

National Observatory for the Impacts of  
Global Warming

# Cities and adapting to climate change

Report to the Prime  
Minister and Parliament

2010



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## A word from the President

Would it be an exaggeration to say that the fate of our world today depends on the ability of the cities and megalopolises of the world to rally in the fight against climate change? Demographics alone would be sufficient to provide an answer. The demographic surge that the world has experienced for more than a century which has pushed the global population from 2 billion people in 1900 to 6.8 billion today has been accompanied by an unprecedented exodus from rural areas and has led to significant expansion of cities. We must never lose sight of the fact that although almost half of the world's population are already city dwellers, according to the United Nations some 70% of the population will live in cities or urban areas by 2050. By 2050, the planet will have to sustain a population of 9 to 10 billion inhabitants. It is in cities, therefore, that the effects of the of climate changes will be felt by the majority of people.

To this demographic fact should be added the IPCC conclusions which confirm that within territories cities are often the focus of particularly high levels of vulnerability.

In fact, the complexity of the organisation of large human cities makes them particularly vulnerable to climate hazards, be they in the form of heat waves, flooding or hurricanes.

The heat wave in France in 2003, which caused more than 15,000 unexpected deaths proved how ill-equipped the organisation of public services and current urban lifestyles are for new climate situations. The damage caused by Hurricane Katrina in New Orleans, in the world's most powerful nation, also demonstrated the vulnerability of human societies to the forces of nature when they are designed and built without regard for the environment.

Today, it is our responsibility to design the city of the future by integrating the climate of the future into it. It is a matter of collective security.

Although it is absolutely crucial to monitor how smaller countries face the impacts of climate change, or how little island states can be provided with the means to adapt to predicted changes, it is equally pressing to look at megalopolises. How will cities in developing countries confront the dangers which researchers predict will probably intensify? It is difficult not to feel concern for all those towns in the north and south alike situated in the deltas of major rivers and directly threatened by rising sea levels which could reach 1 metre in 2100. We should never forget that Europe, the continent with the greatest amount of indented coastline on which major ports and cities are located, is particularly affected by this issue.

This report, which was requested by the Advisory Committee of ONERC, presents a summary of the impacts of climate change on cities and in particular an analysis of vulnerability factors as an aid decision-making. It presents the proliferation of ideas and innovative policies implemented in France by local authorities and looks at certain relevant experiences from abroad. As a staging post in the implementation of adaptation policies, this report shows that knowledge still needs to be supplemented in these fields, but that political decision-making is beginning to factor the climate element into the production of development strategies for our territories.

The creation of ONERC in 2001, on the basis of a law voted by parliament, was the first step towards the process of developing an adaptation strategy for our nation. By adopting almost unanimously the framework law of 19 July 2009 for the implementation of the Grenelle Environment Forum, parliament once again demonstrated its willingness to equip France with the necessary tools to confront the challenge of climate change through the medium of a national plan due to begin in 2011.

The expertise on adaptation policy accumulated by ONERC since its creation led to it being tasked to implement and coordinate the vast consultation exercise on the National Adaptation Plan requested by the Minister of State for Ecology, Energy, Sustainable Development and the Sea. This consultation exercise based on the principle of the Grenelle model meant that a huge debate could be initiated involving the whole of the active civil population and its wealth of suggestions.

I hope that this report, which follows on from the report on the cost of climate change in France, can make a useful contribution to a better understanding of these complex changes and eventually to decision-making.

On behalf of the ONERC Advisory Committee, I would like to thank all those people who have contributed to the writing of this report and call on all the stakeholders, elected representatives, entrepreneurs, associations, members of civil society and citizens to use it to extend the debate, enrich thinking and ultimately to make the activities in which we are all engaged more effective

Paul Vergès

ONERC President

# Executive summary

The work undertaken at international level shows that there is agreement on the fact any action we take in the fight against climate change will need to be a two-pronged approach, one that aims, on the one hand, to reduce greenhouse gas emissions (mitigating the effects of climate change) and on the other, reducing the vulnerability of natural and man-made systems to the impact of these changes (anticipation and adaptation).

Cities are particularly vulnerable given their large concentrations of population and the infrastructure and material goods they encompass and they are very sensitive to any sudden change in their natural or socio-economic environments. The way cities adapt to the growth in intensity or frequency of any unexpected climate event will be an important challenge for the future of society.

As part of its mission to examine and make recommendations on the preventative and adaptive measures that should be taken to limit the risks associated with climate change, the ONERC asked research bodies such as the International Centre for research on the Environment and Development and the Institute for Sustainable Development and International Relations to gather information on the vulnerability of cities and to examine the policies of French and other international cities towards adapting to climate change. The information was added to for this report by an overview of French research that looks at the city and how it faces the challenge of climate change.

## **1- Cities of today, how are they vulnerable to climate change?**

The French urban population more than doubled between the 1936 and 2006 censuses, going from 22 million living in cities to almost 47 million. While one person in two lived in a city in 1936 more than three out of four do now. The distribution of people within cities has also changed; for a number of reasons there has been an acceleration in the development of suburbs and commuter belts

These changes are of crucial importance in the evolution of France's vulnerability to climate change and for the design of mitigating and adaptive strategies. It is becoming clearer and clearer that when most climate change policies are implemented, it will be the local level that will be of major importance.

This is already the case for policies aimed at reducing greenhouse gasses to which local authorities can contribute in a very effective way by shaping the city, influencing the transport infrastructure and the built environment and it will also be the case for policies leading to adapting to climate change; the impact of this is primarily felt at local level and depends, to a large extent, on the particular characteristics of the area. The best adaptive policies therefore differ from one place to another and should be specifically designed for that area.

At town and city scale, which is understood here to mean the whole conurbation, is an ideal scale on which to base adaptive plans for two reasons:

- on the one hand because its scale is not too small; towns and clusters are powerful players, they have the means to put ambitious policies into action
- on the other hand they are not on too large a scale; towns are very integrated systems in which the various networks (water, electricity and transport), the economic make-up and the social fabric are embedded and work together.

### ***Impact of climate change on towns***

Climate change may give rise to and make changes to natural rhythms, i.e. events that may have a negative impact on society. Confronted by each of these changes, any given town may be affected to a greater or lesser degree. This vulnerability depends on a number of factors, which include town planning, the local economy, the existence of a defensive infrastructure and household income.

In urban areas the impact of a heat wave will, to a great extent, depend on the infrastructure in place, on the way the town is planned, the type of housing and the way of life. The high temperatures and humidity in Paris during the scorching heat of 2003 were close to those normally observed in Seville during an ordinary summer where the climatic conditions do not have such serious consequences. The built surface in Seville is better adapted to these high temperatures as are the habits of its inhabitants. Urban heat pockets also influence vulnerability. Heat pockets are micro-climates observed in cities where air temperatures are higher in urban areas when compared to the rural areas which surround them. The increase in heat felt in these micro-climates can go from 2°C for a town with 1000 inhabitants to 12°C for a city with several thousand inhabitants and this plays an important role in vulnerability during heat waves.

Climate change may also have positive benefits for health, such as a lessening of mortality due to cold. However, all things considered, it is probable that we are living through a period where health risks are increasing due to heat waves and illnesses transmitted via food and by carriers such as mosquitos, tics etc. In towns a worsening of local pollution is also probable, even though technical transformations in transport have largely lessened this problem.

The slow submerging of some coastlines due to a mean rise in sea levels may cause significant loss of land. This rise has also led to increased threats to human life given the increase in the geographical area that may possibly be submerged by freak tides; temporary increases in sea level created by wind and a lowering of atmospheric pressure during a storm. This effect may be particularly great in urban areas where there are concentrations of population and heritage and which are very dependent on the various transport, energy and communication networks.

Climate change will also have a marked impact on the amount of water there is available. Dependent on the geographical area, there may be an increase in flooding (or a reduction). The main risk factor however, comes from building on areas liable to flood. To this should be added the risk, in built up areas, caused by the capacity of the drainage system which will need to be able to cope with the most extreme weather conditions.

Some soils are clay which means they expand and contract depending on how much water they hold; non-uniform contraction can cause large-scale damage to buildings and infrastructure, this is the result of the contraction and expansion of clay and the projections suggest that climate change will cause an increase in this phenomenon.

Because of temperature rises caused by climate change, demand for winter heating may lower and demand for air-conditioning may increase. This risks occurring in summer when electricity is harder to come by and may alter comfort levels in cities.

At present, the south of France is overall more attractive than the north and the population in the north is slowly migrating to the south of the country; this trend may change, especially as concerns older people because in heat waves in the south, which climate change may exacerbate, they will start to feel uncomfortable. The attractiveness of a tourist destination is also the result of a number of factors, and many of these are linked to climate. Changes in migration patterns due to climate change (temporary for tourists, permanent for residents) will have implications for investment in facilities and buildings.

### ***The distinctive nature of the urban environment***

The most distinctive impact of climate change on the urban environment will be on interdependence. Because cities are very integrated systems, any impact in one sector will interact with other sectors and they should therefore be looked at in a holistically; a sector by sector approach being particularly unsuited to large urban conurbations. Any impact affecting one part of the city will, potentially, indirectly affect all the rest.

Sectoral impacts therefore, cannot be dealt with in a disconnected way; climate change will compound the effects of all the impacts. This compounding of the effects may also magnify them, for example if there are fewer tourists at the same time as the requirement for coastal defences increases. The total impact on the economy might be good deal higher than the sum of the parts. In addition, although each sectoral impact discussed in this report could be managed and controlled if it appeared singly, the management of a combination of simultaneous impacts in multiple sectors, alongside other urban challenges such as a reduction in population, could be a

great deal more difficult to deal with and would come up against the limits of a local authority's ability to cope (in terms of availability of funds for investment, technical ability and competences as well as attractiveness).

### ***Adaptive strategies***

In large part climate change acts by increasing problems that exist already. In the short and medium terms, leaving aside the most obvious extreme events, climate change is rarely the main environmental pressure factor.

A number of measures that aim to reduce vulnerability to climate change first try to reduce vulnerability to the current climate and its changeable nature, especially as regards present extreme events. Climate change works largely by exacerbating already existing problems and adapting to climate change means first of all adapting to the current situation. This would suggest starting with implementing no regrets adaptive measures to improve the existing situation in towns and this might generate useful side-benefits while reducing future vulnerability to climate change.

Other measures could nevertheless become necessary when changes to the climate become more general or when long term measures become necessary. If this becomes the case, then the review of existing vulnerabilities will become insufficient to construct an adaptation strategy and specific measures will need to be put in place to counter new potential threats. This would be the case for large planning schemes which have irreversible long-term implications.

In the short-term it would be useful to examine the origins and evolution of the vulnerability. The intensification of risk that we are presently seeing, which explains the increase in losses linked to natural disasters, has precise causes that are linked to current socio-economic and demographic changes (migration towards areas at risk, lack of land, economic and political costs of measures to reduce risk, over-consumption of water, etc.). Rather than just looking at ways to reduce risk we need to consider the factors that explain the increase in risk and attack their initial causes.

Policies for urban adaptation can be divided into four main categories: changes to land use and town planning (for example avoiding new developments in areas liable to flooding), direct investment especially in defences and infrastructure to manage water, adaptation of the built environment by direct (investment) or indirect (fiscal and regulatory encouragement) action, increasing an area's resilience by economic diversification or measures to help households and businesses in case of impact. In a general way, regulatory measures whether legal or financial should not be overlooked, adaptation is not undertaken only by direct investment.

The costs of adaptation are relatively lower when policies are thought through in advance. For example it is cheaper to build oversized defences than have to enlarge them later, it is cheaper to designate an area as unsuitable for building than have to re-locate those in an already inhabited area. A way has to be found between tardy policies which are costly but are undertaken when there is a sense of urgency and policies which are cheaper and put into practice earlier, but undertaken without any sense of urgency and which therefore require considerable political investment. For policies which anticipate events, taking into account uncertainty about future climate change is vital and there coordination will be needed between the various players.

Climate change being only one of a number of changes cities need to prepare for we also need to take into account other factors. Adapting to climate change will need to be undertaken alongside measures aimed at reducing greenhouse gasses which will create not only areas of common interest but also areas of conflict. When we draw up a policy to reduce vulnerability it will be necessary to work on a very large canvas, taking into account multiple factors and objectives. A decisive factor often arises from positive or negative secondary effects of measures. Beyond the environmental aspects, it is possible that, due to an ageing population, the numbers of those living in towns will decrease significantly in the second half of 21st century, and this will have a significant impact on the urban dynamic. Therefore we will probably need, to manage the problems specifically linked to climate change in a very different context from the one we are in today.

Today it is still impossible to calculate the costs of climate change in cities or to guess at the sums we will need to invest in adaptation. However, the scientific literature makes it clear that adequate adaptation policies, put in place in a sufficiently timely way, could very significantly limit the total impact of climate change.

## **2- Cities today, test beds for adaptation to climate change.**

The adaptation of cities to climate change and the application of practical measures - in particular the development of adaptive strategies - is still relatively recent. For this report we have explored what is being done in to put adaptive policies into operation in cities and looked at a certain number of trends. We have examined the positives and the negatives so as to be able to reply, in part, to the question - How do cities put in place adaptive policies? This study of French towns was undertaken with the aim of drawing up a precise as possible overview of the steps being taken while that of international cities was rather guided by the possibilities of replication so the choice of cities was based on what experiences might be useful in French cities.

### ***The beginnings of adaptation***

Contrary to what some international rumours may suggest the implementation of adaptive measures in cities is still at an exploratory stage. French cities are no exception and it would be true to say that leaving aside a handful of initiatives, urban adaptation remains in embryonic form. French cities are mainly at diagnostic level; identifying unexpected climate events which might have consequences on a number of different sectors. The development of knowledge about risks and the way they are prepared for and faced is only just starting. Of course some courses of action have been identified as being able to contribute to adaptation - such as being greener and the use of permeable materials which allow rain water to seep through rather than run off and these can be implemented. But we do not have global and transversal adaptive strategies yet and climate change itself is not always taken into account as one of the factors. The courses of action suggested are very targeted and are integrated within other plans that are not proper to them; nothing is on a large scale. There is a sense however of a will to move forward and the various initiatives which are emerging from French cities and towns should be seen as the start of a long-term project.

Internationally, adaptation in cities is overall at the same stage. Nevertheless, a few years ago, some pioneering cities each initiated adaptive measures and eight of these have been examined they are: Chicago (United States), Durban (South Africa), Keene (United States), London (United Kingdom), New York (United States), Port Philip (Australia), Rotterdam (Netherlands), Toronto (Canada). These cities have, for the most part, completed the drawing up of their adaptive strategies and they are beginning to implement their relatively ambitious plans. The number of climate change impacts considered is a testament to these ambitions and is much larger than those considered by French cities who have a tendency to limit themselves to heat stress and flooding. The number of measures suggested and the areas and sectors concerned are also a good deal greater. The processes that the international cities we studied have put in place to draw up their plans for adaptation can therefore be a source of inspiration for French cities and some of their characteristics are listed here: stages, stakeholders concerned, space and time scales, tools used and ways of implementing measures.

### ***Barriers and levers***

The study of adaptive measures in French and international cities has also revealed the existence of a certain number of levers and barriers to their implementation that it is important we understand, use or bypass when putting in place effective adaptive strategies. The overturning of barriers and the optimising of the use of adaptive levers seems to be the main challenge for French cities when they start to put measures into action and every level of society should be concerned. We note that all adaptive initiatives are linked to the presence of one or more of the following four situations: belonging to a network, vulnerability demonstrated by a past climate event, proximity to another area that is adapting or the presence of an elected representative that



is committed to sustainable development. Conversely, the large number of barriers; informational (weight of uncertainty, lack of examples), financial, technical (lack of competences in this area), cognitive (perception of risks for example), normative and institutional (sharing of competences over a same area, propensity to maintain the status quo) may explain the small number of initiatives concerned with adaptation. The identification, understanding and taking into account of these barriers is the first stage in the optimisation of the implementation of adaptive measures for local authorities. The fact that these barriers are common to all towns and cities and that their bypassing is relatively difficult and costly means that action needs to be taken at national level.

### ***City policies***

The plans developed by cities for adapting to climate change are just the tip of the iceberg since they contain policies and measures that have just one effect on adaptation. There are a large number of plans, projects and policies which are already competing or could compete to adapt cities to climate change and the challenge is to identify them in order to optimise them. Among them are policies to prevent natural disasters, information measures aimed at making people aware of risks and also instructions on what to do if there is a crisis. Planning documents can provide a framework for adaptation as can the measures that provide protection for the natural habitat as long as they make reference to the climate. Certain cities like Toronto and Paris, for example, have identified some of these measures and have made them the basis for their initial strategy of adaptation. Some measures for the mitigation of effects may favour adaptation such as increasing insulation of buildings.

### ***The need for national support***

In the end, what emerges from the analysis of the projects, plans and adaptive strategies and from the opinion of those who are themselves in charge of implementing adaptive measures, is that France is at an early stage and that cities abroad, with the exception of a few pioneering cities, are not much further on. Although some initiatives were launched around the middle of the decade, their range and state of advancement mean that it is not yet possible to say whether French cities are truly adapting to climate change. These initiatives should rather be seen as the start of a process that will take time, as measures for continuous improvement and as a sharing of experience from one city to another. They also coincide with commitment at a national level and this joint approach is becoming a source of interesting reciprocal contributions; state bodies will facilitate adaptation by local authorities, and towns and cities will become adaptation laboratories from which will emerge determining experiences and lessons which France will be able to use to adapt to climate change.

Adaptive implementation in cities will require input at national level, in particular for the supply of tools, incentives and common methodological frameworks that can be revised and adjusted in the light of information gained from the stakeholders concerned. Some of these tools are detailed in the report: methodological guides, vulnerability diagnostics, cost estimates, climate services, and the sharing of experience and training. The development of these instruments should however, allow for wide ranging freedom of choice among the solutions cities are experimenting with. No adaptive strategy has yet proved itself, whether in its form or in the course of action it is proposing to take, so it would be risky to limit what might be possible by too constraining a framework. A balance needs to be found between the desire to help cities by furnishing them with the tools they require and the need to encourage experimentation; we need to ensure that these tools do not condition, in too restrictive a way, the adaptive choices made by cities.

### **The future - The urban environment and climate challenges**

In response to the need for both tools and experimentation, research into the urban environment based on the sustainable city - respecting the balance between the three main sectors, economic, social and environmental - has, in the last few years, explored a number of fields in a variety of disciplines, whether it be research into technologies, the social sciences, the living world or research into the management of complex systems.

Nevertheless, the taking into account of climate change in cities and the need, in order to put suitable policies into practice, to commission multi-disciplinary studies and research in this field, is a recent phenomenon, but it is one which, because of strong demand from both public and private bodies, will grow in the future.

Most of the work of the research teams that are at present working in this field are financed as part of large-scale research projects whose aim is to give cities the means to assess their vulnerability in the face of climate change and to give them the means to achieve an adapted urban environment.

These research programmes are divided into:

- three transverse research programmes supported by the National Research Agency (ANR) 'planetary environmental changes', 'vulnerability, environment, climate and society', and 'sustainable cities', as well as the Interdisciplinary Programme on the City and the Environment (PIRVE) which is supported by the CNRS and MEEDDM (the National Scientific Research Centre and the Ministry of the Environment);
- five sectoral programmes with particular city and climate components; the Climate Change Management and Impact Programme (GICC) supported by the Ministry of the Environment, the Energy in Buildings research Programme (PREBAT) supported by the Agency for the Built Environment (PUCA), the Research and Innovation in Land Transport Programme (PREDIT) which includes the PRIMEQUAL programme for a better air quality at local level and the Plant and City Programme;
- targeted calls for programmes linked to future trends, modelling and analysis of the climate;
- the URBAN-NET Programme part of the 7th framework project for research and technological development (PCRDT).

France's recent enthusiasm for research in the field of the sustainable city looking at the effects of climate change is now confronted by the ever-growing expectations of public and private stakeholders. The fact is that these stakeholders need, at this very moment, to take concrete action and are expecting from the research an overview of the ground to be covered as well as concrete results in terms of data, methodologies and operational tools.

## **Conclusions**

This report's aim is to offer an examination and summary of the risks and challenges that cities face when confronted by climate change; Urban Heat Islands, flooding risks and the problem of contraction and expansion of clay and the consequences this has on buildings and infrastructure etc. The report underlines the need to act in order to minimise impacts. An inventory French cities' strategies for adapting to climate change informed by examples from foreign cities shows that even if certain cities are engaged in a strategy of adaptation, this remains incomplete and should be better structured. To this end, a certain number of barriers need to be removed, whether they are technical, scientific or financial. Those research programmes that are being undertaken need to provide the information and tools necessary for the drawing up of public policies.

The laws that were enacted as a result of Grenelle environment, which anticipates a national plan for adaptation to climate change in 2011, regional Climate Plans for Air and Energy, and Climate-Energy plans for local authorities with more than 50,000 inhabitants, offer a framework which should accelerate the putting in place adaptive measures in towns and conurbations.

## Foreword

Working Party II of the Intergovernmental Panel on Climate Change (IPCC) has looked at the impact of possible future instances of climate change on sectors and regions and examined the potential for adapting and the responses to impacts from adaptation. Although it underlined the probable increase in risks linked to high temperatures, air pollution and increase in sea levels, the report did not however, comment very specifically on urban areas which are nevertheless very vulnerable as they are home to a large numbers of people and contain concentrations of facilities and infrastructure.

Since its creation in 2001 the National Observatory on the Effects of Climate Change has worked to disseminate information on climate change and the impact this will have on human and natural systems. It has also, in accordance with its mission, sought to encourage research on the subject of France's adaptation to these impacts and, in particular, guiding the inter-ministerial group 'Impact of Climate Change in France, Adaptation and Associated Costs, whose results were detailed in the 2009 report to the Prime Minister and Parliament. In 2010 the ONERC organised a preparatory meeting concerning the drawing up of the national adaptation plan for France which had been part of the Grenelle Environment Programming Law 2009-967 of 3 August 2009.

The national strategy for adaptation which arose from the work of the ONERC was adopted on 13 November 2006 by the Inter-Ministerial Committee on Sustainable Development. This highlighted the need to work using approaches that were transversal, sectoral and by type of area, hence that of the towns and cities. The ONERC's orientation committee wished the 2010 report to look at the question of French towns and cities and how they were facing the major challenge of our century.

This report is divided into three chapters:

**The aim of the first chapter**, which is the work of the International Centre for Research into the Environment and Development, outlines the general framework of problem; it looks at the various impacts of climate change (positive or negative) that might affect town and cities and at the main factors that make them vulnerable to these impacts. It then offers some leads on how to adapt and lessen urban vulnerability and responds to those concrete questions that address the particularities of the city.

**The second chapter**, a contribution from the Institute of Sustainable Development and International Relations, looks at adaptive strategies, starting with an analysis of adaptive measures put in place by several French and foreign cities. This intersecting analysis highlights the levers and barriers to adaptation; it suggests identifying other policies and measures that are not labelled 'adaptation' but which could be included in the adaptive effort or be part of it. Finally some ideas are suggested for the implementation of adaptive strategies in cities.

**Perspectives**, because implementing a policy of adaptation requires, in parallel, a large investment in research and tools, there is an overview of French research in this area.

It shows, on the one hand, the very recent multi-disciplinary work on the theme of the sustainable city, and on the other, projects that are financed, for the most part, as part of larger programmes on a variety of different subjects which allows cities, with the help of the analysis and operational solutions suggested, to reduce their vulnerability and adapt to the effects of climate change.

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**Eight appendices** complete this report:

- Appendix 1: Research programmes
- Appendix 2 : Groups of cities at an international level;
- Appendix 3 : City surveys

- Appendix 4 : National Plan for Adaptation to Climate Change - preparatory consultation
- Appendix 5 : The observatory's activities in 2009 and 2010
- Appendix 6 : Bibliography
- Appendix 7 : Abbreviations and acronyms
- Appendix 8 : People who contributed to drawing up this report

# Chapter 1 Cities today, how vulnerable are they to climate change?

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## Introduction

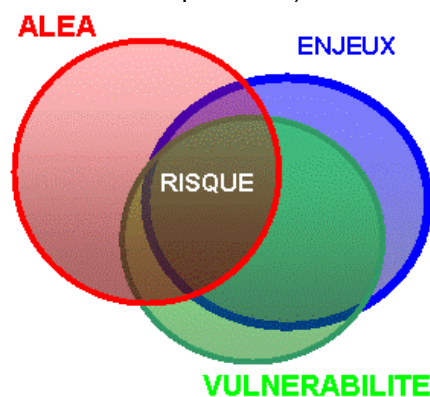
This first chapter will try to frame the problem; it will look at the various different impacts (positive and negative) that climate change may have on towns and cities and the main reasons why these cities are vulnerable to these impacts.

First we need to differentiate between the types of impacts or events that may occur as a result of climate change, the type of risk and vulnerability.

Climate change may give rise to changes in natural rhythms, i.e. events that may have a negative impact on society. These events will have a certain probability, which will alter depending on the event under consideration. The challenge (or exposure) will include everybody and everything that might be affected by the event. For example this might mean all the population, buildings and facilities situated in an area liable to flood.

Faced with each of events, a given city may be more or less negatively affected, depending on the way it has been planned, its history, its economy and its ability to adapt. Vulnerability is measured by the degree to which a city may be negatively affected by this event (this depends on the existence or otherwise of defence systems, the ease with which an affected area can recover etc.)

Finally risk is the result from the three following components; these are the event, the challenges posed by the city and its vulnerability in the face of the event, (see Füssel 2007 for more information on these definitions and their implications).



Reducing the risk requires action in each of the following spheres; the event (and its probability), the challenge and the vulnerability. Lessening the impact of an event and its probability is directly linked to climate change, i.e. encouraging development which creates fewer greenhouse gas emissions. Due to strong climate inertia and current trends in greenhouse gas emissions, it is certain that the climate will undergo large-scale changes during the 21<sup>st</sup> century and that we will therefore have to look at the challenge of vulnerability in order to reduce risk. Acting on these two factors is what is generally known as 'adapting' to climate change.

It is becoming clearer and clearer that when most climate change policies are implemented the local level will be of major importance. This is now the case with policies aimed at reducing greenhouse gasses to which local authorities can contribute in a very effective way (complementing national and international policies) by shaping the city, influencing the transport

infrastructure and the built environment etc. This is also the case for policies leading to adapting to climate change; the impact of these is often felt at local level and often depend on the particular characteristics of an area; its topography, economic structure, the ability of households to adapt etc. The best adaptive policies therefore differ from one place to another and should be specifically designed for that area.

Scaling at town or city level is useful because;

- on the one hand because the scale is not too small; towns and cities are powerful players, they have the means to put ambitious policies into action;
- on the other hand they are not on too large a scale; towns and cities are very integrated systems in which the various networks (water, electricity and transport), the economic make-up and the social fabric are embedded and work together.

Towns are systems that are in a constant state of flux, change being caused and bounded by a number of factors on which it is not always possible to act; demographic, cultural, economic and technological changes etc. These changes affect a city's vulnerability; some will diminish it and others increase it. All public policies act on and influence these trends and an understanding of these is therefore necessary if we want to properly draw up policies for a reduction of vulnerability.

The first part of this first chapter will give a brief overview of the main changes affecting cities, worldwide and more particularly in France. It will also introduce some of the essential facts about the present state of our understanding of climate change.

The second part will examine the various threats to cities posed by climate change as well as how each of these will affect vulnerability.

The third and final part will look at how the vulnerability of cities is changing and current trends and what factors are at the root of this vulnerability and offer suggestions on how to reduce it. This chapter therefore looks at the question of adaptation in an instrumental way (what measures can we take?) while the next chapter will look at adaptation from an institutional and decision-making point of view.

## **An overall view - changing cities and a changing climate**

### **Urbanisation**

#### ***A world view***

The activity undertaken by French cities has been in the context of the major changes affecting all the cities of the world. In order to put the French situation into perspective we will start with a brief analysis of what has been observed around the world. The first thing to report is that we have noted a massive increase in the numbers of city dwellers. While the urban population represented just a small fraction of the world population until the middle of the 19th century, there was a sudden increase in urban numbers at the industrial revolution, first in Europe and then in the rest of the world. Although this transfer is more or less complete in developed countries, in developing countries it is occurring very fast. The threshold of over 50% of the world population living in cities has just been passed and the figures are still rising (unless there is a note to the contrary, all figures quoted are from the United Nations, 2008). Today there are 3.3 billion city dwellers out of a total population of 6.7 billion. Four fifths of North Americans and 90% of Belgians, Islanders and Israelis live in towns (see, for example, Huriot and Bourdeau-Lepage, 2009 for a more detailed discussion of this point). The proportion of urban dwellers is lower in the less-developed countries but is still about 44% of the population and is growing constantly; it is estimated that 50% of the population will be urban by 2020.

When this is viewed in the light of an increasing world population, this increase in urban dwelling is leading to a veritable explosion in numbers living in cities world-wide. on the planet every day, there are 190,000 more urban dwellers. This is the equivalent of the population of the Lyon conurbation added every week. The speed of this growth is matched nowhere in history; It took 130 years for London to rise from one million to 8 million inhabitants but it only took 45 years for Bangkok, 37 for Dakar and 25 years for Seoul to see the same increase in population (UN-HABITAT 2004).

From now until 2020 almost all world demographic growth will take place in the countries of the South, their urban populations growing from 2 to 4 billion out of a total population which will increase from 5 to 7 billion. Housing 2 billion inhabitants means building the equivalent of seven new cities of 10 million inhabitants every year, i.e. seven times Shanghai or Jakarta or ten times London.

What characterises these cities is a concentration of population and goods in a reduced space; when a city functions correctly it draws in businesses who wish to take advantage of spillover economies. In economic terms this designates a growth in productivity caused by geographical proximity. It might for example mean the geographical proximity of businesses in the same sector, in such a way as to have access to specialised products or experts that could not be found without this concentration (for example concentrations of banks in financial districts) or the geographical proximity of businesses in different sectors where the diversity of skills and experience encourages innovation. Empirical research confirms that spillover economies are substantial; average increases in productivity of between 4% and 20% have been measured for each doubling of population. These effects are particularly noticeable in certain industries and especially in certain services (Rosenthal and Strange 2004). The existence of cities is very largely explained by spillover economies (Duranton and Puga 2004).

**Box 1: Density and disasters (Lall and Deichmann 2010)**

The distribution of this growth between cities is not at all homogenous. It is expected (United Nations 2008) that the number of very large cities (conurbations of over 10 million inhabitants, like the Paris conurbation for example) will grow from 19 to 27 by 2025, however, two thirds of these will only experience modest population growths (less than 2% a year). At present these represent 9% of the urban population and by 2025 will represent about 10%; but by 2025 almost half of new urban dwellers will be housed in towns of less than 500,000 inhabitants, towns which already, today, are home to over 50% of the world urban population.

Another important fact to note is that the present growth in cities is more and more land hungry (Angel et al. 2005); average urban density (the number of inhabitants per square kilometre of built surface) has been diminishing for two centuries due to improvements in modes of transport. Therefore in the past decade, the average density of towns in developing countries has lessened by 1.7% per year and that in developed countries by 2.2% per year (for more information see the notes to Chapter 4 of UNFPA 2007). If current trends are maintained during the next 20 years the built surface (green areas therefore excluded) in towns of 100,000 inhabitants and more, which covered in 2005 an area the size of Morocco are set to triple. The built surface of cities in developing countries with more than 100,000 inhabitants will be multiplied by 3 and will reach 600,000 km<sup>2</sup>; (equivalent to the surface of France) while the built surface of cities in developed countries will multiply by 2.5 which will take these to 500,000 km<sup>2</sup> or the surface of Spain.

The growth in the urban population will be accompanied by a growth in populations resident in areas at risk from natural disasters. Historically (Lall et Deichmann, 2010), large numbers of towns have been built in easily accessible areas or areas that are rich in natural resources; by a river, by the sea, regions with fertile volcanic soil etc. These types of geographical area are often associated with a high risk from natural catastrophes; flooding, cyclones, volcanic eruptions etc. In a similar way low lying coastal areas exposed to cyclones and coastal flooding cover 2% of the world's surface but are home to 10% of the world's population, and, importantly, 13% of the world's urban population (McGranahan et al. 2007).

### **A French view**

In France the urban population grew greatly in the sixties and continues to grow today, but more slowly. The density of towns has followed a similar pattern, lessening greatly in those same sixties and similarly continues to lessen today, but at a more sustained pace.

Put more precisely, the urban population of France more than doubled between the 1936 and 2006 censuses, going from 22 million to almost 47 million citizens (Unless specifically stated all

the figures which follow come from Fanouillet and Madinier 1996, Baccaïni and Sémécurbe 2009, Bessy-Pietri 2000). This growth occurred in several stages; between 1936 and 1954 there was a relatively slow period of growth, a direct consequence of the Second World War. There was a second phase between 1954 and 1968 with a massive increase in the number of citizens, caused mainly by the rural exodus, the baby-boom and immigration. From then until now, the rate of growth has greatly lessened and the rate has stabilised at 4.5% since 1968. At the present time, we are therefore witnessing an increase in the number of citizens but this is at a more moderate rate. Finally although one person in two lived in a town in 1936 more than three out of four live there now.

This growth in urban population which, as far as we can tell, is set to continue in the short term may alter if we are looking more long term. It is possible that the French population will start to decline in about 2050 since a lower birth rate and an ageing of the population will naturally lead to a lessening of the urban population in a more or less short space of time. This possible reduction of the population depends on a number of factors, in first place being future immigration policies.

At the present time, the number of citizens is growing, so the demand for housing is too. However, this is growing faster than the number of citizens and for a number of years we have been witnessing a reduction in the number of people per household (Jacquot 2006). Although between 1968 and 1982 this was more of a factor in town centres, the commuter belts being less affected as they attracted more families but since the nineteen nineties the reduction in household size has affected these areas just as much. A little behind town and city centres the commuter belts are starting to age.

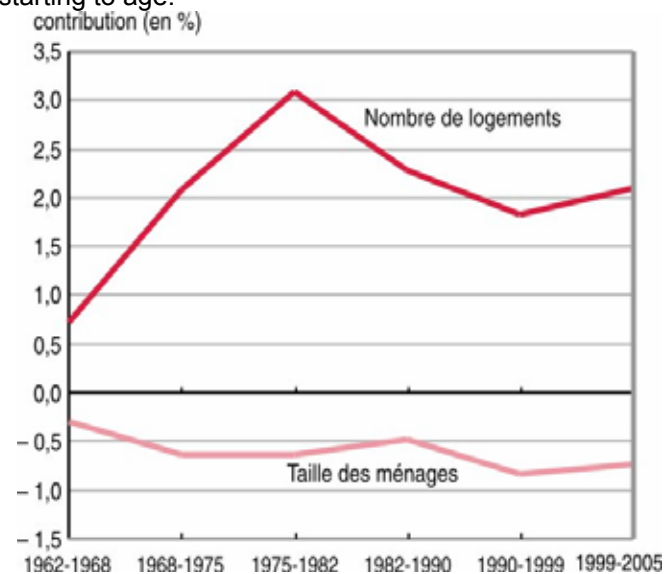


Figure 1: 1: demographic growth in an area can result in two distinct phenomena; an increase in the size of households in existing housing and/or an increase in the number of homes. The graph shows the changes in the two components in commuter belts since the start of the sixties.

Source: Baccaïni and Sémécurbe 2009

Spurred on, not only by the diminution in the size of households but also by a number of other factors (lowering of the price of travel in individual vehicles, cultural changes etc.) the population density in towns and cities has decreased. The amount of urban surface per inhabitant which remained relatively constant from 1936 to 1962 began to grow from 1962. Added to the increase in the urban population this lessening in density has led to a large expansion of the total urban surface of France since the sixties. In the 6 years between 1962 and 1968, 1502 rural authorities with a total of area of 20000 km<sup>2</sup>, became urbanised. This led to the outer limits of commuter belts of conurbations widening very fast until the start of the seventies. Since then, these advances have markedly slowed and we are now seeing a population of commuter belts which is tending to fill them.

The construction of detached houses is the motor that is changing land use in these commuter belts. During the last decade, irrespective of the type of space, the construction of detached



houses has progressed much faster than the construction of blocks of flats; + 23% between 1992 and 2003 against + 13 % for blocks of flats.

The spread of people within cities has also changed; for a variety of reasons (high property prices, older homes in town centres, creation of pools of rented accommodation away from the centre, the desire for home ownership etc.) there has been accelerated development in the suburbs and commuter belts. This has caused almost two thirds of local authorities of more than 50,000 inhabitants to lose population to the periphery; the eight largest of these being: Paris, Marseille, Lyon, Toulouse, Nice, Strasbourg and Bordeaux. Since 1975 it has been rural communities on the periphery of large conurbations that have grown the fastest. This urbanisation of the periphery, which had started to lose momentum, has begun to take off again, but at variable speeds from one region to another.

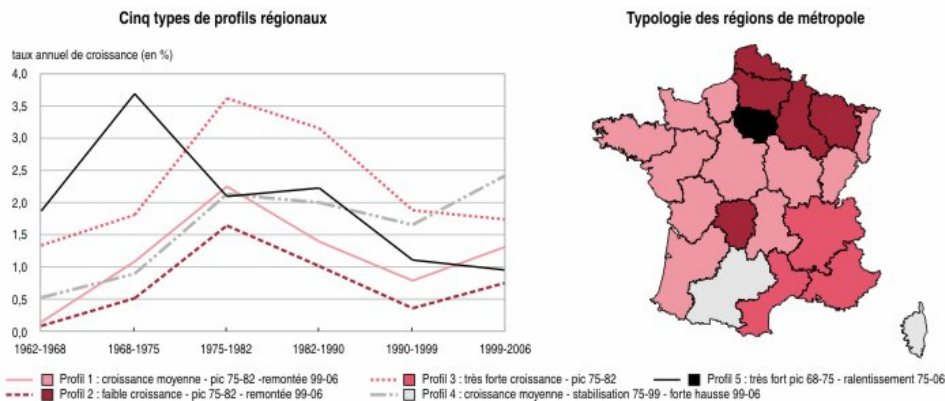


Figure 2 2: The different regional development profiles for the rate of growth in commuter belts. There are three regions in Profile 3 (Rhône-Alpes, Provence-Alpes-Côte d'Azur (PACA) and Languedoc-Roussillon). Here demographic growth on the periphery is relatively strong and peaked between 1975 and 1982. Source: Baccaïni and Sémécurbe 2009

In conclusion, the type of urban growth observed in France has led to a certain number of problems, especially environmental, as any change in land use is generally irreversible, it being only rarely that land is returned to more natural uses. The slicing up and fragmentation of natural habitats (hampering the movement of certain animal species), caused by homes and by the transport infrastructures that are a result of this spread of housing, is having serious effects.

In addition, these trends (there are more details in the second section) lead to an increased risk of flooding to other urbanised parts of the catchment area (Trocherie et al. 2004). Urban areas, which are often impermeable and prevent rain from filtering into the soil, lead to run off which can be a major contributory factor to flooding. At the same time, more and more households are living in areas liable to flood, areas that used to be uninhabited because they were outside the conurbation. The present trend towards urbanisation is therefore leading to an increased risk of a natural disaster.

### Plusieurs schémas de développement urbain

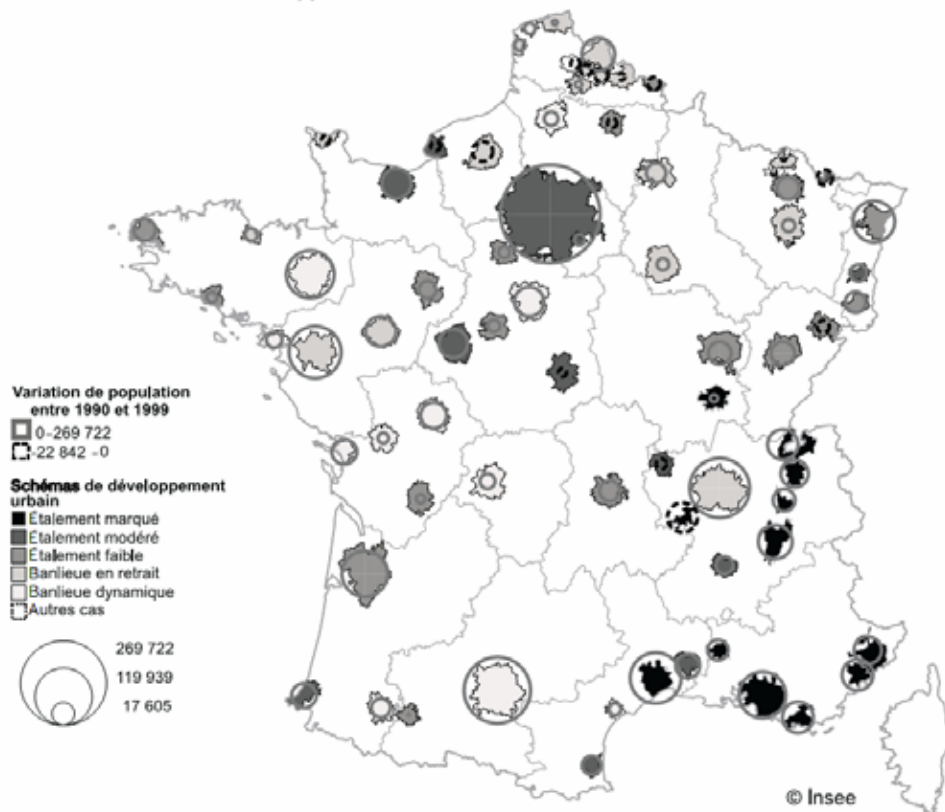


Figure 3 3: the 73 urban areas of more than 100,000 inhabitants in 1999 made up of a town centre, suburbs and a commuter belt. Those urban areas which have no suburbs were not included in the study (this was the case for Vannes). Source: Bessy-Pietri 2000, taken from the 1999 census

In line with trends observed since 1990, [...] those areas when there has been a change of land use have risen from 82,000 hectares (ha), a relative increase of 3%. This has been to the detriment of agricultural land, with 76,000 ha taken and of the natural habitat with 10,000 ha used. The extension of the urban fabric and its infrastructure explains this and there is also a growing fragmentation of semi-natural habitats. The influence of the growth of the rail and road networks with large expropriations has been noteworthy, having increased at a rate of 1,300 ha/yr over the period 2000-2006. In addition to its surface area this type of ground use has shown the largest growth over the period (+19%).

Although an important factor in land use change, the continuous and cumulative process of urban spread seems to be little understood. Use of the Sitadel data on planning permission shows a picture of growing commuter belts. In the 71 main metropolitan areas, the average distance from the city centre to new building was 13 km over the 2000-2008 period after having stabilised at around 11 km during the period 1980-1990. Due to the development of blocks of flats and houses, the present rate of the growth of urban spread is once again closer to that observed at the end of the eighties. Although not all urban areas have the same rate of growth, we should note that it is cumulative over time and its effect on space, especially, is quasi-irreversible.

Certain spaces are particularly sensitive to a change of land use because of their ecological and landscape richness, high population numbers already present, or the risks that weigh on the existing population. An example of this is the coast which is under heavy pressure. With a particularly rich habitat, the coast already has a population that is 2.5 times greater than that of cities and this is widening with the built space in m<sup>2</sup> more than three times that of the national average in 2006.

Change of use in areas liable to flooding is equally a worry; from 1999 to 2006 the increase in the number of homes reached 8%, which is the same level as that in areas not at risk. Whether it is the coast or areas liable to flood, the situation is obviously different depending on the region or area but it engages our attention all the more because these spaces are particularly likely to be affected by climate change. Over the last fifty years we can see a trend to greater levels of flood damage because of the higher exposure to risk.

*Box 2: Changes in land use (SOES 2010)*

### **Urbanisation scenarios for the next few decades**

There are few scenarios which examine the evolution of the French city. Despite the inertia of urban systems which will largely fix the way towns develop for the next several decades, existing studies, such as the MEEDDM research into future trends, state that there are differentiating factors and point to some possible changes.

First the balance between the large cities and smaller towns is shifting to the former and economic activity is in decline in the smaller towns. We can therefore posit that in the next few decades there will be a France where there are economic and population gains in the larger cities to the detriment of the smaller towns. We are also witnessing towns entering into regional networks.

If this movement continues, it will tend to increase the trend towards commuter belts, social and economic differentiation between different neighbourhoods and, as is explained below, vulnerability to climate change.

Within the conurbations, there is a tendency to poly-centrism with the appearance of centres of secondary employment and the coming together of towns on the periphery into large conurbations. However, the continuance of this trend and its consequences for the structure of the city remains uncertain and depends to a large extent on the growth of transport networks.

Another differentiation factor between possible scenarios is that the current peripheral development could continue on the basis of a growing use of individual means of transport, or could be transformed by a re-densification of the periphery, the distances travelled finally reaching saturation. This question is mainly linked to the choice of future means of transport and, more particularly, a choice between increased use of public transport - densification factors - or, on the contrary, developing electric vehicles. These uses of these vehicles would mean that we could combine commuter belts with a reduction in greenhouse gas emissions, with as a consequence large increases in the consumption of electricity which will need to be produced by nuclear power stations or power stations with CO<sub>2</sub> capture and sequestration.

Finally these questions are largely dependent on changes to life-styles (e.g. teleworking, individualisation of work), economic changes (e.g. the development of e-commerce and e-services) and interaction with rural areas (agricultural and natural).

### **Foreseeable changes to the climate during this century**

Changes in towns will occur as the climate itself is changing fast. The changes to the climate that we can expect during this century and beyond have, to a large extent, been detailed in previous ONERC reports and these aspects will not be presented here in detail.

Information on changes in the climate of cities can be gained from international and national climate projections. It is not possible to predict future emissions and so climate projections have been based on scenarios, i.e. possible changes to global emissions in 2100. During the nineties the IPCC therefore built SRES emissions scenarios such as, for example, scenario A2 which presupposes a rapid rise in the world's population and economic growth, the absence of a climate policy and large increases in greenhouse gases. By basing themselves on the results of two climate models and this emissions scenario, Hallegatte et al. (2007) researched the climate equivalents of some large European cities at the end of the 21st century and based their calculations on temperature and precipitation. Using this methodology, in the scenarios in Figures 4 and 5 (the English and Météo-France models respectively) we can see that by 2100 the

climate in Paris will be comparable to that in Cordoba at present or that of Bordeaux. The climate in Marseille would also be close to that of Cordoba or to a Greek climate. This approach allows us to imagine what sort of adaptation might be required for Paris to enable it to face the climate that awaits it. However, this approach can be faulted for its very simplicity, since between now and 2100 the city will have faced definite changes, forced on it by demographic changes or other socio-economic factors, which in their turn will play a part in the micro-climate of the conurbation.

Figure 4 4 : Climate equivalents in 2070, Hadley Centre model, scenario SPES A2 Hallegatte, Ambrosi, Hourcade (2007))

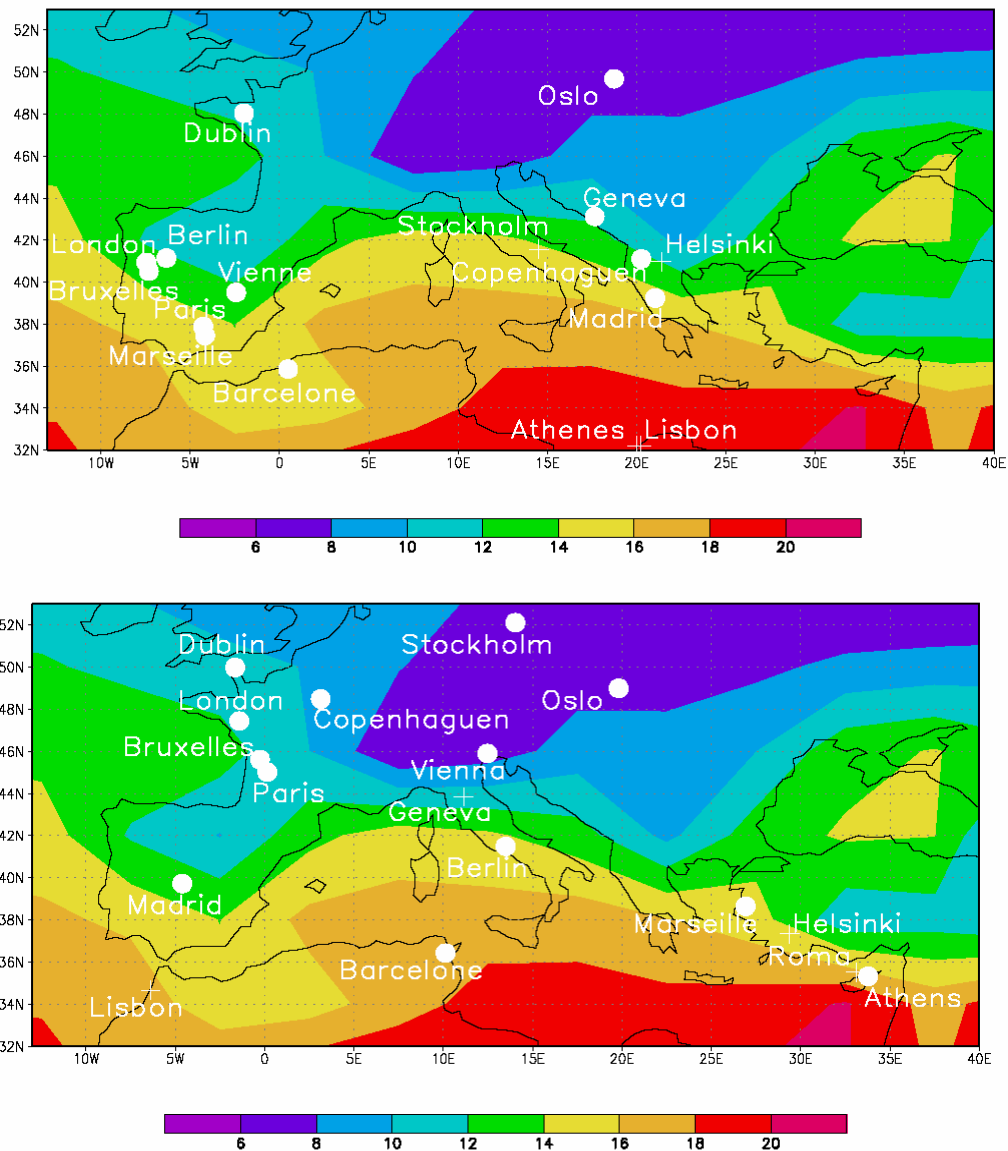


Figure 5 5 : Climate equivalents in 2070, Météo-France model, SRES A2 scenario Source: Hallegatte, Ambrosi, Hourcade (2007))

## Cities and the risks linked to climate change

This section will briefly look at the different impacts that climate change may have on the urban environment. These impacts are very dependent on context, in particular the geographic zone

and the way the city and the society under consideration function. Although we will briefly touch on impacts that may affect cities in other parts of the world we will concentrate on French cities.

Few climate change impacts are specifically urban and most are also felt in rural areas. However some impacts like heat waves, because of the heat island effect (described in section 2.1) will be particularly felt in urban areas. Some impacts will be the same whether in rural or urban area but will call for a particular response in cities. For example the management of natural risks in areas with high population densities cannot be undertaken in the same way as in those with a low population density. The most distinctive impact of climate change on the urban environment will be on interdependence. Because cities are very integrated systems and very dependent on networks (water, electricity, transport, communications), any impact in one sector will interact with other sectors and they should therefore be looked at in a holistically; a sector by sector approach being particularly unsuited to large urban conurbations.

Most of the figures and data are taken from the work of the IPCC (IPCC 2007) and from the ONERC reports Climate Change - Costs of Impacts and Ways to Adapt (ONERC 2009) and Inter-ministerial Group on the Evaluation of the Impact of Climate Change, the Cost of Damage and Adaptive Measures in France (ONERC 2009 ii).

We should remember that knowledge concerning future impacts from climate change is very limited and it may well be possible that impacts we have not anticipated may appear during the course of the century or that impacts may be less serious than we thought.

### The urban micro-climate

Towns and cities create micro-climates, due especially to the existence of urban heat islands (UHI). These designate higher air temperatures, from regular observations close to the ground, in urban areas as compared with the rural areas that surround them. According to several studies looked at by Oke (1987), the maximum intensity of a UHI can go from 2°C for a town of 1000 inhabitants up to 12°C for a city of several million inhabitants.

For example, during the heat wave of 2003, the temperature differences were of 8°C between the centre of Paris and certain rural areas (Figure 6) In practice, the difference in temperature between the centre of a city and rural areas depends on the architectural characteristics of the city (such as its spread, its density and the height of the buildings) and the characteristics of the rural area used as a control. The types of urbanisation described in Section 1 have an influence on UHIs

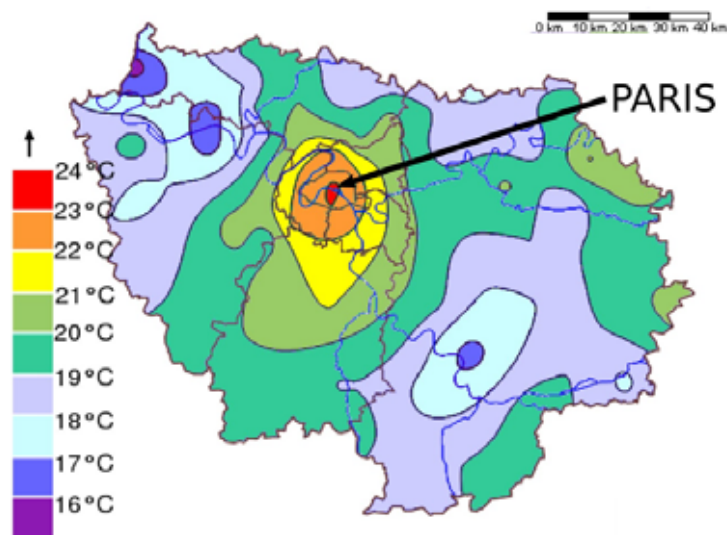


Figure **Erreur ! Signet non défini.** Minimum temperatures (night) in Paris and around Paris during the heat wave of 2003. We can see differences of up to 7°C created by the urban heat island effect. Source: V. Masson, G. Pigeon, A. Lemonsu, C. Marchadier CNRM, Météo-France

A UHI has a recurrent daily variability and its intensity is generally stronger at night. It intensifies or forms progressively during the night time cooling period and is a response to a rate of cooling that is slower in the more built up areas than in the periphery. In the majority of cases, the maximum attained by a UHI seems to be a few hours after the sun has set, often the UHI diminishes rapidly after sunrise.

The intensity of the UHI diminishes as the wind rises. We note that a UHI disappears when wind speeds are over 11 m/s. When there is a moderate wind (3-6 m s<sup>-1</sup>), the temperature field is shaped like an extended plume depending on the wind direction.

The intensity of a UHI diminishes when there is increased cloud. Clouds act by modifying the night-time radiative cooling during which a UHI is formed. The influence of seasons not just on cities in temperate climates but also in other types of climates (Mexico and Cairo for example) has been studied. It has been shown in these studies that UHIs are more frequent in summer and that they are weaker and less frequent when there is rain. Nevertheless, the maximum intensity of UHIs (the difference between temperatures in town and the rural areas that surround them) is the same whatever the season.

The heat island, measured as the difference between the surface temperature of air in the heart of a city and in the rural areas around, is on average 4°C in New York during the night. Generally the greatest divergence in temperatures are found between midnight and 5 in the morning. The map of air surface temperatures in and around the city at 6 in the morning on the 14 August 2002 (the morning of what was to be one of the hottest days of that summer) shows that the city was warmer than the suburbs by several degrees and the difference was as much as 8°C when compared to rural areas less than 100 km from the city.

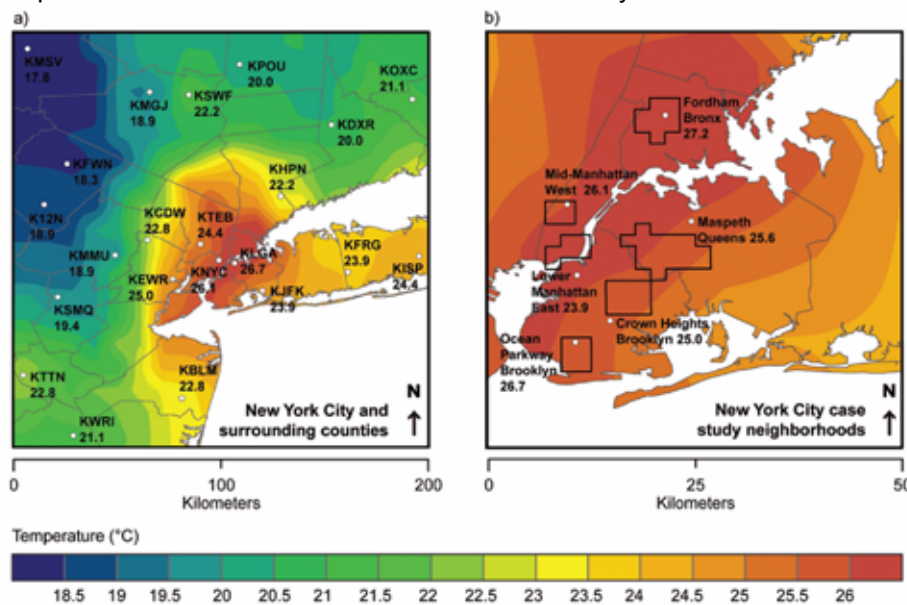


Figure 7 6: Urban heat island in New York on 14 August 2002 at 6 in the morning (Source: Cynthia Rosenzweig et al., "Mitigating New York City's Heat Island: Integrating Stakeholder Perspectives and Scientific Evaluation," Bulletin of the American Meteorological Society 90, No. 9 (2009): 1297-1312)

Three possible strategies for the mitigation of heat islands are the planting of trees, green roofs and high albedo surfaces (i.e. that reflect at large part of the sun's rays rather than absorb them). According to the simulations from the MM5 meteorological model the influence of plants on the climate is more important than albedo on built surfaces. The most efficient way of reducing temperature consists of maximising the quantity of plants and trees in a city by a combination of wooded areas and green roofs. When this strategy is applied to the simulations, the urban air temperature is reduced by 0.4 °C on average and by 0.7 °C at 15.00, the time of day when there is the highest demand for electricity. The simulations show that there could be reductions of up to 1.1% at 15.00 in certain neighbourhoods of Manhattan and Brooklyn, mainly because there are more areas where trees can be planted and green roofs introduced. In Manhattan, the main

temperature lowering would come from the greening of roofs while in Brooklyn a more balanced combination of the two strategies could be employed.

Studies of urban heat islands in several towns and cities with different urban geometries show a range of effectiveness, in the order of  $-0.2^{\circ}$  to  $-3.6^{\circ}\text{C}$  on average over the whole day, of measures designed to lower temperature. The results of the New York study are at the extreme end of the range, mainly because of the relatively high number of built surfaces, the relative scarcity of surfaces on which to apply mitigating measures and taking into account the constraints of infrastructure and the major influence of the coastal climate which generates sea breezes over a large part of the city.

*Box 3: Mitigating New York's urban heat island (Roseinsweg et al 2009)*

## **Risks to health**

Climate change will have some health benefits, such a drop in mortality due to the cold, as winter temperatures rise. However, overall, it is suggested that without suitable adaptive measures, health risks due to a recrudescence of heat waves, especially in southern, central and eastern Europe and a greater incidence of illnesses transmitted via food and by vectors (mosquitos, tics etc.), will increase.

## **Heat stress**

The 2003 heat-wave (see figure 8) caused an increase in mortality of 14,800 persons in France between the 1st and 20th August, mainly of older people; in all, 82% of deaths attributable to the heat wave were of persons aged 75 and more. This heat wave cannot, of itself, be attributable to climate change, as it could have taken place in a climate that had not been modified by man. Nevertheless, figure 8 (b) shows just how exceptional this would be in a non-modified climate. Climate change made this event more likely and will have a tendency increase this probability still more in the future, until it becomes a recurrent feature (Figure 8(d)). It will become normal summer weather by the end of the century according to some climate scenarios if there is no world policy on the reduction of greenhouse gasses (GHG)

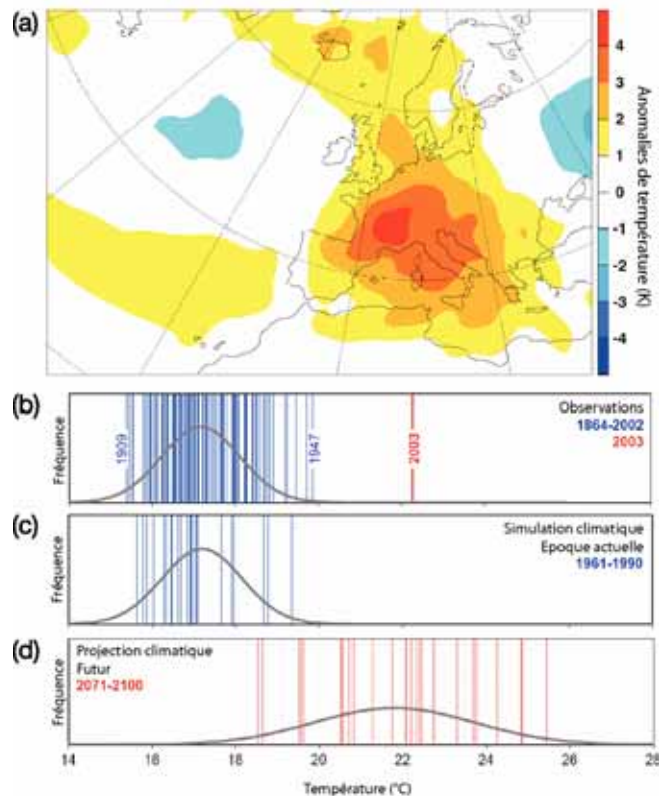


Figure 7: Characteristics of the 2003 summer heat wave; (a) temperature anomalies for June, July and August in comparison with 1961-1990; (b-d) June, July and August in Switzerland; (b) observed between 1864 and 2003 (c) simulated with the help of a regional climate model for the period 1961-1990; (d) projected for the period 2071-2100 using the SRES A2 scenario. The vertical lines in the charts (b-d) show average temperatures on the surface in summer for each year of the period under consideration; the derived Gaussian distribution is shown in black. Source: IPCC 2007.

Whatever the emissions scenario, the projections from the climate models show an increase in average summer temperatures and the variability of temperatures from one year to another; all of this carrying an increased risk of summer heat-waves. Cities are particularly vulnerable because of the existence of urban heat islands. The ageing of the population (see Section 1) obviously reinforces vulnerability and increases health risks.

The impact on health will depend very much on the infrastructure in place, planning policies, types of homes and lifestyles. It can be seen that the high temperatures and humidity in Paris during the scorching heat of 2003 were close to those normally observed in Seville during an ordinary summer where the climatic conditions do not have such serious consequences. This is due to a built environment that is better suited to Seville's high temperatures and to the habits of the population (closing shutters so that heat cannot enter during the day, inactivity when temperatures are at their highest, the habit vulnerable people have of rehydrating themselves properly and avoiding activities that might put them at risk etc.).

The beneficial effect of traditional housing in the fight against the risks associated with heat-waves has also been shown (Shashua-Bar et al. 2009) but this type of housing is in decline and is being replaced by modern homes that are more alike all over the planet including in France.

The policies for reducing vulnerability will therefore need to include adapting building techniques in new builds and neighbourhoods and - eventually - altering existing buildings, in order to meet these sorts of events as well as introducing alert and safety plans.

Adapting homes and planning means, on the one hand, promoting better heat comfort levels in buildings and streets (better protection from heat penetration) and, on the other, fighting the



presence of urban heat islands (putting in place of road surfaces and roofs that reflect solar rays, greening the city (Gill et al. 2007) etc.). One part of this adaptation will need to be undertaken at the level of the building (through the type and position of glazed surfaces for example); another will need to be at conurbation level, when making planning choices (width and orientation of streets, surfaces in parks and garden etc.). We should note that architecture and planning have been very regulated and we should therefore not expect spontaneous changes by professionals in the field or by households. It will probably necessary to change standards, regulations and practices. Municipal authorities will have a crucial role to play in this area, in cooperation with the other national and regional administrative bodies. In the academic world, questions linked to choices for adapting cities to heat stress are at present the subject of very lively research (see Perspectives).

### ***Extensions to ranges of illnesses***

In Europe some studies show that climate change may be the cause of the extension northwards of the range of several illnesses, notably Lyme disease (a parasitic illness transmitted by bites from ticks) and Leishmaniasis (a parasitic illness transmitted by mosquitoes and where dogs are the main carriers). This last illness is, at the moment, present in the Mediterranean region. In the same way, because of changes in the distribution of plant species, climate change may have an impact on the occurrence of certain allergies caused by pollens. However, the results as a whole remain very uncertain. The re-emergence of endemic malaria in Europe seems, in any event, seems to be very unlikely (this was rampant in former times in Europe, on a large scale, and has been almost eradicated on the continent during the 20th century thanks to progress in medicine, disinsectification and the drying out of marshes etc.).

However, the opposite is true in developing countries which are particularly vulnerable to an increase in the range of several illnesses and especially malaria. This extension may impact on European countries by increasing the possibility of locally importing these illnesses. Finally we also need to note that higher temperatures may have an impact on food security, the risk of salmonella being, for example, particularly sensitive to higher temperatures.

These impacts have, in themselves, no urban component but concentrations of populations in cities make the risks greater.

### ***Lessening of access to water resources***

Water stress will probably increase in central and southern Europe and especially in southern France. At European level, the percentage of areas suffering from intense water stress will probably increase by 19 to 35% in the twenty seventies and the number of people in danger from 16 to 44 million (IPCC 2007)

To evaluate the impact of climate change on the hydrology of the Seine and its basin, a study was undertaken looking at a number of climate change scenarios on two hydrological models. It concluded that in all probability, the humidity of the soil and minimum water flow would diminish in summer due to climate change. Changes to flooding patterns are much less certain and the simulations show cases of increases as well as decreases, linked to a large dispersion of changes in precipitation (positive or negative according to the climate simulation.)

Water quality is, at present, a major concern for those managing water in the Seine basin because of the large pressures exerted on it by human activity. The diminution in summer flows is obviously harmful to this quality (from a biogeochemical point of view, i.e. as concerns nutrient content like nitrates, eutrophication and oxygen).

A number of the systems' key factors may modify the impact of climate change on the hydrology and water quality of the Seine. Farming, in particular, will continue to expand during the next 50 years, in response to climate change but also to its own socio-economic dynamic. The changes resulting from farming and agricultural practices will probably have repercussions on the hydrological and biogeochemical functioning of the Seine river system, altering especially the amount of water available and there will be an effect from the nitrogen cycles in the soil and their

evacuation into the water tables. The changes to flows will certainly also affect the management of the Seine's large dams and reservoirs, i.e. the volume and the timing of the withdrawal or discharge of water from streams that feed these works. Finally demography, urbanisation and water treatment techniques will alter over the period of the simulated climate changes which should limit occasional discharges into the water network and reduce the deterioration of the water quality caused by reduced flows.

*Box 4: Influence of climate change on the hydrology of Seine basin ( Ducharne et al. 2003)*

Beyond the quantitative problem (reducing of the quantity of accessible water), there is a qualitative one; a lessening of water resources generally also lowers the quality of the water, since the dilution of polluting substances takes place in a lesser volume.

This impact is not particularly urban but it will be felt in towns and cities and especially in southern France where already, at present, there is a certain amount of water stress. Difficulty in accessing water will be how the impact will be felt and this will make its use less sustainable. Mitigation policies will consist in reducing the demand for water and the pollution of the resource.

### ***Air quality***

Climate change may cause a worsening of local pollution, in particular in cities where there are large concentrations of certain pollutants. Indeed some pollutants, such as ozone, are created by heat and sunlight acting on certain exhaust fumes. The increase in uninterrupted sunny weather in summer could also favour an increase in episodes of this sort of pollution, a risk which will be moderated dependant on whether the context is an increase or decrease in automotive transport and greater or lesser emissions from vehicles in terms of exhaust fumes and emissions of volatile organic compounds.

In the same way as it impacts on water resources, climate change will act to accentuate pollution and this impact will be especially felt by those areas already suffering from high levels of ozone pollution. However, climate change by lessening the demand for heating might also contribute to the lessening of certain emissions. The main adaptive policies should consist in trying to immediately reduce pollution (lessening of road traffic, replacement of older cars, creation of Priority Air Action Zones (ZAPA), lowering of industrial emissions) and its impact on the population (giving out information on pollution levels, disseminating information in a suitable form, monitoring those at risk etc.).

### ***Migration and tensions created by environmental impacts***

This section deals with the indirect impacts of changes to the climate that may not necessarily occur in France. These may be tensions within a country or between countries caused by the environmental impacts of climate change or from large-scale migrations caused by rising sea-levels, for example. This may be particularly true in developing countries where the rural exodus is accelerating due to the lowering of productivity of livestock farming in the countryside. The existence of this type of impact is not very likely in France, but we should not exclude the possibility out of hand.

### ***Risks caused by natural disasters***

In France, the most common natural meteorological disasters are flooding, storms and the expansion and contraction of clay soils. As concerns flooding we need to distinguish between coastal flooding, which is likely to increase due to rising sea levels, and inland flooding, where the risk will vary as a consequence of changes to patterns of precipitation and the flow of watercourses. Here too the impact is not just on urban areas, but the high concentrations of population and heritage as well as the very integrated way the urban economy is organised

makes these risks particularly difficult to manage in an urban environment. Because of the growing urbanisation of France, especially in areas at risk (see Section 1), these risks have greatly increased in the last few decades.

### ***Drowning of coasts and coastal flooding***

Rising sea levels, on the one hand, will have consequences in terms of material losses due to the slow submerging of the coast and on the other, potential consequences on terms of a threat to human lives from the increased risk of coastal flooding following storms.

Due to the melting of the ice-cap, the progressive receding of the ice in Greenland and the Antarctic and especially dilatation due to the warming of the sea, it is estimated that the level of the oceans will rise during the coming centuries. The actual size of this increase is difficult to determine but there is a strong probability that it will be between 20 cm to 1 m by 2100 even though there are more pessimistic projections in some of the literature (IPCC 2007). At the present time we are measuring a rise in sea level of the order of 3 mm per year.

The impact felt of such a rise does come from the progressive rising, since this will happen only very slowly, but rather from the impact of the rise on tides and storms. During a coastal storm the local sea level rises suddenly due, on the one hand, to the local lowering of atmospheric pressure and on the other because the winds associated with the storm 'chase' the seawater onto the coast. This sudden rise in the level of the sea can cause coastal flooding and have serious consequences. This was what was observed in New Orleans when hurricane Katrina struck in August 2005, and in the Vendée in Charente-Maritime when the European windstorm Xynthia struck in February 2010.

The permanent raising of sea levels caused by climate change will lead to an increase in the geographic spread of areas submerged by these storm tides and an increase in their intensity and in the frequency with which they occur in areas already at risk. This effect will be all the more marked since climate change may well be at the bottom of an acceleration in the coastal erosion and therefore altering the existing natural barriers to coastal flooding.

The OECD undertook a study which looked at the exposure of large port cities (more than 1 million inhabitants in 2005) to coastal flooding at the present time and also in the 2070's, based on socio-economic development and climate scenarios. The analysis suggested that about 40 million people (0.6% of the world's population or about 1/10th of the cities under consideration) are at present exposed to one in a hundred year floods. In financial terms the total value exposed in 2005 in all the cities under consideration was estimated to be 3,000 billion dollars, which corresponds to about 5% of world GDP in 2005, the United States, Japan and the Netherlands being the countries with the highest figures. By the twenty seventies, the total exposed population could triple due to the combined effect of the rise in sea levels, demographic growth and increasing urbanisation.

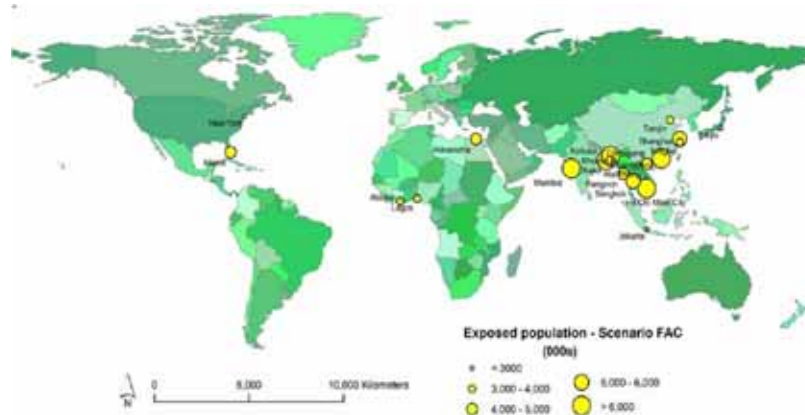


Figure 9 8 : Map showing the Top 20 cities for exposed population under the future climate change and socioeconomic change scenario. Source: Nicholls et al. 2007

The exposure of assets would increase more than tenfold reaching more than 9% of world GDP projected for this period.

At world level demographic growth, socio-economic growth and urbanisation are the most important factors which are leading to increased exposure to risk, in particular in developing countries, since the areas close to sea level are often the ones that are urbanised. Climate change and erosion may accelerate this movement and considerably aggravate the growth in exposure to risk.

In rich countries, such as France, demographic and economic growth is slower than in countries of the South and the role of climate change and rising sea levels in increasing the risk of coastal flooding is greater and sometimes even dominates the socio-economic effects.

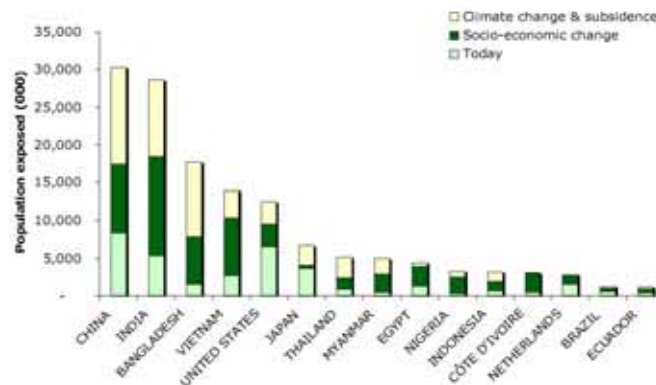


Figure 9 : Top 10 countries by assets exposed today and in the 2070s showing the influence of future climate change vs. socioeconomic change Source: Nicholls et al. 2007

Box 5: Changes in exposure to risk of large port cities (Nicholls et al. 2007)

It is the low lying areas such as the Mediterranean regions or the Vendée, Charente-Maritime, Nord-Pas-de-Calais and the Aquitaine region that are the most seriously threatened.

As an illustration the following map shows the level of risk for part of the Languedoc-Roussillon region. With a 1m rise in sea level, a very pessimistic scenario, the areas in red are the ones that would be directly threatened by drowning; the orange areas show the areas already threatened by tides and storms and they will see their risk increase; the areas in yellow are the areas considered as safe today but which would be at risk with an average higher sea level of over one metre. In blue are the areas that are at present urbanised and which have grown strongly in the last decades for reasons which have been explained in this chapter's first section. In particular due to the lack of land in the Languedoc-Roussillon region, there is strong pressure to develop areas at risk. The report of the Economic Council for Sustainable Development (de Perthuis et al. 2010) suggests research into the potential economic costs of a rise in sea level in this region, and offers methods that could be used to estimate the benefits of possible mitigation policies.

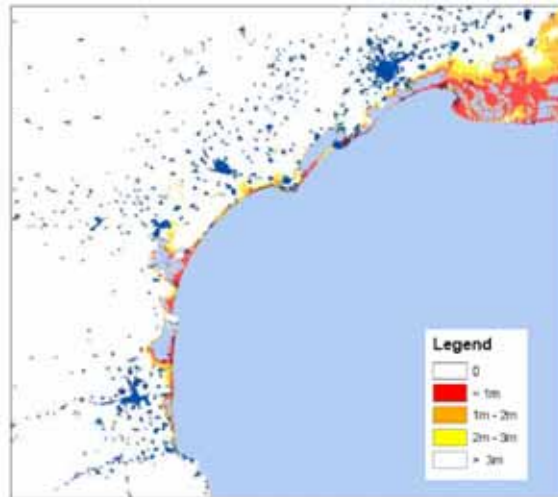


Figure 11 10 : Map of the Languedoc-Roussillon region, with urbanisation in blue and altitude in relation to sea level in yellow/orange/red. (Source: de Perthuis et al. 2010)

The slow drowning of some coastlines due to the mean rise in sea levels may cause significant loss of land. This phenomenon should not be analysed in isolation but added to that of the erosion that we can see at present and which climate change may also influence. Erosion is a natural phenomenon of receding coastlines and is observed throughout the world but is one that is getting worse due to a variety of pressures, especially pressure from human activity.

In France, for example, according to the EuroSION database, one quarter of the coastline of the mainland (27%) is suffering from erosion while 44% is stable and only in 10% is there any extension. The rest of coastline consists of coasts that are artificially fixed (port areas and sea walls) or coasts whose properties have not been studied (respectively 17% and 5% of the coast line). Sandy coasts are more affected by erosion. An increased risk of coastal erosion from climate change is almost a certainty during the 21st century in France; rising sea levels, wind, the temperature, atmospheric pressure and swell can influence the occurrence and gravity of the phenomenon of erosion.

Vulnerability to this impact will come from the geographical situation of area and also the type of development; it is essential to limit vulnerability by avoiding implanting people and property in areas at risk and to protect those that are already there, while making sure that these defences do not justify new people and buildings in areas at risk which would only increase vulnerability.

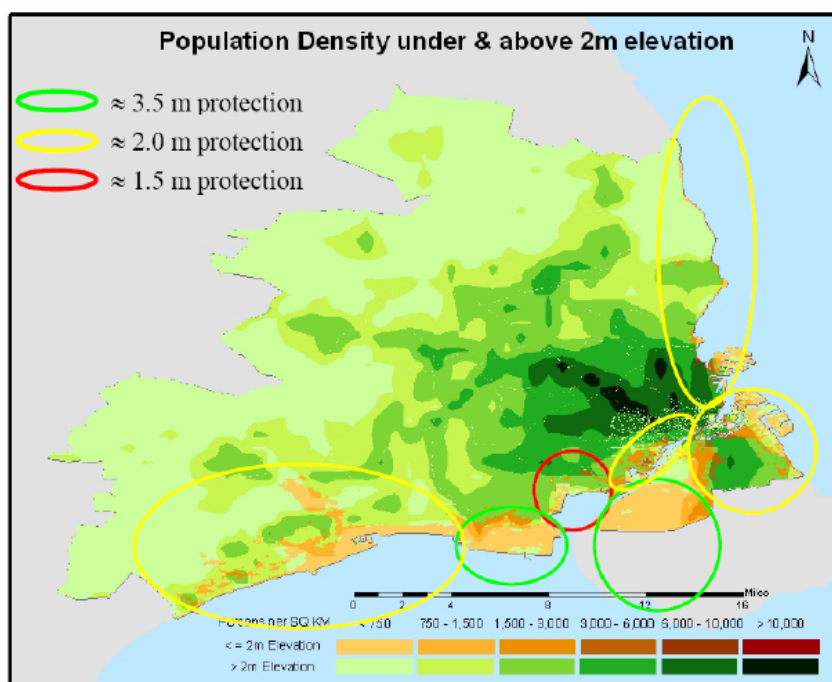
We need to make clear the fact that sea defences are not generally considered to be the only adaptive solution when faced with the risk of submerged coastlines. Although they may carry out their defensive role well, they may aggravate or create problems elsewhere; the solution to the problems of some creating a problem for others. In addition in some cases, the construction of defences may lead to an increase in vulnerability. This occurs when, from a false sense of security brought on by the defences, new facilities are developed in the protected areas; the risk in these areas being never zero, this can lead to even higher losses if there is a serious climate event and so, in the final analysis, increased vulnerability. It would seem more sensible to consider a policy of prevention which limits the implanting of goods and people in areas that are at risk and protect what is already there rather than consider new defences. We need to note, therefore, that physical defences (for example sea walls) will never be sufficient unless they are linked to a land use policy. In particular it is vital to avoid urbanisation and development of areas liable to flooding situated outside the defended area.

We also need to take account of the fact that policies for the reduction of risk may also have potentially negative impacts; for example restrictive management of land may lead to an increase in its price with consequences for the cost of living and access to property and even consequences in terms of investment in an area since businesses might prefer to locate to areas where the policies are less strict and where the price of land is lower. These consequences are

complex and indirect; they depend on a number of factors about which local authorities have little say (for example national taxes or the economic situation).

An OECD study looked at the vulnerability of Copenhagen if faced with rising sea levels. At present this city is not very vulnerable to coastal flooding thanks to the quality of its defensive system but unless this system is reinforced, the city's exposure to the risk of flooding will increase as sea levels rise. The areas concerned are limited in size but include important places such as the port and the historic centre. The construction of a reinforced defensive system, at an estimated cost of several million euros, will have additional costs in addition to the simple cost of construction and these will need to be taken into account. First there will be financial costs, such as the cost of adapting the way the port works, the cost of maintaining the sea walls, the maintenance of pumping facilities etc. There will also be non-monetary costs; aesthetic considerations and the attractiveness of the city etc. These indirect cost may also be large compared to the direct financial costs.

This study also evaluated the quantitative economic impact of flooding. If the sea defences are breached there would be an increase of 2 m in sea level above the present level (this might equate to a 50 cm increase in sea level due to climate change to which might be added a once every hundred years storm) which would result in, besides the material losses, the loss of about 7,500 jobs in the three months following the disaster. The most seriously affected would be small businesses, hotels and restaurants. In time the economy would recover, led by the need for reconstruction, but it is estimated that, compared with the disaster not having happened, at the end of a year there would still be a deficit of 500 jobs. These aggregated figures do not take into account the fact the jobs created do not call for the same skills as the jobs lost and therefore underestimate the socio-economic impact of the disaster. In addition these figures suppose that all the reconstruction costs will be borne by insurance companies and that the cost of reconstruction will not diminish household consumption (a hypothesis that might be true for Denmark, a country where homes and business usually have insurance cover, but might not be true in numerous other places).



*Figure 12 11 The colours represent density of population in Copenhagen, green for the areas that, at present, would not be flooded and orange for those areas that, at present, are dependent on sea defences. The circles represent the levels of protection from flooding, 1.5m (red insufficient at present), 2 m (yellow sufficient at present but insufficient if there is a rise in sea levels) and 3.5m (green sufficient) Source: Hallegatte et al. 2008*

*Box 6: Vulnerability of Copenhagen to a rise in sea level (Hallegatte et al. 2008)*

### ***Inundation due to flooding and runoff***

Climate change will have a marked impact on flows in water courses, due to variations in the rainfall pattern, snow fall and also the shrinking or disappearance of glaciers. Dependant on geographical location, the risk from flooding might also increase. It is quite difficult to make predictions on changes to flood risks and a large number of local studies are underway on this subject.

To the risk of flooding from water courses, particularly serious in urban areas, should be added that of flooding from runoff when the rainwater drainage system cannot cope with the amount of rain falling. This risk is particularly great because certain climate projections include an increase in episodes of violent precipitation. In addition, we need to add the part played by the growing use of impermeable ground cover which reduces the capacity of the soil to directly absorb water and therefore increases those flows that the drainage system has to cope with. This risk is particularly high in areas where there are intense periods of precipitation, in tropical regions (not only Mumbai, Miami and Singapore where major investments are underway but also in the French overseas territories and dominions) and in the Mediterranean area (for example in areas affected by episodes in the Cevennes such as recent floods in Draguignan).

The policies for the reduction of vulnerability in the face of this type of flooding are fairly similar to those that aim to confront coastal flooding; the main risk factor is seen as coming from poorly controlled extensions to towns and cities into areas at risk from flooding, and where defensive systems, although they might be able to protect what is already there, are far from being the best solution (Trocherie et al. 2004). We need to remember that extending towns and cities, by extending non-porous surfaces, hampers the filtration of rainwater into the soil and increases the risk of flooding elsewhere in the same catchment area. To this should be added the risks in built up areas caused by the size of the drainage system which will need to be able to cope with the most extreme weather conditions.

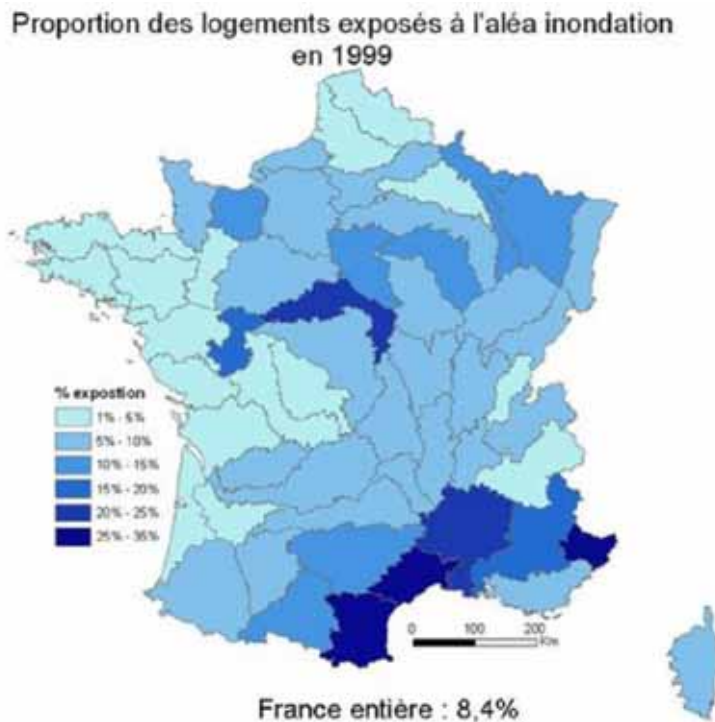


Figure 12 : Number of individual homes in France exposed to a risk of flooding by catchment area in 1999. Source: ONERC 2007

The flooding seen in the Department of the Gard on the 8 and 9 September 2002 was considered by the inspection team from the Ministry of Ecology and Sustainable Development to be "a very serious event, rare but not exceptional". The scale of the material damage (1.2 billion euros of damage) was about double that of previous events of the same type. This conclusion is explained in large part by the scale of building, over at least a thirty year period, in an area liable to flood (this was the case for Aimargues and Gallargues-le-Montueux) or behind defences that were breached or submerged by the flood (as in Aramon). An estimate made by the Languedoc-Roussillon regional environmental body (DIREN) using a 2001 map of areas likely to flood and the population census of 1990 showed that in the entire region, except the Lozère with its population of 384,000, one inhabitant in six lived in area liable to flood of which 321,000 were in areas with a high or very high risk of flooding i.e. water level higher than 1 m and/or strong winds for the highest flood level recorded

Box 7 Gard example (Trocherie et al. 2004)

### **Contraction and expansion of clays**

Some soils are clay which means they expand and contract depending on how much water they hold. When subsidence under a building or infrastructure is not uniform, as perhaps, for example, when the soil under a building does absorb water and dry out at the same rate as the surrounding soil, there can sometimes be a large amount of damage to a structure especially if it does not have deep foundations. The, sometimes, large soil movements due to the expansion and contraction of clays are in general not very rapid and in most cases, thankfully, the number of victims is not very large. On the other hand they are very destructive of design and landscape which are sensitive to this movement. Damage to assets is often considerable and irreversible and may require the destruction of structures.



Since 1989 there have been almost 15,000 French local authority areas, spread over 89 Departments that have been declared disaster areas due to this phenomenon. Detached houses are particularly vulnerable to this, due especially, to their foundations not being very deep. According to the national reinsurance fund, if in 2003 all the local authorities who had asked for their area to be considered as having suffered from a natural disaster had all had their requests agreed, the total cost might have reached 3.5 bn €. This would have been more than all the French drought associated costs together for the period 1989-2002, which reached 3 bn €.

An increase in frequency and intensity of droughts, a rise in temperatures and very heavy bouts of rain are all factors to the contraction and expansion of clays, and predicted climate change might well provoke the occurrence of these two phenomena. In France, according to research and the various studies undertaken, an increase in the risk of the contraction and expansion of clays as a result of climate change seems almost certain during the course of the 21st century. Depending on the nature of the soil some regions will be more affected than others. It will be the local authority areas already affected by this phenomenon and therefore those with more clay soils which will feel the effects of climate change most strongly. Any diminution of the vulnerability caused by this phenomenon will need a stricter application of the current building regulations for new-builds and for existing buildings the development of evaluation tools to assess vulnerability.

### **Storms**

In the matter of storms, such as the 1999 storm, the most recent studies suggest that their intensity should not increase or not very much. Damage linked to strong winds should not change. On the other hand rising sea levels could make these same storms more destructive, due to increased coastal flooding (see above).

### **Other types of disaster**

Other problems likely to occur due to climate change are forest fires, avalanches, earth movements (besides erosion and expansion) risk of a technological accident, maybe major, due to climate change. The impact of climate change on these events is however not well understood. In the case of forest fires this question is of importance for urban areas since large-scale development around cities is taking place in southern France which means there are many more homes in direct contact with forests. Overall the population is now more vulnerable to fire than in the past and this trend seems set to continue. The consequences for urban areas can be illustrated by reference to events in California and Australia (CRED 2010) Australian bush fires in 2009 affected almost 10,000 people and caused over 180 deaths and economic damage of 1.3 billion dollars. However, it was in Los Angeles that the consequences were the greatest; there the fires caused losses of 2 billion dollars in 2008 and 8 dead and 2.5 billion in 2007. In this case it was the fact that the forest and the housing were embedded together that made the fires so dangerous and so difficult to manage for the emergency services.

We cannot say for certain whether the number of forest fires will increase in the future. Higher temperatures and more frequent droughts are evidently factors that will increase the risk as the joint studies by Météo-France and the two national forestry bodies show (see GCEDD, August 2010). Changes to patterns of vegetation could increase the level of risk in certain areas (with the extension of the green belt in the Mediterranean area) and diminish it in others. At all events, the lessening of vulnerability when faced with these possible impacts will need, by definition, to start with a reduction of today's vulnerability to these same phenomena - no regrets strategy.

## **Risks affecting certain economic activities**

### ***Changes in patterns of electrical consumption***

By reason of changes to temperatures engendered by climate change, the consumption of energy for heating and for air conditioning will certainly change. These changes will not be concentrated only in urban areas but since today most of the population lives in towns and cities, it is urban changes that should mainly be considered when looking at the size and management of energy infrastructures. In addition, urban phenomena, especially UHIs, interact with the regional climate to determine changes to energy consumption patterns.

The demand for heating in winter is likely to lessen, and that for air conditioning to rise. According to some climate scenarios it is projected that, towards 2050, in the Mediterranean basin each year there will be, on average, a requirement for 2 to 3 weeks less heating and 2 to 5 weeks more air conditioning. As a consequence the peaks in demand for electricity will, in some areas alter, moving from winter to summer.

This might, in some cases, make access to electricity difficult in summer (and therefore perhaps higher prices or power cuts). This is because electricity production is very dependant on water resources; an increase the temperature of water courses and lakes could affect sources of cold water for nuclear power stations and standard power stations and the lessening of water reserves in dams in summer (due to a combination of climate phenomena such as length of time it snows, the drying out of ponds, river courses and periods of drought etc.) will have an effect on hydraulic power production. Changes in demand for water, other than in the energy sector, could increase this phenomenon by multiplying usage conflicts, especially with farming and tourism. Expected changes to the climate could also have an impact on the production of other renewable energies. If the impact on the production of electricity is hedged about with uncertainties, then that of changes to the patterns of energy consumption is relatively certain, especially in areas in the south of France. A reduction of this vulnerability will need the same measures as for the reduction of vulnerability to heat stress which has been discussed above, i.e. the putting in place of urban policies and a built environment suited to a rise in temperatures.

### ***Impact on tourism***

Tourism is an important economic activity for a large number of French towns and cities and also justifies a certain level of infrastructure, like accommodation (hotels and camp sites), transport (rail networks, stations, road and motorways etc.) and energy infrastructure. Future changes to tourist demand in a region may well have major consequences on the current choices being made for infrastructure and on economic activity and town and cities just as in rural areas.

The attractiveness of a tourist destination is also the result of a number of factors, and many of these are linked to climate. Some are directly linked, numbers of days of sunshine and mean summer temperatures in summer, snowfall for ski resorts etc. Others are indirect; quantity and quality of available water, natural habitats and landscapes in the different seasons when considering nature tourism etc.

In 2005/2006 the Tourism Authority commissioned an exploratory study on the potential impacts of climate change on tourism in France (Dubois and Ceron 2006, INSEE 2008, ONERC 2009). This study looked at the vulnerability of a number of branches of this activity in France. One of the more vulnerable activities is that of skiing and winter sports, especially at lower altitudes. However tourism may also be a victim of a diminution of water resources; the habits of tourists like the infrastructure they use (accommodation, green spaces, leisure facilities such as swimming pools, golf courses etc.) make intense use of water, especially during the summer when the resource is scarce and required for other purposes (irrigation etc.). Climate change may also have an impact on tourism because of its impact on ecosystems; water stress and forest fires that may go with it could lead to consequent changes in patterns of vegetation and alter the landscape.

Discomfort due to heat caused by an increase in summer temperatures in urban areas may also have a strong influence on tourism, especially around the Mediterranean and in large cities where temperatures will be increased still higher by UHIs. This discomfort may lead to variations in overall tourist activity (which may be on the positive side in the north, the west and in mountain areas since they are cooler) and a redistribution in the timing of tourist activity (increase in tourism in the spring and autumn for example).

We should not overlook the fact that exposure to the health risks that have been detailed above could translate into a redistribution of tourist patterns, depending on the place, season, client segment (older people for example).

The impacts of climate change on tourism are therefore very varied and policies to reduce vulnerability will depend on the impact considered. However, in part, these policies are often in place to reduce current vulnerability in the sector; the capacity of ecosystems to adapt can be improved by reducing these present stresses that are created by humans, the consequences of a diminution in water resources will be less if the overall demand for water is reduced straight away.

### ***Changes to French migratory flows***

Another consequence of climate change may come from changes to French migratory flows. Up till now southern France has been overall more attractive than the north (Baccaini 2007) and we can see a slow migration of population from the north to the south of the country. This trend may change, especially as concerns older people because in heat waves in the south, which climate change may exacerbate, they will start to feel uncomfortable. This may have multiple long-term consequences on local economies. Demographic projections for French departments and cities may have to take into account the impact of climate change on attractiveness and therefore on migration. Towns such as Montpellier, that have a desirable climate are growing fast at present but, if they see their attractiveness reduced they may need to invest to compensate for this loss (air conditioning in public transport, planning and architectural changes etc.).

The policies to limit vulnerability when faced with this impact are the same as those whose aim is to limit the health effects of heat stress.

### **The spread of economic losses in one sector to others and the particular roles of networks (energy, water, communication and transport).**

Cities having very integrated systems with complex links that are by their nature extended and varied, any impact which affects one part of a city will indirectly affect all other parts. For example, less tourism will generally mean there will be less economic activity in a number of other economic sectors (for example services to businesses or property. In the same way, a flood may have serious direct consequences due to the damage it causes (roads, homes, factories destroyed), but it will also have indirect consequences (temporary breaks in communications or electricity supply caused by a flood may have very high economic costs and affect areas that have not been directly flooded).

Networks are obviously very important in cities, networks like transport, water management (drinking water and water purification), energy (electricity supply, heating and cooling networks) and communication. A modern city cannot function properly, as a whole, unless each of these networks works perfectly. Any interruption or lowering in performance of public transport or electricity supply can easily paralyse or handicap all economic activity (see below for a study on the impact of climate change on the Boston Metro system)

Research was undertaken to study the effects of climate change on the performance of the Boston Metro. The methodology included changes to projected land use, demography and climate conditions to explore the impact of an increase in the risk of flooding caused by climate change. This study looked at the consequences of a doubling of late running trains on the economic activity of the city and on the attractiveness of the area for businesses and people. The potential consequences justified the main metro lines being adapted

Box 8 Impact of climate change on the Boston metro (Suarez et al. 2005)

It follows that a purely sectoral approach is completely unsuited to an examination of impacts within an urban environment and that systemic studies are vital. They show the importance of these indirect effects and how important it is to take them into account.

In the case of natural disasters the indirect effects are particularly important. These indirect impacts depend, on the one hand, on what has been most directly hit by the direct destruction and on the other by the characteristics of the supply networks.

For example electricity supply has a major role in the whole economy and its vulnerability is critical. During the big power cut in Los Angeles in 2001, half the business affected had to make reductions in activity. About 15% of business did it because they were unable to carry on their business easily and 14% because their clients were unable to make journeys. It was estimated that the total cost of the power cut was in the order of twice the cost of the direct effects.

In an evaluation of vulnerability it is also essential to look at the risks there may be to nodal points such as hospitals (since the risks linked to transport and the evacuation of patients are important), emergency services (some fire stations are in areas liable to food which might paralyse a response to an emergency) and decision making centres.

A number of local characteristics will diminish these indirect effects (Kroll et al. 1990, Webb et al. 2002); diversification of the economy, a redundant transport network, a very brief closure of municipal services (greatly limiting, for example, the consequences of the Loma Prieta - California earthquake in the US in 1989 - on the local economy).

The consequences of the Seine flooding were felt far from the area that had actually been flooded. The electricity supply, telecommunications (fixed and mobile) and the public transport networks which feed the whole city are, in effect, very vulnerable if there is a flood. There are 335,000 homes and 780 sites that are linked to the power supply and which are in an area of fragile power supply if there were a flood such as the one in 1910. It is the same for public transport, flooded underground lines would cause reduced accessibility in those areas beyond the reach of the flood. Here too, the analysis shows that the affected areas (and needing specific action) go beyond the area actually physically affected and an approach which only deals with any direct impacts may miss a large part of the consequences of such a flood.

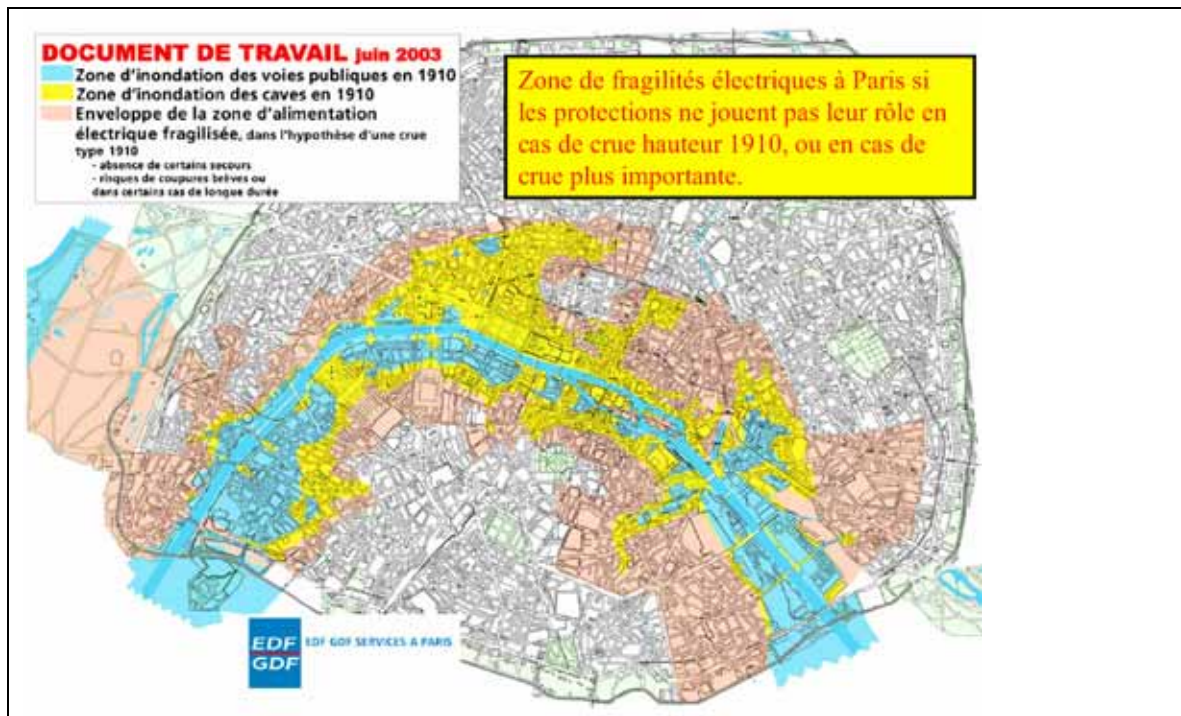


Figure 14 Area of fragile electric power supply if the present protection fails to meet the threat of a flood of the height of that in 1910, or if it floods higher. Source: Préfecture de Police, secrétariat général de la zone de défense de Paris, "Le risque inondations en Île de France"

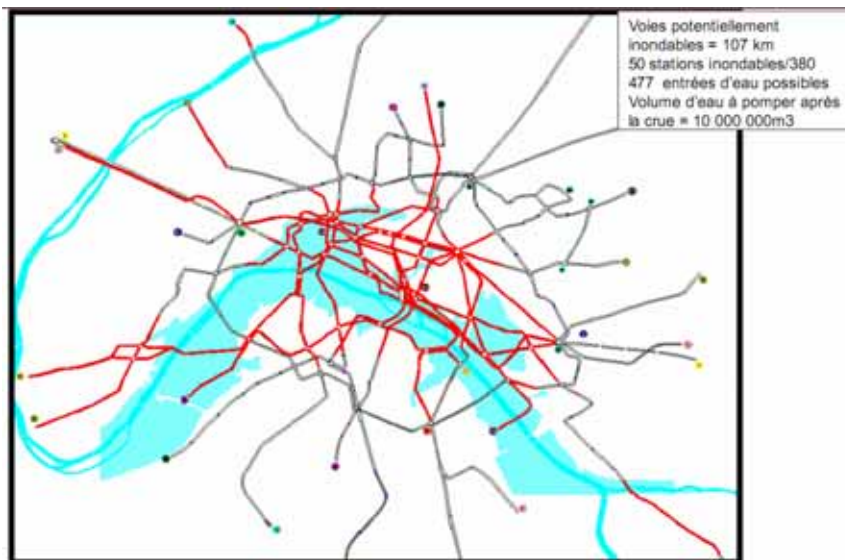


Figure 15 Vulnerability of the Paris metro network if there were a repeat of the 1910 flood. Source: Préfecture de Police, secrétariat la zone de défense de Paris, "Le risque inondations en Île de France"

Box 9 Consequences of the flooding of the Seine on electrical supply and public transport (Préfecture de Police 2009)

The CEPRI (European Centre for the Prevention of Flooding Risks) and the UMR CITERES, (a research institute of University of Tours and the CNRS) have evaluated the vulnerability of the city of Tours to flooding. A particularly interesting analysis concerning mean accessibility to different areas of the conurbation before and during flooding. The results show that some areas which would not be directly affected by a flood would lose accessibility by reason of the cutting of certain road connections. These zones could suffer indirect economic losses, without themselves being flooded. The taking into account of these indirect effects is crucial in the analysis of risks and the construction of prevention strategies and also in the design of emergency plans in case of flood.

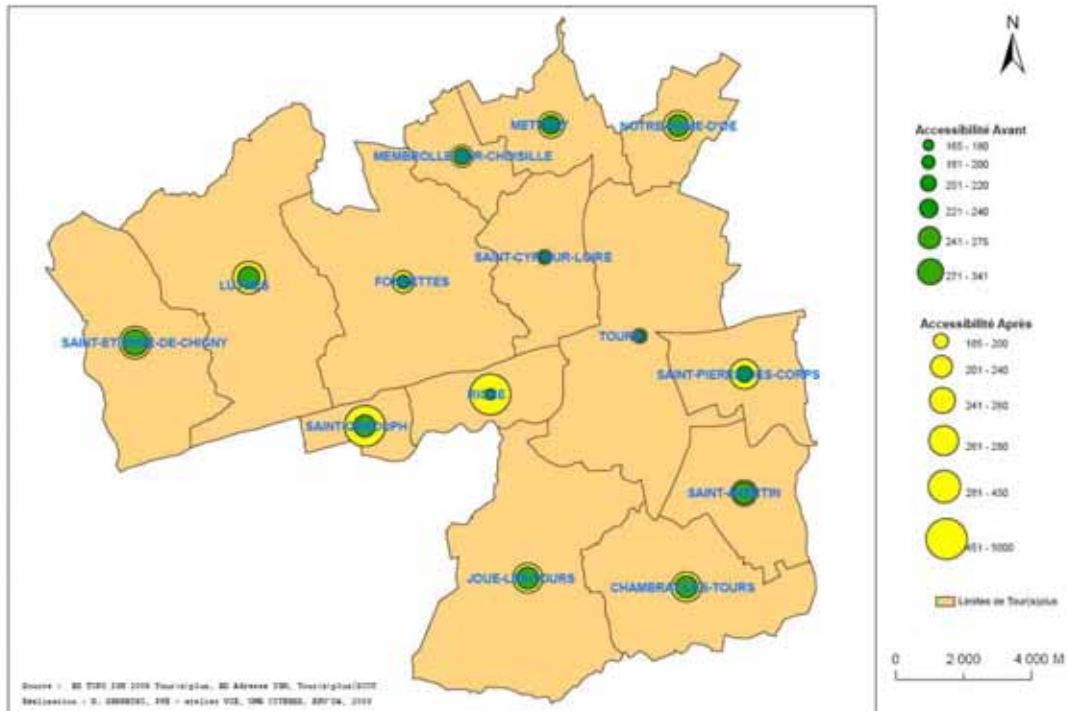


Figure 16 Change in accessibility by reason of a flood in the Tours conurbation. The more the disc is large the more accessibility is difficult. A green disc represents accessibility before the flood; the yellow during the flood. The increase in diameter of the disk represents the loss of accessibility.

Box 10 Consequences of the Loire flooding on transport systems in Tours (CEPRI and CITERES 2009)

In urban areas a particular problem in the management of natural disasters concerns evacuation in the case of imminent danger. In towns and cities where climate change is increasing the possibility of a natural disaster or where the population is protected by defence works, particular attention needs to be paid to this question. This is particularly true in areas liable to flood which are protected by defences since any breach of these defences might be particularly dangerous for the population.

The case of New Orleans and Hurricane Katrina shows what difficulties might be faced. First of all, the transport infrastructure may be inadequate for the rapid evacuation of the population, which means that any evacuation needs to be better anticipated which in turn may lead to a higher risk of a unnecessary evacuation if there is a false alert. Very densely populated areas, so therefore large urban centres, are naturally, particularly difficult to evacuate. Then particular attention needs to be paid to the various categories of vulnerable people who are often

concentrated in certain quarters. These people may lack information or means of transport or be vulnerable to the risk of burglary and looting. Persons with reduced mobility, older people and the sick often find it difficult to leave their homes without external support. Finally, insufficient understanding of the risk, evident in those areas that are rarely affected, is a crucial risk factor, something that was clearly seen during the Xynthia storm.

A natural disaster leads to material damage but it can also lead to indirect losses due to the economic shock caused by the cutting of transport and communications links. Evaluating these indirect losses is the subject of a number of research projects. It is impossible to reproduce all the socio-economic mechanisms there are, but these studies are trying to include as large a number of indirect effects as possible. Often this work concentrates on the role of transport infrastructure and electrical and water supplies. All these studies conclude that the indirect costs are responsible for a large part of the total cost of these natural disasters. Below are the results of some of these studies, looking at flooding, earthquakes or power cuts.

When the Northridge earthquake occurred, near Los Angeles in 1994, the indirect losses amounted to 25 to 30% of the total losses. Following the 1994 earthquake, the unemployment figure (Sungbin Cho et al. 2001) of 69,000 people/year was caused by the fact that factories ceased working. About half the unemployment was south of the area that had suffered material loss. Broken supply lines (Tierney, 1998) caused by the earthquake were at the bottom of most of the interruptions in economic activity, ahead of the interruptions caused direct destruction. About one shop in four was affected by problems in the delivery of goods and services due to the earthquake and on average, all shops were closed for two days following the earthquake. Direct damage caused to buildings was only one of the causes of closure, and was cited in only 32% of cases.

In the same way, the indirect economic losses in Louisiana after Hurricane Katrina have been estimated as being (Hallegatte 2008) 42 billion dollars as compared with 107 million dollars in direct damage. The model used shows that indirect losses increase in a non-linear fashion as compared with direct losses, which suggests that there is a threshold in the capacity of the economic system to adapt. In the case of Louisiana, the indirect losses remained negligible when direct losses were less than 50 billion dollars, but then increased very quickly and reached 200 billion when there was direct destruction at this same value.

Box 11 Evaluation of indirect losses after a disaster

## Combination of sectoral impacts

What we need to remember is that the sectoral impacts cited should not be looked at in isolation; climate change will compound the effects of all the impacts, probably in parallel. This combination might create increased problems, for example if there is a lessening of water resources at the same time as there is an increase in the frequency of heat waves, or if there is a reduction in tourism at the same time as there is a demand for investment in coastal defences. The total impact on the economy might be good deal higher than the sum of the parts.

Climate change being only one of a number of challenges cities need to prepare for we also need to take into account other factors. Adapting to climate change will need to be undertaken alongside measures aimed at reducing greenhouse gasses which will create not only areas of common interest but also areas of conflict. These conflicts may be over policies, when a measure helps to adapt but increases emissions (or the opposite), or on resources when investing in mitigation and adaptation at the same time goes beyond the total investment capacity.

Beyond the environmental aspects, it is possible that the French population, and therefore those in cities, might decrease significantly in the second half of the 21st century which would be a large shock to the urban dynamic. East Germany is an example; there population decrease in towns is a widespread phenomenon and shows how difficult it is to manage towns with declining populations. We will therefore probably need to manage the problems specifically linked to

climate change in a very different context from the one we are in today. In addition, these demographic changes are likely to increase vulnerability due to the ageing of the population which means that large numbers of people will be less able to withstand the high temperatures and will be more difficult to evacuate when they are in imminent danger (for example of there is a flood).

This combination of factors will have important consequences. In addition, although each sectoral impact discussed in this report could be managed and controlled if it appeared singly, the management of a combination of simultaneous impacts in multiple sectors, alongside other urban challenges such as a reduction in population, could be a great deal more difficult to deal with and would come up against the limits of a local authority's ability to cope (in terms of availability of funds for investment, technical ability and competence and attractiveness). At present there is no exhaustive analysis of the impacts of climate change on a city or region and it remains difficult to judge the difficulties there may be in overcoming impacts. Research work is now being undertaken on these questions (see Chapter 3) and the results should enable us to evaluate the size of the risk of climate change on French cities.

## **Principal determinants of risk and avenues of adaptation**

First we should summarise the main vulnerability factors; unsuitable planning and built environment (heat stress, energy consumption), unsuitable defensive work and extension of the built up area into areas at risk (flooding), widespread pollution and non sustainable use of water supplies, (diminution of water resources and impact on tourism), poor protection of sensitive natural resources, building regulations not adhered to (contraction-expansions of clay soils), inadequate diversification of the economy and vulnerability of networks to impacts (direct or indirect economic impacts).

A number of measures that aim to reduce vulnerability to climate change first try to reduce vulnerability to the current climate and its changeable nature, especially as regards current extreme events; adapting to climate change means first adapting to the current situation. In large part climate change acts by increasing problems that exist already and leaving aside the most notable extreme events, climate change is rarely the main pressure factor in sustainability. It is therefore possible to imagine measures that adapt to climate change by modifying, at the edges, measures designed to reduce the existing risks (for example putting higher sea walls in place to defend built up areas on the coast). Other measures may however become necessary when the change in climate becomes more serious. If this becomes the case, then the review of existing vulnerabilities will become insufficient to construct an adaptation strategy and specific measures will need to be put in place to counter new potential threats.

In the short-term it would be useful, in the first place, to examine the origins and evolution of the vulnerability. The higher risks that we are now seeing and which explains the losses linked to natural disasters have precise causes, linked to current socio-economic changes:

- migration of people to the south where the risks are higher
- lack of land leading to building on areas liable to flood, intensified by an increase in households and the development of detached houses that are very land hungry
- spatial inequalities in conurbations and social segregation which concentrates problems in certain areas and may push the more fragile towards areas at risk.
- cost of policies to reduce risk, evident in the case of policies for the construction of defensive infrastructure but equally evident in other cases; as for the example the constraints on new buildings which have a high economic and political cost (especially for the lowest tier of government)
- Lack of political will, except in the few years that follow a disaster.
- Loss of the safety reflex (like not living on the ground floor in areas liable to flood) and a poor understanding of the risk (not listening to advice in the case of an alert) despite recent developments like the warnings given out by Météo-France for example.

To control the current increase of risk and adapt to climate change we first need to attack these problems. Then measures can be amended to take account of climate change.



Some ideas for adaptation are developed below. These consist mainly of investment in and changes to standards and regulations. As it was stated in the CEDD report on the economics of adaptation (de Perthuis et al. 2010) the production and supply of information has also an important role. Not being specifically urban these questions are not addressed here.

Furthermore there is rarely an optimal adaptation option. Often the most appropriate adaptation strategy depends on political and social policies and the vision a region or city has of its own future.

The costs of adaptation are relatively less high when policies are thought through in advance; it is cheaper to build oversized defences than have to make them larger later, it is cheaper to designate an area as unsuitable for building, than have to re-locate those in an already inhabited area etc. A way has to be found between tardy policies which are costly but are undertaken when there is a sense of urgency and policies which are cheaper and put into practice earlier, but undertaken without any sense of urgency and therefore require considerable political investment. Some ideas suggested here should therefore be considered as being part of an adaptation tool box, the choice of measures remaining a political decision which merits a wider political debate.

Policies for urban adaptation can be divided into four main categories; changes to land use and town planning; for example avoiding new developments in areas liable to flooding; direct investment especially in defences and infrastructure to manage water; adaptation of the built environment by direct (investment) or indirect (fiscal and regulatory encouragement) action) means; increasing an area's resilience by economic diversification or measures to help households and businesses in case of impact.

## Land use and urbanisation

A number of towns historically having been built close to watercourses or by the sea, the city centres of a number of conurbations are often now in areas liable to flood. Although the historic centres are in general situated away from areas at risk, recent extensions to town and cities have created heavy pressure on land in these areas leading to larger and larger proportions of the population and the local economy placing themselves at risk. It is a classic scenario that we find in every city in the world, from New Orleans to Shanghai and including Paris. In France, this progressive urbanisation of areas that are more and more at risk is increased by the lessening of the density of the urban habitat which itself is linked to the greater number of detached houses; each household is occupying more space than before, land becomes scarcer and prices rise which leads the next arrivals to live in riskier areas. This explains, in part, why growth in the number of homes in areas liable to flood has exploded in France over the last fifty years; between 1999 and 2006, there was an increase of 7% in the number of homes build in areas liable to flood, which is almost 100,000 extra homes in 424 local authority areas of more than 10,000 inhabitants which are now at high risk of flooding (Laporte 2009) In some areas, this urbanisation is increased by the presence of amenities which attract people to live in areas at risk, such as a view over the sea or having a river nearby (see next box).

New Orleans was founded in 1718 and by the beginning of the 19th century had become the largest city in the southern United States. Because the area protected by natural dykes was very small, most of the city developed on marshland that was artificially dried out with pumps, drainage canals and man-made defences. At the beginning of the 20th century, the use of more reliable electric pumps and the development of dykes accelerated the development of the city. Since then however, New Orleans has been flooded four times despite its defences, in 1915, 1947, 1965 and in 2005. In 1915 it was a category 4 hurricane which affected the city and caused the defences to fail along the side of Lake Pontchartrain. There was 4 metres of flooding in some districts and it took four days to pump the water out of the town. Following this the pumping stations were improved and the drainage canals were embanked. In 1947, the city was hit by a category 3 hurricane and the defences along Lake Pontchartrain gave way. 75 square kilometres were flooded and the water in some places reached 1.8 m, 15,000 people were evacuated. As in 1915 major improvements were made to the defensive systems following the disaster, with the embankments raised and extended. Nevertheless in 1965 hurricane Betsy (category 3) flooded the city again. About 13,000 houses were flooded, 60,000 people were without shelter and there were losses of over 1 billion dollars. This event led to the adoption by Congress of the Flood

Control Act of 1965 and an ambitious plan to protect New Orleans. This plan was supposed to be fully operational within 13 years. Confronted by a number of difficulties including conflicts with environmental protection agencies the plan was implemented very slowly and finally revised into the High Level Plan which was implemented very slowly in the eighties and was considered to have been 60-90% in place when Katrina hit in 2005. The total failure of the defences in 2005 showed that their construction and maintenance had not been adequately supervised and monitored. What is particularly striking in this series of catastrophes is the systematic implementation of ambitious action to renew the defensive systems after each incident without any long term action on the management of the risk.

Box 12 The management of floods in New Orleans (Hallegate 2010)

One of the first things an adaptation plan for the management of risk must touch on should therefore be controlling the occupation of land to limit development in areas that are at risk of flooding i.e. to reduce the challenge as defined in the introduction.

However it will be impossible to stop all new building in areas liable to flood, and a zero risk does not exist. In addition, the impact of restrictions on building would lead to an increase in the price of land which would be a problem for ordinary people and especially the less well off. Intermediate solutions therefore need to be found for areas where flooding was a possibility but would be exceptional. In these areas building would need to meet certain standards which would limit the risks and so reduce vulnerability as defined in the introduction. This would require; avoiding one storey buildings that did not allow people to take refuge on an upper floor if there were a flash flood, placing services (such as electricity) above homes so that they would not be affected by a flood, use building materials that were more waterproof or even put homes on stilts or make evacuation mandatory in case of a flood alert.

As a general rule, encouraging greater density allows development to take place in safer areas and therefore avoids building in areas at risk. Planning regulations in safer areas will have an impact on the risk of flooding, which demonstrates the importance of a systemic approach to the management of risk and spatial planning.

Planning regulations do not just concern areas at risk from flooding; they also influence, for example, the permeability of the soil which has an influence on flooding risk.

Several studies have shown that the possibility of the risk of a natural disaster lowers the price of land, all other things being equal. For example in Istanbul property prices in 2000 were lower near the Sea of Marmara fault line than further away from this line. In 1995 this difference was not observed; it is likely that households became aware of the risk of an earthquake after the 1999 Kocaeli earthquake.

Another example is North Carolina in the United States; here there is a requirement to advise of the risk of flooding so that potential purchasers are aware of the risk before buying a property. Studies showed that any risk of flooding was reflected in the price with, on average, a 7.3% lowering in property prices which, in turn, reflected the extra cost of flood insurance. These studies were also carried out following hurricane Floyd in September 1999 which affected 2 million people and caused 6 billion dollars of damage. Most homes did not have flood insurance before the hurricane and the event brought home to people the reality of natural disasters, especially the risk of flooding as homes in areas liable to flood lost between 4% and 12% of their value.

The consequences of this phenomenon is that we see a concentration of low income families in the most exposed areas; those people who prefer to live in areas where property prices are lower will be more likely to live in areas where there is a risk rather than financially more secure families. This was observed in Bogota; on average poorer households are twice as likely to live in an earthquake zone than more affluent households. This phenomenon however only occurs when all other things are equal, i.e. there are no other factors that alter the attractiveness of a place. In coastal towns for example, we can sometimes see concentrations of the richest households on a sea front which is at risk from flooding, this is however, due to the intrinsic attractiveness of the place which overcomes this risk.

Box 13 Areas at risk tend to be lived in by poorer households (Hall et Deichmann 2010)

Strategies to limit urban spread and that try to ensure a contiguous urban space have been used in a number of countries to create agreeable, fair and ecological urban communities. This urban containment may however, have serious involuntary consequences; increasing vulnerability to natural disasters as it may encourage residential and commercial development and make more attractive areas that are particularly dangerous or may increase the value of land. This will be all the more true as when vacant development land becomes scarce, the land situated in areas at risk may be the only land available and given that the constraints on construction, such as risks of natural disasters, are generally expressed in the price of land, dangerous land may be the cheapest land available, all other things being equal. This problem may be countered if programmes for the containment of urban spread are accompanied by complete and integrated plans to reduce vulnerability to natural disasters.

Sydney, in Australia, can be used as an example; there because of a plan for the containment of urban spread there was growing pressure on areas at risk of flooding. Urban consolidation was introduced by the Sydney Regional Plan 1970-2000 and the updates that followed, as well as by the related plans which encouraged a re-visiting of development in areas of high density. This programme of consolidation and the high price of land contributed to a substantial increase in occupation of land liable to flood, occupation which government policies allowed by leaving decisions on where to allow development in these areas to local deciders.

Box 14 Links between natural disasters, urban planning and access to housing in Sydney (Burby et al. 2001, Burby et al. 2006)

### ***Defensive infrastructure and other direct investment***

As has already been mentioned, defensive infrastructure - like seawalls and dykes - are important for the prevention of risk and therefore adapting to climate change. In particular, seawalls and dykes are vital for the protection of densely populated and urbanised areas relatively cheaply. However the putting in place of defences implies (i) regular maintenance, the absence of which may cause a defence to increase vulnerability, and lead to dramatic loss of life (ii) a planning document which clearly lays out the protected areas, to ensure that the defence does not attract investment and people to an area at risk (iii) an alarm and evacuation system, since a defence can always be breached or overcome by the intensity of a natural disaster.

The construction of defences should only be considered when it is one of the components of a larger risk management plan that includes the maintenance of the defence system, building restrictions in the non-protected area and a warning and evacuation plan.

In addition, the defence approach is not necessarily the best and it is important to understand its negative impacts. First defences lead to changes in the structure and shape of a coast or riverbed, with consequences for the landscape and biodiversity. For example sea wall and dykes which protect the coast against flooding may, in some cases, contribute to the exhaustion of fish stocks by destroying their ecosystem (Clark 1998), 90% of fish species depend on coastal areas at one moment or another in their life cycle (this secondary impact leads also to monetary losses because of its impact on the fishing industry). Also the attractiveness of altered areas may be lessened with a knock-on effect on recreation and tourism. Finally protection of an area might increase risk on another part of the coast or downstream of a river. We therefore need to be careful not to simply transfer the risk, so we need to work at a sufficiently high spatial level to be able to take in all the effects of protection.

Defences are not the only investments that might potentially be required when facing climate change. The upgrading of water management systems - and especially drainage and water treatment - will equally be necessary; in particular in areas that are subject to high rainfall (the South of France is included in this). Other infrastructure may also require direct investment; improvement of roads and transport infrastructures, moving and/or burying of electric cables etc.

### ***Adapting the built environment to higher temperatures***

Changing climate conditions will probably call for changes to town planning and urbanisation. In a number of towns and cities in southern Europe and the Maghreb, traditional buildings are suited to high temperatures with narrow and shady lanes which stay cool, patios etc. Recent studies have tended to demonstrate scientifically the beneficial effects of the traditional house in the fight against those risks caused by heat waves (for example Shashua-Bar et al. 2009).

The increases in risk observed and climate change may lead us to use these skills and export them to other regions of the world; thus the traditional practices that we find in Spain and in North Africa may be found to be useful for France before the end of this century.

We note also that in warmer climates modern extensions to towns and cities are more sensitive to heat stress like the blocks built in the nineteen seventies, air-conditioned office towers, wide avenues that allow traffic to circulate. This 'loss' of traditional skills often has a cultural as well as economic basis; the need to allow cars to flow through the city, standardised construction techniques used on modern buildings that are cheaper than traditional techniques etc. It is therefore not obvious that we should be using these traditional techniques.

To respond the consultation on the challenges facing the Paris conurbation (<http://www.legrandparis.culture.gouv.fr/>), a varied team that included architects and town planners (Ateliers Lion, François Leclercq, Seura architects), landscape specialists (Atelier Alfred Peter), social science researchers (Laboratoire Techniques Territoires et Sociétés) and meteorologists (Météo-France, CNRS) as well as specialists on energy (Transsolar) was formed. Together they were able to draw up projections for the urbanisation of the Ile de France region for 2030, using a number of criteria among which was a preoccupation with the urban micro-climate. Two digital simulations of weather patterns during the 2003 heat wave were constructed. The first considered the present state of land use and second a new planning scenario.

In this project, action concerned increasing forested areas (30% more) around conurbations, an increase in the amount of vegetation in the less dense of commuter belt areas and a change in ground surface coverings in commuter belts and in the centre of Paris. The results show that in this planning scenario night time temperatures during a heat wave lessened by 2 to 3°C by comparison with the actual land use situation.

(Figure 17). This study shows that we can reduce the impact of a heat wave by modifying land use at a reasonable distance from the city where pressure on land is less.

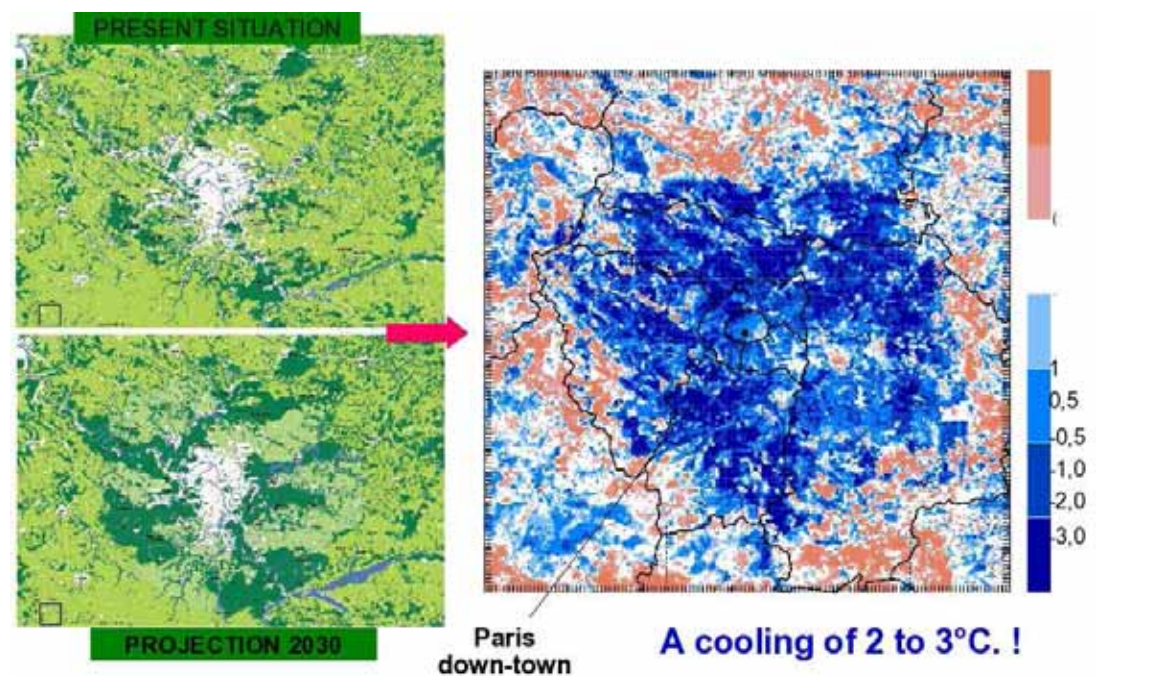


Figure 17 Differences in night temperatures between the two simulations based on the 2003 heat wave. The control simulation was drawn up with the actual land use characteristics in the Ile de France region and the other was undertaken with a scenario of expanded forests circling Paris

and the use of reflective materials on roofs (study undertaken in partnership with the Lion, Peters et Transsolar studios as part of the Challenges facing the Paris conurbation. [Descartes Group])

Box 15 Impact of changes to the built environment to reduce vulnerability to heat waves - Applied to Paris Ile de France

Today the adaptation of the built environment poses new questions by reason of the cost of this adaptation (probably several hundreds of billions of euros for the Ile-de-France region for example) and the time required for a transformation to be significant and have a visible impact. We need therefore to ask ourselves whether we should change standards for new buildings only or insist on the refurbishment of existing buildings. In the case of refurbishment, timescales will be important; the quicker the adaptation is undertaken the costlier it will be (and pose manpower and training problems); we will definitely need to start as soon as possible so as to be able to undertake this transformation at a sufficiently slow pace to make it possible economically.

If this adaptation is undertaken correctly it could also provide some important side-benefits; accelerated refurbishment of homes in a poor state of repair, reduction in energy use from heating, improvements in the quality of life of the population.

### ***Increase in urban resilience***

Towns are likely to have to face a number of shocks linked to climate change, whether they are extreme events like storms or job losses due to changes in tourist flows. In addition to strategies that aim to reduce the vulnerability of these shocks (adaptation of the built environment, modification of infrastructure etc.) it should be possible to try and increase the overall resilience of the area.

This might be done by diversifying the local economy; for example a town that is dependent on tourists or fishing might try to create additional job opportunities which do not have the same vulnerability as existing activities, in order to lessen the risk that all local jobs will be affected by the same shock at the same time. In addition towns and cities, being very vulnerable to an interruption in networked services (transport, communications, energy), could work on the redundancy of these networks.

Towns and cities could also put in place specific tools which aim to help local people and businesses face up to shocks whether they are regular or spread over time. These may be bodies giving information on those local impacts that might be expected from climate change to local deciders, or mutual support systems or insurance.

One of the strengths of strategies that aim to increase resilience is that they bring benefits, that may go way beyond adapting to climate change, by reducing the general vulnerability of a region.

## **Conclusions: putting reductions in vulnerability into practice**

The main conclusions of this chapter are at many different levels.

First towns and cities have vulnerabilities that are peculiar to climate change, but these vulnerabilities are often an amplification of already existing problems (for example flooding). This would suggest starting with implementing no regrets adaptive measures, to improve the existing situation in towns and also generate interesting side benefits at the same time as reducing future vulnerability to climate change.

Other measures could nevertheless become necessary when changes to the climate become more general or when long term measures become necessary. If this becomes the case, then the review of existing vulnerabilities will become insufficient to construct an adaptation strategy and specific measures will need to be put in place to counter new potential threats. This would be the case for large planning schemes which have irreversible long-term implications. For policies which anticipate events, taking into account uncertainty about future climate change is vital and there will need to be coordination between the various players.

The present vulnerability of cities can be explained by unfavourable socio-economic and demographic changes (migration towards areas at risk, lack of available land, overconsumption of water etc.) to which specific responses need to be made; but rather than just looking to reduce risk we need to consider the factors that explain the increase in risk and attack their initial causes.

Finally one of the particularities of cities is the way they function as systems, which means that adaptation strategies need to be designed in an integrated way that takes into account any combined impacts in the various different sectors and areas as well as other political and economic objectives (Bulkeley et al. 2005); (reductions in emissions but also reductions in spatial inequalities and economic development).

When drawing up a policy to reduce vulnerability it will be necessary to work on a very large canvas; which takes into account multiple factors and objectives. Adaptation can only take place on a case by case basis for each area, taking into account the secondary effects of the measures, whether positive or negative, their costs and local political choices.

It is particularly important to consider the interaction between adaptation policies and policies to reduce greenhouse gases (Hamin and Gurran 2009). These two series of policies use, by definition, the same tools (for example policies on land use, transport infrastructure, building regulations etc.) and should be drawn up in a consistent way. For example, lessening requirements for heating or air conditioning in buildings or improving the planning of journeys are effective adaptation measures since they help reduce the effect of UHIs and demand for energy and they are also effective policies for the reduction of greenhouse gasses. On the other hand, large scale development of air conditioning although it might reduce vulnerability to heat stress, will increase energy consumption and goes against policies for the reduction of greenhouse gasses. In the same way, increasing the number of parks in a city may be effective for lessening UHIs but reduces the density of the city and increases the distances covered by inhabitants and therefore may increase the numbers of journeys made and energy use. While objectives for the reduction of greenhouse gasses have been drawn up at international level, independently of adaptive policies at local level it is useful to plan for both types of policy together.

Finally adaptive policies may themselves have positive secondary effects in the sense that they are often no regrets policies, i.e. they reduce current vulnerability of a town or city to climate events and are therefore beneficial whatever the scale of climate change. An effective and progressive way of starting to reduce vulnerability to climate change consists therefore of taking climate change into account in any course of action that has an influence of level of current natural risk and on the sustainable management of resources, to avoid having to reinvest uselessly in a future that is more or less imminent. These no regrets measure will not however be enough on their own, and it will be necessary to put in place specific climate change courses of action to face up to conditions that will be very different from those for which our towns and cities were designed.

Today it is still impossible to calculate the costs of climate change in cities or to guess at the sums we will need to invest in adaptation. However, the scientific literature makes it clear that adequate adaptation policies, put in place in a sufficiently timely way, would be able to very significantly limit the total impact of climate change.

## Chapter 2 Towns today, laboratories for adapting to climate change

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### *Introduction: adaptation, a process in the making*

The first chapter of this report presented the main impacts climate change is expected to have on towns and cities, and their vulnerabilities in the face of climate change. This second chapter considers the adaptation of towns and cities to climate change. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as an adjustment in natural or human systems in response to a climatic stimulus (present or anticipated) or its effects, its aim being to moderate the negative consequences of it or to benefit from the opportunities arising.

Adaptation to climate change is a relatively new subject despite the fact that it has appeared in scientific and political discourse since the early 1990s at the same time as the reduction in emissions. The United Nations framework convention on climate change (1992) underlines the need for adaptation as much as for a reduction in emissions. In practice, however, consideration of adaptation has lagged behind mitigation as it was seen as a way of avoiding commitment to reducing greenhouse gas emissions. The turn of the century witnessed a change in approach, the consequence of an awareness of the inevitable nature of an at least partial change in the climate. Adaptation shifted from the status of option to that of necessity.

This need for action could not however be based on a mature and applicable science of adaptation, as this had scarcely been born and is still relatively young. The decision was thus reached to learn by trial and error, i.e. to launch a global

effort to implement adaptation, translated in practice principally by financing small projects in the context of cooperation for development. A non-negligible part of adaptation was thus implemented in developing countries, mainly in the areas of agriculture, water management and coastal zones. The developed countries have nonetheless been caught up in this international effort at implementation and it is mainly in towns that adaptation initiatives are concentrated.

This chapter has a dual objective. The first task is to review this implementation in towns and to answer the question: “what are towns doing in the field of adaptation today?”

This review then needs to be analysed to define a number of trends, positive factors or shortcomings which it is worthwhile identifying in order to respond, at least in part, to the question: “how can an adaptation policy be implemented in towns?”

To this end, an overview of adaptation in French towns has been produced (**section 1**), then the adaptation initiatives of foreign cities which are relevant to French cases are examined (**section 2**). An examination of these French and foreign initiatives shows, on the one hand, that they are still relatively rare and in their early stages and, on the other, that the identification of levers and barriers to the introduction of adaptation strategies is a major challenge for their future (**section 3**). It also shows that numerous urban policies and measures which are not labelled “adaptation” contribute to the adaptation effort, or can contribute to this effort if they take climate change into account, or to the contrary can contribute to a “maladaptation”. The integration of these measures in an urban adaptation strategy is a further major challenge for successful urban adaptation (**section 4**). **Section 5** reviews the main lessons drawn from each of the previous sections and suggests a framework of thinking for the design of urban adaptation strategies.

The two types of town, French and foreign, were not treated in the same way. The French towns were studied with a concern for producing the most precise overview possible of the measures taken. Our approach for the cities abroad was instead guided by a concern for reproducibility: we selected cities whose experience can be used by French towns. The methodology is however the same: the data comes from existing publications (see appendix 6) and a series of interviews conducted with local stakeholders in the context of this study (see the list of people interviewed in appendix 3). They were collected between June and August 2010, and the chapter does not therefore include subsequent developments. Given the conditions at which the study was conducted, we have often acted on the basis of the views of experts. However, we accept sole responsibility for the results presented here, including any errors or omissions. Moreover, the views expressed in this chapter are solely those of the authors, and do not necessarily reflect those of the National Observatory of the Effects of Climate Warming.



## ***Current adaptation practices in French towns and cities***

This initial section gives an overview of the implementation of adaptation in the French towns and cities. Over and above a simple catalogue of initiatives, the objective is to analyse the main characteristics of urban adaptation measures. One of the main findings is that this implementation has barely commenced in the French towns and cities: the will to adapt to climate change is still limited and considers only a limited number of impacts of climate change.

### **What frameworks for adaptation in towns and cities?**

Adaptation to climate change is a recent topic in France, and towns are no exception to the rule. The interviews conducted show that the few initiatives developed in this regard are proactive and occur principally in the context of Territorial Climate and Energy Plans (PCET) and / or local Agendas 21. At present, 200 PCETs are under way in France, 4 of which being in overseas *départements* and regions.

To support local authorities wishing to produce a PCET, in 2009 the ADEME (Environmental and Energy Management Agency) produced a methodological guide entitled *Building and Implementing a Territorial Energy-Climate Plan* which stipulates that a PCET should have two complementary and indispensable parts: a mitigation part (reduction of greenhouse gas emissions) and an adaptation part (which it defines as a reduction in the vulnerability of the territory to climate change). However, the majority of the PCETs developed to date place the emphasis on mitigation, and adaptation is often neglected, with some confining themselves to a general and largely non-operational paragraph. The Grenelle II act however now requires an adaptation section in PCETs (article L. 229-26, II, no. 2 of the Environment Code adopted in the context of the Grenelle 2 Act of 12 July 2010).

Only a few rare cases (in particular the city of Paris and Grand Lyon) have a chapter dedicated to adaptation, suggesting concrete lines of action.

Towns can thus incorporate their adaptation approach in their Agenda 21, an initiative which is both older and broader, since - focussing on all aspects of sustainable development - local Agendas 21 are much more numerous than PCETs. Currently, over 550 local authorities (19 regions, 40 *départements*, 107 inter-municipal networks and 266 municipalities, including 39 in towns with populations in excess of 50,000) have committed to the production of an Agenda 21. These Agendas 21 do not therefore automatically include PCETs, and towns without PCETs can theoretically start to reflect and take measures with regard to adaptation to climate change in the context of their Agenda 21. The Urban

Community of Lyon (Grand Lyon), whose PCET already includes an ambitious adaptation section, considers for example that adaptation should be treated transversally in the various sections of its Agenda 21.

Finally, action for adaptation to climate change taking place outside the frameworks proposed by the PCETs and Agendas 21 is in the minority, and comprises above all initiatives at district level and not at the level of an entire city. This is the case for example with the Luciline district of Rouen.

Finally, it is still difficult to gain a complete view of the current adaptation situation in French towns: those which have taken measures are still more the exception than the rule, are still in the early stages and the information is still barely diffused. An initial balance however shows that, despite the subject being so young, initiatives are emerging. The analyses below are based on a study of the following towns: Béthune, the Urban Community of Bordeaux, the Urban Community of Dunkirk, the Urban Centre of Grenoble, Grand Lyon, Paris, the Urban Community of the Centre of Martinique, the Urban Centre of Mulhouse Alsace, Nanterre, Metropolitan Nantes, the Urban Community of Poitiers, Le Port (La Réunion), Rennes, Rouen. Of them, particular attention is paid to Grand Lyon, Paris and the Luciline district of Rouen, whose adaptation approaches have made more progress (see text boxes 1, 2 and 3).

In 2004, Grand Lyon launched a Territorial Climate Plan in the context of its local Agenda 21, which did not deal with adaptation. Under the influence of an association specialising in the development of renewable energies and energy efficiency (Hespul, <http://www.hespul.org/>), and a European network of local authorities working in the field of the protection of the global climate (Climate Alliance, <http://klimabuendnis.org/>), Grand Lyon was prompted to incorporate the challenges of adaptation in its development.

The link was made via a European project, AMICA (<http://www.hespul.org/Programme-AMICA.html>), the purpose of which is to identify the possible synergies and to avoid conflicts between mitigation measures and adaptation measures. In the context of this project, Grand Lyon was required to choose a risk associated with climate change: it was the thermal stress associated with heat islands, which allowed in particular certain contradictions to be identified between measures to reduce emissions which promote the densification of the town and adaptation measures which in contrast recommend less dense towns to combat the effect of urban heat islands (UHI).

The end of the AMICA project in 2007 prompted Grand Lyon to continue this work by incorporating it in the various aspects of its Agenda 21.

Some actions taken are:

- UHI mapping. Very detailed modelling of the districts likely to suffer from UHIs. Intention to use satellite maps subsequently.
- Incorporation of the topic in the SCOT and the PLU (exploratory work).
- Establishment of a collaboration network: Grenoble, Lyon, Saint-Étienne.

- Tree planting, choice of species based on resistance.
- Permeabilisation of ground.
- Turfed roofs.

### ***Box 16: Grand Lyon***

The adaptation plan for the city of Paris is incorporated in its Territorial Climate and Energy Plan and dates from 2007. It suggests action to deal with the risks of heat waves and the flooding of the Seine, which the city has identified as the two main climate risks following the consequences of the heat wave in 2003 (excess mortality of 127% in the capital) and the floods in 1910.

The city proposes three measures to deal with the risk of heat waves:

- Activation of the Paris Heat Wave Plan;
- Adaptation of buildings to improve comfort in summer (controlling recourse to air-conditioning and developing a dedicated professional sector);
- Extension of the programme for planting in the capital.

The flood risk is to be managed by a review of the Flood Risk Prevention Plan.

### ***Box 17: The city of Paris***

The origin of this project is the desire of the city of Rouen to renovate the Luciline district, an old industrial district on the banks of the Seine. It has entrusted the implementation of the project to Rouen Seine Aménagement (RSA, <http://www.rouen-seine.fr/>), a public-private partnership bringing together private capital (banks) and public capital (city hall of Rouen and conurbation of Rouen). Wishing to incorporate a geothermal dimension in the project, RSA sought financing from the European *Future Towns* network (<http://www.future-towns.eu/fr.html>). In return, the project had to integrate an adaptation section, the principal actions of which are:

- Upgrading of water in the public space (making the currently underground River Luciline visible, creation of rainwater recovery trenches);
- Planting in the district.

These two elements aim to reduce temperatures in the district and to increase the permeable areas, and thereby to address the risks of thermal stress and flooding.

### ***Box 18: The Luciline district of Rouen***

## **Impacts taken into account and scenarios used**

In this section, we consider the purpose of adaptation, i.e. the climate impacts to which towns are endeavouring to respond in their approach. As shown in the first chapter, the potential impacts of climate change on towns are numerous. However, not all towns face the same risks. Via the cases studied, we find that

they examine only a limited number based on those to which they consider themselves most vulnerable.

No detailed study of vulnerability to climate change at town level was to be seen in the course of our inquiry. Instead towns use the knowledge available about current climate risks to target their adaptation. This knowledge comes in the main from past events, historic data and the opinion of local experts. The main risks considered by the towns are the various forms of thermal stress (heat waves, heat islands etc.), flooding (which can be caused by run-off water, saturation of the water table, high river water, or the sea in the event of storms), droughts and storms or cyclones. Towns sometimes take into account combinations of these risks which then create new ones: this is the case with the shrinkage and expansion of clay soils, erosion or indeed landslides, as described in the first chapter.

None of the towns studied seems to draw a clear distinction between gradual climate changes (rise in average temperatures or rise in the sea level, for example) and extreme events (storms, heat waves, droughts). In reality, they seek only to adapt to extreme events and any changes in their intensity and occurrence, and have not so far considered the specific challenges of long-term changes. They often even think they can adapt to climate change by reducing their vulnerability to extreme events. Two explanations are advanced. The first is that a town prepared to withstand an extreme event considers itself prepared also for gradual changes. The second is the general belief that adaptation to a gradually changing climate occurs spontaneously, and that there is thus no need to prepare for it. According to this belief, citizens adapt automatically to gradual changes, and the towns thus consider their role to be confined to planning adaptation to extreme events and their development.

The overall finding is thus that towns adopt a relatively limited view of the impacts of climate change, not taking into account any positive impacts, and have a great tendency to focus on past emblematic climatic events without really considering their future development. This point will be studied in the third section of this chapter.

### **Scenarios and climate data used**

Adapting a town to climate change requires knowledge of the climate projections for decades to come. The study shows however that towns make limited use of climate data: they do not base the definition of adaptation measures on climate projections but instead on trends, as no interactive tool is available today (although one is being defined in the context of the DRIAS research project, presented in Appendix 1). Grand Lyon has thus published maps of temperature change in France, but takes as a basis, temperature rises of between 2 and 6°C and a greater variability in rainfall. Consultants sometimes simplify the climate

information they provide to municipalities by taking only the broad lines, for example a temperature rise of 2°C and a rise in the sea level of one metre by 2100.

Finally, climate data are rarely used precisely, but are regarded simply as pointers. Towns tend instead to use past extreme event data, possibly centred on an increase in the occurrence of these events under the effect of climate change. Paris or Grenoble, endeavouring to adapt to thermal stress, thus rely on data from the heat wave of 2003; the city of Rouen has adapted its Luciline district by preparing it for flooding similar that in 1910, and Paris has added a 25% margin to the height of the flooding in 1910. It is interesting here to note that, according to the RexHyss project of the Agence Nationale de la Recherche conducted by the Sisyphe laboratory, it is more probable that the flood risk is decreasing rather than increasing in Paris. However, the margin of uncertainty accompanying this result is sufficient to justify this flood-prevention policy.

Insofar as the adaptation measures proposed by the towns are often “no regrets” measures, they do not need to have a precise understanding of climate changes to implement them. Not using more precise climate data is thus not necessarily a problem in the short term. For example, towns which adapt to the risk of thermal stress by reinforcing their heat wave plan (such as Paris) or by seeking to limit the phenomenon of UHI (such as Grand Lyon) do not need to know whether the summer temperature rise in the town centre will be +2.5 or +3°C in 2100. They simply need to know that the risk will increase with the rise in temperatures.

## **Areas and sectors concerned**

A study of the adaptation approaches of French towns shows that they tend to adopt a risk-based approach rather than a sector-based or area-based one. As discussed below, one of the triggers for them taking adaptation into account is a feeling of vulnerability in the face of an extreme event, generally flooding or the phenomenon of heat islands. Consequently, towns reflect on a raft of measures to reduce their vulnerability to this risk, rather than adapt sectors to all the impacts of climate change. Table 1 lists the risks to which five French cities are endeavouring to adapt and the adaptation measures which they propose. It shows that the two main risks are invariably thermal stress (heat wave, urban heat islands) and flooding (coastal or river). This table is not intended to be exhaustive: the information available about the adaptation approaches undertaken by the cities is often inadequate.

Being two of the main competences of towns and urban communities, water and risk prevention are the transversal areas most often considered in towns' adaptation plans. However, the management of a plan for adaptation to climate

change is sometimes entrusted to the water department or the risk department (this is the case for example with Metropolitan Nantes).

With regard to the sectors as such, the action of the urban authorities is limited by their competences. The sector in which they have the greatest power is without doubt that of urban-development and the built environment. Towns often concern themselves with adaptation when they review their Local Urban-Planning Plan (PLU) or their Territorial Coherence Scheme (SCOT), when they choose the materials used for highways, when they are developing green spaces and when they install rainwater management systems. Grand Lyon has built its PCET in direct connection with its SCOT, and the Lyon Urban-Planning Agency is responsible for consistency between the PCET, SCOT and PLU. The perspective of building or developing “for the long-term” is one of the factors of taking into account the impacts of climate change. Moreover, towns also act as models for individuals involved in construction and for building contractors by producing public buildings adapted to climate change (in terms of comfort in summer, air quality and resistance to flooding, for example).

Towns, moreover, such as Metropolitan Nantes, sometimes mention the importance of partnerships between local authorities and research centres in their adaptation plans. Thus, proposals for including climate challenges in professional training, in particular in the building industry, are found. Towns, finally, stress the need to communicate their adaptation plans, once drawn up, for example by utilising the resources used for the mitigation section of their climate plan. But, despite acknowledgement of this need, practice shows that their communication about the adaptation actions which they implement or the strategies which they adopt is still limited.

	Urban Community of Dunkirk	Grand Lyon	Metropolitan Nantes	Paris	Luciline District (Rouen)
<b>Flooding</b>	<ul style="list-style-type: none"> <li>• Diagnosis of the state of the sea-protection structures</li> <li>• Maintenance work on these structures</li> <li>• Modelling of the rupture and breaching of sea-walls and map of flood-risk zones</li> <li>• Better management of wet zones, buffer in the event of submersion</li> </ul>	<ul style="list-style-type: none"> <li>• Permeabilisation of ground</li> </ul>	<ul style="list-style-type: none"> <li>• Modelling of the Loire</li> </ul>	<ul style="list-style-type: none"> <li>• Review of the PPRI</li> </ul>	<ul style="list-style-type: none"> <li>• Creation of rainwater collection ditches</li> <li>• Separation of rainwater and wastewater</li> <li>• Increase in permeable area</li> <li>• Analysis of the flow of the River Luciline</li> </ul>
<b>Thermal stress</b>	<ul style="list-style-type: none"> <li>• Upgrading of the place of water and planting in the city centre</li> </ul>	<ul style="list-style-type: none"> <li>• Modelling and mapping of UHIs, and temperature measurements by satellite</li> <li>• Green spaces</li> <li>• Turfed roofs</li> <li>• Use of water for refreshing purposes on the banks of the Rhone</li> </ul>	<ul style="list-style-type: none"> <li>• Upgrading of green spaces</li> <li>• Turfed roofs</li> </ul>	<ul style="list-style-type: none"> <li>• Activation of the Paris Heat Wave Plan</li> <li>• Adaptation of buildings to improve comfort in summer (controlling recourse to air-conditioning, development of a dedicated professional sector)</li> <li>• Extension of the planting programme</li> </ul>	<ul style="list-style-type: none"> <li>• Planting in the city</li> <li>• Upgrading of water as an air-conditioning element</li> </ul>
<b>Eco-systems</b>		<ul style="list-style-type: none"> <li>• Choice of suitable species for the future climate</li> </ul>			

*Table 1: Risks considered and measures proposed in the adaptation plans of five French cities*

NB: The information available about the anticipated impacts, the risks considered and the actions proposed by the cities is incomplete. This table should therefore not be regarded as an exhaustive list of the approaches adopted by the cities cited, but a list of examples of some of the action they are taking or are planning to take.

## **Adaptation action**

Adapting to climate change covers a huge diversity of potential actions, from preliminary discussion through to the construction of infrastructures, via the creation of an institutional framework of action, and information and education. Just like “urban development”, a town's adaptation to climate change does not have any set contours. It is therefore worthwhile studying what towns propose in terms of action in the adaptation plans they put in place. These adaptation “actions” can be classed by type or by the risks or impacts they address. Five types of action can be identified: reinforcement of knowledge, information for the public, production of strategies, institutional and regulatory aspects, and physical investment. These types of action are complementary and the towns generally propose a number of them to manage a risk. Table 2 proposes adaptation actions on the basis of this type / risk matrix.



Risks	Reinforcement of knowledge	Information	Strategies	Institutional and regulatory aspects	Physical investments
<b>Thermal stress</b>	<ul style="list-style-type: none"> <li>• Mapping of urban heat islands</li> <li>• Identification of the most vulnerable populations</li> <li>• List of endangered species</li> <li>• Identification of potential new pathologies</li> </ul>	<ul style="list-style-type: none"> <li>• Diffusion of risk and the behaviours to be adopted</li> </ul>	<ul style="list-style-type: none"> <li>• Heat Wave Plan</li> </ul>	<ul style="list-style-type: none"> <li>• Adaptation of institutions to act in accordance with the Heat Wave Plan</li> </ul>	<ul style="list-style-type: none"> <li>• Planting in towns</li> <li>• Increase in the number of water points in town</li> <li>• Construction of ventilated buildings</li> </ul>
<b>Flooding</b>	<ul style="list-style-type: none"> <li>• Mapping of flood-risk zones</li> <li>• Modelling of the behaviour of rivers</li> </ul>	<ul style="list-style-type: none"> <li>• Diffusion of information about risk zones</li> <li>• Diffusion of information about the behaviours to be adopted</li> </ul>	<ul style="list-style-type: none"> <li>• Choice of material and plant species for urban development</li> <li>• Improvement in rainwater management</li> </ul>	<ul style="list-style-type: none"> <li>• Review of the PPRI</li> <li>• Bans on construction in risk zones</li> </ul>	<ul style="list-style-type: none"> <li>• Use of permeable materials</li> <li>• Demineralisation of the town</li> <li>• Development of rainwater management systems</li> <li>• Building on piles</li> </ul>
<b>Cyclones and storms</b>	<ul style="list-style-type: none"> <li>• Studies at regional level</li> </ul>	<ul style="list-style-type: none"> <li>• Diffusion of information about the behaviours to be adopted</li> </ul>	<ul style="list-style-type: none"> <li>• Orsec Plan</li> </ul>		
<b>Drought</b>	<ul style="list-style-type: none"> <li>• List of endangered species</li> <li>• Improvement in the knowledge of the flows of water courses and the volume of aquifers</li> <li>• Mapping of zones at risk of clay shrinkage and swelling</li> </ul>	<ul style="list-style-type: none"> <li>• Encouragement for the rational use of water resources</li> <li>• Diffusion of information about clay shrinkage / swelling zones</li> <li>• Diffusion of information about the behaviours to be adopted</li> </ul>	<ul style="list-style-type: none"> <li>• Choice of material and plant species for urban development</li> </ul>	<ul style="list-style-type: none"> <li>• Building standards in clay shrinkage / swelling zones</li> </ul>	<ul style="list-style-type: none"> <li>• Use of drought-resistant plant species</li> <li>• Development of rainwater management systems</li> </ul>
<b>Multi-risk</b>	<ul style="list-style-type: none"> <li>• Prospective projects and competitions</li> <li>• Reduction in scale of climate models</li> <li>• Monitoring of wet zones</li> </ul>	<ul style="list-style-type: none"> <li>• Establishment of a network for sharing experience</li> <li>• Awareness-raising</li> <li>• Training and awareness-raising</li> </ul>	<ul style="list-style-type: none"> <li>• Use of adaptation as a criterion of strategic orientation</li> <li>• International cooperation with developing towns on adaptation projects</li> </ul>	<ul style="list-style-type: none"> <li>• Inclusion of the criterion of adaptation to climate change in the SCOT and PLU</li> <li>• Creation of a department responsible for adaptation</li> </ul>	<ul style="list-style-type: none"> <li>• Conservation of wet zones</li> </ul>

*Table 2: Examples of adaptation actions (proposed or potential) by type and by risk*

## **Characteristics of adaptation approaches**

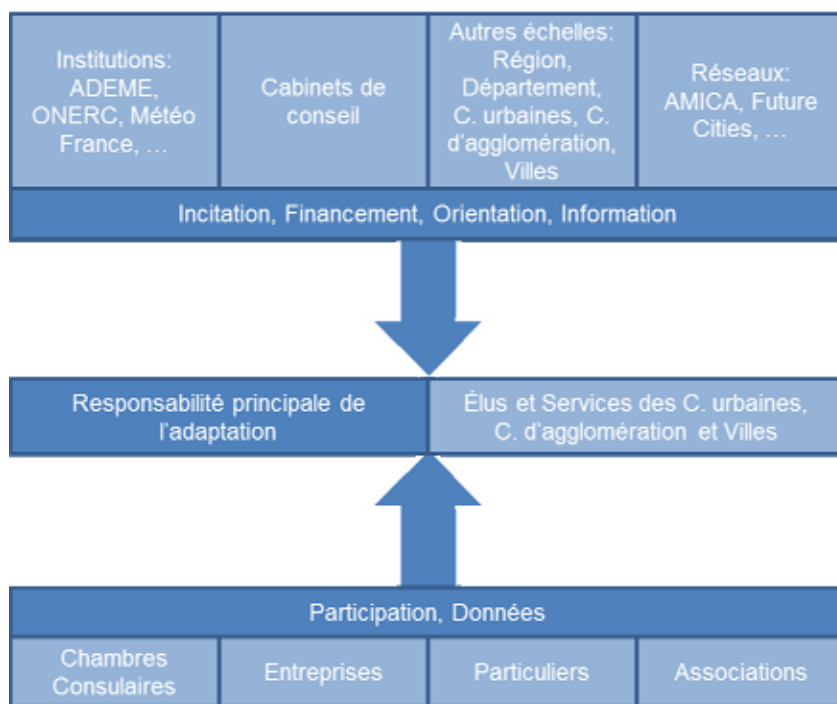
We have seen that French towns undertake their adaptation actions principally in the context of a plan, be it in the form of a PCET or an Agenda 21. For simplification purposes, these approaches are called “adaptation plans” here, although it is legitimate to consider that they do not yet intend to be so. A study of these adaptation plans reveals a certain number of common characteristics which it is worthwhile presenting to define in greater detail what they cover. We would mention here the stakeholders who play a part in their design, the spatial scale and the time horizon considered, the mode of financing to which the towns have recourse, the tools they use, the evaluation of actions and finally the effort devoted to the communication of their approach.

### ***The stakeholders involved***

The production of adaptation plans is often intended to be a participatory process. The Urban Community of Bordeaux, Rouen, Grand Lyon and the Urban Community of Dunkirk thus insist on the importance of consultation, whether to identify the action to be taken or to inform and raise the awareness of stakeholders. The supervision of the project itself is entrusted to a department of the municipal authority, and one part at least of its implementation is delegated to consultants. In the majority of cases, the department responsible for the PCET or Agenda 21 is given the task of adaptation, but it may also be another department, such as in Nantes where the adaptation section is managed by the risk-prevention department. The consultants provide expertise in the field of climate and adaptation, and also often guide project leaders on the route to be taken (role of assistance to the client). In Nantes, they helped produce the vulnerability diagnosis tool.

Consultation with the stakeholders involves the consular chambers (trade guilds and chambers of commerce and industry) which serve as the liaison between the private sector and the city, and also other territorial levels (in particular neighbouring municipalities, *département*, or region) and businesses, NGOs and citizens.

In some case, a co-financer of the adaptation plan gets involved in the project in the capacity of member of the steering committee. This may be, for example, the region or the ADEME. In some cases too, the networks to which the cities belong are involved in the project in a fairly flexible way, which can consist of sharing information, recommendations or simply incentives. Figure 18 shows these various stakeholders classed by whether they have a supporting role, whether they are at the heart of the project or whether they are involved in the consultation.



**Figure 18:** Stakeholders involved in the adaptation of towns to the impacts of climate change

### Keys

Institutions: - Institutions:  
 Cabinets de conseil - Consultants  
 Autres échelles: - Other levels:  
 Département, C. urbaines, C. d'agglomération, Villes  
 - *Départements*, urban communities, conurbations, towns and cities  
 Réseaux: - Networks

Incitation, Financement, Orientation, Information  
 - Incentive, Finance, Orients, Information

Responsabilité principale de l'adaptation  
 - Main responsibility for adaptation

Élus et Services des C. urbaines, C. d'agglomération et Villes - Elected representatives and  
 Departments of Urban Communities, Conurbations and Towns and Cities

Participation, Données - Participation, Data  
 Chambres Consulaires - Consular Chambers  
 Entreprises - Businesses  
 Particuliers - Individuals  
 Associations - Associations

### Scales of time and space

The issue of scale is inherent in the implementation of adaptation to climate change. The objects to be adapted are always spatially interwoven in a complex way, and it is often difficult to combine the will for subsidiarity, i.e. preference for the most appropriate scale, and the will for coordination. In the case of towns, the problem is recurrent: the municipal authorities are not alone competent for the entirety of their territory. They nonetheless decide whether to include the entire town or conurbation in their adaptation plan. It may be that certain districts are used as pilot zones for part of the project. Rouen is a particular case in point, since only the Luciline district is affected by the adaptation project.

Many towns meet to work out their adaptation plans, reaping the benefit of the structure provided by the Public Inter-municipality Cooperation Establishments (EPCI). These groupings have formed for two main reasons: to allow economies of scale (putting in place an adaptation plan requires financial

investment or the investment of human resources which can be easily shared, above all between neighbours facing the same climate risks) and to provide a certain territorial coherence (the configuration of towns into conurbations renders adaptation by one town alone without involving its neighbours a less than optimum way to proceed).

The towns studied do not feel any need to define time horizons for their adaptation approaches; Bordeaux and Nantes seem to be exceptions as they plan to study the impacts and their vulnerability with a horizon of 2050 and 2030 respectively.

In general, the most "time-hungry" part of putting in place an adaptation plan is the stage of diagnosis and data collection. The AMICA project, for example, was the first project associated with adaptation in Grand Lyon and consisted principally of a diagnosis phase and then a phase of reflection and proposal of ideas; this lasted two years (2006-2008). Similarly, with the Luciline project, it took over one and half years to complete the diagnosis stage. The inclusion of the adaptation plan in an Agenda 21 or a PCET does not change matters: the initial reflections and the first diagnoses last around one year. PCETs and Agendas 21 are however approaches intended to last and to change, with regular evaluations and readjustments. This timescale is incidentally found at national level: the work of the interministerial group on the evaluation of future damage due to climate change in France took two years, and it will take over one year to produce the French national adaptation plan taking into account the stage of consultation with all the stakeholders.

## ***Tools and resources used***

### **Finance**

The finance for the studies and for producing the adaptation project comes principally from the local authority. If the initiative is linked to inclusion in a broader project, as in Lyon (AMICA project), some of the finance comes from the institution in charge of the said project, but the proportion of this support often represents a small part of the total budget. The adaptation project for the Luciline district of Rouen is an exception: financial aid from the European Regional Development Fund (ERDF), obtained thanks to its membership of the "*Future Cities*" network, was crucial to the ability of the concessionaire (Rouen Seine Aménagement) to put it in place. The Urban Community of Dunkirk also has the benefit of aid from the ERDF and the Regional Aid Fund for Energy and Environmental Management (FRAMEE). Metropolitan Nantes has access to finance from the National Research Agency (NRA).

The costs of adaptation projects vary greatly depending on their content. The initial stages (reflection, data collection and preparation) require above all an investment in time, but since more detailed diagnoses require technical expert appraisal, or ad hoc modelling work, they are more costly. As the actual implementation of adaptation plans is not very advanced, it is still difficult to obtain an estimate of the real costs of this stage. Moreover, the integration of adaptation in broader frameworks (PCETs or Agendas 21) does not allow us to provide a precise cost of the adaptation sections, but it appears that some tens of thousands of euro are the norm for the adaptation projects currently found in the French towns. The actions regarding information, regulation and adjustment of policies and measures will probably not be very costly, but the construction of dedicated infrastructures will be more so. In this regard, it is remarkable that the adaptation plans presented by the towns do not include any evaluation of the costs of adaptation.

### **Tools**

Tools have been developed internationally to help the stakeholders put in place adaptation strategies. There are thus methodological guides, adaptation project databases and climate services (see Appendix 6). The towns putting in place adaptation plans do not use this type of tool in the production of their adaptation plans. For example, Grand Lyon has not undertaken any vulnerability study including all risks, and the Urban Community of Dunkirk has limited this study to a summary of documents existing at local level. This finding is explained in part by the absence of such tools in France, or in French. The ADEME is in the phase of production of a tool to diagnose vulnerabilities at urban level, linking climatic occurrences with socio-economic sensitivity factors and institutional action levers.

## **Evaluations**

Evaluation is a key phase in the management of a project, and the adaptation projects of towns are no exception to this. As adaptation is not, at our current level of knowledge, directly measurable, it is consequently difficult to evaluate the progress or the success of an adaptation action. The PCETs and Agendas 21, in which many adaptation plans are incorporated, specify evaluations of the actions undertaken. But while the latter are relatively simple for mitigation measures (for which tonnes of carbon avoided constitute a reliable unit of measure), they are rarely planned or are more complex in the area of adaptation. To measure progress with regard to heat islands, Rouen is considering measuring the temperature in the Luciline district by using thermometers, and Grand Lyon plans to use satellite data. It would thus be possible to count the areas of turfed roofs (heat islands) or the permeabilised areas (flooding). These indicators are not direct measures of adaptation to climate change, but provide realistic approximations.

## **Communication**

Communication is an important element in PCETs and Agendas 21. Since they serve as a support for the majority of adaptation plans, the latter have the benefit of an existing communication framework (forums, working groups, diffusion by e-mail, public debate etc.). However, at present, towns communicate relatively little about their adaptation plans and projects. This finding is explained by the fact that the subject is relatively young and by the as yet still small progress of work in this area. Thus, certain towns (such as Metropolitan Nantes) provide a communication section in their adaptation plan but have not yet implemented it. The towns which do communicate about their adaptation plans, such as Grand Lyon, confine themselves to targeted communication to professionals, principally via symposia or a few publications.

## ***International experience: overview***

Some of foreign towns started to put in place climate change adaptation plans in the early 2000s, some years before the French towns presented in the previous section. Their number and their relative experience in the subject allow a certain number of points to be identified which could potentially benefit French towns.

Internationally, experience of implementing adaptation is on the rise, principally via local initiatives in developed countries and in the context of cooperation in developing countries. The references to cases in this chapter were selected on the basis of various criteria: pioneer towns, towns cited by way of example in studies about adaptation, towns located on different continents or presenting interesting characteristics. Exhaustiveness is thus disregarded - though not representativeness - in favour of maximising the utility of the information. Thus, eight cities were studied: Chicago (United States), Durban (South Africa), Keene (United States), London (United Kingdom), New York (United States), Port Philip (Australia), Rotterdam (Netherlands), and Toronto (Canada). Developing countries are under-represented as, on the one hand, their urban characteristics are generally very different from those of French towns and, on the other, the triggers for adaptation, and thus the determinants of forms of adaptation, are specific to them (it is principally development aid which is at the origin of adaptation measures in these countries).

## **What form does adaptation to climate change take?**

### ***Multiple frameworks for action***

Adaptation plans are found in a number of documents: climate plans, sustainable development plans, independent adaptation plans, sectoral plans etc. Climate plans combine adaptation with the imperative of mitigation. The mitigation of climate change has been on the agenda for a long time now and the need to reduce greenhouse gas emissions is increasingly included in the policies of towns. Thus, Rotterdam initiated its measures to reduce emissions before taking adaptation into account. The cities in the sample mention a number of reasons for including adaptation and mitigation in the same document.

It is primarily to draw attention equally to both elements. The stakeholders habitually have a better understanding of the actions to be taken to reduce their greenhouse gas emissions and it is easier to put in place monitoring indicators for the mitigation section than for the adaptation section. By including adaptation in the same plan, they prompt them to take into consideration this other facet of the actions they need to implement within a town regarding the issue of climate change. Chicago was thus prompted to take adaptation into account by scientists whom the city had called upon to reflect on its mitigation strategy, and who urged it to incorporate the challenges of adaptation from the outset.

Then, the inclusion of adaptation in a mitigation plan allows their inter-relationships and their indissociable character to be emphasised. As stated in the first chapter, there can be a certain antagonism between the actions of mitigation and adaptation (the installation of air-conditioning in residential homes for the elderly in order to adapt to episodes of extreme heat contributes, for example, to an increase in greenhouse gas emissions). The cities gamble that, by making a climate plan, the vision will be more global, and will allow this antagonism to be avoided. This is also one of the objectives of the integration of climate considerations in a sustainable development plan. Thus, although the city of Keene initiated a mitigation strategy, followed by an adaptation plan, it has now integrated the global objectives of resilience of the city in an integrated development plan. In this way, the importance of adaptation to climate change will be taken into account in a more transversal way within the various sectors of the city.

As mitigation plans appeared before the importance for the cities of adapting to the inevitable climate change was raised, some cities preferred to create a new document for adaptation rather than integrating it in these pre-existing plans. Mitigation and adaptation, although forming part of a global strategy, thus exist in parallel documents. For certain cities such as Port Phillip (Victoria, Australia), this also allows each to be afforded their own importance.

Finally, the form which the adaptation approach takes can also be influenced by its level of acceptability in the population: in a city with little awareness of climate change, broader urban development plans can be an effective way to integrate this problem. This is the gamble taken by the city of New York by integrating the issues of mitigation and adaptation in a sustainable development plan (PlaNYC). These sustainable development plans are starting to see the light of day or are being planned but, at present, the most frequently encountered adaptation approach is a plan dedicated specifically to it. The city of Keene, which already has separate mitigation and adaptation plans, intends to bring them together in a broader development plan.

### ***The adaptation process***

Initiatives which started at different times, the political will, the resources allocated and the barriers encountered are some of the factors which may explain why the cities cited as examples in this report are not all at the same stage of progress in their adaptation strategy. However, one can identify a similar sequence of stages: the establishment of a vulnerability diagnosis, followed by the production of an adaptation plan and implementation.

### **The establishment of a vulnerability diagnosis**

To adapt to climate change, the contours of what is to be adapted to and what is to be adapted need to be identified. From the national climate data and scenarios regarding the changes in greenhouse gas concentrations, some institutes and research centres produce climate projections for the near or more distant future. However, vulnerability in the face of these possible occurrences still needs to be determined. An increase in rainfall may affect a town only slightly or indeed be regarded positively by a town, whereas for another, it may represent a real challenge to be met. The establishment of a vulnerability diagnosis is thus an essential and preliminary stage in the development of an effective adaptation strategy.

The cities in the sample generally focus on exposure to impacts to establish this diagnosis. They aim to understand the impacts of climate change on the city, starting generally from certain possible occurrences which they identify as being key. To this end, the municipal authorities gather around the discussion table people responsible for various sectors of the city, usually in the public domain, and ask them to reflect on the possible consequences of these contingencies on their sectors. All the

climate projections and the expert appraisals of the stakeholders thus involved allow the city to put in place an adaptation strategy.

### The putting in place of an adaptation strategy

It is not sufficient to know a town’s level of vulnerability to climate change to adapt to it. The identification of orientations, objectives and targets to be attained allows global considerations to be translated into concrete action to be taken, and indeed to be taken in a concerted manner by the town.

This stage needs to be accompanied by a hierarchisation of risks and vulnerabilities, as necessary to prioritise the actions. The method used for this stage differs from town to town.

In the city of **Durban**, it is based on political priorities, the urgency of risks and the chances of success of measures.

It is focussed, inter alia, on the following types of measures:

- reduction of water leaks in municipal mains to cope with the reduction in the water resource
- creation of natural spaces in the town, providing eco-systemic services useful for adaptation (refreshment, prevention of erosion, water storage and filtration) to cope with the increase in temperature and intense rainfall
- promotion of local agriculture to cope with the anticipated risks to the security of the food supply.

For the city of **London**, a matrix was produced based on the probabilities of occurrence of each risk and its anticipated scope (see figure 19). The measures were also classed as “no regrets” (i.e. would be justifiable without climate change), “few regrets” (the costs are low but the anticipated benefits are big), “win-win” (they help with adaptation but have other benefits too) and “flexible” (able to manage the uncertainties associated with the impacts of climate change).

With regard to the city of **Toronto**, the short-term action priority was given to measures already in place but which necessitate changes, and for which there is often already an approved budget. The new measures are considered just as important, but will be introduced subsequently (probably from 2011) and over a longer horizon. These new measures are those which go beyond the scope of measures which are strictly “no regrets”, and which concern in particular infrastructures with a long service life and also planning and development in the long term (increase in size of high-risk zones, the redefinition of the use of ground floors in these high-risk zones, the protection or movement of vulnerable transport infrastructures etc.).

Examples of adaptation measures proposed by the cities in the sample are presented in box 19.

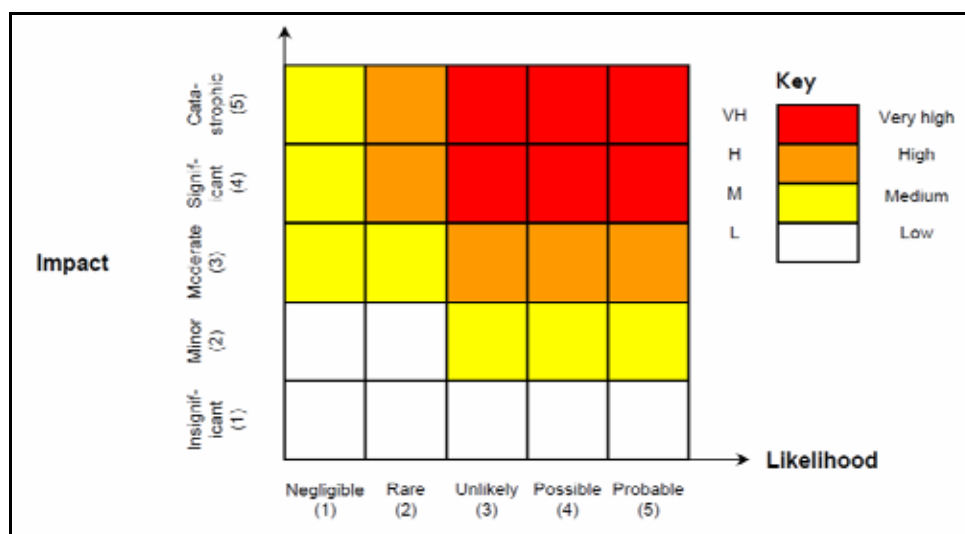


Figure19: Matrix used by London to prioritise the risks associated with climate change, based on the one hand on the probability of the contingency (likelihood) and its consequences (impact) on the other. Source: City of London, 2010 – Rising to the challenge, the City of London climate change adaptation strategy (2010 Update).

The cities in the sample propose a large number of adaptation measures, which they have started to implement or plan to do so. We present a few examples of them here, classed by area or sector. The publications cited in appendix 1 are substantially more complete in terms of actions proposed by the various cities.

Infrastructures:

- Use of permeable materials in roads
- Creation of alternate routes for transport
- Construction of developments to combat coastal erosion associated with the sea level (replenishing sand, groins, sea walls, planting of dunes)
- Gradual replacement of road materials and railways with more permeable materials and materials more suitable for heat
- Protection, adaptation or movement of particularly vulnerable transport infrastructures (tunnels, bridges, metro entrances etc.).

Water:

- Installation of rainwater collection barrels
- Increase in the capacity of drainage, sewer and holding systems
- Increase in storage capacities to cope with droughts

Urban planning and built environment:

- Definition of coastal strips which cannot be built on due to the forecast rise in the sea level
- Provision of “fresh zones” for the inhabitants
- Isolation and ventilation of public buildings
- Identification of 200-year flood zones, and restriction on construction in these zones

Biodiversity:

- Planting of plant species suitable for the future climate
- Turfing of roofs
- Increase in areas of green space
- Protection of wet zones to reinforce their utility in the face of extreme events

Energy:

- Burying of electricity lines to limit their vulnerability to storms and cold snaps
- Management of the energy demand during peaks associated with periods of very hot weather

Health:

- Information to the public about the behaviours to adopt to protect themselves from the vectors of new diseases (mosquitoes, ticks)
- Putting in place and adaptation of air quality warning systems

Waste management:

- Design of waste processing plant so that they can operate during periods of very hot weather

***Box 19: Examples of adaptation measures proposed by the cities in the sample***

## **Implementation**

It is clearly not enough to define a strategy for it to be automatically implemented. However, as adaptation is a dynamic process, involving technical solutions, administrative changes and above all the integration of climatic considerations in the daily actions of the stakeholders, it is sometimes difficult to state precisely what level of implementation has been achieved. The towns studied here are generally starting this implementation stage (Keene and Toronto for example). Chicago is a few years ahead as, in 2010, it issued an initial interim report after the first two years of implementation of the adaptation plan.

However, this sequence of stages is not linear. The categorisation used serves only to describe in a general way the process followed by the various cities. Each stage may overlap another, and returns to previous stages are possible and common. The evolution of knowledge and new data produced about the climate should allow towns to review their vulnerability diagnoses. With regard to the adaptation plan, some cities have planned to readjust it after a certain number of years or have identified factors which would require its re-evaluation.



Thus **London** has identified four factors, the occurrence of which would automatically trigger an update of its strategy:

- the publication of new climate projections or new scenarios regarding the rise in the sea level;
- a significant event in London;
- the election of a new mayor;
- an evaluation by the British government.

The implementation of measures can also start, in part, before a plan on the scale of the city has been published, and can thus help to increase the acceptability of the measures. This can also allow for the identification of vulnerabilities not previously taken into account and for the recognition of the effectiveness of certain measures proposed in the plan. Thus, a feedback loop can come into play and allow each stage to be reviewed in the light of the new knowledge developed.

## Risks considered and sectors mobilised

The adaptation plans for the foreign cities differ from those of the French towns and cities by the fact that they take into account numerous impacts and sectors. This finding testifies to the more advanced nature of the implementation of adaptation in the foreign cities selected - bearing in mind that they were chosen for this reason - compared with their French counterparts. Table 3 lists the impacts and sectors considered by the eight cities in the sample.

A comparison of tables 1 and 3 shows clearly that the foreign cities studied have a lead over the French towns. The number of risks considered is much higher (all the cities take into account around ten risks, while the French towns confine themselves at present to thermal stress and flooding). Certain risks are less represented: either because they are highly dependent on the location of the city (coastal erosion or ground subsidence), or because they relate to challenges regarded as more national concerns (migrations, security of the food supply). In contrast, the risk of flooding and thermal stress are constantly taken into account, which testifies to a strong association with climate change in the perception of the stakeholders. Economic impacts, also taken into account by all the cities, seem to be a fluid category which covers all the impacts of climate change on the economic activities in the territory of the city. This can be the impact of gradual changes which cast doubt over current models (of tourism for example), or the direct or indirect impact of extreme events on economic activities (on logistics, production processes, availability of raw materials etc.).

### Anticipated impacts

	Chicago	Durban	Keene	London	New York	Port Phillip	Rotterdam	Toronto
Water - availability		X	X	X	X	X	X	X
Water - quality	X	X			X <sup>1</sup>	X	X	X
Flooding	X	X	X	X	X	X	X	X
Disease	X	X	X	X	X	X		X
Fall in agricultural production / insecurity of food supply		X	X	X				
Coastal erosion		X			X	X		
Thermal stress	X	X	X	X	X	X	X	X
Sensitivity of infrastructures	X	X	X	X	X	X		X
Insurances			X	X	X	X		
Economic impacts	X	X	X	X	X	X	X	X
Eco-systems	X	X	X	X	X		X	X

<sup>1</sup> The city of New York has stressed that water quality could improve in some cases; the rise in temperatures may improve water quality for bathing, by reducing the number of pathogenic organisms present on some beaches.

Increase in demand for emergency services / security	X	X	X		X	X		
Increase in storms / extreme events	X	X	X	X	X	X		X
Ground subsidence				X			X	
Migration								X
Rise in energy demand	X	X	X	X	X	X	X	X

### **Sectors mobilised**

Infrastructures (including transport, airport and port activities, energy infrastructures)	X	X	X	X	X	X	X	X
Urban planning and built environment	X	X	X	X	X	X	X	X
Health	X	X	X	X		X		X
Energy	X	X	X	X		X		X
Biodiversity / natural environment	X	X	X	X	X	X	X	X
Water	X	X	X	X	X	X	X	X
Emergency services	X	X	X	X		X		
Agriculture / food		X	X					
Tourism		X						
Research and development							X	
Waste management				X				

**Table 3: Anticipated impacts and risks considered in the adaptation plans of eight foreign cities**

### **Characteristics of existing adaptation strategies**

Despite their specific features, existing adaptation strategies share a certain number of characteristics other than a similar implementation process. The latter are essential to identify the emergence of adaptation initiatives of the cities and to understand the different facets of them.

#### ***The stakeholders involved***

The stakeholders involved in the production of the adaptation strategy, and likewise its implementation, differ from one city to the next. This can be explained by differences in the involvement of civilian society, pre-existing links with certain circles, the mandate entrusted to some departments or teams and their resources, and indeed the presence of a leadership. The project manager is generally the department of the environment but a number of stakeholders are involved in the writing of an adaptation plan. The city of Keene was one of the pilot cities of the *Climate Resilient Communities* programme of the ICLEI - Local Governments for Sustainability, and thus had the benefit of its support when putting in place its adaptation plan. The city of Toronto, for its part, called upon the Clean Air Partnership (CAP), a non-governmental organisation (NGO) which had helped place the issue of adaptation on the city's agenda. Consultants are also called upon for help, as was the case with *Acclimatise* in the strategy of the city of London. These various stakeholders can contribute to the development of expertise and provide external resources for towns which do not always have much in the way of resources for developing their strategy.

### **Municipal administration**

The municipal administration is quite obviously involved in the production and implementation of adaptation measures. The various reports produced on the strategies of the cities and their production processes clearly show the importance of having permanent employees allocated to the issue of adaptation. This finding can be divided into two requirements: having employees whose mandate is to

monitor the achievement of adaptation objectives, and identifying the human resources in each department or sector responsible for attending inter-departmental meetings. Moreover, it appears that the department for the environment is not always best placed to manage an adaptation project. The adaptation of a city to climate change is not simply an environmental problem: it is clear to see that the sectors mobilised are highly diverse. Furthermore, the departments for the environment are rarely the most powerful and the study revealed that they hesitate to encroach on the prerogatives of other departments. According to many, it would be far more efficient to entrust, initially, the task of adaptation to a more powerful and more technical department, on the understanding that in time the issue will need to be addressed by all the departments and stakeholders in the city.

## **Research**

The scientific community and researchers are essential stakeholders in the identification of risks and the establishment of a vulnerability diagnosis. By producing regional and local data, and by explaining them to the stakeholders responsible for decision-making, they facilitate the transfer of knowledge and the taking into account of the imperative of adaptation. This stage is essential in the approach and makes these stakeholders front-line partners with local governments. Some cities elect furthermore to act following receipt of scientific data identifying potential risks by putting in place channels for exchanges with research environments. To this end, New York put in place the New York City Panel on Climate Change (NPCC), a group of scientists and experts from various domains responsible for developing climate projections for the city and for supporting the municipal authorities in their adaptation approach.

## **Civilian society**

Non-governmental organisations, such as the Clean Air Partnership (CAP) in Toronto, can also encourage towns to include this issue in their priorities. In the initial consultation for a climate plan organised by the city of Toronto, the CAP thus stressed the need to take adaptation into account and was crucial in the city's decision to include this section.

In some cities, stakeholder partnerships have seen the light of day and have become key actors in the adaptation project. A notable example is the London Climate Change Partnership (LCCP), comprising some thirty organisations in the London region aware of the importance of making adaptation to climate change a leading issue in the management of the city and its activities. The LCCP, although independent of the local government, is a primary partner of the latter. The links between a city's administration and stakeholders from all sources - scientific community, experts from various domains, non-governmental organisations etc. - are thus common currency in the city in the sample in the context of their adaptation projects.

Citizens are also stakeholders involved in the adaptation strategies of towns and cities. Not only can they put pressure on the authorities, following a significant climate event or being aware of the problems of climate change, but they are also included in the approach by public consultation at the time of production of the adaptation plan and clearly its implementation. However, not all the cities include a stage of public consultation on the issue of adaptation; public consultations slow down the adoption of a plan and involve additional effort to reach the public and give it a chance to express its views. Nonetheless, a number of the cities consider them an essential element for successful adaptation. The city of Port Phillip thus underlines their importance to take the pulse of the population, to raise its awareness and also to inform it of what it can itself do.

## ***Scales of time and space***

The process of production of an adaptation plan takes time. Less than one year for the speediest (the city of Keene, for example, had scheduled twelve months for this process but completed it in eight) to several years for broader plans (four or five years for Durban, London, New York, Port Phillip, Toronto). The size of the city and the resources available play an important role.

Without precise dates necessarily being set for the achievement of objectives - Rotterdam being the exception in this regard since it has set itself the target of 2025 for the climate challenge - the cities all differentiate the actions they intend to implement in terms of timing. The method generally used consists of classing the objectives and targets to be achieved in the short, medium or long term. The

city of Toronto elected to split its adaptation into two phases: in the short term, concentrating on the integration of considerations associated with climate change in the existing instruments (heat wave plan, run-off water management plan etc.), and in the longer term, working on a more global adaptation of the city. This longer term phase has currently just started and is not intended to stop. The calendar of actions to be taken can also be dependent on the hierarchisation of risks and vulnerabilities.

The spatial scale favoured by the cities for putting in place their adaptation projects is generally their entire territory. The implementation of the action plan can however include a certain number of pilot projects on *arrondissement* or district scale (this is the case of landscaping projects in Chicago or New York's *greening the Bronx*).

Cooperation between towns in the same region is furthermore essential insofar as the actions of one town are never isolated: the choices made by one town about its adaptation can have repercussions on its neighbours. One of the most striking examples is probably the city of Port Phillip, located in a bay. Facing the anticipated risks of a rise in the sea level, flooding and erosion, the city could elect to build sea walls. It goes without saying that this decision would have a significant influence on the ten or so municipalities located around the bay - including the city of Melbourne. Cooperation and dialogue are thus favoured to facilitate the adaptation of each of them.

## ***Tools and resources used***

### **Scientific data used**

The data used by the cities to evaluate their risks come from international climate scenarios or national projections. The KNMI (the Royal Meteorological Institute of the Netherlands), for example, has produced four different climate scenarios based on **GIEC** projections, today used by towns in the Netherlands. In the United States, the National Oceanic and Atmospheric Administration (NOAA) is responsible for providing data about the climate.

The cities use these scenarios and certain work on a more local scale which allows more local data to be produced. This is true of New York, which works in close collaboration with the numerous scientists and research centres present in the city and which are integrated in the approach via the NPCC, and of Chicago, which has conducted a regional evaluation of the vulnerabilities associated with climate change, in particular the mapping of future UHIs.

### **Diffusion of information, communication and awareness-raising**

As mentioned by the city of Chicago, its adaptation plan is not simply a plan for the city administration, but a plan for the entire city. The diffusion of information and raising the awareness of all the stakeholders are described as crucial stages for the success of the approach and are generally taken into account in the adaptation strategies of the cities studied here. Raising awareness of the issue of adaptation can be effected in particular by public consultations, the distribution of leaflets and the diffusion of information by the media. This issue of awareness-raising is moreover the reason mentioned by several cities for holding public consultations: the population and the various stakeholders do not, according to it, necessarily have new factors to provide for the strategy, but it allows them to be informed about the process and the action to be taken. They suggest that this dialogue allows the stakeholders to become aware of the variety of action which can be taken at every level to facilitate adaptation and resilience. To some, adaptation appears to be a sizeable challenge which only the municipal administration, with its resources of all kinds, can take on. But citizens also have a role to play: Keene informs its inhabitants about how to protect themselves against mosquitoes and ticks and thus reduce their vulnerability to new diseases; Chicago asks its inhabitants with gardens to install rainwater butts; Durban offers individual measures to reduce water consumption to cope with the expected reduction in this resource.

### **Finance**

Like any other action to be taken, adaptation costs. Convincing stakeholders to invest to adapt to uncertain risks in the (sometimes distant) future is difficult. Nor do the economic difficulties of recent years favour expenditure in any area whatever. A number of cities have thus sought external financial aid, from foundations (such as the Rockefeller Foundation in the case of Chicago, New York and

Toronto) and international or national subsidies. The latter sometimes issue conditions, such as compliance with a calendar, or demand something in return, such as the production of a report on the process of producing the plan (as was the case with Chicago). The latter allows other towns who would not have had the chance to benefit from such finance to nonetheless profit from the experience and the lessons learnt by the town financed.

More generally, the research efforts and the creation of new frameworks agreed by pioneer towns can often be re-used by other towns, thereby lowering their future entry costs to adaptation processes. Some tools and methodologies developed in this way are today available free of charge and easily accessible, allowing the towns so wishing to benefit from them. Chicago, New York, Toronto and London have thus made public the vulnerability diagnoses and risk prioritisation methods they used, and anyone can use them or take inspiration from them. They have also diffused the main lessons they learnt from their experience. With regard to the implementation of adaptation, big investment is not always needed: this is the case for example with measures to integrate considerations about climate in the normal operation of the town (see section 4), which finally represent a large proportion of recommended adaptation actions. We would note here that the cost of the adaptation projects studied here is not representative of the true costs of adaptation, which cannot yet be calculated. This is explained by the fact that all the cities studied started by putting in place "no regrets" actions, i.e. those with a zero or negative cost. In this context, the potential savings on entry costs are relatively important.

### **Tracking, evaluation and adjustment processes**

The relative novelty of the action plans put in place by the cities makes it difficult to evaluate the adaptation strategies they have adopted. The study shows that they have attempted to put in place tracking and evaluation indicators in order to adjust these action plans based on intermediate results and data. However, the same evaluation difficulties are encountered as in the French towns: directly measuring the progress of a town in terms of adaptation is still impossible, above all because adaptation is a concept which is not properly controlled. Similarly, thus, the foreign cities choose to evaluate the achievement of more physical objectives, such as water storage volumes and additional turfed roof areas in the case of Rotterdam. Some cities, such as Chicago, put in place external evaluation committees working on a continuous basis (see box 20), to ensure that the initially devised indicators are still being tracked (these indicators are, for example, the permeabilised area, the number of "green corridors", the area of turfed roofs, the canopy area etc.). Some cities also establish partnerships with the scientific community in order to update their objectives based on new climate data. But such continuous evaluation and amelioration processes tend to be the exception: the towns studied content themselves instead with a redefinition of objectives when a new climate event occurs or after a certain number of years.

In its climate plan, the city of Chicago anticipates the challenges associated with the evaluation and tracking of objectives. This is why it created the *Green Ribbon Committee* (GRC), a team of stakeholders from the private sector and the community, responsible for ensuring that the various departments put in place the objectives which they set in their three-year plans. As team which is independent of the city administration, it ensures that the latter is accountable for its intentions to adapt to climate change, and is so in a transparent manner: its reports are public.

The GRC thus evaluates the progress of the city's departments, questions them about the progress made and formulates recommendations for adjustments and improvements. Its report is passed to the mayor, then to the team responsible for implementing the CCAP (Department for the Environment, the Global Philanthropy Partnership and the Civic Consulting Alliance, and other strategic groups in various sectors) which may include them in the plans of the different departments.

Thus, rather than revise its climate plan every four or five years, Chicago elected to embark on a continuous process of evaluation and improvement in order to ensure that the various teams effectively integrate adaptation to - and mitigation of - climate change in their normal actions and make progress in their adaptation. The GRC's mandate was initially for just one year; it was renewed once and the intentions of the city of Chicago seem to be to repeat the operation when its mandate expires in 2011.

*Box 20: the Green Ribbon Committee of Chicago, a continuous process of evaluation and improvement*

## ***Levers and barriers to adaptation: discussion***

The previous two sections have allowed us to take stock of the situation with regard to adaptation to climate change in French towns and then in cities abroad. This gives rise to a general observation: contrary to what a certain international resonance may lead one to think, the implementation of adaptation in towns is still at an exploratory stage. French towns are no exception and urban adaptation in them can be regarded as being still in an embryonic stage, apart from a handful of initiatives. They are mainly at diagnosis stage: identifying the climatic occurrences which will have consequences on their various sectors. The development of knowledge about risks and the way to prepare for them and deal with them have scarcely got off the ground. Certainly, some actions have been identified as supporting adaptation - such as planting and the use of permeable materials to facilitate rainwater infiltration rather than run-off - and can be implemented. But these again are not global and transversal adaptation strategies, as the climate change factor itself was still not taken into account. The proposed actions are, moreover, very targeted and tend to be integrated in plans specific to them; nothing has yet been developed on a large scale. One does however sense a will to make progress, and the various initiatives which arise in French towns are to be considered as the start of a long-term effort.

The study of the implementation of adaptation in towns and cities in France and elsewhere does however reveal the existence of a certain number of levers and barriers to this implementation which it is important to know, to use and to avoid in order to put in place an effective adaptation strategy. The relatively short history of this situation does not yet allow the identification of all these drivers or brakes, but a certain number of recurring points are noted by practitioners. Getting over barriers and optimising levers to adaptation appear to be the main challenge in the early stages of implementation in the French towns, and all levels need to be involved in this. We present here the main triggers for the establishment of adaptation strategies, and also the most frequently cited barriers and some pointers for avoiding them.

### **Triggers**

If the establishment of an adaptation strategy is still the exception rather than the rule in towns and cities in France and elsewhere, it appears from a study of them that the initiatives are all associated with the presence of at least one of the following four situations: the fact of belonging to a network, vulnerability demonstrated by past climatic events, proximity with another territory which is reflecting on adaptation, presence of an elected representative. Other than explaining why certain towns are ahead of others, the identification of these triggers is useful for encouraging adaptation to be taken into account in other towns.

### **Membership of networks and participation in international projects**

The main trigger for taking adaptation into account in a town seems to be the town's participation in an international, and usually long-term, urban development project. These urban development projects, common to the cities in several countries and often managed by an NGO or foundation, encourage or even demand each city to include an adaptation dimension in the project. Towns, which generally participate in an international project to gain access to substantial finance and to belong to a knowledge and experience sharing network, are thus forced to consider this issue of adaptation.

After a few years during which it addressed the challenges of mitigation, Grand Lyon did not, for example, start to reflect on adaptation until 2006, on the occasion of its participation in the European project AMICA which forced it to work on the synergies and contradictions between mitigation and adaptation measures. Likewise, participation in the Future Cities project was also decisive in the Luciline district project in Rouen positioning adaptation as one of the priority axes in the design of the district: it was one of the conditions of participation in the project, which brings together cities in the northwest of Europe.

In addition to participation in an international project which includes an adaptation section, membership of a network (regional, national or international) can also serve as a trigger for adaptation in a town, if for example another town in the network has tackled the subject and passes its experience on to its partners. Exchanges of knowledge and experience on the one hand, and the prospect of sharing preparation and implementation costs on the other, seem to have a certain bearing on cities' decisions to embark on an adaptation project. The network formed by Grand Lyon, Metropolitan Grenoble and Metropolitan Saint Etienne allowed them to work together on various subjects, in particular adaptation and urban heat islands. Similarly, it is probable that the Climate Summit of the C40 cities in New York in 2007 played a part in the city's decision to produce an adaptation strategy. The Urban Community of Dunkirk, finally, regarded its membership in numerous international and regional networks as an essential learning tool.

### **Vulnerabilities and events experienced**

The second trigger is the feeling of vulnerability to climate change which the cities may have. This feeling of vulnerability can be linked to various physical conditions (coastal city in the case of Dunkirk, density in the case of Paris, area subject to high temperatures in the case of Grenoble) and is generally exacerbated by recent extreme climatic events or those which left their mark on the collective memory. The most advanced cities in terms of adaptation were often affected by such events in the previous decade, and the two most frequently cited phenomena are heat waves and floods, phenomena often accompanied by public pressure for better risk management. Paris and Lyon were thus more affected by the heat wave in 2003 than the average French town (with excess mortality figures of 127% and 80% respectively, higher than the average excess mortality for France which stood at 60%), which partially explains their interest in the impact of climate change on thermal stress. In contrast, awareness of the need for adaptation can be slow to catch on in towns which have not yet been victim to major events or which face less serious risks.

### **Link with other territorial entities**

A third potential trigger is proximity to another territorial entity which is embarking on an adaptation project. This other entity may be a neighbouring municipality or town, or even a local authority on a different level: urban community, *département* or region for example. Some municipalities thus produce their PCET from that of the conurbation or urban community; the urban community of Poitiers plans to take inspiration from the approaches taken by the Poitou-Charentes region; on the other hand, the urban community of Bordeaux started to produce a PCET once the city of Bordeaux, which represents one third of its population, had completed it.

### **Role of elected representatives**

A third trigger, often crucial and present in almost all the cities which already include or plan to include the subject of adaptation in their public policies, is the existence of an elected representative involved in sustainable development. This is both a trigger and a success factor: not only can the elected representative provide the political will to allow it to embark on an adaptation project, but he can also promote dialogue between the technical bodies and administration or other elected representatives by his knowledge of the subject.

### **Barriers**

Here, we draw a distinction between four categories of barrier to adaptation: information-related barriers, technical and financial barriers, cognitive barriers, and regulatory and institutional barriers. These final two categories are sometimes combined under the name "social barriers to adaptation". Some are identified expressly by the actors of adaptation implementation, while others are not but are revealed by analysis. Here, we present the main barriers to adaptation, but do not claim to provide an exhaustive review.

#### ***Information-related barriers***

Adapting to a phenomenon - here climate change - requires a certain knowledge of this phenomenon and how to act. However, on the one hand, there are many uncertainties as to the impacts of climate

change, and on the other there is little available knowledge about potential adaptation strategies; above all, the knowledge and understanding the stakeholders have about available existing sources of information remains singularly limited. For all stakeholders involved in approaches to adaptation to climate change, these information barriers represent real brakes to action.

Uncertainties about the future impacts of climate change come from three sources. The first is the future development of greenhouse gas emissions, which is the main cause of climate change and depends in part on choices to be made in the future. To overcome this uncertainty, climate models are based on greenhouse gas emission scenarios over the forthcoming century which are thought to cover a good part of what is possible. In practice, scientists use six, but practitioners often confine themselves to one or two. Above all, they have a great tendency to choose the most optimistic, arguing that it is both simpler to adapt to a situation close to that which is known and politically better to limit pessimism. In terms of effectiveness of adaptation on the other hand, this situation is not optimum. If no scenario was more probable than any other at the time they were conceived, the last ten years have not allowed us to position ourselves on serious emission-reduction trajectories and have rendered the most optimistic scenarios illusory. Adapting only to the most optimistic scenarios is thus not sufficient, and often not effective either. On condition that the actions taken can be adjusted, this can however be a realistic starting point for a long-term adaptation process.

A second source of uncertainty is linked to climate modelling: our knowledge of the physics, chemistry and biology of the climate system is incomplete and the available computing power is limited. These first two sources of uncertainty mean that it is not possible to give categorical climate forecasts, and that no more than ranges of possibilities can be provided. While there is no doubt about the reality of climate change, its magnitude remains uncertain - above all at a smaller scale than a region.

A third and final source of uncertainty is the transformation of climate changes into impacts on human societies and eco-systems. This transformation requires the interaction of a multitude of natural, social, economic and technical factors with climate data and it is difficult to predict the effect of a change of one variable (for example, an average temperature rise of 3.5°C) on natural and human systems in the future. A prediction such as this requires knowledge which we do not have of these systems' reaction and capacity to anticipate.

In the end, some of these uncertainties are irreducible and the reduction of the others would take time which could potentially be longer than the time available to predict climate change and adapt to it. Others finally may paradoxically increase with scientific progress (updating of tipping points and threshold effects, for example). Adapting to climate change by anticipation thus requires decisions to be taken in a context of great uncertainty, and it is clearly a barrier to action, identified by practitioners - in the French and foreign cities alike.

The lack of examples and the absence of a raft of standard measures are seen by many as another brake to action in the field of adaptation. With the subject and its implementation both being recent, the sources of inspiration are rare for the towns which are embarking on it, and the little experience which does exist is still insufficiently shared. Adaptation measures are, furthermore, very context-dependent: what is valid for one territory is not necessarily so for another. It is thus essential for towns to make a major effort to appropriate solutions which others may have put in place. In the end, the cost of learning how to put together an adaptation strategy can be reduced by an optimised sharing of experience.

### ***Technical and financial barriers***

A second type of barrier frequently cited by the towns and cities, in France and elsewhere, is the lack of human and financial resources. While it has not been demonstrated that heavy investment is often needed, the introduction of an adaptation plan remains a process which requires a financial commitment by the town. So it is a process involving long-term challenges and the return on investment is distant and diffused. The combination of these two factors is often reflected by a huge difficulty in integrating adaptation to climate change in municipal budgets, and thus puts the brakes on any action in this regard.



The definition of an adaptation plan is moreover complex, as it requires a range of technical skills: knowledge of climate changes, models and uncertainties, understanding how a town functions, its vulnerabilities and its stakeholders etc. However, the French towns often make use of employees who already have a particular job and for whom adaptation adds to their workload, or take the route of temporary employment (the most usual example being trainees). Clearly, neither situation is clearly optimum in a long-term perspective: they allow neither the complexity of the subject to be embraced nor the long-term continuity of the approach to be ensured. This can however also be a realistic way to launch the adaptation process, but the interviews carried out indicate that frequent recourse to trainees is also a reason for the lack of ambition of the approaches and their premature suspension.

The adaptation of a town is a continuous process, requiring tracking, analyses and regular adjustments of the vulnerability diagnosis and choices regarding the action to be taken. It is not a one-off project. The lack of human resources deployed is thus a notable brake on adaptation beyond the report stage. However, many local authorities, because they are relatively small, do not and will not have the means to have a dedicated employee for this, and reflection is needed on the conditions of engagement so they are not disproportionate (for example, by grouping together skills on a broad territorial level and thus allowing "economies of scale"). We would note here that in future, adaptation to climate change is not destined to remain in the hands of one agent or one dedicated team. To the contrary, it must be included in the responsibility of each engineer, landscape architect, architect, town-planner etc.

### ***Cognitive barriers***

The cognitive barriers to adaptation to climate change are generally the biases caused by the different individual and collective understanding and perceptions of climate change, of adaptation and associated concepts (for example, risk, vulnerability and uncertainty). Research in this regard is in its very early stages, but identifying and overcoming cognitive barriers and regulatory and institutional barriers are seen as major challenges for the production of adaptation strategies. The study of the projects put in place in the cities shows that these barriers are indeed present, are sometimes identified as such by the stakeholders, but that not all of them are always acknowledged. Providing the means to overcome these barriers is a major challenge for the implementation of adaptation.

An initial cognitive barrier is, for example, the low weight of long-term challenges in individual or collective decisions, which leads to climate change being regarded by many as a problem which is not urgent, or individuals or groups preferring to await the impacts before reacting. However, we know that this approach is far less effective than anticipating changes and preparing for them. In the same logic, individuals and groups tend to overestimate their capacity to adapt (in particular retroactively) and to underestimate their vulnerability, and thus to put in place less ambitious measures than are necessary.

Adaptation itself is often perceived as a difficult process, requiring substantial investment. This perception, shared by many of the cities, is a big brake to action. However, the study shows that by far most of what has been done in the name of adaptation, whether in the cities or elsewhere, has been done at a relatively low cost, rarely above marginal adjustment costs. In truth, it appears that the measures proposed by way of adaptation are principally "no regrets" measures, the costs of which are by definition low, and they are therefore no indication of the real costs of adaptation which can still not be calculated (see chapter 1).

Similarly, we have seen that uncertainties are a true barrier to adaptation. Interviews with the actors of adaptation in towns show that this barrier is reinforced by the perception individuals have of these uncertainties: they judge them to be too big to act, yet, on the one hand, they have limited knowledge of them and, on the other, many decisions have already been taken in a context of great uncertainty without encountering the same perceptions.

Finally, the stakeholders' limited perception of climate risks does not prevent action but very often renders adaptation strategies sub-optimum. Indeed, the study of adaptation plans in the French and foreign towns and cities reveals a fairly limited vision of the risks taken into account, and thus the adaptation choices made. The risks taken into account in adaptation plans are above all known risks from the past. The current approach leaves little room for reflection about new risks which climate change can create - whether still unknown in the city studied or whether not yet occurring anywhere. In

particular, combinations of events are never studied: if climate change increases the occurrence of heat waves and flooding, what will happen if they both happen at the same place just 2 months apart? Worse, the cities often tend not to integrate change in the risks they are familiar with, and thus adapt only to the past climate although they believe they are adapting to climate change. The heat wave of 2003 or the floods in 1910 are thus often considered as standard risks to which towns need to prepare themselves, whereas Météo-France estimates, for example, that it is probable that the temperatures reached in summer 2003 will become the norm before the end of the century.

Furthermore, the fact that climate change is perceived as a warming results visibly in the risks associated with cold (such as frosts, snow storms etc.) being forgotten by people involved in adaptation. However, this does not prove from the outset and in all cases that these risks and the vulnerability of towns to these risks are decreasing. Extreme events are also found to be over-represented in the impacts of climate change taken into account by the cities, to the detriment of the impact of more gradual changes. Finally, the cities only exceptionally interest themselves in possible positive impacts of climate change. Yet there are some, at least in the short and medium term, and the way to optimise them is by anticipating them. For example, an increase in tourism is expected in the north and west of France. Metropolitan Nantes plans to consider this question. In total, the impacts of climate change considered by the cities are not sufficient to allow optimum adaptation.

### ***Regulatory and institutional barriers***

The implementation of adaptation is constrained by the environment of the various stakeholders concerned, in particular the organisation and structure of social institutions: these are regulatory and institutional barriers. For towns, there are many such barriers and they are often identified as one of the main difficulties with a subject such as adaptation.

One of the barriers cited most often is the spread of skills over different territorial levels: the municipal authority which implements its adaptation strategy does not have the power to act on all the components in its territory and is dependent on choices made at other levels. Rouen, which tends to put the accent on the use of green spaces for rainwater and flood risk management, finds that this adaptation measure is rendered difficult by the fact that the green spaces are in the competence of the city, while rainwater is managed by the conurbation. The measures proposed require joint finance and maintenance.

Similarly, in Dunkirk the maintenance of internal drainage districts - drainage works in the low-altitude coastal zones of the Netherlands, Belgium and the north of France - enabling a reduction in vulnerability to flooding, is braked by a spread of competences between state departments, environmental protection associations and local stakeholders.

Thus, it is not enough to propose actions: the stakeholders need to be able to implement them. An adaptation strategy must therefore take into account any discrepancy between what the stakeholders want and what they are allowed to do by the system.

Furthermore, understanding climate risk and prioritising action are often different across a single group and from one group to another, in particular at different territorial levels, which puts the brakes on action by even the most determined. Thus, the departments for the environment of towns are often more aware of the question of climate change impacts than more technical departments, but they have fewer levers for action.

It appears clearly that putting in place reflection and an action plan with regard to adaptation requires a particular political will. Yet the political agenda often demands that the focus be placed on issues judged to be more urgent, more short-term and highlighted by different stakeholders. Some specific characteristics of adaptation (uncertainties of impacts, long-term challenges, novelty of the subject and lack of knowledge about the measures to be taken) place it on the margins of normal decision-making processes. In towns in which climate risks are lower - or rather judged to be so due to the absence of any precedents - it is more difficult to convince stakeholders of the essential nature of adaptation. It is moreover sometimes difficult for local governments to embark on actions which have not yet "proved their worth", and the relevance and effectiveness of which have yet to be demonstrated.

Finally, generally speaking, institutions can be held back from putting in place reflection on adaptation by a strong propensity to maintain the *status quo*. While this characteristic is not specific to issues of adaptation, it is reinforced by the other previously mentioned barriers, such as the uncertainties and the diffuse nature of the concept. The *status quo* is often the default option, and any departure from it

is often marginal and incremental. This organisational rigidity is an obstacle to the adoption of an ambitious adaptation plan, and strong triggers are needed to remedy this.

Identifying, understanding and taking into account these barriers is an initial stage in optimising the implementation of adaptation in local authorities. The fact that these barriers are common to all the cities and avoiding them is relatively onerous and costly prompts action at national level. This will be subject of the fifth part.

What place should be given to policies and measures not labelled “adaptation” in a perspective of adaptation to climate change?

The adaptation plans developed by towns and cities are simply “the visible part of the iceberg” of the policies and measures which have an effect on their adaptation to climate change. There is indeed a multitude of plans, projects and policies which have already or may come together to adapt the town to climate change, and the challenge is thus to identify them in order to optimise their role. Some cities, such as Toronto or Paris for example, have identified some of these measures and made them the basis of their initial adaptation strategy. Presented here are some of these policies and measures via a classification whose sole purpose is to highlight their different relations to adaptation. A distinction should thus be drawn between the policies and measures already aimed at adaptation, and those which can contribute to adaptation to climate change on condition that climate factors and potential maladaptations are included in them. The case of mitigation measures will be considered at the end.

In a certain way, all a town’s policies have or can have an impact - be it positive or negative - on adaptation. The purpose of this section is thus not to provide an exhaustive list of them, but instead to propose a framework for thought and concrete examples which can allow stakeholders to identify these measures and to integrate them in their adaptation approach. Two complementary strategies allow these measures to be understood: the first starts with climate impacts (rise in temperatures, rise in sea level etc.) and goes on to policies and measures which have an impact on the management of these impacts; the second is the reverse and consists of examining the consequences of each urban policy on adaptation to climate change.

## **Policies and measures already aimed at adaptation**

These measures are generally devices which allow towns to adapt to existing climate risks such as floods, droughts and heat waves. They are not intended to adapt to climate change as such, but to better integrate and protect against extreme climate events in the current climate. However, starting from the principle that the territories are often not adapted to current risks, they contribute to an initial stage of adaptation to the future climate: adaptation to the present climate. This comprises what are often called “no regrets” measures as they are beneficial whatever happens and allow some of the uncertainties associated with the impacts of climate change to be overcome. They thus contribute to adaptation to climate change. We find moreover that the adaptation plans of many foreign towns integrate some of these measures in their first phase, mainly because it is relatively simple and not onerous to do so. For example, the entire first phase of the Toronto plan is dedicated to taking account of this type of measure. To optimise this contribution, however, they would need to integrate an anticipation of changes in risks, rather than simply regarding a risk level as constant, as they often do. This integration can be a simple and effective measure in a town’s adaptation strategy.

### ***Regular survey of climatic events***

A first type of measure which is already aimed at adaptation is an inventory of climatic events. It meets the need of maintaining the collective memory of risk and thus avoiding the occurrence of senseless urbanisation. But this survey today is still divided by topic and does not form an index of all events. There are two methods of recording phenomena, one at municipality level, the other at national level. Thus the municipality is responsible for recording risks resulting from known events: production of the local inventory of high river levels, and the establishment of references. For their part, the state departments rely basically on a reference event identified for a phenomenon of exceptional intensity (atlas of flood-risk zones based on the 100-year return flood). Likewise, Météo-France creates databases about meteorological events, which can allow events to be recorded and their development to be detected.

## ***Prevention plans***

There is however a type of measure whose direct effects on the town's adaptation to climate change can be recorded, even if the word "adaptation" does not feature; they are the Natural Risk Prevention Plans (PPRN) which apply to a territory comprising one or more municipalities. They concern in particular floods, landslides, forest fires and storms, i.e. phenomena whose frequency and scale will potentially be affected by climate change.

PPRNs, which are part of a governmental prevention policy, are thus not based on climate change impacts, but to a certain extent allow a town to adapt to the latter. Among the objectives and actions associated with a PPRN, are a number of crucial elements which are intended to adapt the town to the effects of climate change: better knowledge of phenomena and their impacts, monitoring, raising the awareness of the population, taking risks into account in projects, protecting and adapting installations.

## ***Prevention, awareness-raising and protection of the population***

A third type of measure already contributing to adaptation is a set of measures which allow populations to be prepared for the various climate risks. The population is often ignorant of its vulnerability to climate risks, in particular the characteristics specific to its territory and past events, and one of challenges of adaptation is to provide it with the information and tools needed to deal with the impacts of the climate and climate change.

## ***Informing the population about plausible risks***

Since 1987, a series of legislative and regulatory provisions imposed the citizen's right to preventive information about the major risks to which he may be exposed (article L. 125-2 and L. 125-5 to 27 of the Environmental Code). These provisions allow an individual and collective awareness of the risk. Summary information about risks is produced by the prefectural departments in the form of a Departmental Dossier of Major Risks (DDRM) and by the production, by the mayor, of a local information document on major risks (DICRIM). These documents describe the risks to which the territories are exposed and the foreseeable consequences on people, property and the environment, and likewise the chronology of known phenomena. The mayor has a duty to inform the population of the major risks present in the local territory, based on these dossiers.

## ***Preparation for an emergency situation***

The major climate events which have affected the national territory (storms in 1999, heat wave of 2003 etc.) showed that local authorities were not all prepared to face this type of crisis. Responding to an emergency situation requires the rapid mobilisation of all public and private resources and their effective coordination. The at-risk municipalities are obliged to produce a Local Safeguard Plan (PCS) which incorporates in particular the DICRIM, establishing a link between preventive information and behavioural risk information.

## ***Protection of the population in the face of an imminent or proven risk***

Where a climatic phenomenon is forecast in the near future, the population must be alerted promptly. This short-term information is an opportunity to remind the population of the risks and the associated appropriate behaviours. This information is diffused by warning systems: the media, telephone, sirens etc. As the event may change, the methods of diffusion also allow the population to be kept informed of changes. We would mention in this regard the innovation of the vigilance card, following the experience of the storms of 1999: it improves the communication of the risk directly to the citizen and provides forecasts and prudent advice in a single document. The Heat Wave Plan is another a type of measure which already exists and can help with adaptation to climate change, especially if the development of the risk of extreme hot weather is incorporated.

## **Policies and measures which can help with adaptation**

Other policies and measures do not contribute directly to adaptation to climate change, in the sense that they are not linked to the climate. But they can provide a framework for action for putting in place adaptation measures, on condition that a climate and climate change dimension is included. It is thus important to identify them in order to integrate them in an adaptation strategy, because they are also potentially effective and low-cost measures. More precisely, an adaptation strategy should suggest ways to include considerations associated with climate change in these measures.

### ***Urban-planning documents***

An initial system which may offer a framework such as this would be to bring together decentralised planning documents (article L. 121-1). The law relating to solidarity and urban renewal (SRU) instituted two urban planning documents - territorial coherence schemes (SCOT) and local urban-planning plans (PLU) - which allow risks to be taken into account in any development project on any scale. The production and revision of the urban-planning document requires the inclusion in the presentation report of information about the existing situation in the territory and in particular a description of the risks and the impacts they represent. This report can provide a framework for the town's adaptation to climate change, as it is obligatory to offer measures enacted in the regulations to reduce or eliminate dangers.

In the planning document, the existence of risks in the territory leads either to a ban on or to an authorisation, subject to certain conditions, of the urban development of land. Thus, the forecasting function of the SCOT will orient the organisation of the space and the regulatory function of the PLU will set easements regarding land taking account of the risks. The long-term management of concerns associated with risks is at the heart of the planning system. This is why, in strategic planning and orientation documents, the "climate change" aspect merits forming the subject of particular attention in order to optimise its consideration in the context of the transformation of towns.

### ***Protection of natural spaces***

It appears that the measures to protect natural spaces are often measures which do not directly contribute to adaptation but can be influential if they integrate climate change. Two emblematic examples are the Coasts Act and the Mountains Act which, although not within the competence of the town, are important determining factors for its adaptation to climate change and the rise in the sea level. Their urban-planning provisions significantly reduce the vulnerability of urban planning in the face of natural risks. By way of example, the municipalities subject to the Coasts Act are involved in the strategic withdrawal of the town and developments on the sea front which would risk in time being endangered by submersion or coastal erosion. The adaptation of towns is thus optimised also by taking account of climate change in this type of regulation.

## **Potential irreversibilities and maladaptations**

Some of a town's policies, measures and projects may have a negative effect on adaptation because they increase the vulnerability of part of the territory or its population to climate change. They can in particular make their future adaptation more difficult or lead to irreversibilities. The term usually used for this type of situation is "maladaptation" (see box 21).

The concept of maladaptation is currently used in the field of adaptation, but there is no agreed definition. The definitions generally encountered take a restricted view of the term by describing it as an adaptation action which misses its target, i.e. which increases vulnerability instead of reducing it.

However, one frequently finds the term used for a broader view, a view which we take here: that of defining a maladaptation as any action which increases the vulnerability of a group or an eco-system to climate change, today or in the future. A maladaptation can thus be an action whose the primary aim is adaptation, but which increases the vulnerability of the target group instead of decreasing it, or which increases the vulnerability of a group other than the target group, today or in the future. The

generalisation of air-conditioning is a maladaptation of this kind as, since it contributes to greenhouse gas emissions, it increases future climate change and thus the vulnerability of populations in the future. A maladaptation can also be an action whose sole aim is adaptation and which indirectly increases the vulnerability of a group to climate change impacts. Planning approval for flood-risk zones (be they current or future) is an example of this type of maladaptation.

### *Box 21: maladaptations, attempts at definition*

## **Protection of the heritage**

The adaptation of towns to climate change will necessitate physical modifications to buildings, for example to insulate or ventilate them. Any measure which prevents changes to these buildings, in particular measures put in place to preserve the cultural heritage, thus risks coming into conflict with an adaptation approach. By limiting the flexibility of surroundings, they can thus help increase vulnerability instead of reducing it. These risks of maladaptation must not be under-estimated, more particularly where there is an issue of safeguarding the historical heritage.

## **Impermeabilisation of the ground**

Urban development which does not take into account the future impacts of climate change can lead to a certain number of irreversibilities which increase the risks associated with climate change. This is true of the impermeabilisation of the ground for example: the gradual artificialisation of natural spaces and their covering with roads, concrete slabs and structures restrict infiltration and greatly increase rainwater run-off. This impermeabilisation is currently one of the main causes of the increase in the flood risk in towns, and it will greatly limit their ability to adapt to a change in this risk associated with a rise in the frequency and intensity of heavy rain. We would note here the urban rainwater management tax, established by the Grenelle II Law, which includes an incentive scheme potentially allowing impermeabilisation to be restricted by deducting permeable areas from the area on which the tax due is calculated.

## **Mitigation measures**

The measures put in place by towns to mitigate climate change can have various effects with regard to adaptation. As we have just seen, they can also help to contribute to adaptation, to provide a framework of action for adaptation (on condition that risks are taken into account in such action), or to the contrary to work against adaptation.

The most emblematic case of potential synergies between mitigation and adaptation, and which we look into here, is the use of standards, certifications, acronyms, labels and regulations for construction. These measures are all intended to achieve **better thermal comfort and a lowering of energy consumption**. Since 2000, three thermal regulations have been produced. While the purpose of these measures is to reduce French greenhouse gas emissions, **they can also allow, fairly directly, buildings to be adapted for climate change**. Indeed, the reduction in energy consumption, the lowering of the internal temperature in summer, insulation and the improvement of thermal performance will allow buildings to adapt to the rise in the average temperature as a result of the effects of climate change.

In contrast, some mitigation measures can reduce the town's ability to adapt. Some ways of reducing heating consumption can increase the air-conditioning demand: the use of floor-to-ceiling windows is one example of this. The densification of the town, a measure sometimes proposed to reduce greenhouse gas emissions, can also increase the risk of heat islands. Identification of these conflicts is recommended to allow any adjustments to mitigation strategies to be devised in such a way that they also reduce vulnerability to climate change.

## **Necessary conditions**

In the end, it is clear that many of a town's policies and measures can help it to adapt to climate change, subject to certain conditions.

A first condition may seem evident but practice shows that it is not: these policies and measures must take climate change into account, i.e. they must no longer be based on standards calculated from the past climate but instead must integrate the gradual changing of this climate. There is nothing to guarantee that a measure which does not take climate change into account is appropriate, i.e. that it will be valid if the climate changes.

After this first stage, it must also be possible to track and review these measures regularly on the basis of the change in the climate, and to understand this change and the tools enabling impacts to be evaluated. There are thus two changes to be tracked: firstly, that of the climate, by regularly re-evaluating the standards used for example, then that of science. The evaluation of the impacts of climate change and vulnerability is an area which is constantly changing. Allowing the provisions taken by the town to be updated on the basis of these changes is extremely important to ensure that their adaptation is effective.

A third essential condition is to start to reflect on threshold effects. Indeed, some measures may prove highly effective in the face of a given climate event, of a given intensity and frequency. But it is probable that climate change involves an increase in the frequency and occurrence of many phenomena: heat waves linked to the rise in temperature, flooding associated with the rise in sea level or changes in rainfall patterns, storms, mudslides etc. What needs to be asked is whether the plans, measures and projects designed to address cases of exceptional phenomena will still prove to be effective if the phenomena become more commonplace or more powerful. This is the case for example with adaptation to the heat wave of 2003: if the heat wave risk increases due to climate change, and the 1 in 100 year heat wave becomes 1 in 10 years or even annual, thought must be given to adaptation strategies other than those planned or allowed by the Heat Wave Plan today. It is thus also necessary to take threshold effects into account when integrating a town's plans, measures and projects which are not labelled adaptation. Moreover, the very existence of a protection plan can excessively reassure the population unless something is done to update the protection or the preparation in the light of the development of the risk, and finally to increase vulnerability. This neglect of risk once protection is in place can also constitute a strong brake to towns' adaptation for the effects of climate change.

One can thus see that it is important not to restrict an adaptation strategy to the creation of new measures, intended specifically to reduce a town's vulnerability to climate change: there is in fact the huge challenge of integrating a town's policies which pre-exist the adaptation strategy and which already play a role in this adaptation or can play this role under certain conditions. It is moreover essential to avoid the maladaptations potentially created by measures which do not take climate change into account and which increase the vulnerability of a territory or a group to these impacts. Finally, the boost given to measures to reduce greenhouse gas emissions is an opportunity to optimise the synergies and avoid the conflicts which they can have with adaptation challenges.

## ***Perspectives***

Although this is a relatively young subject, the study of the implementation of adaptation in towns in France and abroad allows some characteristics and trends potentially useful for the future to be identified. The previous sections have allowed an overview to be formed of the urban adaptation initiatives in France and abroad, then the main levers and barriers to adaptation to be identified. Finally, one of the main future areas of adaptation has been presented: the integration of all town policies which are not labelled "adaptation" but which relate to the adaptation effort or should be integrated in it. The purpose of this final section is to review the main lessons raised by these various points and to highlight a few perspectives regarding the implementation of adaptation in towns.

### ***Balance: the early days of adaptation***

It is clear from an analysis of adaptation projects, plans and strategies and the opinion of those responsible, that the implementation of adaptation is, in France, at a preliminary stage, and that towns abroad are no more advanced, with the exception of a few pioneers. A study of the pioneer towns reveals, by comparison, a still embryonic adaptation approach in French towns: projects are short,

ignore the stage of vulnerability diagnosis and do not adopt a strategic view of the town's adaptation the years to come. Furthermore, the rare adaptation plans which do exist are confined to one or two climatic events (generally the urban heat island and flooding), and that they do not really consider the impact of climate change on these events. Finally, the number of measures proposed and sectors or areas involved is still very small.

While initiatives have been taken since the middle of the decade, their range and their progress do not allow us to say that French towns are really adapting to climate change. These initiatives must instead be viewed as the start of a process which will take time, in an approach of continuous improvement and sharing of experience between one town and the next. They also coincide with national level involvement in this subject, and this synchronisation is a source of interesting reciprocal contributions: French state services are to facilitate adaptation in local authorities, and the towns will be an adaptation laboratory from which experience and lessons crucial to France's adaptation to climate change will emerge.

### ***The need to put in place tools at national level to facilitate adaptation at local level***

The balance of implementation of adaptation in French towns is thus clear: it is just a beginning. Section 3 of this chapter has shown that many barriers can be mentioned which explain the lack of ambition of current adaptation approaches in French towns. Getting over these barriers requires commitment at national level, in particular by the provision of joint tools, incentives and methodological frameworks, which are revisable and adjustable based on the feedback of experience from the stakeholders involved. The production of these tools must however allow enormous freedom in the choice of solutions which the towns try out. No adaptation strategy is yet proven, whether in its form or in the actions it proposes, and it is risky to limit the range of possibilities by overly constraining frameworks. So a balance needs to be found between a concern to help towns by providing them with tools, and the need to favour experimentation by ensuring that these tools do not excessively condition the choices of towns with regard to adaptation.

Some tools which appear necessary for adaptation are detailed here; some of them already exist to a certain extent in France, and it is not the job of the inventory of needs undertaken here to disregard them. Its objective instead is to provide a global vision of the tools necessary for adaptation in towns.

### ***Methodological guides***

The first tool - and perhaps the most obvious - is a methodological guide to adaptation in local authorities. A framework such as this would enable a town worried about embarking on an adaptation approach to be guided in the various stages of production and implementation of a strategy. It would thus be useful for optimising adaptation plans, by permitting for example greater allowance for impacts, sectors and vulnerabilities. Finally, it would suggest prioritisation solutions for various adaptation actions, to be adjusted for each community. Tools such as this already exist in the context of development aid: the major financial backers, mainly multilateral development banks, have thus published advice about devising adaptation projects in developing countries which are often used by local property owners. In France, the report by the Economic Sustainable Development Council (CEDD) entitled "Economie de l'adaptation au changement climatique" (C.de Perthuis, S. Hallegatte et F. Lecocq) proposes, for example, a seven-stage process to construct an adaptation strategy.

### ***Vulnerability diagnoses***

The stage of vulnerability diagnosis, often ignored in the adaptation plans of French towns, is therefore of prime importance for putting in place an effective adaptation strategy: understanding the vulnerability of the territory and everything in it, based on the risks posed by climate change should then allow the identification and the prioritisation of the adaptation actions to be implemented. Experience shows that this stage is only considered seriously if vulnerability diagnosis tools are provided. These tools are generally methodological guides describing a process to be followed and offering examples to serve as inspiration. ADEME is preparing a guide such as this which it should be making available to the stakeholders in towns in the course of 2011.



As recalled moreover in the first chapter, global warming will not be the only factor of change in the future, and socio-economic dynamics may sometimes change the conditions under which a town functions more than environmental changes. Thus, climatic change and society dynamics are to be considered together. Prospective socio-economic tools integrating demographic, economic and social dimensions are indispensable alongside prospective climate tools, and continue to be developed by development agencies, engineering offices and research laboratories.

### ***Evaluation of costs***

Finally, it appears essential and even urgent to improve our knowledge of the cost of adaptation. Various types of cost arise: costs of ex-ante analysis, production of action plans, implementation, technologies, communication, and evaluation. We find furthermore that the current implementation of adaptation does not allow the real costs of adaptation to be predicted. The implementation of more costly measures, specifically dedicated to adaptation to climate change, has not really started.

Better knowledge of the costs and their hierarchy will allow, on the one hand, actions to be prioritised on the basis of the budget and, on the other, essential additional resources to be provided. The objective is to render adaptation policies more consistent in the long term. Adaptation to climate change, however, presents characteristics which render cost evaluation very difficult: uncertainties about impact, lack of knowledge about the solutions to be applied, preponderance of gentle solutions and “no regrets” measures, all difficult to estimate. Reflection at national level would therefore be helpful, to propose tools to evaluate these costs.

### ***Climate departments***

For a successful vulnerability diagnosis, up-to-date climate information, understood by those using it, is needed. The deployment of climate departments at national level appears to be essential for the implementation of adaptation, whether urban or with regard to other levels and stakeholders. Climate departments are defined as a group of departments providing a user with information about both the science of the climate and how it functions, and also about the results of climate models. This information may be generic, i.e. common to all users, or bespoke, i.e. tailored to the specific requirements of each user. It is essential to allow towns to move past the current stage of taking account of risk and to properly integrate climate change in their approach. Climate department projects have started in France, but they are still far from providing a complete offering on the subject. The DRIAS project, for example, financed by the MEEDDM in the context of the GICC programme, aims to build a website which will serve as a platform for climate information.

### ***Sharing experience***

A final tool, of prime importance, which needs to be developed at national level, is an interface for sharing experience at all levels of implementation. The lack of experience and examples on which to rely has been identified by a majority of stakeholders as a major brake to action in the field of adaptation. Diffusing information about existing experience, in a regular and readily accessible way, would greatly facilitate the task of taking adaptation into account in towns and other local authorities. This interface can take various forms, for example that of an internet platform (on its site<sup>2</sup>, ONERC has an area called “local initiatives” intended to allow for this interface) or dedicated conferences. In fact, scientific symposia and conferences about adaptation also allow the sharing of experience about implementation, across all sectors and all levels. With the implementation of adaptation being still recent, it would also be very useful to facilitate stronger interaction between research and action, by establishing bridges and partnerships between universities and towns, and between researchers and technicians.

The study has also showed that networks of towns and cities, whether abroad or in France (see for example the international networks of ICLEI or C40, and the French network ViTeCC) have been

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<sup>2</sup> <http://www.developpement-durable.gouv.fr/-Initiatives-locales-.html>

essential in promoting mutual emulation enabling adaptation approaches to be initiated and to be ambitious. It thus appears essential to support such networks, to encourage towns to join them, and to promote the integration of adaptation issues. It is worthwhile in this regard not restricting ourselves to the French experience but to integrate international initiatives. The study also pleads in favour of groupings of municipalities and of adaptation efforts at local level: groups of neighbouring towns or conurbations and the integration of different territorial levels facilitate the initiation of adaptation efforts.

### ***Training and awareness-raising***

Finally, while the tools exist and will exist in ever greater numbers, it is crucial that those for whom they are intended are able to stand back from the guiding principles, methodologies and the case studies described. This assumes that the people responsible for producing strategies, upstream and downstream, have the skills to judge the relevance of other experience with regard to the specific context of their town.

Interviews conducted in the context of the production of this report show that there is a real deficiency in this area. This is why the "training and awareness-raising" section appears indispensable in order to promote the introduction of adaptation approaches, but also and probably above all to guarantee that these approaches will be increasingly robust and realistic, and thus in time that adaptation efforts (in terms of human and financial resources in particular) will pay off. This section concerns in particular the decision-makers and the political leaders, the consultants involved in the adaptation approaches of local authorities, the personnel of these authorities (whether they are responsible or their sector is targeted), researchers in the disciplines concerned, and more broadly the populations of towns.

### ***Conclusion: a framework of thinking for adaptation in towns***

It is possible, with the help of selected case studies, the documents studied and the interviews conducted, to draw a certain number of lessons from past and present experience in adaptation to climate change. Thus, on the scale of an urban community, six elements appear fundamental to building a framework of thinking for the production of adaptation strategies. Before embarking on a process of identifying lines of adaptation and producing a general strategy, the decision-makers and stakeholders in a town need to appropriate these principles, debate them and define a shared vision of the adaptation of their territory.

### **Regarding adaptation as an opportunity**

Climate change is most often presented as a new source of constraints. However, we saw in chapter 1 that its main effect is that of increasing the frequency and intensity of current climate events, and thus largely of exacerbating the risks which towns already face. The decision-makers and stakeholders in a town have a certain amount of experience in the management of these natural catastrophes (in terms of failures and successes), and this experience can be seen as a fundamental lever for putting in place a proactive approach in the face of the threats of climate change. Rotterdam (Netherlands), hugely threatened by the rise in the sea level due to its geographical location, thus deliberately chose to regard adaptation as an opportunity and to embark on an anticipatory strategy (see box 22).

It is the city of Rotterdam's ambition to be climate proof by 2025, i.e. to be flexible and resilient by this date. The city anticipates a number of consequences of climate change, but inevitably places the accent on the risk of flooding.

The city's strategy in terms of adaptation, "Rotterdam Climate Proof", has three ambitions: that Rotterdam be (1) protected against climatic events, (2) economically strong and (3) attractive, a place where life is good. This strategy, centred on sustainable development, serves inter alia to reassure investment: we should bear in mind that Rotterdam is the centre of one of the most important ports in the world. But it is above all else representative of the role which the city hopes to assume. Rather than perceiving adaptation as a misfortune, Rotterdam has elected to see it as an opportunity. An opportunity to position itself as a leader in know-how and innovation, and as a test site for adaptation in deltaic towns.

## ***Box 22: Climate-proof Rotterdam***

### **Thinking about resilient towns**

Adapting means both anticipating and being capable of coping with unforeseen events. This final area is that of resilience which the **GIEC** defines as a society's or eco-system's ability to absorb shocks (known and unknown) while maintaining the same basic structures of operation. Seeking to increase the resilience of an urban system in the face of climatic disturbances (storms, floods etc.) must be understood as a "no regrets" process, because it is beneficial even if there is no climate change. However, resilience is just one dimension of a town's adaptation, which must thus not be simply relegated to the position of an emergency relief valve for extreme events.

### **Recognising the existence of divergences of interests**

The town is a complex object and this is largely because it brings together a diversity of stakeholders. The sheer number of these stakeholders and the actions they take can have a positive effect on adaptation logic (promoting innovation, transfers of experience, the formation of networks etc.), but it also invites recognition of the existence of divergences of interests and logic among stakeholders, and thus potential conflicts about the adaptation actions to be implemented. A classic example is that of sharing water between different sectors: if climate change results in a reduction in the water supply in the long term, arbitration will be necessary and not everyone will be the winner. It is essential not to feign ignorance of these issues as they can result in adaptation approaches being abandoned. Not all adaptation measures will be "win-win" but this does not mean they should be disregarded.

### **Adapting interventions to the specific features of local contexts**

We have said this a number of times: the adaptation of a territory occurs via measures specific to this territory. There are no generic solutions, and an adaptation strategy must include an in-depth diagnosis of the vulnerability of the territory in question, allowing effective measures to be devised and prioritised. The interfaces for sharing experience must not be considered as lists from which it is possible to crib turnkey adaptation solutions, but rather as inspirational and discussion tools and tools for calling into question.

### **Favouring the diversity of forms**

Adaptation can occur at many levels, not only technical but also behavioural, economic, financial, political, institutional etc. The capacity for adaptation is often reduced to economic and technological attributes, but modes of social organisation and administrative structuring, for example, are also important elements of the aptitude of a town (i) to react to a crisis or a succession of crises and (ii) to anticipate future potential crises. Thus, conceivable practical solutions do not come only from transfers of technology or instruments for the creation of wealth, although they do evidently play a role. One can, for example, see in actions favourable to the maintenance of social links an indirect means of reinforcing the urban community's ability to unite at a time of crisis (social self-help, insurance etc.) and also to implement anticipatory policies (developing transport networks, reinforcing emergency structures and units etc.). In a context of great uncertainty about the future impacts of climate change on the one hand and on the effectiveness of the adaptation strategies which are proposed on the other, it is moreover extremely important not to restrict practical implementation to a small number of actions, seen possibly as good practices. On the contrary, innovation must be at the heart of adaptation approaches and a diversity of choices must be encouraged.

# Perspectives: urban research relating to climate issues

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## Introduction

Of all the major environmental challenges, climate change is one of the main areas in which the scientific community has issued an early warning. This is why French climate research has developed significantly, contributing to the advancement of knowledge in many fields: from the refinement of climate models to produce data on a more operational scale for the various disciplines involved in identifying and managing impacts, through to technological research to develop methods for mitigating and adapting to climate change.

In the area of urban research, the concept of the sustainable city, balancing the three economic, social and environmental spheres, has given rise to many areas for research and projects in recent years in a variety of disciplines, including research into new technologies in human or life sciences and into the management of the complex systems which are the preserve of cities.

However, consideration of the effects of climate change on cities and the need to initiate multidisciplinary work and research in this area in order to implement appropriate policies stem from recent increased awareness. In France, the Grenelle Environment Forum has provided the main impetus, notably through discussions on the form and methods for implementing a sustainable city. International conferences such as the Fifth Urban Research Symposium in Marseille in 2009 on the theme “Cities and climate change”, the International Conference on Urbanisation and Global Environmental Change in Tempe, Arizona in 2010 – or other conferences organised by city groups on an international scales, such as Resilient Cities 2010 – bear witness to a new joint impetus on the part of politicians and researchers.

This chapter presents very recent French research developments on the theme of adapting to climate change by teams organised in multidisciplinary networks and through projects largely, but not exclusively, funded by major research programmes on a variety of topics with the aim of providing cities with the tools to analyse their vulnerability and methods for appropriate urbanisation. Details of the programmes and research areas are outlined in detail in Appendix 1.

## Organisation of research teams and expertise

### Research team groupings

One of the highly unusual features of the French research system is the very diverse nature of its organisation, comprising university teams, organisations commissioning research and national applied research bodies. National research facilities offer a wide range of options for collaboration and the state encourages networking between research laboratories (e.g. the ESPACE laboratory combining 4 universities in the Provence Alpes Côte d’Azur (PACA) region and the CNRS on the process in the territories), the creation of test platforms and clusters of excellence in cooperation with other European clusters such as URBAN-NET.

Also of note is the creation of the Climate-Environment Scientific Interest Group (GIS) in March 2007, whose founder members are: the CNRS (National Centre for Scientific Research), the Atomic Energy Commission (CEA), Versailles Saint-Quentin University in the Yvelines département, the Ecole

Polytechnique and the Agency for the Environment and Energy Conservation (ADEME). It brings together 13 research and higher education establishments in the Ile de France département, five of which constitute the Institut Pierre Simon Laplace joint research body on environmental science, working on climatology hydrology, ecology, health and human and social sciences.

The 13 establishments comprising the Climate-Environment Scientific Interest Group IPSL (Institut Pierre Simon Laplace), BIOEMCO Bio-geochemistry and ecology in continental environments (Bio-géochimie et écologie des milieux continentaux), C3ED Centre for Economics and Ethics for the Environment and Sustainable Development (Centre d'économie et d'éthique pour l'environnement et le développement durable), CEPT Centre for the Study of the Terrestrial and Planetary Environment (Centre d'étude de l'environnement terrestre et planétaire), CIRED (International Centre for Research on the Environment and Development), ESE (Systematics Ecology and Evolution), LISA (Inter-university Laboratory for Atmospheric Systems), LMD (Laboratory for Dynamic Meteorology), LOCEAN (Oceanography and Climate Laboratory), LSCE Laboratory for Climate Science and the Environment), Laboratories of the Medical Research and Training Unit for the Paris Iles de France Ouest area, the Econometrics Laboratory of the Ecole Polytechnique, SA (Aeronomics Department) and SISYPHE (Structure and Functioning of Continental Water Systems).

*Text box 23: The composition of the Climate-Environment Scientific Interest Group*

It aims to develop interdisciplinary research relating to the effects of climate change on nature and human health, as well as its economic repercussions. Five broad areas of research have therefore been defined targeting energy policy and economic growth, climatic extremes and vulnerable regions, ecosystems and water resources, the impact of climate change on health and adapting to climate change. In order to maximise the scientific potential of interdisciplinary climate research by providing access to the necessary stakeholders and tools, the GIS climate special interest group has funded the establishment of the RAMONS project (Research, organisation, mobilisation and structuring of interdisciplinary climate knowledge and the interface between climate science and social and political science) which aims to implement interdisciplinary research in concrete form by rooting it in the social and political realities of climate change via two projects: HUMBOLDT, whose objective is to model the impacts of climate on biodiversity, and CCTV, which explores the connection between green urban networks and adaptation to climate change.

Moreover, in the field of urban policy, a “sustainable cities” Multidisciplinary Subject Network combining the INEE (Institute for Ecology and the Environment) of the CNRS and the IMD Institute for Sustainable Cities (Institut des Métropoles durables) under the aegis of the City of Paris is being set up to enable a world renowned multidisciplinary cluster of excellence to be created bringing together different types of stakeholders – scientists, politicians, economists – around the topic of sustainable urban development. Based on the challenge of how cities adapt to climate change, to changes in lifestyle and the vulnerability of territories more generally, research will focus on five main themes: the spatial organisation of major urban areas, the energy efficiency of existing buildings, technical networks and urban services, the role and function of living organisms in cities and the relevance of evaluation tools.

In terms of the physical and scientific grouping of research teams, one can cite the Paris-Est scientific and technical cluster which aims to bring together the following scientific and technical bodies and educational institutes situated wholly or partly to the East of Paris around the common theme of the sustainable city: CSTB (Scientific and Technical Centre for the Building Industry), INRETS (National Institute for Research into Transport and Transport Safety), SETRA (Department for Research into Transport, Routes and their Infrastructure), LCPC (Highways and Bridges Department), les Ecoles Nationales des sciences géographiques (National Geographical Sciences Higher Education Institutes), Ecole des Ponts ParisTech (ParisTech Engineering Institute), CIRED (National Centre for Research into the Environment and Development).

The focal point for this grouping is the cité Descartes campus, bringing together world-level expertise in the form of 1,500 researchers, engineers and PhD students. Located in the new town of Marne la Vallée, the cité includes many disciplines ranging from basic research to full-scale trials. It has been identified as a priority development centre under the Greater Paris Plan and within this framework EPAMARNE is driving an economic and urban development project in this area.

Within the scope of the joint public/private research dynamic and the drive to develop synergies around innovative projects, a process is planned to promote competitive clusters, twelve of which are

involved in the fields of transport, energy, building, the sustainable city and some thirty in technological fields linked to sustainable development and eco-technologies. New Echotech clusters could therefore be created, in particular in the Rhône-Alpes region on the theme of sustainable development and in the Provence-Alpes-Côte d'Azur region on sustainable cities and coastlines.

In the town planning field, a group of stakeholders from various backgrounds - urban planning agencies, universities and the research community - led by MEEDDM (the Ministry for Ecology, Energy, Sustainable Development and the Sea) is taking part in the process of transforming cities and territories sustainably as part of the young urban planners competition, with topics connected, for example, to the development of our urban architectural and landscape heritage and controlling urban sprawl.

## **The emergence of expertise**

The multidisciplinary dynamism surrounding cities and climate is not restricted to the research sector per se, but can also be identified in the consultancy sector where organisations and consultancies have seen an increase in activity across all these areas in recent years.

The Climate branch of the Deposit and Consignment Office (CDC), founded in 2010 and dedicated to the fight against climate change in partnership with Paris Dauphine University and the Ecole Polytechnique, supports a programme of research into climate economics (PREC, Programme de Recherche en Economie du Climat), is a member of VITeCC (the Cities and Territories Climate Change Club), and develops expertise disseminated in a number of publications, notably on the topic of adaptation.

**The Institute for Sustainable Development and International Relations (IDDRI)** promotes scientific work carried out in France and abroad, identifies new issues and provides a forum for dialogue between different stakeholders, enabling them to gain a shared understanding of problems. Among the issues covered are climate change (vulnerability, risks and adaptation) and the city (public policy and directions in urban development).

**The European Foundation for Sustainable Territories (FONDATERRA)**, a partnership between Versailles Saint Quentin en Yvelines University and the industrial groups EDF, GDF-Suez and Vinci, runs a multidisciplinary research and expertise network on issues surrounding sustainable development and territories with particular emphasis on “the challenges of climate change for territories” and “cities and sustainable development”.

**The French Association of Businesses Working for the Environment (L'Association française des Entreprises pour l'Environnement, EpE)** comprises some forty major French and international companies with the aim of factoring the environment into their strategic decision-making and day-to-day management. This association aims to be a hub of expertise for all of its members, with the objective of analysing and anticipating the first signs of new innovations and contributing to better mobilisation by exchanging approaches, methodologies, tools and actual achievements.

Lastly, a number of **private consultancies** used by the state and local government in recent years are developing their expertise on climate issues and sustainable cities. Examples include SOGREAH, EXPLICIT, BURGEAP and ETD, although this list is not exhaustive.

## **Research programmes**

### **The general framework**

Within the framework of issues in urban research linked to climate change challenges, the National Research and Innovation Strategy implemented in 2009 has identified four major objectives:

- 1- achieving a better understanding of changes in the climate and ecosystems
- 2- conserving energy
- 3- developing eco-technology and eco-design
- 4- promoting sustainable cities and mobility

Several cross-cutting research projects have been devoted to the first and last objectives, namely understanding the challenges of climate change on the one hand, and the promoting the sustainable city on the other hand. Moreover, sectoral programmes have included them in their road maps, as have a certain number of projects and calls for targeted research proposals. (see text box below).

- **Three cross-cutting research programmes:**
- The programmes “Global Environmental Changes”, “Vulnerability: Environment, Climate and Society” and “Sustainable Cities” are led by the National Research Agency (ANR) and the Interdisciplinary City and Environment Programme (PIRVE) backed by the CNRS and MEEDDM.
- **Five sectoral programmes with specific city and climate components:** the research programme “Managing the Impacts of Climate Change (GICC) backed by MEEDDM, the Programme for Research and Experimentation on Energy in Buildings (PREBAT) supported by the Urban Planning, Construction and Architecture Plan (PUCA), the Programme for Research and Innovation in Land Transport (PREDIT) incorporating PRIMEQUAL for better air quality on a local scale and the Plant and City (Plante et Cité) project.
- **Calls for targeted projects**, in particular:
  - on the theme “Rethinking cities in a post-carbon society”, with a view to the 2050 deadline.
  - on modelling urban morphology and analysis of urban climate, especially within the framework of the ACCLIMAT, EPICEA, INVULNERABLE, CLIM2 and VILLE NUMERIQUE (Digital city) projects.
  - linked to French research, the **URBANET programme** within the 7<sup>th</sup> Framework Programme for Research and Technological Development (PCRD).

*Text box 24: “Sustainable City” research programmes*

This group of research programmes stands out on account of the specific themes approached, but also demonstrates coverage of topics exploring the connections between climate impacts, urban planning and mobility, regional government and perspective planning.

These programmes are located at the interface of engineering, human and social sciences. This can be explained by the fact that climate and environmental challenges have a systemic dimension and the urban system lies at the centre of this complex structure.

**The diagram below presents the impact and coverage of these different programmes:**

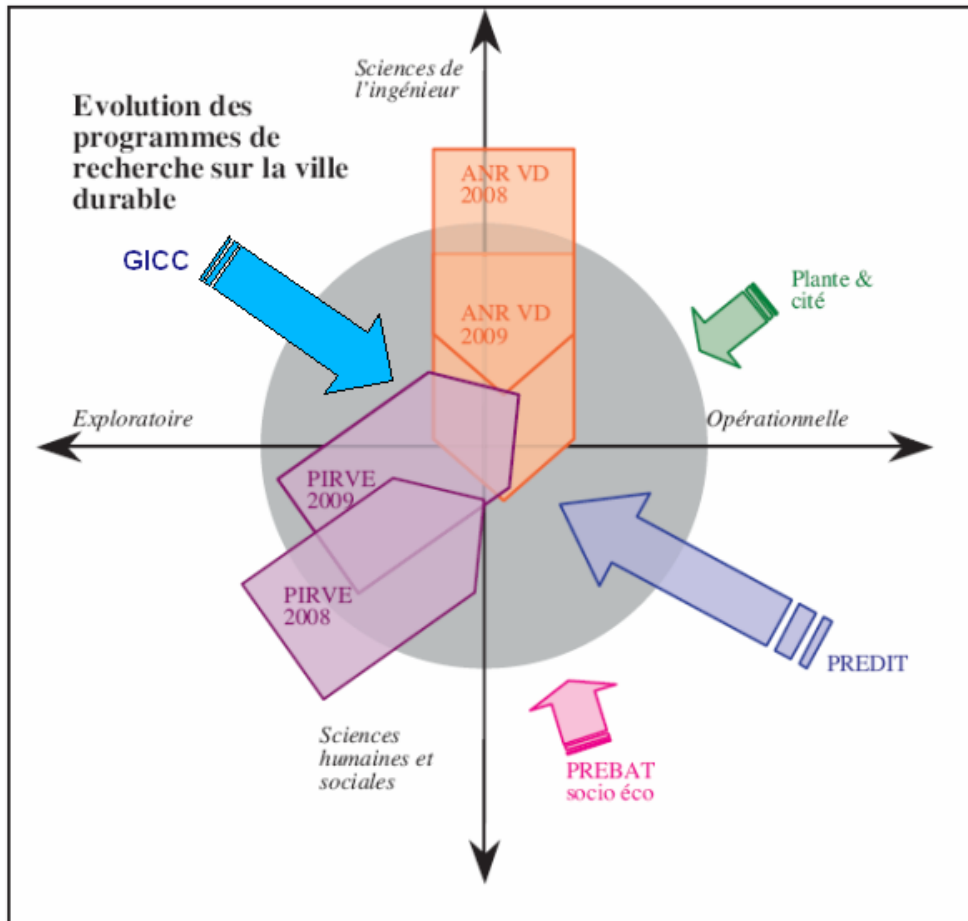


Figure 20: Composition and coverage of the “sustainable city” programmes. Source: ADEME (author: Anne Grenier)

### Programme content: an overview

Research programme	Organisation	Projects
“Global Environmental changes” (CEP)	ANR	
“Vulnerability: Environment, Climate and Society”	ANR	VURCA
“Sustainable cities”	ANR	<ul style="list-style-type: none"> <li>- Trame verte urbaine (Urban green network)</li> <li>- MUSCADE</li> <li>- VegDUD</li> <li>- INOGEV</li> <li>- OMEGA</li> <li>- D2SOU</li> <li>- RESILIS</li> <li>- INCERDD</li> </ul>
Interdisciplinary City and the Environment Programme (PIRVE)	CNRS / MEEDDM - PUCA	<ul style="list-style-type: none"> <li>- VuLiGAM</li> <li>- Urban forms, modes of living and urban climate in the Toulouse peri-urban area-</li> <li>- CLIMURBS</li> </ul>



		<ul style="list-style-type: none"> <li>- Vulnerability and resilience to climate change in the urban environment: towards new sustainable urban development strategies</li> <li>- Health risks in the urban environment: context effect, vulnerability and resistance</li> </ul>
Managing the Impacts of Climate Change (GICC)	MEEDDM	<ul style="list-style-type: none"> <li>- SAOPOLO</li> <li>- the ability of coastal societies to adapt to erosion phenomena – submersion of coastlines affected by climate change</li> <li>- DRIAS</li> <li>- Adapting to climate change in the Rhône-Alpes region</li> <li>- The challenges of an integrated approach for territories- ADAP’Ter</li> </ul>
The Urban Planning, Construction and Architecture Plan (PUCA) and the Programme for Research and Experimentation on Energy in Buildings (PREBAT)	MEEDDM	
Programme for Research and Innovation in Land Transport (PREDIT)	MEEDDM	
Plant and City Programme (Plante et Cité)	INH and INRA	
Other targeted projects		<p>The city of tomorrow from a post-carbon perspective</p> <p>Modelling tools for urban morphology:</p> <ul style="list-style-type: none"> <li>- ACCLIMAT</li> <li>- EPICEA and Greater Paris 2030</li> <li>- INVULNERABLE</li> <li>- CLIM2</li> <li>- Assessment of the impact of climate change on the functioning of an urban area</li> </ul> <p>Vulnerabilities and the concept of adaptation:</p> <ul style="list-style-type: none"> <li>- Climate change as a pointer to territorial vulnerabilities</li> <li>- Challenges and processes in the implementation of adaptation strategies in Montreal and Paris</li> </ul>
URBAN-NET programme	UE (PCRD)	<ul style="list-style-type: none"> <li>- The effects of heat waves on urban structures in Europe-Optimisation of urban planning and architectural parameters to reduce thermal effects in Mediterranean cities</li> <li>- Urban tourism and climate change</li> <li>- Implementation of a research network on how cities adapt to climate change</li> </ul>

Table 4: Research programmes and projects

These programmes are outlined in detail in Appendix 1.

## Conclusion

This survey of research in the field of the sustainable city and how it can adapt to climate change demonstrates a new dynamism in recent years within the framework of major research projects in France and also abroad, a dynamism brought about by an awareness on the part of the scientific community of the social challenges resulting notably from changes in climate in the coming decades.

Paradoxically, however, this dynamic on the part of multidisciplinary teams which can only be viewed in the medium to long term perspective is now faced with the need for immediate responses by stakeholders in the public and private sectors out in the field who must commit, or are already committing, to policies and concrete action and expect research to provide coverage of all the relevant needs as well as concrete results in terms of data, methodologies and operational tools.

The tension between these two speeds can only be beneficial for the future, providing motivation for researchers and stakeholders faced with problems on the ground to work together to find analysis methods and operational solutions which will enable cities to reduce their vulnerability and adapt to the effects of climate change.

# APPENDIX 1 : Research programmes

## National Research Agency (ANR) programmes

The programmes described below are:

- the Global Environmental Changes Programme (CEP):
- the Vulnerability: Environment, Climate and Society Programme
- the Sustainable Cities Programme

### Global Environmental Changes Programme (CEP)

Taking as its starting point the forecastable global changes for the next 30 to 100 years, this programme studies their impacts on a more regional scale.

The main six subject areas agreed in the call for proposals for 2010 include:

- Vulnerability and adaptation to global environmental changes with an analysis of joint changes in demography and lifestyles, which are a major challenge for the cities of tomorrow, and their consequences in terms of adaptation, organisation and governance
- Town and country planning and land occupancy in this context, including:
  - the urban regional scale and intermediary areas between the urban and the rural (variability of ecosystems, mixed use, anthropogenic constraints)
  - coastal areas subject to risks and demographic and economic pressures
  - the production of tools to represent the complexity of systems and associated policies
  - the health impacts of global environmental changes including the characterisation of at-risk populations, notably in the face of extreme impacts (heat waves, storms, drought) and their repercussions on morbidity and mortality

### Vulnerability: Environment Climate and Society Programme

Within the framework of this programme, whose aim is to improve knowledge about the vulnerability of natural and anthropogenic systems to global environmental change, a current research project relating to the subject of the city, climate change and adaptation policies is of particular note: the Urban Vulnerability to Strategic Heat Wave Episodes and Adaptation Project (VURCA, Vulnérabilité Urbaine aux épisodes Caniculaires stratégiques et d'Adaptation).

Launched in 2008, this project is coordinated by CIRED (the International Centre for Research on the Environment and Development), CSTB (the Scientific Centre for Research in Building Techniques) and CNRM (the Météo-France National Meteorological Research Centre). This project aims to provide a first view of the complex interaction between the urban economy and climate change using a multidisciplinary approach and to propose options for useful operational adaptations.

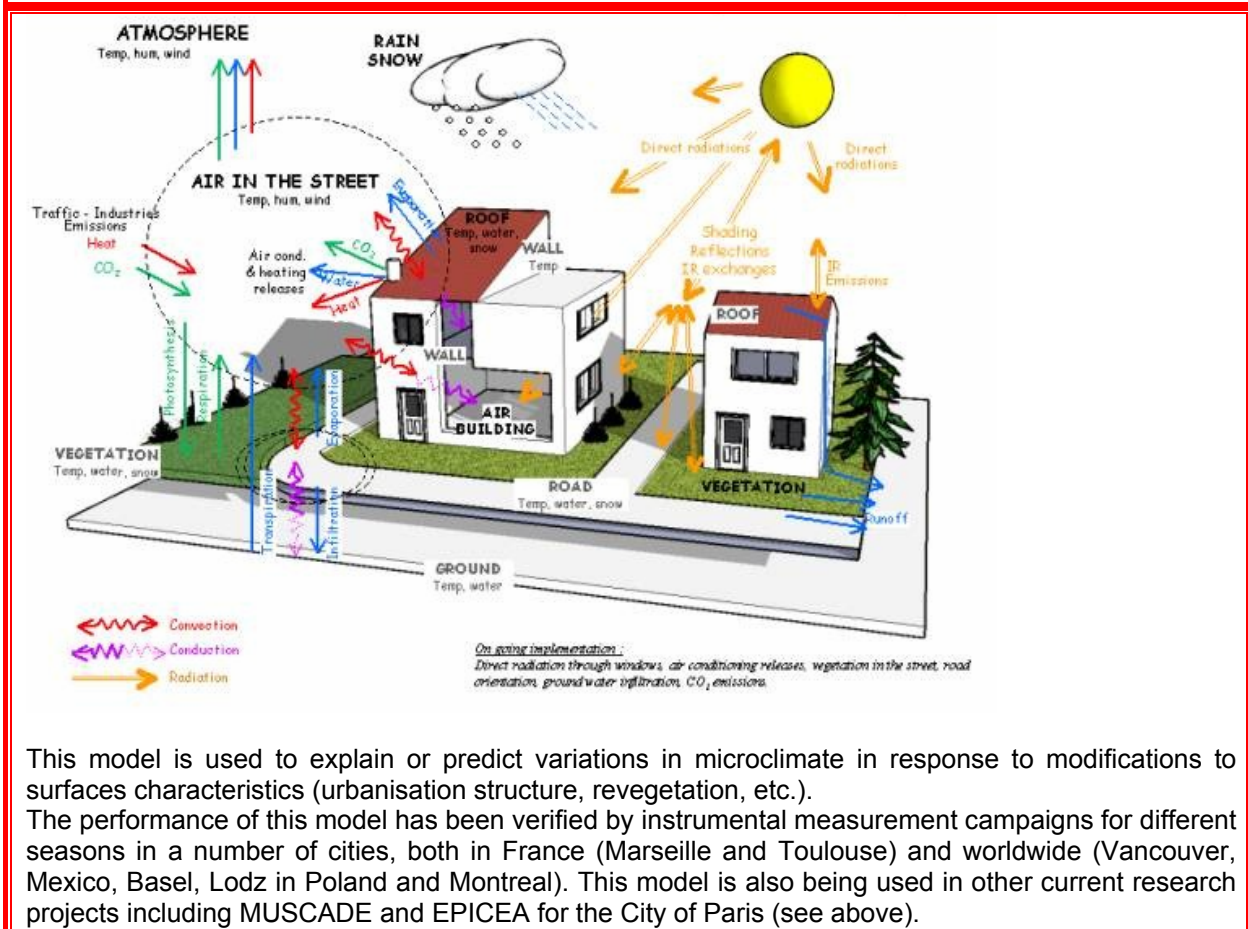
The primary objective of this project, whose results have not yet been published, consists of evaluating the degree of vulnerability or "severity index" of the urban structure (in terms of increased discomfort) and the sensitivity of energy demands to heat waves (in terms of air cooling). Several heat waves and the probability of their occurrence have been studied to this effect in order to develop a vulnerability indicator.

The second objective consists of evaluating the effectiveness of potential adaptation strategies in response to these vulnerabilities by acting on urban parameters such as the radiative properties of the surface of buildings and roads or the proportion of green space. These parameters are evaluated using the Town Energy Budget urban model (TEB) (see text box below) which enables variations in microclimate in response to modification of the characteristics of surfaces to be predicted.

Finally, the project aims to calculate the benefits accrued from different adaptation strategies by combining detailed analysis of the urban microclimate with an economic assessment. To this end, it is intended to draw comparisons between the gains in terms of reduced vulnerability to heat waves and the socio-economic costs incurred by including spatial inequalities.

The TEB Town Energy Budget model (Valéry Masson, 2000) is a digital model developed to calculate energy and water exchanges between cities and the atmosphere. Included in the surface-atmosphere

modelling module SURFEX, which is itself coupled to the atmospheric weather forecasting module AROME and the research module MesoNH, it incorporates shadows, radiative capture, heat conduction through roofs, roads and walls, interception of rainwater, evaporation or runoff, turbulence exchanges and the microclimate in the street into a 3D geometry of the town.



This model is used to explain or predict variations in microclimate in response to modifications to surfaces characteristics (urbanisation structure, revegetation, etc.). The performance of this model has been verified by instrumental measurement campaigns for different seasons in a number of cities, both in France (Marseille and Toulouse) and worldwide (Vancouver, Mexico, Basel, Lodz in Poland and Montreal). This model is also being used in other current research projects including MUSCADE and EPICEA for the City of Paris (see above).

Figure 21: Diagram of the different systems and processes represented in the TEB model - Source Météo France

## The Sustainable Cities Programme

This programme, which covers the period 2008-2010 and includes three successive calls for proposals in 2008, 2009 and 2010, has its origins in an awareness of the importance of the role of cities both as a relevant territorial scale factor and as stakeholders in sustainable development.

It mobilises both the scientific community and practitioners (local authorities, business) to feed into public decisions and produce tools and techniques allowing cities to accommodate the requirements of sustainable development more effectively.

Cutting across local, global, economic and social environmental issues (improving energy efficiency on an urban scale, reducing ecological impacts, reducing vulnerability to extreme events, offering a framework favourable to creating a sustainable local economy, ensuring the well-being of inhabitants and equality of access to urban services and amenities, etc.), it seeks to prioritise systemic approaches concerning, for example the spatial dimension of the city, coupling of timescales (short, medium or long term), other specific issues (energy management, preserving quality of life, etc.), or several urban aspects or functions combined (mobility, habitat, urban forms, urban metabolism, etc.).

Within the framework of the annual call for proposals for the 2008-2010 programme, several research projects were funded which might be able to provide direct answers to the problem of

adapting cities for climate change, or even indirect answers to the extent that they contribute to greater adaptability of urban policy.

The majority of these projects have already been launched and some are about to be launched.

- Trame verte urbaine (Urban green network): the role of urban green networks in bringing nature into cities, maintaining biodiversity and impacting on local climatology and the wellbeing of citizens (2008 call for proposals).

- MUSCADE - Urban Modelling and Strategies for Adapting to Climate Change and Anticipating Energy Demand (Modélisation Urbaine et Stratégies d'adaptation au Changement Climatique et Anticiper la Demande Energétique): a study of interactions between energy and climate change on the scale of the Greater Paris Area and the consequences in terms of mitigation and adaptation policies (2009 call for proposals).

- VegDUD - The role of vegetation in sustainable urban development (Rôle du végétal dans le développement urbain durable): an assessment of the impacts of vegetation coupled with those of urban form on several interacting urban systems: climate, ambiances, energy and hydrology on different temporal and spatial scales (2009 call for proposals).

- INOGEV - Innovations for sustainable water management in cities (Innovations pour une gestion durable de l'eau en ville): helps designers and local government to define effective strategies for managing pollution flow (2009 call for proposals).

- OMEGA - Methodological tool for the integrated management of a sanitation system (Outil méthodologique d'aide à la gestion intégrée d'un système d'assainissement): to enable different stakeholders in urban water management to manage future environmental challenges (flood risk, the chemical and ecological status of bodies of water, water resource management, energy saving, etc.) (2009 call for proposals).

- D2SOU - Sustainable development of the subsoil (Développement durable des sous-sols): develops the necessary foundations for the integrated inclusion of the soil and subsoil in urban development (2009 call for proposals).

- RESILIS - Developing urban resilience by improving aids to governance of urban systems: to propose improvements to urban resilience by developing methods and tools to assist in the governance of urban systems (2009 call for proposals).

- INCERDD - Developing methods to allow uncertainty to be factored into the management of urban projects and town and country planning (2010 call for proposals)

## **TRAME VERTE URBAINE**

In response to the issues of adapting to climate change, this project aims to assess the importance of urban green networks in providing a natural environment in the city, maintaining biodiversity and their effect on local climatology and the wellbeing of citizens.

It draws on a multidisciplinary team comprising ten laboratories working in human and social sciences, life sciences and engineering, as well as several local government partners.

The project, which recently started in 2010 for a three-year period, comprises four phases of work consisting of a preliminary summary of urban green networks, an assessment of their ecosystem services and public policy strategies leading to the elimination or retention of certain green corridors in urban planning projects, and lastly the production of frames of reference for those interested in maintaining or even expanding them.

For the problems linked to the needs and constraints of local authorities for the integration of green networks into urban planning projects, this project will use the Paris region, the city of Marseille and the town of Angers as analysis fields.

The scientific outcomes of this project include:

1- validating the effects of green networks on the reduction in air pollution and the reduction in the Urban Heat Island (UHI)

2- an indication of the urban forms best adapted to the climate and to well-being of citizens as well as a better understanding of the socio-political challenges contributing to the creation of green network projects on different scales in the urban territory.

A conference organised by the Climate Scientific Interest Group in the spring of 2010 concerning this research indicates that although making cities greener constitutes a response to the heat island, it must be done advisedly. In addition to the absence of empirical data on the extent of the reduction in temperature (the available data is based on modelling), other consequences of making towns more green must be assessed (emission of allergens, durability of the networks depending on the materials and plants used and the availability of water, watertightness of roofs and carbon emission levels, the cost of infrastructures and land, etc.).

Coordinators: LADYSS-CNRS (Laboratories for Social Dynamics and Restructuring Spaces-National Centre for Scientific Research) and MNHN (the National Natural history Museum)

## **MUSCADE**

Launched in 2010 for a three-year period and coordinated by CNRM (Météo France) within the framework of a multidisciplinary partnership, this project highlights three elements involved in the sustainable development of the city: **energy, the structure of the city and climate change**, all closely linked on different scales, be they global, national or local.

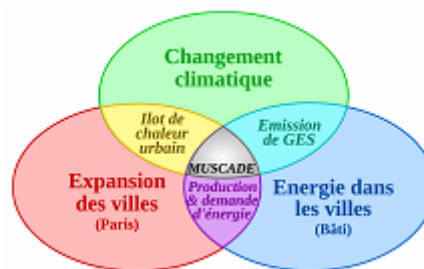


Figure 22

Presentation of MUSCADE

### **Key:**

Changement climatique – Climate change

Expansion des villes (Paris) – Expansion of cities (Paris)

Energie dans les villes (Bâti) – Energy in cities (Built environment)

Ilot de chaleur urbain – Urban heat island

Emission des GES – GHG emissions

Production & demande d'énergie – Energy production & demand

The study of these interactions focuses on the Paris urban area with a 2100 horizon and should enable the city's energy consumption and local and renewable energy production capacities, urban development, expansion and climate change to be put in perspective, on the basis of scenarios and simulations.

Using digital modelling linking the NEDUM model developed by CIRED into the framework of a dynamic relationship of transport networks and the housing market and the TEB model (see above), the main urban processes and their interactions on a building, island, city and urban area scale are analysed in succession. Different variables are introduced using coupled scenarios: socio-economic (access to housing, transport costs and duration, productive capital), climate, energy, data on land utilisation and the Paris expansion zone, types of building materials used.

Validation of the results of the simulations carried out using the NEDUM model was carried out by analysing Parisian urban sprawl since the 1970s.

For each scenario used, results can be expected in energy terms for the types of building and CO<sub>2</sub> emissions, the potential for local energy generation, the effects of the urban microclimate on the comfort of residents, etc.

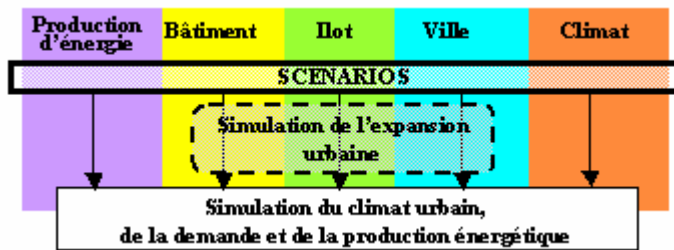


Figure 23: General diagram of the simulation process

**Key:**

Production d'énergie – Energy production

Bâtiment – Building

Îlot - Island

Ville - City

Climat – Climate

Simulation de l'expansion urbaine – Simulation of urban expansion

Simulation du climat urbain, de la demande et de la production énergétique – Simulation of urban climate, of energy demand and production

This project is designed to open up new areas of multidisciplinary research on sustainable cities and to increase awareness on the part of urban planners to energy and climate change issues, i.e.:

- energy consumption connected with heating and air conditioning in buildings
- demand and decentralised energy generation and the distribution of different types of energy
- the urban heat island
- greenhouse gas emissions

Overall, the research in progress should identify strategies for mitigation and adaptation to climate change which can be generalised on an urban scale.

*Coordinator: Météo France*

**VegDUD**

The VegDUD project or “the role of vegetation in sustainable urban development” brings together ten research teams including LCPC (London Climate Change Partnership) Nantes, ONERA (National Centre For Aerospace Study and Research)Toulouse, the CSTB (Scientific Centre for Research in Building Techniques), CNRM (National Centre for Meteorological Research)Toulouse and several CNRS teams, as well as a partner local authority, the city of Nantes.

It aims to assess the impacts of vegetation in association with those of urban form in several interacting urban systems: climate, ambiances, energy and hydrology on different spatial and also temporal scales.

The aim is also to develop tools and methods designed to bring concrete solutions to operational issues raised in all European cities.

The research for 2010-2013 is divided into 6 stages which aim to answer the question: How and where should we focus revegetation activity depending on the issues relating to society, ambience, energy and water problems caused notably by climate change?

The six scientific stages are as follows:

- to inventory urban vegetation practices and knowledge already acquired and to create a classification system
- to adapt evaluation tools in order to include vegetation in a realistic manner
- to acquire the necessary knowledge to establish a baseline urban situation
- to evaluate the revegetation mechanisms for their local effects on an individual basis
- to implement growth scenarios for vegetation associated with the growth of the city
- to evaluate scenarios built on climatic, hydric, energetic, economic factors, ambience and usage

Coordinator: CERMA Centre for Methodological Architecture Research (Centre de Recherche Méthodologique d'Architecture).

### **INOGEV**

INOGEV, Innovations for sustainable water management in cities, aims to help local authorities to define effective strategies for managing the flow of polluted water based on understanding and controlling urban rainwater contamination. The results will facilitate better water management through knowledge about the flow of micro-pollutants in urban areas and could be used in the future within the context of extreme events (flooding) resulting from climate change.

The stages of this research are as follows:

- to quantify the flow of micro-pollutants in different compartments (the atmosphere, deposits on urban surfaces, outlet of the catchment area) and to specify their origin in order to model them more closely and to be able to define the efficiency of management systems
- to suggest methods by which local authorities can manage pollution flow and monitor the effectiveness of actions carried out (simplified monitoring procedures, measurement indicators, etc.):
- to analyse the mechanisms for knowledge transfer to optimise the management of urban sanitation
- to perpetuate the network of field observatories in urban hydrology within HURRBIS, which is unique in the world

The multidisciplinary team comprises six scientific partners, CNRS, LCPC (London Climate Change Partnership) Nantes, ENGREF/ENPC (National water and Forestry Institute/Paris Tech Engineering Institute), INSA (National Institute for Applied Science) Lyon, IRSN (Institute for Radioprotection and Nuclear Safety) Cherbourg, ENPC/EDF RetD, several regional authorities, the Nantes urban area, the Greater Lyon area and the Val de Marne Region Council.

### **OMEGA**

The aim of this multidisciplinary research is to develop a methodological tool for the integrated management of a sanitation system, to enable different stakeholders in urban water management to tackle the major environment challenges they will face in the future effectively: flood risk, threats to the good chemical and ecological condition of bodies of water, water resource management, energy savings, etc. Confronted with these challenges, a sustainable waste water and urban rainwater system will be able to respond without significant increase in the financial means available.

For example, when rainwater is managed in the traditional manner by a joint network, there is a major risk of flooding or polluting the receiving system. Collecting it and using it to cool the city by evapotranspiration of vegetation presents a number of advantages: financial savings, energy savings, absence of polluting waste, reintroduction of nature into the city, strengthening biodiversity, air pollution control, etc.

The aim of this research is therefore to provide a genuine tool for dialogue between different stakeholders from different scales of territory (urban and catchment area) and for decision-making. It will facilitate a better assessment of the functions of the rainwater management system and offer in particular the means to adapt management in an uncertain or even unpredictable environment.

The local authorities involved in the research are the cities of Bordeaux, Lyon and Mulhouse.

Coordinator: INSA (National Institute for Applied Science) Lyon, CEMAGREF (Institute for Research into Environmental Science and Technology), Lyonnaise des Eaux.

### **D2SOU**



This 2010-2013 project aims to develop the necessary basis for an integrated inclusion of the soil and subsoil in urban development. This environment offers both resources (space, water, aggregates, geothermal energy, storage capacity, etc.) and constraints (relief, suitability for construction and underground works, geological risks, polluted ground). Governance of urban systems generally underestimates these problems or sometimes ignores them totally.

By combining urban management (local authorities, land planners) and work by scientists (human and earth scientists), a conceptual model will be developed making it possible to represent subsoil issues in relation to urban projects and their adaptability to future constraints.

Coordinators: Fondaterra (European Foundation for Sustainable Territories), BRGM (Bureau for Mining and Geology Research).

## **RESILIS**

The ability of a city to cope in the long-term in the event of extreme conditions either climatic (heat waves, flooding, etc.), industrial (breakdown of a technical infrastructure, etc.) or health-related, depends on its ability to continue to provide certain services: water supply, food, energy, waste disposal, a response to sanitation and medical crises, etc. The level of predictability of systems today with regard to unforeseen events is very low and it is very difficult to anticipate the reaction of complex systems correctly. An imperfect awareness of the threats and triggers and subtle signals, which are evolving continuously moreover, make analysis very difficult.

This project aims to suggest methods and tools to enable cities to become more resilient by using better multi-scale and multiparty governance, by working with populations and optimising management of the most structural technical networks. To this end, an urban system and subsystem will be defined, an ideal resilient systemic and functional urban model will be proposed and the practices of decision-makers on the scale of their own urban systems will be analysed and developed using the Orleans urban area community and the town of Mantes-la-Jolie as experimental areas.

Associated scientific partners: Fondaterra (European Foundation for Sustainable Territories), Egis, EIVP, IOSIS, CEMAGREF (Institute for Research into environmental Science and Technology).

## **INCERDD**

The INCERDD project aims to develop a methodology and a collection of methods to assist with decision-making, whilst trying to clarify the influence of existing uncertainty factors on different scales in the urban territory. In practical terms, the project is attempting to evaluate the consequences of a decision according to different criteria (economic, technical, social, environmental, etc) and according to probabilistic or possibilistic approaches.

To support these developments, two fields of application are used in relation to the management of works and urban land planning. These fields of application differ in the scale of the system studied.

- on the “local” scale of a local district, for example, the project will focus on the problem of managing submerged systems (transport, sanitation, etc.) with decisions relating to maintenance, extension or improvement of in the context of ageing facilities, changing needs, climate change (increased number of storms), urban growth, etc
- on the “global” scale, of an urban area as a whole, the project will focus on the problem of managing natural risk and decisions relative to tackling unforeseen events (flooding, earth movement, etc.), the reduction of vulnerabilities and the regulation of land use (PPRN, PLU).

The INCERDD project considers different families of uncertainty which can affect:

- the long-term objectives of local authorities, taking into account the multiplicity of different stakeholders (politicians, local authority technical departments, citizens, companies and traders, etc.). Is it possible to define a shared objective which would allow the relevance of different development strategies for the local authority to be assessed (in particular those relating to the management of networks and natural hazards)?
- data relating to the natural anthropogenic physical world. (What is the current state of the network? What are the building materials used? What are the mechanical properties of the land?, etc.):
- changes in context (changes in population needs, climate change, budget changes, etc.)

- models and methods used to formalise the problems treated (scoping methods for hydraulic networks, ageing models, event prediction models, evaluation methods for vulnerability, etc.)

The partnership which has been formed brings together multidisciplinary scientific fields (economics, sociology, engineering, etc.) with seven university or associated partners and three “operational” partners: the Nancy Urban community, the city of Nancy urban planning agency and the Meurthe et Moselle *département* authorities.

Coordinator: Geomechanical and Geoenvironmental Engineering Laboratory (Laboratoire Environnement Géomécanique et Ouvrages, LAEGO). Ecole des Mines de Nancy.

**The 2010 call for proposals** combines three topics focusing on the sustainable city:

➤ **Identifying, understanding and defining urban sustainability.**

This topic aims to define and measure the sustainability of a city by:

- using a selection of indicators, predictive approaches and systemic modelling tools for urban dynamics
- shedding new light on morphologies, urban functions, lifestyles and mobility (densification, mixed use, urban sprawl, multipolarity) in order to gain a better understanding of the effects of the spatial organisation of the city on greenhouse gas emissions and its compatibility or incompatibility with adaptation policies
- jointly analysing two energy consumption sectors – building and transport – as well as the forms and role of governance in the energy transition
- studying the sustainable urban metabolism – defined as all the transformations and the flow of matter and energy which are involved in the lifecycle of an urban area – taken into account in practical terms and from the point of view of reduction
- improving awareness of vulnerabilities, risks and resilient urban systems: social vulnerabilities linked to major changes (reduction in greenhouse gases, adapting to climate change); spatial dynamics (fragmentation, specialisation of territories, etc) and/or mobility; vulnerabilities linked to the organisation and functioning of the city and how to reduce them; risk prevention in urban areas (suggested methodologies enabling risk prevention plans to be constructed).

➤ **Designing and governing the sustainable city**

This topic aims to design tools to facilitate the transition to a sustainable city: tools for planning, global design and governance, tools to assist in designing and urban projects and evaluating them. Within this framework the objective is to:

- clarify interdependent policies and associated instruments of governance (SCOT, PLU, PDU, PCET, SRCAE, etc.)
- study the paths to becoming a sustainable city: transitional paths, choice of levers for action
- develop modelling tools to assist in making decisions and redesigning the city with a view to energy transition and climate change and the adaptation of urban systems to these changes and also to develop quantitative evaluation tools for land planning impacts on different scales in the city (urban region, urban area, district, island).

➤ **Building and managing a sustainable city**

This topic aims to rethink engineering methods in line with the problems of the sustainable city. In particular:

- rethinking engineering methods taking into account the constraints of future scarcity (water, energy optimisation) with a view to improving the use of available urban space
- developing the capacity of buildings and infrastructure to adapt to future needs (flexibility for integration into the life cycle of new technologies, preparation for more stringent new requirements or standards, reduction of their vulnerability to natural and technological risks, extension of their lifetime).

# Interdisciplinary Research Programme on the City and the Environment (PIRVE)

Set up in 2006 by the CNRS, the programme entered its operational phase in late 2007 in partnership with MEEDDM under the joint leadership of the Research Department and the Urban Planning, Construction and Architecture Plan (PUCA). This programme combines two important issues - the predominance of the urban phenomenon and the importance of ecological issues, in particular climate change. In this context, the field "City and the Environment" involves both the quality of life of city dwellers and the vulnerability of populations and the growth of cities on an urban area and urban region scale, as well as their impacts on regional and national or even global level.

**PIRVE's objective** is to achieve a better awareness of the dynamics of urban societies and their environment on different temporal and spatial scales and from different perspectives, notably human and ecological.

Twenty-four projects have been funded based on the call for proposals in 2008 and 2009 from multidisciplinary university teams on three broad themes:

Urban metabolisms: the city as a social, spatial technical and natural hybrid

The urban environment as a place to live

Futures of the city, vulnerability or sustainability

## Research on this latter topic aims:

- on the one hand to identify, evaluate, and model probable changes and risks, as well as their impacts on urban populations, on a city and urban network scale
- on the other hand, to contribute to the formulation of joint social, spatial, scientific or technical solutions likely to mitigate the vulnerabilities and risks by mixing preventive measures (development, urban planning, means of production and consumption) with those of adaptation.

Five ongoing projects on the theme of the city and its vulnerability caused by the current climate or as the result of the future effects of climate change are receiving funding:

- Vulnerability of coastal systems of a large Mediterranean urban area (Marseille) (Vulnérabilité des systèmes littoraux d'une grande agglomération méditerranéenne (Marseille), VuLiGAM), identifying the emerging risks from climate change.

- Urban forms, lifestyles and climate in the Toulouse peri-urban area, and the identification of interactions between them.

- Study of climate impacts and forms of resilience in urban settings in history (CLIMURBS), proposing the city as a reliable and sustainable indicator of the main tendencies of the climate and its extremes

- Vulnerability and resilience to climate change in an urban setting aims to provide a clearer definition and characterisation of the multidisciplinary notions of vulnerability, resilience, adaptation and sustainable urban development.

- Health risks in an urban context, aims to study the differentiation between cities in health risks linked to air quality and care available.

## **VuLiGAM**

The aim of the research consists of analysing emerging coastal risks linked to climate change in the **City of Marseille** and neighbouring urban areas (submersion by the sea, withdrawal of the coastline) threatening the Mediterranean coastline, as well as the vulnerability of local biodiversity subjected to various forms of anthropogenic pressure (urbanisation, over-occupancy of natural sites, soil pollution on historic industrial sites, polluted spray).

The city of Marseille coastline is a representative of a large number of issues in towns around the Mediterranean coastline: urban pressure, diversity of the coastline (natural and artificial beaches, rocky coasts), the presence of rich natural areas which are preserved, polluted sites and urban pollution.

The approach taken by this project therefore focuses on the essential adaptation to new climate constraints which Mediterranean towns must undertake.

The effectiveness and limitations of legislative tools applicable to management of these risks both for the natural environment (protected areas) and the urban environment (notably the town planning documents, PLU, SCOT, PPR), will be evaluated, focusing on the needs and questions of local stakeholders and decision-makers.

Furthermore, this legal analysis will be accompanied by a sociological exploration of the ways in which different people represent the coast line and the risks in order to improve sharing and ownership of the decisions to be taken in the future.

A certain number of public policy improvement measures in this area both in terms of mobilisation and/or adaptation of various legal tools (PPR, PN, biotope protection decrees, closing off areas to grazing, expropriation or pre-emption, compensation, charters, contractualisation), and in the extension of consultation processes, local appropriation of the challenges for better social governance of constraints, are planned.

The long-term objective will consist of establishing an observatory which will bring teams together for the long-term as part of a process of scientific monitoring of these risks and of legal and sociological monitoring of the development of normative or motivational tools. This observatory will be both a source of information and a compendium of data and a proactive force for stakeholders and decision-makers.

Coordinator: Aix Marseille University.

### ***Urban forms, lifestyles and climate in the Toulouse peri-urban area***

The research project falls within the framework of an initiative to identify, understand and clarify the interactions between climate in the suburban area, urban forms and lifestyles, notably through modelling.

The approach is based on an empirical observation exercise led by a multidisciplinary team comprising meteorologists, geographers, engineers, architects, sociologists and anthropologists using a variety of concepts and tools (remote sensing, landscape analysis, architectural and urban analysis, social surveys, etc.) on a common site: the Toulouse peri-urban area.

This research aims to link climate heterogeneities (notably thermal in nature) to various scales and to specific territorial configurations from the point of view of urban forms and/or lifestyles.

It will be carried out in the following three stages:

- spatial characterisation of climate heterogeneities in the Toulouse urban area (*macro scale*) based on spatial imaging and meteorological measurement campaigns to produce a cartographic synthesis
- identifying several "zones ateliers" or study sites (*meso scale*) characterising the climatic heterogeneities observed by using intersecting criteria:
- on the basis of these zones, to analyse the interactions between urban forms, lifestyles and climate heterogeneity observed in order to create an integrated mapping of the area on different spatial and temporal scales.

Coordinator: Interdisciplinary Solidarity Society Territories Laboratory (Laboratoire Interdisciplinaire Solidarités, Sociétés, Territoires, LISST) Toulouse II University.

### ***Study of climate impacts and forms of resilience in urban settings in history (CLIMURBS)***

Using a rich urban documentary corpus covering the last five centuries (council sessions, urban processions, society directories) the research aims to offer the city as a reliable and lasting indicator of major climate trends and extremes. Furthermore, it also envisages a social and political approach to unforeseen climate events in the urban environment.

Taking into account some fifteen urban sites spread out across the whole country representing different types of climate, the study intends to use methods for evaluating climate impacts on urban

areas implemented by different European research laboratories (Berne, Freiburg, Sunderland, Barcelona and Perugia) to develop, in the first instance, a database on the basis of which events will be able to be quantified according to their severity in economic, social, political and health terms.

A fine-grained chronology of past climatic events in urban environments will fuel the current debate on the sustainability of urban environments and will determine whether they are increasing in amplitude and frequency. It will connect them by illustrating their effects in past socio-economic domains (religious manifestations, famines, riots, etc.).

The study will attach particular importance to ancient urban landscapes (ecosystems, architecture), and evaluate their greater or lesser resilience over the last five centuries.

Lastly, the appearance of a feeling of vulnerability and the different forms it takes in urban communities faced with the climate and its extreme manifestations will be highlighted.

Coordinator: Centre for Quantitative History Research, Caen University

### ***Vulnerability and resilience to climate change in an urban setting: towards new strategies for sustainable urban development***

This project aims to define and characterise interdisciplinary notions of vulnerability, resilience, adaptation and sustainable urban development more effectively.

It aims use field research in cities in the north and south to increase understanding of the impacts of climate change and to identify the factors determining the capacity of urban societies to respond to environmental risks.

Finally, in association with the objectives for sustainable urban development, guidelines and suggestions will be framed to contribute to the emergence of renewed adaptation and mitigation to improve urban resilience to climate change.

The approach adopted in this research must broaden the concepts of the impacts of climate change and adaptation to a more global analysis of territorial vulnerabilities by connecting future long-range climate forecasting with socio-economic development scenarios for the urban areas studied. The challenge is to try to extract general tendencies or specific features with the aim of formulating recommendations for action intended notably for decision-makers.

Answers will be offered to the following questions:

- Under what circumstances can the appearance or worsening of territorial vulnerabilities due to the effect of climate change act as a trigger for inclusion of global issues in local activity?
- How can essential connections, coherence and coordination between mitigation and adaptation activities be achieved within a coherent strategy integrated with sustainable urban development concerns?
- How can urban dynamics be adapted to make cities less vulnerable to climate change and produce fewer greenhouse gases?

The answer to these questions lies in analysis of the connection between different spatio-temporal scales with regards vulnerability to the effects of climate change and the perception of risks and their social acceptability among local leaders.

A systemic multidisciplinary approach to the city and to the vulnerability of different urban systems and their interrelationships will be pursued, notably taking into account domino, threshold and feedback effects.

Coordinator: CRESS-Lessor Centre for Research in the Social Sciences, Rennes II University

### ***Health risks in an urban setting: the effects of context, vulnerability and resilience***

The aim of this project is to study interurban differences in health risks and to suggest a way of defining greater or lesser resilience in the face of health risks.

Observations are based on the 54 French urban areas with more than 100,000 inhabitants and on the most vulnerable members of the population: children and the elderly.

Databases of air quality, health and care facilities are used to observe spatial variations in the state of respiratory health of urban populations linked to exposure to external atmospheric pollution in France.

The study is shaped by several hypotheses:

- the variation in health risk between cities stems from a combination of the unforeseen events and the vulnerability of urban populations. Certain cities are disadvantaged by this, raising the issue of “environmental fairness”.

- the aggregate level of cities is relevant to an examination of the situation of populations regarding pollution, but only in the context of an approach which takes into account variations in environmental and socio-demographic conditions within the cities

- urban areas whose local stakeholders prioritise environmental or health issues are more resilient

Coordinator: Environment, City, Society Joint Research Unit, Lyon II University

**The 2010 call for proposals** specifies complementarity or even interactivity between the following two topics:

- The city in the environment: metabolisms, footprints, trajectories.
- The urban environment as a place to live: resources, heritage, landscapes, inequalities, transformations.

## **Managing the Impacts of Climate Change programme (GICC)**

Launched by MEEDDM in 1999, the research programme “Managing the Impacts of Climate Change” (GICC), forms the “impacts” section of national research on the atmosphere and climate, focusing on future climate risks. It aims in particular to develop useful knowledge to assist various stakeholders (public authorities and investors) in making decisions about identifying and reducing impacts, as well as mitigation and adaptation projects for climate change. It therefore incorporates both policy and action by mobilising skills in a number of disciplines (human and social sciences, physical and biological sciences).

In the area of the city and the consequences of climate change, the 2008 call for proposals provided funding for several topics contributing to a better understanding of the vulnerability of territories and fed into thinking preceding the implementation of adaptation policies, either in the form of a compendium of data on climate change or by raising awareness among local stakeholders.

The five ongoing projects funded within the framework of the 2008 call for proposals are as follows:

- Adaptation strategies for coastal defences or modes of coastal occupation in relation to rising sea and ocean levels (Stratégies d’adaptation des ouvrages de protection marine ou des modes d’occupation du littoral vis-à-vis de la montée du niveau des mers et des océans SAOPOLO (2008)
- Adaptive capacity of coastal societies to erosion phenomena – submersion of shores affected by climate change (2008)
- Providing access to regionalised French climate impact scenarios for adapting our societies and environments (Donner accès aux scénarios climatiques Régionalisés français pour l’Impact et l’Adaptation de nos Sociétés et environnements, DRIAS (2008)
- Adapting to climate change in the Rhône-Alpes region: an operational partnership between research teams and regional authorities (2008)
- Adapting to climate change: the challenges of an integrated approach for territories (L’adaptation au changement climatique: les défis d’une approche intégrée pour les territoires, ADAP’Ter (2008)

### **SAOPOLO**

Under the combined effects of climate change and population growth on the coast, the vast majority of coastal areas and towns will experience an increase in vulnerability to natural phenomena in the years and decades to come. Furthermore, this tendency will be exacerbated by the increase in damage to defensive structures for the coastline and sea ports. The study aims to provide economic or political decision-makers with a coherent system of technical tools enabling them to shape their adaptation strategy, with priority being given to coastal defences, but also if necessary to sustainable development of land in the coastal area. Developing technical proposals for modifying structures

whilst stating the limitations on their implementation as a function of the development or occupation of protected zones constitutes an essential part of the study.

A methodological guide describing the series of procedures to be followed in carrying out studies and a catalogue of sample solutions for reinforcing a whole series of standard defences (dykes, jetties, stone pitching) will be proposed. The analysis will also include an evaluation undertaken on pilot sites of the impacts and potential damage in vulnerable zones of the coastal territory for the different possible strategies, facilitating a comparison of the cost of intervention on the defences and the socio-economic cost of non-intervention.

In mid-2010, a rapid inventory of port and coastal defences along the coastline was completed, as was a comparison of digital models propagating the swell from the sea to the coast. The standard rules of sizing were applied to evaluate the impact of climate change on the defences. This work will be supplemented by a statistical study. A programme of trials to test the adaptation solutions for these defences has been established. Trials have just begun in the wave tanks at the University of Le Havre and the Saint-Venant Laboratory in Chatou. A vulnerability study will also be carried out in the towns of Le Havre and Saint Malo.

Coordinator: CETMEF (Centre for Technical, Maritime and River Studies)

### ***Adaptive capacity of coastal societies to erosion phenomena – submersion of coasts affected by climate change***

The project aims to combine an analysis of adaptation strategies of coastal societies in the face of climate change with an analysis of the vulnerabilities of communities potentially exposed to this kind of risk.

The study site is the coastal fringe of Brittany with unstable urbanisation affected both by the withdrawal of coastlines inland and the inverse movement of human settlements towards the sea. The project is based on research devoted to hazards and human vulnerability, interpreted here from the perspective of risks and the ability to deal with them, in other words, resilience. This analysis of the response of the coastal area will enable vulnerabilities and challenges to be identified and in particular for the most appropriate adaptation measures to be implemented.

Coordinator: CNRS (National Centre for Scientific Research)

### ***DRIAS***

This project aims to provide regionalised climate scenarios established on the basis of several emission hypotheses, several regional climate models developed by the National Meteorological Research Centre (CNRM) and the Pierre Simon Laplace Institute (IPSL) and several downscaling methods.

This range of products will provide an initial assessment of the uncertainty inherent in the exercise of constructing climate scenarios.

This service targets users involved in impact and adaptation studies operating in their own area of expertise who have scientific and technical skills but who are not directly involved in climate research or modelling the Earth system.

Users, whatever their discipline, will be able to access the service through the Météo-France climate resource library which offers a large number of climate-related products (in particular access to the national atmospheric instrument collection managed by Météo-France). A DRIAS prototype web portal is planned for early 2011 and will facilitate access to regionalised French climate scenarios offering digital data and products. For the French climate community, this project may also increase the potential for climate research in terms of time devoted to it by facilitating access to simulations and the proper use of scenarios by user groups who are not familiar with climate modelling (research teams, government departments, research departments).

The mechanism in place aims to integrate data which is currently available and will ensure that it is easy to integrate future developments so that a permanent service can be established in this area.

The project actually began in April 2010 with an analysis of existing climate services which showed on the one hand that they did not cover the full spectrum of possible services ranging from basic data (in digital form) through to graphical products with a high valued-added component (maps, graphs, thermal shadow diagrams, etc.) and on the other hand that they are often specific to one sector of activity (hydrology, agronomy, ecology). This preliminary inventory should enable a functional specification to be developed for a new communal service on a web portal, reusing as much of the existing technical data already available as possible.

Other studies carried out in parallel have touched on the group of components to be implemented for this service. A glossary covering all the main aspects of the project is in preparation, as is a catalogue of simulations and data produced by different centres which will be useful for future users and for those producing scenarios and developing the portal alike in defining their respective commitments. DRIAS also has the merit of reinforcing dialogue between modelling teams who will be required to harmonise their products in the future.

Lastly, a Users' Committee representing different communities will form part of the project. The survey which has just been carried out makes it possible to fine-tune the definition of the forthcoming service. An analysis of the requirements expressed has been shared with the project team. Two categories of users emerged: researchers accustomed to manipulating simulations and complex data and another category termed "decision-makers" who are newer to climate information and require a different sort of support.

Partner organisations: Météo France, CNRS (National Centre for Scientific Research), IPSL (Institut Pierre-Simon Laplace), CERFACS (European Centre for Research and Advanced Training in Scientific Computation), GAME (Meteorological Atmosphere Study Group).

### ***Adapting to climate change in the Rhône-Alpes region: an operational partnership between research teams and territorial authorities***

The Group for Reflection and Action on Adapting to Climate Change (Groupe de Réflexion et d'Actions sur l'Adaptation au Changement Climatique, GRAACC) was established in June 2008 with the aim of raising awareness among stakeholders of this issue and sharing examples of best practice for concrete adaptation projects. A guide will be produced within the framework of the project to motivate decision-makers to take the problem of adapting to climate change into account and to provide them with tools.

This guide will consist of three parts:

- How to make an elected representative aware of the issue of climate change
- A catalogue of sample adaptation projects
- How to implement territorial adaptation strategies

In order to illustrate the problem in real terms, experiments will focus on revegetation of buildings in urban zones in the City of Lyon area and on change scenarios for water resources in connection with agro-forestry and tourist activities in a medium height mountain zone in the Drôme *département*.

Trials in urban areas will allow adaptation scenarios to be proposed by evaluating the impact of:

- roof planting on management of heat peaks and water resources
- bio walls on the management of heat peaks

Coordinator: Rhône-Alpes Energie-Environnement (RAEE)

### ***Adapting to climate change: the challenges of an integrated approach for territories, ADAP'Ter***



The project focuses on finding territorial responses to the impacts of climate change based on an analysis of the process of integrating the “climate issue” into local politics from an adaptation perspective.

This involves understanding the way in which the effects of climate change are apprehended and acted on at a territorial level, taking into account the fact that they are characterised by great uncertainty and go through a process of appropriation and localisation to which the notion of vulnerability is key. Moreover, adaptation takes many forms and is integrated into other public policies: adapting to “natural” effects (exacerbation of unforeseen hazards) but also “artificial” effects i.e. modifications brought about by measures to combat GHG emissions (mitigation). Therefore, strategies for adaptation to new climatic conditions can contradict mitigation measures.

Timescales and consistency of planned adaptation strategies, as well as territorial action in the short, medium and long term, are the issues at stake.

The project output will focus on:

- a “state of the art” report of the adaptation measures of local government authorities (a comparative summary of regional and urban initiatives in France), a European overview of “post-carbon” movements (Great Britain, Italy, Sweden, France)
- in-depth surveys on an urban scale (Lyon, Montreal) and on a regional scale (Burgundy, Rhône-Alpes region)
- discussion of material gathered by a monitoring committee comprising scientific and operational partners

This project will make it possible to:

- develop a classification of territorial responses on adaptation issues and their interconnection with GHG emission mitigation measures within the framework of local climate policies, so that convergence factors between adaptation methods and post-carbon strategies can be established
- identify adaptation methods for knowledge (data relating to impacts, vulnerabilities and solutions) providing an understanding of how climate challenges are translated at a territorial level
- identify factors for putting the issue of adaptation on the agenda, which entails understanding the decisive factors that will make local stakeholders commit to adaptation strategies
- discuss concepts of adaptation, resilience and vulnerability of the territories in the light of information gathered in the field
- define and discern the signs of a renewal of territorial activity (change of frame of reference for the temporal and spatial recording of public action)
- advance descriptive models for local adaptation processes, taking all these different aspects into account.

Coordinator: UMR/CITERES Tours (Joint Research Unit/Interdisciplinary Centre for Cities, Territories, Environment and Societies, Tours)

Within the framework of the 2010 call for proposals, research needs were expressed in the following areas:

- Identifying the impacts of climate change, developing appropriate indicators to monitor their evolution and estimate their cost
- The study of extreme events, their impacts and changes in frequency and magnitude
- Analysis of vulnerabilities associated with risks linked to climate change and management of the hazard-vulnerability-risk triptych in order to define public policies and management of systems
- Adapting to climate change and necessary downscaling: short-term timescale (15-30 years) and a more localised scale to develop more robust regional models.

- Management or quantification of additional uncertainty linked to the conjunction of economic and climate models and to cost evaluation, in order to gauge the relevance of adaptation policies to be implemented
- Developing regionalised socio-economic scenarios in order to analyse the interaction of adaptation policies with the other components of local development
- Policy interaction between mitigation and adaptation and also between these two aspects of the fight against the effects of climate change and other sectoral or territorial policies

Of the ten projects selected or featuring on the list of supplementary projects, none focused on the urban field, with the exception of the INVULNERABLE project (see section 1.3) within the framework of the extension of its work.

## **The MEEDDM Urban Planning, Construction, Architecture Plan (PUCA) and the National Research and Experimentation Programme on Energy in Buildings (PREBAT)**

### **PUCA**

Since its creation in 1998, this plan has been developing programmes of commissioned research, action-research and experimentation, and provides support for innovation and scientific validation on the three topics given in its title – urban planning, construction and architecture.

These research and experimental projects on sustainable construction, urban planning in the city and its districts, architecture and overall social cohesion are all facets of several important basic questions: How can we build the city or renovate it to achieve a better natural, social and economic balance? To what extent is the vulnerability of certain social groups or a number of territories taken into account? How can building techniques and development facilities integrate environmental concerns and build or renovate buildings to be energy efficient and reduce greenhouse gases, while promoting the development of a knowledge society and access to nature for all citizens?

PUCA initiatives are based on a partnership: with the CNRS within the framework of the City and the Environment programme (PIRVE), or other research networks, with central or decentralised government departments, notably as part of local research programmes initiated by DREALs (regional environment, development and housing departments) which take part in the national programme through “regional study development and regional planning programmes” (PREBAT), seven of which are now active (in Nantes, Strasbourg, Rennes, Toulouse, Montpellier, Bordeaux and Tours), notably on the topic of the suburban area and nature in the city.

Lastly, on a European scale, PUCA is involved in the two ERA-NET projects: ERACOBUILT on the construction and management of sustainable buildings and URBAN-NET on urban research.

Finalised PUCA programmes for the period 2007-2012 take the form of finalised research projects involving the scientific community and calls for proposals from the professional community.

Research carried out in 2010 refocuses on global issues in a post-Grenelle Environment Forum perspective, highlighting three areas – the sustainable city, buildings and social cohesion – and also the need to rethink the way in which we approach the urban issue.

**In terms of the sustainable city**, the issue focuses on the one hand on the interconnection of the different scales of governance within the city and urban area, and on the other hand on issues connected with the suburban area (without calling into question its total dependence on private vehicles and on the consumption of space but by considering issues of flexibility, reversibility, resilience, notably in relation to the effects of climate change) as well as questions about nature in the city as part of a unitary vision combining agriculture in the suburban area, green spaces and green corridors to act on the effects of global warming, Co2 capture, absorption of floods, and pollution management.

Mention should also be made in this respect of funding for projects or the organisation of research seminars directly or indirectly linked to climate change and adaptation issues:

- the connection between the different scales when considering the sustainable city (house, quarter, town, urban area) and the fight against climate change in terms of mitigation and adaptation
- the observatory of French urban strategies (over 370,000 inhabitants), and in particular “urban weaknesses”: economic, social, organisational and environmental (the problem of water).
- Nature in the city in association with the Nature in the City Plan (topics: ecological functions, water, nature and the city, production of urban forms, the natural economy in the city): a survey of knowledge, practice and experiments.

**The buildings plan**, one of the top priorities for the Grenelle Environment Forum in the fight against the effects of climate change, aims to develop research projects in the housing field alongside other stakeholders (ADEME, ANR, etc.), to encourage professional research and innovative activity in the “positive energy” building field, to improve the quality of housing - as part of the *Sustainable City* programme focusing on acceptable density levels, the individual/joint report on the environmental and urban quality of services - to put forward solutions for improving existing residential areas and promoting the homes of tomorrow within the framework of experimental projects or debates on architectural approaches.

## **The Programme for Research and Experimentation on Energy in the Building Sector (PREBAT)**

PUCA projects on the topic of “building” have a common thread with the main approaches of PREBAT. This multiyear programme was launched in 2005 in response to the 2004 Climate Plan which set out to cut greenhouse gas emissions in the building sector by 74% by 2050. Financed by ADEME (Environment and Energy Conservation Agency), ANAH (National Housing Association), ANR (National Research Agency), ANRU (National Agency for Urban Renovation) and MEEDDM (PUCA), it aims to achieve significant, sustainable and finalised research, experimentation and dissemination of new solutions to improve energy efficiency in new and existing buildings. It focuses mainly on mitigating the effects of climate change, but also addresses adaptation projects in certain cases.

Two successive programmes have been implemented, PREBAT 1 from 2005- 2009 and PREBAT 2 from 2010-2014. They take the following strategic approaches:

1. Sustainable modernisation of existing buildings. The research and development objective is to find technical solutions to the widespread renovation of buildings achieving an energy efficiency rating as close to possible to new buildings in a way which is technically, economically and socially acceptable by 2015-2020
2. To foresee the buildings of tomorrow. The research objective is to enable widespread construction of highly energy-efficient buildings of all types by 2015-2020
3. The emergence of positive energy buildings. The research objective is to be able to build and renovate a major number of buildings which can supply more energy than they consume. A significant proportion of renovated buildings will benefit from the methods and techniques which will be developed

To this end, four themed committees – the technology committee, existing buildings committee, new buildings committee and a socio-economic committee – are developing an operational action programme incorporating innovative technical solutions, simulation tools and the construction of demonstration buildings. Of these committees, the socio-economic committee is following the approach of a future vision of town planning and the role of stakeholders, offering in particular an analysis of the impact of morphology and the urban dynamic on the assessment of greenhouse gas emissions caused by buildings.

## **The Programme for Research and Development in Land Transport (PREDIT)**

As the successor to three previous programmes, PREDIT 4 (2008-2012) is cited here for information, as many mobility issues touch directly on greenhouse gas emissions, and although research in this area focuses largely on mitigation, joint research with adaptation cannot be precluded in the future.

In its current form, the programme's priorities are to reduce greenhouse gas emissions by a factor of four by 2050, reduce impacts on biodiversity and systems, develop intermodality and non-road transport methods while guaranteeing the mobility of people and goods and the quality of transport systems.

These objectives can be divided into six areas: energy and the environment (noise and air quality within the framework of the PRIMEQUAL programme); quality and safety of transport systems; mobility in urban areas; logistics and the transport of goods; competitiveness of the transport industry; transport policies.

The call for proposals launched in 2009 and 2010 dealing more specifically with the topic "mobility in urban areas" as part of the ANR's "Sustainable Cities" programme aims to produce new knowledge in the field of mobility as well as to design and trial mobility services adapted to changes in society and territories in an economic and technological context undergoing profound change. Among the questions asked are: Do observations of mobility show any new practices on the part of public or private stakeholders linked to new timescales and a new geography of movement? How is the relationship between transport and urban morphologies changing in the face of climate change and rising transport costs?

## **The Plant and City programme**

Launched in 2006, the Plant and City programme is a national research and experimentation hub which aims to share and improve techniques for managing green spaces within the optic of the sustainable development of the city. It incorporates research bodies, in particular the INH (National Horticultural Institute) and INRA (National Agronomy Research Institute), local authorities and companies.

This programme comprises six research topics, some of which may provide useful answers in terms of the adaptation of the city and its green spaces to climate change and water scarcity:

- agronomy and the artificialisation of urban land: management of scarce water resources and improving the physical properties of land
- managing plant health and integrated biologically-based protection eliminating harmful species
- plant innovation and diversification: drought resistance, plant diversification, useful plants notably on roofs, the development of a network of native plants
- economy and management of green spaces: development of a frame of reference for environmental management
- managing biodiversity: developing tools for defining useful levels of biodiversity in a space, definition of routes which respect urban and peri-urban ecosystems.
- urban landscape: the use of vegetation in different types of urban space (on the approach to cities, etc).

Current research areas:

- The identification of ranges of herbaceous plants for revegetating roofs which are suitable for limited water supplies
- Development of a design tool for green spaces combining types of vegetation and uses

## **Targeted projects**

In addition to the programmes outlined above, some of whose topics attempt to answer questions about the sustainable city and more particularly the effects of climate change, there are other research projects which do not fit into the framework of these major programmes but are worth mentioning as their approach is linked to this topic. They can be divided into three areas corresponding to the different issues that they are aiming to resolve:

- 1- What is the position of the city of tomorrow in a post-carbon perspective and within a process of adaptation?
- 2- What modelling tools would enable us to assess the urban morphology of today and tomorrow?
- 3- What will the impacts of climate change be on the city and adaptation strategies?

In parallel with this research, whether it is looking to the future or producing tools to gain a better appreciation of the issues and to help stakeholders make decisions, it is also appropriate to mention

the growth of research in the area of cognitive and social sciences, notably around the concept of adaptation and the way in which it is perceived by different stakeholders.

## **The city of tomorrow in a post-carbon perspective**

Coordinated by MEEDDM and ADEME, three calls for research proposals were launched in succession in 2008, 2009 and 2010 with the aim of rethinking cities within the framework of a post-carbon society in 2050 and focusing notably on questions related to the urban transition implied by such a change. The aspect of the link with climate change and its consequences is not specifically addressed within this framework, but the overall approach can provide some interesting insights into the problem of adaptation. There are three approaches to this theme in the research undertaken:

### **- 1) Vulnerable territories and populations: what are the social impacts of the transition to post-carbon cities?**

This topic aims to evaluate the dynamic of social and territorial inequalities which could be the result of difficulties in adapting to a context characterised on a permanent basis by an increase in the cost of energy and carbon. The responses will undoubtedly vary depending on the social categories, means of transport used and the type of housing occupied. Towns and territories will therefore be differently affected.

Several forward planning research studies are currently being carried out in partnership with urban areas (Tours, Mulhouse, Grenoble, Lille, Plaine de France). This research aims to construct and simulate scenarios for the transition to post-carbon cities with classifications of the process (dynamics at work, populations involved, corrective policies envisaged, etc.).

### **- 2) Forward study into lifestyles in post-carbon cities.**

This involves suggesting reasoned global visions of what alternative lifestyles linked to the constraints of carbon in 2030-2050 could be like, discussing the plausibility and circumstances of a break with the way in which we move and travel, possibly by differentiating between geographic areas, reflecting on the dynamic of the change to these alternative lifestyles in the form of transition scenarios or monographs summarising successful experiences of change.

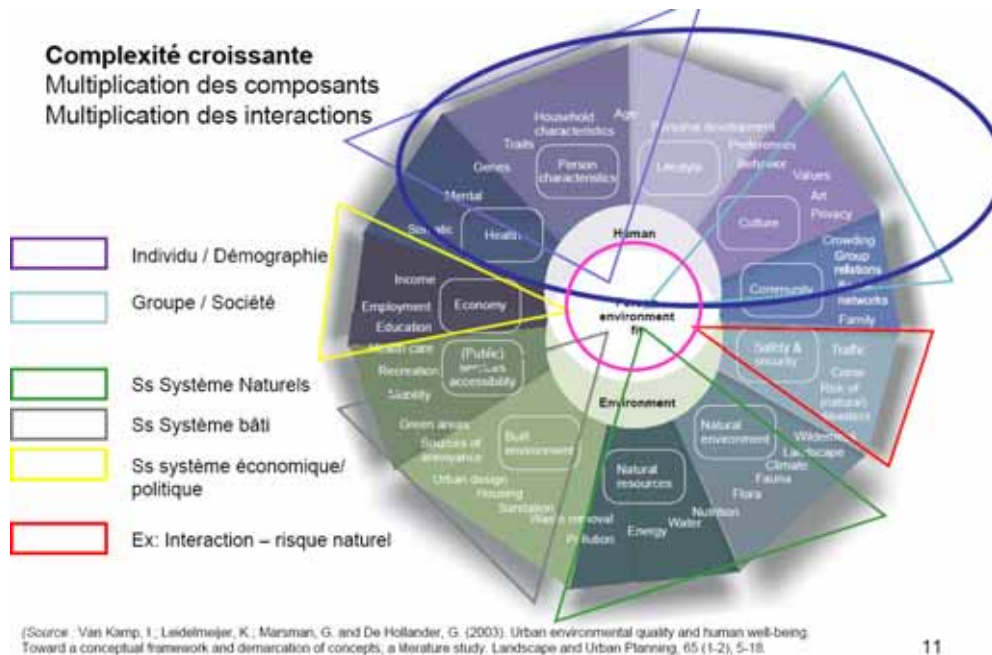
### **- 3) Stakeholders, institutions and policies in post-carbon cities.**

The dynamics of the activities of local stakeholders and institutions will be analysed taking possible trajectories into account according to the barriers and opportunities which will facilitate or hinder this transition. Based on case studies of cities or urban areas, the specific focus will be on the type of governance implemented to ensure a transition to the model of a post-carbon city.

## **Modelling tools for urban morphology**

Although climate scenarios use projections based one century ahead, the difficulty lies in establishing urban planning scenarios on the same timescale in order to link them to the climate scenarios. Functionality models of the city which take into account all the components of this complex system are required to build these scenarios.

Different research studies describe this complexity which is the result of interactions between different systems – environmental, economic, political or social – as described below:



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Figure 24: Diagram of the complexity of the city. Source CNRS

**Key:**

- Complexité croissante – Increasing complexity
- Multiplication des composants – Multiplication of components
- Multiplication des interactions – Multiplication of interactions
- Individu/Démographie – Individual/Demography
- Groupe/Société – Group/Society
- Système Naturel – Natural environment
- Système bâti – Built environment
- Système économique/politique – Political/economic system
- Interaction-risque naturel – Interaction-natural risk

Other studies describe the city as an “urban metabolism”, studying the transformations and flow of matter and energy involved in the life cycle of an urban zone as a whole. The city is therefore represented as an ecosystem which manages its inputs and outputs through regulation.

**The ACCLIMAT project (2010-2012)**

Consisting of a multidisciplinary Toulouse-based partnership coordinated by CNRM-GAME (Météo France) (National centre for Meteorological Research-Meteorological Atmosphere Study Group, Météo France), with assistance from the scientific cooperation foundation STAE Toulouse, ACCLIMAT complements two other research projects financed by the ANR (National Research Association) in the structure shown below within the framework of the VURCA and MUSCADE projects discussed above:

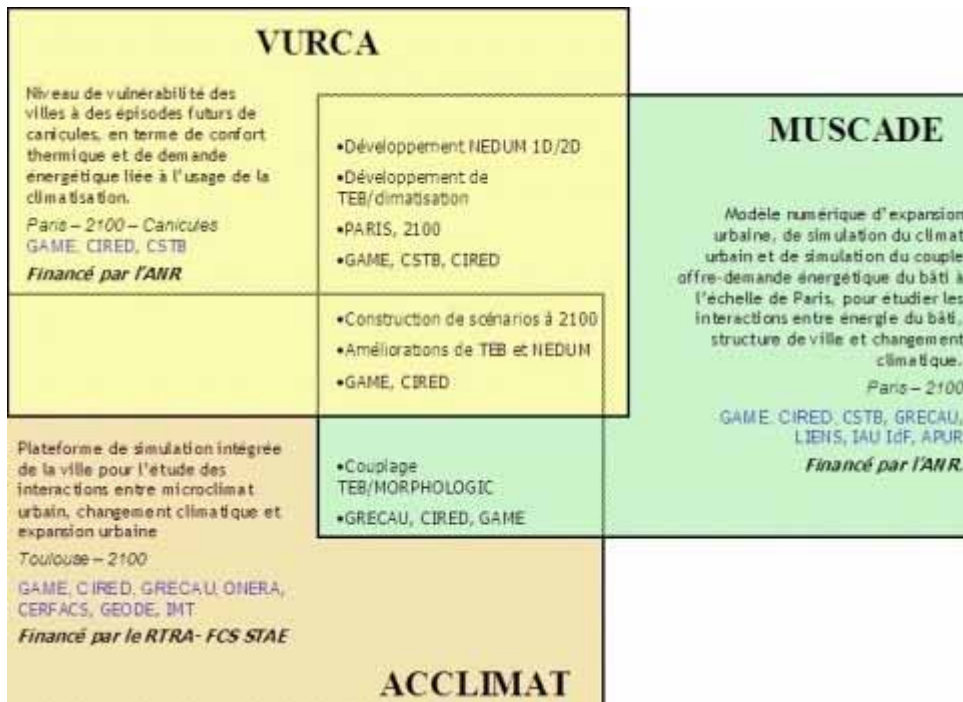


Figure 25: Simulation tools for a 2100 horizon used within the framework of the three research projects - VURCA, MUSCADE and ACCLIMAT. Source CIRED

**Key:**

VURCA: Vulnerability level of towns to future heat waves in terms of thermal comfort and energy demands linked to air conditioning.

Paris -2100 – Heat waves

GAME, CIRED, CSTB

**Funded by ANR**

MUSCADE:

Digital model for urban expansion, climate simulation and energy supply/demand in the built environment on a Parisian scale for studying the interactions between energy in the built environment, town structure and climate change.

Paris -2100

GAME, CIRED, CSTB, GRECAU, LIENS, IAU, IdF, APUR

**Funded by ANR**

ACCLIMAT:

Integrated simulation platform of the city for the study of interactions between the urban microclimate, climate change and urban expansion

Toulouse 2100

GAME, CIRED, GRECAU, ONERA, CERFACS, GEODE, IMT

**Funded by RTRA-FCS STAE**

Développement NEDUM 1D/2D – Development of NEDUM 1D/2D

Développement de TEB/climatisation – Development of TEB/air conditioning

Construction de scénarios à 2100 – Construction of 2100 scenarios

Couplage TEB/MORPHOLOGIC – TEB/MORPHOLOGIC coupling

Within this framework, the ACCLIMAT project is a digital simulation tool developed for the city of Toulouse, but which can be adapted to other urban areas. It aims to test measures for adaptation to

climate change, to identify the levers for action and evaluate the results of the measures planned in order to suggest an adaptation plan for the city with its future climate.

The scientific approach consists of coupling climate scenarios (extracted from climate scenarios on a European scale and relevant meteorological circumstances from the Toulouse region by adopting an appropriate downscaling method) with future planning scenarios for the growth of the urban area. The NEDUM urban expansion model developed by CIRED is used, coupled with a land occupancy model which can simulate urban sprawl. In order to model the impact of climate change and urban planning on the local climate, the Meso-NH meteorology model and Town Energy Budget (TEB) model were also used. All of these models will be integrated into a single platform which will enable complex parallel applications to be assembled.

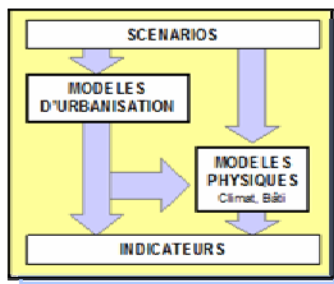


Figure 26: General diagram of the ACCLIMAT project. Source Météo France

**KEY:**

MODELES D'URBANISATION – URBANISATION MODELS

MODELES PHYSIQUES Climat, bâti – PHYSICAL MODELS Climate, built environment

INDICATEURS – INDICATORS

This tool will eventually provide some responses to concrete questions:

- What socio-economic levers act on the process of urban expansion and on what timescale?
- What are the consequences of the interactions between climate change and changes in urban planning in terms of urban climate, energy consumption, CO<sub>2</sub> emissions, the comfort of the inhabitants and the economic and environmental cost of implementing this strategy?

### **EPICEA and Greater Paris 2030 projects**

**The EPICEA project**, a multidisciplinary study of the impacts of climate change on the scale of the Paris urban area (Etude Pluridisciplinaire des Impacts de Changement climatique à l'Echelle de l'Agglomération parisienne) launched for a three year period was funded by Paris City Hall as part of the development of its Climate Plan to provide decision support.

It works with Météo-France to model urban meteorology and with the CSTB (Scientific and Technical Centre for the Building Industry) to integrate climate change issues into the different mechanisms for intervention in the city. The study aims to bring together and quantify on a Parisian scale urban planning, urban climatology and the health risks associated with heat waves in order to identify relevant vulnerability indicators across these three areas and define associated adaptation strategies.

The research method chosen focused on three components: changes in the urban climate in the light of climate change, specific study of the extreme heat wave of 2003 and the link between town planning and climate.

In addition to climate data for the period 1970 to 2000, the 2070-2100 projection required the use of the ARPEGE-climat global model to assess the change in the urban climate, However, these climate projections with a spatial resolution of 50km are not adapted to an urban area scale and a downscaling technique was employed based on two surface models, the TEB (Town Energy Budget) model for the city showing the parameterisation of exchanges of energy and water between built surfaces and the atmosphere and the ISBA (Interaction Soil Biosphere Atmosphere) for natural zones. These two surface models were forced by the SAFRAN system by geographically and climatically homogeneous areas, offering a resolution of 8km which is more appropriate for an urban area.



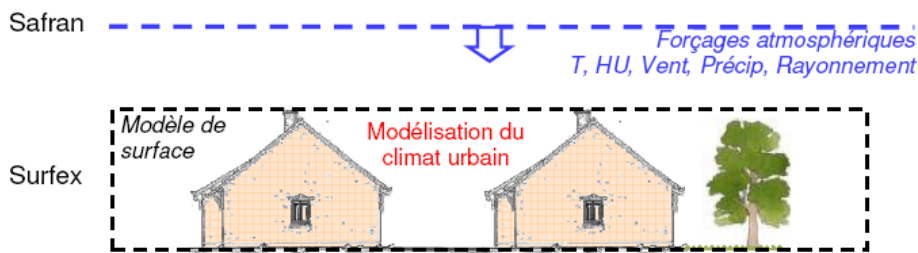


Figure 27: Simulations in forced mode on the Paris region with the SURFEX surface model including the TEB town model for urban surfaces over long periods of time.

**KEY:**

Forçages atmosphériques T, HU, Vent, Précip, Rayonnement – Atmospheric forcing Temperature, Humidity, Wind, Radiation

Modèle de surface – Surface model

Modélisation du climat urbain – Modelling the urban climate

Moreover, within the framework of a more specific study of the 2003 heat wave and its consequences in terms of its occurrence at the end of the century and the vulnerability of sensitive populations, simulations using the MesoNH and TEB digital models with a finer mesh of 2km enabled the City of Paris to be configured with uniform urban parameters (road width, building heights, roof surfaces and roofing materials, road, rail and water services). This data was used to evaluate the spatial distribution of temperature within Paris.

Lastly, in order to identify the interactions between urban infrastructures and local climate and to propose priority action areas in urban planning, Paris was simulated in “real city” mode, on the basis of data provided by APUR, the Paris Urban Planning Agency. This enabled a database of urban Paris cover to be created with a very fine resolution of 250m.

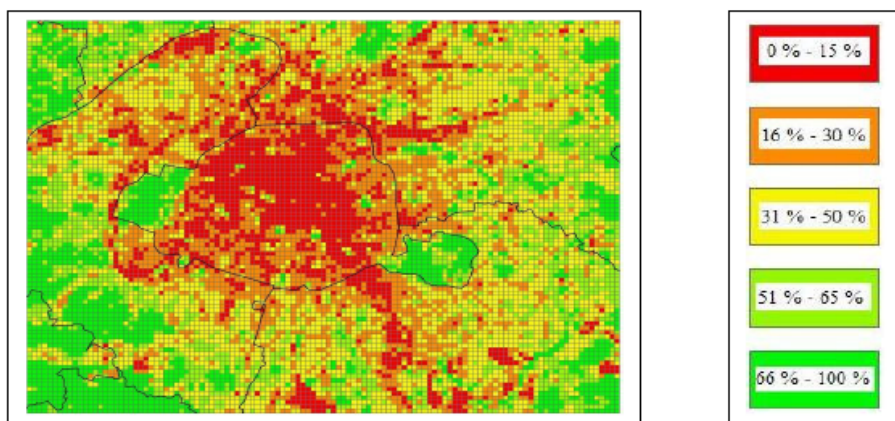


Figure 28: “Real city” configuration, simulation of the ‘surface vegetation cover’ parameters . Source APUR.

The project, which is linked to the Greater Paris Plan, falls into the same geographic field of the Paris urban area, but in a different context: a global study commissioned by the Ministry of Culture on “The major challenge of the Paris urban area” calling on ten consortia based around urban planning consultancies with the aim of exploring general aspects of how to developing the Paris urban area by 2030.

The work carried out has quantified the impact on the microclimate of urban development scenarios in the Ile de France region based on a 2030 horizon.

The scenario used (cf. chapter 1, text box 15) coupled with the MesoNH atmospheric model and based on a 30% expansion of forests, the presence of stretches of contained water, the transformation of cereal crop production to summer fruit and vegetables and the application of more reflective paint to roofs and roads in the three *départements* enclosing Paris (*petite couronne*) and outer ring of four *départements* (*grande couronne*) demonstrated a reduction in the night heat island during heat waves of 3 degrees in the suburban area and 2 degrees in the centre of Paris.



Figure 29: Paris region - 2030 simulation

### ***The INVULNERABLE project***

The INVULNERABLE project (Industrial VULNERABILITY) 2006-2010 has been extended to 2012 as a result of its selection in the Managing the Impacts of Climate Change (GICC) 2010 call for proposals. It brings together under the aegis of IDDRI (Institute for Sustainable Development and International Relations) several scientific partners (Météo-France, CERFACS European Centre for Research and Advanced Training in Scientific Computation, ONERC) and industrial partners (Dalkia, GDF-Suez, Veolia and EDF) in order to gain a better understanding of the vulnerability of industrial operations within the context of climate change.

It follows an approach of co-production and development of data (climatic and socio-economic) to gain a better understanding of the vulnerability of urban and in particular industrial systems to climate change. It also responds to a need for dialogue between climatologists and users to define relevant indicators.

This project approaches the vulnerability of industrial operations under five main headings:

- Will resource availability be impacted?
- Are the statistics used in the design of installations /infrastructure robust in the context of climate change?
- What are the prospects for change in the factors determining demand for goods and services?
- What are the prospects for change affecting the management of the industrial sector?
- What are the likely future cases of industrial “climate incidents”?

In the case of the study of the functioning of heat networks taking into account the effects of climate change, in addition to producing a specific vulnerability threshold indicator, the interactive methodology will enable industrialists to grasp the climate change phenomenon using climate data and also its limitations in terms of uncertainty. It will launch a dialogue between climatologists and industrialists which can be formalised in the future.

The INVULNERABLE project was extended as part of the GICC programme call for proposals in 2010.

### ***The CLIM2 project***

aims to evaluate the impact of heat releases from air conditioning systems during heat waves such as the 2003 event, using the Paris urban area as its test area. Digital simulations based on the coupling of the atmospheric model Méso-NH and the TEB urban climate model should make it possible to calculate the increase in temperature in the streets for several types of heat release (dry or wet), in the air in rivers, etc. Several groups of air conditioning equipment (of different types and with different performances) are integrated and simulated to quantify the impact of these scenarios on the external temperature of Paris.

CLIM2 is a joint research project between three partners, the public research laboratories CNRM-GAME (National Centre for Meteorological Research-Meteorological Atmosphere Study Group) and CNAM (National Conservatory of Arts and Crafts) and a private company. The study focuses on CNAM's expertise in refrigerated air conditioning systems and the private company's skills in air-conditioning (knowledge of product characteristics, location and quantity of heat released, future developments, etc.).

This study can be viewed in conjunction with work being carried out on a European scale within the framework of the URBACOOOL project “Towards effective urban cooling strategies”, which will offer alternative strategies to air conditioning with trials in three major European cities: Athens, Seville or Madrid and Paris.

### ***Evaluation of the impact of climate change on the functioning of an urban area (Nice)***

This research project led by CNRS-UMR ESPACE<sup>3</sup>, aims on the one hand to develop a systemic modelling method for a territory based on future climate change issues, and on the other hand to produce simulation tools for use by local decision-makers. The sample site selected is the Nice urban area.

Systemic modelling used within this framework is designed to measure local climate change impacts over the period 2000-2050 – temperature, precipitation, seasonal variations and extreme events – on the urban system viewed under six main headings: water resources, population growth, tourist activity, land occupancy and water consumption by type of housing and type of agriculture.

Modelling can be divided into two phases:

- an initial “go with the flow” phase in which population growth, the pace of urban sprawl, types of housing and water consumption are observed up to 2050
- a second “with intervention” phase testing the effects of different measures to adapt to climate change: the problem of urban sprawl, the risk of flooding or water shortages. By way of example, urban sprawl is prohibited if the threshold for artificialisation of land has been reached (a hypothetical 50%). In this case, individual homes are limited and the densification of existing buildings advocated:

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CNRS-UMR ESPACE: National Centre for Scientific Research-Joint Research Unit Study of the Structures, the Adaptation Process and Changes of Space.

population gains will therefore be distributed differently: 5% to individual housing compared to 50% previously, 60% to mixed housing compared to 40%, and 35% to dense housing compared to 10%.

Two interactive tools based on this modelling will be made available to decision-makers.

### **A prototype knowledge-based system (SereNiCim).**

This experimental prototype aims to offer decision-makers territorial management measures to enable them to develop a policy for adapting to the effects of climate change in an urban environment. Based on a systemic model, this version has currently only been developed for water management and is applicable to the Nice urban area.

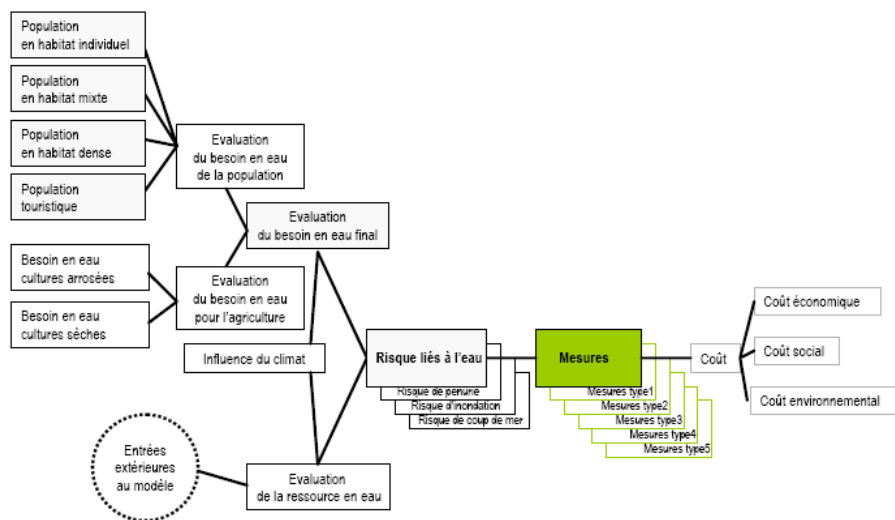


Figure 30: Diagram of the conceptual model and stages of reasoning. Source: CNRS - UMR ESPACE

#### **Key:**

- Population en habitat individuel – Population in individual housing
- Population en habitat mixte – Population in mixed housing
- Population en habitat dense – Population in dense housing
- Population touristique – Tourist population
- Besoin en eau cultures arrosées – Water requirement for wet crops
- Besoin en eau cultures sèches – Water requirement for dry crops
- Evaluation du besoin en eau de la population – Assessment of the population's water requirements
- Evaluation en besoin d'eau final – Assessment of the final water requirement
- Evaluation du besoin en eau pour l'agriculture – Assessment of the agricultural water requirement
- Risque liés à l'eau – Risk related to water
- Risque de pénurie – Risk of shortages
- Risque d'inondation – Risk of flooding
- Risque de coup de mer – Risk of heavy seas
- Mesures – Measures
- Coût – Cost
- Coût économique – Economic cost
- Coût social – Social cost
- Coût environnemental – Environmental cost
- Entrées extérieures au modèle – Inputs external to the model
- Evaluation de la ressource en eau – Evaluation of water resources

**Virtual models of the territory.** Virtual models of the territory simulate it in 3D using different time horizons, translating the results of the systemic model into visual displays according to the different scenarios selected.

This highly interactive governance tool enables managers and decision-makers to see spatial and temporal evolutions of their territory over the coming decades in live form and to define the impacts of climate change and the adaptations required.

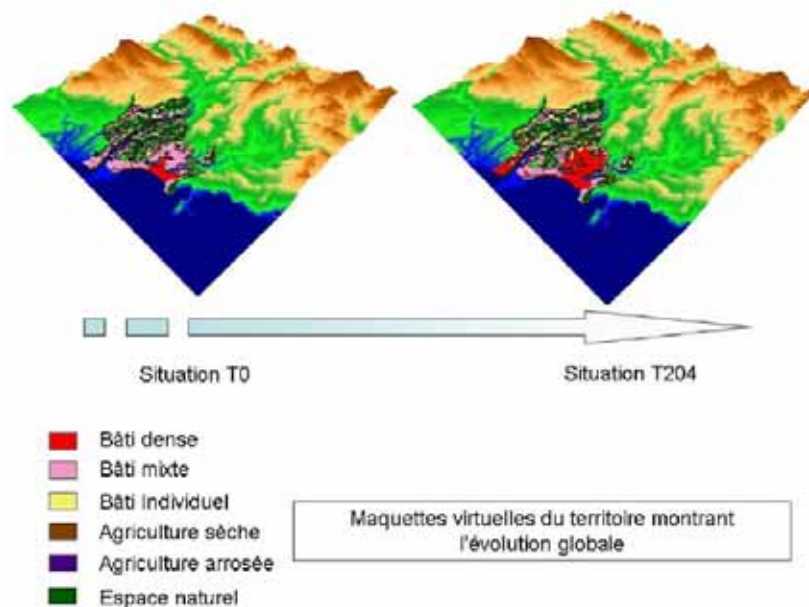


Figure 31: virtual models of the territory. Source: CNRS-UMR ESPACE

**KEY:**

Bâti dense – Dense building

Bâti mixte – Mixed building

Bâti individuel – Individual building

Agriculture sèche – Dry farming

Agriculture arrosée – Wet farming

Espace naturel – Natural area

Maquettes virtuelles du territoire montrant l'évolution globale – Virtual models of the territory showing overall change

***Vulnerabilities and the concept of adaptation to climate change applied to the local dynamic***

The consideration of vulnerabilities and the emergence of the concept of adaptation to climate change on the part of different local stakeholders are analysed, notably within the framework of initial research on this theme funded by PUCA 2005-2007 and the current 2007-2011 project.

**Climate change as an indicator of territorial vulnerability**

Focusing on observation of three territories, the Greater Lyon urban community, the commune of Villard-de Lans in the Isère département and the Île de Ré - this research concentrates on the following three preliminary questions:

- Does climate change highlight vulnerabilities associated with territories?
- Are the territories most at risk from the potential consequences of climate change, i.e. the most vulnerable, in a position to integrate these risks into their policies?
- Does the development of public action linked to an awareness of climate change constitute a forum for discussion in which a particular perception of the vulnerability of territories and ecological inequality develops locally? In other words, how do local stakeholders understand and translate the global challenge into territorial measures?

Analysis carried out on the territory shows that depending on their natural and geographic configurations (coastal area, island), but also social and economic factors (single industry or touristic activity), territories prove to be unevenly matched when confronted with the consequences of climate change.

Moreover, implementation of mitigation and adaptation strategies interacting with local issues of sustainable development requires the reformulation or updating of territorial issues and presupposes organisational changes on a local level to integrate the “climate issue” as required into local public policy, by sector or in a cross cutting approach and the implementation of intervention or planning programmes. The issue of the stakeholders, organisations and institutions mobilised in the range of

local issues, and hence of the expertise required, can also be a source of inequality between territories.

Coordinator: CITERES (Interdisciplinary Centre for Cities, Territories, Environment and Societies) Tours University

**Issues and dynamics involved in the implementation of strategies for adapting to climate change in the urban area: Montreal and Paris.**

This research project aims to achieve a clearer view of the process of adapting to climate change defined by the IPCC (2007) as “an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts and capitalise on the benefits” by reducing semantic incongruities, notably in relation to mitigation (or reduction) – in order to make this component more comprehensible and operationally useful. It therefore aims to suggest the concept of adaptation as a tool for gaining a better understanding of the relationship between the environment and society from a systemic perspective of joint initiatives, notably by rebalancing top-down and bottom-up approaches used to develop adaptation policies (cf. figure 32).

Lastly, it aims to implement this conceptual approach with different institutional stakeholders in Paris and Montreal based on the lessons learned during the participative approach used for the development of the Paris Climat Plan in 2007 and the sustainable development plan developed by Montreal.

Joint doctoral research between UQAM, Quebec (Chair of Studies on Urban Ecosystems, UQAM, Quebec) and Ladyss, Paris Ouest Nanterre La Défense ( Spatial Dynamics and Composition of Spaces Laboratory).

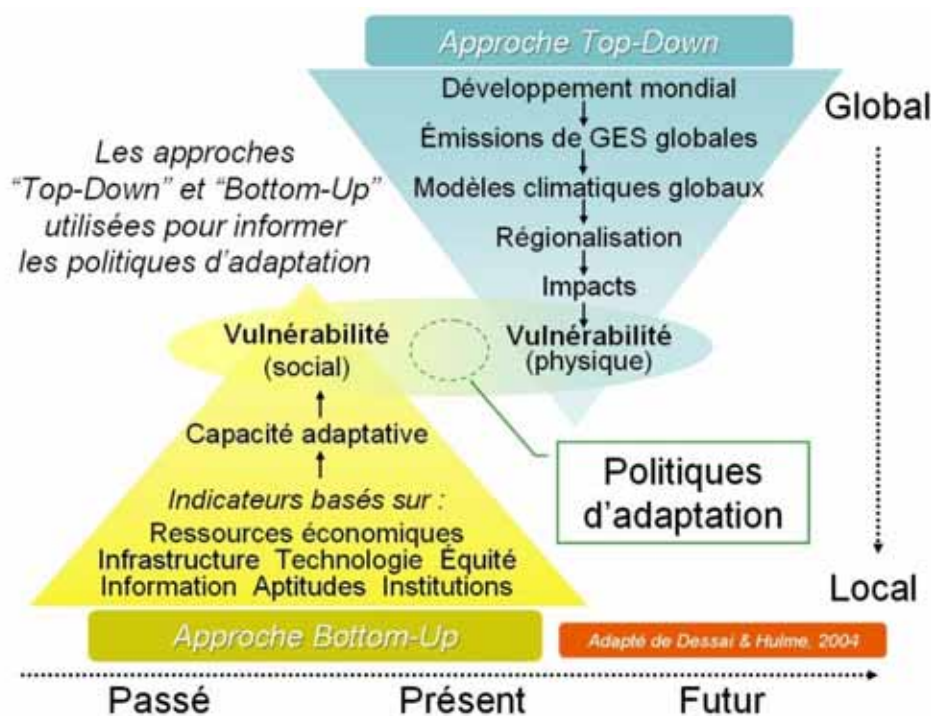


Figure 32: The concept of adaptation. Source: Dessai and Hulme, 2004, adapted by Guillaume Simonet, 2010"

**KEY:**

Les approches “Top-down” et “Bottom-up” utilisées pour informer les politiques d’adaptation –Top-down and bottom-up approaches used to inform adaptation policies  
 Vulnérabilité (sociale) – Vulnerability (social)  
 Capacité adaptative – Adaptive capacity

Indicateurs basés sur: Ressources économiques Infrastructure Technologie Équité Information Aptitudes  
Institutions – Indicators based on: Economic Ressources Infrastructure Technology Equity Information Skills  
Institutions  
Approche Top-down – Top-down approach  
Développement mondial – Global development  
Émissions de GES globales – Global GHG emissions  
Régionalisation – Regionalisation  
Impacts – Impacts  
Vulnérabilité (physique) – Vulnerability (physical)  
Politiques d'adaptation – Adaptation policies  
Global – Global  
Local – Local  
Passé - Past  
Présent – Present  
Futur – Future

## European research within the URBAN-NET programme framework

The European framework offers interesting opportunities in the field of urban research in the context of climate change as a number of European cities will be affected, either as heat islands or because they are at risk from flooding or submersion, and this is why one of the four topics chosen within the framework of the URBAN-NET research project funded by the 6<sup>th</sup> (2002-2006) and 7<sup>th</sup> (2007-2013) Framework Agreements for Research and Technological Development (PCRD) focuses on climate change in the urban context.

The URBAN-NET project, which brings together 16 research bodies from 13 countries including France in order to pool research which is of shared interest and to increase the number of tools and areas of applications, has already funded 11 research projects within the framework of the first call for proposals in 2008. Four of these are related to climate and two will be pursued in response to a new call for proposals in 2009-2010. They are:

**The effects of heat waves on urban structures in Europe.** The aim of this research is to determine the possible link between different types of urban structure and urban heat levels using recorded measurements and applying simulation models, in order to propose urban structures which limit the heat island effect.

This research, which should continue within the framework of the call for proposals for 2009-2010, brings together Sweden (coordinator), Germany and the United Kingdom.

**The optimisation of urban planning and the architectural parameters for a reduction in thermal effects in Mediterranean cities.** By analysing the city as a whole and its urban form and urban network, this research project aims to understand what elements can contribute to urban ventilation to combat the heat island phenomenon. The sample area is a typical Mediterranean town in Cyprus. Digital and simulation tools will be used to measure the temperatures of surfaces and urban ventilation.

This research project brings together Cyprus (coordinator), Bulgaria and Sweden.

**Urban tourism and climate change.** This project aims to verify the hypothesis of a shift in urban tourism linked to the effects of climate change. In order to do this, interviews with tourists, tour operators, shopkeepers and city officials were carried out in cities in Sweden, Portugal and Turkey - the three partner nations in this research. Levels of comfort and thermal stress, the level of awareness and involvement of different stakeholders facing the consequences of climate change, tourist destinations and preferences depending on the season and type of climate, adaptation strategies and their economic and social consequences will all be monitored.

**Implementing a research network on how cities adapt to climate change.** This research project has as its ultimate objective to support the integration of aspects linked to climate change in European urban planning. In its initial phase, research issues will be formulated and evaluation criteria developed. The research network comprising Sweden (coordinator), Germany, the Netherlands and Spain will focus on a group of fifteen European cities (including Barcelona, Delft, Hamburg and Troyes), with Stockholm as the lead city.

## APPENDIX 2 : Associations of cities on an international scale

Associations of cities are ideal places to launch and implement this new dynamic which integrates the issue of climate change with the policy of sustainable development. After aiming in the first instance to reduce greenhouse gases, these associations are now turning their attention towards mitigation policies. Just recently, some of them have been proposing and promoting the joint implementation of adaptation policies.

### The CEMR

#### Creation-organisation.

The Council of European Municipalities (CEM) was founded in Geneva in 1951 by a group of European mayors, before opening its ranks to the regions in and becoming the **Council of European Municipalities and Regions** (CEMR).

Today it constitutes the biggest organisation of local and regional authorities in Europe. Its members include over 50 national associations of cities and regions from 38 countries, representing approximately 100,000 cities and regions.

The annual CEMR budget is 2 million euros comprising mainly subscriptions from association members. The European Commission contributes just over 10% of the budget through an annual grant within the framework of the European Active Citizenship Programme.

The CEMR covers a vast array of activities such as transport, regional policy, the environment, equal opportunities, governance, etc. Its commissions and working parties try to influence European legislation so that the interests and concerns of local and regional authorities are taken into account early on in the European legislative process. The CEMR founded the network of twin towns which is unique to Europe (approximately 26,000 town twinnings between European towns).

#### Scope.

The CEMR aims in particular to help to influence legislation, policy and best practice in the field of sustainable development and climate change.

In the area of sustainable development, the CEMR has been playing an active role in the *Sustainable Cities* campaign for over ten years and contributes to the debate on the future of the European Union (EU) sustainable development strategy, taking part in intergovernmental activities on the implementation of the EU territorial agenda and the Leipzig Charter on sustainable European cities and notably in the preparation of a European frame of reference for sustainable urban development.

Within the framework of this objective, and following an informal meeting of ministers for urban development in Toledo on 22 June 2010, the CEMR is taking part in developing an online tool available directly to cities to promote their sustainable development. The prototype for this tool will be tested by between 50 and 70 European cities as part of a test phase jointly led by France and the European Commission.

On the topic of energy and the effects of climate change, the CEMR is a partner in the Sustainable Energy for Europe Campaign and is working in close cooperation with the European Commission to promote sustainable sources of energy and energy efficiency. It is monitoring the implementation of the White Paper on adapting to climate change published by the European Commission on 1 April 2009, setting out the necessary measures to build up the capacity of the European Union to confront climate change and is taking part in events and activities in this area following on from the United Nations conference in Copenhagen in December 2009.

### The Covenant of Mayors

The Covenant of Mayors is a cities initiative promoted by the European Union. It is a response to the European Union's adoption in 2008 of the Climate and Energy Package – 20-20-20 targets (20%



reduction in CO<sub>2</sub> emissions, 20% reduction in energy consumption and 20% renewable energy in the European energy mix). In February 2009, 350 mayors from European cities (including Paris, Grenoble and Rennes) signed the Covenant of Mayors together at the European Parliament and by the summer of 2010 almost 2,000 mayors were committed to the process.

This ambitious initiative aims to place European cities in the forefront of the fight against global warming and to encourage signatories to make a formal commitment to “exceed the objectives set by the European Union” for CO<sub>2</sub> emissions by 2020. In order to achieve this, a demanding framework is required, because although membership of the Covenant of Mayors is voluntary, once the charter has been adopted, cities who are signatories must rapidly implement concrete and quantifiable projects. Furthermore, they can be excluded from the initiative if they do not respect certain fundamental points. They are therefore required:

- to establish a baseline reference for energy consumed and produced in their territory in addition to the corresponding Co<sub>2</sub> emissions and to define their objectives to reduce the CO<sub>2</sub> levels quantified both globally and by area
- to prepare an action plan for sustainable energy in the medium term in collaboration with local stakeholders and citizens within one year of signing the Covenant and to prepare an initial progress report within three years of signing the Covenant

The European Commission has made a parallel commitment to make available to signatory cities:

- a Covenant of Mayors’ Office to promote, coordinate and provide support, notably for the smaller cities (Energy-Cities in collaboration with the European networks Climate Alliance, Eurocities, CEMR and the European Federation of Regional Energy and Environment Agencies)
- A website, tools and methods to help to prepare and harmonise emissions assessments and action plans, as well as organising events to raise the political profile of the member cities on a European level
- Funding mechanisms: European Commission (within the framework of the Intelligent Energy Europe programme), European Investment Bank, Structural Funds, etc.

## Energy Cities

The **ENERGY CITIES** network is a European association of local authorities with 1,000 members in approximately thirty countries, whose aim is to invent their energy future. This network is also the leader of the consortium including EUROCITIES, the Climate Alliance, CEMR and the European Federation of Regional Energy and Environment Agencies (EFREE) coordinating the Office of Mayors of the **Covenant of Mayors**, offering support, promoting it and advising its members. It offers the benefit of its experience through the following excellence initiatives which inspire cities to take action:

**The European Display** campaign which encourages European local authorities to publicly display the energy performance statistics of public buildings for water and greenhouse gas emissions. French towns taking part: Rennes, Rochefort.

“ **IMAGINE**” - a long-term initiative to reduce the energy vulnerability of cities.

**Ad Personam** - encouraging the use of public transport in medium-sized European cities, with 7 pilot cities in 7 different European cities. Jointly funded by the European Commission within the framework of the Intelligent Energy Europe programme. The town of Besançon is taking part.

**REVE d’Avenir (Dream of the future) involving 27 Franco-Swiss local authorities taking up the climate and energy challenge in municipal projects around the 3X20% target. French participants:** Annecy, Annemasse, Besançon, Montbéliard, Chamonix, Lons le Saunier, Chambéry, Chalon sur Saône, Dijon, Echirolles, Besançon, Dole, Lyon, Grenoble, Montmélian, Mulhouse.

**ENGAGE** aims to provide direct support to achieve the objectives of the European Climate and Energy Package legislation by encouraging local authorities to communicate about European 3X20% objectives at a local level and to mobilise all stakeholders (civil servants, local stakeholders and citizens) around their work: **12 pioneer cities are representing 12 different countries, including Rennes.**

The **MODEL** project aims to help local authorities to take energy issues into consideration by establishing departments or officials responsible for “energy” within cities and implementing multi-year local authority action plans, funding concrete projects and disseminating information, results, methodologies and practical tools on a wide scale.

SESAC, STACCATO and ACT 2, **within the framework of the CONCERTO initiative led by the European Union, aim to promote technological innovation in the field of renewable energy and polygeneration systems in eco-building projects.** Participating French cities: Grenoble and Nantes.

BELIEF **aims to promote the concept of sustainable energy communities on a European scale by creating local forums for Intelligent Energy in 20 municipalities in 11 European countries.** The project aims to jointly develop an Action Plan for sustainable energy linked to an investment plan. Participating French towns: Rennes and Dunkirk.

## Euro Cities

The **EUROCITIES** network established in 1986, brings together over 130 cities with more than 250,000 inhabitants from 30 European countries. EUROCITIES offers its members a hub to exchange ideas and experiences, identify problems encountered, develop innovative solutions, organise events and set up joint projects.

EUROCITIES also ensures that urban issues and the role of cities are included in the European Union political agenda (e.g. the European Union’s funding plans, Green and White Papers on climate change, the Territorial Agenda, etc.). The network is active in the following public policy areas: economic development and cohesion policy, public services, the environment, transport and mobility, employment and social affairs, culture, education, the information society and new technologies, as well as governance and international cooperation. Through its 7 fora and their working parties, EUROCITIES represents the voice of major European cities in European community institutions including the Environment Forum and its respective working parties - Energy Efficiency, Air Quality and Climate Change. The Climate Change Group also aims to exchange skills and practical knowledge, to pool tools and research results, especially with regards adaptation to the effects of climate change.

It should be noted that 84 mayors from municipalities across Europe including Bordeaux, Grenoble, Lille, Lyon, Marseille, Nancy, Nantes, Nice, Paris, Rennes, Saint Etienne, Strasbourg and Toulouse have signed a joint declaration since 2008 emphasising the crucial role of cities as privileged partners in cooperation with European institutions and member states and their commitment to fight against the effects of climate change by implementing appropriate policies immediately and in the long term in this field.

## C40 Cities

C40 Cities is a group of 40 capital cities on five continents – with Paris, London, Berlin, Madrid, Rome, Athens and Warsaw representing the European Union – pooling their efforts to fight against the effects of climate change. Established in October 2005 in London, this group initially consisted of 18 cities and quickly expanded, benefitting in August 2006 from its partnership with the Clinton Climate Initiative (CCI) within the framework of funding and intellectual assistance for the cities as a whole or for one city in particular on request, with the common objective of reducing greenhouse gases and improving energy efficiency in cities.

Within this partnership, the C40 Cities network offers member cities a common framework for activity, a forum for exchanging and sharing ideas and offers action programmes and lists of case studies and examples to follow in areas connected to urban issues, construction, energy, transport, lighting, water, waste and recycling. Thus, within the framework of adapting to climate change, members are offered the results of a study published by the New York Academy of Sciences “Climate change adaptation in New York City: building a risk management response” which emphasises the short-term need for adaptation in the city and identifies an action plan and best practice.

The C40 Cities network is also involved in various important events, for example the United Nations Climate Conference in Copenhagen in December 2009 and the parallel Copenhagen Climate Summit for Mayors which brought together representatives from 80 cities worldwide including 55 mayors who delivered the message to world leaders: “we must, we can and we will”. More recently, the C40 organised two workshops in 2010, one in Berlin on “Strategies for resilient cities” and the other in Hong Kong on “Cities with low carbon consumption and high quality of life”. The next C40 conference will take place in Sao Paulo in 2011.

## The Climate Alliance

**The Climate Alliance** is a European network of local authorities concerned with global climate issues and their effects, which aims to combat these through concrete objectives, notably a significant reduction in CO<sub>2</sub> emissions: 10% every five years with the target of cutting emissions to half of the 1990 level by 2030.

Established in 1990, this network brings together over 1,500 municipalities and urban areas across 17 European nations, including France (four municipalities, among them Nantes and Metz). Furthermore, more than 50 regions and non-governmental organisations have joined the Climate Alliance as associate members.

In order to meet the agreed climate targets, notably the reduction of CO<sub>2</sub> emissions, members of the Climate Alliance undertake strategies and projects in the construction sector, transport systems and forms of mobility, urban planning (especially within the framework of local Agenda 21), as well as in other areas such as agriculture, forestry and tourism.

## ICLEI

**ICLEI - Local Governments for Sustainability** – is an international association of local authorities and local or regional government committed to a policy of sustainable development. Established in 1990 during the World Congress of Local Authorities for a Sustainable Future, which brought together 200 local authorities from 43 countries, the organisation now comprises more than 1,118 local authorities and their associations, representing over 300 million people in 68 countries, as well as associate members such as research institutes, non-governmental organisations or national governments.

Through its international programmes, campaigns and local projects, ICLEI helps to make local authorities aware of the importance of sustainable development and brings its expertise to the implementation of concrete projects. ICLEI also supplies information, offers training, organises conferences, facilitates networking and dialogue between towns, carries out research and pilot projects and offers technical services and consultancy as well as software and tools to help local authorities to achieve their sustainable development goals.

As a result of the work carried out within this framework as well as the internal research capability developed based on multidisciplinary teams, ICLEI has acquired expertise in a number of fields such as Local Agenda 21, public participation and good governance, climate protection, energy efficiency, water management, management of sustainability and sustainable sourcing. In 2002, for example, ICLEI developed a partnership programme with the International Centre for Developing Sustainable Cities, UN-Habitat, and UNEP (United Nations Environment Programme) on the theme “Resilient communities and cities” to develop a methodology for managing local resilience.

ICLEI activity in the climate field focuses in particular on the “Cities for Climate Protection” campaign (CCP). This was first initiated in 1993 at the Rio Summit and spread rapidly in the United States, Australia and Europe, becoming a permanent tool for raising awareness and launching concrete projects for mitigation and adaptation in the urban environment in many developing countries (South Asia, Latin America and Africa). The availability of software for recording and monitoring greenhouse gas emissions in the urban environment, capacity building and training activities for cities and a training support network provide the logistical support which is essential for implementing the five-step action plan to which member cities commit: measuring greenhouse gases, commitment to an emissions target against a baseline year, a climate action plan which is to be implemented, monitoring of progress and an evaluation of the results.

Moreover, ICLEI Europe has been committed to the area of adapting cities to climate change since 2006.

Its activity in this field can be seen in:

- the creation of a working group bringing together local authorities, scientists and practitioners in a forum for information, discussion, sharing of ideas on strategies and useful adaptation measures for local authorities
- the organisation in May 2010 of the first “2010 Resilient Cities” conference
- its contribution to the work of the Regions Committee on best practice and adaptation tools implemented in 20 European cities and urban areas A report due to be published in January 2011 will identify a range of actions and instruments and will propose approaches and make recommendations for implementing adaptation strategies in an urban environment
- collaboration with the European Environment Agency on a forthcoming report (2011) on vulnerabilities to climate change, vulnerability indicators and adaptation projects in cities and urban areas
- coordination of the 2011-2013 programme “Asian cities, development and adaptation to climate change” with the aim of improving the resilience of cities in India and the Philippines to the effects of climate change in the social, economic and environmental spheres.

ICLEI Australia has also developed a questionnaire to assist local authorities in their initiatives to adapt to climate change: ‘The Local Government Climate Change Adaptation Toolkit’. ICLEI North America has collaborated on a report ‘Preparing for Climate Change: A Guidebook for Local, Regional and State Governments’<sup>4</sup>.

Lastly, ICLEI constitutes the focal point for local authorities at the UNFCCC Secretariat as an observer on the Intergovernmental Panel on Climate Change (IPCC).

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<sup>4</sup> (<http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf>)

## APPENDIX 3 : City surveys

List of people interviewed:

### **French cities:**

Virginie ADUBE (Montpellier urban area)  
Camille AUVRAY (Montrouge town hall)  
Thomas BLAIS (ADEME)  
Antoine CHARLOT (Comité 21)  
Pierre CREPEAUX (Greater Lyon)  
Benoit DAREM (Artois urban area)  
Yann FRANÇOISE (City of Paris)  
Joël GARREAU (Nantes Métropole)  
Sylvain GODINOT (Greater Lyon)  
Alexia LESEUR (CDC Climat)  
Thierry LAFONT (ADEME)  
Julie LAULHERE (ADEME)  
Jimmy MARY (Dunkirk)  
Valéry MASSON (Greater Paris)  
Nicolas MAT (Consultant)  
Mlle MUNIAC (Ville du Port, La Réunion)  
Bruno REBELLE (Consultant)  
Bénédicte SALLE (Rouen Seine Aménagement)  
Damien SAULNIER (Greater Lyon)

### **International cities:**

Anke ALTHOFF (Future Cities Project)  
Joyce COFFEE (City of Chicago)  
Mikaela ENGERT (City of Keene)  
Stephen HAMMER (Columbia University)  
Rachel JOUAN-DANIEL (Consultant)  
Rhett LAMB (City of Keene)  
David MACLEOD (Toronto Environment Office)  
Anne MARIANI (Metropolitan Washington Council of Governments)  
Daniel MORCHAIN (ICLEI European Secretariat)  
Alex NICKSON (Greater London Authority)  
Julia PARZEN (City of Chicago)  
Jennifer PENNEY (Clean Air Partnership)  
Lalitha RAMACHANDRAN (City of Port Phillip)  
Debra ROBERTS (City of Durban)  
Fern UENNATORNWARANGGOON (Rockefeller Foundation)  
Hans VAN AMMERS (Arnhem, Netherlands)  
Nick VAN BARNEVELD (Rotterdam Climate Proof)

# APPENDIX 4 : Consultation in preparation for the national climate change adaptation plan

## Background

France's adaptation to climate change has become a major issue which calls for a national mobilisation. This adaptation should now be viewed as an essential supplement to the mitigation activities already under way.

The interministerial group report "Impacts of climate change, associated costs and adaptation strategies", which was made public in September 2009, provides information demonstrating the significance of the impacts of climate change and the cost or opportunities for France.

For 2050 and 2100 horizons, the report highlights:

- losses in the agricultural sector caused by heat waves and drought which would cancel out the positive effect of the increase in yield of plants as the amount of CO<sub>2</sub> in the atmosphere rises
- a lack of water resources in areas already experiencing difficulties
- national assets in the form of main roads estimated to be worth 2 billion euros would be affected by a one-metre rise in sea levels
- in the Languedoc Roussillon region, 140,000 homes and 10,000 businesses would be affected by a one-metre rise in sea levels
- an extension of the areas affected by the shrinkage/swelling of clay caused by drought leading to damage to homes would multiply the actual cost of damage by a factor of between 3 and 6
- gains in energy consumption, although the increase in air conditioning would offset some of these gains

Article 42 of the 2009-967 framework law of 3 August 2009 relative to the implementation of the Grenelle Environment Forum provides for a national adaptation plan for different sectors of activity to be prepared by 2011 at the latest. It will bring together ambitious approaches on subjects as diverse as the fight against flooding and the adaptation of coastal zones, the spread of forests, water issues and adapting the economy.

The Minister of State for the Economy, Energy, Sustainable Development and the Sea, responsible for green technologies and climate negotiations, opted for an extensive consultation exercise prior to the national adaptation plan beginning on 8 December 2009 and launched by Chantal Jouanno, Secretary of State for Ecology.

The aims of the consultation exercise chaired by Paul Vergès, president of French Observatory for the Impacts of Global Warming (ONERC) are:

- to mobilise public authorities as a whole, private stakeholders and civil society so that adaptation is seen as being on a par with mitigation and to raise awareness of the issues involved
- to gather advice and recommendations to define a national climate change adaptation plan as provided for under article 42 of the framework law for implementing the Grenelle Environment Forum

## The national consultation phase

It was organised on the basis of the Grenelle Environment Forum colleges -elected representatives and local authorities, the state, employers, staff unions, and associations - divided into three working parties:

- group 1 - chaired by Michel Havard, deputy for the Rhône *département* – is tackling the cross-cutting themes of water, biodiversity, health and natural hazards
- group 2 - chaired by Jean Jouzel, climatologist and member of the IPCC, - is tackling sectoral themes of agriculture/forestry/fishing, energy, tourism, transport infrastructures, town planning and the built environment

- group 3 - chaired by Martial Saddier, deputy for Haute Savoie, is tackling governance, knowledge information/education and funding

National groups met in four plenary sessions between January and May.

The report from the working parties was submitted to Chantal Jouanno on 15 June during a press workshop. This report contains 202 suggestions and was made available to the public on the ONERC website.

## **The report by national groups**

### ***Joint recommendations:***

Out of all the recommendations common to all the groups, four actions prior to the public decision emerged as priorities:

- improving knowledge, which implies work in the area of basic and applied research, notably knowledge about unforeseen events, evaluation methods for direct and indirect effects, reduction of vulnerability and resilience to extreme events
- improving observations through long-term collection of data available to all the stakeholders and territories
- implementing evaluation facilities and evaluation methods to learn lessons from past events which could prefigure future climate changes (heat waves, flooding, fires, etc.)
- bringing citizens together and asking them to take part in developing a decisions and implementing them

In order to implement an adaptation policy in every area, participants also highlighted the need:

- to establish baseline values and the climate scenarios to be taken into account (the role of the state), in such a way as to enable stakeholders to make decisions, especially those relating to long-term investment (urbanisation, energy, infrastructures, or also the forestry sector, for example.)
- to mobilise collective thinking rapidly in order to define the notion of acceptable risk, a key factor in choosing, for example, between a protection or withdrawal strategy on the coastline
- to distinguish more clearly what relates to national solidarity and what falls within the responsibility of individuals and professionals
- to carry out policies on an experimental basis taking adaptation into account on voluntary test sites

A consensus also emerged highlighting the fact that although certain measures did not need to be applied immediately, others should be implemented straightaway as they were justified, whatever the scale of climate change. These are termed “no regret” measures and thus urban planning decisions with long-term effects on town and country planning which integrate the problem of adaptation into policy on the subject must go ahead as soon as possible. This also applies to decisions concerning investment in infrastructure.

Taking adaptation to climate change into account very quickly also holds true for prevention, vigilance and monitoring systems. It will also be necessary to strengthen the synergies and coordination between these different systems. In health, for example, if the anticipated impact of climate change does not justify the development of new monitoring systems, then existing systems should be reinforced and perpetuated.

At the end of the day, adaptation policy will increasingly take the form of integrating adaptation into to current policy rather than creating specific policies which may not be consistent. The measures adopted should aim to minimise the additional funding required to adapt to climate change. This will take the form notably of factoring adaptation into planning documents and funding decisions, the production of information, training and specialist technical expertise.

This policy will need to be developed both on a national scale and on a territorial scale. The territorial aspect of climate change impacts draws on solutions which are adapted to local contexts.

However, this adaptation policy cannot be effective without the commitment of the stakeholders involved and their willingness to take on the measures advocated. This involves immediately reinforcing the mechanisms for keeping the public informed. It involves sharing knowledge on the risks presented by the impacts of climate change and helping people to understand the adaptation measures required. Acceptance of public decisions is a key factor for success in being able to act promptly and effectively.

### ***Interactions between the different topics:***

Alongside recommendations specific to each group, the discussions highlighted a number of interactions between the different topics. These underline the need to consider adaptation from a cross-cutting perspective in order to avoid inconsistencies in the strategies adopted. The main interactions highlighted by the groups were as follows:

#### **1-Adaptation in coastal areas: intersects with coastal risks, urban planning, tourism and social acceptance**

The rise in sea level caused by climate change will bring new constraints to many sectors which will need to align their adaptation strategies. In all low-lying coastal areas, adaptation now requires all buildings with a long lifespan to be built in areas protected from sea flooding in order to avoid increasing the vulnerability of assets and associated economic activities.

For assets in low-lying areas, the rise in sea level implies making a choice in the medium term between three strategies: protection, relocation or management of temporary disruption. In the short term, an assessment of existing defences is also necessary, taking into account climate change.

These different aspects of adapting in a coastal zone lie at the intersection of urban planning policy and management of risk to people, goods and key activities in these territories (tourism in particular). The choices in which citizens will be involved, beyond a purely socio-economic analysis, will have to take into account adaptation to climate change, its environmental cost and the financial resources available. Climate change could improve the potential of certain coastal areas and open up new opportunities for long-term investors.

#### **2- Water resources at the heart of many areas: agriculture, energy, transport, tourism, biodiversity, etc.**

The issue of water resources is crucial to the analysis of the impact of climate change and the solutions which can be applied. In fact water lies at the heart of many areas: agriculture (the lack of water in the summer leads to a drop in crop yields), tourism (via the impact of the demand for drinking water in tourist resorts, for example), energy (due to the limitations placed on hydroelectric generation and the constraints of cooling some power plants), and river transport and biodiversity (via habitat degradation).

Therefore, it would appear necessary to promote a concerted strategy for water conservation and optimal use immediately, with the aim of reducing the pressure on the resource and thus limiting scarcity, preventing conflicts by appropriate governance and preserving aquatic environments.

#### **3- Preserving biodiversity and its gene pool for adaptation**

Climate change will aggravate the existing pressure on biodiversity. Biodiversity is our main gene pool and a fundamental source of the elements which will enable us to adapt to the new climate situation in the future and use it to our advantage, for example in terms of foodstuffs, biomass production or health.

Efforts to maintain and restore biodiversity in the context of climate change are therefore strategic for agriculture, forestry, health and well-being in the future.

#### **4- Heat in the city and in public places: a cause of concern for health, housing, water resources, biodiversity and energy**

The rise in temperatures, particularly in the summer, will have a negative effect on the comfort and health of people living in buildings which are not adapted for it. Urban planning and architecture will



have a part to play in limiting these effects, as will the introduction of water and nature into the city, which will reduce the need for cooling.

It is therefore necessary to predict now how our cities will adapt to climate change and to promote buildings which are adapted and adaptable to climate fluctuations within the framework of development which is more energy efficient, especially during hot spells when the cost of producing it is higher.

Cities which are more open to water and nature would have the cumulative effect of reinforcing urban biodiversity and ecological continuity, but this approach would also require closer monitoring, especially of the quality of the surface water involved in terms of health.

## **5- The overriding need to integrate adaptation and mitigation policies**

The mitigation policy which is already under way aims to reduce greenhouse gas emissions to stabilise rising temperatures eventually.

Adaptation policy will have to take into account the approaches agreed as part of a mitigation policy so that overall climate change policy in France remains coherent.

The approach advocated in the report, which involves integrating adaptation policy into existing policies and revising these policies periodically, forms part of this search for coherence, but trade-offs may however need to be made. Therefore a dense city conducive to a reduction in greenhouse gas emissions needs to take the heat island phenomenon into consideration. A balance must therefore be struck by optimising thermal insulation and the role of green spaces or stretches of water in the urban morphology.

### ***The issues raised by the adaptation process:***

The consultation process clearly demonstrates that adaptation to climate change raises fundamental questions for French society and its organisation and the National Adaptation Plan must address the following questions:

- How can the city of tomorrow be planned to respond to the challenges both of mitigation and adaptation?
- How can agriculture be adapted, not globally and uniformly, but by taking into account the specific features of each area and the various territories of production?
- How can the mountain economy adapt to reduced snow cover?
- How can we predict and manage conflicts in the use of water resources more successfully?
- How can we adapt monitoring, alert and health systems to the new climate situation?
- How can we ensure equity in the adaptation measures which we will choose?
- How can we develop society's capacity to anticipate the opportunities and tackle climate change?

### ***A selection of measures advocated by the working parties***

The recommendations produced by the working parties focus mainly on metropolitan France, but most of them could apply to French overseas regions. It should be noted that certain recommendations have been made which are specific to overseas regions, notably by the biodiversity group.

<p><b>Biodiversity:</b> To carry out adaptation trials in volunteer territories (recommendation 16)</p> <p><b>Water resources:</b> Promote water conservation in all sectors and by all users (recommendation 21)</p> <p><b>Natural risks:</b> to develop methods to evaluate the impact and effectiveness of preventive measures planned in order to enable a cost-benefit analysis to be implemented (recommendation 33)</p> <p><b>Health:</b> To develop national prevention and care plans to face the health consequences caused by extreme events (recommendation 80)</p> <p><b>Agriculture:</b> To direct research and development towards agricultural systems which are better adapted to climate change (recommendation 85)</p> <p><b>Energy:</b> To ensure that baseline references used in public service contracts remain appropriate to a climate change context (recommendation 111)</p> <p><b>Infrastructure:</b> To review and adapt technical frames of reference for construction, maintenance and the operation and safety of transport systems (recommendation 116)</p> <p><b>Tourism:</b> To conduct forward studies of the changes in tourism in the face of climate change (recommendation 124)</p>
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**Town planning:** To take the effects of climate change into account in town planning documents (recommendation 133)  
**Funding:** To integrate adaptation to climate change into the criteria for eligibility of investors for public and private funding, in order to exclude “ill-adapted” policies (recommendation 139)  
**Governance:** To initiate thinking into whether the population will find the decisions on adaptation acceptable (recommendation 158)  
**Information:** To define a communications strategy on adaptation targeting the general public, in association with professionals in the field (recommendation 167)  
**Research:** To create a Foundation for research into adaptation in connection with the climate component of the ALLENVI alliance and based on the model of the Foundation for Biodiversity Research (recommendation 188)

Conscious of the fundamental challenges which climate change poses for overseas territories, the groups have set considerable store by the results of the consultation carried out in the French overseas regions which allowed them to supplement their recommendations. Lastly, the process of consulting the public and the regions which will follow up this work falls within the scope of a general willingness to include citizens and regions in defining this political adaptation.

### **Consultation with French overseas regions**

In parallel with the national consultation, consultations also took place in the four French overseas regions. Each region had a free choice in the format of its consultation. The reports submitted at the end of June to the Secretary of State for Ecology focused in particular on the following meetings organised by Prefectures, regional state departments and certain Regional Councils:

- Guadeloupe: two meetings on 17 May and 14 June
- Guyana: one meeting on 29 June
- Martinique: one meeting on 29 June
- La Réunion: two meetings on 27 May and 18 June

### ***General comments resulting from consultations with the French overseas regions***

Like metropolitan France, the French overseas regions are also affected by climate changes in the form of rising temperatures, changes in rainfall patterns, etc. Nevertheless, their geographical location, their climate, which is very different from the metropolitan zone, and their particular geomorphologic characteristics mean that the impacts of climate change and adaptation measures envisaged could be very different from those in mainland France.

The overseas regions have an additional specific vulnerability because coastal zones are the main dwelling and settlement areas. Future changes in sea levels by several tens of centimetres and erosion/sedimentation phenomena could affect these areas, causing a severe concentration of problems. The geography of these areas and the pressure on land make the option of strategic withdrawal a difficult option as the relief of island areas or forest massifs mean that there is very little “free” space available.

Furthermore, the French overseas regions are exposed to the risk of tropical storms. Climate projections regarding this type of extreme phenomenon are still unreliable. However, several studies project an increase in their intensity as a function of climate change, but also a decrease in their frequency. These trends must be treated with caution, but suggest that the phenomenon should not be underestimated.

### ***The following general points emerge from the contributions***

Most of the recommendations formulated by the national working parties cover the adaptation requirements of the French overseas regions. However, certain measures would need to be adapted in their implementation and scope in overseas regions. Supplementary elements have been drawn up and are described below.

Certain specific adaptation requirements produce additional recommendations to those made by the national groups.

It was emphasised during the discussions that many relevant adaptation proposals will require additional prior technical input (especially in the case of knowledge about future climate scenarios, hydrological functioning, etc.).

Lastly, all the regions supported and stressed the need for proposals for communication and raising awareness about climate change. Echoing the national consultation, an urgent need was identified to target the public and decision-makers.

### List of new recommendations proposed by the Overseas regions

**General recommendation:** To take the IPCC hypotheses concerning rising sea levels into account on a systematic basis when investment choices are being made in coastal zones or areas vulnerable to rising sea levels.

**Water resources:** to produce a vulnerability diagnosis for waste water disposal in the event of a rise in sea levels and to identify adaptation methods

**Energy:**

- to encourage the replacement of energy-inefficient air conditioning units with more efficient air conditioning

- to reduce vulnerability to extremes of climate by developing an electrical power connection between Martinique, Dominica and Guadeloupe

- to provide development scenarios for renewable energy sources linked with the climate (wind, sunshine, etc.) to integrate them into proposals for establishing production facilities

**Tourism:** to assess the implications of climate change for eco-tourism, in particular in forest areas in French overseas regions.

**Research:**

- to develop and make available regionalised climate projections which can be used as a tool for vulnerability studies and decision-making

- to develop knowledge under the heading "Water and climate change in French overseas regions": surface and underground hydrology (including coastal aquifers), modelling of runoff into catchment areas, coastal erosion/sedimentation dynamics, the behaviour of saltwater wedges and mapping of areas vulnerable to rising sea levels

- to create an experimental centre to evaluate knowledge and develop practices for adapting to climate change in French overseas regions

### The final stages

In September-October, the reports from national groups and overseas regions were submitted for regional consultation as outlined below:

- North-west area group, meeting in Lille: Basse Normandie, Haute Normandie, Nord-Pas-de-Calais and Picardy
- West area group, meeting in Rennes: Brittany, Pays de la Loire and Poitou-Charentes
- East area group, meeting in Strasbourg: Alsace, Burgundy, Champagne-Ardenne, Lorraine and Franche-Comté
- South-west group, meeting in Toulouse: Aquitaine, Languedoc-Roussillon and Midi-Pyrénées
- Central area group, meeting in Clermont Ferrand: Auvergne, Limousin and Centre
- Ile de France area group, meeting in Paris: Ile-de-France Region
- South-East area group, meeting in Lyon: Corsica, Provence-Alpes-Côte-d'Azur and Rhône-Alpes

From 13 September to 15 October, the opinion of the general public was sought in an electronic consultation on the internet. Over 4,000 people responded to the consultation, demonstrating French interest in this work.

Lastly, a final round table will be held in November to summarise the proposals and comments received.

Following the submission of reports from national groups, the Secretary of State for Ecology has already authorised two exploratory projects. The first project, led by Jean Jouzel, Vice-chair of IPCC Working group 1, aims to:

- define criteria for the choice of climate projections to be used to define a climate scenario which is consistent with the work of the IPCC
- suggest several climate scenarios to cover a range of potential future scenarios with at least one optimistic and one pessimistic scenario consistent with the work of the IPCC
- define the baseline climate period to be used to estimate future climate change

The second project entrusted to Alain Grimfeld, chair of the Committee for Prevention and Precaution, is exploring:

- the definition of an acceptable level of risk in different areas tackled during the consultation process on adaptation to climate change: natural risks and town and country planning, energy, transport infrastructures, etc.
- the governance process accompanying this definition

The information gathered during this consultation will provide the basis for the development of a national adaptation plan which will be adopted in 2011 in accordance with the framework law for implementing the Grenelle Environment Forum.

## **APPENDIX 5 : The Observatory's activities in 2009 and 2010**

ONERC's activities have been affected by two major events. The first, on an international scale, was the Conference of Parties of the United Nations Framework Convention on Climate Change held in Copenhagen in late December. The second, on a national level, was the launch by the Secretary of State for Ecology of the national consultation process in preparation for the drafting of the national adaptation plan.

As a major event on the international calendar, the Copenhagen conference was preceded by several working meetings and received significant media coverage. ONERC was represented by its President Paul Vergès, its Director Pierre-Franck Chevet and Secretary-General Nicolas Bériot.

The consultation in preparation for the drafting of the national adaptation plan launched by Chantal Jouanno was presided over by Paul Vergès. The Observatory and the Department for Energy and Climate to which it is linked will be responsible for its secretariat and operations. The work will take place throughout most of 2010.

### **Implementation of a network of correspondents and a database**

A network of correspondents and a database will make it possible to gather, interpret and present information relating to impacts already observed and potential future impacts, in order to bring them to the attention of decision-makers, local authorities and the public. ONERC will call on an external partner, Atema Conseil associated with Thalix, Météo-France and the Public Interest Group Ecofor, for technical support with running the network in 2011.

### ***Change indicators observed***

Indicators were established with the scientific and operational bodies involved and are presented on the ONERC website: <http://onerc.gouv.fr>.

An indicator for global ocean levels has been added this year to the 24 indicators presented on the ONERC website at the time of the writing of this document.

An update of indicators was carried out in 2010.

### ***Technical seminar "The French Regions and Climate Change Research"***

In parallel with the national plan, regional activity is planned through the future Regional "Climate, Air, Energy" plans created by the law of 12 July 2010, relating to the national environmental commitment under which "climate-energy plans" will have to be drawn up by *départements*, urban communities, communities of agglomerations, municipalities and communities of municipalities with over 50,000 inhabitants by 2012.

The aim of this seminar was to facilitate dialogue between the regions and the research community.

The three highlights of the seminar were:

- 1- climate change research projects
- 2- regional adaptation activity
- 3- dialogue and exchanges between participants

The active involvement of technical departments of Regional Councils and DREALs in the seminar was noteworthy.

### ***Bibliography***

The greenhouse effect bibliography available on the public website has been supplemented with references from the work carried out by the interministerial working party on the associated impacts and costs, as well as with bibliographies provided by ONERC correspondents on indicators. The bibliography now comprises almost 800 references.

### ***Climate simulator***

The ONERC website has a climate simulator which provides an interactive demonstration of what the French climate might be like in the second half of the century. Climate models cannot really predict

what the weather will be like in a particular year, but the purpose of this tool is to raise public awareness and it has proven educational value. Traffic on the website has remained steady for several years.

### **Access to the indicators/bibliography and simulation website**

The internet site managed by Thalix for ONERC provides climate indicators, a bibliography and a climate simulator. It can be accessed via [www.onerc.gouv.fr](http://www.onerc.gouv.fr) under the heading “données essentielles” (essential data).

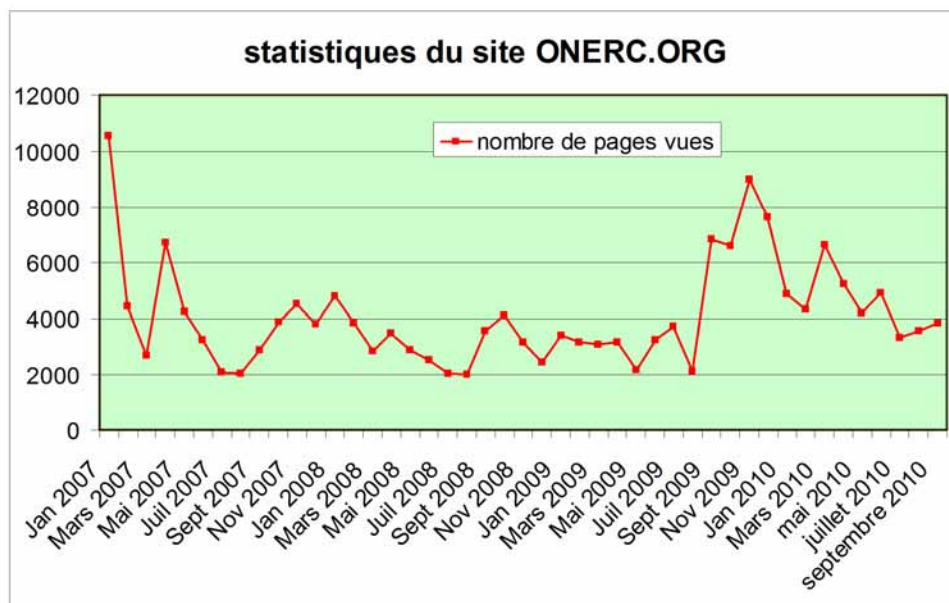


Figure 33: Number of pages visited

#### **Key:**

Statistiques du site ONERC.ORG – Statistics for the website ONERC.ORG  
(Jan/March/May/July/September/November)

Nombre de pages vues - Number of pages viewed

A significant increase in traffic can be observed on the site since the publication of the interministerial group report in September followed by the ONERC report. This traffic remains steady in early 2010.

## **Providing information for decision-makers and the public**

### **Publications**

ONERC has published its third report to the Prime Minister and Parliament which was submitted by its president, Paul Vergès, to the Minister of State, Jean Louis Borloo, on 25 November 2009.

This third report presents the main results of Interministerial group “Impacts of climate change, adaptation and associated costs in France”, and a comparison of adaptation strategies in Europe.

This report generated a great deal of media interest and ONERC was very much in demand on TV and radio and in the written press in the months following publication.

### **Touring Exhibition**

The programme of presentations by the ONERC touring exhibition, which consists of 13 free-standing display panels showing the consequences of climate change, is displayed below. The circulation figures for the exhibition are very pleasing. The advertising strategy of using targeted mailings and an insert in the quarterly ONERC Letter no.1 – has tripled usage compared to 2008.

Organisation	Type	Event
Eko Actions	Association	"Living Naturally" fair
DREAL Limousin	DREAL	Internal exhibition
Calais town council	Local authority	Environment Days event
Saint-Quay-Portrieux city council	Local authority	Les Océaniques
ADEE (EIE) association	Association	Broadcast
DREAL Aquitaine	DREAL	Internal exhibition
DREAL Limousin	DREAL	Sustainable development week
Créteil town council	Local authority	Sustainable development week
Greater Roanne urban area	Local authority	Sustainable development week
Mission Planète Terre association	Association	Lecture for schoolchildren, Garges Lès Gonesse
Chambéry métropole	Local authority	Climate forum
St Etienne Region Urban Development Agency	Association	Internal exhibition
Eure Solaire/local agency for energy and the environment	Association	Raising awareness among students at the Evreux university technology institute carried out by the local environment and energy agency
Sophia Antipolis community of agglomerations	Local authority	Opening of an Energy Information Area (EIE)
Pays de Morlaix	Joint union	Discussion days
Bureau de Jérôme BIGNON	Local authority	Exhibition in multimedia libraries in the district
ADEME Rhône-Alpes	EPIC	Internal exhibition
Pays Barrois Joint Union	Joint union	Woodland days
City of Paris	Local authority	2 <sup>nd</sup> Parisian Energy and Climate Event
Châteaubriant Community of municipalities	Local authority	Internal exhibition
Véolia Transport	Company	Exhibition at Epernay town hall
Véolia Transport	Company	Exhibition at Saint Dizier town hall
Véolia Transport	Company	Exhibition at Saint Dié town hall
Véolia Transport	Company	Exhibition at Luneville town hall
Véolia Transport	Company	Exhibition at Chaumont town hall
Véolia Transport	Company	Exhibition at Saint Avold town hall

## ONERC quarterly newsletter



Figure 35: ONERC Letter n°5

Requested by the 2007 and 2008 advisory committees, this letter was established in 2009 with the support of the agency ID Communes. An editorial committee set out the following editorial framework for this letter:

Page 1: president's editorial and a topical article introducing a subject tackled in the issue

Page 2: a member of the advisory committee is given the opportunity to speak

Page 3: an interview with a personality

Page 4: reserved for accounts of local projects.

Three issues were published in 2009 including a September issue focusing on the sea and a December issue on the Copenhagen negotiations, and three issues were published in 2010 on agriculture, biodiversity and the city.

The letter is sent to almost 7,000 correspondents, national elected representatives, Regional Councils, General Councils and public bodies for cooperation between municipalities.

## Website

The ONERC website is integrated into the DGEC section of the MEEDDM. The site was completely redesigned in 2010.

It presents:

- ONERC and its work
- general information about the IPCC, in particular its mode of operation, and call to authors for the next report
- a substantial section on adaptation (general principals, national consultation strategy on adaptation)
- ONERC publications including reports and the quarterly letter
- Examples of projects or studies undertaken in the French regions

The statistics for the number of hits are shown below:

March	3,230 hits
April	1,855 hits
May	1,731 hits
June	2,538 hits

## Projects targeting local authorities and economic agents

In so far as possible, ONERC supports the development of projects on a local level. This is carried out by disseminating information on climate change, its impacts and adaptation to its effects, by providing a touring exhibition, or by taking part in debates, colloquia or information sessions in the regions. The "local initiatives" section of the website presents examples of local projects on adaptation.

## The ViTeCC club

The ViTeCC club (Towns, Territories and Climate Change) was launched in 2008 on the initiative of the Climate Branch of the Deposit and Consignment Office (CDC), following a colloquium on



adaptation to climate change in the presence of Dr Pachauri<sup>5</sup>. ONERC is one of the cofounders of the club alongside the CDC and Météo-France and it represents MEEDDM. The ViTeCC club comprises over 25 local and regional authorities and service companies.



Four meetings were held in late 2009 and early 2010:

- 19 October 2009 in Paris: “Adaptation, Transport and Climate on a Territorial Scale”
- **22 January 2010: “Funding and Management of Infrastructures & an Evaluation of the Copenhagen Negotiations”.**
- 1 April in Paris “Carbon tax, adaptation and an inventory of greenhouse gases”
- 1 July in Paris “Access to carbon funding for cities, Extreme Events and Managing Climate Risk”

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ONERC participates in the activities of the club by providing articles for documents distributed to participants and by providing speakers for sessions.

Figure 36: Report n°8 of the ViTeCC club

## International activities

In this area, the most significant activities have involved following the work of the IPCC and supporting adaptation and climate change projects in the south-West Indian Ocean.

### ***Participation in the work of the IPCC***

ONERC is associated with the work of the IPCC as a focal point for the French government. Alongside Jean Jouzel, who has a seat on the Bureau as Vice-chair of Working Group 1, the Secretary-General has a seat as a representative of the government

The Secretary-General took part in Bureau meetings in September 2009 and May 2010.

The French delegation to the Plenary Assembly of the IPCC in Bali in October 2009 consisted of 4 people and was led by the Secretary-General of ONERC. The French delegation issued an invitation to host the second meeting of authors in Group 1 in July 2011 in France.

Participation in World Climate Conference-3

The Secretary-General of ONERC attended WCC-3 in Geneva from 31 August to 4 September 2009. This conference launched an exploration of the future global framework for the provision of climate information services which may be the focus of a decision at the WMO conference in May 2011 and will play an important role in adaptation projects in the coming decades.

### ***Participation in UNFCCC projects***

ONERC has contributed to the UNFCCC as part of the French negotiating team. It took part in meetings of subsidiary bodies in Bangkok in October 2009, in Barcelona in November and then in the Conference of Parties in Copenhagen in December. The first meeting of 2010 was held in Bonn in June 2010.

As a member of the French negotiating team, ONERC provided expertise in scientific matters – research and observation systems, common metrics, relations with the IPCC – and adaptation.

At a European level, expert groups helped to prepare negotiating positions. ONERC sent a representative to the EGSCI (scientific matters) and a representative to the EGAD group (adaptation). In between UNFCCC meetings, these EGSCI and EGAD groups met on average once a month in Brussels or in the country responsible for the European Presidency at that time.

ONERC also monitored the implementation of the “Nairobi work programme on impacts, vulnerability and adaptation to climate change” which aims to define a shared vision of the scientific and technical aspects of the subject. The objectives of this 5-year programme (2005-2010) are to help all countries assess the impacts of climate change on projects and to implement practical adaptation measures. It

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5 President of the IPCC (Intergovernmental Panel on Climate Change) who was awarded the Nobel Peace Prize in 2007 with Al Gore.

is an international framework implemented by the Parties, non-governmental and intergovernmental organisations, the private sector and local authorities. Further information about this programme and its findings is available on the UNFCCC website ([www.unfccc.int](http://www.unfccc.int)) notably under "Compendium on methods and tools".

The Copenhagen Agreement mentions adaptation requirements several times, notably for developing countries, small island states and Africa. "Fast start" funding of 30 billion US dollars for 2010-2012 will be used for mitigation and adaptation projects.

### ***Participation in adaptation projects in Europe***

The European Union published its White Paper on adaptation in April 2009. The approach suggested in the White Paper will take place in two phases. The objective set for the first phase lasting until 2012 is to achieve a better understanding of the impacts of climate change and to examine potential adaptation measures and how they can be integrated into the main European Community policies. The European Commission plans to implement a hub for exchanging information on the effects of climate change by 2011. The second phase consists of producing a complete Community strategy on adaptation to climate change by 2013.

ONERC has taken part in defining a French response to this document and attended two working meetings in Brussels.

ONERC liaises with the European and International Affairs Office of MEEDDM and takes part in drafting French opinions and positions on European documents.

### ***Project on adaptation in the Indian Ocean***

This cooperation project was prepared in association with the Ministry for Foreign and European Affairs (MAEE), the Réunion Region, the French Development Agency (ADF) and the French Global Environment Facility (FGEF), and its objectives have already been presented in detail within the framework of the 6<sup>th</sup> Advisory Committee. It follows on from two decisions made by the Indian Ocean Commission (IOC) states (the Comoros, France, Madagascar, Mauritius, the Seychelles) which were taken in 2005. Its overall objective is to strengthen regional cooperation between IOC members on the effects of climate change, vulnerability and adaptation. This cooperation will deal with scientific, economic, technical and institutional aspects.

The FGEF Steering Committee approved the project in 2007, with one million euros of funding out of a total cost of 3.625 million euros. A technical assistant has been recruited by the MAEE to implement it and he has been based in Mauritius in the Indian Ocean Commission offices since September 2008. The first meeting of parties involved in the project was held on 24 and 25 February 2009 in order to draw up a detailed programme of work. The second meeting of the Steering Committee took place on 29 and 30 April 2010.

### ***Other international cooperation projects***

In July 2010, ONERC carried out a one-week mission at the request of the Mauritian government through the French Development Agency to help to establish a programme of work for the climate change group of the new Ministry of Ecology and Sustainable Development. This mission provided an opportunity to meet the Minister for the Environment and Sustainable Development and most of the ministers involved with adaptation.

At the request of the President of the Syndicate for the Promotion of Municipalities in French Polynesia and of Senator Richard Tuheiava, Madame Jouanno's department delegated the Secretary-General of ONERC to represent MEEDDM at the 22<sup>nd</sup> Congress of French Polynesian Municipalities from 2 to 6 August 2010, on the theme "Municipalities facing change", which included a component on climate change. After the conference, a Declaration by the

Municipalities of French Polynesia on Climate Change was adopted, demonstrating the concern of these elected representatives and their enthusiasm to take the fight against the greenhouse gas effect and adaptation into account in the sustainable development of municipalities.

## **Miscellaneous**

### **Participation in the French Initiative for Coral Reefs (IFRECOR (Initiative Française pour les REcifs CORalliens,))**

ONERC is taking part in IFRECOR's work within the framework of a cross-cutting climate change project (thème d'intérêt transversal, TIT). The main aim of this project is to create observatories for coral in all the areas involved. ONERC has helped to define indicators allowing the impacts of climate change on coral and its environment to be observed.

ONERC has also been asked to lead a new cross-cutting project (TIT) on adaptation to climate change which aims to factor the issue of coral reefs into all planning and adaptation exercises relating to climate change implemented by French overseas regions and local authorities.

### ***Other activities***

ONERC is taking part in a variety of scientific working parties in France, principally the MEEDDM advisory committee for the programme Managing the Impacts of Climate Change.

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## APPENDIX 7 : Abbreviations and acronyms

AAP Appel A Projet  
ABF Architectes des bâtiments de France  
ADEME l'Agence de l'Environnement et de la Maîtrise de l'Energie  
AMICA Adaptation and Mitigation - an Integrated Climate Policy Approach  
ANR Agence Nationale pour la Recherche  
ANAH Agence Nationale de l'Habitat  
ANRU Agence Nationale pour la Rénovation Urbaine  
APR Appel à Proposition de Recherche  
AVAP Aire de mise en valeur de l'architecture et du patrimoine.  
BRGM. Bureau de Recherches Géologiques et Minières  
C3ED Centre d'Economie et d'Ethique pour l'Environnement et le Développement  
CAP Clean Air Partnership  
CCAP Chicago Climate Action Plan  
**CDC Caisse des Dépôts et Consignations**  
**CEA Commissariat à l'Energie Atomique**  
CEDD Conseil économique pour le développement durable  
CEMAGREF Institut de Recherche en Sciences et technologies pour l'Environnement (anciennement: Centre national du machinisme agricole, du génie rural et des eaux et forêts)  
CEPRI Centre Européen de Prévention des Risques  
CERFACS Centre européen de recherche , formations avancées en calcul scientifique.  
CEPT Centre d'étude de l' environnement terrestre et planétaire  
CETMEF Centre d'études techniques maritimes et fluviales  
CGEDD Conseil Général de l'Environnement et du Développement Durable  
CIRED Centre International de Recherches sur l'Environnement et le Développement  
CITERES Centre Interdisciplinaire Cités, TERRitoires, Environnement et Sociétés  
CNRM Centre National de Recherche Météorologique  
CNRS Centre national de recherche Scientifique  
CRESS Centre de Recherche en Sciences Sociales  
CSTB Centre scientifique et technique du bâtiment  
DOM-TOM Départements d'Outre-mer - Territoires d'Outre-mer  
DDRM Dossier départemental des risques majeurs  
DICRIM Document d'information communal sur les risques majeurs  
DRIAS Donner accès aux scénarios climatiques Régionalisés français pour l'Impact et l'Adaptation de nos Sociétés et environnements  
ENGREF Ecole nationale du génie rural des eaux et forêts  
ENPC Ecole nationale des ponts et chaussées Paris Tech  
EPAMARNE Etablissement public d'aménagement de Marne la Vallée  
EPCI Etablissement public de coopération intercommunale  
ESPACE Étude des Structures, des Processus d'Adaptation et des Changements de l'Espace  
FEDER Fonds Européen de Développement Régional  
FONDATERRA Fondation Européenne pour les territoires durables  
FRAMEE Fonds Régional d'Aide à la Maîtrise de l'Energie et de l'Environnement  
GAME Groupe d'étude de l'atmosphère météorologique  
GES Gaz à effet de serre  
GICC Gestion des impacts du changement climatique  
GIEC Groupe d'experts intergouvernemental sur l'évolution du climat  
GRC Green Ribbon Committee  
GIS Groupement d'intérêt scientifique  
HURRBIS Hydrologie Urbaine Réseau de Recherche Bassins Inter Sites  
ICLEI International Council for Local Environmental Initiatives  
ICU ilot de chaleur urbain  
IDDRI Institut du développement durable et des relations internationales  
INEE Institut Ecologie et Environnement  
INH Institut National d'Horticulture  
INSA Institut national des sciences appliquées

INRETS Institut national de Recherche sur les Transports et leur Sécurité  
 INRIA Institut National de Recherche en Informatique et en Automatisation  
 INSEE Institut national de la Statistique et des Etudes Economiques  
 IPSL Institut Pierre Simon Laplace  
 IRSN Institut de Radioprotection et de Sureté Nucléaire  
 KNMI Koninklijk Nederlands Meteorologisch Instituut  
 LADYSS Laboratoire des Dynamiques Sociales et Recomposition des Espaces  
 LCCP London Climate Change Partnership  
 LCPC Laboratoire central des Ponts et Chaussées  
 LISA Laboratoire inter-universitaire des systèmes atmosphériques  
 LMD Laboratoire de météorologie dynamique  
 LOCEAN Laboratoire d'océanographie et du climat  
 LSCE Laboratoire des sciences du climat et de l'environnement  
 MEEDDM Ministère de l'écologie, de l'énergie, du développement durable et de la mer  
 MNHN Muséum National d'Histoire Naturelle  
 NOAA National Oceanic and Atmospheric Administration  
 NPCC New York City Panel on Climate Change  
 OCDE Organisation de Coopération et de Développement Economique  
 ONERA Office national d'études et de recherches aérospatiales  
 ONG Organisation non-gouvernementale  
 PACA région Provence Alpes Côtes d'Azur  
 PADD Plan d'aménagement et de développement durable  
 PCET Plan climat énergie territorial  
 PCRDT Programme cadre pour la recherche et le développement technologique  
 PCS Plan communal de sauvegarde  
 PDU Plan de déplacement urbain  
 PLU Plan local d'urbanisme  
 PIB Produit intérieur brut  
 PIRVE Programme Interdisciplinaire Ville et Environnement  
 PPRN Plan de prévention des risques naturels  
 PREBAT Programme de recherche et d'expérimentation sur l'énergie et le bâtiment  
 PREDIT Programme de recherche et d'Innovation dans les transports terrestres  
 PRIMEQUAL pour une meilleure qualité de l'air  
 PUCA Plan Urbanisme, Construction et Architecture  
 RAEE Rhône Alpes Energie Environnement  
 RExHySS Impact du changement climatique sur les Ressources en Eau et les Extrêmes  
 Hydrologiques dans les bassins de la Seine et la Somme  
 RSA Rouen Seine Aménagement  
 RT Réglementation thermique  
 SA Service d'Aéronomie  
 SCOT Schéma de cohérence territoriale  
 SISYPHE unité mixte de recherche Structure et fonctionnement des systèmes hydriques continentaux  
 SRU Loi relative à la solidarité et au renouvellement urbains  
 SRES Special Report on Emissions Scenarios  
 SETRA Service d'études sur les transports, les routes et leurs aménagements  
 SRCAE Schéma Régional climat air énergie  
 UQAM Université du Québec à Montréal  
 UFR Unité de Formation et de Recherche  
 UMR Unité mixte de Recherche  
 URBAN-NET Réseau européen de recherche dans le domaine de la ville durable  
 ViTeCC Villes, Territoires et Changement Climatique  
 ZAPA Zones d'Action Prioritaires pour l'Air  
 ZPPAUP Zones de protection du patrimoine architectural, urbain et paysager

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## Cover photos crédits

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## Outside back cover

Studies carried out on an international scale all concur that work in the fight against climate change requires a two-fold approach involving a reduction in greenhouse gas emissions on the one hand (mitigation of climate change) and the reduction of the vulnerability of natural and human systems to the impact climate change on the other hand (anticipation and adaptation).

Cities are particularly vulnerable on account of their high population density and the infrastructures and tangible assets consolidated on their territories and they are therefore very sensitive to sudden changes in their natural or socio-economic environment. The way in which cities adapt to increases in the intensity or frequency of certain unforeseen climate events therefore presents an important challenge for the future of our society.

Since its creation in 2001, ONERC has played a part in providing public authorities and elected representatives with the necessary information to make strategic choices and political decisions in the area of climate change.

Within the framework of its mission to reflect and propose recommendations on preventive and adaptive measures to reduce the risks associated with climate change, ONERC has asked two research bodies, the International Centre for Research on the Environment and Development and the Institute for Sustainable Development and International Relations to produce a summary of the vulnerabilities affecting cities and a survey of the state of policy in French and international cities in terms of adaptation. This summary was set in context and supplemented with an overview of French research on cities as they confront the challenge of climate change.