of 2% of the proceeds from clean development mechanism projects that allow a State or a company to invest in an action to reduce greenhouse gas emissions in a developing country in exchange for a certain quantity of certified emission reduction units. These funds are managed by the adaptation fund advisory board, in which governments are represented in accordance with the regional distribution of the United Nations, with a majority of developing countries. The board must report directly to the Conference of the Parties.

Recent progress

In 2005, the Conference of the Parties defined a work programme, known as the Nairobi work programme, with two objectives:

- assist countries, especially developing countries, to improve their understanding and assessment of the impacts of and vulnerability to climate change;

• aid countries in taking decisions regarding practical adaptation actions and measures in order to respond to climate change on sound scientific, technical and socioeconomic bases, by taking into account current and future climate change and the climate variability.

This programme defined 9 work areas

1. Methods and tools
2. Data and observations
3. Climate modelling, scenarios and downscaling
4. Climate-related risks and extreme events
5. Socioeconomic information
6. Adaptation planning and practices
7. Research
8. Technologies for adaptation
9. Economic diversification.

The principle expected outcomes from the Nairobi work programme are: (1) Strengthened capacities at international, regional, national, sectoral and local levels in order to identify and understand impacts and vulnerability, and to select and implement practical, effective and high priority adaptation actions, (2) Improved information to advise the Conference of the Parties to the Climate Convention and its subsidiary bodies on the scientific, technical and socioeconomic aspects of impacts, vulnerability and adaptation, (3) Enhanced dissemination and use of knowledge and know-how relating to adaptation, (4) Enhanced cooperation between the Parties, key organisations, private players, civil society and decision-makers in order to improve their ability to manage climatic hazards, (5) Enhanced integration of actions to adapt to climate change with those aimed at achieving sustainable development goals.

During its 13th session in Bali in 2007, the Conference of the Parties adopted a decision known as the Bali Roadmap, which defines the calendar for a new negotiation process for tackling climate change and preparing the follow-up to the Kyoto protocol in the period after 2012. The Bali Roadmap also insisted on the need to improve action within the framework of adaptation and in particular providing financial resources, investments and technologies to support adaptation-related actions.

In order to implement this process, a subsidiary body was created under the Convention, known as the Ad-hoc Working Group on Long-Term Cooperative Action under the Convention (AWG-LCA). This Working Group met for the first time in Bangkok in April 2008. The Parties agreed a work programme that provided for negotiations of a period of two years in order to reach a long-term agreement. Given that the themes of mitigation and adaptation are closely linked, the Parties agreed to discuss the five principle elements – i.e. adaptation, mitigation, technology, finance and a shared vision for long-term cooperative action – in conjunction at every session. Furthermore, each session will tackle specific subjects related to each of these elements.

During the second meeting of this Working Group in June 2008, adaptation was examined in a workshop on “advancing adaptation through finance and technology”. At the end of these discussions, the questions were divided into four adaptation action categories, likely to constitute future lines of discussion :

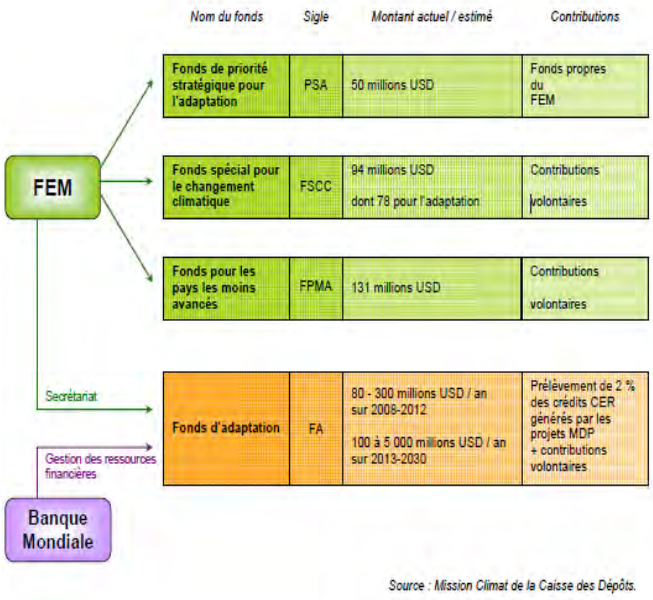
• national adaptation planning;
• rationalisation of the support process and an increase in financial and technological support;
• improved knowledge sharing;
• institutional frameworks for adaptation.

The agreement obtained in Poznan, during the 14th COP, gave the adaptation fund the legal capacity to be henceforth operational to finance adaptation projects in the most vulnerable countries. This fund will be financed in particular by the proceeds from carbon market auctions, the European Union having undertaken to provide 50% of the proceeds from quota auctions to combating climate change, of which a substantial part is for non-member countries. It reflects the European Union’s

financial commitment towards developing countries, without their contribution necessarily being secured, which is still subject to debate. Southern countries, future users of this fund, would in fact like to be able to count on proceeds taken from all the Kyoto protocol quota transaction mechanisms, and not just on the clean development mechanism tax, which concerns investments made by industries from the North in Southern countries, in exchange for CO_2 quotas.

Developing countries, and especially the less advanced countries, often the most vulnerable to the impacts of climate change, demand that the theme of adaptation benefit from the same attention as that of mitigation. Financing adaptation constitutes a crucial question for developing countries and will be one of the major subjects of discussion during the 15th Conference, which will take place in Copenhagen in December 2009. We should expect there to be no agreement with the developing countries if this point is not tackled in a satisfactory fashion.

In order for adaptation to be implemented by all players concerned, France would like the developed countries to undertake to financially support, in an appropriate manner, the institutions concerned (multilateral and bilateral, within the framework of the Climate Convention and beyond this), and to use the funds available through existing competent bodies, including the Kyoto Protocol Adaptation Fund, efficiently and in an optimised fashion.



Graph 4 – Adaptation finance mechanisms (Loans Fund Climate Mission)

Key:

Nom du fonds	*= Fund name*
Sigle	*= Acronym*
Montant actuel / estimé	*= Actual/estimated amount*
Fonds de priorité stratégique pour l'adaptation	*= Strategic priority adaptation fund*
50 millions USD	*= USD 50 million*
Fonds propres du FEM	*= GEF own funds*
FEM	*= GEF*
Fonds spécial pour le changement climatique	*= Special climate change fund*
94 millions USD dont 78 pour l'adaptation	*= USD 94 million, of which 78 for adaptation*
Contributions volontaires	*= Voluntary contributions*
Fonds pour les pays les moins avancés	*= Fund for the least advanced countries*
Secrétariat	*= Secretariat*
Fonds d'adaptation	*= Adaptation fund*
80 – 300 millions USD / an sur 2008-2012	*= USD 80-300 million/year over 2008-2012*
100 à 500 millions USD / an sur 2013-2030	*= USD 100-500 million/year over 2013-2030*
Prélèvement de 2 % des crédits CER générés par les projets MDP + contributions volontaires	*= Debit of 2% of the CER credits generated by CDM projects + voluntary contributions*

Gestion des ressources financières = *Financial resource management*
Banque Mondiale = *World Bank*
Source : Mission Climat de la Caisse des Dépôts = *Source: Loans Fund Climate Mission*

Adaptation in the European Union

Green Paper

In its COM (2005) 35 communication "Beating global climate change", issued in February 2005, the European Union devoted a chapter to adaptation and the need to invest in this for both developed and developing countries. The European Council asked the Commission to explore the role of the European Union in reducing vulnerability and promoting adaptation. To this end, the Commission set up a work programme, "European Climate Change Programme – Working Group II – Impacts and Adaptation", which has led to ten thematic meetings.

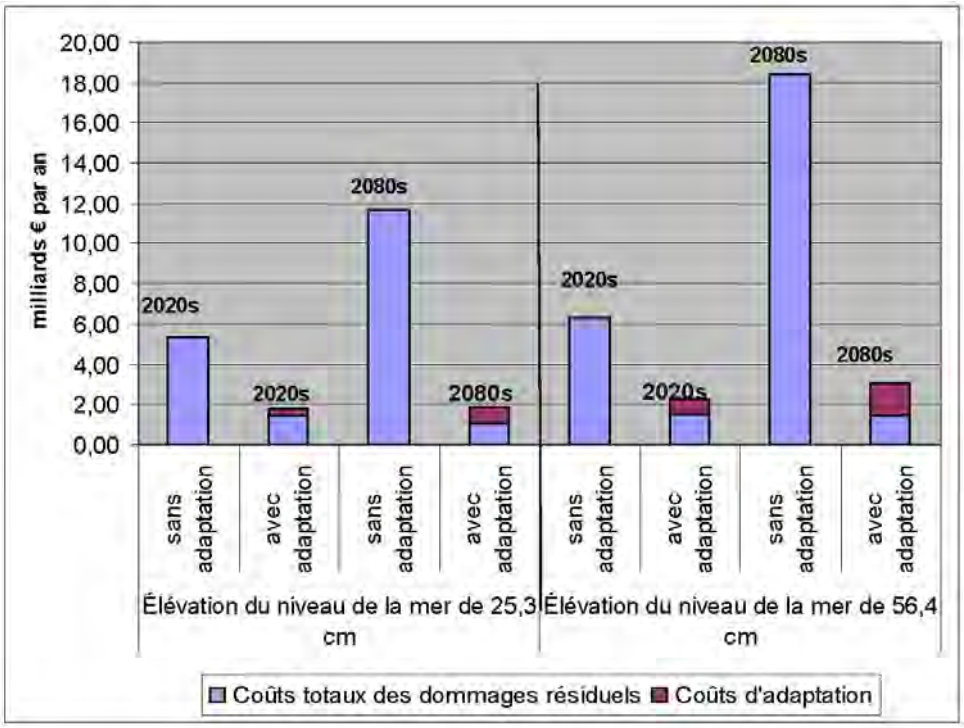
In 2007, the European Commission published a Green Paper on adapting to climate change, encouraging the participation of the Member States in defining the adaptation process and coordinating efforts to limit adaptation costs. This Green Paper confirmed that the impacts of climate change in Europe and the Arctic are already significant and measurable. Climate change will have serious consequences for Europe's natural environment and for practically every sector of society and the economy. Due to the non-linear nature of the impacts of climate change and the sensitivity of ecosystems, even small variations in temperature can have a considerable impact.

The Green Paper is based on the Stern review[18] on the economic aspects of climate change, which concluded that adaptation measures could reduce costs provided that a system was implemented with a view to removing obstacles to private action. It is improbable that the market mechanisms alone will enable efficient adaptation because of a certain degree of uncertainty in the climatic projections and a lack of financial resources. Efficient adaptation in terms of cost is therefore the most appropriate solution.

According to the initial estimates of the Stern review, in the event of an increase in the average global temperature of between 3 and 4°C, the additional costs of adapting infrastructures and buildings could already reach 1 to 10% of the total investment made in construction by the OECD countries. The additional expenditure to be undertaken to render new infrastructures and new buildings more resistant to climate change in the OECD countries could be between USD 15 and 150 billion each year (0.05 to 0.5% GDP). If nothing is done to prevent the rise in temperature reaching 5 to 6°C, the adaptation measures will probably see their costs increase sharply and, what's more, their relative efficiency decrease.

As the following figure taken from the Green Paper shows, the cost of damage caused by the rise in sea level, should the situation remain status quo, may be up to four times higher than the cost that would be borne if additional flood protection measures were installed. In the absence of any measures, the costs relating to damage will show a sharp increase from the 2020s up to the 2080s.

[18] http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm



Graph 5 – damage costs (EU Green Paper)

Key:

milliards € par an	*= EUR billions per year*
sans adaptation	*= without adaptation*
avec adaptation	*= with adaptation*
Élévation du niveau de la mer de 25,3 cm	*= Rise in sea level by 25.3 cm*
Élévation du niveau de la mer de 56,4 cm	*= Rise in sea level by 56.4 cm*
Coûts totaux des dommages résiduels	*= Total costs of residual damage*
Coûts d'adaptation	*= Adaptation costs*

The Green Paper recognised that, by acting quickly, we could draw undeniable economic benefits by anticipating potential damage and minimising the risks to ecosystems, human health, economic development, property and infrastructures. In addition, if they play a driving role in strategies and adaptation technologies, European companies could benefit from competitive advantages. This underlines the importance of possessing adequate knowledge of climate change timescales in order to establish priorities.

Noting that Europe would not be saved from the impacts of climate change, the Green Paper suggested targeting the action around four pillars:

- Integrating adaptation when implementing legislation and sectoral policies, as well as into existing community funding programmes
- Integrating adaptation in actions outside the Union
- Reducing uncertainty by expanding the knowledge base through integrated climate research
- Involving European society, companies and public sector in creating coordinated and global adaptation strategies

This document constitutes a superb summary of the problems posed by climate change and it considers relevant adaptation lines. However, France has stated several desires for improvement. Firstly, the analysis carried out seems to be both very general and simplistic regarding the nature of the impacts. The uncertainties relating to climate modelling and the large situational differences across Europe have not been taken sufficiently into account. Furthermore, the social consequences of climate change for Europe remain underdeveloped, possibly due to a lack of information on these issues. Questions specific to the outermost regions of Europe have not been tackled. This is a major hole in the document, because in addition to their specific vulnerabilities, these territories are a

window on Europe for neighbouring countries and may play a vital role in action outside the European Union.

White Paper

Following on from this Green Paper, the White Paper was published in April 2009. In this document, the commission justified several reasons for taking adaptation into account in European policies because while, due to regional variability and the seriousness of climatic impacts, most adaptation measures will be taken at a national, regional or local level, these measures may be based on and strengthened by an integrated and coordinated approach at community level. Furthermore, from an economic point of view, public action is indispensable to optimising the adaptation of climate change systems because autonomous adaptation, implemented on a private level, has no reason to allow this optimisation and some spontaneous actions by economic players are likely to lead to contradictory or even negative effects.
The White Paper confirmed that the “European Union has a particularly strong role to play when the impacts of climate change transcend national boundaries (for example, river and sea basins and biogeographic regions). Adaptation will require Member States to prove their mutual solidarity in order for disadvantaged regions and regions that will be the most seriously affected by climate change to be capable of taking the adaptation measures called for. Furthermore, coordinated European Union action will be necessary in certain sectors (such as agriculture, water, biodiversity, fishing and energy networks) that are closely integrated at EU level thanks to the single market and common policies".

The approach proposed by the White Paper would be implemented in two phases. The aim of the first phase, up to 2012, is to better understand the impacts of climate change and to examine possible adaptation measures and the way in which adaptation can be integrated into the main community policies. The Commission therefore plans to set up by 2011 a centre for exchanging information on the impacts of climate change. The second phase would consist in creating for 2013 a full community strategy for adaptation to climate change.

As France had requested following the Green Paper, the development of knowledge appears to be the prime objective. It is certain that the bases for this knowledge must still be strengthened in order to be able to provide regional indicators that could guide an efficient adaptation policy. The information exchange centre, the creation of which was proposed in this White Paper, would serve as an IT tool and database for the impacts of climate change, vulnerability and good practices within the field of adaptation. There are numerous scientific works of great value on impacts and adaptation, but they have been created from extremely varied hypotheses and therefore the barely uniform presentation could confuse the best will in the world. It is essential to better gather, structure and distribute scientific data likely to help States, territorial collectivities, companies and all interested players to study the adaptation measures they would like to take in the future. It is highly desirable to define a coherent technical framework for action, compatible with and linked to national and local frameworks.

Also recommended for 2011 is the definition of indicators allowing better control of the impacts of climate change, vulnerability and progress in terms of adaptation, advancement in perfecting methods, models and all the planning data and instruments, and finally, assessment of the costs and benefits of the adaptation options.

Last of all, it was proposed that the problems of adaptation be integrated in sectoral policies implemented at European Union level, for the following sectors: agriculture and sustainable development, industry and services, energy, transport, health, water and other natural resources, fishing and marine environments, ecosystems and biodiversity. It was also pointed out that a re-examination of the legal framework relating to competition could be justified in certain fields, in order to take into account the unequal impacts of climate change

in different activities. Finally, as some policies have already been implemented at European level, the European Union must play a coordinating and integrating role.
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The need to increase the strength of several sectors has been clearly highlighted: these are the sectors relating to health, agriculture and forests, biodiversity, ecosystems and water resources, coastal and marine areas, production systems and physical infrastructure; actions have been suggested in this regard.

Actions recommended by the European Commission White Paper

1- Build the knowledge base :

- take the measures necessary to create, for 2011, an information exchange centre;
- update methods, models and all prediction data and instruments for 2011;
- define for 2011 indicators allowing better control of the impacts of climate change, vulnerability and progress in terms of adaptation;
- assess the costs and advantages of adaptation options for 2011.

2- Reinforce the strength of health and social policies

3- Reinforce the strength of the agriculture and forest sectors

4- Reinforce the strength of biodiversity, ecosystems and water resources

5- Reinforce the strength of coastal and marine zones

6- Reinforce the strength of production systems and physical infrastructure

7- Finance :

- estimate the costs of adaptation in the political fields concerned so that these can be taken into consideration in future financial decisions;
- examine in greater detail the potential use of innovative finance measures with the goal of adaptation;
- study the possibilities for insurances and other financial products to supplement adaptation measures and operate as risk-sharing instruments;
- encourage Member States to use the EU ETS income for adaptation purposes;

8- Partnership between Member States :

- take the decision to establish, by 1 September 2009 at the latest, an “Impacts of climate change and adaptation” steering group for increasing cooperation in terms of adaptation;
- encourage the perfecting of national and regional adaptation strategies in the aim of rendering them compulsory, in order to provide for the adoption of compulsory strategies – as from 2012.

9- External dimension (UNFCCC)

- redouble efforts so that adaptation plays an integral role in all policies outside the EU;
- strengthen dialogue between partner countries on adaptation-related subjects;

advance the adaptation framework action within the UNFCCC framework.

In order to maintain cooperation in terms of adaptation and guide the progress of a European action framework, the Commission intends to create a steering group devoted to the impacts of climate change and adaptation. While France is very pleased with the strengthening of cooperation on this subject, it has put forward the idea of limiting this, initially, to a consultation group that could be widened to territorial collectivities, the first players in the field of adaptation.

Comparative view of National Adaptation Strategies in Europe

Up until 2006, only three European countries (Finland, France and Spain) had formally adopted a national adaptation strategy (NAS); no less than five new strategies have been adopted between

2007 and 2008 (Denmark, Germany, Hungary, the Netherlands and the United Kingdom) and this dynamic is continuing.

Most of the European countries who still do not have their strategy are planning its impending creation, and several States have already programmed the next phase, i.e. national adaptation plans (NAP), for the period 2010-2011.

As highlighted in the previous section, the White Paper on adaptation encourages this dynamic by calling for a community adaptation strategy to be put in place for 2013.

The Partnership for European Environmental Research (PEER[19]) recently published a comparative study of adaptation strategies in ten European States: Denmark, Finland, France, Germany, Latvia, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. The study aimed at identifying the lines of force for current strategies, points to be strengthened and successful experiences that could inspire non-member States[20]. A summarised review of this analysis is given below.

Subject spotlight No. 1: Science/policy interaction in support of NAS

Cooperation between science and policy in the adaptation sector has rapidly increased over the last 10 years. However, it is still not reached the scope of that in relation to mitigation.
The specific nature of research into adaptation must combine pure research into processes with more applied research based on concrete adaptation experiences that have already been tried or are to be tried at a local level.

Several European countries have launched ambitious programmes for applied research into adaptation (this list is not exhaustive) :

- Germany has set aside EUR 75 million for the study of impacts and adaptation at regional level;
- the Netherlands are consecrating EUR 100 million between 2004-2011 for research into town and country planning in the face of climate change. 50 million has also been programmed for adaptation of "strategic national key points", co-financed by the private sector (airports, ports, etc.);
- the United Kingdom recently announced a global budget of EUR 1 billion for research into combating climate change, including both adaptation and mitigation[21].

Subject spotlight No. 2: Communication and awareness raising in NAS

The current communication campaigns relating to climate change are focussed above all on mitigation and energy savings. Few information or awareness raising campaigns have been run in Europe in relation to adaptation. Only four countries from those assessed by PEER have developed or planned a communication strategy structured around adaptation to climate change (Finland, Germany, the Netherlands and the United Kingdom).

While most of the countries have their own web-sites relating to the question of adaptation to climate change and adaptation strategy, the British portal, developed by the UKCIP[22] programme is

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[19] *PEER is a partnership between seven European environmental research centres. CEMAGREF is part of this. For further details on PEER, visit* www.peer.eu

[20] *Swart R. & al. (2009). "Europe adapts to Climate Change: comparing national adaptation strategies", PEER report No. 1, Helsinki, 280 pp. The summary made here by ONERC has been approved by PEER network authors.*

[21] *For reference, over the last few years France has devoted comparable budgets of around EUR 10 million/year to research into the impacts of climate change. Nevertheless, these funds were principally directed to the assessment of vulnerability and impacts, and not specifically to effective adaptation or dire regional applications.*

[22] *United Kingdom Climate Impact Programme* www.ukcip.org.uk*. Contrary to its title, this programme goes well beyond the question of the impacts of climate change. It plays the role of*

considered as a benchmark. In addition to purely informative aspects, it offers free access to a range of on-line tools for the various players involved in adaptation (public, local elected representatives, companies, authorities) in order to enable them to plan their own adaptation strategy. Several countries wanting to put tools on line to help with adaptation are drawing inspiration from the UKCIP model (Finland, Germany).
In most States, information on the impacts of and adaptation to climate change is centralised. On the other hand, France and Portugal have information spread over various sites, particularly by sectoral topic. The PEER report does not, however, identify tools to measure the performance of this communication to the public.

Subject spotlight No. 3: Governance of national adaptation strategies

We can see three forms of governance adopted by NAS:

- in Finland, the strategy was developed at national level, while implementation of adaptation actions will be delegated at regional level;
- in the United Kingdom, the local level is the front line for defining a strategy suitable for the country. The national level ensures that suitable tools and a suitable institutional environment are made available, checks the implementation of adaptation at local level and ensures coordination/arbitration in the case of regional differences;
- Germany and France have taken the approach of widened consultation with players at sub-national levels, which has led to the definition of a global strategy.

Nevertheless, the exact division of roles between the national and local scales is not clearly defined in the existing strategies and could be greatly perfected. At this time, only the United Kingdom and Denmark have clearly distributed tasks and responsibilities. We could cite the British case here, where local frameworks for the governance of performance measurement, supervised by the Government, have since 2008 included an indicator relating to the implementation of actions for adaptation to climate change.

In terms of strategy financing, none of the ten States reviewed have concretely drawn up the finance method for its strategy and the implementation of adaptation measures. The breakdown of the costs of adaptation and the control of the funds allocated across the various levels of governance therefore still remains outstanding.

Subject spotlight No. 4: Integrating climate change into sectoral policies

Integration into sectoral policies basically presents two advantages:

- it permits assurance that each sector takes this dimension into account, which contributes to sustainable development policies;
- it enables identification of synergies and sticking points to be raised, in a generally efficient way.

The PEER review considers, however, that none of the current strategies allow real crossover integration of adaptation into these policies. The report recommends that this question be clearly addressed in future adaptation plans and that monitoring and evaluation matrices are associated with this integration.

Subject spotlight No. 5: Implementation and review of national adaptation strategies

Very few NAS have an effective review and evaluation system. Most of these strategies do not have an established monitoring framework or precise indicators to follow, and rarely have established agendas for periodic reviews. This observation would be particularly related to the fact that research and knowledge have still not sufficiently clarified the field of adaptation monitoring and evaluation.

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both a technical resource centre and a bridge between players, in order to facilitate the development of local to national level adaptation actions.

This is a major challenge for the future implementation of adaptation plans, in order to enable a periodic review of their achievements and a relevant update to their objectives.

Common points

The report underlined a certain number of common points between the various NAS.

They have similar aims and structures: these are document analysing vulnerability, formulating recommendations on the directions to be favoured, and announcing a future planning and implementation stage. The strategies all state the need for spatial research on vulnerabilities and improved scientific knowledge in order to allow the planning phase to begin. Research and analyses in the field of adaptation are still few in number compared to those for mitigation and, in most countries, the dynamic of the NAS has been more rapid than that for the production of knowledge.
A second common point concerns the low level at which the international factor has been taken into account. NAS are extremely centred on actions in their own country with little mention of the dynamics and undertakings outside their borders. Thus, only Germany has made the international issue a structural theme in its strategy, with concrete directions, in particular in its policy for aiding development.

Finally, a last major common point is the responsibility at national and interministerial level for creating the NAS. The governments of the European countries reviewed are steering or have steered the NAS creation process in an internalised fashion, with the exception of Portugal, which assigned a private operator for this purpose.

Some specifics from national approaches

Three types of approach can be distinguished:

- top-down strategies dividing all the tasks and responsibilities (Finland for example);
- collaborative strategies calling for consultation and subsidiarity in the definition of actions and tasks (France and Spain in particular);
- strategies coordinating initially disjointed sectoral approaches (United Kingdom);

Of course, the priorities of the strategies vary depending on the different States, taking into account the conditions specific to each country, but often based on the experiences of major hazards already suffered and that may become more frequent in the future. In spite of this diversity relating to national and regional specifics, it appears to draw distinct geographical sensitivities between the North and South of Europe.

- Northern countries often have lines structured around the problems of flooding and land slippage (the Netherlands, Sweden), whereas in more southerly countries the central questions are heatwaves and water availability (Spain and France);
- While not being an absolute rule, the report highlights that if the analysis of impacts is almost systematically negative in general in the southern countries, the strategies of the northern countries can identify more climate change-related opportunities.

This potential North/South Europe dichotomy implicitly refers to the different trends modelled for the future climate. If, for example, we take the case for agriculture, the drop in the climatic harshness in the North of Europe is considered as bringing new potential for crops. In the South of Europe, in contrast, the projected increase in water deficits leads to a pessimistic outlook.
Lastly, the report commented that not all NAS had a well identified monitoring-assessment and periodic review system. Therefore, with the exception of Germany, the Netherlands and the United Kingdom, no formal mechanism had been put in place to assess the implementation and repeated re-frameworking necessary for the strategies adopted. This aspect could, however, be compensated for during the creation of adaptation plans.

The major recommendations of the PEER report

In addition to comparative analysis, the report concluded by a series of recommendations to decision-makers. The follows a summary of some of the key recommendations for the “knowledge”, “implementation” and “coordination” fields:

Knowledge-related recommendations

(i) develop information more suited to a local level;
(ii) develop studies on the costs of inaction and adaptation, mapping climatic vulnerability and uniform evaluation methodologies in order to have a cost comparison at a transnational and European level;
(iii) establish practical knowledge databases on adaptation (often of local origin) and share experiences beyond national borders.

Implementation-related recommendations

(iv) develop and coordinate exchanges of experience and practice-orientated tools;
(v) provide for the legal mechanisms that can push adaptation to be taken into account (performance indicators for institutions, etc.);
(vi) encourage the development of “Strategic regional points of interest” that may serve as a laboratory for the concrete implementation of adaptation actions;
(vii) compare sectoral adaptation strategies regularly in order to have good practices become visible and to complete technical inventories for adaptation.

Coordination-related recommendations

(viii) consider the international question as an integral part of national action strategies and plans;
(ix) refine the governance of adaptation: sharing of responsibilities and visibility of financial resources;
(x) name “adaptation” focal points in the governance structures in order to make the climate change integration process easier for sectoral policies;
(xi) strengthen dialogues between policy and research in order to develop bodies that can respond scientifically to policy questions.

Table X: Recapitulative matrix of the ten national strategies reviewed by PEER (adapted from PEER)

	Policy commitment	**Science/policy interface**	**Communication strategy**	**Governance**	**Sectoral policy integration**	**Monitoring, evaluation and review**
Germany						
Denmark						
Spain						
Finland						
France						
the Netherlands						
the United Kingdom						
Countries without a formalised strategy as yet						
Portugal						
Latvia						

1 Key						
	Strong political commitment and broad stakeholder involvement	Research programmes for adaptation and well-organised science/policy interface	Formalised communication strategy and reference information portals on adaptation	Formalised multi-level governance and coordination for adaptation measures in place	Adaptation measures integrated into most sectoral policies	Formalised strategy monitoring and review mechanisms
	Significant political commitment and involvement by several stakeholders	Some research programmes for adaptation and partially organised science/policy interface	Informal communication strategy and information portals exist on CLIMATE CHANGE	Formalised multi-level governance and coordination for planned adaptation measures	Adaptation measures partially integrated into sectoral policies	Informal strategy monitoring and review mechanisms
	Limited political and stakeholder commitment	No science/policy interface	No communication or information portals	Multi-level governance and coordination for informal adaptation measures	Integration of adaptation measures into sectoral policies is an exception	No strategy monitoring and review mechanisms

Some examples of international level strategies

In addition to the comparative vision created by PEER's work, it is of interest to examine the specifics, choices made and adaptation measures planned in the various international level strategies.

Germany

Kompass
KomPass is the specialised centre for diffusing knowledge on climate change (bulletins, conferences, workshops) that is suited to non-experts. It carries out a support-advisory role with government agencies, coordinates research activities and leads an expertise network.
KomPass is currently involved in the spatial planning of vulnerability, tools to help decision making within companies and municipalities, defining adaptation indicators and water sector strategies.
Its next works will concentrate on (i) the development of cost-benefit analyses for adaptation, (ii) global assessments of adaptation levels, and (iii) the analysis of different concrete adaptation measures.

A study of scale was carried out in 2005 in order to identify the vulnerabilities of each region of the country. The main conclusions drawn related to:

- The need to adapt buildings to the increase in temperatures;
- The need to prepare for more substantial flooding in winter and spring;
- The tension over water resources for agriculture and cooling power stations;
- Optimising the agricultural factor: even if some already dry regions will be very negatively affected by climate change, the adoption of new agricultural practices must enable something to be drawn from this change;
- The forest sector must, at least initially, draw benefits from global warming;
- Biodiversity will be strongly impacted, especially in alpine formations;
- Coastal states could be severely affected by the rise in sea level.

Germany adopted its NAS in December 2008. The document sets out reference national climate scenarios, identified sectoral impacts, priority lines of adaptation, remaining scientific uncertainties and several examples of adaptation measures.
In addition to these general approaches, the strategy contains concrete undertakings by the Federal Government:

- all international cooperation actions will be systematically subjected to "climate checking" in order to verify their strength and their suitability to combat climate change;
- an interministerial group will be created to draw up an NAP for April 2011. The structure of the NAP has so far been decided on;
- the strategy provides for the development of a climate change monitoring system and adaptation-specific monitoring indicators as from 2009;
- the Federal Government is encouraging the local level to define concrete adaptation measures, but will set up a tool box based on the UKCIP model for companies, organisations and local authorities;
- a scientific support programme for regions in order to enable them to define their adaptation actions (KLIMZUNG) will be financed to the amount of EUR 75M;
- a climatic risk mapping system will be put on line;
- communication actions regarding adaptation will be implemented with multimedia support;
- the Kompass agency will continue its work in making knowledge available for public and private action. A scientific resources centre has been created in order to ensure a watch and scientific communication on the developments in climate sciences;

- an execution level review of the NAP will be carried out in 2013.

The governance of the NAP is still not clearly specified at this stage. The general idea is that the local level will build its strategies, the national level focussing on coordinating these strategies, additional scientific or financial support, advice and steering national level actions. Regular consultation cycles between the Ministry for the Environment and the States in relation to the question of adaptation are already happening and will be deepened.

German adaptation plan

In 2011, the working group responsible for defining the plan will submit its report, organised as follows :

(i) principles and criteria for defining and evaluating adaptation actions;
(ii) list of priority measures from a national point of view;
(iii) overview of measures implemented by other players;
(iv) information on finance methods;
(v) monitoring and evaluation of adaptation actions undertaken;
(vi) follow-ups to be made to the NAP and the next steps.

The Netherlands

The Netherlands is without doubt one of the countries the most vulnerable to climate change in Europe: 1/3 of its territory is below sea level and another third is extremely sensitive to flooding.
After having validated its strategy in 2007, the Netherlands undertook a series of regional consultations in order to define suitable territorial policies: these consultations must lead by the end of the year 2009 to a national adaptation agenda. The current strategy places great emphasis on town and country planning against the risks from rising sea levels and floods, with an engineering approach.

In parallel, a specific commission entitled “Commission Delta”, the mission of which was to define how to render the country climate-proof in 2050, 2100 and 2200, was created in 2008. This commission proposed the creation of an Adaptation Law setting adaptation objectives and tasks, an Adaptation Director who would ensure implementation and correct fund management, and finally, an Adaptation fund with an annual secured budget of EUR 1 to 1.3 billion/year. In relation to the technical aspects, the commission concretely proposed :

(i) redefining the scale for flooding;
(ii) redefining urban planning programmes;
(iii) differentiated adaptation measures in accordance with precise territorial division (additional sedimentation, protection barriers, delimiting flood plains for torrents, diverting water courses, freshwater reservoirs, leaving natural processes alone).

Funds for the research into combating climate change have been provided over a period of 7 years (EUR 100 million), a mixed public and private fund of EUR 100 million aimed a rendering 8 strategic national points of interest (hotspots), such as Amsterdam airport and the port of Rotterdam, climate-proof.

At regional level, the planning process is making the regions take responsibility. All town and country planning and regional development must be “climate-proof”. The Netherlands also plans to modify their pre-project environmental impact assessment standards, their law on water and their law on national building standards in order to make it compulsory *de facto* for the inclusion of the climate change perspective.

Spain

The Spanish NAS was validated in 2006 following wide regional consultation. The adaptation strategy approaches are given at national level and the autonomous regions are then responsible for precisely defining the adaptation measures in their territory.

The Spanish agency for climate change (OECC) coordinates the implementation of the strategy, distributes useful information for implementing adaptation and leads long-term research programmes along priority lines.

Over the period 2006-2009, the OECC focussed on the production of regionalised climate scenarios and the evaluation of the impacts on water resources, biodiversity and coastlines. For the period 2009-2012, the working lines will be: (i) analysis of impacts and adaptation scenarios on around ten key sectors, (ii) integration of adaptation into sectoral policies, (iii) mobilisation of and awareness raising in stakeholders and (iv) creation of a database of indicators for the impacts of and adaptation to climate change.

Implementation of adaptation plans is extremely decentralised at autonomous region level.

United Kingdom

The British NAS was adopted in July 2008. It aims at coordinating long-term activities that are underway. In fact, the UKCIP programme, established in 1997 and initially focussed on impacts, coordinates research into the impacts of climate change, develops economic analyses of the impact, organises information workshops and provides scientific, technical and methodological support for defining adaptation strategies.

The NAS is based along 4 major lines: (i) improving knowledge on the impacts of climate change on the United Kingdom; (ii) raising players' awareness of the need to take adaptation measures; (iii) developing a monitoring system and specific indicators for adaptation and (iv) working towards integrating climate change into public policies.

The Climate Change Bill adopted in 2008 obliges the Government to develop a national adaptation programme to remedy the impacts of climate change on the basis of a national climatic risk assessment. The national adaptation plan must be in place in 2012 and will be audited on a five-yearly basis.
This bill also gives the Government the right to demand local governments, public entities and purveyors of public services and major general interest groups to draw up a statement on their vulnerability to climate change and develop an action plan to combat this.

Very active in terms of research and tools production, the United Kingdom orientated itself very early on towards raising awareness at local level, in particular via the development of cost-benefit studies. The UKCIP programme has also invested in designing didactic tools enabling various institutional and private players to define their own adaptation strategies. The global approach to adaptation is bottom-up, which explains why the strategy only emerged in 2008: the NAS seeks to encompass current actions rather than imposing steps.

At regional level, bodies known formally as “Regional Climate Change Partnerships” have been set up. These entities, which bring together public and private stakeholders, work in collaboration with the UKCIP programme to evaluate the impacts and adaptation measures specific to their territory, and to share experiences and knowledge at regional and national level.
At local level, the question of adaptation has already seen several concrete developments. For some coastal zones subject to erosion, strategic withdrawal choices have been carried out and debates are underway in other territories. Conurbation groupings in the London region have set up a working group on impacts and adaptation. London has produced its own adaptation strategy. An indicator related to taking adaptation into account has been introduced by the central Government within the framework of local government performance.

In 2008, a global fund of EUR 1 billion over five years was announced in support of the research into combating climate change.

United States

As yet there is no US federal strategy for adaptation to climate change.
In June 2009, a detailed report on climate change and its sectoral impacts was, however, published by the White House[23]. This document, presented as a reference document for the Administration, calls for an acknowledgement of the need for rapid and widespread action against climate change, combining mitigation and adaptation.
The report nevertheless stands out as an illustration of several strategic adaptation choices already undertaken in the country. We will therefore consider some very concrete examples:

- City of New York: study of the vulnerability of strategic installations in the city to the rise in sea level, renovation of the drainage systems taking into account the climate change variable;
- Louisiana: raising of a coastal road and a bridge in order to resist the most intense submersion episodes;

Recommendations of the California adaptation strategy

1. Creation of a group of consultation experts on the climate in order to assess the major risks from climate change and propose adaptation measures by December 2010;
2. Reduce fresh water consumption by 20% across all sectors;
3. Redefine construction projects that could be affected by floods or the rise in sea level in relation to climate change;
4. State agencies responsible for public health, infrastructures and habitat must implement adaptation plans by September 2010;
5. All major State projects must consider the impact of climate change;
6. Set up a web portal to promote adaptation and mitigation. It will contain interactive maps of scenarios and impacts modelled for California;
7. The impact on Californian biodiversity will be assessed and proposals for the adaptation or modification of practices made;
8. Recommendations to local Public Health structures will be produced by September 2010 in order to allow the implementation of adaptation and mitigation plans;
9. Municipal development plans must be reviewed with regard to the climate change restriction;
10. Fire fighting services must consider the climate change dynamic in their strategic programmes;
11. State agencies will encourage energy saving and increase the stock of renewable energies;
12. Current research into climate change must be called upon and highlighted for planning and public use.

- Philadelphia: establishment of a heatwave plan and grant for insulation against heat for vulnerable citizens;
- East Coast islands: prohibition on the construction of protective walls on properties to prevent the rise in sea level. Priority is given to the migration of ecosystems;

This local dynamic will find a new echo in the publication in August 2009 of a climate change adaptation strategy for the State of California[24]. On the basis of an estimate of the direct costs of climate change by the University of Berkeley (see box X), climate change could cost California several tens of billions of dollars per year.

[23] *T.R. Karl & al. (2009) "Global Climate Change Impacts in the United States", US Global Change Research Programme, Cambridge University Press, 193 pp.*

[24] *California Natural Resources Agency (2009) "California Climate Adaptation strategy – Public review draft", Report to the Governor of the State of California, 3 August 2009, 161 pp.*

Australia

In 2007, Australia adopted a climate change adaptation action framework that set two objectives over seven years:

- Create a national adaptation capacity (Specialised research on impacts and adaptation for advising decision-makers, communication on regional impacts, making information and tools available);
- Reduce sectoral and regional impacts (impact evaluation, development of sectoral action plans at horizon 2010 and increasing knowledge over the period 2007-2014).

The national programme, which facilitates the implementation of this long-term adaptation framework, frequently puts tools and regional climatic projections on line. This site plays the role of a reference site in combating climate change on a national level.

The implementation of adaptation actions is provided for in accordance with the principle of subsidarity. The State provides support and knowledge to assist local governments in defining and planning their adaptation actions.

In 2009, an adaptation guide was published for local governments. According to a sectoral check-list approach, it recommends actions to be implemented in view of the expected climate changes. Illustrations of existing experiences are given as examples for some measures. Nevertheless, there is no recommendation for concrete action: it has been left to the local level to define its own means of adaptation. By way of illustration, the guide sets out a list of several case studies:

- the town of Melville has developed a list of requirements so that public investments or residential extensions will enable energy and water savings;
- the town of Clarence has assessed the fixed assets that will be exposed to the effects of a rise in sea level. For each asset at risk, various adaptation options are suggested to its constituents. The town is currently invested in adding sediment to the beaches, raising coastal roads, coastal reforestation and the development of new water treatment stations;
- the coastal strategy of the state of Victoria predicts that new constructions in zones that may be affected by the rise in sea level will not benefit from any protective measures.

All the communications on good practices and adaptation to climate change are categorised under the same label, “ThinkChange”, the Government’s integrated communication strategy.

APPENDIX III: Observatory activities in 2007, 2008 and 2009

Administrative organisation

In October 2007, ONERC joined the offices of the Ministry of Ecology, Energy, Sustainable Development and the Sea, to which it has been responsible since 2004.
By the Decree of 9 July 2008 on the reorganisation of the ministry's central administration, ONERC was attached to the *Direction Générale de l'Energie et du Climat* (DGEC = General Department for Energy and the Climate), the director of which, Pierre Franck Chevet, also runs the Observatory. Within the Department for Combating the Greenhouse Effect, the observatory constitutes the centre for adaptation to climate change. All the ministry's departments are now grouped together at La Défense.
Two officers have been assigned to ONERC within its activities on adaptation, therefore bringing its staff to 5. Marc Gillet, General Secretary, was replaced by Nicolas Bériot in September 2009.

Indicator database and organisation of network of experts

Via the network formed with the scientific and operational bodies concerned, some indicators have been developed for presentation on the ONERC website: http://onerc.gouv.fr. These indicators number 23, of which 12 were put on line since the last ONERC report in 2007. They are available to the public, in graphic and digital format, and can be used by everyone.
In order to supplement the indicators relating to living organisms, a study was entrusted to the Bird Protection League, which ended at the beginning of 2008.
ONERC is endeavouring to present indicators relating to every field likely to be influenced by climate change, and for that is basing itself on the support of a network of experts in their specific sphere of competence.
A seminar was organised on 5 February 2008 in the offices of the *Centre National d'Etudes Spatiales* (CNES – National Centre for Spatial Studies) in Paris, in which 48 people took part, mainly from the field of research. The seminar mainly aimed to develop exchanges between ONERC members working on indicators and to explore new fields where indicators could be envisaged, for example, forests, hydrology and socioeconomic aspects.
The participants judged it important to distinguish the indicators by type, and to accompany them by a text explaining their motives and placing them at a European and worldwide level. Their educational role was also underlined on several occasions. The diversification of indicators towards socioeconomic aspects or fields that are physically too-little explored, must be encouraged.

Following the cease of activity by GIP Medias-France, Atema Conseil, together with Météo France and Thalix, is providing the technical monitoring of ONERC's activities, including the organisation of the network of experts.

List of indicators:
1. Average air temperatures on the mainland,
2. Number of summer days on the mainland,
3. Number of freezing days on the mainland,
4. Winters at the Porte pass (Charteuse-Isère massif),
5. Breakdown of the mass of temperate glaciers in the French Alps,
6. Breakdown of the mass of the Ossoue glacier (Vignemale-French Pyrenees massif),
7. Sea surface temperatures in the Overseas Departments and Collectivities,
8. Tidal sea level,
9. Air temperature in the French departments in America,
10. Ocean colour – Concentration of chlorophyll a

11. Sea surface temperature by high resolution remote sensing,
12. St Emilion harvest dates
13. Southern Côtes du Rhône harvest dates,
14. Champagne flowering and harvest dates,
15. Stages of vine development in Alsace,
16. Fruit tree flowering dates,
17. Pine processionary caterpillar spread front,
18. Exposure of populations to natural hazard,
19. Sea surface salinity in the Overseas Departments and Collectivities,
20. Torrential rainfall in the southeast Mediterranean,
21. Changes to crop practices (wheat and maize),
22. Climatic restrictions,
23. Changes to the populations of certain bird species.

Travelling exhibition

The ONERC travelling exhibition has been presented some thirty or so times in 2007, 2008 and the beginning of 2009. It comprises panels tackling the following themes:

- observations,
- monitoring and simulation
- consequences in all fields
- water resources
- health
- biodiversity
- agriculture
- the sea
- the forest
- the mountains
- towns

This exhibition has been updated with the addition of two new panels, thus bringing the total number of panels to 13:
Can we simulate the climate of the future? This explains the possibilities and limits of digital climate modelling
The risks of climate destabilisation: presenting the main mechanisms that are still little-known, but which may be likely to rapidly and severely worsen climate change: melting of permafrost, release of clathrates, slowing of the Gulf Stream, Amazonian deforestation.

The ONERC letter

At the request of its streaming committee, Onerc has begun writing a quarterly newsletter and sending this to a large number of local elected representatives (7,000 copies, 3 times a year), in order to inform them on the reality of global warming, introduce a positive discussion on adaptation and make the works of ONERC known. An editorial committee has set the approach for the letter, which will contain accounts of local actions, a themed dossier and a celebrity opinion. The first edition was distributed in June 2009. The second, in September 2009, tackled the subject of the sea, following the Grenelle Sea Consultation. The letter is available on the ONERC website.

“The Islands and the European Union: Strategies tackling climate change and the loss of biodiversity” conference

Taking the position that the European overseas territories are directly concerned in all their diversity (whether this is in the islands, tropical zones or polar regions) by the climatic threat and the risks of the disappearance or erosion of biodiversity, ONERC and the Regional Council for Reunion jointly agreed to subscribe to the IUCN (International Union for the Conservation of Nature

and Natural Resources) initiative to organise an international conference, on Reunion from 7 to 11 July 2008, gathering together all the European ORs (Outermost Regions) and the PTOM (Overseas Countries and Territories), as well as the Small Island Developing States (SIDS) of the Caribbean, Pacific and Indian Ocean zone, tackling the dual problem of biodiversity and climate change.
This conference comes within the framework of the cooperation agreement between France and the IUCN. It was entered into the official agenda for the French Presidency of the European Union, at the request of the Ministry of the Interior, Overseas and Territorial Collectivities (MIOMCT).
This event was also recorded in the targeted actions under the memorandum of understanding of 22 February 2007, signed at Saint-Denis de la Reunion, between ONERC and the Regional Council, within the framework of approaches taken by the collectivity in relation to climate change and biodiversity. Lastly, it figures in the Region's contributions to the Grenelle Environment Forum.
Aiming at strengthening the mobilisation of decision-makers and players at local, national, European and worldwide level, this conference must lead, on one hand, to a long-term themed initiative, particularly within the framework of the IUCN's 2009-2012 programme, and on the other to the implementation of a true European policy objective on the ecological challenges for European overseas territories, especially climate change and the loss of biodiversity.
This report is available at the following website: http://www.reunion2008.eu/pages/fr/fr-publication.html

Actions towards collectivities and economic agents

The observatory has contributed to various seminars, meetings and information or training sessions organised by territorial collectivities. It has invested in particular in several actions, as set out below.

The ClimChalp project

ONERC participated in the European Commission Regional Office's ClimChAlp project, in conjunction with 22 public institutions from seven Alpine countries, and in particular the Grenoble Centre for Natural Hazards from the Rhône-Alp Region. The aim of the project was to evaluate the consequences of climate change on the Alps.

Mountain environments are areas that are particularly sensitive to climatic variations. Changes to biodiversity, melting of permafrost, and development of natural hazards are some of the possible impacts of climate change. The assessment of global warming and its impacts in mountain areas constitutes a challenge both in its uncertainties and in the sensitive nature of these environments. This issue is therefore forced on managers – decision-makers and technicians – both in the conduct of the short-term actions and in the choice of strategic planning approaches and land management. The pamphlet entitled "climate change and natural hazards: what are the trends in the Alps?" was widely distributed in the region and beyond in 2008.

ONERC published a technical report outlining the summary created by the French ClimChalp project partners, which offers a common knowledge base on climate changes and their impacts in the Alps.

The ViTeCC club

The ViTeCC (Towns, territories and climate change) club was launched in 2008 on the initiative of the Consignments and Loans Fund (CDC) Climate Mission, following the conference on adaptation to climate change held in the presence of Dr Pachauri, President of the IPCC (Intergovernmental Panel on Climate Change), which won the Nobel Peace Price in 2007 jointly with Al Gore. ONERC

is one of the club's co-founders, alongside the CDC and Météo-France, and represents the MEEDDM therein. The ViTeCC club today unites more than 20 local and regional collectivities and service companies. This initiative comes under the international programme on research into the development of economic instruments enabling local players to find innovative responses suited to the challenges of climate change.

The contributions expected of the ViTeCC club are:

- pooling of first-hand information on the economics of climate change, in conjunction with recognised experts, rendering this comprehensible and useable for territorial decision-makers;
- development of tools to aid decisions related to financing the reduction of emissions and the management of urban infrastructures adapted to the climatic hazards of tomorrow;
- access to a network that enables members to interact, be informed of what is happening in the world in the field of carbon savings and to exchange innovative pilot experiences from France and abroad.

Five meetings were held in 2008 and the beginning of 2009:

- 27 June 2008 in Paris: Energy networks in the face of natural hazards
- 13 October 2008 in Marseilles: Climate change and flood risks
- 17 December 2008 in Paris: Territorial action and international climate negotiations
- 24 March in Nantes: Energy-CO_2 performance and Building adaptability
- 23 June 2009 in Paris: Integration of Territorial Collectivities into International Processes on Climate Change

Information on the club and minutes of the meetings are available on the web at the following address: http://www.aprec.fr/vitecc.php

Participation in IPCC works

ONERC is a partner in the IPCC works, as a focal point for the French government. The years 2008 and 2009 are devoted to the preliminaries to the preparation of the 5th assessment report, to start with the election of a new Board. A plenary meeting was held in Budapest in March, where it was decided in particular that the 5th assessment report would be issued in 2013 for Group I and 2014 for groups II and III. All these works will be based on the new greenhouse gas concentration scenarios, the main ones of which were published in 2008 (http://www.ipcc.ch/pdf/supporting-material/expert-meeting-ts-scenarios-fr.pdf). The election of the new Board, which will coordinate the preparation of this new report, took place in September 2008. France is represented by Jean Jouzel.
The IPCC also decided in 2008 to draw up a special report on renewable energies, which will be published in 2010. It further decided during this meeting to study the possibility of drawing up a report on catastrophes and extreme events in relation to climate change.
The IPCC reports are available in the ONERC website http://onerc.gouv.fr or the IPCC website http://www.ipcc.ch/ .

Participation in the UNFCCC works and the French presidency of the European Union

ONERC contributes to negotiations within the framework of the UNFCCC, on the subject of research and observation, on one hand, and adaptation on the other. It has participated in several European meetings, meetings of subsidiary bodies and Conferences of the Parties to the Convention. Under the Slovenian and then French presidencies of the EU, work to inform delegations to the UNFCCC was undertaken in order to better inform these delegations of the results of the 4th IPCC assessment report and feed the dialogue between the parties to the negotiation on questions relating to the results of climate research and the systematic observation of climate parameters.

ONERC also monitored the implementation of the "Nairobi work programme on impacts, vulnerability and adaptation", which aims to define a shared vision of the scientific and technical aspects of this subject. The aims of this 5-year programme (2005-2010) are to help all countries assess the impacts of climate change and make suitable decisions on practical adaptation actions and measures. This is an international framework applied by the Parties, Non-governmental and Intergovernmental organisations, the private sector and collectivities. Additional information on this programme and its results, and in particular the "Compendium of methods and tools" can be found on the UNFCCC website (www.unfccc.int).

Other works

Interministerial group

ONERC has greatly contributed to the organisation and success of the works by the interministerial group "Impacts of climate change, adaptation and associated costs in France", created following the recommendations of the National Adaptation Strategy. From March 2007 to August 2009, this group mobilised over 200 people and held nearly 80 meetings. The reports on this group's work are published on the ONERC website.

Impact of climate change in the subantarctic islands

Due to their location in the middle of the ocean (which presents greater thermal inertia than the continents) and their insularity (which in particular shapes the flora and fauna, arriving today at a singular biodiversity), the subantarctic islands are a world apart. They do not present an "extreme" climate, but rather "limited" climatic conditions. These conditions are optimal for the often endemic organisms that present a high degree of specialisation and adaptation. The recent warming in this islands risks weakening the local flora and fauna and opens the way to colonisation of species that are potentially invasive, or in the least, competitors to the subantarctic species.
This report is interested in the observed and projected climate changes and the resulting past and future impacts in these territories. ONERC has been joined in this step by the International Polar Foundation (IPF), with the scientific support of the Institut Polaire Paul-Emile Victor, Terres Australes et Antarctiques Françaises (French Antarctic and Southern Lands) and the International Union for Conservation of Nature and Natural Resources, in order to put the situation in the French subantarctic islands into perspective with developments in other subantarctic islands (British, Australian, South African and New Zealand) that are all located north of the 60° South parallel which marks the delimitation of the Antarctic Treaty.

Bibliographical database

ONERC provides the support of the bibliographical database set up for the works by the interministerial work group *Impacts of Climate Change, Adaptation and Associated Costs in France.* This base, which is participative in nature so that all those involved in the works can add to it, possesses more than 200 references, of which many have commentaries. This database is in addition to that already present on the ONERC public website, and these two databases will be merged at the end of 2009. Access to this bibliography will be via the http://onerc.gouv.fr website, in the bibliography section.

Technical Notes

Since its creation, ONERC has drawn up 6 technical notes or reports. The technical notes are summary documents, whereas the reports correspond to more in-depth work on the subject concerned. These documents have been published as a limited quantity paper edition and on the publications section of the ONERC website, http://onerc.gouv.fr.

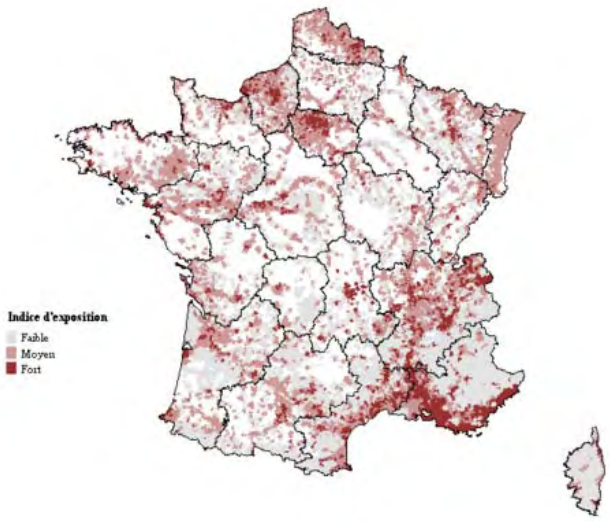
In March 2008, ONERC technical note No. 4, which lists the studies concerning impacts of climate and global warming on mountain species (*sic*) in mainland France, was updated. This work was carried out in partnership with the International Polar Foundation.

List of technical notes and reports

- Note technique n°1 - Recensement des études concernant les effets du climat et du changement climatique sur les espaces côtiers dans les DOM-TOM - mars 2005 (Technical note No. 1 – List of studies relating to climate impacts and climate change on coastal areas in the Overseas Departments and Territories – March 2005)
- Note technique n°2 - Impacts du changement climatique sur le patrimoine du Conservatoire du littoral - septembre 2005 (Technical note No. 2 – Impacts of climate change on coastal protection property – September 2005)
- Note technique n°3 - Impacts du changement climatique sur les activités Viti-vinicoles - janvier 2006 (Technical note No. 3 – Impacts of climate change on wine-growing activities – January 2006)
- Note technique n°4 - Recensement des études concernant les effets du climat et du réchauffement climatique sur les espaces de montagne en France métropolitaine - Version actualisée mars 2008 (Technical note No. 4 – List of studies relating to climate impacts and climate change on mountain areas in mainland France – Version updated March 2008)
- Rapport technique n°1 - Changements climatiques dans les Alpes : Impacts et risques naturels - mars 2008 (Technical Report No. 1 – Climate change in the Alps: Impacts and natural hazards – March 2008)
- Rapport technique n°2 - Impacts du changement climatique dans les îles subantarctiques - mai 2009 (Technical report No. 2 – Impacts of climate change in the subantarctic islands – May 2009)

APPENDIX IV: Climate change indicators

Exposure of populations to climatic hazards in metropolitan France in 2005



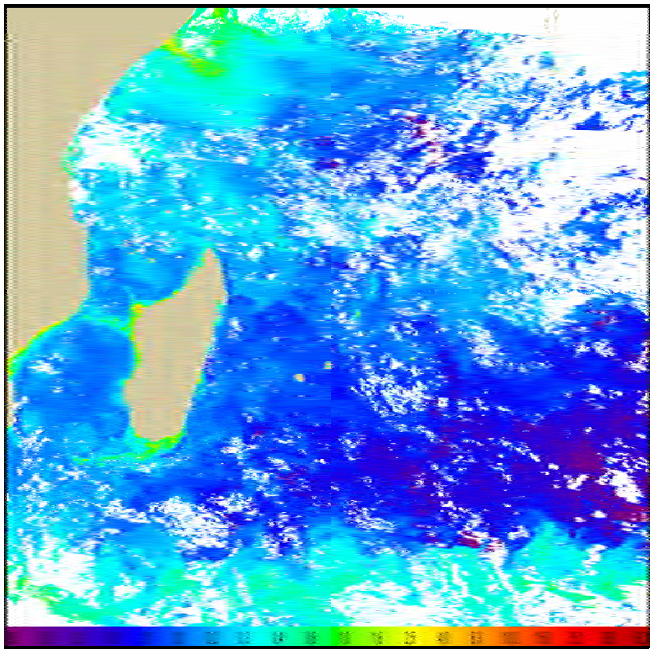
This map shows the extent of the Metropolitan France population's exposure to natural hazards, which are likely to increase with climate change (avalanches, storms, forest fires, floods, ground movements): the higher the population density = the higher number of natural hazards identified per municipality and thus the higher the index.

The given areas are liable to be increasingly vulnerable because of climate change as we expect extreme weather events to become more frequent, widespread and/or intense. The degree of possible risk is thus increasingly linked to land development and management choices.

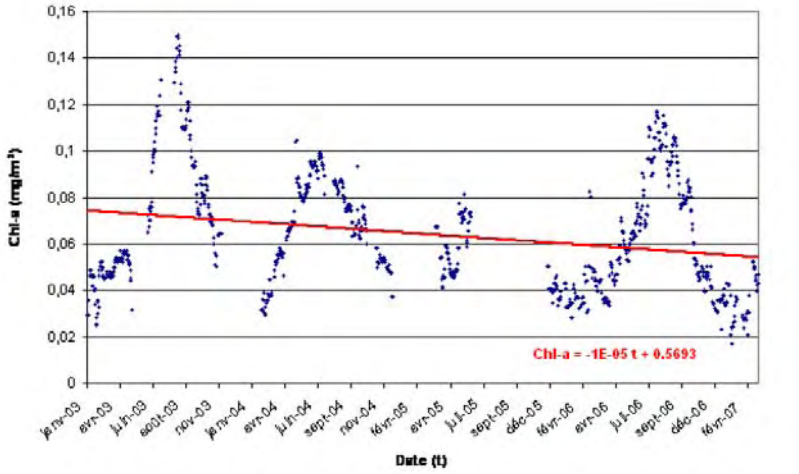
An analysis of statistical data shows that 7% of French Metropolitan municipalities are highly exposed according to this criteria and this figure rises to 29% if we add municipalities with medium exposure. The most affected French regions are as follows: Rhône-Alpes (488 municipalities with a high index, thus 17% of municipalities), Provence-Alpes-Côte d'Azur (327 municipalities, thus 34%), Ile-de-France (264, thus 21%), Languedoc-Roussillon (231, thus 15%), Haute-Normandie (217, thus 15%).

Source ONERC/IFEN/ INSEE/MEEDDM/DGPR

Ocean colour Chlorophyll-a concentration



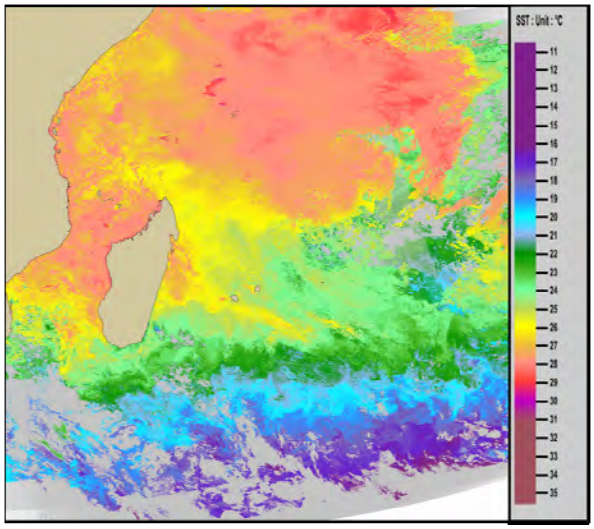
This figure shows a map of chlorophyll-a concentration from aggregate data, over an eight-day period (08/10/2002 to 15/10/2002), from the Reunion Island's satellite receiving station



This graph shows the development of mean chl-a concentration, calculated in a circle with a 2° radius around Reunion Island The data shows us that chl-a concentration was being reduced in the area over this short period of time. This will require to be confirmed or ruled out via SEASnet's monitoring. Please note that this reduction coincides with increasing sea surface temperatures, which is one of the parameters that enables us to quantise the climate's variability, partly linked to global climate change.

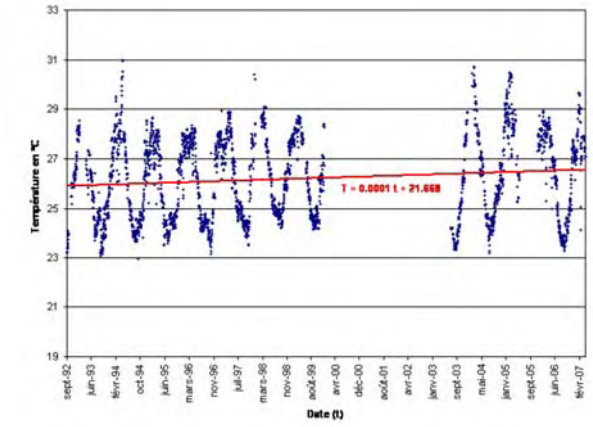
Source IRD - Unité Espace SEASnet framework

Sea surface temperature via high-resolution remote sensing (SST-HR)



SST image, synthesis of 28/10/1999. Reunion Station.

This graph shows an example of an SST-HR image, representing sea surface temperatures. It is a sliding pentad synthesis of several centred images dated 28 October 1999. These synthesis are produced each day in order to obtain a daily image of the most probable sea surface temperature. The temporal series of images that stems from it, on a given site, makes up a database from which this indicator's spatial and temporal dynamics can be studied.

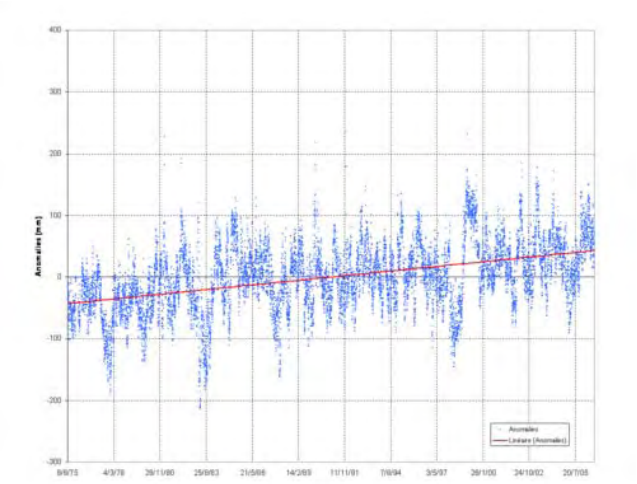


SST-HR mean changes since 1992. Reunion Station.

This graph shows the development of mean sea surface temperatures, calculated in a circle with a 2° radius around Reunion Island. The sea surface temperature changes around Reunion Island are representative of the seasonal fluctuations in the tropical Indian Ocean. There seems to be a clear trend of a rising mean temperature over this period. The hottest years are 2004 and 2005. Please note that we could not include data from January 2000 to June 2003 in this example, as it is currently being reprocessed.

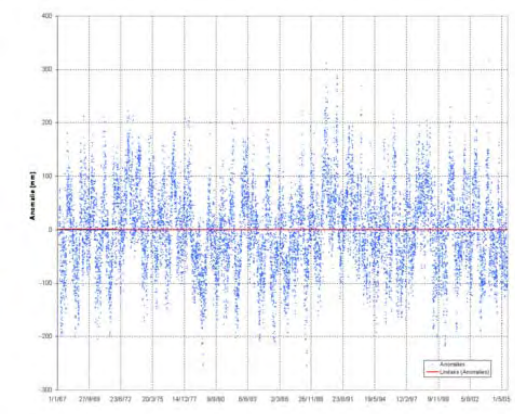
Source IRD / Unité Espace - SEASnet framework

Tidal sea level



Sea level anomalies detected by the Papeete (French Polynesia) tide gauge between 1975 and 2005

The daily sea level changes found at the Papeete tide gauge are shown as anomalies (as deviations at a mean level calculated over the full chronological series). The linear trend (straight red line on the graph) shows the thirty-year trend. This trend clearly indicates a sea-level rise. This curve also shows sharp drops followed by a sharp rise in the sea level corresponding to the oceanic response to the El Niño climatic events: 1976-77, 1982-83, 1986-87, 1997-98. These variations are especially spectacular for the two events of 1982-83 and 1997-98, which were major El Niño events in the 20th century.

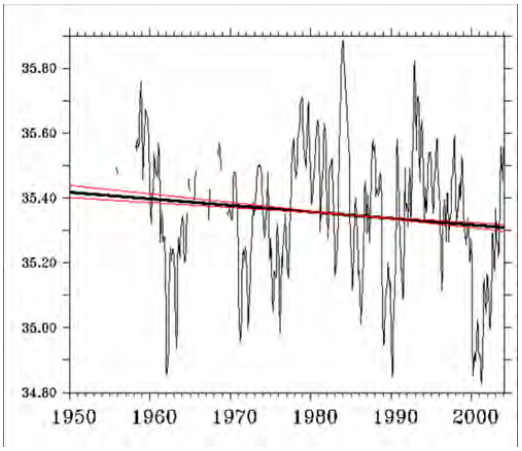


Sea level anomalies detected by the Noumea tide gauge between 1967 and 2005

The daily sea level changes found at the Noumea tide gauge are shown as anomalies (as deviations at a mean level calculated over the full chronological series). The linear trend (straight red line on the graph) shows the thirty-eight-year trend. The latter does not show a sea-level rise trend, even if there are major variations in these anomalies from year to year.

Source Sea Level Center (Hawaii university)

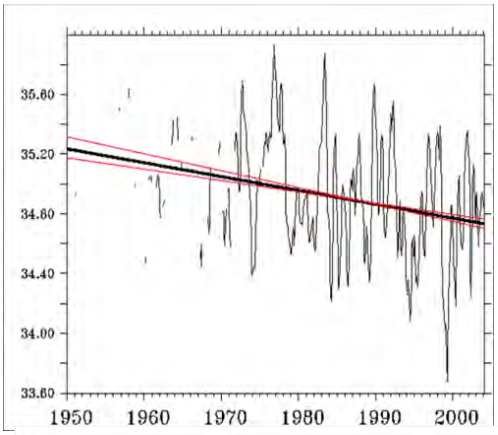
Sea surface salinity



Monthly mean sea surface salinity variations on a square of 1° longitude by 1° latitude centred on New Caledonia.

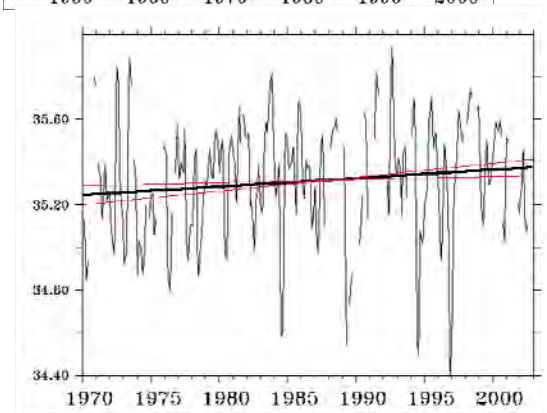
New Caledonia's sea surface salinity changes are rather representative of regional changes in the tropical South-West Pacific. There is a clear lower salinity trend (-0.1 pss in 50 years), despite slightly more salinisation during the El Nino years (i.e.: 1972-73, 1982-83, 1987-88, 1992-94, 1997-98).

The black line represents the linear trend calculated for 1950-2003. The two red lines enable us to assess this trend's error.



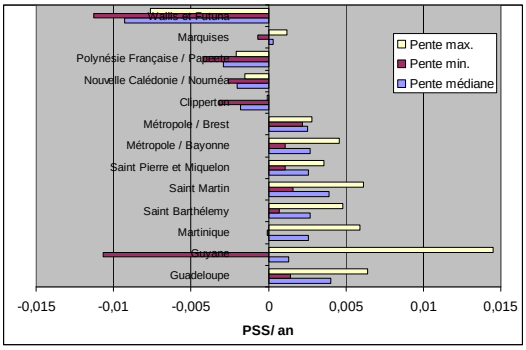
Monthly mean sea surface salinity variations on a square of 1° longitude by 1° latitude centred on Wallis and Futuna.

Wallis and Futuna's sea surface salinity changes are closely linked to rainfall variations, combined with South Pacific Convergence Zone (SPCZ) movements. There is a clear lower salinity trend (-0.46 pss in 50 years), despite slightly more salinisation during the El Nino years (i.e.: 1972-73, 1982-83, 1987-88, 1992-94, 1997-98).



Monthly mean sea surface salinity variations on a square of 1° longitude by 1° latitude centred on Guadeloupe.
Guadeloupe's sea surface salinity changes are rather representative of regional changes in the Caribbean Sea. There is very clear salinisation of about +0.18 pss in 50 years.

The black line represents the linear trend calculated for 1970-2003. The two red lines enable us to assess this trend's error.



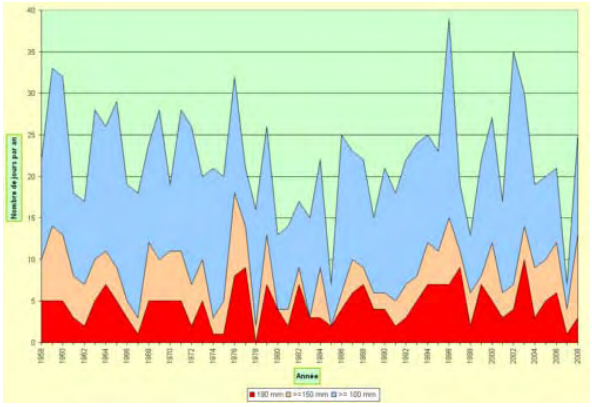
Sea surface salinity linear trend variation for 1950-2003 on Pacific sites and for 1970-2003 on Atlantic sites. The sites were grouped together in geographical areas.

Sea surface salinity changes show very clear salinisation on Atlantic sites, while on the other hand, there is a significant drop in the sea surface salinity of Pacific sites, in compliance with the rainfall modification forecasting model results in response to global warming.

Source Observatoire de Recherche en Environnement for sea surface salinity (ORE-SSS)

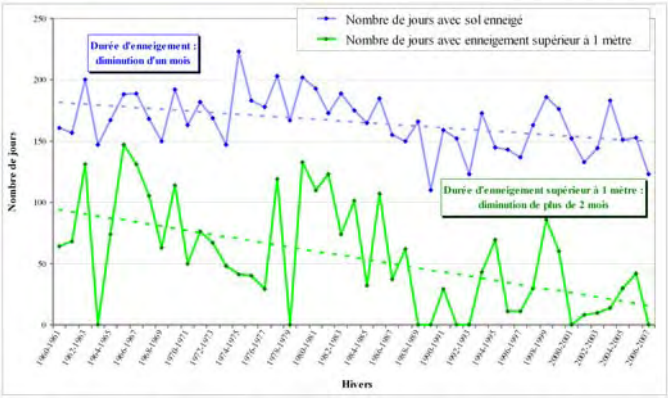
Heavy rain in South-East Mediterranean France

The regions of Mediterranean France are regularly affected by periods of heavy rainfall, which sometimes produce huge amounts of water in a very short space of time. There is very often as much rain in one day as the normal monthly total, while the heaviest downpours provide half (sometimes more) the normal annual rainfall in just a few hours. . Heavy rain is studied in the 15 departments of South-East Mediterranean France (except Corsica): Alpes de Haute Provence (04), Hautes Alpes (05), Alpes-Maritimes (06), Ardèche (07), Aude (11), Aveyron (12), Bouches-du-Rhône (13), Drôme (26), Gard (30), Hérault (34), Lozère (48), Pyrénées-Orientales (66), Tarn (81), Var (83), Vaucluse (84).

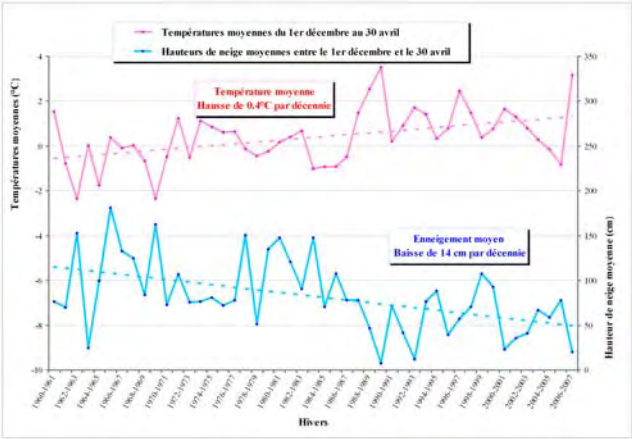


Changes in the annual number of rainy days >= 100, 150 or 190 mm in 24 hours in Mediterranean France (except Corsica) from 1958 onwards. We can see that interannual heavy rain occurrences vary a lot, for any threshold. For the 100 mm threshold, the average is 22 annual occurrences, and the record years (exceeding 30 events) are 1959, 1960, 1965, 1969, 1976, 1996, 2002 and 2003. On the other hand, the least turbulent years are 1980, 1981, 1989, 1998 with less than 15 cases and 1985 and 2007 with only 7 cases. For the 190 mm threshold, the average is 4 annual occurrences, and the record years (exceeding 7 events) are 1964, 1976, 1977, 1979, 1988, 1994, 1995, 1996, 1997 and 2003 with its record 10 cases. On the other hand, the least turbulent years are 1978 (no event), 1967, 1974, 1975 and 2007 (all only 1 case). We do not presently observe a trend for heavy rain occurrences in Mediterranean France.
Source Météo France

Porte Pass Winters (Massif de la Chartreuse, Isère)

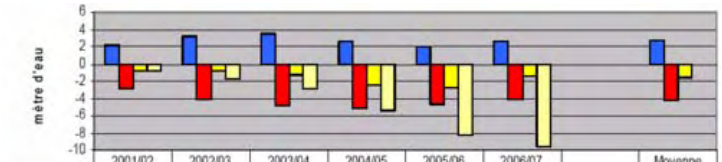


Graph 1 shows snow cover duration development above the thresholds of 0 cm and 100 cm, at the Porte Pass, in the Massif de la Chartreuse, at an altitude of 1,325 metres. These fluctuations attest of both the climate change and major interannual variability. The trend is that snow cover periods are about a week shorter per decade for the 0 cm threshold and over two weeks shorter for the 1 m threshold.



Mean temperature and snow depth development at the Porte Pass, in the Massif de la Chartreuse, at an altitude of 1,325 metres. These averages are calculated over the five months from 1st December to 30 April of each Winter. These fluctuations attest of both the climate change and major interannual variability. We can see a mean temperature rise of almost 2°C, thus 0.4 degrees per decade over the period, combined with a loss of more than half the mean snow cover (14 cm per decade). Statistical tests show that these trends are significant and do not result from natural variability. There is no particular snowfall trend from 1960 to 2007, which seems to suggest that there is a direct link between the mean temperature rise and shorter snow cover over the same period.
Source Météo France

Ossoue Glacier (French Pyrenees) mass balance



	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07		Moyenne
Accumulation	2,08	3,23	3,55	2,58	1,95	2,66		2,68
Ablation	-2,93	-4,11	-4,77	-5,07	-4,66	-4,04		-4,26
Bilan	-0,85	-0,88	-1,22	-2,49	-2,71	-1,38		-1,59
Bilan cumulé	-0,85	-1,73	-2,95	-5,44	-8,15	-9,53		

Annual Ossoue Glacier mass balance (Massif du Vignemale - French Pyrenees) since 2001
("mètre d'eau" = metre of water / "bilan" = balance / "bilan cumulé" = cumulative balance / "moyenne" = average).

This diagram shows the various annual balance parameters (gain or loss of glacier mass). Accumulation (blue) corresponds to additional matter (Winter snow), while ablation (red) is the loss of mass (Summer snow and ice melt). The balance (dark yellow) is the result of accumulation minus ablation. We can also add the balance value, year by year, and thus obtain the total balance (light yellow).

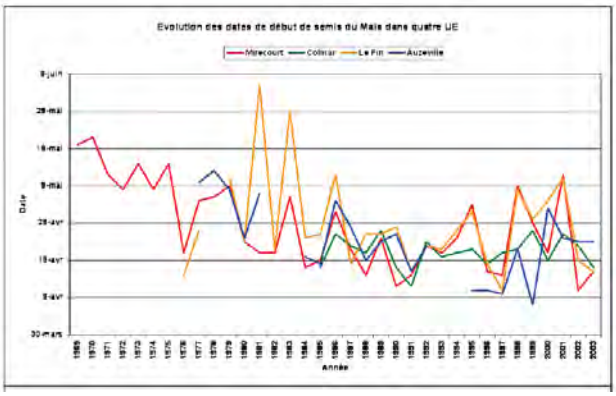
The annual balance is increasingly negative, despite its fluctuating accumulation and ablation values. The Ossoue Glacier lost 9.53m of water equivalent, thus about 10.6m of thickness from its full surface area in six years. This short series of measurements shows a major loss of ice, which is also found throughout the Pyrenees.

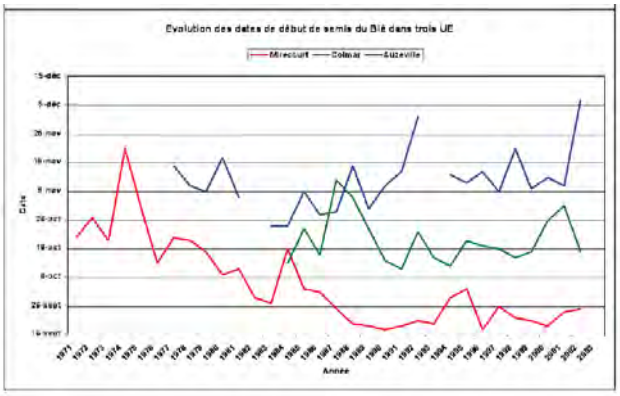
Photos showing the Ossoue Glacier's development

The Ossoue Glacier has been shortened by 530m since 1911. It is now only 1.5km long. Its surface area changed from about 110 to 50 ha, thus a 55% loss in ninety-six years.

Source Association Moraine (Association pyrénéenne de glaciolologie

Agricultural practice changes

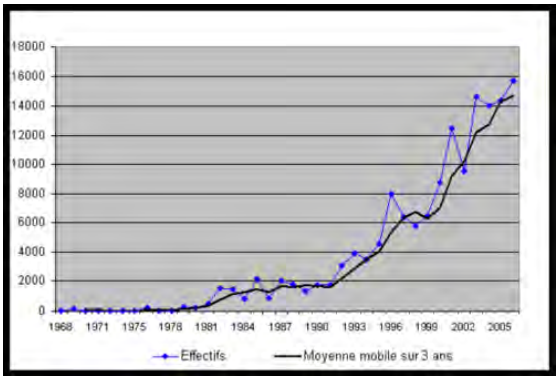




Annual sowing date changes.
The analysis of a crop's annual sowing start date changes in various experimental units shows the following: (1) a trend towards earlier corn cultivation, mainly found at Mirecourt, with a significant cut-off period starting in 1980; (2) corn sowing start dates are not very different from one experimental unit to another; (3) there is a significant development for wheat cultivation at Mirecourt (coefficient of determination R^2=0.80), with notably earlier dates throughout the 1970s and stabilisation around mid-September from 1987 onwards (thus one month earlier than in 1970!);(4) wheat sowing start dates are however very different from one experimental unit to another: a twenty-day gap between Colmar's sowing dates (semi-continental climate) and those at Mirecourt, while there is a forty-day difference at Auzeville, (5) there is generally persistent interannual variability. There might be several reasons for generally earlier sowing dates in the last few decades: (1) a low perception of the spring frost hazard by EU pilots during corn sowing, (2) shorter physiological cycles due to earlier seasonal maturity (average three to four-and-a-half weeks over 30 years for wheat and corn respectively), (3) choice of varieties suited to local conditions and more resistant (genetic selection: example of wheat varieties that have outgrowth with low sensitivity; corn more suited to warmer days, etc.). "We try to catch up on varieties if the weather is an obstacle" (Colmar EU); (4) looking for a optimal yield combined with satisfactory quality at harvest time - "early sowing of late varieties for an earlier seasonal harvest" (Mirecourt EU); (5) changing cultivation systems (switching from durum wheat to soft wheat; preferring a spring crop after corn; reviewing soil preparation, fertilisation and irrigation strategies, etc.) and crop (less late harvest of crops preceding wheat in South-West France: "It is sometimes better to change crop if you can no longer fit into a climatic niche"). You must have sufficient knowledge of the 'climate / plant / soil' complex before changing cultivation practices; (6) extending surface area schedules (starting to prepare sowing as soon as possible on the farm, in order to complete sowing before the given deadline, and freeing some time, after harvest, to prepare the next cycle); (7) enhanced agricultural machinery size and performance (faster soil preparation before sowing and thus earlier sowing); (8) adopting tilling strategies (vertical splitting, via a harrow, to enable the crop to benefit from good root development, ploughing before sowing Winter cereals by lifting the wet soil layer for a better emergence, etc.) and sowing strategies (sowing at a correct depth and more densely to limit risks), which enable you to avoid certain weather restraints: "We can suit the sowing date to climate restraints thanks to today's cultivation methods" (Colmar EU).
Source Institut National de la Recherche Agronomique

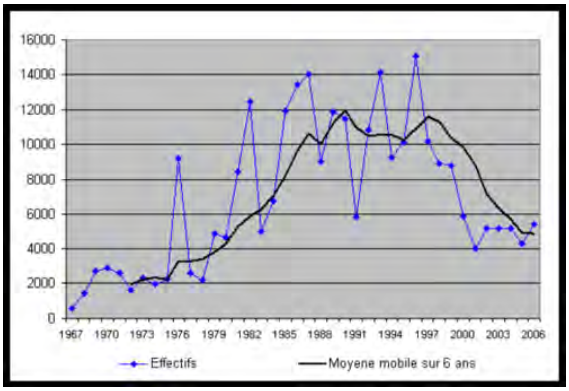
Population changes of certain bird species

Wintering greylag geese population changes in France from 1968 to 2006.



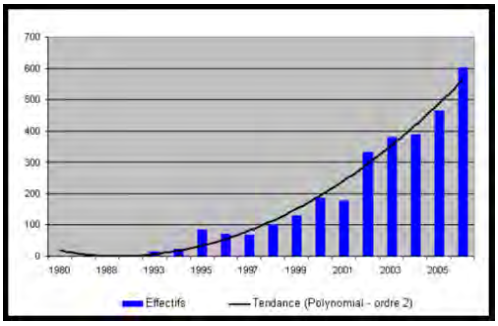
There is an increasing number of wintering greylag geese (Anser anser) in France. There are several reasons for this very clear phenomenon, which started fifteen years ago. On one hand, the European breeding bird population increased between 1990 and 2000 (BirdLife International 2004). On the other hand, modified wintering conditions, due to the climate change, which now enables birds to spend the Winter in temperate Europe, notably in France, but also in Southern Scandinavia, mean that the majority no longer stay in Southern Europe, as in the past (until the early 1980s). Birds now have shorter migratory journeys, which has a positive effect on their pre-mating physical condition (less energy expenditure). Both the gross population and moving average clearly show an increasing wintering greylag goose population from the early 1980s onwards. This increase speeded up from the mid-1990s. The start of substantial more-northerly wintering occurred in the late 1980s, which was also when France enjoyed a significant rise in its annual mean temperatures (notably during Winter).

Sea duck population changes (scaup, velvet scoter, eider, golden-eye) in France from 1967 to 2006



Contrary to the greylag goose, there is a trend of fewer sea wintering ducks. We have chosen four species that regularly spend Winter in French maritime waters: the scaup (Aythya marila), eider (Somateria mollissima), velvet scoter (Melanitta fusca) and golden-eye (Bucephala clangula). The combined results of mid-January counts (Wetlands International) for these four species show a global declining population of these ducks in France. The increase found in the 1970s and first half of the 1980s is undoubtedly due to better surveying (more available sites). However, we have seen a major and continuous drop in the Winter population of these four duck species since about the last ten years (1997). At the same time, these species' European populations are stable or slightly rising (golden-eye, eider); or stable and/or slightly declining (scaup, velvet scoter). But this cannot explain such a declining population. It is likely that they now spend their Winters further North, around the North Sea and Baltic Sea. It will thus be especially interesting to follow the development of these four species wintering on the French coast, as well as the development of breeding populations.
Source LPO/ Wetlands International/

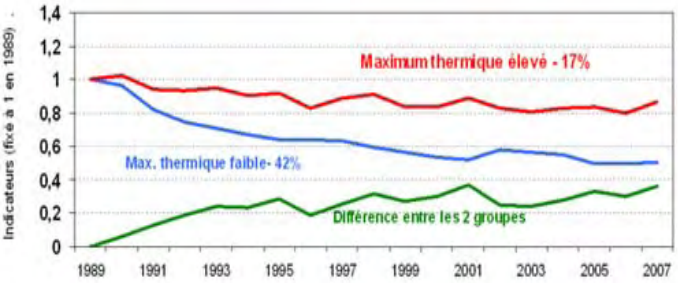
Wintering white stork population changes in France from 1980 to 2006



This species, Ciconia ciconia, which was reputed to migrate across the Sahara, has now been wintering in Southern Europe and France in the last few years (rare before the 1990s). It is often present and its numbers are rising significantly. Like the greylag goose, it started wintering in substantial numbers in 1993, which is a few years after the significant rise in

annual mean temperatures (notably in Winter) in France. Also, wintering which was mainly located in Mediterranean France, notably around Lattes, in the Hérault department (205 in 2005-2006), is now not only increasingly taking place in North-West France, but also in the country's interior such as Allier, Moselle, Alsace or Dombes (Dubois et al. 2008). Farm-reared storks and reintroduced in the natural environment are not counted for this indicator.
Source Groupe France Cigogne blanche/LPO

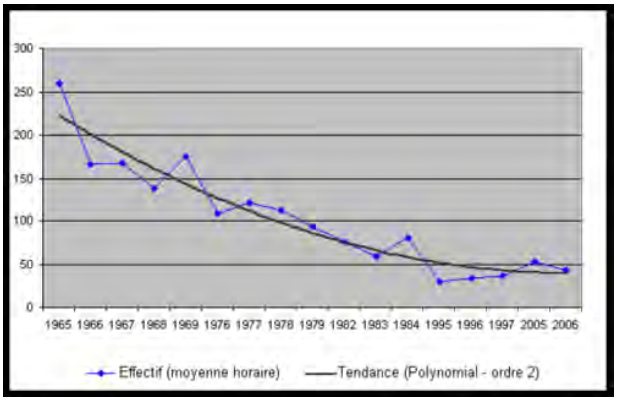
Indicator of the climate change impact on common breeding birds



An indicator was perfected by the ornithologists of the Paris National History Museum ("Muséum National d'Histoire Naturelle") from data collected by the Common Birds Temporal Monitoring Programme (STOC), which also gives us a good insight of the impact of global warming for fifteen species (including fourteen songbird species) with northern affinities (Jiguet et al. 2007; Jiguet 2008). This indicator shows the quantitative development of common breeding bird populations, per species. These fifteen "northern" species are as follows: meadow pipit, willow warbler, willow tit, bullfinch, goldcrest, hedge sparrow, wood warbler, crested tit, whinchat, yellowhammer, garden warbler, tree pipit, rook, marsh tit and stock dove. These authors showed that the indicator's long-term declining trend was partly explained by the thermal maximum, which is the maximum bird breeding temperature in Europe (March to August monthly mean temperatures from 1960 to 1990). The study follows this indicator's development over nearly twenty years. It starts in 1989, which is the reference year when the indicator was arbitrarily set to 1. The fifteen species with the lowest thermal maximum were chosen to build the indicator for these species. The assessment shows a 42% drop in nineteen years (blue curve on the figure). We can check the impact of global warming by looking at the change in the difference between both constructed indicators (green curve on the figure). This corresponds to the different response from the two groups of studied breeding birds. Each bird group, which includes fifteen different species, is characterised by its thermal maximum. The latter is low for species with northern affinities (blue curve), while it is high for species with southern affinities (red curve). We can see that this difference is increasing. Note that there is a 17% drop for species with southern affinities. Also, the indicator of agricultural species drops by 28% and the indicator for all species (n = 65) only drops by 18%. This variable thus seems to be a good predictor of the impact of climate change on common breeding birds
Source CRBPO/Muséum national d'histoire naturelle

Black scoter population changes at Gris-Nez Cape (Pas de Calais) Autumn monitoring from 1965 to 2006.

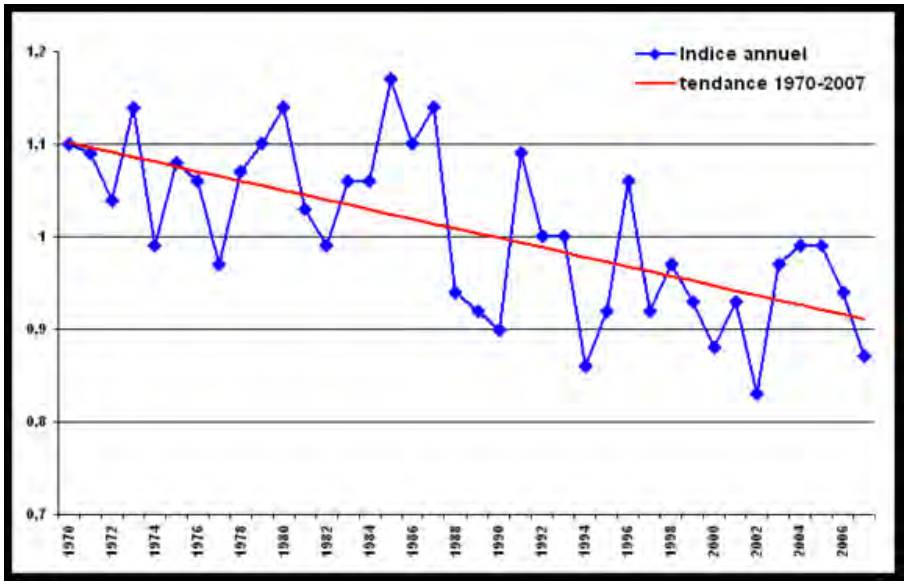
The direct or indirect impact of global warming is not only measured via wintering Anatidae. If the black scoter (Melanitta nigra) is still a rather common wintering bird in France (about 30,000 birds), it is however very difficult to record in January, as it keeps well away from the coast. Counts are very disparate from one year to the next. This is why Autumn monitoring of scoters at the fixed location of the Gris-Nez Cape (Pas-de-Calais) provides rich information. It provides us with better information about the populations that transit along the French Channel coast, to spend Winter further South (as far as Portugal), than simple Winter counts. Calculations were made according to



the hourly mean of their passage throughout Autumn and years of sufficient monitoring (100 hours and more). We notably see that the hourly mean dropped from 260 to 43 scoters (less 83%) between 1965 and 2006. European populations (including Russian) are stable since the 1970s (BirdLife International 2004), so we cannot announce that the declining Autumn passage in Northern France is correlated by a larger scale decrease. We can therefore think that the decline in French figures is mainly due to the species wintering further North in Europe than in the past. Thus, the post-breeding passage of black scoters, which is successfully monitored in Northern France, especially at the Gris-Nez Cape, shows us that we have an excellent indicator for many years to come.

Source Association Skua

Climatic rigour



Climatic rigour index development from 1970 to 2007

This index enables us to characterise how rigorous the Winter period is during a year (from January to May and October to December, when **housing** requires **heating**) in relation to the mean value for 1976-2005. An index of 0.9 indicates that the sum of HDDs (Heating Degree-Days) of the Winter period for the given year was milder than the reference period's mean value. Thus, we find that "climate-sensitive consumption" was 10% lower, that year, than it would have been for a "normal" climate (equal to the reference period of 1976-2005). We can see a significant drop in this index, especially since 1988.

Source Sous direction de l'Observation de l'énergie et des matières premières – MEEDDM

APPENDIX V: climate research in France

General view of climate research in France

French climate research contributes greatly to the advance in knowledge in multiple fields: from the refinement of climate models, in order to produce data at more operational scales for the various disciplines involved in locating and managing impacts (confirmed or potential), to technological research which develops climate change adaptation and mitigation devices. All these fields of research currently benefit from a central place in French research priorities, both for the more-or-less long-term aims and for the implementation of suitable responses in a short space of time.

This appendix gives a summary presentation of the main research programmes in France during 2006-2010 on the climate, its development, impacts and responses to climate change. The vast majority of these programmes are national and, for some, may come within the framework of a European or international programme.

Research action by public authorities

In the face of the preoccupying assessment of ecological urgency, France is highly involved in combating climate change. The action by French public authorities aims to be the most complete and efficient possible, especially by taking into account a maximum of human activities. This objective was set within the framework of the Grenelle Environment Forum and confirmed by the 2009 National Strategy for Research and Innovation (SNRI).

In order to find better synergy between public and industrial research, France created a new support mechanism for the best public and private laboratory projects and for innovation. This mechanism included the creation in 2005 of the National Research Agency (ANR), the Industrial Innovation Agency (AII) and the OSEO-ANVAR. The action of these three agencies comes within a long-term policy: the budget of EUR 350 million in 2005 will grow to EUR 2.5 billion in 2010. The three agencies participate in financing 66 competitivity centres recognised in 2005 and supplements the joint action of the Environment and Energy Management Agency (ADEME), the Ministry for Ecology, Energy and Sustainable Development and the Sea (MEEDDM) and the ministry responsible for research, in order to define the approaches for national research programmes.

The French government decided to launch a wide consultation in 2009 in order to efficiently list the great scientific, social and economic challenges of tomorrow by taking advantage of the cross viewpoints of several players from the worlds of academia, economics and the community. The National Strategy for Research and Innovation therefore bears the recommendations from the Grenelle Environment Forum's "Research" operational committee and comes within the European strategic plan for energy technologies (Set Plan). Debates took place within work groups over several months and served as a basis for drawing up a reference document on the clear major approaches for the next five years. This document therefore enables the budgetary priorities to be set for the State; these will be divided between the objective contracts of research organisations and ANR programming.

Financial commitment

The State's financial commitment in terms of climate research is fully convergent with France's policy on combating climate change. It can be assessed at **EUR 1.4 billion** for the year 2009, through all the public aid in different research topics on the climate, including those relating to the energy sphere. Furthermore, the planning law on implementing the Grenelle Environment Forum provides for the mobilisation by the State of an additional EUR one billion by 2012 in relation to research into sustainable development, in particular on climate change, energies and future

engines, biodiversity, the impact of the environment on health, and technologies relating to the treatment of waste and recycling.

The ANR plays a central role in climate research. The global amount of research credits it devoted to financing its 20 research programmes on the subjects "Sustainable Energy and the Environment" and "Ecosystems and Sustainable Development" over the period 2005-2008 reached approximately EUR 560 million, allotted to 766 projects (i.e. a budget of nearly EUR 860,000 per research project). It can be estimated that approximately 60% of these directly relate to the climate problem, i.e. EUR 330 million over this period (over EUR 80 million per year)[25].

Main directions for climate research

In 2009, the National Strategy for Research and Innovation identified the four major aims inherent to French climate research, thus defining approaches for the future.

Better understanding climate change and ecosystems

The French research effort comes under the highest level of the IPCC framework, in which works permitting climate change to be given a scenario over the medium and long term, in accordance with various hypotheses in GHG emissions. The margins for progress are considerable for modelling the climate and its changes. The challenges to be overcome are numerous, from spatial and temporal densification of data to the regionalisation of climate change models, via better understanding of the role of the various sectors and their connections.
A major advance will be the modelling of long-term changes to ecosystems. This requires understanding of the dynamics of biological resources, the development of ecosystems and their component parts, and the ability to measure the impacts of socioeconomic activities. The pertinent scientific fields come within life and environmental sciences, as well as human and social sciences.
In terms of environmental hazards, the research into ecotoxicology and environmental ecology allow us to understand and predict the transfer processes and the effects of contaminants on the environment and human health. It calls for a strengthened dialogue between the researchers themselves, and with other researchers, companies and public authorities. The support given by France to the Foundation for the research into biodiversity and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) falls within this objective.

Energy control in the four key fields

By its choice of nuclear energy, France is less subject than other economic powers to energy challenges. A leader in nuclear industry, it intends to strengthen its position while developing clean energies, in particular solar photovoltaics, second generation biofuels and marine energies. Each euro spent by the State on nuclear research must be matched by one euro for research into clean energies and preserving the environment.

Promoting towns and sustainable mobility

Globalisation and an increasingly knowledgeable society leads to a very high increase in global urbanisation and the mobility of people and property. Furthermore, a very large part of GHG emissions relates to the housing, tertiary and transport sectors. From a global point of view, disciplines such as urbanism, economics, organisational sociology, information sciences and operational research are certainly major contributors, alongside "hard" sciences and engineering.

Developing ecotechnologies and ecodesign

The development of ecotechnologies enables competitive products and services to be designed with a weak, or even zero environmental impact, throughout their life cycle. The applications are extremely varied and concern the subjects mentioned above, but also more generally all economic

[25] These statistics are taken from ANR activity reports, in which the sum has been validated by the ANR's governing board.

activity. “Green” chemistry comprises a particular field in which France, with its strong pluses and industrial fabric, must position itself. It contributes to developing new solutions to reduce and finally eliminate the use and generation of polluting substances via innovative chemical processes or new applications offered by synthetic biology.

The Climatic system and past climates

Thanks to research efforts to understand the climatic system, our planet appears more than ever to resemble a global assembly in which the climate depends on complex interactions between the ocean, atmosphere, cryosphere, biosphere and… human activities. To this end, glaciological records are an invaluable source of information on Earth’s past climatic conditions, because they record in their composition and structure valuable information on climate changes and polar cap discharge. In fact, by relating a temporal resolution to the fossilisation of the physico-chemical characteristics of the atmosphere within the ice matrix, analyses conducted on glaciological records obtained by French research allow indisputable advances in understanding the climatic system and its variability.

LEFE inter-organisation action

Created in 2006, the LEFE “Fluid Envelopes and their Environment” inter-organisation action is a programme associating all the former Ocean-Atmosphere programmes run by the INSU. LEFE comprises 5 research programmes that correspond to the dynamic of the major international programmes on planetary environmental changes of the International Council for Scientific Unions (ICSU) and the United Nations Environment Programme (UNEP):

- Data assimilation (ASSIM);
- Atmospheric chemistry (CHAT);
- Bio-geochemical cycles, environment and resources (CYBER);
- Climate change and variability on a global scale (EVE);
- Ocean-atmosphere interactions and dynamic (IDAO).

Finances allocated by LEFE following annual tendering procedures are on average EUR 2 million per year for 60 projects, with a consolidated cost of EUR 30 million.

The EPICA project

The European EPICA (European Project for Ice Coring in Antarctica) programme, placed under the aegis of the European Science Foundation (ESF), was launched in 1995. It has enabled the implementation of successive glacial core-drilling campaigns in the Antarctic, the last of which was 3,260 m deep, revealing the climate for the last 800,000 years. The award of the 2008 Descartes Prize by the European Union attests to the importance of the works carried out within the framework of EPICA.

Organised as a consortium, the EPICA project has been led by 12 partners from 10 European countries (Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom). The responsibility for drilling operations at Dome C has been entrusted to LGGE. Leading French laboratories, LGGE and LCSE have played a major part in the climatic analyses and interpretations, and have been signatories to the main articles presenting the results obtained to date, published in famous reviews such as *Nature* and *Science.* The last IPCC report largely included information drawn from EPICA. EPICA’s haul of results is not over and a series of measurements will be taken in 2009, 2010 and beyond.

The France NEEM project

The NEEM (North Greenland Eemian ice drilling) project is a new deep-drilling project in the ice in the northwest of Greenland. It is taking place from 2007 to 2011 in Greenland and is supported by IPEV and ANR via the VMCS programme. Its aim is to obtain samples of ice covering the last 140,000 years, i.e. the entirety of both the last ice age and the Eemian, the preceding interglacial period, in order to characterise climate change in Greenland during these two periods.

NEEM involves 14 countries (Belgium, Canada, China, Denmark, France, Germany, Iceland, Japan, the Netherlands, South Korea, Sweden, Switzerland, the United Kingdom and the United States), and international coordination is overseen by the University of Copenhagen. The French participation, via 3 laboratories (LSCE, LGGE and Game), brings a team of specialists in modelling ice discharge, climate dynamics and their interactions (4 people on average per year).

The French NEEM project relates, on one hand, to the characterisation of the polar firn, analysis of ice cores from deep drilling (stable water isotopes, particles, physical properties of ice, elementary and isotopic analysis of the air contained in the ice), and on the other to modelling the regional atmospheric circulation, global climate and modelling the discharge of the Greenland cap in order to improve the connection between climatic and cap models.

Climate modelling and forecasts

France has two climate models, one developed by MétéoFrance and CERFACS, the other by IPSL; these differ mainly in their atmospheric component.

IPSL chose a multidisciplinary approach integrated with the Earth System in order to study past and future climate changes in a coherent fashion. This approach calls for the interactions between the ocean, atmosphere, biosphere and cryosphere in all their physical, chemical and biological aspects. It is based on the climate modelling activities carried out in the various IPSL laboratories, as well as at the LGGE, and is coordinated by the IPSL climate modelling centre, known as "IPSL Global Climate Modelling Group" (IGCMG). Developments related to these questions are coordinated at national level by the LEFE inter-organisation programme's MISSTERRE project. The activities of the modelling centres involve about a hundred researchers and engineers. In addition to these people there is a wider circle of approximately 200 people who use the results and benefit from the data being made available.

The Toulouse teams (CNRM and CERFACS) have invested much into the characterisation of current climate change, progressing to the understanding of climate system sensitivity and working on the impacts of climate change, both in terms of physical variables and other fields: hydrology, vegetation cover or nivology. To do this, a major effort is devoted to studying large variability trends and their teleconnections, as well as polar regions. The global scale climate change projection is insufficient to determine the regional impacts for which the CNRM has developed nested models to meet the needs of smaller and smaller scales (50, 25 and 10 km): CERFACS itself has explored other methods based on weather patterns.

France's participation in IPCC group 1 has allowed the teams involved to be gathered within the framework of a common project, ESCRIME, under the aegis of the INSU. This project has brought together teams from IPSL (LOCEAN, LMD, LSCE), LGGE, CERFACS and CNRM (Météo-France) by encouraging the emergence of joint scientific activities and shared modelling exercises based on the two French climate models. The ESCRIME project was financed by the INSU with the support of ONERC and IDDRI, and involved the wide participation and support of major calculation methods of several organisations (CNRS, CEA, Météo-France and CERFACS).

Use of the IPCC simulation results was also made in the European FP6 ENSEMBLES project, for which additional simulations enabled the results obtained with the IPCC simulations to be refined and the next simulations to be prepared; these will be made from 2009 within the framework of the preparation of the fifth report, on the following research subjects: chemistry/aerosol/climate interactions; the carbon cycle; retroaction and clouds; the hydrological cycle; variability trends; detection and allocation; parallelisation; the cryosphere; and lastly, regionalisation and extremes.

The impacts of climate change

The problem of global warming has become a major challenge for natural and man-made ecosystems. The inclusion of the ecological hazards caused by climate change and man-made

pressures requires accurate measurement and the anticipation of these effects on the environment and on man. These impacts disturb the major bio-geochemical and hydrological cycles on a planetary scale and generate combined effects, of which nature and scale comprise the heart of the fields of research. The research programmes detailed here are directly in line with this need to understand and assess the scale of these climate change impacts, in order to implement mitigation and adaptation strategies.

The subjects tackled by this research therefore relate to the major problems that are **natural resources, ecosystems, and natural hazards,** comprising 3 lines of research fully concerning France, because climate change leads to hazards across the entire country that need to be measured. French research is running investigations that specifically aim to assess the possible impacts of climate change on national territory (including Overseas Departments and Territories) and the adaptation measures likely to be implemented in the most vulnerable geographical zones and sectors of activity.

The GICC programme

Launched in 1999 by the MEEDDM, the "Management and Impacts of Climate Change" research programme constitutes the "Impacts" factor of the national mechanism for research into the atmosphere and the climate. 60 projects have been financed on various topics, mobilising the French scientific community around very concrete problems for running public policies. The GICC currently comprises two phases (GICC-1 and GICC-2). It operates by an annual appeal for research proposals (APR). Thus, GICC-1 issued APRs in 1999, 2000, 2001 and 2002. GICC-2 has issued 3 APRs in 2003, 2005 and 2008 as well as a joint tendering procedure with the *Institut Français de la Biodiversité* (IFB = French Biodiversity Institute) on the theme "Biodiversity and global changes". The research projects selected following these APRs generally last for 3 years. The research actions into climate change carried out at European level are also taken into account. The GICC is involved in the European ERA-NET CIRCLE programme.

The projects financed within the framework of the GICC programme can be divided into several subjects:

- Scenarios for the development of 21st century climate characteristics;
- Climate/economy/society interactions and time management;
- The role of forest carbon sequestration and agricultural practices in climate policies;
- Links between national and international action;
- Towards new inventories of net greenhouse gas emissions (direct or indirect) and aerosols;
- The impact on the terrestrial biosphere;
- The impact on hydrosystems;
- The impact on health;
- The impacts on biodiversity.

The ANR "Vulnerability: environments, climates and societies" programme

The "Vulnerability: Environments, Climates and Societies" (VMCS) programme aims to strengthen national scientific production, result in useful knowledge for public action and strengthen French capacities in international negotiations on global change. This programme is aimed at teams proposing to develop pure or industrial research into the problem of the vulnerability of essential parts of our environment in the face of climate change and man-made pressures. VMCS closed its project tender cycle in 2008. The 1st edition of the programme took place over 3 years, from 2005 to 2007, was entitled "Vulnerability: Climate and Environments", and allowed 29 research projects to be financed, representing for the programme's 3 appeals for projects an amount of nearly EUR 18 million. The social component was added for the 2nd edition of the programme, also running over 3 years, and for which the projects selected will be carried out over the years 2009, 2010 and 2011. The total amount allotted by the tendering procedure was EUR 8.1 million, i.e. EUR 610,000 per project on average.

The ANR biodiversity programmes

Even though it is not specifically targeting climate change, the "6th extinction" programme on biodiversity, launched in 2009, merits a mention. It meets the need to better understand the changing ecological processes, to document the scale and characteristics of the erosion of biodiversity and its consequences, to predict the change to biodiversity using models, to promote suitable ecological and social engineering, and to develop incentive tools enabling human societies to integrate biodiversity preservation objectives into their development.

The 4th ANR biodiversity programme, the regional Era-Net "NET BIOME", which will be launched in 2010, is in line with the continuity of the "6th extinction" programme, and targets research into urgent and important subjects concerning the outermost regions of Europe and the Overseas countries and territories. In fact, the biodiversity of the outermost regions is exceptional, but little known. The French islands have 26 times more plant species, 60 times more bird species and 100 times more fish species than mainland France. The support of Europe for the knowledge of worldwide biodiversity must therefore include that of the outermost regions, in particular the French outermost regions.

The AFSSET "Climate change and human health" programme

Within the framework of ERA-Net EnvHealth (2008-2011) led by the French Agency for Working Environment Health Safety (AFSSET) with the support of MEEDDM, an international appeal for research projects financed jointly by France, the United Kingdom (Natural Environment Research Council) and the Netherlands (VROM, Ministry of the Environment and Public Health) was launched in 2008. The 3 projects selected could include partners from other European community member states, for a maximum duration of 3 years. The total amount of finance offered in the project tendering procedure is EUR 3 million.

The subject of this project tendering procedure was the study of health vulnerability resulting from the impacts of global climate change in the west-European regions, i.e.:

- direct impacts on the sun/water ecosystem;
- the indirect effects that these impacts will have on human health;
- potential adaptation or mitigation measures in the fields of ground use and water resources.

The EPOCA project

The EPOCA (European Project on OCean Acidification) project was launched in June 2008 for 4 years. Its main objective is to improve our understanding of the biological, ecological, biogeochemical and social mechanisms of the ocean acidification phenomenon. Coordinated by the CNRS Oceanography Laboratory, it groups together more than 100 researchers of 9 European nationalities from 27 institutes. The works are grouped into 4 subjects:

- **Past and present changes to ocean chemistry and the biogeography of key organisms.** Paleo-reconstruction methods are used on several archives, including foraminifera and deep-sea corals, in order to determine past variability in ocean chemistry. Biological parameters are also studied, such as the geographical distribution and quantity of plankton present in the oceans.
- **Effects of ocean acidification on marine organisms and ecosystems.** Several methods are used to study major biogeochemical processes such as calcification, photosynthesis and nitrogen fixing. The organisms are exposed to CO_2 concentrations corresponding to the levels predicted for the end of the century. These experiments are carried out in laboratories and in the field. The organisms' capacities to adapt are assessed. The studies are conducted in areas likely to be the first affected by ocean acidification, such as the North Atlantic and Arctic oceans.
- **Combination of the results of subjects 1 and 2 in climate models** in order to calculate the changes and impacts by 2100. Particular attention is being given to carbon, nitrogen, iron and sulphur cycles in order to determine in what fashion they will be affected and retroact themselves onto the climate.

- **Summary of the results of other subjects in order to determine if there are "tipping points"** (or thresholds) which, if they are exceeded, will cause a new and irreversible condition. This information, and the level of CO_2 emission reduction needed to avoid reaching these thresholds, is be communicated to the general public.

The ANR "Planetary Environmental Changes (CEP)" programme

Financed by the ANR, this programme aims at developing prospective or retrospective research, not only studying processes and impacts, but also encouraging research into the development of various economic, social, ecological systems etc. interacting under the impact of global change, in order to allow projections, in particular for the next 30 to 100 years. The programme is open internationally and covers the years 2009, 2010 and 2011. The programme is allotting a budget of between EUR 500,000 and 1.5 million per project selected.

The lines of research are:

- societies' vulnerability and adaptation to CEP;
- town and country planning and ground occupation within the context of CEP;
- the role of biodiversity in ecosystem operation within the context of CEP;
- natural resources and food safety within the context of CEP;
- planetary environmental changes and the effects on health;
- tools and methods for Earth system science.

On an international level, Earth System Science Partnership (ESSP) aims to link the four major thematic programmes in the study of global change, namely the climate programme (WCRP), the biosphere/geosphere (IGBP), biodiversity (DIVERSITAS) and the human dimension (IHDP). The CEP programme aims at representing the French contribution to ESSP. Consequently, the programme's structure is close to the interface with the major international programmes making up ESSP. The goal is therefore to unite the scientific communities involved in the interface of these main themes in order to display an international visibility of the CEP programme in relation to these international programmes. The interface will be carried out in coordination with the French National Committee on Global Change (CNFCG). As the CEP programme is essentially designed to establish international partnerships, it is open to international consortia and in particular to teams from developing countries. For example, the 2009 appeal for projects was open to Franco-Brazilian projects.

The ANR "Natural Hazards: Understanding and Control" programme

The ANR offered two tendering procedures for this programme, in 2008 and 2009. The 12 projects in line with the 2008 appeal framework have benefited from an average of EUR 540,000, i.e. a total budget of 6.5 million for the 1st edition. The aim of this programme is the reduction of human, physical, social and economic impacts of rapidly occurring natural hazards (of hydro-meteorological origin: torrential rains and floods, avalanches and glacial hazards, storms, tornados and cyclones, snowy or freezing periods, etc. or of telluric origin: earthquakes, volcanoes, tsunamis, gravitational instabilities).

The programme intends to tackle all the problems of the research needed for correct management of these hazards, in the short, medium and long term. It encourages projects involving close collaboration between specialists from various fields (Earth sciences and the environment, engineering sciences, human and social sciences) and is interested in several components of the hazard chain: risk, vulnerability, expertise, public policy support, challenge for society, etc.

Consequently, the field of research tackled by this programme is extremely wide, and comprises in particular:

- quantitative estimation of natural hazards, in particular probabilistic
- analysis of various vulnerabilities (physical, social, economic, organisational): estimation methods, their interactions, means of reduction, cost/benefit studies;
- detailing of hazard acceptability and uncertainty management;
- improvement of early warning and rapid reaction processes;

- technological innovations relating to the measurement, transmission and analysis of relevant parameters (precursors, danger indicators, etc.).

The ANR "Sustainable Towns" programme

The sustainable town is a field of research that is still little exploited in its totality by European research (7th PCRD example), covering many topics and mobilising much scientific knowledge. By encouraging the emergence of project consortia that are highly multidisciplinary (even if in fact about two-thirds of projects proposed still maintain a highly sectorised logic), the "Sustainable towns" programme aims at rendering our towns more compatible with sustainable development, by consolidating the body of knowledge, creating new tools for professionals (methodologies for aiding decision-making and assessment, etc.) and helping companies that shape the frame of urban life (engineers, service providers, designers and infrastructure managers, etc.) to better take into account the three dimensions of sustainable development in their service offer.

With a 3-year duration (2008-2010), in 2008 the programme financed 11 projects for a total sum of EUR 8.2 million, of which 30% was granted to companies. This programme's approach is strongly directed toward systemic research, which allows several town dimensions and functions (mobility, habitat, hazards, urban forms, economic activities, urban metabolism, etc.) to be understood in their totality.

On a European level, Urban-net aims to link the agencies financing research programmes in the urban field. On a French level, PUCA is a member of this ERANET. The ANR has been asked to participate in the future Urban-net appeal for projects, which will take place at the end of 2009. Opening the "Sustainable Towns" programme to co-finance projects submitted to this European project tendering procedure could be envisaged.

The ANR "Contaminants, Ecosystems and Health" programme

The 24 projects selected by AAP 2008 benefited from a total budget of EUR 11.2 million, i.e. EUR 450,000 per project. The heart of the programme only marginally concerns climate change. However, as its crossover objective is to enable better basic knowledge of contaminants and their cycles in ecosystems, it integrates a research dimension on the mechanisms causing disturbance to environmental determinants. It must be considered in conjunction with the ANR "Planetary environmental changes" (CEP) programme opened in 2009 for aspects linked to the pathologies generated by climate change.

The ADEME "Outlook and socio-economics" programme

The budget devoted to this programme for the period 2007-2010 is EUR 4 million. The programme has 3 objectives:

- improving knowledge about the players and their strategies, by following the changes to French opinion, values and practices and by analysing the roles of the players and the capacity for change by consumers, companies and public authorities;
- continuing the development of knowledge in the fields of the design, analysis and assessment of tools for public policies of an environmental nature, in order to best adapt them to institutional, economic, social and political changes;
- construction of future macro-economic, sectoral, territorial and technological visions in order to establish public policies and identify the priority research topics on long-term shared and coherent visions.

The major players in climate research and observation

The **ADEME** (*Agence de l'Environnement et de la Maîtrise de l'Energie* = Environment and Energy Management Agency) is a public institution of an industrial and commercial nature, placed under the joint supervision of the Ministry for Ecology, Energy, Sustainable Development and the Sea and the Ministry for Higher Education end Research.

The **Agence nationale de la recherche** (ANR = National research agency) is a public agency that finances research projects. Its objective is to increase the number of research projects from the entire scientific community, financed after being put to tender and evaluation by peers.

The **Bureau de Recherches Géologiques et Minières** (BRGM = Geological and Mineral Research Office) develops knowledge on geochemical reports, especially with regard to underground systems.

The **Commissariat à l'Energie Atomique** (CEA = Atomic Energy Commission), in parallel to its works on nuclear energy, develops a major line of research into New Energy Technologies (NTE).

The **Centre d'étude du machinisme agricole, de génie rural, des eaux et des forêts** (CEMAGREF = National Centre for Agriculture and Forestry, Engineering and Water Management) is particularly involved in analysing man-made pressures on the continental factors of natural interactions with the climate, such as rural areas, surface hydro-systems and forests.

The **Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement** (CEREGE = European Centre for Environmental Geoscience Research and Education) is a Mixed Research Unit with five supervisory bodies: The Université Paul Cézanne, the CNRS, the *Institut de Recherche pour le Développement* (Institute of Research for Development), the Collège de France and the Université de Provence. CEREGE is an interdisciplinary unit that develops research into Earth and environmental science disciplines.

The **Centre de coopération internationale en recherche agronomique pour le développement** (CIRAD = Centre for International Cooperation in Agronomical Research for Development) is involved in assessing gas flows and carbon stockage in tropical ecosystems and agrosystems.

The **Centre national de Recherche Météorologique** (CNRM = Weather Research National centre) ensures the essentioel research activities of Météo-France. Its Toulousaine part is an research unit of CNRS: le Groupe d'étude de l'Atmosphère Meteorologique (Game).

The **Centre National de la Recherche Scientifique** (CNRS = National Centre for Scientific Research) is a main contributor to the major programmes run within the framework of the **Institut**

des Sciences de l'Univers (INSU = National Institute for Science of the Universe) with the support of the **Institut Paul Emile Victor** (IPEV), deflecting many of the problems of impacts of climate change (frequency of extreme phenomena, glaciology, hydrology, ocean acidification, biological systems, human health, etc.) and studying risks and public policies.

The **Centre Scientifique et Technique du Bâtiment** (CSTB = Building Scientific and Technical Centre) works in research subjects on the vulnerabilities of buildings, especially in the face of extreme events, as well as changes to the urban fabric in relation to the climate (comfort, winds, extreme temperatures, precipitations and related pollution, etc.).

The **Fonds Français pour l'Environnement Mondial** (FFEM = French World Environment Fund) is a bilateral public fund created in 1994 by the French Government following the Rio Summit. It aims to encourage the protection of the world's environment via sustainable development projects in developing and transitional countries. It is an instrument of the French policy on cooperation and development.

The **Institut Français de la Biodiversité** (IFB = French Biodiversity Institute) is a scientific interest group (SIG), otherwise known as a federation of institutions (17 members: ministries, research bodies, NGOs and professional associations) uniting their efforts with a view to promoting scientific research into biodiversity. It aims to coordinate, lead and raise awareness of research in the field of biodiversity, in response to numerous requests by researchers and environment and society managers.
The **Institut Français pour l'Exploitation de la Mer** (IFREMER = French Oceanographic Institute) is a major contributor to monitoring and observing the marine sector, essential for analysing its reactivity in climate systems and the carbon cycle.

The **Institut National de l'Environnement Industriel et des Risques** (INERIS = National Institute for the Study of Industrial Environment and Risks) handles the development of certain climate-related hazards: soil and sub-soil stability, impacts on air quality (chronic or in heatwave-type crisis).

The **Institut National de la Recherche Agronomique** (INRA = National Institute for Agricultural Research) leads works on assessing greenhouse gases and carbon stocks in relation to soils, forests and natural ecosystems and through crop methods. These works tackle analyses of the impacts of climate change.

The **Institut National de la Santé et de la Recherche Médicale** (INSERM = National Institute for Health and Medical Research) and the **Institut Pasteur** conduct works on the health impacts relating to infectious epidemiology, especially tropical, heatwaves and coldwaves, exposure to ultra-violet rays and the spread of allergies.

The **Institut National de Recherche sur les Transports et leur Sécurité** (INRETS = National Research Institute for Transport Systems) studies the new most low-carbon motorisation methods suitable to terrestrial transport (fuel cells, batteries, hybrid systems, new engines, etc.).

The **Institut de Recherche pour le Développement** (IRD = Institute of Research for Development) angles its work on the specific problems of southern countries. The institute is called on more and more to play a unifying role in cooperative programmes.

The **Laboratoire Central des Ponts et Chaussées** (LCPC = Central laboratory for Bridges and Roadways) is a major player in the fields of civil and urban engineering. Its main works on adaptation to climate change relate to designing improvements, scaling of works, the production and content of their materials, and the control of major urban and man-made systems, with regard to extreme phenomena, especially those that are water-related.

The **Laboratoire d'Etudes en Glaciologie et d'Océanographie Spatiale** (LEGOS = Laboratory for Studies in Glaciology and Spatial Oceanography) is a mixed laboratory under the supervision of 4 entities: the CNES, the CNRS, the IRD and the Université Paul Sabatier. It is one of seven

laboratories from the Midi-Pyrenees Observatory. It groups together approximately 100 people (including 40 researchers, 20 ITAs, and 30 PhD or post-doctorate students). It is also an SHOM (CMO-Toulouse) reception unit, reporting to the *Service Hydrographique et Océanographique de la Marine* (Marine Hydrographic and Oceanographic Service).

The **Laboratoire des Sciences du Climat et de l'Environnement** (LSCE = Laboratory of Climatic and Environmental Sciences) is a mixed research unit (UMR 1572) between the CNRS, the CEA and the Université de Versailles Saint-Quentin (UVSQ), located over two sites (Saclay and Gif-sur-Yvette). With 250 people, of which 150 are permanent, the LSCE forms part of the Institut Pierre Simon Laplace (IPSL).
The **Laboratoire de Glaciologie et de Géophysique de l'Environnement** (LGGE = laboratory of Glaciologie and Geophysics of Environment) is a Mixed Unit of Research under the double supervision of the National centre of the Scientific research (CNRS) and of University Joseph Fourier (UJF, Grenoble I). He works on study the climate and the composition of atmosphere through the files which the snow and the ice constitute accumulated during time.

Météo-France is the main operator of French meteorological research. Its field naturally opens up to the international sharing of its work and the resulting data and development. One very specific dimension of this consists in the regionalisation of extreme events (for example, within the framework of the Nairobi programme) as well as the hierarchical organisation of data requirements in relation to projected vulnerabilities.

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APPENDIX VII: Initials and Acronyms

ADAGE	Agriculture Durable par l'Autonomie, la Gestion et l'Environnement
ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie
AEP	Alimentation en eau potable
AFPCN	Association Française pour la Prévention des Catastrophes Naturelles
ANR	Agence Nationale de Recherche
AOC	Appellation d'Origine Contrôlée
ARP	Atelier de Réflexion Prospective
CAS	Centre d'Analyse Stratégique
CC	Climate change
CETE	Centre d'Études Techniques de l'Équipement
CGAAER	Conseil Général de l'Agriculture, de l'Alimentation et des Espaces Ruraux
CGEDD	Conseil Général de l'Environnement et du Développement Durable
CIRED	Centre International de Recherche sur l'Environnement et le Développement
CIRE	Cellule inter-régionale d'épidémiologie
CO_2	Carbon Dioxide
COM	Collectivité d'Outre Mer (Overseas Collectivity)
COP	Conference of the Parties
CRE	Commission de Régulation de l'énergie
CREDOC	Centre de Recherche pour l'Etude et l'Observation des Conditions de vie
CSTB	Centre Scientifique et Technique du Bâtiment
D4E	Direction des Etudes Economiques et de l'Evaluation Environnementale
DCE	Directive Cadre européenne sur l'Eau
DDASS	Direction Départementale des Affaires Sanitaires et Sociales
DFCI	Dispositifs de défense des forêts contre les incendies
DGALN	Direction Générale de l'Aménagement, du Logement et de la Nature
DGEC	Direction des Générale de l'Energie et du Climat
DGITM	Direction Générale des Infrastructures, des Transports et de la Mer
DGS	Direction Générale de la Santé
DIACT	Délégation interministérielle à l'aménagement et à la compétitivité des territoires
DMA	Dommage moyen annuel
DOM	Département d'Outre-mer (Overseas Department)
DRASS	Direction Régionale des Affaires Sanitaires et Sociales
GDF	Gaz de France
HCSP	Haut Conseil de la Santé Publique
ICT	Indice climato-touristique
IFM	Indice Forêt Météo
INRA	Institut National de Recherche Agronomique
InVS	Institut National de Veille Sanitaire
INSEE	Institut National de la Statistique et des Etudes Economiques
IPCC	Intergovernmental Panel on Climate Change
LCPC	Laboratoire Central des Ponts et Chaussées

MAAP	Ministère de l’Alimentation, de l’Agriculture et de la Pêche
MEA	Millénium Ecosystem Assessment
MEDCIE	Mission d'études et de développement des coopérations interrégionale et européenne
MEEDDM	Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer, en charge des technologies vertes et des négociations sur le climat
MEIE	Ministère de l'Economie de l'Industrie et de l'Emploi
MRN	Mission Risques Naturels
MSA	Mutualité Sociale Agricole
NAS	National Adaptation Strategy
OECD	Organisation for Economic Cooperation and Development
ONERC	Observatoire National sur les Effets du Réchauffement Climatique
PCT	PlansClimat Territorial
PEER	Partnership for European Environmental Research
PNC	Plan National Canicule
PPRN	Plan de Prévention des Risques Naturels
RGA	Retrait-gonflement des argiles
RTE	Réseau de Transport d’Electricité
SACS	Système d’alerte canicule et santé
SETRA	Service d'étude sur les transports, les routes et leurs aménagements
SNRI	Stratégie Nationale de Recherche et d’Innovation
SOeS	Service de l’Observation et des Statistiques
TCU	Transports en commun urbains
Toe	Ton of oil equivalent
UKCIP	United Kingdom Climate Impact Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
ZRE	Zone de répartition des eaux

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