Alliance HQE GBC FRANCE

RESILIENCE AND ADAPTATION TO CLIMATE CHANGE

For a built environment which meets the issues of today and tomorrow

DEFINITION FRAMEWORK FOR RESILIENCE AND ADAPTATION IN THE BUILT ENVIRONMENT

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie

CSTB le futur en construction

SUMMARY

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EDITORIAL

STRATEGIC FALL-BACK OR BUILDING OF RAMPARTS, WILL WE HAVE HELPED TO MAKE A FUTURE POSSIBLE?

These are the questions that several territories are already asking themselves in front of climate hazards, such as warming or coastal erosion, and these will undoubtedly be the questions that building owners and managers will regularly keep asking themselves in the coming years.

Despite the complexity of projecting ourselves several years or decades ahead to understand the impact of climate risks and to accept the uncertainty as to their magnitude, do we have any other choice but to anticipate?

Because global warming has accelerated in recent years [The latest IPCC AR6 report shows that the global surface temperature has already increased by 1.09°C compared to the period 1850-1900. It underlines the modifications of the climate and the climate hazards in cascade], it is essential, alongside actions of attenuation (More than ever, it remains necessary to contain global warming below 2°C, by aiming 1.5°C), to implement adaptation actions.

Considering that no territory is immune, the subject is at the convergence of all interests: communities, investors, managers, occupants and insurers, and the issues are multiple: safety, health and comfort of people, attractiveness of territories and buildings, maintenance cost (it is cheaper to anticipate today than to repair tomorrow), insurance costs, supply of resources and construction materials (of which the current shortages call us painfully to order).

If we still had to be convinced of the need to act, this «Definition framework for resilience and adaptation in the built environment» proposed by Alliance HQE-GBC highlights very rich food for thought and several useful levers for:

- Reinforcing or, at least, preserving the comfort of use, the safety of the occupants and the integrity of the buildings; the concept of resilience must now systematically be taken into account by developers, contractors and owners. From the design stage on, and then in the management or rehabilitation phases, the interior and exterior layout of buildings become as important as their structure.
- Anticipating the changes that are coming and preparing for the new conditions that will be imposed on everyone. It is no longer just a question of «fighting against», but of learning to «live with», in solidarity in front of hazards, by reducing the consequences and the severity of their impacts.

Levers that will also allow to define an adaptation strategy, by assessing the exposure and vulnerability of goods and territories, by integrating systems aimed at making them more resilient and by relying in particular on solutions based on Nature.

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INTRODUCTION

In recent years, the Intergovernmental Panel on Climate Change (IPCC) has produced numerous scientific reports explaining global warming and its effects. The climate projections detailed in these reports show an increase in natural hazards – heat waves, droughts, strong winds, intense rainfall – in the coming years, both in their intensity and in their frequency.

The scientific production of the IPCC is at the heart of international climate negotiations. It is also fundamental to alert decision-makers and the civil society. Firstly underlining the need to control greenhouse gas (GHG) concentrations in the atmosphere with a view to mitigation, the IPCC also invites the various sectors of activity to study the possibilities of adapting themselves to climate change, its latest report stressing the irreversibility of certain already visible consequences.

In France, in the field of urban planning and construction, it appears that the mitigation of climate change remains the primary concern. The notion of adaptation, although mentioned in the IPCC reports and transcribed in the National Plan for Adaptation to Climate Change (PNACC: Plan national d'adaptation au changement climatique), appears to be poorly defined and barely taken into account. However, the integration of an adaptation to climate change in this sector appears necessary, insofar as the questions of resistance and robustness entail as consequence an issue of population security.

This is what led the Alliance HQE-GBC to propose this definition framework which sets out the issues of climate change in the built environment and proposes 5 action areas and 15 levers for a more resilient built environment, in order to encourage those involved in the act of building to take action.

CONCEPTS AND GENERAL DEFINITIONS

Building and climate change…
In front of the magnitude of the phenomena and the consequences of climate change linked to the increase of greenhouse gases in the atmosphere, but also to the erosion of natural resources and biodiversity, it is necessary to initiate structural, systemic and cultural evolutions. Cities and their inhabitants must prepare to face the crises and recover from them as quickly as possible.

In this context, the urban planning and construction sector has a preponderant role to play: making of the city, geometry and urban functions, robustness and suitability of buildings to local climate (particularly via their location, which plays an important role in solar masks, air flows, potential for extension, etc.), are all fields of action that will allow to meet the issues of adaptation to climate change.

… from mitigation as a prerequisite…
In front of the climate issue, the position of the building sector is strategic, because, while it represents a very large share with around 25% of national emissions, it also has the capacity to reduce them in a relatively short time compared to the energy or transport sectors, in particular by working on existing buildings. Taking carbon into account has also greatly accelerated in recent years, driving an entire sector lead by ambitious regulations: the RT 2020 which will soon be in force for new buildings.

However, all projects of renovation and construction, buildings, infrastructures and planning must now be part of a 2°C, or even 1.5°C trajectory in order to minimise any contribution to climate change.

… to adaptation as a necessity…
The processes of climate change being underway, the actors of the built environment must, in their practices, both of construction, rehabilitation and of use, anticipate the changes which are announced to prepare for the new living conditions which will be imposed on everyone.
As no territory is now safe from consequences affecting daily life or catastrophic events, it is no longer just a matter of fighting against them, but of learning to live with them, in order to reduce the consequences and the seriousness of their impacts on the built environment, the economic performance and the quality of life.

… and to resilience as a response to uncertainty
The phenomena in progress being unprecedented in their magnitude and their temporality, not everything is predictable, and the forthcoming environment seems less and less determined.
The existence of main uncertainties on climate change leads to adopt a new approach and to start a reflection not directly leading to adaptation, but rather to develop a capacity of adaptation.
At the same time as it requires to take many constraints into account (the weight of the existent, physical or economic limits, intersectoral, systemic, territorial dependencies at different scales), adaptation leads to change the level of analysis, to consider multiple scenarios, but also to avoid any saturation in the use of natural resources, and to restore a certain flexibility, to manage an uncertain future, which means to increase environmental resilience.

DEFINITIONS

The concept of resilience in communities and urban areas is relatively new. It is a complex concept, for which there is no consensual definition as of now, and which integrates many other concepts. Here, it therefore seemed useful to get back to the terminology associated with resilience and adaptation to climate change.

Several definitions are available for resilience, this definition framework specifies them for construction and sustainable development.

For UN-Habitat: Resilience is the capacity of any urban system and its inhabitants to face crises and their consequences, while adapting positively and transforming itself to become sustainable. Thus, a resilient city assesses, plans and takes action to prepare for and respond to all hazards – whether sudden or of slow evolution, planned or unplanned. Resilient cities are therefore better able to protect and improve people's lives, secure their assets, promote an investment-friendly environment and foster positive changes.

For IPCC: Resilience is the ability of a system or community exposed to hazards to resist, absorb, adapt and recover in a timely and effective manner.

For OID: The capacity of an ecosystem to withstand shocks and overcome alterations due to internal or external disturbance. In the real estate sector, it will be a question of promoting this capacity for resilience by identifying the risks incurred and by applying adaptation solutions to respond to these risks.

For CEREMA: A settlement is resilient if it knows and can find the capacities necessary for its adaptation in front of the hazards that threaten it. For territories, resilience therefore refers to their ability to transform changes, and in particular climate changes, into long-term social and economic opportunities.

For the "Fabrique de la Cité": With resilience, the approach to risk is modified: we abandon the hope of zero risk and accept the crisis; we try to lessen its shock and its shock wave and to ensure that the affected system is stable enough not to collapse but on the contrary to be able to transform itself, thus recalling that the resilience, which comes from «resilere» (jump, bounce) opposes to resistance, that comes from «stare» (stand straight).

The notion of system emerges from these definitions as a major notion associated with resilience: resilience cannot be considered otherwise than in a systemic way. Thus, the resilience of the built environment can only be addressed by taking into account all the constituents of urban environments.

Also, here we consider the notion of resilience as the ability to resist, deal with a shock (punctual or chronic) or a disturbance, and to return to a stable situation, which is not necessarily identical to that which prevailed previously.

RESILIENCE STRATEGY

Taking resilience into account to improve adaptation to climate risks and the management of their consequences can be defined at the strategic and operational levels. The action levers proposed in the second part will provide concrete and operational examples of implementation, and here, we propose the steps for the implementation of a resilience strategy in the built environment aiming at reducing the impacts of the risks.

A resilience strategy cannot be fully effective without a comprehensive identification and assessment of climate risks and their direct and indirect impacts, but also the strengths and benefits of systems.

■ **Map future climate risks in the built environment.**

Based on the climate projection scenarios, using the results of the models allows to identify, at the scale of the urban fabric, the physical quantities that may represent risks for the built environment and its occupants.

■ **Assess the vulnerability of the buildings**

Vulnerability can be linked to design and planning choices, to the use or conditions of the occupants or other sensitivity factors. As for its assessment, it can be done by means of simulation, measurement, retex, or evaluation of human, material and financial risks...

■ **Prioritise the risks of the built environment**

Studying the built environment as such must therefore take into account **the critical functions** of the built environment, the **impacts of the risks** on these functions and the **potential interactions of the different systems.**

■ **Assess and prioritise technical, organisational or behavioural adaptation solutions and provisions and define the resilience strategy.**

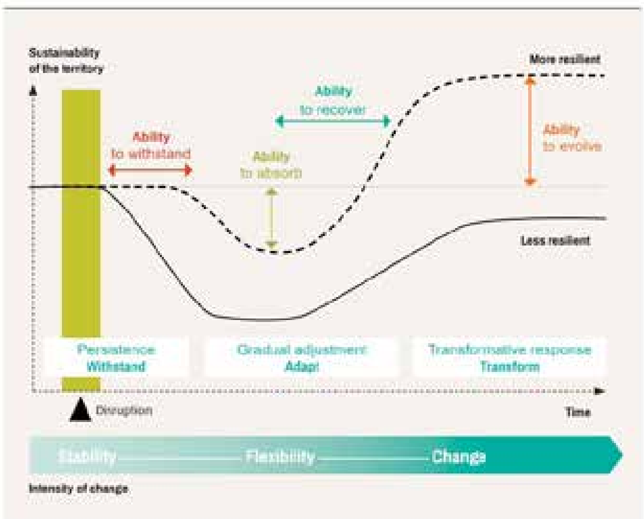
The actions to increase the level of resilience of an urban system must be detailed and prioritised. They can be implemented:

← by **anticipation,** in order to **prevent** and **avoid** the risks, **reduce exposure or vulnerability** (proactive);

↔ when a climatic **event occurs** to deal with it: **resist, delay, absorb, give way, degraded mode**… (reactive);

→ following a climatic event, for a **return to stability** (palliative) and not necessarily to the initial state;

↗ post-disruption, through **feedback** to assess the level of resilience of the system in a **dynamic of continuous improvement and transformation to gain resilience**.



Céréma[1] represents the evolution of the **sustainability** of a territory, subject to an initial disruption (e.g. climate hazards) by proposing three main phases, which may follow one another or be concomitant:

■ The first phase corresponds to the period immediately following the shock: the way in which the system reacts shows its **sensitivity** to the shock, determined by its ability to **withstand** the impact and its physical fragility (**vulnerability**).

■ The second phase begins when the system experiences the effects of the disruption and attempts to deal with it. It refers to the ability to **absorb** the disruption. The system then reacts to the shock and gradually re-establishes its trajectory: the ability to **recover** then comes into play. This second absorption recovery phase constitutes a phase of gradual adjustment or **incremental adaptation**.

■ Finally, the third phase is that of the **transformative** response and corresponds to the territory's ability to evolve and transform in order to orient its trajectory towards a new equilibrium characterised by greater sustainability.

SOURCES

[1] The Resilience Compass, CEREMA (2020) – adapted from Tendall and al. (2015).

CLIMATE HAZARDS: ISSUES IN THE BUILT ENVIRONMENT

In France, the territory is highly exposed to natural hazards, due to the diversity of its climatic and geomorphological characteristics.

IPCC reports show that climate change has changed the probability of occurrence of natural hazards, as well as their intensity.

These hazards, described below, are those which are directly related to the consequences of climate change that fall within the scope of this definition framework.

Global warming has an effect on extreme climate hazards in France. According to the National Observatory on the Effects of Global Warming (ONERC), the following changes can be anticipated, already beginning 2021-2050:

- More frequent summer heat waves
- Less frequent cold waves, but still present
- Increased risk of drought
- Extreme rainfall events
- Increased risk of marine flooding
- Increased risk of storms and strong winds

Indeed, in a 2015 report, the French Insurance Association estimated that the cost of property damage caused by climate change will increase by 90% until 2040.

Flooding

Even the expected evolutions in France vary greatly from region to region, there is a general trend towards an increase in intense rainfall which can cause severe flooding.

Since the recognition of the state of natural disaster in France in 1982, the frequency of accidents linked to flooding has surpassed that of other events. According to the OECD, the cost of a 100-year flood in the Île-de-France region could amount to 30 billion euros, taking in particular indirect costs into account, including those linked to network malfunction.

Drought and groundwater depletion

Southern Europe and France are particularly affected by the increase in droughts, whose average expansion has been very significant since the 1990s. Climate projections indicate that metropolitan France is likely to experience almost continuous agricultural droughts of great intensity, totally unknown in the current climate.

The deficit in cumulative rainfall observed in recent years, leading to soil dryness, is the cause of a geological phenomenon known as clay shrinkage and swelling, caused by a water imbalance of the soil in presence of clay, which generates serious damage to the built environment. 60% of the territory of metropolitan France has a soil composed of clay, of which 20% is particularly exposed to this phenomenon.

Storm, cyclone or hurricane

Storms are one of the climatic extremes that can have a particularly severe impact on the built environment.

Indeed, due to the combination of their effects (strong winds, intense rainfall, etc.), the damage caused is extensive, on a human level, as well as in human, environmental and financial terms.

Currently, there is a lack of reliable data for the knowledge of the evolution of this phenomenon in relation to climate change.

Heat waves

Heat waves are one of the most worrying climatic phenomena, due to the vulnerability of our societies and the expected evolution of their frequency and intensity. In France, the number of heat waves recorded since 1947 on a national scale has been twice as high over the last 34 years as over the previous period. Moreover, we notice an increased duration and global intensity in the last years. Climate projections describe an increase in hot extremes and summer heat waves that are at the same time more frequent, longer and more intense. In France, in all scenarios, twice as many days of heat waves are expected.

Marine flooding and coastal erosion

France, with its 7000 km of coastline, is also vulnerable to marine submersion and coastal erosion.

Forest fires

50% of metropolitan forests will be subject to high fire risk by 2050 (PNACC2).

NB: A description of the effects of these hazards on buildings and their occupants from the ADEME publication of 2015: «Etude prospective sur les impacts du changement climatique pour le bâtiment à l'horizon 2030 à 2050» (Prospective study on the impacts of climate change on buildings from 2030 to 2050), is proposed in the annex (p.26).

ISSUES OF THE ADAPTATION OF THE BUILT ENVIRONMENT TO CLIMATE CHANGE

A resilience and adaptation strategy in the built environment addresses multiple challenges to urban planning and construction decision-makers, such as ensuring the health and well-being of populations, the safety of populations and the continuity of services in the event of a climate shock, but also limiting the costs linked to the degradation of the built environment.

Adaptation applied to the built environment invites us to **make decisions differently** and to develop skills:

- on the one hand, in terms of **anticipation**, with regard to the inertia of buildings, developments and infrastructures and the long timeframe of the impacts of choices, whether in terms of prevention or preparation for crisis management;
- on the other hand, in terms of **risk-taking and acceptability of the latter**, given the degree of uncertainty (climate scenarios and modelling, risk accumulation and feedback, etc.) which we are all forced to deal with.

It should be a **call to action at all levels**:

- at all scales of the built environment, from building to infrastructure, via the parcel or the development operation;
- in both new and existing buildings, according to differentiated but complementary strategies;
- from a technical as well as a human and financial point of view (constructive solutions, uses, insurance, property value).

The technical and architectural consequences of climate change differ according to the **hazards** considered. This **vulnerability** is already raising questions about the act of designing, building, renovating and operating in order to meet a commitment to the building quality of life.
The resilience of a territory, neighbourhood or building cannot be limited to a list of action levers that can be selected and implemented one or another. Above all, resilience must be thought of according to a **multi-scalar and systemic** approach. It is a complex mix which integrates many elements: soil, vegetation, buildings, roads, public space elements, energy flows and supplies, water, sanitation, human mobility, etc. Each element is interconnected.

CEREMA identifies eight qualities of territorial resilience: **autonomy, robustness, flexibility, diversity, redundancy, inclusion, integration and capacity to learn** (see the resilience compass). A resilience strategy must therefore integrate actions to improve all of these characteristics, hence a significant number of proposals for action levers.
The challenge is also to succeed in (re)defining the action scales, to develop continuity solutions between the scales, to create seams between territories. Climate change, through the risk it represents, forces a reflection that can reveal and question the unsustainability of some organisational and technical choices. It must also lead to particular attention about the risk of mal-adaptation.

FOCUS - THE BUILT ENVIRONMENT, A KEY ELEMENT OF STRATEGIC ADAPTATION PLANS

The main effects of climate change are well known: **rise in average temperatures** of over 2°C, **rise in sea levels** and more violent and frequent **extreme weather events** (droughts, floods, storms, forest fires, etc.)

Excerpts from the PNACC

In 2017, ONERC published a second climate change adaptation plan for France (PNACC-2). Its main actions applying to the real estate sector are the integration of climate change adaptation issues in various sectoral regulatory texts such as the RE2020 or the SNBC, the review of technical construction standards and existing labels, but also of Territorial Climate Air and Energy Plans (PCAET) in view of these issues.

States, regions, cities, etc. are already involved in implementing territorial adaptation processes. Although the strategies and objectives are set at national level, it is **the local levels that must really define and implement the action plans**. Indeed, the latest IPCC report reinforces this obviousness by recalling that 50 to 70% of mitigation and adaptation measures are intended to be «implemented at the sub-national level».

Buildings are an essential part of strategic adaptation plans because they are directly exposed to climate hazards and their primary function is to create a microclimate for humans as an alternative to the external climate.

However, the reflection on building adaptation cannot be done without a link to wider urban and territorial scales. This is why this definition framework proposes a structuring vision of resilience and adaptation to climate change in the built environment, considering the scale of the building to that of development operations, including infrastructure.

Indeed, the actions in the field of adaptation to climate change are today mainly carried out on an urban scale, as this is the relevant scale for action concerning some hazards.

The concrete technical and social consequences of climate change in buildings and more generally in the built environment are still a source of uncertainty and the issue still requires investment, research and experimentation to be better understood, however, some solutions are emerging and invite to act.

DEFINITION FRAMEWORK

The definition framework for resilience and adaptation to climate change in the built environment proposed by the Alliance HQE-GBC applies at different scales, from building to development, including infrastructure, and for all types of operations, new, renewal and rehabilitation, and even for existing buildings and operations.

It proposes a structuring vision in order to support the actors and facilitate their operational implementation in the construction and development sectors.

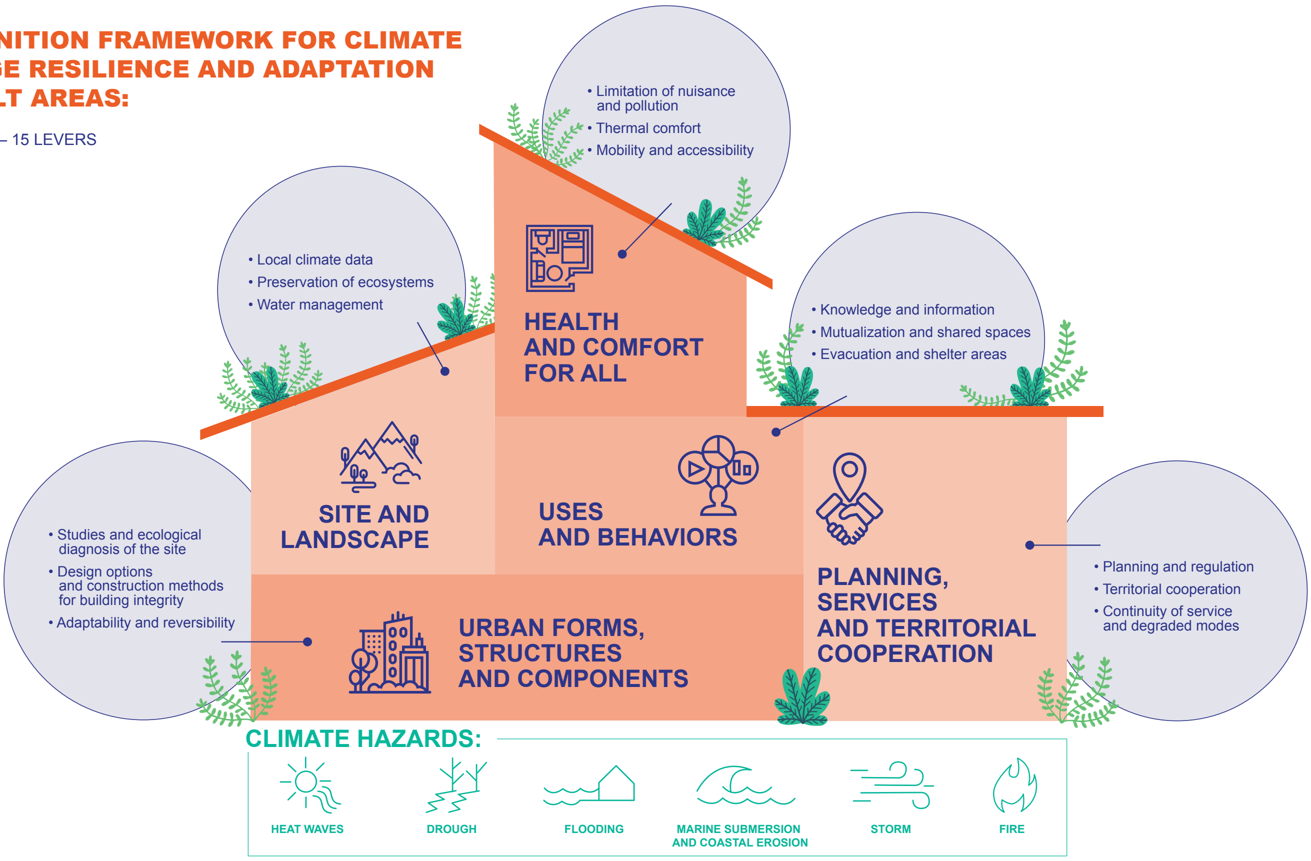
Through these shared benchmarks, common vocabularies understandable by all, this framework should facilitate transversality and encourage the various stakeholders (local authorities, developers, promoters, etc.) to work together.

From the Prefect, the Council... or the elected representative who makes the planning choices, to the building manager who participates in the resilience of their building stock.

This framework is part of the Alliance HQE's collection of works and is linked to the reference framework for sustainable building. It is not based on a typical operation scheme and all the fields and levers are transversal to the different scales and phases of the project. **The action levers identified may be organisational, technical or behavioural, and therefore cover a wide range of possible actions depending on the context.**

A DEFINITION FRAMEWORK FOR CLIMATE CHANGE RESILIENCE AND ADAPTATION IN BUILT AREAS:

5 DOMAINS – 15 LEVERS



USE AND BEHAVIOUR

Use and behaviour are key points to improve the resilience of the built environment and urban areas, as well for prevention as also for crisis management. Indeed, efficient technical solutions can be compromised by inappropriate behaviour. The culture of resilience, adapted behaviours, the reactivity of people and their interactions are powerful levers in terms of flexibility and adaptation to a wide range of situations, in particular critical ones. They often are complementary to technical adaptations, easily generalised and can be initiated immediately.

LEVER. KNOWLEDGE AND INFORMATION OF THE POPULATION

Training people on the subject of resilience is certainly one of the first levers to set up. Raising this awareness of the resilience issues concerning climate hazards can take various forms, depending on the topics addressed or the target populations, ranging from a simple **communication element, to collective intelligence workshops**. Providing easy access and **dissemination of information** is a fundamental principle for improving the skills of each stakeholder. Conducting awareness campaigns is a key action to empower stakeholders and integrate these issues into the design and implementation of construction or urban development projects.

Appropriate **behaviours** can reduce human exposure and vulnerability of the buildings (e.g. protecting windows and doors and returning furniture and potential projectiles when strong winds are approaching limit the risk of glass breakage and property damage).

Social cohesion combined with the application of other levers, in particular the training of users on future issues, can enable individuals to become aware of how to achieve a desirable future and thus motivate them to act.

Examples of actions:
Several levers seem particularly important, and about which it is necessary to communicate to the various stakeholders in order to ensure a resilient area:

- ← Inform about the risks linked to climate hazards and train the inhabitants (first aid, use of the buildings, behaviour in case of crisis, etc.)
- ← Develop a common culture of resilience and preparing the community for crisis management
- ↗ Carry out post-occupancy assessments of the buildings, to compare actual performance with expected performance, and identify causes of discrepancies and possible adjustment

LEVER. MUTUALISATION AND SHARED AREAS

Resilience puts the **social dimension** on the same level as the technical dimension. Also, it is in the **human factor**, in the **relationships** between individuals, that many solutions for a more resilient built environment can be found. Beyond the shelter, the challenge of «buildings as a good place to live» is an essential lever for fostering **social interactions,** crucial for developing mutual aid and solidarity, which are factors that help to limit human vulnerability, both in general and particularly in emergency situations.

To achieve this, it can be interesting to design a built environment which has **shared and mutualised areas** favouring **encounters and social links**, for example oasis schoolyards that are open to the public in the neighbourhood, shared gardens within the block, the common laundry within the condominium, etc.

Examples of actions:
At the building level, several actions can promote good social cohesion:

- ← Develop a strong identity and culture at the city, neighbourhood or territorial level, and encourage the development and active participation in local associations
- ↔ Identify, train and support resource persons for crisis management
- ↗ Carry out a post-crisis evaluation of solidarity schemes

LEVER. EVACUATION AND REFUGE AREAS

For each of the main risks identified and taking into account vulnerabilities, **intervention, evacuation and subsistence plans** can be drawn up. It is essential to anticipate **crisis management** by training the emergency teams, by teaching the inhabitants and users how to execute these plans (following the example of fire or terrorist attack plans) and by ensuring that the equipment necessary to activate these plans is present, operational and understood.

It will also be necessary to plan the proper functioning of the economy during slowdowns caused by climate hazards in order to ensure maintaining as many activities as possible and **thus ensure the continuity of economic functions**.

Identification or programming of **refuge areas or premises for collective shelter** in the event of extreme climatic shocks is an interesting avenue. **Flexibility** is a key quality to increase the capacity to adapt, that of uses and organisations can allow a fast and inexpensive adaptation of buildings and their occupants, and reduce their exposure or their vulnerability to climate hazards.

Examples of actions:
Evacuation plans and refuge areas should have been determined, but actions, in particular concerning uses, can be identified:

- ← Prepare an action and evacuation plan
- ← Think about warning systems linked to the connected building, and the development of sensors
- ↔ Provide basic communication capacity and communication equipment
- ↔ Provide refuge areas in the attic, in case of flooding and cool refuge areas in case of heat waves
- → Provide for necessary livelihoods after a shock
- ↗ Identify and evaluate appropriate concrete actions and procedures to address the identified risks

HEALTH AND COMFORT CONDITIONS

One of the first challenges of the built environment is to ensure health, comfort and protection of populations from external threats, including climatic events, according to the primary vocation of the dwelling as a shelter.

Health and comfort of populations depend on a multitude of criteria, firstly temperature and air quality. The influence of temperature on mortality and on the use of health care is now established. The built environment, to become resilient, must therefore take these health and comfort criteria into account, regardless of the outside weather conditions.

LEVER. LIMITATION OF NUISANCE AND POLLUTION

Health issues at the scale of the built environment encompass various topics. Indeed, frameworks and approaches for **health-friendly urban planning** have helped to identify them: **air circulation**, ambient and indoor **air quality, acoustics, lighting comfort, summer comfort, biophilia** and also pest management.

In this area, it seems necessary to encourage and facilitate the quantitative and qualitative assessment of the **health impacts of public policies and actions for the adaptation** to climate change, in order to avoid bad adaptation and maximise the health and environmental co-benefits. In order to better inform about the choices, we still need more research work and programmes to compare health, urban planning and meteorological data in order to model **climate health risk** maps to prioritise interventions.

Indeed, climate change could increase health risks due to food-borne diseases or vectors, or even worsen local pollution in cities.

For example, the invisible «micro-biodiversity», which is both a solution factor (absorption of pollutants, etc.) but also a risk factor (bacteria, etc.), is still too often absent from diagnoses; the risks of proliferation of mosquitoes (in particular the tiger mosquito), which are carriers of potential diseases, are not sufficiently taken into account in revegetation actions, or the return of the presence of water or wetlands in the city.

Examples of actions:
There are ways to reduce exposure to nuisance and pollution, also at source, with a view to creating a more resilient built environment:

- Consolidate monitoring tools for thermal comfort and outdoor and indoor air quality
- Apply the principles of health-friendly urban planning and promote urban design that takes sources of nuisance and pollution into account
- Systematise taking into account of health issues in diagnoses

LEVER. THERMAL COMFORT

Urban heat islands (UHI) are now well documented phenomena and qualitative approaches are being developed to reduce their impacts. Among the UHI **mitigation** measures, we can mention: vegetation, water and nature spaces, the orientation of the project, in particular the orientation of the streets in relation to prevailing winds, the shading of paths and public spaces, taking into account the albedo of built spaces or the choice of clear coated surfaces to limit radiation, the reduction of the ratio between built spaces and free planted spaces, the revegetation of the building to take advantage of the benefits of evapotranspiration.

In buildings, thermal regulations were mainly aimed at heat production, whereas the major issues will now concern coolness production. The notion of summer comfort is introduced in the next RE2020.

At the scale of the building, there is also a range of solutions that can avoid massive use of air-conditioning: systematic use of blackout systems, passive cooling, thermal inertia of materials, revegetation of the plot, etc.

Examples of actions:

← Train building and land-use planning professionals on the health risks associated with a heatwave and reinforce the consideration of summer comfort in new and renovated buildings

↔ Create green spaces and shaded areas in the city to structure the territory with islands of coolness

↔ Provide cooling areas in buildings, especially those housing vulnerable people

FOCUS - TOOLS

The already observed increase in the number of days of heat waves and more frequent and intense heatwaves now force us to deal with these constraints, both at the building and development levels. (see Sources and Resources)

The adaptation of buildings, both in new construction and in renovation, is becoming essential to preserve the comfort of the occupants and limit the systematic use of air conditioning. Technical and technological solutions exist.

We also notice a development of design and planning assistance tools linked to Geographic Information Systems (simulations, modelling, parametric design, etc.) which allow comparisons of planning scenarios, particularly with regard to urban heat island issues.

LEVER. MOBILITY AND ACCESSIBILITY

Mobility issues must also be integrated to ensure that people can travel in all circumstances and limit their exposure to hazards (where possible), without worsening (or even while reducing) the impact of transport on climate change. **Mobility should therefore be adapted to the climate issues.**

Accessibility and travel issues are also to be linked to **the demographic challenges in connection with the ageing of the population**. In degraded mode, this lever should also be used to question the accessibility during crises, which can be addressed through construction methods (e.g. piles).

Examples of actions:

← Encourage active mobility and improve accessibility to non-motorised and public transportation

↔ Ensure access to care and emergency services

↔ Equip with floating displacement systems (e.g. boats) - flooding

↔ Arrange transport schedules and routes according to sunshine hours - heat waves

→ Have petrol reserves

↗ Facilitate access to a robust health system and to quality care.

URBAN FORMS, STRUCTURE AND COMPONENTS

Commitment to an approach of resilience and adaptation to climate change in the built environment necessarily involves a transformation of urban planning, operational development and construction practices to deal with future hazards. The actions must be taken at different scales to reduce the vulnerability of the built environment, to encourage its evolutivity, and to draw its inspiration from the nature in urban planning and development operations that integrate climate change.

LEVER. FIELD DIAGNOSIS AND SITE ANALYSIS

Developing a project taking into account the interactions between humans, climate and ecosystem and the characteristics of the site is the basis of bio-design. **Knowledge of the field and geography of the site**, in terms of hydrology, geology, geomorphology or exposure to wind or sun, is thus a lever for designing a more resilient built environment, as these characteristics can either reduce or greatly increase exposure to hazards, and can represent an asset for adaptation or a risk factor.

Heavy rainfall and flooding as well as repeated drought waves to which the territories are subjected may destabilise **the structure of the buildings**. The deficit in overal precipitation leading to dryness of the soil is thus at the origin of a geological phenomenon called **shrinkage-swelling of clays** (RGA), land movements can also be caused by a hydric imbalance of the soil.

Examples of actions:
Various actions can allow take advantage of a site analysis for a more resilient built environment:

- ← Carry out comprehensive site analyses with regard to climate risks
- ← Systematise soil investigations before any construction in areas subject to RGA
- ← Protect steep slopes and hillsides to avoid exposure and risks linked to erosion and landslides
- ← Design the orientation of buildings, streets, squares and parks in order to reduce the impact of hazards
- ↔ Promote construction methods that take hazards into account
- ↔ Build on nature-based solutions for risk prevention

LEVER. PLANNING OPTIONS AND CONSTRUCTION METHODS FOR BUILDING INTEGRITY

The form, structure, geographical exposure or spacial organisation are parameters that can strongly influence the level of exposure of buildings and their occupants to climate hazards. The strategy of urban space planning has an influence on resilience by playing on long-term factors (health of the inhabitants, social cohesion, daily well-being) but also on the response to crisis situations (access to food, solidarity between inhabitants thanks to social cohesion, speed of return to the initial state, etc.). Depending on the solutions implemented in a neighbourhood, the impact of climate hazards can be reinforced, or on the contrary reduced. It is therefore possible to adapt the **geometry and urban forms and planning to reduce the vulnerability** of the built environment and its inhabitants.

Adaptation of the built environment to climate change is also a major economic challenge and **planning choices** can help **limit the costs linked to the deterioration of the built environment**. Indeed, the study «Climate change and insurance by 2040» published in 2015 by the French Insurance Federation states that the cost of insurance for natural hazards will increase over the next 25 years.

Overall damage from floods, droughts and clay shrinkage-swelling, storms and marine submersions is expected to rise by 90%. In this study, the French Insurance Federation estimates that unfavourable land-use planning is the third factor explaining this projected increase.

Examples of actions:
Several actions regarding the adaptation of urban geometry planning and construction methods are identified:
- ← Limit the artificialisation of land, promote urban renewal and thus land management
- ← Organise the space and the form of the building according to aerolic and climate data and to flood zones
- ← Spreading vital functions across the territory
- ← Limit the exposure of buildings to hazards through their layout / orientation and through the size and location of openings and glazed areas
- ← Limit energy storage by buildings / road elements (albedo)
- ← Provide for and organise mixed uses in the local built environment (essential services in the vicinity or within the building)
- ↔ Create refuge areas
- ↔ Strengthen the robustness and reliability of the systems, promote robust protection infrastructures

LEVER. ADAPTABILITY AND REVERSIBILITY

Adaptation involves requirements in terms of new construction and renovation, and in this context the notions of **reversibility and adaptability** can provide answers to the question of **uncertainty**. It also involves the **ability to adapt and transform an existing building** which is part of a specific architectural, urban, heritage and sometimes social context

Off-site construction can be seen as an interesting solution in terms of resilience and adaptation. The modularity facilitates deconstruction, which may allow building in areas known to be subject to hazards in the future (e.g. by anticipating displacement in the short to medium term), as well as reconstruction in a post-crisis management context. This construction method, based on the principles of prefabrication and industrialisation, also offers advantages in terms of improved quality, reduced environmental impact, shorter lead times and possibly lower costs.

Finally, from a life cycle perspective, designing buildings that are less obsolete as possible over time, while thinking of them as bank of resources that can be exploited (simplified construction/deconstruction) appears to be an important principle of building resilience that favours the extension of the life span and circularity of the buildings.

Examples of actions:
Several avenues can be highlighted to promote the adaptability and reversibility of buildings and planning:
- ← Promote modular flexibility and scalability of use or convertibility in every approach
- ↔ Keep buildings healthy, even if standing in the water, for example, by using removable plasterboard or easily removable partitions
- → Plan from design on, tools to facilitate water discharge, cleaning and drying - Flooding

SITE AND FIELD

An adaptation strategy requires knowledge of the consequences of climate change and a regionalised inventory of current and future vulnerabilities. On a finer scale, a vulnerability assessment of the city, neighbourhood, site, plot or building, to understand exposure and sensitivity, allows to bring to light the risks and their degree of intensity. However, the intensity of the effects of climate change remaining uncertain, it is necessary to prepare for any eventuality, to accept some degree of risk and to develop resilience skills.

LEVIER. DONNÉES CLIMATIQUES LOCALES

The **production of data** on the impacts of climate change has made significant progress in recent years. Although experts agree on global trends, there is still a great **part of uncertainty**, since the degree of impact depends on the speed at which our societies will make their ecological transition, but also on the place where it occurs, since not all parts of the world are subject to the same climate risks.
Weather files, used for example in dynamic thermal simulations, are a way of assessing the resilience of a building or development under climate constraints **through sensitivity analyses according to more or less pessimistic tested scenarios**.

Thus, they allow to check whether a built environment can be resilient in a context of 1.5°C warming in 2050, and whether it will still be resilient in a context of 3°C warming, or in 2100.

Examples of actions:
- Develop and share knowledge
- Use regionalised weather files that take into account the most pessimistic climate scenarios
- Increase the number of sensitivity assessments in design and operation
- Improve and disseminate modelling tools

FOCUS - « PROSPECTIVE SCENARIOS »

The future climate depends, among other things, on the emissions or concentrations of GHGs and aerosols caused by human activities. IPCC has defined four reference scenarios, as Representative Concentration Pathways of GHG, ozone and aerosol precursors for the 21st century and beyond, for each of which climate scientists derive climate conditions and associated climate change impacts.

Various resources are already available for regionalized climate projections:
- IPCC Interactive World Atlas: https://interactive-atlas.ipcc.ch/
- DRIAS, the Climate Futures for France: http://www.drias-climat.fr/

LEVER. WATER MANAGEMENT

Urbanisation patterns and increased land artificialisation are partly responsible for the vulnerability of the built environment to climate risks. The development and management of the environment in urban areas through the **services provided by ecosystems** (food, water management, temperature regulation) are ways to improve resilience.

In terms of adaptation to climate change, the **un-permeabilising or demineralisation** of public spaces and built heritage, by favouring **infiltration of rainwater**, plays a central role that is increasingly implemented in development projects. **Sustainable and integrated management of rainwater** offers multiple advantages: reduction of volumes discharged into the sewage systems, groundwater recharge, fight against urban heat island phenomenon with creation of coolness islands. Together with the **reconstitution of natural functioning of soils or vegetation**, these solutions are recognised for their advantages in reducing exposure to hazards (infiltration, physical barriers, shading, etc.).

Examples of actions:
Many actions can promote ecosystem services:
- ← Unseal where possible, or mineralise spaces without sealing them (e.g. porous material solutions, draining pavement, grass slabs, porous asphalt).
- ← Prefer alternatives to specific structures for rainwater management
- ← Protect and recreate wetlands
- ↗ Connect ecological corridors
- ↗ Preserve and restore disturbed habitats and soils
- ↗ Support alternative solutions for the maintenance of green and natural areas (grazing)

FOCUS - GESTION INTÉGRÉE DES EAUX PLUVIALES

It consists of managing the drop of water as close as possible to its drop point, keeping it on the surface (no buried system), avoiding its runoff (which causes 80% of the pollution that will require treatment), and infiltrating it to respect the natural water cycle (natural management).

The new floodable spaces offer great potential in terms of reappropriation, uses, landscaping, depollution, microclimate, etc. The consequences in terms of maintenance must however be considered, as they represent new operating cost items at the scale of the building.

LEVER. PRESERVATION OF ECOSYSTEMS

Adaptation can take the form of the promotion of **«nature-based solutions»** which, since the 2010s, have referred to projects and initiatives that seek to benefit both biodiversity and the well-being of human societies. They call on nature in development projects, whether urban, suburban or rural, while ensuring preservation or restoration of biodiversity and are mobilised in particular in the field of **risk management:** hydraulic slow down (hedges, return to the natural bed, preservation of thalwegs, flood expansion areas, ditches, etc.) or construction solutions in moderate risk areas.

Nature-based solutions pick up various existing concepts, for example such as **plant engineering**, which uses planting, seeding and cutting techniques, in particular to clean up soil pollution and **restore biodiversity** on degraded sites. Other examples include **«green infrastructure»** afforestation along waterways, roads or **ecological corridors**, or also **«nature in the city»**, which involves planting trees or creating islands of green coolness, or also **revegetation of buildings,** which does not only encourage biodiversity but also helps reducing peak rainfall, cooling through evapo-transpiration, without forgetting that it promotes social links when it creates shared spaces or the supply of locavore food when it is a question of roofing urban agriculture for example. We can also talk about **«Low-Tech»** solutions or solutions based on the principles of **bioclimatism** or biomimicry

Examples of actions:
- ← Apply low-tech principles or those inspired by ancestral techniques or adapted to regions already facing climate hazards
- ← Plant outdoor spaces with species adapted to local climate conditions to filter the air and cool urban spaces
- ↔ Promote water bodies to mitigate the effects of UHI
- → Design retention ponds with recreational use

FOCUS - ECOSYSTEM SERVICES

Six services provided by seven ecosystem types according to Bolund and Hunhammar (1999):
- **air filtration;**
- **regulation of the microclimate;**
- **noise reduction;**
- **rainwater drainage;**
- **wastewater treatment;**
- **cultural and recreational values.**

The seven ecosystem types are: avenue trees, park lawns, urban forest plots, urban cropland, urban wetlands, rivers, lakes and the ocean (their case study template was Stockholm).

PLANNING, NETWORKS, SERVICES AND INFRASTRUCTURE

The robustness issues of networks and supplies of energy, water, food resources, information, etc. or waste disposal are at the heart of this area in connection with climate and urban planning on a territorial scale. The reflection leads to consider the built environment by taking into account its critical functions, the impacts of risks and potential failures on the latter as well as the interactions of the various systems. From the PCAET (Plan Climat-Air-Energie Territorial / French Territorial Climate-Air-Energy Plan) to the building as a link in the chain, which can also contribute to the resilience of the territory...

LEVER. PLANNING AND REGULATION

The logic of resilience aiming to make the territory evolve in anticipation in order to limit the frequency and impacts of hazards implies **public policies in terms of urban planning**, and **choices of location** which take into account the climate risks as well as all the elements of the territory diagnosis.

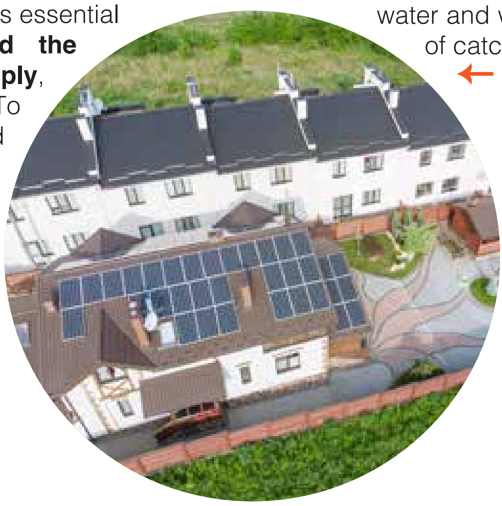
Action on buildings is carried out through planning, with territorial adaptation plans, but also **urban planning documents, risk prevention plans** (PPRN and PPRT) or other risk maps introducing the need for a large number of actors to take into account a diversity of possible scenarios and to ensure robustness and adaptability in order to increase the resilience of the territories through restrictions or constructive measures on buildings and infrastructures for example.

<u>Examples of actions</u>:
In order to encourage and ensure the implementation of resilience mechanisms, it seems important to work with public actors in order to:

- ← Appropriate and deploy the support tools for an adaptation to climate change offered by urban planning documents
- ← Update, enforce and respect territorial planning documents (PLUi, PPRN, PPRT, SRADDET…)
- ← Establish dissuasive or even punitive measures to prevent and limit non-compliance with good practices and regulations
- ↗ Identify the processes and modalities for steering resilience by establishing a territory-wide management system, similar to environmental or safety management systems.

LEVER. TERRITORIAL COOPERATION

Adaptation and resilience raise the creation of new relationships between territories and between territorial scales, particularly in the **management of flows and supplies** (of food, water, energy and access to health care are mainly concerned) in such a way as to guarantee access to essential needs and to ensure a minimum level of health and comfort in all circumstances.
This lever raises the question of the **degree of autonomy of the territories** to be sought, for which it seems relevant to systematically integrate as essential principles the **local aspect and the diversity of production and supply**, redundancy and buffer stocks. To ensure effective interactions and the sustainability of the territories, another axis of improvement is to encourage and contribute to **intra- and inter-territorial cooperation and transversal approaches** for territorial projects that also promote **solidarity**.



Examples of actions:
In order to put the cooperation between territories at the service of their resilience, different courses of action can be envisaged:

- ← Encourage Industrial and Territorial Ecology (ITE) approaches
- ← Interconnect territories and develop territorial cooperation
- ← Optimise and continuously improve the management of water and wastewater cycle as well as the protection of catchment areas
- ← Preserve the water resource on a daily basis to cope with particular periods of restriction
- → Consider local supply of materials, food, water, power, heat networks
- → Calculate the coverage rate of energy needs by local resources in case of a disruption of energy supply from the networks
- ↗ Propose, for each system, diversity of production and supply, redundancy

LEVER. CONTINUITY OF SERVICES AND DEGRADED MODES

Improving the resilience of the built environment means anticipating to **ensure the continuity of services in case of climate shock and to guarantee an access to basic needs**.

Reducing the **vulnerability of the networks** is a major focus of prevention, given our growing dependence on networks that are interconnected: a power cut can compromise sanitation and water distribution, and a road cut can compromise emergency services, not only leading to material damage but also to serial malfunctions and major impacts on activities and exchanges. The increase in hazards leads to an accelerated deterioration of electrical equipment, resulting in longer and more frequent power cuts and an increased risk of network saturation.

It is therefore necessary to define what constitutes the functionality of the built environment and its acceptable levels with regard to chronic stress or during extreme weather events and to anticipate its functioning in degraded mode. **Access to water, energy and communications**, as well as the ability to store waste or access to emergency care, are thus essential **to maintain vital needs and critical or emergency functions** in case of intense climate hazards.

Examples of actions:
The logic of autonomy and anticipation of operation in degraded mode and continuity of access to services must be sought through following actions:

- ← Protect networks, for example, by burying power cables in areas subject to cold waves or strong winds
- ↔ Provide a minimum service or guarantee autonomous operation for water and power (e.g. power generator, etc.) and telecommunications
- ↔ Provide accessibility to buildings during the crises
- ↔ Ensure sufficient thermal conditions, and provide energy for critical building needs in case of failure of energy networks (e.g. natural ventilation, passive heating, autonomous lighting of common areas, ...)
- → Think about the degraded mode and prioritise uses to differentiate the networks and allow offloading of comfort uses if necessary
- → Provide local services, in particular food services
- ↗ Program urban agriculture spaces and common storage areas (production and storage)

FOCUS - DRAWNIG INSPIRATION FROM THE MEDICAL WORLD

Hospital projects must guarantee service continuity for patient's safety. Great care is taken with the various risks, which are ranked in terms of probability and severity. A strategy is put in place to prevent, avoid and compensate for the risk of power cuts. Several scenarios of electrical failures are reviewed during the design phase and back-up systems are systematically integrated.

CONCLUSION AND PERSPECTIVES

At the risk of paying a high price, our societies cannot afford to wait for severe and repeated climate events to occur. Resilience is not only about enduring and resisting climate hazards, but also about anticipating them, preparing for them and knowing how to recover from them.

Resilience is a plural and systemic concept.

When applied to the built environment, that means the places where people live, resilience touches on many closely intertwined spheres. Indeed, if buildings can withstand shocks, neighbourhoods and cities need to be involved in mitigating the effects. The resilience of the built environment includes above all resilience for its users to ensure their vital needs and comfort.

The concrete levers must be applicable to already existing buildings, as 80% of the buildings that will constitute the built environment of 2050 already exist.

These levers are all at once technical, of varying technicality, **organisational and behavioural**, and involve one or several stakeholders.

The examples of actions proposed here are not exhaustive and many illustrations and feedbacks can be found in other publications such as the IDO's Adaptive Action Sheets for example.

To go further, it would be interesting to explore the possibilities and opportunities for the implementation of indicators to assess the degree of resilience of a building, neighbourhood or territory.

Finally, several tools in line with the definition framework of the Alliance HQE-GBC France are already operational:
- The resilience tool proposed by Cerqual Qualitel Certification
- The resilience diagnostic tool proposed by Resallience.

GLOSSARY

Adaptation to climate change
Adjustment approach to the current or expected climate and its consequences. In human systems, it is a question of mitigating or avoiding prejudicial effects, and exploiting beneficial effects.
There are three potential adaptation types of the built environment to climate change:

- incremental: aims at a rapid but limited evolution of the building to adapt it to climate change (e.g. installation of a complementary technical system).
- systemic: aims at a more structuring adaptation, by adapting the current organisational system of the building sector (production chain, risk culture, financial balance, etc.).
- transformative/transformational: adaptation that changes the fundamental elements of a system in response to climate and its effects.

Albedo
Reflectivity of a surface, that means the ratio of reflected to incident light energy. When the sun radiation reach the ground on our planet, it is partly reflected. This reflection, which depends on the colour and material of the surface concerned, is called «albedo».

Climate hazard
Natural phenomenon linked to the climate, which leads to disturbances compared to normal situation. Hazards are characterised by their intensity, probability of occurrence, spatial location, duration of impact and degree of suddenness.
There are two main types of climate hazards:

- Sudden shocks, with immediate impacts (storms, floods, submersions, etc.)
- Chronic, slow-onset sources of stress (heat waves, rising average temperatures, etc.).

Climate change will affect their intensity and probability.

Built environment
The physical environment built or developed by humans to support community development and individual fulfilment. The built environment notably includes places and spaces to meet accommodation, travel and recreation needs, and stands for buildings, facilities and infrastructure.

Climate change
Long-term (decade to million-year) change of statistical parameters (mean parameters, variability) of the Earth's global climate or its various regional climates. These changes can be caused by natural phenomena or, as at present, by human activities. Greenhouse gases trap more energy on Earth and lead to global warming (causing summer heat waves, melting ice and rising sea level) and climate disruption, which is illustrated by the multiplication or intensification of extreme weather events (floods, droughts, cyclones, storms etc.).

Free Cooling
A passive cooling technique for buildings. It uses outside air when its temperature is lower than the ambient temperature of the building. It can be the only cooling system chosen or it can be combined with other systems. This mechanical, natural or hybrid free-cooling has a limited cooling potential in the mid-season and in the summer during the day.

Urban heat island (UHI)
Artificial urban microclimates in which maximum daytime and in particular night-time temperatures are higher than in neighbouring less urbanised areas. The UHI phenomenon is linked to several factors: the thermophysical properties of the materials used for buildings and roads; the nature of the soil (mineralised soils, lack of vegetation); the urban morphology; the release of heat from human activities (engines, heating and air-conditioning systems...). As a result, there is an amplifying effect of the heat waves themselves due to climate change.

Risk
Possibility of an undesirable event occurring: uncertainty relates to the probability of occurrence of a hazard or risk, and the extent of potential damage given the contextual and environmental issues.

Vulnerability
A property resulting from intrinsic factors (physical, social, economic, environmental) that predispose elements exposed to the manifestation of a hazard to suffer harm or damage. In the real estate sector, a vulnerable building is one that could be affected by a hazard, for example a climate hazard, because of not having considered the risk that the hazard may occur. Vulnerability is inversely proportional to resilience.

SOURCES AND RESOURCES

- **ADEME**
- **Association française de l'assurance *(French Insurance Association)***
- **Céréma Boussole de la résilience (2020) *(Resilience compass)***
- **Météo France**
- **OID, Lexique de l'immobilier responsible *(Responsible real estate lexicon)***

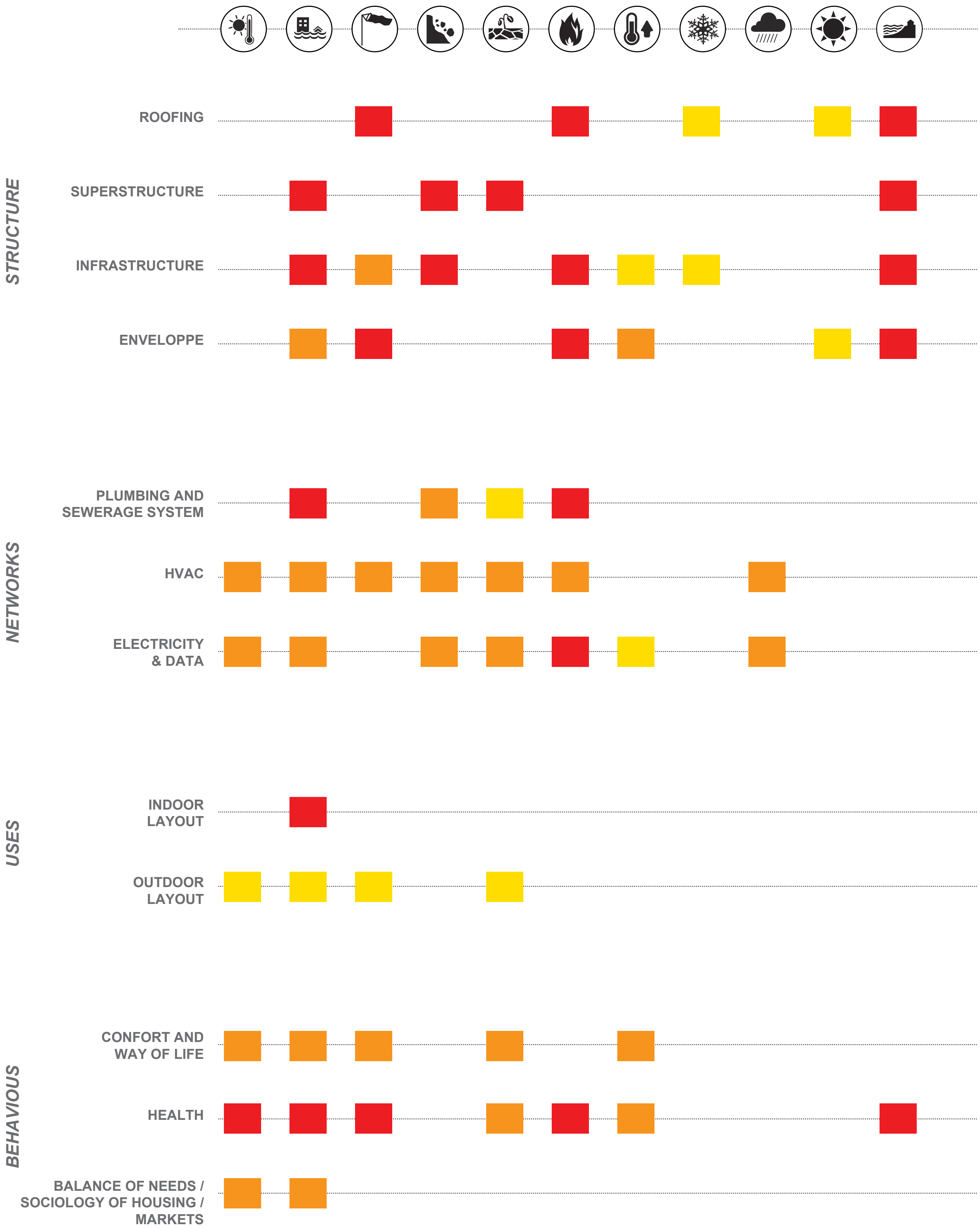
CLIMATE DATA:

- **CGDD, Climate risks**
- **Portail Drias, futur climats**
- **Fédération française des assurances, (2015) *French Insurance Association***
- **L'Observatoire national sur les effets du réchauffement climatique (ONERC) *National Observatory on the Effects of Global Warming***

ANNEX

EXERPT FROM THE DOCUMENTATION FROM ADEME:

Prospective study on the impacts of climate change for the building sector by 2030 to 2050



ACKNOWLEDGEMENTS

Alliance HQE-GBC would like to thank all the participants of the Resilience and Adaptation to Climate Change Working Group and the members of the Board of Directors who participated in the review of this document.

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- **Thanks also to** 2020-2021 class of EME UniLaSalle's Specialised Master's Degree in Circular Economy which accompanied the Working Group in the framework of the project «Resilience and adaptation to climate change in the built environment»: Pierre CHARPENTIER, Cécilia DARÇOT, Antoine GILLES, Anaïs GUILLAUME, Pauline JOUANNE, Isabelle MARCHADIER and their referent professors: Dany HULOT, Karine DUFOSSE, Anne-Bérengère SIROËN

- **Design :** Studio Cirsé
- **Photos :** Adobe Stock
- **Publication :** December 2021

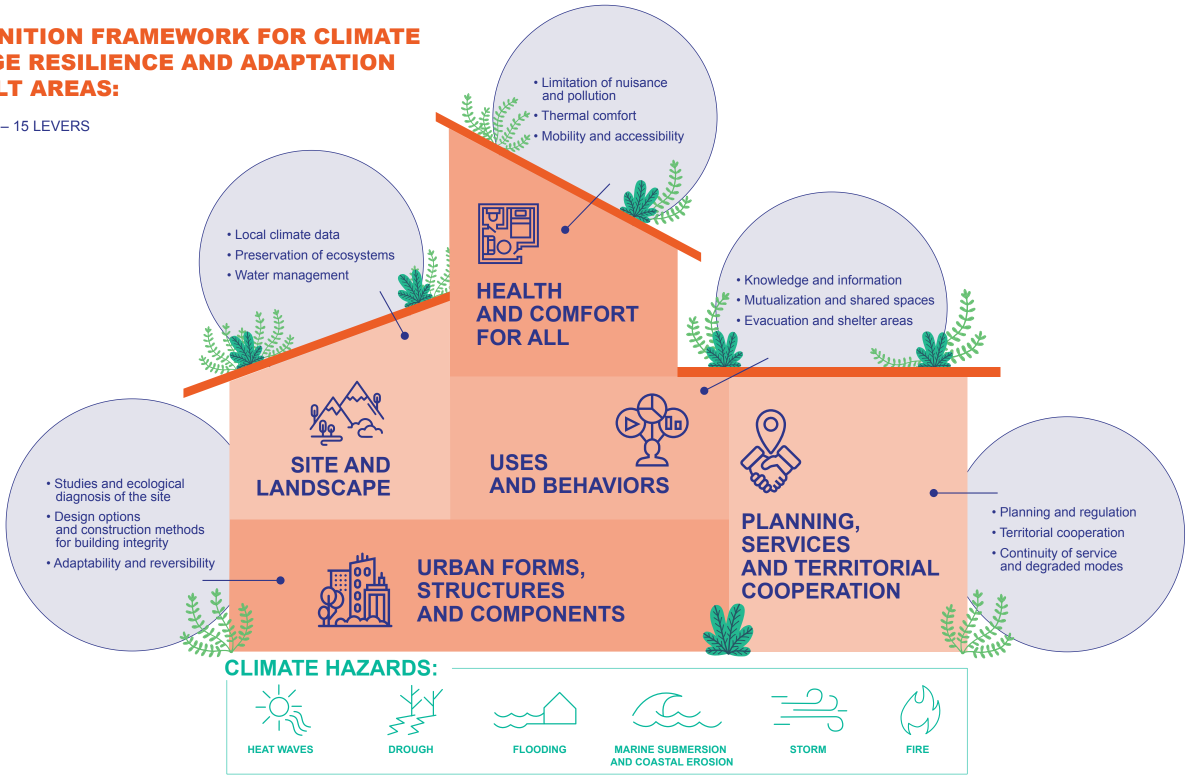
Alliance HQE GBC FRANCE

DEFINITION FRAMEWORK FOR RESILIENCE AND ADAPTATION TO CLIMATE CHANGE IN THE BUILT ENVIRONMENT

15 LEVERS TO ACT

A DEFINITION FRAMEWORK FOR CLIMATE CHANGE RESILIENCE AND ADAPTATION IN BUILT AREAS:

5 DOMAINS – 15 LEVERS



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