Global Alliance
for Buildings and
Construction

Buildings and Climate Change Adaptation

A CALL FOR ACTION

In association with

OID
Penser l'immobilier responsable

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SOMMAIRE

>> EDITORIAL

Cities, urban infrastructure, and buildings occupy a central place in climate change resilience strategies. Indeed, social, and economic mechanisms rely on the smooth functioning of this troika, which itself is highly dependent on environmental conditions.

Investing in buildings adaptation and the financing of resilient urban infrastructure is therefore crucial to prevent further problems related to climate change. However, in order to build a solid city resilience plan toward climate change, high priority must be given to forecasting and early prevention, the commissioning of future-oriented studies, and the adoption of a long-term mindset. At present, due to the lack of tools and data to reinforce such forecasting and long-term decision-making processes, short-sighted policies tend to be prioritized instead; even as awareness of future risks and the necessity for resilience is growing, it is still not enough to have an impact on policies in urban areas. This is the case even though there are real advantages to rapid action: the sooner organisations invest in adaptation and begin to tackle climate change-induced threats, the lower the future costs will be, both in terms of facing the hazards to come and in implementing crisis management measures.

One of the other major challenges involved is to define an adaptation plan that sets priorities among various sectors. Improving adaptation and resilience requires different actors at all levels of the real estate, building and construction sector value chain to mobilise and mix different skillsets and levels of expertise.

This GlobalABC "green paper" provides recommendations and takes stock of tools for actors in the RBC sectors to implement measures and what to consider in setting up an adaptation plan. All actors of the value chain are concerned and should make such plans a priority in the coming years.

Our hope is that this "green paper" will serve as a launching pad for discussions and debates on adaptation that will move the sector forward.

Soraya KHALIL,
Directrice of Quality and Technical Affairs Direction -
Ministry of National Territory Planning,
Urban Planning, Housing and City Policy - Morocco

Loïs MOULAS, ***CEO*** - **OID**

>> FOREWORD

This report is the first output of the **GlobalABC "adaptation" working group** (see appendix methodology), launched at COP24 in Katowice. During the GlobalABC meeting in Rabat in October 2018, the representatives of the Kingdom of Morocco and GlobalABC members expressed their mutual wish to see the challenges of climate change adaptation and the benefits of initiatives in the real-estate, building, and construction sector (referred to in this report as the RBC sector) be put in the spotlight, as up until now they have not been given due attention. The report was coordinated by the Green Building Observatory (OID, Paris) with the support of the French Ministry of Ecological Transition.

This report is the first component of a working plan including the organization of an upcoming **international conference on "Climate Change Adaptation in the Built Environment Sector"** to be hosted by the Kingdom of Morocco in 2021. This conference was announced in 2019 at COP25 in Madrid by Ms Nouzha Bouchareb, the Moroccan Minister of National Territory Planning, Urban Planning, Housing and City Policy. It was subsequently postponed due to the COVID-19 pandemic. The following report should therefore be considered as the background paper for this international conference, with the challenges and recommendations mentioned within the report serving to feed future debates on the subject.

This report also aims to establish a common strategic vision on climate change adaptation and its priorities. At the upcoming COP26 in Glasgow, key principles and actions will be announced to strengthen climate change adaptation in the RBC sector globally, and among key public and private stakeholders of the "construction-building-real estate" value chain, thereby promoting this common vision and further understanding.

The first section of the report deals with global challenges regarding adaptation of the built environment: definitions and relevance, macro-economic impacts (costs of adaptation vs non-adaptation) as well as the strong links between adaptation and mitigation in the RBC sector.

The second section highlights ongoing and necessary changes in the RBC sector to better integrate adaptation challenges: processes based on the building lifecycle, risk assessments, regulatory frameworks and stakeholder engagement, i.e. creating an enabling environment for change. This section introduces concrete actions to this end.

The third and most important section presents a framework for suggested action for key actors in the RBC sector. It summarizes specific challenges faced by each actor in adapting buildings to climate change and identifies the current global state of their practices along with recommendations for each stakeholder group in order to improve the adaptation of buildings to climate change. The action plan was informed by surveys and interviews held with relevant stakeholders and has been reviewed by sectoral organisations. Five challenges and five recommendations are presented, selected in order to focus on the most critical issues.

>> EXECUTIVE SUMMARY

Climate change is regarded as the major issue that humanity will face this century. Extreme weather events and failure to implement climate-change mitigation and adaptation actions are the two greatest risks that the global economy will face in terms of their likelihood and impact, according to the World Economic Forum (2019).

Climate change is reflected by two different kind of physical hazards:

- **Chronic hazards** with long-term impacts: average temperature, rainfall patterns, and sea level rise. The Earth's average surface temperature has risen by about 1°C from the period between 1850 and 1900. By 2100, the scientists involved in the Climeri-France research initiative foresee a **temperature increase of 7°C**. Moreover, in the next century sea levels will rise by several metres due to the thermal expansion of the ocean, and the consequences of this will only be observed further in the future as ocean system inertia leads to rising water levels.

- **Acute hazards** with short-term impacts: **heatwaves, storms, floods, landslides, droughts, and wildfires.** Stringent action is required to reduce greenhouse gas emissions as impacts of climate change are already being felt and will increasingly intensify if a radical shift is not made to follow a 1.5° C consistent pathway. In the meantime, the forecast of these climate events calls for a comprehensive approach that includes the implementation of adaptation measures regarding extreme events.

The built environment is particularly at risk from climate change, and as such so are the people living and working within buildings. Governments and all actors along the buildings and construction value chain therefore need to take action, as climate risks pose a real threat to the lives and economic activities of people. Buildings as long term assets should be resilient to climate change, and also to other future risks such as pandemics and potential behavior changes.

Despite the fact that potential direct or indirect damages and losses to real estate are considerable, the actors in the building industry are often caught between the urgency of the present and the demands of the future. Two questions emerge from this observation: how to encourage balanced decision-making in spite of uncertainty, and how to properly put together the timeline against which to enable the transition.

To answer these questions, the RBC sector must first be aware of the consequences of climate change specific to this sector:

- **We already know what the climate will be like in 2050: the inertia of the climatic system is such that** no matter how great the emissions reductions that may be achieved until then, the average temperature will be 1.5 °C to 2°C higher compared to the preindustrial era, and there will be a significant increase in the frequency of extreme climate events.
- The impact of climate change on buildings **is a threat to people's health and safety**: 800 million people in more than 570 coastal cities will be affected by a sea-level rise of 0.5 metres by 2050.
- Climate risks have an impact on both the structure of a building **and the economic activities** taking place within. Besides physical damages and economic operational losses, extreme events can **reduce a property's value** by 5% to as much as 20%. (UNEP FI 2018).

Although **climate projections** are available to better understand the extreme events that are expected to occur in the future, **legislation**, and in particular on norms and urban planning, do not currently **factor in these future climate risks. Climate uncertainty** is sometimes given as a reason to delay action, and although there is indeed an element of uncertainty in the reduction of greenhouse gas emissions, that alone is not reason enough to postpone action on climate adaptation. However, any action taken does need to allow for a margin of flexibility in order to accommodate various future scenarios.

Developing countries are highly affected by climate change and already having to confront and tackle this issue on a regular basis. The developed parts of the world are also feeling the impact - Canada, for example, is experiencing climate change-induced warming at twice the global rate, with its northern communities experiencing warming even faster.

Along with the knowledge acquired through the experience of developing countries and the resources available in developed nations, the RBC sector plays an important role in putting forward **knowledge and economic resource sharing**.

Adaptation and mitigation need to be pursued simultaneously. Implementing adaptation cannot mean giving up on mitigation measures. This is particularly relevant to the RBC sector because buildings are among the main emitters of greenhouse gases, responsible for 39% of energy and process-related carbon dioxide (CO_2) emissions in 2018 (GlobalABC 2019). Although many current measures contribute to both mitigation and adaption, some can be conflicting. For example, cooling systems are relied upon in order to maintain a decent temperature inside buildings during a heatwave. However, these cooling systems contribute to GHG emissions, therefore in order for cooling systems to meet both adaptation and mitigation objectives they must be designed to reduce their GHG emissions and be integrated into energy-efficient buildings.

Submersion and heatwaves are the two biggest risks to combat. Against these hazards, two main recommendations are put forward: limiting urbanization in risk-prone areas and anticipating the increasing needs for cooling (GSR 2019), and choosing more resistant foundations, structures, and materials.

Climate Adaptation in the RBC Sector: An Urgent and Necessary Shift

Adaptation aims to avoid the negative impacts of climate change by reducing climate vulnerability and increasing climate resilience. Hard resilience is characterised by an improved robustness and redundancy, while soft resilience is characterised by resourcefulness and rapid recovery.

The **climate hazard risk** of a system is based on its propensity to suffer damage because of climatic variations. In the RBC sector, this depends on the exposure of a building to various climate hazards and its vulnerability to them.

Exposure therefore depends on the asset’s location and will vary across global regions, countries, and land plots, since not all locations will be equally impacted. Elevation, impervious or permeable surfaces, distance to water courses…all these parameters have an impact on local climates. The exposure to climate risks is thus a direct result of our ability to mitigate climate change. **Vulnerability** is defined by the technical components, or building sensitivity, and economic, social and demographic factors. This includes construction choices, networks reliability, use of the building, adaptation measures, crisis management processes, and anticipation combined with prevention mechanisms.

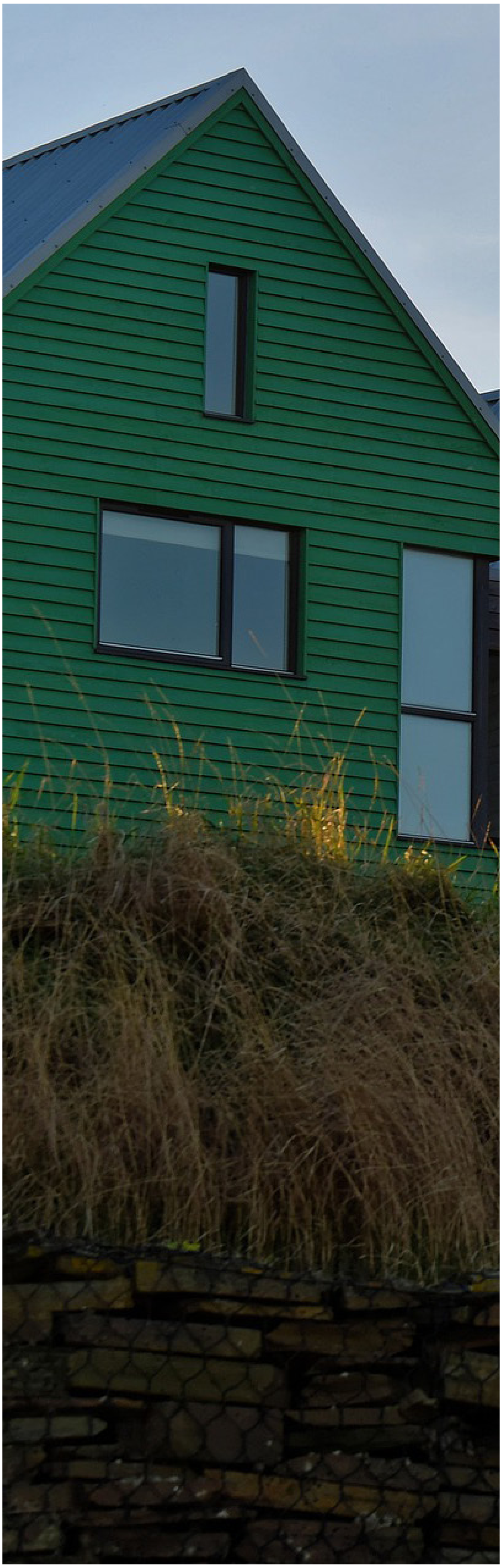
Adaptation to climate change should be factored into both the building's conception and the choice of its location. Although many adaptation measures may be implemented during the building operation, most will need to be designed with adaptation in mind from the very beginning in order to avoid construction that is not suitable to adaptation at all. Having an overall view of an upstream project necessitates mobilising all the actors that are involved in the different phases of a building's lifecycle. Therefore, **all actors along the built environment value chain need to undertake action towards adaptation**.

The cost of inaction will far outweigh the cost of taking action. Damages from climate change will cost more tomorrow than the implementation of their respective preventive actions today. The cost of inaction can be evaluated by estimating the financial risk without adaptation and comparing it to the financial risk with adaptation and the cost of adaptation itself. If, in the future, climate change is considered in insurance schemes and if the loss in financial value of assets are indexed to their use, the main parameters that will make a difference are:

- The costs of repairing damages caused by climatic events that would not be covered by future insurance schemes,
- The decrease in rental or property value of non-adapted assets,
- The energy demand that would be minimised in case of partial energy autonomy.

Adapting buildings to climate change requires developing a **culture of risk** and improving resilience, beyond regulations. It needs to be interconnected with **disaster management**, whether linked to climate-related events or not. **Access to insurance** may become more difficult if prices increase due to higher risks. Accordingly, adaptation and resilience measures should be considered from the outset, when setting insurance premiums.

Implementing adaptation measures in the **informal sector**, and in case of the **lack of ownership title** or lack of insurance are complex challenges to address. Specific measures are therefore required to protect the most vulnerable populations. Similarly, the adaptation of the **cultural sector and of heritage buildings** is an issue that must be considered since our world heritage may also be affected by climate change.



PART 1

Why Does Adapting Buildings to Climate Change Matter?

>> INTRODUCTION

The number of extreme weather events has increased by more than 250% since the period between 1980 and 2013, and this upward trend is continuing. Among the 100 fastest growing cities in the world, 84 are at an extreme risk from climate change. This comes with a human cost: by 2050, over 800 million people will be vulnerable to sea-level rise and coastal flooding if nothing is done. Other risks include heatwaves, droughts, a rise in average temperatures, coastal erosion, storms, forest fires, floods, landslides, rainfall patterns, clay and soil movements, and thawing permafrost.

The world is currently experiencing an unprecedented year with the **COVID-19 pandemic, a situation that has shown just how important resilience is and what such resilience should look like.** Resilience is also of particular importance to the building and RBC sector, since climate change will have a larger impact on it than the COVID-19 pandemic. This is because climate risks will affect all aspects of a building: its structure, uses, accessibility, provision of services, and also the safety, health, and well-being of its occupants.

GHG emissions of buildings need to be reduced. The sooner adequate action is taken, the lower the overall cost. In 2018, the IPCC stated that following a 1.5° C consistent pathway would require:

- A building emissions reduction of 80–90% by 2050
- Entirely fossil-free new constructions, reaching near-zero energy by 2020
- A raise in the energy refurbishment rate of existing buildings to 5% per year in OECD countries
- However, staying under a +1.5°C global temperature increase is no longer possible, as the objective to reach near-zero energy in new construction was not reached by 2020. At present, staying under 2°C is still achievable, but the longer the sector waits to make a transition the more abrupt this transition will have to be.

Independently of our success in maintaining a below 2°C trajectory, the impacts of climate change are already felt and will continue to grow in intensity and frequency. The benefits of adaptation measures will be directly felt by the users: improved comfort, resistance to natural disasters and health are few amongst many examples. Adaptation measures for buildings may contribute to climate mitigation, as showcased by passive cooling solutions, but may also release GHG: the number of air conditioning systems has increased by 40% from 2010 and may reach 5.6 billion in 2050, up from 1.6 billion today (Climate Chance 2019). This need can be answered by acting on the building envelope through passive solutions (see GlobalABC roadmaps).

Adaptation to climate change is recognized as a global issue (Paris Agreement, 2015), and climate change is also integrated in standard risk management at the international level (Sendai Framework, 2015). For instance, Article 7 of the Paris Agreement establishes that adapting to climate change is as important as mitigating is.

Yet most countries do not have in place explicit measures to improve the adaptation of buildings to climate change. If such policies are not established, adaptation will remain inaccessible to the majority of the global population, as increased adaptation expenditure in the RBC sector currently favours populations that are already relatively privileged, as poorer people will find it difficult to pay for the necessary adaptation investments. The informal sector (slum areas or substandard and unsafe housing) will be more subject to vulnerability. Similarly, specific measures must be implemented to protect the most vulnerable populations in the case of a lack of ownership title and insurance.

INTERNATIONAL ADAPTATION-RELATED ORGANIZATIONS AND INITIATIVES

CLIMATE CHANGE

UNFCCC

- **The Paris Agreement** (2015) introduces a **Global Goal on Adaptation** addressing both “adaptation” (art. 7) and “loss & damage” (art. 8), thereby recognizing adaptation as a global issue. Governments should regularly provide **Adaptation communications** (Art 7. 100, 11) publicly accessible here (Art 7.12).
- The **Adaptation Committee** (2010) provides support and technical guidance to parties.
- **Technical Examination Process on Adaptation** (TEP-A) identifies concrete opportunities for strengthening resilience, reducing vulnerabilities, and increasing the understanding and implementation of adaptation actions.
- Developing countries are invited to complete **National Adaptation Plans** (NAP).

Adaptation related multilateral funds

- **Adaptation Fund** (AF, 2001) supports concrete, small-scale adaptation projects in favor of the most vulnerable people in developing countries.
- **Green Climate Fund** (GCF, 2010) supports both mitigation and adaptation projects in developing countries.

Initiatives

- **Global Commission on Adaptation** (2018), convened by 17 countries, seeks to accelerate adaptation action and support and is backed by the **Global Center on Adaptation** (GCA), funded by the Kingdom of Netherlands.
- **Global Alliance Buildings and Construction** (2015) launched at COP21 and convened by 30 countries and the private sector, seeks to facilitate the transition towards efficient and resilient zero emission buildings (GlobalABC).

DISASTER REDUCTION

UNDRR

- The “**Sendai framework on disaster risk reduction 2015-2030**” under (UNDRR) builds a larger resilience framework that is, however, limited to extreme events. Chronic climate change-related events are therefore not included in the framework.

Multilateral funds related to disaster reduction

- **Global Facility for Disaster Reduction and Recovery** (GFDDR) is a grant-funding mechanism managed by the World Bank that supports risk management projects aimed at reducing vulnerability to natural hazards and climate change.

Initiatives

- The **InsuResilience**, initiated by the G7 and adopted by the G20, has been focusing on disaster risk finance and insurance solutions to provide insurance coverage against risks arising from climate change to a large number of additional beneficiaries. The **InsuResilience Global Partnership** for Climate and Disaster Risk Finance and Insurance Solutions (IGP) aims at supporting indirect insurance solutions. The World Bank established the **Global Risk Financing Facility** (GRiF) to provide technical assistance.
- **The Coalition for Disaster Resilient Infrastructure** (CDRI, 2020) is a global partnership that aims to promote the resilience of new and existing infrastructure systems to climate and disaster risks, thereby ensuring sustainable development. CDRI is championed by the Government of India and seeks to rally stakeholders towards addressing the issue of promoting investments in resilient infrastructure on a global scale.

1. Definitions

CLIMATE

A statistical description of weather in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period for averaging these variables is **30 years,** as defined by the World Meteorological Organization.

- Weather and climate change

The atmospheric conditions that comprise the state of the atmosphere in terms of wind, temperature, cloudiness, moisture, pressure, cloud and precipitation, etc. Weather reflects short-term conditions of the atmosphere while climate is the average of these conditions over a long period. Climate change makes some aspects of weather forecasting more difficult as some patterns have never been experienced before. Climate change and weather do not always correlate: Weather variability might for instance result in colder temperatures during a particular year in Northern regions even if the climate is warming.

- Global warming and climate change

Global warming" refers to the long-term and non-linear warming phenomenon of the planet; since the pre-industrial period (1850-1900) the average surface temperature has risen by over 1°C. "Climate change" encompasses global warming, but refers to the broader range of changes that are happening to our planet, such as sea level rises, biodiversity losses, extreme weather increases, the rapid deglaciation of polar ice, etc. Climate change also means more climate instabilities and uncertainties.

CLIMATE MITIGATION

Action to limit the magnitude or rate of global warming by directly addressing the causes of climate change. This includes measures aimed at reducing the sources of greenhouse gases (GHGs) or enhancing their sinks. It is important here to note the delay between action and response: even if the concentration of greenhouse gases in the atmosphere stabilises in the few next years, the warming trend will not immediately level off because of climate inertia (IPCC, 2018). Similarly, sea levels are already set to rise for several centuries.

CLIMATE ADAPTATION

The process of adjustment to an actual or expected climate and its effects. The objective of adaptation is to anticipate, reduce, and avoid the impacts of climate change by making current systems less vulnerable and more resilient. Adaptation to climate change also encompasses the ability to seize opportunities raised by climate change.

- Setting up an adaptation plan requires evaluating a combination of socioeconomic and physical conditions. Such a plan must be implemented through a continuous, systemic and local approach. Unlike mitigation which is based on objective scales, adaptation depends on context, definition, and operationalisation.
- Mitigation and adaptation strategies may go in the same direction or, conversely, contradict each other. For instance, adding cooling systems may be a part of adaptation strategies, but the resulting increase in energy consumption collides with mitigation strategies.
- Adaptation provides a good incentive for design innovation and adapted architectural and engineering solutions, as it has a direct and visible impact on building construction.

CLIMATE MALADAPTATION

An increase in vulnerability caused by the implementation of mis-designed adaptation measures: adaptation that would postpone the risk while in fact increasing it, implying an inefficient use of resources such as with cooling systems (increasing GHG emissions); transfer of risk from one actor to another; transfer of risk to future generations; etc.

CLIMATE RESILIENCE

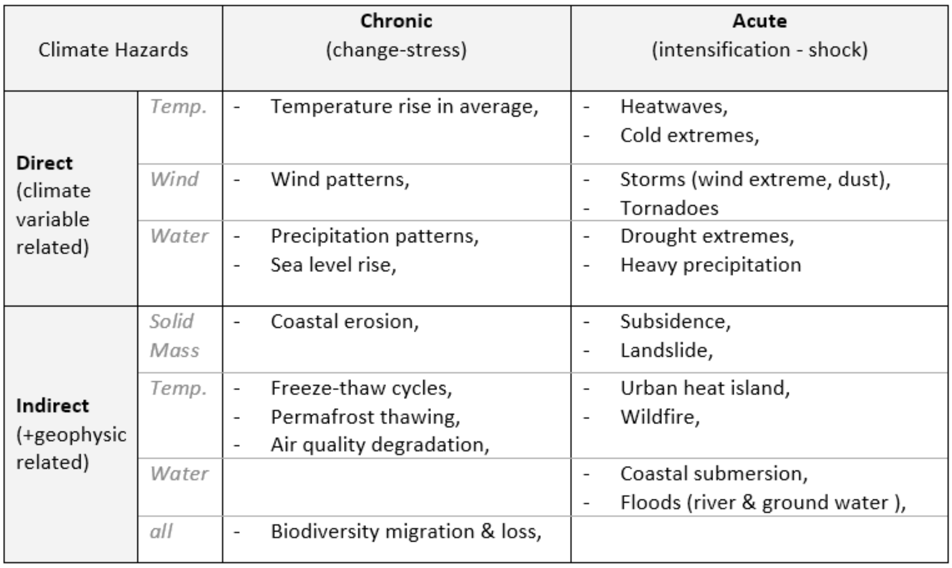
The capacity of a system to absorb stresses and maintain its functioning in the face of climate change. The techniques used to adapt, reorganize, and evolve to an improved state that is more desirable and sustainable include societal and governance dimensions. The components of resilience are summarized by the 4Rs (Bruneau et al., 2003): **Robustness (Inherent strength, Resistance), Redundancy** (property to allow Alternative options, Substitutions), **Resourcefulness** (Capacity to mobilize needed resources), and **Rapid Recovery** (Speed to overcome disruption & restore services).
Robustness and Redundancy form the "hard" resilience (hardening solutions). Resilience can be evaluated at the individual building scale or at the overall community level.

CLIMATE RISK

The possibility of being negatively impacted by climate change. This type of risk is assessed by investigating the interaction between the potential of climate change negative impacts related to the climate vulnerability of a system, and its exposure to a physical climate hazard (IPCC). Climate risks can be reduced by enhancing adaptive capacity and strengthening ecological, societal, and economic resilience.

Climate risks can be divided into two categories :

- **Physical climate risks**: Risks that are directly linked to physical hazards that can affect the value of assets. They can be chronic (slow onset shift, such as change in radiative forcing, change in average temperature, change in rainfall patterns and sea-level rise) or acute (events driven by climate change such as the intensification of heatwaves, storms, floods, marine submersion, landslides, droughts, and wildfires). Climate change also affects biodiversity (loss of marine biodiversity due to ocean acidification and water temperature increase, loss of species due to changes in natural habitats), which in turn affects the ecosystem functions, thereby posing a threat to the most vulnerable populations. [...]



Climate Hazards		**Chronic** (change-stress)	**Acute** (intensification - shock)
Direct (climate variable related)	*Temp.*	- Temperature rise in average,	- Heatwaves, - Cold extremes,
	Wind	- Wind patterns,	- Storms (wind extreme, dust), - Tornadoes
	Water	- Precipitation patterns, - Sea level rise,	- Drought extremes, - Heavy precipitation
Indirect (+geophysic related)	*Solid Mass*	- Coastal erosion,	- Subsidence, - Landslide,
	Temp.	- Freeze-thaw cycles, - Permafrost thawing, - Air quality degradation,	- Urban heat island, - Wildfire,
	Water		- Coastal submersion, - Floods (river & ground water),
	all	- Biodiversity migration & loss,	

Direct risks depend directly on climate variables and can be captured by climate modelisation. Indirect risks depend also on local geophysical context which may mitigating or aggravating the risk.

- **Transition climate risks** are related to the potential changes in the regulatory environment and public policies landscape affected by technology, and other market forces. These changes are made in response to climate change, in order to mitigate or adapt the RBC sector and the land use industry. They are implemented to decrease physical risks but can have a financial and reputational impact.

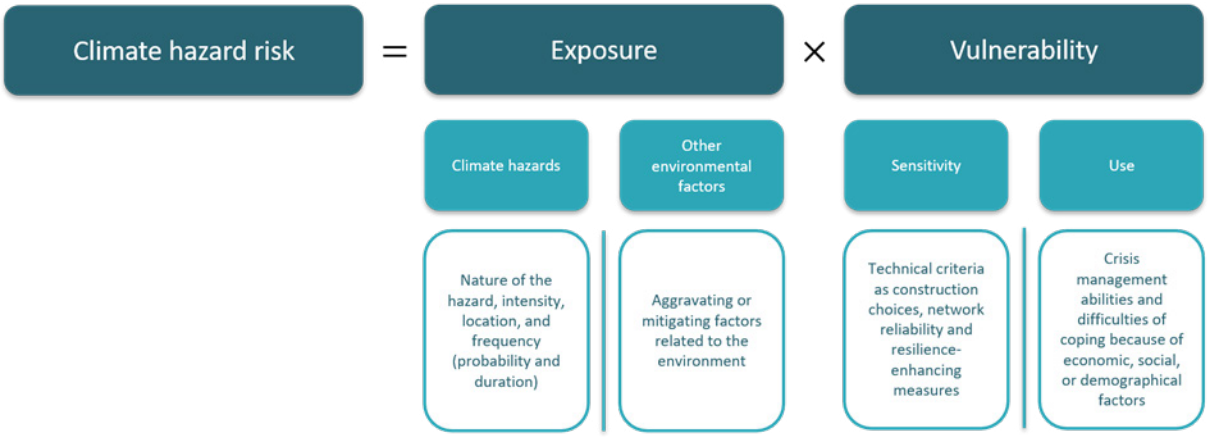
The relative share of transition and physical risks will depend on the increase of temperatures. If global warming is maintained below 1.5°C by the end of the century, transition risks are expected to be relatively high (due to stringent policies to limit GHG emissions in order to limit climate change), while physical risks are expected to be relatively low as climate change is limited. On the other hand, if global warming reaches 4°C or more, physical risks are expected to be high and transition risks are expected to be low as it would imply that political measures to limit GHG emissions were not implemented or that they were not strict enough.

CLIMATE VULNERABILITY

Propensity or predisposition to be adversely affected by climate change and to suffer damages in the event of climatic variation. Vulnerability is a function of the sensitivity of the building to this hazard.

- **Exposure to a climate hazard**: Identification of the impacts of climate change that will affect a building as well as the people relying on it. It varies according to the location of a building and its immediate environment, as well as its land plot and microclimate. Exposure is determined by the geographical location of the asset, which will determine the likelihood of it being affected by a climate hazard and also the intensity of the impact (UNEP FI 2019). The environmental factors either aggravate or mitigate the risk of being affected, depending on the vulnerability of the territory.
- **Sensitivity to a climate hazard**: Degree to which a building could be affected by a considered climate hazard if subjected to it. Sensitivity depends not only on the characteristics of the building (technical criteria and resilience-enhancing measures) but also on the resilience of essential networks, the crisis management abilities and the capacity to cope and adapt.
- **Coping capacity**: Ability to limit the adverse effects of a phenomenon related to climate change in the short and mid-terms, with existing resources.
- **Adapting capacity**: Ability to limit the adverse effects of a phenomenon related to climate change in the mid to long-term.

Figure 1: Assessment of buildings vulnerability to a climate hazard, OID



Impacts of climate change on the building sectors

TRANSITION RISKS

Climate risks **reduce** attractiveness of assets that have not incorporated climate adaptation measures in the long run.

Climate **regulation** reduces attractiveness of assets that have not incorporated climate mitigation.

Changes in the availability of key **resources** (energy and water for example) can increase costs to adapt to this scarcity and reduce net operating income.

Regulation and taxes to address climate change result in increased cost in building management.

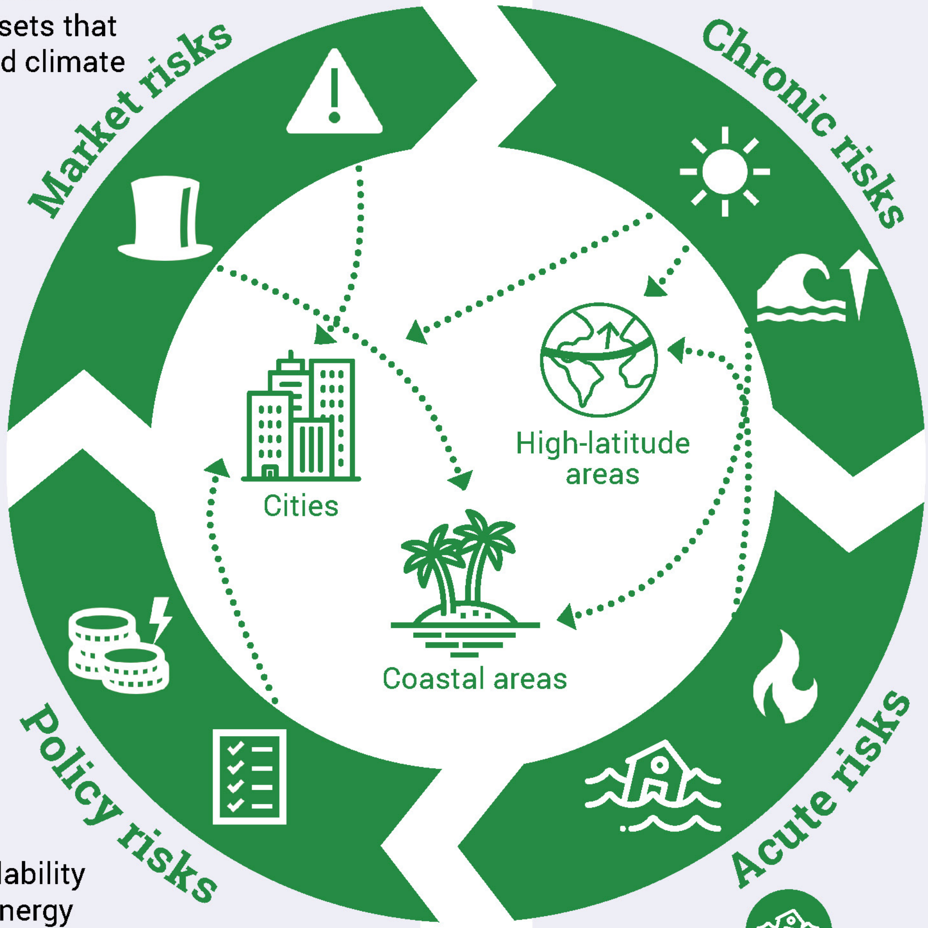
PHYSICAL RISKS

Heatwaves will impact high and middle latitude areas. Urban artificialisation put cities particularly at risks.

Sea level rise will affect coastal cities and small islands.

In many parts of the world, **intense precipitation** combined with urbanisation will damage buildings.

Fires will become more frequent because of more intense and longer droughts.



Source : OID, december 2020

2. Identifying the Impacts of Climate Change on the RBC sectors and the Major Regions at Risk

2.1 CLIMATE CHANGE IMPACTS AND THE RBC SECTORS

Climate change has caused a shift in the traditional way in which natural risks are addressed.

The RBC sectors refer to a definition set by the World Business Council for Sustainable Development in its report "Building system Carbon framework – a common language for the building and construction value chain" (WBCSD, 2020). It includes all those who produce materials (material companies), who design and construct buildings (architects, consulting engineering companies), and who own and operate them (property developers and property managers). It also includes those who finance and insure the assets (investors and asset managers, insurers and reinsurers), and regulators (national and local governments). Climate change impacts every single actor in the RBC sectors.

One of the main goals of the RBC sectors is to provide safe living spaces, particularly in the face of natural risks such as landslides, flooding, earthquake, and hurricanes. To ensure a certain level of comfort, the sector uses technical methods that ensure robustness in the construction in order to avoid the effects of certain natural hazards. These methods are implemented according to historic experience (records of past climate events and statistics of climate hazards).
At present, structural and fire safety are the key components of building codes. Buildings are therefore largely unsuited to face extreme climate events, and insurance is only taken out in case of damage. In the case of urban codes, although rules regarding urban planning are intended to prevent construction in locations exposed to hazards, implementation is poorly controlled.

"Climate change" introduces a shift :
The current climate measures in place within the RBC sector are no longer sufficient, as relying on past climate data and knowledge no allows for the design of safe buildings that can face the uncertain climate of the future.

Extreme events are changing in frequency and intensity. Until very recently Category 5 hurricanes were considered more hypothetical than real. The increasing frequency therefore of Category 4 hurricanes becoming Category 5 is a clear illustration of the alarming rise in intensity of extreme events.

The intensity and frequency of such events will continue to change depending on emissions scenarios. Similarly, the impacts of chronic climate change, such as heatwaves sea-level rise, will amplify in the next century. **These changes will** have a major impact on buildings that are not in a suitable state to be exposed to such temperatures or rising water levels.

In the following graph, ULI offers a **global approach of physical and transition risks for real estate**.

	Category	Potential impact
Physical risks	**Catastrophic events** Extreme weather such as hurricanes and wildfires.	• Costs to repair or replace damaged or destroyed assets; value impairment • Property downtime and business disruption • Potential for increased insurance costs or reduced/no insurance availability
	Changes in weather patterns Gradual changes in temperature and precipitation—such as higher temperatures, rising sea levels, increasing frequency of heavy rain and wind, and decreased rainfall—which are likely to exaggerate the impact of catastrophic events.	• Increased wear and tear on or damage to buildings, leading to increasing maintenance costs • Increased operating costs due to need for more, or alternative resources (energy and/or water) to operate a building • Cost of investment in adaptation measures, such as elevating buildings or incorporating additional cooling methods • Potential for increased damages from catastrophic events • Potential for increased insurance costs or reduced/no insurance availability
Transition risks	**Market** The possibility that markets vulnerable to climate change will become less desirable over time. Rising capital costs to pay for building and maintaining infrastructure to manage climate risks.	• Reduced economic activity in vulnerable markets • Reduced occupier demand for properties • Reduced asset value • Potential for increased real estate taxes
	Policy and regulation Regulations to address climate change—e.g., climate risk disclosure, tougher building standards, carbon pricing, emissions caps, changes to subsidies—as well as changing policies for providing funding for infrastructure or rebuilding after major events.	• Increased cost of doing business due to new disclosure requirements and compliance measures • Increased taxes—both those resulting from public policies such as carbon taxes and those for funding adaptation infrastructure • Loss of subsidies or other funding opportunities • Additional capital investment to comply with stricter regulation
	Resource availability Changes in the availability of key resources such as energy and water, including water scarcity.	• Increased costs and reduced net operating income due to higher prices for water and energy • Additional capital expenditures to adapt buildings to operate with reduced/alternative resources
	Reputation and market position Growing stakeholder preference to work with companies incorporating climate risk into investment decisions, and consumer preference for real estate products incorporating climate mitigation.	• Risk to company brand and reputation if no action taken • Lower liquidity and/or reduced attractiveness of assets that have not incorporated climate mitigation

Figure 2: Types of climate risk and their potential impact on real estate (Source: ULI 2019)

In the context of climate change, the RBC sectors will be facing more uncertainty and will have to manage more risks in the coming years and decades. **Building norms therefore need to be adjusted in order to respond to these new levels of risk,** and new management rules will need to be introduced in the areas exposed to higher risks, for example those facing permanent coastline retreat. Measures introduced in new regulation could include building bans, land-use change, obligation to provide upgrades, etc.

To face a rising level of stress, RBC sector private stakeholders could be waiting for new regulation and adjustment of norms that would set minimal common obligations only and which is a long process. However, be more pro-active would be in their best interest as buildings will not withstand all disasters. Waiting for action would not only postpone the investment but also increase the amount to rebuild. In the case of a late decision, the remaining question is how to be prepared to build back better and be more resilient in case of climate related disaster?

While the RBC sector has the responsibility to protect humanity from assaults from the environment, including chronic or acute climate events, the **future climate conditions are not yet taken on board at all levels of decision-making, and particularly at regulatory levels**.

Climate change has impacts on the whole life cycle of a building: designing, construction, owning and operating buildings, financing and insuring the assets.

Several players of the RBC sector must then be involved in the redefinition of public policies and norms. **This report therefore concerns all the actors of the RBC sector: governments, local authorities, investors & asset managers, property developers, insurers & reinsurers, architects, consulting engineering companies, material companies, and property managers.**

2.2 MAJOR REGIONS AT RISK : CLIMATE IMPACTS ON THE MOST VULNERABLE REGIONS AND THE TYPES OF RISKS

While all regions already face risks (in particular, urban areas with heatwaves and coastal areas with submersion) South-East Asian, African and small island countries remain the most vulnerable, as poverty limits the capacity to act against these risks.

In all regions concerned the stakes for cities are particularly high, as they potentially concentrate factors of risks such as artificialized urban areas (aggravating impact of heatwaves and floods) or coastal location (exposing population to marine submersion).

Potential Impact of Climate Change On Cities by 2050

- *1.6 billion people living in more than 970 cities will be regulary exposed to extreme high tempertatures*
- *Over 800 million living in 570 cities will be vulnerable to sea-level rise and cost flooding*
- *650 million, in over 500 cities, will be at risk of water shortages*
- *2,5 billion people will be living in over 1,600 cities where national food supplies will be threathened*
- *The power supply to 470 billion people, in over 230 cities, will be vulnerable to sea-level rise*
- *215 million poor urban residents living in slum areas in over 490 cities will face disproportionate climate risks*

(UCCRN, 2018)

Impacts in cities can be exacerbated by the urban heat island effect, increasing average temperatures above regional norms. These heat islands are artificial urban microclimates in which maximum day-- and especially night-- temperatures are higher than in nearby, less urbanized areas. This phenomenon is linked to several factors: the thermophysical properties of materials used for buildings and roads, the nature of the soil (mineralized soils, absence of vegetation), urban morphology, and the release of heat from human activities (engines, heating, and air conditioning systems, etc.).

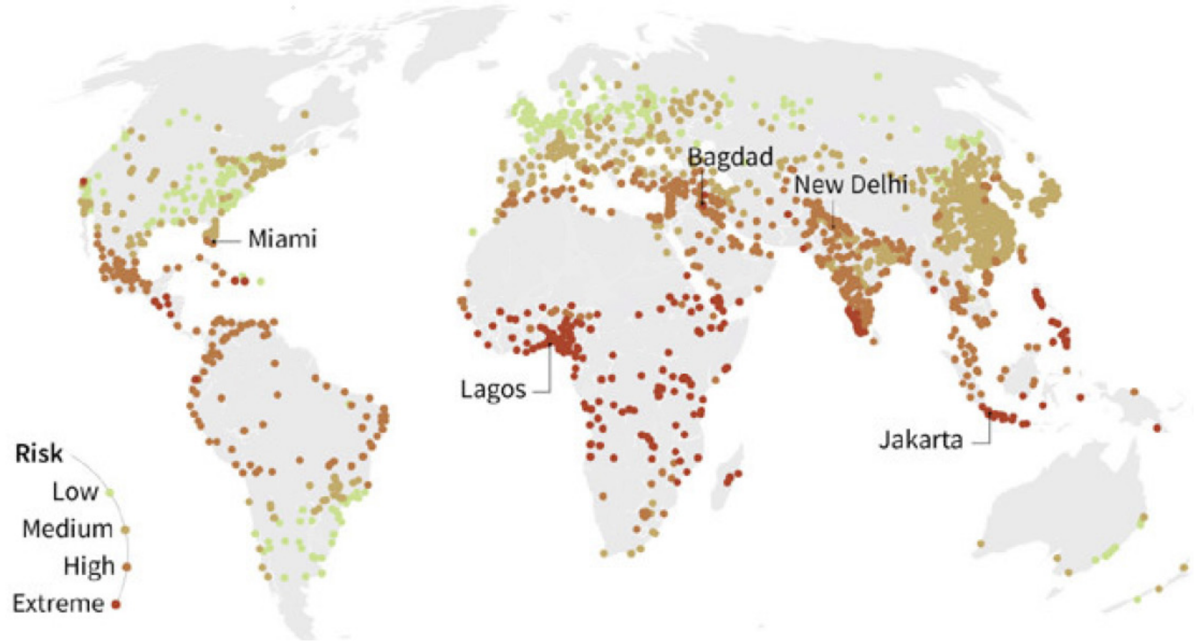
As a result, we observe an amplifying effect of the heat waves themselves due to climate change.

Increasing soil artificialization restrains the fight and climate change and decreases resilience to climate hazards. Global building floor surface is expected to double by 2060 as urbanization accelerates, particularly in Asia and Africa (GlobalABC GSR 2016). Rapid and massive artificialization of soils destroys local biodiversity and prevents natural cycles, such as water or carbon cycle, from performing their regulatory functions.
On the other hand, preserving open grounds enables to grow vegetation that helps decrease outdoor temperatures. This plays a non-negligible role in the **absorption of rainwater in the event of flooding or intense rainfalls**.

Exposure to chronic and acute risks also depends on location. The figure below displays the relative climate impact vulnerability to cities around the world (Verisk Maplecraft, 2019). Cities that are nearer the equator are subject to extreme risks, and coastal cities are also more vulnerable than cities inland at the same latitude.

CITIES AT RISK FROM CLIMATE CHANGE

Estimates of the vulnerability of larges cities



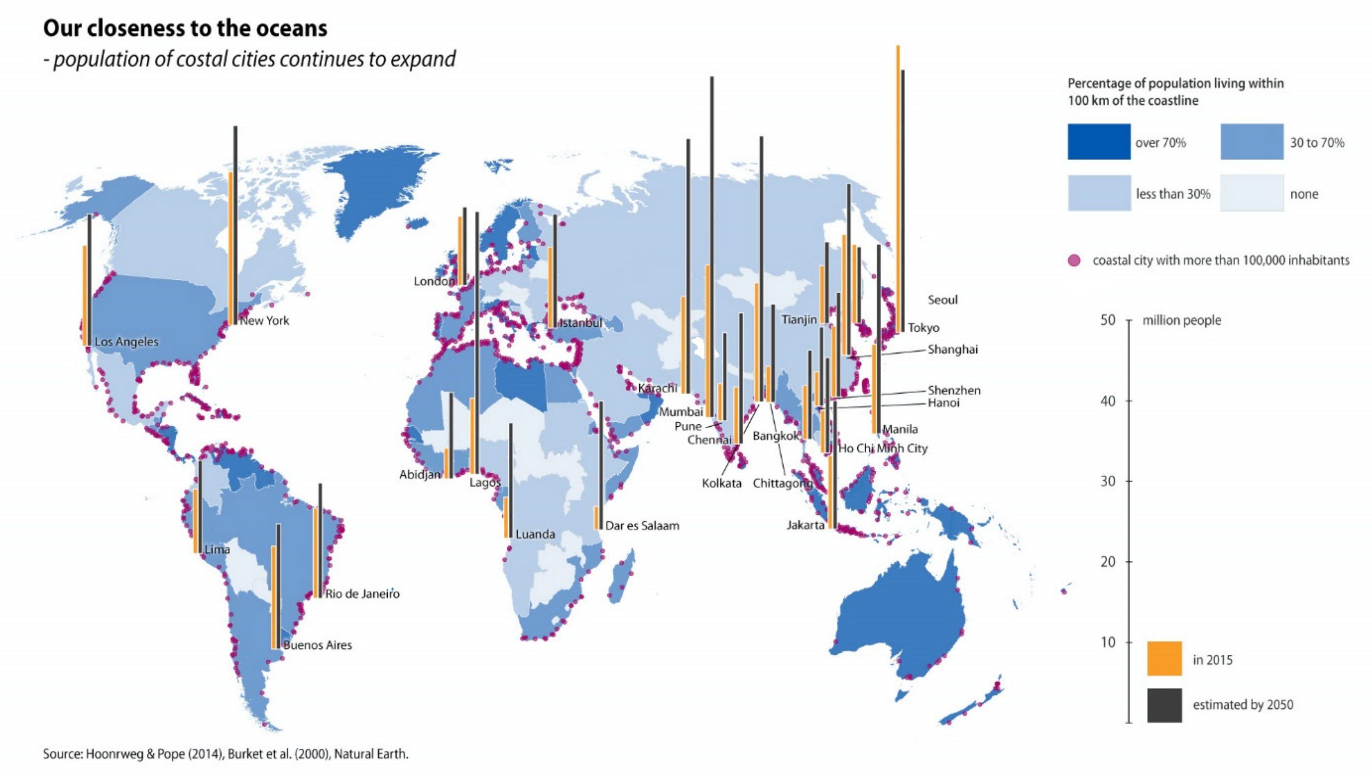
this map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area

Figure 3: Estimates of climate change vulnerability of large cities (source: Verisk, 2019)

Coastal cities are particularly vulnerable to climate change impacts such as severe storms and sea-level rise. The majority of big cities are built in coastal areas and are becoming increasingly more populous. The overpopulation of these cities combined with their closeness to the ocean make them particularly at-risk to climate change. The main impacts of sea-level rise and submerging cities are submergence and flooding of coastal land, saltwater intrusion into surface waters and groundwater, increased erosion, and dire social and economic repercussions. Beyond people and buildings, infrastructure will be affected: roads, railways, ports, sanitation and drinking water pipelines and reservoirs, and even mass transit systems.

Coastal cities on all continents will be affected by sea-level rise, some will be hit harder than others. Of these, Asian cities will be the most concerned, as every four out of five people potentially affected by sea-level rise will be living in East or South Asia: Shanghai, Hong Kong, and Osaka are among the most potentially impacted cities, with 17.5, 8.4 and 5.2 million people affected respectively. Africa is also highly threatened due to rapid urbanization in coastal cities and the crowding of poor populations in informal settlements along the coast. In Europe three-quarters of all cities will also be affected by rising sea levels, especially those in the Netherlands, Spain and Italy. Globally, even if we collectively manage to keep global temperatures from rising to 2°C, by 2050 at least 570 cities and some 800 million people will be exposed to rising sea levels and storm surges.

However, this is not just a future problem and some coastal cities are already being affected. Over 90 US coastal cities –particularly those located on the East and Gulf coasts-- are already experiencing chronic flooding, with the number expected to double by 2030. “Delta cities” a sub-category of coastal cities, are already the worst affected by sea-level rise, and over 340 million people live in deltas cities like Dhaka, Guangzhou, Ho Chi Minh City, Hong Kong, Manila, Melbourne, Miami, New Orleans, New York, Rotterdam, Tokyo, and Venice.



Our closeness to the oceans

- population of costal cities continues to expand

Source: Hoonrweg & Pope (2014), Burket et al. (2000), Natural Earth.

this map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area

Figure 4: Projection of population in coastal cities over the world (source: Natural Earth, 2014)

Developing countries, and within them the most vulnerable populations, already are and will be more affected by climate hazards (UNISDR 2009). For small island developing states, such disasters are an existential threat (United Nations 2015). Cities most at risk are located in Asia, Africa and South America. Therefore, among all regions that are particularly concerned, South-East Asian, African, and small island countries remain the most vulnerable, as poverty limits the capacity to act. As an example, according to the index of climate risks produced by GermanWatch (2018), Sri Lanka, Puerto Rico and Dominica are the most affected.

In middle-latitude cities, such as in European and north and south American countries, one of the major issues facing buildings is their non-adaptation to high temperatures. Due to stability of the climate in the past centuries, buildings were designed to deal with relatively low temperatures, a fact that makes them unsuited to facing heat. The inability of cities and buildings to face increased heat will result in significant comfort issues and, in some cases, social and sanitary problems.

However, although improving the **adaptation of cities to climate change is essential**, it alone will not be sufficient to provide sustainable living conditions. City Climate change resilience is linked to the resilience of their rural surroundings, but as **increased climate risks in rural areas** deteriorates the economy in these areas, the resulting increase in **the migration towards** cities may increase the latter's vulnerability.

Mitigation and Adaptation Solutions to the Challenges of Tomorrow's Buildings

When selecting the measures to implement to fulfill the requirements of tomorrow's buildings, **mitigation and adaptation must always be considered together.**

- ⌂ adaptive measure
- GHG mitigation measure

Adapted to the local environment

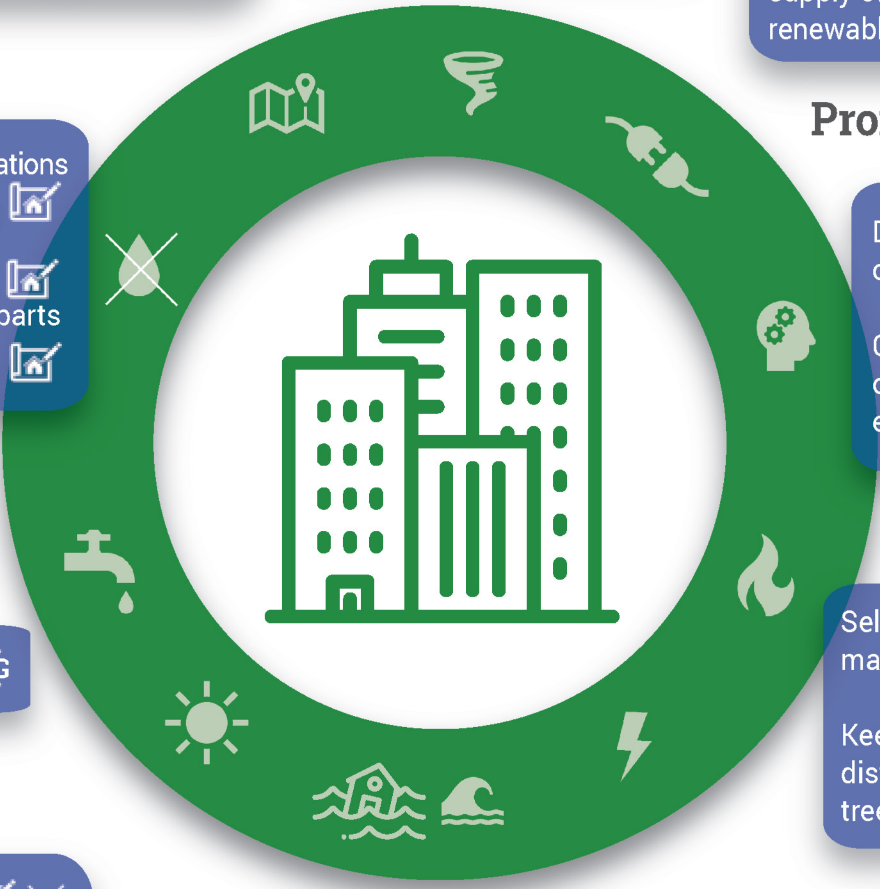
- Orient the building to limit summer sunlight → ⌂ GHG
- Select local and bio-sourced building materials → GHG
- Adapt vegetation to the local climate → ⌂ GHG

Resistant to storm

- Anchor outdoor furniture and roof equipment → ⌂

Limited dependency on power grids

- Rely on self-consumption of geothermal energy → ⌂ GHG
- Use local energy supply of renewable energies → ⌂ GHG



Resistant to Expansive soils

- Adapt the building's foundations → ⌂
- Strengthen the structure → ⌂
- Disconnect the different parts of the building → ⌂

Promoting disaster preparedness

- Develop common areas → ⌂
- Create an area of refuge in each building → ⌂

Limited dependency on water supply networks

- Reuse rainwater → ⌂ GHG

Fire-resistant

- Select fire-retardant materials → ⌂
- Keep the safety distances between trees and buildings → ⌂

High thermal comfort

- Use high albedo coating → ⌂ GHG
- Install green roofs → ⌂ GHG
- Equip facades with shading devices → ⌂ GHG
- Plant trees → ⌂ GHG
- Reduce the windows-to-wall ratio → ⌂ GHG
- Use natural ventilation → ⌂ GHG

Resistant to flooding

- Elevate the building above base flood elevation → ⌂
- Use waterproof materials → ⌂
- Protect the building's openings → ⌂
- Limit soil sealing → ⌂ GHG

Limited energy consumption

- Ensure a good building insulation → ⌂ GHG
- Select energy-efficient systems and equipment → ⌂ GHG

Source : OID, december 2020

3. Synergies with Mitigation, Adaptation, and Disaster Risk Reduction

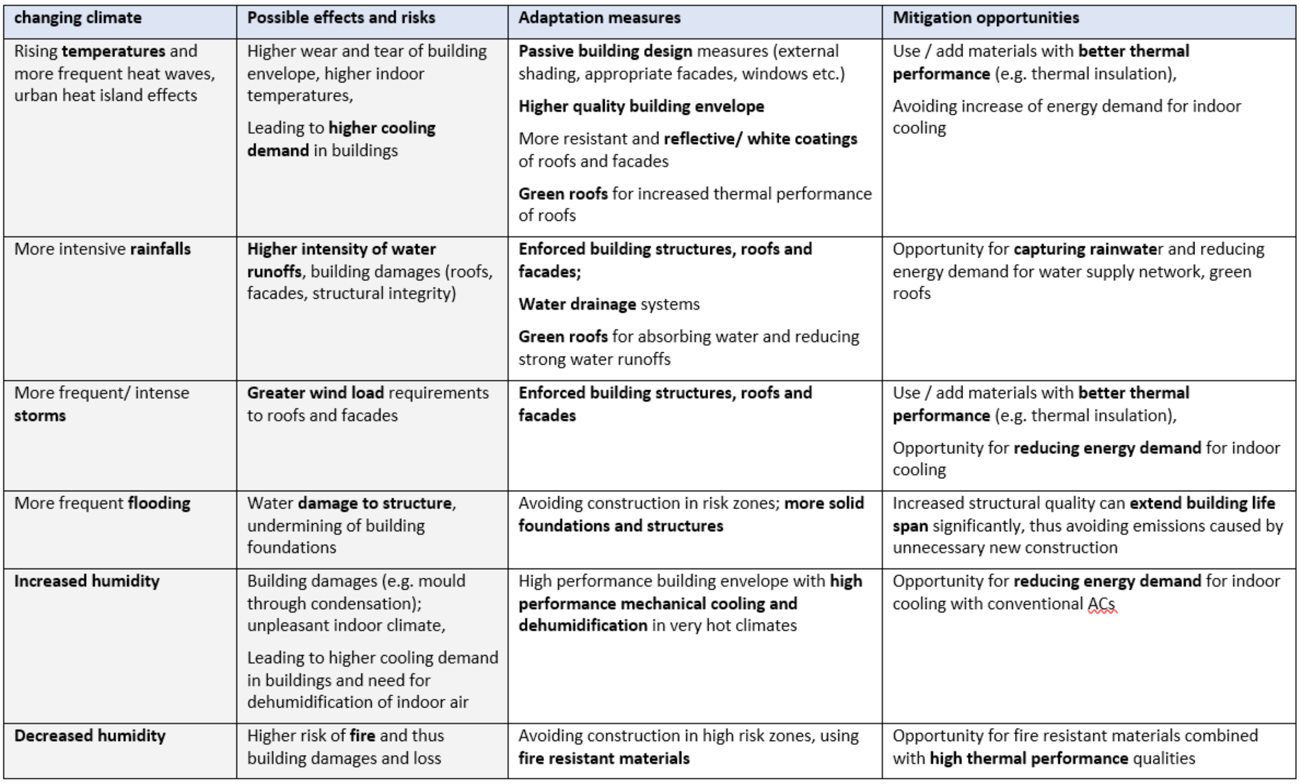
These inter-relations between mitigation, adaptation, and disaster risk reduction are particularly strong in the RBC sectors since it is both a driver of climate change and one of the sectors that will suffer the most from its consequences. The measures put in place must therefore comply with multiple criteria, designed to achieve simultaneous mitigation, adaptation, and disaster risk reduction.

3.1 CLIMATE CHANGE ADAPTATION AND MITIGATION

Adaptation and Mitigation must always be considered together. Adaptation aims to manage the unavoidable while mitigation seeks to avoid the unmanageable.

Considering adaptation alone without mitigation would imply a climate changing faster, with more climate change consequences. Adaptation would be necessary again, to adapt to more important impacts. A vicious circle, or feedback loop, would then be unleashed by this lack of synergies. Furthermore, preparing buildings for a changing climate and reducing emissions from buildings and construction to minimize global warming often go hand in hand, as they mutually re-enforce each other. Therefore, taking mitigation opportunities into account, when financing adaptation measures or vice versa is the most effective way to operate an RBC project.

Adaptation measures often represent an opportunity to add mitigation performance and inversely, as illustrated below:



changing climate	Possible effects and risks	Adaptation measures	Mitigation opportunities
Rising **temperatures** and more frequent heat waves, urban heat island effects	Higher wear and tear of building envelope, higher indoor temperatures, Leading to **higher cooling demand** in buildings	**Passive building design** measures (external shading, appropriate facades, windows etc.) **Higher quality building envelope** More resistant and **reflective/ white coatings** of roofs and facades **Green roofs** for increased thermal performance of roofs	Use / add materials with **better thermal performance** (e.g. thermal insulation), Avoiding increase of energy demand for indoor cooling
More intensive **rainfalls**	**Higher intensity of water runoffs**, building damages (roofs, facades, structural integrity)	**Enforced building structures, roofs and facades;** **Water drainage** systems **Green roofs** for absorbing water and reducing strong water runoffs	Opportunity for **capturing rainwate**r and reducing energy demand for water supply network, green roofs
More frequent/ intense **storms**	**Greater wind load** requirements to roofs and facades	**Enforced building structures, roofs and facades**	Use / add materials with **better thermal performance** (e.g. thermal insulation), Opportunity for **reducing energy demand** for indoor cooling
More frequent **flooding**	Water **damage to structure**, undermining of building foundations	Avoiding construction in risk zones; **more solid foundations and structures**	Increased structural quality can **extend building life span** significantly, thus avoiding emissions caused by unnecessary new construction
Increased humidity	Building damages (e.g. mould through condensation); unpleasant indoor climate, Leading to higher cooling demand in buildings and need for dehumidification of indoor air	High performance building envelope with **high performance mechanical cooling and dehumidification** in very hot climates	Opportunity for **reducing energy demand** for indoor cooling with conventional ACs
Decreased humidity	Higher risk of **fire** and thus building damages and loss	Avoiding construction in high risk zones, using **fire resistant materials**	Opportunity for fire resistant materials combined with **high thermal performance** qualities

Figure 5: Adaptation & mitigation synergies (source: GIZ, 2020)

Many features in buildings are multi-functional and their choice during the designing phase has multiple impacts. This is why building designs that take into account a changing climate are more complex than those that do not have to meet these requirements. The example of a building envelope is indicative: it ensures protection against water and wind, but also the transfer of vapor and heat, and is responsible for the control of air flow. At the same time, it has impacts on energy consumption, thermal comfort, indoor air quality, and resilience.

Here are three detailed examples of measures where mitigation, disaster risk reduction and adaptation co-benefit :

A) PASSIVE BUILDING DESIGN

Passive design can reduce the massive need for space cooling in hot climates. Facing more frequent and intensive heat waves that would put in danger vulnerable populations is a major adaptation challenge in the RBC sector. Cool buildings functioning without a high energy demand is required to limit greenhouse gas emissions while maintaining thermal comfort. According to the Programme for Energy Efficiency in Buildings (PEEB), **the key element to keep a building cool with the method of passive design are** :

- **Designing buildings that are adapted to the local climate to avoid high cooling demand**: this type of building design takes advantage of the site's surroundings. Orientation, shape, openings, and windows-to-wall ratio choices are determined to provide shade rather than expose the building to the sun. This design also focuses more on the performance of features related to the envelope and relies less on the use of mechanical equipment to provide building services like comfort or a healthy indoor space. High thermal performance of the envelope includes wall and roof high insulation, exceeding regulatory requirements, high performance glazing, sunlight protection from internal external shading and cool surface coating with high albedo and heat reflectance capacity. Other passive design features, such as natural ventilation, day lighting, rain harvesting, are also providing services by maximizing the benefit of natural surroundings. Providing an healthier environment while reducing the energy demand and therefore CO2 related emissions in case of the use of cooling appliances is a no-regret solution, valuable in all climate scenario. There are multiple kinds of hot climates that vary according to rainfall, humidity, and extreme meteorological events. The designs for energy efficient buildings differs for each of these climates.
- **Reducing cooling demand through efficient systems and appliances**: the remaining energy needs for cooling, lighting and household devices must be met by means of the most energy-efficient systems and equipment.
- **Replacing carbon-intensive energy supply with renewable energy**: where mechanical cooling and ventilation are still necessary, the required energy should be covered through renewable energy, district cooling systems, solar powered cold chains, or similar climate-friendly approaches.

In this way, buildings contribute to climate change mitigation as well as, especially in hot climates. Moreover, building services are less sensitive to the availability of infrastructure networks, and therefore are more resilient to disaster.

BIOCLIMATIC DESIGN

*The research project "Africa-Europe Bioclimatic Collaboration for the 21st Century " (see **ABC21**), founded by the European Commission and launched in 2020, aims at securing the validity of bioclimatic design approaches in the context of climate change.*

B) GREEN FEATURES: REVEGETATION

Revegetation refers to the voluntary process of replanting and reconstructing ground surfaces in areas that have been disturbed by human activity. This includes the installation of planted roof gardens. Revegetation is a powerful asset in the fight against climate change and can be implemented on multiple levels.

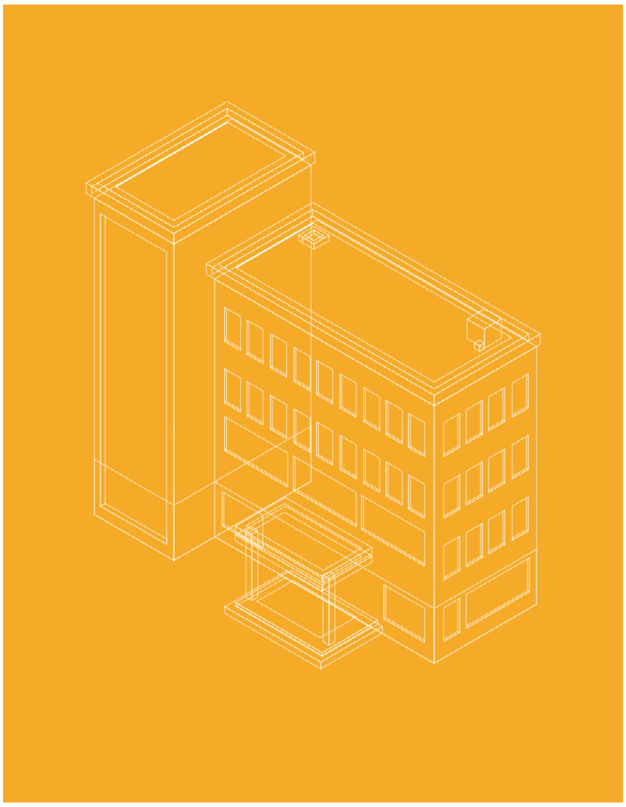
At urban level, revegetation operates through two processes: evapotranspiration and shading. Evapotranspiration is a part of photosynthesis and refers to the process by which plants lose water through evaporation and perspiration. The water that is lost is subsequently captured by the soil and leaves. When the water transforms into vapor it has a cooling effect on the surrounding environment due to the energy consumed in the process. Shading refers to the plant's interception of a portion of the solar rays descending on a given area. Shading the ground and the surfaces of buildings contributes to cooling down the urban microclimate, including surrounding buildings.

Another benefit from revegetation is the capacity it has to reduce flash flood impacts in case of heavy rains, thanks to the ground absorption of water. At the same time, the soil and other layers on the roof provide a thermal insulation and inertia contributing to the indoor thermal comfort. Better access to the roof also means better access to a higher floor, something that is potentially useful in the event of flash flooding as roofs can be safe areas during such events. Finally, vegetation is also valued for its secondary benefits: maintaining biodiversity, or the improvement of an area's aesthetic appearance, for example.

At buildings level, the extensive revegetation of roofs (of individual and collective buildings as well as sheds) is of interest because it can reduce the demand for air conditioning, especially if buildings are poorly insulated. Although their cooling potential is rather limited (less than 0.5°C on the air temperature at street level), the decrease in demand for air conditioning would result in the decrease of heat emitted by air conditioner units, thereby limiting heating at street level. While the energy performance of green roofs has been demonstrated at any time of the year, energy savings can increase by 12% in the summer if the green roofs are watered.

In terms of greening the city at ground level, below are a few key elements of the cooling potential of Nature-Based Solutions:

- The water resource for summer watering is a sine qua non for the cooling power of urban vegetation. Therefore, the assessment of water resource availability is a key element to consider upstream of any greening project aimed at regulating the micro-climate.
- The combination of different types of vegetation can enable action to be taken on the same adaptation objective or to mitigate different types of impacts.
- The higher the rate of vegetation is, the greater the cooling is, the better thermal comfort is and the lower demand for air conditioning is.
- Deciduous trees (trees that lose their leaves in autumn and winter) have a significantly higher effect on micro-climate regulation than herbaceous vegetation.
- Vegetation roofs should be favoured in areas where the ground surface is limited. Beyond their effect on building insulation, green roofs also have effects on the regulation of other urban services, such as rainwater regulation and the preservation of biodiversity.



C) PROMOTING DISASTER PREPAREDNESS

As climate change is leading to more frequent extreme events, and increasing physical robustness will not be able to cover all risks economically, adaptation to this new climate will require the development of a culture of risk as well as the development of social capital.

- **Communication to building users is essential to prepare for new eventualities** and to deal with them more effectively. This upstream communication allows to react quickly and in the right way, to be prepared in case of an extreme climate event, and more broadly to develop a culture of risk. Communication about extreme events can also foster communication about other topics, such as the behavioural changes needed to mitigate climate change.
- **Social capital, or the strength of social ties, is one of the factors that make a community resilient**. If the organization of spaces in buildings is thought out in advance to promote social exchange, this would help improve the resilience of the communities that occupy these buildings.

In certain cases, favouring investments that reduce the sensitivity of a particular space can be a wise choice. **If an entire building cannot be economically "climatic proof" then part of it could be designed as a shelter or refuge zone** for a specific type of extreme event. These zones would reduce the vulnerability of the building users' and eventually of the surrounding community. For example, in order to face heatwaves some buildings maintain cooling spaces. Similarly, higher areas could be adapted as refuge zones to cope with floods.

3.2 DISASTER RISK REDUCTION AND CLIMATE CHANGE ADAPTATION

Disaster Risk Reduction (DRR) is defined by UNDRR as "the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events".

Disaster risk reduction and climate change adaptation are both vital strategies for achieving the SDGs, as demonstrated by the inclusion of the Sendai Framework for Disaster Risk Reduction and the Paris Agreement in the 2030 Agenda. These strategies cannot be pursued in siloes (UNDRR, 2019). This provides a clear mandate to increase coherence between these two strategies that share common objectives.

Disaster risk reduction (DRR) and Climate Change Adaptation (CCA) are converging. DRR is shifting from response and recovery to awareness and preparedness: from short term actions (civil security, emergency) to a longer-term vision (development), from managing disasters to managing risks. These changes provide a strong basis for coherence and mutual reinforcement between CCA and DRR (OECD, 2020).

Climate change impacts on buildings

Technical impacts

Heatwaves – Lack of thermal comfort and sanitary issues (risks of hyperthermia and dehydration)

Flood Degradation and craking, **supply disurption**, water contamination

Strong winds – roofs blown off, structure damages injuries for users

Forest fires – Gas fuel propane supply may explode, highly dangerous for users

Coastal erosion – collapse of buildings, and risk of falling rocks.

Infrastructures & networks

Roads, bridges, power systems, telecommunication, water supply infrastructures, and other networks ensure the continuity of services in a building

Buildings supporting urban networks should be listed among the most **important infrastructures** to protect in case of climate hazard.

Economic & Social impacts

Non-anticipated relocation - communities being torn apart and families being separated, **Crisis, Distress, Unemployment**

21 million climate migrants every year

Informal housing industry - Buildings housing populations illegally are **more fragile.**

Over 1 billion squatters worlwide

Source : OID, december 2020

Public access buildings have a high importance :

1) Hospitals, schools or libraries offer important services to communities and constitute a safe zone for vulnerable populations.

2) To mitigate the economic, social, sanitary and human impacts of climate change, it is essential to create permanent or temporary areas of refuge within private and public buildings.

4. Climate Change Impacts on Buildings

Climate change affects buildings and in turn the human life and economic activities they host. Climate change impacts on buildings vary according to the nature of the hazard, the type of building, the use made of them, the vulnerability of occupants, the dependency to infrastructure network services, the urban coping context, and their cultural and social value.

At the level of buildings, technical impacts of climate hazards include different aspects that cover impacts on the building structure (safety) and the building use (building services). Impacts are also social, at the level of the RBC sectors, stressing costs and responsibilities all along the value chain, and of the whole society, causing breakouts in activities and potentially implying long-term displacement from highly exposed places.

TECHNICAL		SOCIAL	
SAFETY	BUILDING SERVICES	CONSTRUCTION & RE SECTOR	SOCIETY
Damages to buildings Risks to health and human safety Premature aging of components	Reduced comfort and well-being Loss of use of buildings Reduced accessibility Malfunction of building systems	Increase in building (capital) costs and reduced affordability Increases in operations and maintenance costs Legal and professional liability Increases in insurance premiums	Displacement / migration Instability Loss of external services and networks Loss of cultural property

Figure 6: Classification of climate change technical and social climate impacts on buildings and their users (Source, GlobalABC & OID, 2020)

4.1 TECHNICAL AND SOCIAL IMPACTS

The main climate hazards that have technical impacts on building are the followings: heatwaves, floods, storms, landslides, droughts, forest fires, higher average temperatures, change in frosts cycle, increase in the temperature of watercourses and lakes, changes in the precipitation regime, solar irradiation variation, and coastal erosion.

The impacts on buildings include the degradation of the structure (roof, envelope, foundations), the deterioration of networks (water, gas, electricity, cold supply), and the downgrading uses of equipment (cannot be used to full capacity) and adverse effects on users' behaviour (comfort, health, asset values). Climate hazards affect lands and the built environment. The following figure, based on a study led by ADEME and BURGEAP in 2015, offers a more precise view of the technical impacts of climate change, analysed by type of hazard.

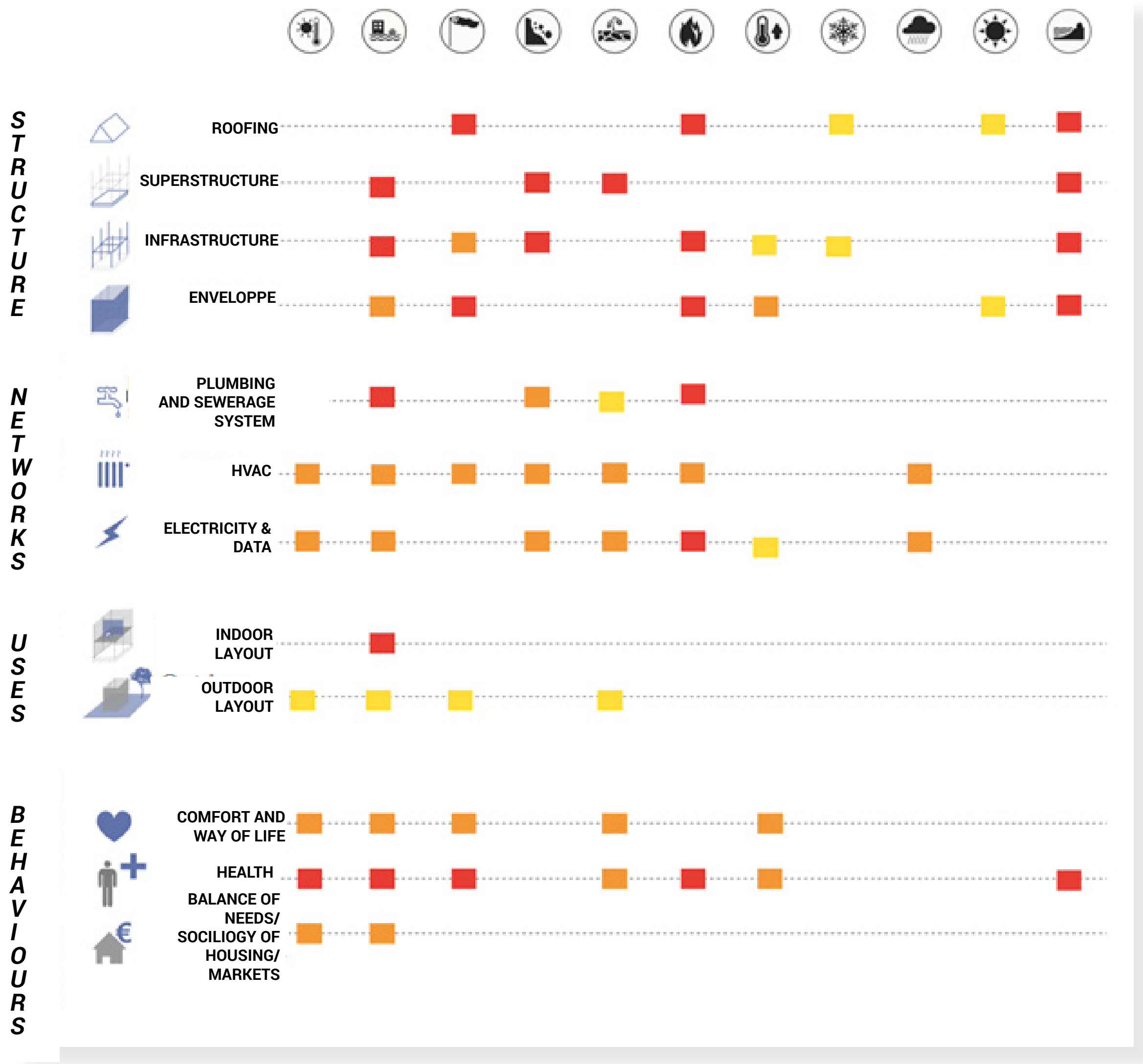


Figure 7: Impacts of climate change for buildings by climate hazards (Source: ADEME & BURGEAP 2015)

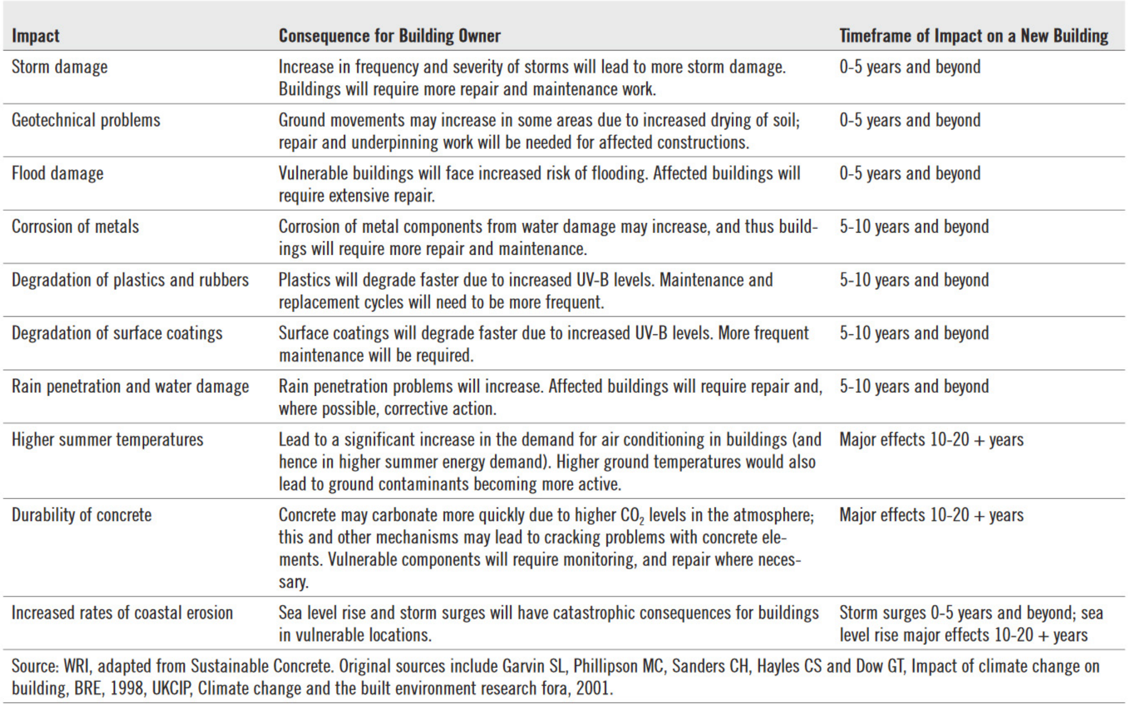
The level of impact is denoted by the colour of boxes: the darker the colour, the stronger the impact. The symbols at the top correspond to the climate hazards: heatwaves, floods, storms, landslides, droughts, forest fires, rise in average temperature, change in freeze-thaw cycles, change in precipitation patterns, change in radiative forcing, and coastal erosion. The graph however does not include information on the reduced transport accessibility of the building.

According to an upcoming study on climate change impacts on buildings produced by ADEME (French ecological transition agency), the main impacts are :

- Heatwaves: physical risk of hyperthermia and dehydration, can also lead to the dysfunction of equipment such as air conditioning, ventilation, and IT infrastructures.
- Floods: surface, walls and furniture deterioration and cracking, clogging of sanitation networks, supply disruption and water contamination.

  The same concerns apply for electric and energy supplies. Humidity can cause degraded air quality and lead to allergies, while flooding itself can result in injuries and drownings.
- Strong winds: risk of roofs and openings being torn away, damages on the structure, and injuries for individuals.
- Ground movements and landslides: the cracking or even collapse of buildings, risk of electricity, gas, or water supply cuts.
- Droughts: desertification and foundations fragilities. In case of a lack of drinking water, it can also lead to dehydration in individuals.
- Forest fires: severe harm on the whole building, risk of water and gas, fuel or propane supplies exploding, serious risk injury to individuals.
- Coastal erosion: besides the obvious risks related to water penetration itself, coastal erosion can cause cracking or even the collapse of buildings, and also lead to the threat of falling rocks.

The effects of climate change — including temperature variations, and changes in humidity, solar radiation, wind, and precipitation patterns — can cause paint staining, movements in building structures, cracks in concrete, and corrosion to building materials. Water damage from increased precipitation can damage buildings' structures, create mould, increased bacterial activity, undermine drainage systems, and cause power disruptions. In the long run, warming temperatures and increased humidity could affect structural building components and reduce building lifespans. Many building materials also require time to dry out after construction, and higher humidity extends the process, although this may be compensated with the use of additives in the materials. Increased humidity may also limit the ability of building envelope systems to dry out after rain events. Volatility in temperatures can cause materials to expand and contract, creating cracks and structural faults.



Impact	Consequence for Building Owner	Timeframe of Impact on a New Building
Storm damage	Increase in frequency and severity of storms will lead to more storm damage. Buildings will require more repair and maintenance work.	0-5 years and beyond
Geotechnical problems	Ground movements may increase in some areas due to increased drying of soil; repair and underpinning work will be needed for affected constructions.	0-5 years and beyond
Flood damage	Vulnerable buildings will face increased risk of flooding. Affected buildings will require extensive repair.	0-5 years and beyond
Corrosion of metals	Corrosion of metal components from water damage may increase, and thus buildings will require more repair and maintenance.	5-10 years and beyond
Degradation of plastics and rubbers	Plastics will degrade faster due to increased UV-B levels. Maintenance and replacement cycles will need to be more frequent.	5-10 years and beyond
Degradation of surface coatings	Surface coatings will degrade faster due to increased UV-B levels. More frequent maintenance will be required.	5-10 years and beyond
Rain penetration and water damage	Rain penetration problems will increase. Affected buildings will require repair and, where possible, corrective action.	5-10 years and beyond
Higher summer temperatures	Lead to a significant increase in the demand for air conditioning in buildings (and hence in higher summer energy demand). Higher ground temperatures would also lead to ground contaminants becoming more active.	Major effects 10-20 + years
Durability of concrete	Concrete may carbonate more quickly due to higher CO_2 levels in the atmosphere; this and other mechanisms may lead to cracking problems with concrete elements. Vulnerable components will require monitoring, and repair where necessary.	Major effects 10-20 + years
Increased rates of coastal erosion	Sea level rise and storm surges will have catastrophic consequences for buildings in vulnerable locations.	Storm surges 0-5 years and beyond; sea level rise major effects 10-20 + years

Source: WRI, adapted from Sustainable Concrete. Original sources include Garvin SL, Phillipson MC, Sanders CH, Hayles CS and Dow GT, Impact of climate change on building, BRE, 1998, UKCIP, Climate change and the built environment research fora, 2001.

Figure 8: Physical impacts of Climate change on building and impact time frame (Source: WRI 2010)

Consequences of climate change on buildings are not always immediate. Chronical climate hazards have impacts that are visible only on the long run, after several years. The World Resource Institute (WRI) classified climate change impacts on buildings in: storm damage, geotechnical problem, flood damage, corrosion of metals, degradation of plastics and rubbers, degradation of surface coatings, rain penetration and water damage, higher summer temperatures and durability of concrete, increased rates of coastal erosion. The previous table provides details on the consequences of these impacts on the building owner as well as the timeframe of these impacts.

Impact on buildings depends also on the local urban context. The physical urban context (density of buildings, density of greenery, urban layout...) has a huge impact on the wind flow, the water flow, the urban heat island... for example the "MIT concrete sustainability Hub" has shown that the layout, or the texture of the city, can considerably amplify the wind loads, and damages on buildings. However, current building codes do not consider this contextual effect, leaving many communities at risk. The city management of networks (electricity, sewerage...) and urban planning also greatly contribute on the resilience of buildings.

SOCOTEC Climate Risk Matrix

The Global Testing - Inspection – Certification company (sustainable building branch) developed a matrix tool summarizing the climate resilience of a building for each major climate hazard selected, based on three parameters: climate context, urban context, and a resilience indicator attached to the building (low, medium or high).

Each evaluation is mapped according to two axes: climate and urban contexts.

The resilience indicator for each climate impact takes into account the risk concerning the "structure," the "networks," and the "use" of the building. It also evaluates the quality of the adaptation solutions implemented.

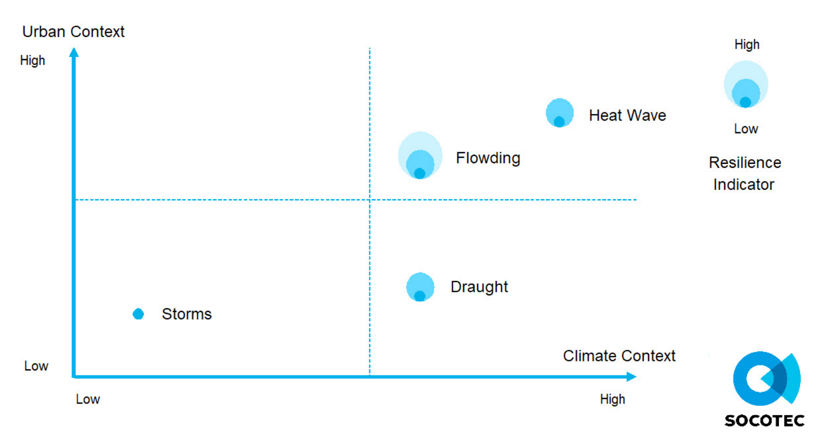


Figure 9: example of SOCOTEC climate risk matrix

The vulnerability of a building not only depends on construction choices, but also on the type of activities and occupants hosted. There are critical factors that help define the vulnerability of a building in the face of climate change impacts: the vulnerability of sheltered people, the number of people in the building, the building's dependency on technical equipment or on networks. This table illustrates the main factors of vulnerability of buildings according to their use (commercial, residential, public, industrial or transportation). It suggests that there is no single profile, and that a building's vulnerability depends first on its characteristics to house certain activities that determine its basic exposure, sensitivity, and coping capacity, and not only on location.

Beyond physical risks, human health risks may include poor indoor environmental air quality, uncomfortable indoor temperatures, and in some cases mental disorders. In addition, extreme temperatures or meteorological events prevent construction processes and create difficulties in completing them. The priority of adaptation measures to be implemented is then determined by the extent of social and economic impacts that would be felt in case of climate disasters affecting a building.

BUILDING	EXPOSURE			SENSITIVITY				COPING CAPACITY
Type	**Vulnerable people**	**Number of people**	**Link to nature**	**Technicity**	**Dependancy to Infrastructure networks**			**Potential shelter**
Central Product Classification					1	2	3	
				RESIDENTIAL				
One- two- dwelling (5211-1)								
-rural house	🟫		🟧 *Wildfire*		🟧 *Water*	*Road*		*Roof*
-urban house	🟫		🟫		🟧 *Water*	*Transit*		
-informal	🟧		🟫		🟧 *Water*			
Multi-dwelling (5211-2)								
-apartement bldg	🟫	🟫	🟫 *Heatwave*	🟫	🟧 *Water*	*Transit*		
				NON-RESIDENTIAL				
Industrial (5212-1)								
-Data center				🟧	🟧 *Data*	*Elec.*		
-Warehouse					🟧 *Road*			
-Factory/plant		🟫	🟫		🟧 *Elec*	*Road*		
Commercial (5212-2)								
Office building								
-high rise		🟧	🟫 *Wind*	🟧	🟫 *Transit*	*Elec.*	*Data*	
-low- and middle- rise								🟩
Retail								
-Shopping mall		🟧		🟫	*Road*	*Transit*	*Elec.*	
-Main street			🟫					
-SuperMarket		🟫		🟫	*Road*	*Elec.*		🟩
Transport				🟫				
-Airport terminal		🟧	🟧	🟧				
-Port Terminal		🟫	🟧	🟫				
-Railway Station		🟧		🟫				🟩
-Carpark					🟫 *Road*			
Public entertainment (5212-3)								
-Theatres, Concert hall		🟧		🟫	🟫 *Transit*			
Hospitality (5212-4)								
-Hotel	🟫		🟫		*Transit*			
-LeisurePark		🟫	🟧		*Road*			
-Stadium (5227-1)		🟧	🟫	🟫	🟫 *Transit*			🟩
Educational (5212-5)								
-School	🟫	🟫						🟩
-University		🟧		🟫				
-lab.					🟫 *Data*	*Elec.*		
-Museum		🟧		🟧	🟫			
Health (5212-6)								
-Dispensary	🟫							
-Hospital	🟧	🟧		🟧	🟧 *Road*	*Elec.*	*water*	🟩
-Retirement house	🟧							
Other (5212-9)								
-Farm shed	🟫 *animals*		🟧					
-Gvt buildings		🟫						
-Heritage		🟫		🟧				

Legend

***Vulnerable people** : beige (children, elderly), orange (diseased, poor); in case of climate event some vulnerable categories of people present in large majority in this type of building are more exposed to danger. Localization of this type of building is very important.*

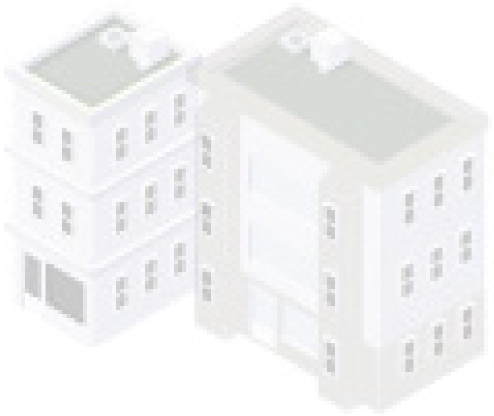
***Number of people in the facility**: beige (+100), orange (+1000); in case of climate event more people using this type of building are impacted*

***Link to nature**: beige (presence of garden, vegetation, open space as accessory to the main function,..), orange (proximity to sea, forest, land,…); presence or proximity of nature can be an advantage but can represent a danger (tree fall, wildfire, submersion of seashore area,..). Some type of building are more exposed to specific danger such as rural house (wildfire), apartment (heatwave), high-rise building (extreme wind)*

***Technicity**: Beige (elevator, central ventilation, air conditioning..), orange (data network, building management system, scarce resources..); some building integrate more technical features and system, their operation is more sensitive to potential disruption*

***Dependency to networks**: white (access), beige (criteria of localization), orange (vital access, first criteria of localization,..); some activities and operations in this type of building depend more on their access to transportation (road, transit), water, energy or data networks.*

***Potential shelter** : white (accessible roof can represent an emergency shelter against flooding in case of remote house) green (proximity of population: this type of building by its size and proximity of population offer a potential shelter in case of disaster. for example supermarket could be "cooling space" in case of heatwave.*



4.2 ECONOMIC AND SOCIAL IMPACTS

As extreme weather events intensify and become more frequent and temperature rises, the lack of adaptation of the build environment to climate change will have severe economic and social, direct and indirect consequences.

A) LOSS AND DAMAGE OF HOUSING

Beyond the cost of rebuilding, non-anticipated relocation can have significant economic consequences. Considerable economic and social costs can be anticipated in the event of a major climate-related crisis which would render people unable to remain in their homes.

- **Investment**. Costly solutions to rehouse populations would need to be thought of by the relevant authorities. While shelters and hotels provide a short-term solution, a long-term option must be offered when a building suffers major damages.
- **Community**. Disaster would lead communities being torn apart and families being separated as they would be housed in different places. The social and psychological consequences of such a split should not be underestimated during times of distress, as a sense of familiarity and belonging are extremely important to mental well-being. The loss of reference points for an entire population may have serious social repercussions. Additionally, people being rehoused on a site far from their workplace could increase the risk of job losses for reasons as diverse as the lack of transportation means or the increased tiredness.
- **Migration**. As populations leave their neighborhoods to be rehoused or flee for their lives, they may settle in existing communities which can potentially generate new conflicts in places that are not affected by a major climate hazard. Despite it seeming anecdotal, climate migrants number more than 21 million every year according to the International Organization for Migration (IOM).

The unexpected population increase may lead to a scarcity of resources such as food, water, or fuel that would then endanger the well-being of both communities. At the same time, cultural differences and a fierce competition for resources could lead to increasing tensions between the communities that could result in an increasingly violent situation. Additional challenges may arise if the displaced communities exist in an area not easily accessible to state authorities, for instance a region controlled by the mafia or under the authority of tribal chiefs.

Climate change has particularly severe economic, social, and sanitary consequences on people living in informal settlements. One of the greatest challenges for climate change adaptation is how to build resilience for the estimated billion urban dwellers who live in what are termed informal settlements (IIED 2018).

- According to the UNDESA's SDG report 2019, the proportion of the urban population living in slums grew to 23.5 per cent in 2018. The total number of people living in slums or informal settlements grew to over one billion, with 80 per cent attributed to three regions: Eastern and South- Eastern Asia (370 million), sub-Saharan Africa (238 million) and Central and Southern Asia (227 million). But the current need for good standard engineered housing will go far beyond slums: an estimated three billion people will require adequate and affordable housing by 2030.
- People living in slums or informal settlements are most at risk from climate change impacts since they live in poor-quality housing that is significantly more likely to be damaged or destroyed during an extreme climate event. These people also generally lack access to basic infrastructure and services (such as water, electricity, thermal comfort, modern cooking stoves...).
- Moreover, as the populations relying on informal housing are mostly poor, the loss of their homes and belongings will very likely mean the loss of everything they own. The importance of tackling this issue is therefore undeniable, a fact highlighted in several United Nations Sustainable Development Goals (SDGs): SDG 11 in particular stresses that cities and human settlements should be inclusive, safe, resilient, and sustainable.

Small economical actors also face obstacles in the implementation of climate change adaptation measures. While big companies have the ability to invest massively in the adaptation of their buildings, the vast majority of individual homeowners and shop owners do not have the funds to do so. Moreover, while it may be cost efficient for big companies to invest in adaptation to protect their buildings and the contents inside them, this may not be the case for small actors. The costs and the gains of adaptation are indeed not carried by the actors: the investment is made by the building's owner and the gain by the insurance company. Therefore, policy incentives must take into account small actors and provide special measures for them.

B) ROLE OF SPECIFIC BUILDINGS: REFUGE, PUBLIC, STORAGE, HERITAGE BUILDINGS

Refuge buildings: Permanent or temporary areas of refuge within private and public buildings help people avoid danger during hazards. They therefore play a critical role in saving lives. On a day-to-day basis they are used by the most vulnerable populations, such as people living in informal settlements who may not be sheltered from chronic climate hazards in their homes. For instance, a ventilated room in a public building can be used to shelter people at risk during the summer. It goes without saying that these areas of refuge should be resilient to the climate hazards that they are exposed to.

Public buildings: The resilience of communities is dependent on public access buildings. Hospitals, schools, and libraries offer important services to communities and often constitute a safe zone for vulnerable populations. Their inaccessibility could have severe social, psychological and health consequences, such as an increase in the number of deaths of the population, greater isolation of old people or a higher number of school dropouts of youths. Public access buildings are particularly important for people who are in danger inside their own homes, for example due to a toxic environment or unhealthy conditions. They also are often at the heart of community life, helping create a sense of unity and belonging which are essential to a resilient social fabric, and a resilient social fabric lies at the heart of a resilient society.

Storage buildings: Buildings used to store goods and foods. Now electronical equipment and data are also key elements that must be protected. If their contents were to be damaged during an extreme climate event, the economic and strategic consequences could be enormous. Companies and/or public entities could lose essential equipment, rough material, or strategic data. As more and more organizations transfer their data to the cloud and societies rely ever more on the internet, protecting the data servers must become a priority. A crisis management plan for storage buildings should therefore be put in place preemptively, and a safe place designated to move the contents of these buildings to safety, should time allow.

Heritage buildings: The adaptation of the cultural and heritage buildings is a question that must be considered. Indeed, heritage may be affected by climate change risks and its destruction could have significant social and economic impacts because heritage assets are cultural and economic resources for both individuals and communities. For example, heritage buildings often play an important role in the tourism industry of a region, and their degradation would subsequently have several consequences including the loss of a primary source of income for many. Heritage properties like old religious buildings also play an essential role in gathering communities, and if destroyed could lead to the significant deterioration of their social fabric. As such it is important that heritage assets be protected and preserved for future generations, yet they are rarely included in climate change plans. More broadly, concern for architecture should be constantly demonstrated in climate policies.

ICOMOS
international council on monuments and sites

Heritage Buildings and Climate Change Adaptation

Cultural heritage offers immense and virtually untapped potential to support just transitions by communities towards a low carbon, climate resilient future. SDG11.4 recognizes the power of cultural heritage to support safe, resilient and sustainable communities. Heritage plays an important role through its power to connect people to places and to each other, thereby fostering a sense of identity and community which in turn help create stronger social fabric. Cultural heritage is also a source of creativity and inspiration that promotes innovation and supports economies.

The Paris Agreement notes that adaptation should be guided by not only the best available science but also by appropriate traditional knowledge, knowledge of indigenous peoples and local knowledge systems. Traditional building technologies tend to be adapted to local conditions and can employ local materials. Traditional approaches to building design, orientation and spatial arrangements often have characteristics, sometimes called 'inherently sustainable features' (ISFs), that maintained occupant comfort before modern mechanical hardware.

Together, the historic built environment helps define and express the character and values of communities while reflecting a diversity of knowledge systems, trades and livelihoods, and local self-sufficiency that are crucial to resilience.

Climate change impacts are challenging in profound ways the adaptive capacity of diverse types of cultural heritage including built heritage and landscapes as well as intangible heritage and associated communities. Heritage may also be impacted by well-intended climate adaptation and mitigation measures, in some cases as a result of considered balancing of needs and values and in other cases through maladaptive actions or ill-conceived responses. Climate change is causing novel weather conditions that may not be predictable by local knowledge and experience; however, past adaptability may be transferable across regions as climatic conditions shift.

There are often no effective substitutions or adequate compensation for lost cultural significance. Climate change adaptation for built heritage aims to increase the capacity of these properties to retain the knowledge and values they carry, both for contemporary benefits and as a legacy to future generations.

ORGANISATIONS ON "HERITAGE AND CLIMATE CHANGE ADAPTATION":

- **World Heritage Convention**. WHC parties decided at its 16th session in 2007 on Policy guidance including binding policy. A new draft policy expected early 2021. The current policy addresses both the impacts of climate change on world heritage properties and the power of cultural heritage to support climate action. It addresses the intersection of climate change and world heritage processes in areas such as nominations, reactive monitoring, periodic reporting, international assistance, and capacity building, as well as the strategy for reducing risks from disasters at WH properties". Key messages of the 2007 Policy Guidance are the following :

  o WH properties will be used wherever appropriate and wherever possible as a means to raise awareness about the impacts of climate change and to communicate best practices in vulnerability assessments, adaptation strategies, mitigation opportunities, and pilot projects.
  o State parties and managers of individual WH properties will consider undertaking site-level adaptation measures.
  o Make climate vulnerability assessment part of the WH site nomination and inscription process.

- **International Council on Monuments and Sites.** In 2017 ICOMOS committed to mobilizing cultural heritage for the climate and to this end formed the ICOMOS Climate Change and Heritage Working Group (CCHWG). [...]

  In 2019 the CCHWG published its report "The Future of Our Pasts: Engaging Cultural Heritage in Climate Action."
  The report takes stock of hundreds of ways in which cultural heritage can drive climate change adaptation and mitigation and also catalogues the myriad impacts that climate change is having on diverse types of heritage. The report concludes that addressing these impacts while simultaneously fulfilling the potential of culture to support equitable climate action requires (1) adjusting the aims and methodologies of heritage practice and (2) better recognizing the cultural dimensions of climate change.

- **Climate Heritage Network**, The Climate Heritage Network is comprised of organisations committed to using the arts, culture and heritage to aid communities in tackling the climate change emergency and achieve the ambitions of the Paris Agreement. Network members include the arts, culture and heritage units of government at all levels, NGOs, universities and research organizations as well as design firms, artists, and other businesses. The CHN working groups include those working to promote the use and value of traditional knowledge in climate action, as well as those who are committed to promoting the reuse of buildings through better metrics for avoided, operational, and embodied carbon.

- **Initiative on Protection of Cultural and Natural Heritage from Climate Change** led by UNESCO and Greece, was launched at UN Climate summit (NY, 2019).

4.3 IMPACTS ON NETWORK INFRASTRUCTURE

The resilience of infrastructure and the resilience of buildings is linked. Buildings supporting urban networks such as water and electricity are also critical infrastructures.

If a resilient building is a necessary condition to assure the continuity of building's service, it is not sufficient to ensure the continuity of services of a building, which also depends on the resilience of the infrastructure that supports the building. The exposure of the supporting infrastructure to hazardous events should therefore be considered as part of the building's overall exposure. Thus, enhancing the resilience of a building alone is not sufficient, and buildings must be viewed as part of a network or system that supports human activities, with the supporting infrastructure together forming the built environment. On the other hand, in terms of the impact of hazardous events on human activities, the resilience of infrastructure systems cannot be considered separate from the resilience of the buildings that are part of the system. Similar considerations would have to be made to ensure the disaster and climate resilience of individual buildings as well as that of entire infrastructure systems.

Infrastructure constitutes the basic physical and organizational structures that provide vital services to the economy. Roads, bridges, power systems etc. constitute the infrastructure stock, with buildings forming an essential part of every infrastructure sector. As infrastructure systems are interdependent, it is important to understand the interlinkages between infrastructure systems and services and adopt an integrated systems approach when planning for infrastructure resilience. For instance, if a storm directly impacts a road that supplies cargo to a port, then the port is also affected even though there is no direct physical loss from the storm. Similarly, if the building of a telecommunications exchange, housing the computer servers and switches, gets affected by a fire or flood, the entire downstream telecommunications system could get disabled.

Because of the increasing occurrence of extreme events, the risks posed to the built environment calls for focussed attention on fragilities in an integrated manner. Site selection is a crucial aspect when it comes to reducing the exposure of infrastructure and buildings to hazards. For instance, often in the case of airport development environmentally sensitive sites such as low-lying areas, sites alongside coasts, floodplains, and reclaimed land are used due to restricted availability and supply of land. This increases the exposure of the airport infrastructure, including the airport terminal building, to natural and man-made hazards, increasing the possibility of disruption to services. This demonstrates the need for risk-sensitive land use planning to enhance the resilience of infrastructure assets, including the buildings associated with the infrastructure system.

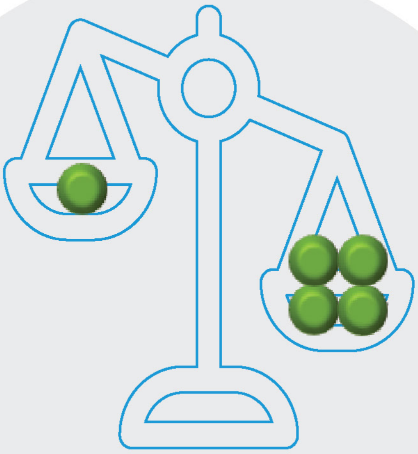
Apart from adopting risk-sensitive land-use planning, it is also critical to conduct disaster risk assessments of the building structures and other assets that constitute the infrastructure system. To determine the fragility of the structure a set of probabilistic vulnerability functions will be useful for understanding the risk. These vulnerability functions characterise the expected structural behaviour of the asset in terms of damage during the occurrence of hazardous events. Based on these risk assessments, the robustness of the structure can be increased, and redundancies can be established to achieve the desired performance in response to hazards and thereby enhancing the resilience of the system.

Cost of non-adaptation

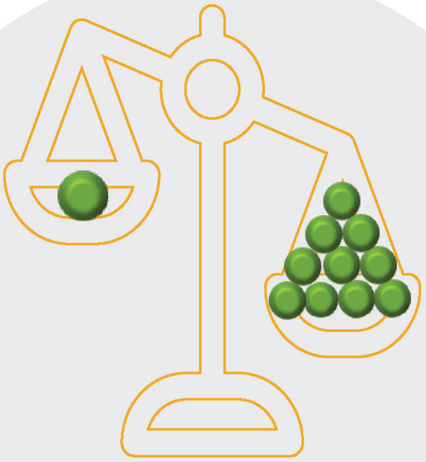
The cost of non-adaptation is the losses induced by climate change if no measures have been implemented to anticipate and diminish climate impacts on buildings :

Cost of non-adaptation = **Financial risks without adaptation** - (**Financial risks with adaptation** + **Cost of implementing an adaptation action**)

Examples



Benefit-cost ratio of making infrastructures resilient



Benefit-cost ratio of adaptating coastal cities

The longer the action is delayed, the higher the cost of adaptation will be.

Source : OID, december 2020

5. Cost of Non-adaptation, Benefits, and Costs of Adaptation

What would be the financial and –most importantly– human cost of choosing not to take action to adapt buildings to climate change lives? Conversely, what would be the cost of adaptation?

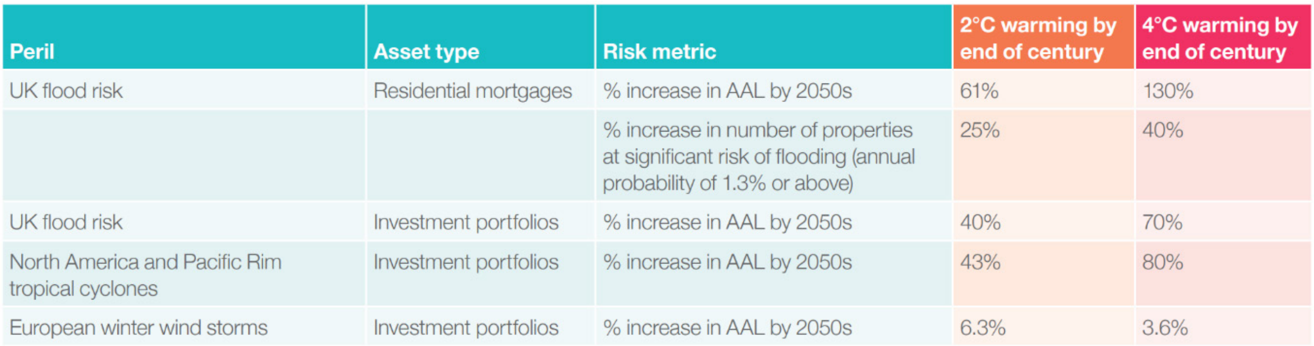
5.1 WHAT IS THE COST OF NON-ADAPTATION?

Extreme events already translate into a significant and increasing burden for the real estate industry.

The cost of non-adaptation is the cost that would be associated with climate change effects if there are no measures implemented to anticipate and diminish climate hazards impacts on buildings. No evaluation cost can be precise or exhaustive. This is because:

- The evaluation of the cost of climate change often only relies on first-order impacts (eg. the destruction of an asset), since second-order impacts (eg. The decrease in productivity of workers due to a heatwave) are extremely complex to assess.
- Current methodologies do not cover the entire value chain of the counterparties they examine (UNEPFI, 2019).
- Few methodologies integrate both physical and transition risks.
- Most of the assessments are focused on a system of exposure to climate change risks while the assessment of sensitivity and the analysis of the adaptive capacities of an organization would go beyond the first assessment and provide more information. However, these analyses require a large amount of data and strong analysis.
- At the level of buildings, it may also be difficult to separate investments made specifically to improve adaptation from those that are usually made.
- The cost of non-adaptation is therefore always underestimated.

Future costs will also depend on the emissions path that is followed. Carbon Brief explains the different impacts of climate change and costs resulting from the increase in global temperatures. The study indicates that if the global temperature increases of 1.5°C, global GDP per capita would decrease by 8% by 2100, and in case of an increase of 2°C, global GDP per capital would decrease by 13%. Similarly, ClimateWise has modelled losses for residential mortgages and investment portfolios for a 2°C and 4°C warming by the end of century. Across all hazards, the stronger the warming is, the higher the danger.



Peril	Asset type	Risk metric	2°C warming by end of century	4°C warming by end of century
UK flood risk	Residential mortgages	% increase in AAL by 2050s	61%	130%
		% increase in number of properties at significant risk of flooding (annual probability of 1.3% or above)	25%	40%
UK flood risk	Investment portfolios	% increase in AAL by 2050s	40%	70%
North America and Pacific Rim tropical cyclones	Investment portfolios	% increase in AAL by 2050s	43%	80%
European winter wind storms	Investment portfolios	% increase in AAL by 2050s	6.3%	3.6%

Figure 9: Modelling of average annual loss (source: ClimateWise 2019)

Figures are often underestimated, particularly when they include only insured losses, which concern only a part of total losses, as shown below.

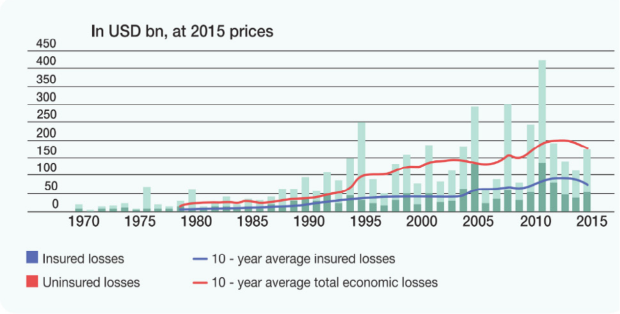
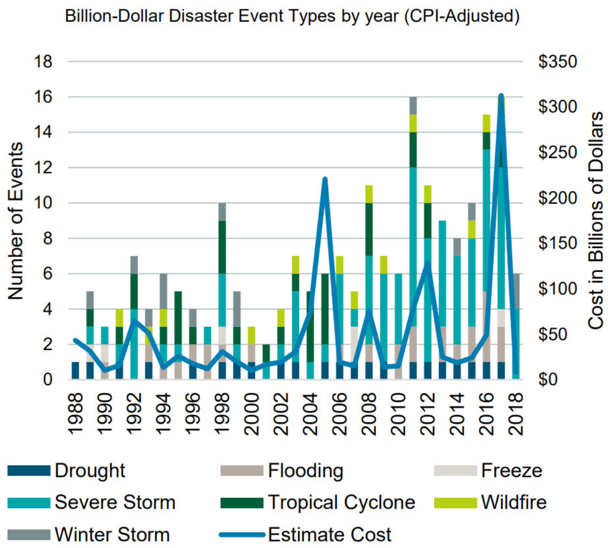


Figure 10: Economic versus insured catastrophe losses over the period 1970-2015 (Source: Munich Re Economic Research & Consulting 2015 in ClimateWise 2016)

Extreme events already translate into a significant and increasing burden for the real estate industry. Filipino Insurance Commission estimates the number of damages to real estate properties to be PHP 12 billion (approximately USD250 million) from the two 2009 tropical storms, Ketsana and Pepeng. Flood events in Jakarta in 2007 caused more than USD900 million in total damages, while the 2002 floods caused an estimated USD1.1 billion in property damage (Wall Street Journal 2009). The following graph shows the rise of the cost of disasters on the built environment. In Pakistan in 2010, over 15 million people were affected by flooding. Over 200 health care facilities were destroyed by such floods (WHO 2018).



Source: National Oceanic and Atmospheric Administration, July 2018.

Figure 11: Billion-Dollar Disaster Event Types by Year (Source: NOAA 2018 cited in DWS 2018)

Turning to projections, by 2070 more than 150 million people in the world's largest port cities are likely to face a heightened risk of flooding (Nicholls 2008 cited in Global ABC 2018). T**he potential cost burden of this is unevenly spread**, with four cities accounting for 43% of average annual losses: Guangzhou, Miami, New Orleans, and New York.

According to UNISDR (2015) the amount of damage will be so high **that many vulnerable countries will not have the financial resources to cope with a 1-in-100 years loss** (severe but infrequent). This in turn increases indirect losses due to disasters.

According to a study from the UK National Oceanographic Centre, the global cost of rising sea levels would reach 14 trillion USD per year in 2100 (WEF 2019). As a comparison, Hurricane Irma, which was the costliest natural disaster for insurers in 2017, had recorded around 32 billion USD of insured losses and evaluated at around 67 billion USD of total losses (Munich Re 2018). China would face the biggest costs in absolute terms. Looking at it in terms of GDP percentage, the impacts will be highest for Kuwait (24%), Bahrain (11%), the United Arab Emirates (9%), and Vietnam (7%). Analysis by Heitman and the climate risk analysis firm "Four Twenty-Seven" focused on institutional exposure to climate risk. It showed that more than 24% of the NCREIF (National Council of Real Estate investment Fiduciaries) Property Index value in the United States corresponds to assets that are in metropolitan areas. The city centres of these areas are among the 10% of cities most exposed to sea-level rise, which translates in an amount of more than 130 billion USD of real estate (ULI and Heitman 2019).

At the level of buildings, utility costs will increase if action is not taken to adapt to climate change. There is however very little awareness among developers, building owners, and tenants of the cost of utilities over the life of a building as well as the high cost of backup power.

5.2 WHAT ARE THE BENEFITS AND COSTS OF ADAPTION MEASURES?

The cost of inaction is far greater than the cost of action, and the longer we wait, the higher the cost of adaptation and the cost of climate hazard impacts will be.

The cost of adapting to a 2°C global warming scenario by 2050 varies greatly depending on the region, climate impact scenarios, and the sector. All sectors combined, the cost of adaptation at the global level would be between 140 and 300 billion USD per year by 2030 and between 280 and 500 billion USD per year by 2050 (UNEP 2016 cited in GlobalABC 2018). Figures may be complex to compare as scopes and methods differ, but the message is clear: **the longer action is delayed, the higher the cost of adaptation will be** (GlobalABC 2018).

In 2011, the East Asia, Pacific and South East Asian regions faced the highest proportion of adaptation costs due to their large populations, while Sub-Saharan Africa is projected to experience the largest increase until 2050 (GlobalABC 2018). According to the US Global Change Research Program (US 2018), by 2090 22% of expected damage to coastal property could be avoided if we followed RCP4.5 compared to RCP8.5 (for more information on RCP scenario, see the annexes). For inland flooding, damages avoided will be 47%.

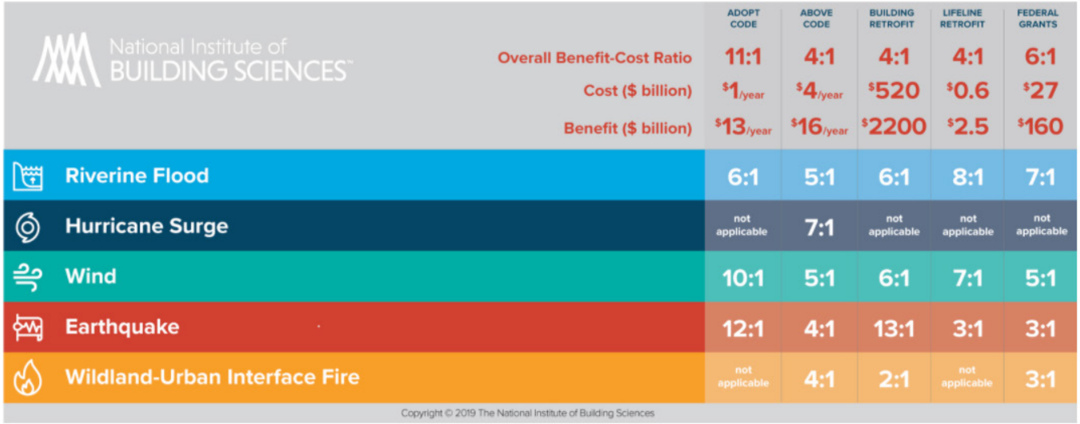
The French Federation for Insurance studied the impact of climate change expected by 2040 for the insurance industry

Comparing expected damages over 2014-2039 and historical damages over 1988-2013, it concluded that damages in France from natural disasters will increase by 44 billion euros. Climate change with 13 billion euros is the second explanatory factor, behind the increase of assets value. In a study on the financial impacts of climate scenarios the CCR, in charge of the reinsurance for natural disasters, concluded that climate change would account for 20% of the increase in losses that is expected in metropolitan France by 2050.

Climate Change Impact on Real Estate in Ho chi Minh City

In the worst-case scenario (RCP 8.5), by 2050 climate change could increase flood-related damage to real estate in Ho Chi Minh City (Vietnam) by up to sixfold. This would raise the damage costs from 1,5 to 8,4 billion for a 100-year flooding, and from 1 to 6,6 billion USD for a 1-year flooding) (McKinsey, 2020).

Making infrastructures resilient can add 3% to their overall cost but has a benefit-cost ratio of about 4 to 1. In a comparison of costs and benefits, research conducted by to the Global Commission on Adaptation (2019) found that investing 1.8 trillion USD globally between 2020 and 2030 in five areas --including early warning systems and climate-resilient infrastructures-- could generate 7.1 trillion USD in total net benefits. In coastal cities, the cost of successful adaptation is one-tenth the cost of no action being taken. The following table shows the average cost-benefit ratios for five types of mitigation and perils in the United States:



	ADOPT CODE	ABOVE CODE	BUILDING RETROFIT	LIFELINE RETROFIT	FEDERAL GRANTS
Overall Benefit-Cost Ratio	11:1	4:1	4:1	4:1	6:1
Cost ($ billion)	$1/year	$4/year	$520	$0.6	$27
Benefit ($ billion)	$13/year	$16/year	$2200	$2.5	$160
Riverine Flood	6:1	5:1	6:1	8:1	7:1
Hurricane Surge	not applicable	7:1	not applicable	not applicable	not applicable
Wind	10:1	5:1	6:1	7:1	5:1
Earthquake	12:1	4:1	13:1	3:1	3:1
Wildland-Urban Interface Fire	not applicable	4:1	2:1	not applicable	3:1

Source: Average USA average cost-benefit ratio for five types of mitigation and perils National Institute of Building Sciences (USA,2019)

Adaptation should therefore be included in all phases of the construction project: design, construction phase planning, delivery models, type of use, type of adaptation strategy, insurance, adaptation planning, regulations, codes of practice, etc., as explained in Parts II and III of this report.

In order to highlight the benefits of adaptation, tools are currently being developed to better assess its benefits. For instance, the African Development Bank's Adaptation Benefits Mechanism provides a methodology to agree, value, implement, and self-certify a project (i.e., without external parties). The objective is to define the expected benefits of adaptation in advance, sign agreements with donors, and pay only upon delivery of certified adaptation benefits. This mechanism is particularly suitable for adaptation measures in rural or low-income areas where climate impacts are significant.

Investing in the improved adaptation of buildings will have co-benefits. Heitman and ULI (2019) stressed that these benefits include, in the short-term: reduced damages from weather events, reduced utility expenses, improved tenant experience, reduced health issues, and operating expense stability. In the long-term, benefits include the potential to attract more private capital and institutional investment as demonstratable results are achieved in addressing climate change.

Benefits of adaptation measures for the building owner

The Quebec Order of Architects cites the following benefits for the client in its 2019 "esquisse" magazine:

- *increased safety*
- *lower life span cost (reduces possible damage)*
- *a quicker recovery to normal activity (after the event)*
- *control on insurance premiums*
- *easier access to financing (preservation of assets either as collateral or lower overall risk)*

How much is currently being invested to fund adaptation?

Climate Chance & Comité 21 (2019) explain that less than 5% of the funds for climate-related projects are used for adaptation purposes (22 billion USD out of 463 billion USD). Focusing on international finance flows for climate in 2017, Carbon Brief (2018) explains that about 16 billion USD per year went to mitigation projects alone, compared to 9 billion USD or adaptation projects. 6 billion USD went to projects aiming at both mitigating and adapting climate change.

However, it is important to note that adaptation will not always be feasible. In some areas facing hazards such as sea-level rise, there may be no solution for adaptation (ecbi 2019). The European capacity building initiative (ecbi) specifies that the adaptation limit is "the point at which an actor's objectives or system needs cannot be guaranteed against intolerable risks by adaptive actions". A "hard" limit implies that no adaptive action is possible. A "soft" limit implies that "adaptation options are not yet available but could be available in the future through new technologies or changes in laws, institutions, or values, because it depends primarily on human factors".

The Impact of Climate Risk on the Price of Real Estate in the United States

Does exposure to flooding reduce the price of a property? Bernstein, Gustafson and Lewis (2018) found an average decrease of about 7% in the value of homes exposed to sea-level rise in the United States over the period between 2007 and 2016. Properties that will not be flooded before the end of the century are expected to experience a decrease in value of 4%.

The authors explain: "this reduction is driven by non-owner occupiers, who [...] are more sophisticated investors. Within this market segment, the average Sea-Level Rise [SLR] exposure reduction of value is approximately 10% and has increased over time, coinciding with the release of new scientific evidence on the extent and timing of ocean encroachment. Among buyers who we argue are less sophisticated (i.e., owner occupiers), we find that the SLR exposure discount varies at the county level by the degree to which inhabitants are worried about the effects of climate change: with more worried areas impounding a significant discount and unworried areas demanding no concessions for SLR exposure." A study published by McAlpine and Porter (2018) in Miami-Dade, Florida, arrived to the same conclusion: "We find empirical support for significant and negative impacts, in property value appreciation due to the increasing risks of tidal flooding. This is likely related both to the observable increase in flooding in the Miami-Dade area and the documented increase in media coverage of these events."

6. The Rise of Climate Liability Concerns the RBC Sectors

Climate liability is on the rise, and companies whose buildings and infrastructures are threatened by climate risks will be facing an increasing number of lawsuits (E&E News 2019). In the case Conservation Law Foundation, Inc. v. Shell Oil Products US filed in 2017, a federal district court allowed the Conservation Law Foundation to sue Shell Oil Co. for failing to integrate climate risks into its investments. Following regulatory guidelines and standards may not be sufficient to meet legal claims. For Setzer and Byrnes (2019), "**more cases of this nature are expected, as investors and insurers pay particular attention to the growing gap between scientific understanding of climate change and adaptation efforts.**" Cases are also filed when organisations fail to report their exposure to climate risk to their investors and shareholders.

Climate risks have commercial implications, particularly for contracts where a force majeure clause may be invoked. The construction sector will therefore be increasingly concerned. McCarthy Tétrault LLP (2018) explains: "The effect of a force majeure clause is to release a party from its contractual obligations in certain circumstances, which often include environmental conditions (often referred to as "acts of God") that make it impossible to perform the contract. As climate change increases exposure to extreme weather events, contracting parties may be more likely to invoke force majeure clauses to avoid liability where conditions beyond their control have occurred". To invoke a force majeure clause, the event that has occurred must have been impossible to foresee and prevent. Yet is this really the case for extreme events related to climate change, given the increasing availability of data on future risks? By addressing these questions during the negotiation phase, the contracting parties will be better able to manage climate risks.

PART 2

Adapting the RBC Sector to Climate Change

>> INTRODUCTION

This section highlights some of the changes that are either underway or needed in the construction sector in order to better incorporate adaptation challenges such as risk assessment, extended life cycle building process, regulatory framework and stakeholder engagement. It also presents concrete actions, and the main messages to be retained from this section are as follows:

Need to develop a risk management culture. In order to deal with the consequences of climate change, it is first necessary to ensure that each stakeholder has a good understanding of the risks. Strengthening risk assessment capacity is therefore essential.

Need to change the organisation of the building construction process: Integrating climate change adaptation into the challenges of building construction requires a systemic approach that goes beyond current practices that are often limited to short-term issues and contractual relationships.

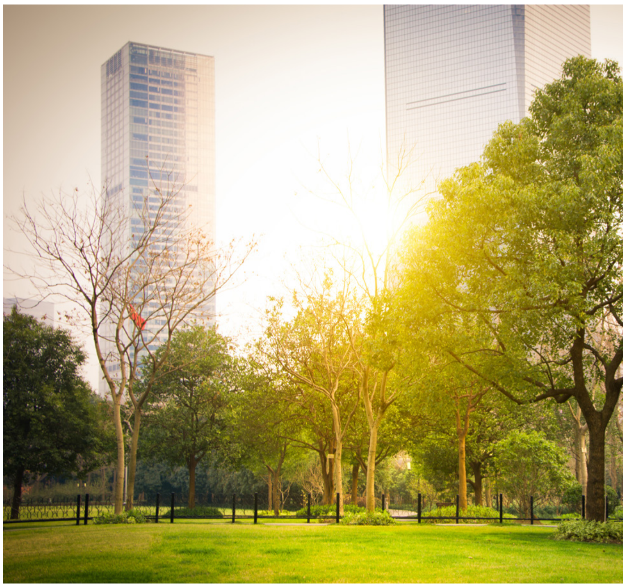
- ***Develop an extended life cycle approach****:* The aim is to involve the entire value chain and integrate long-term issues. To this end, life-cycle planning and assessment of adaptation is determined both at the building level -- including the products incorporated into a building-- and at the level of assets and services. In practical terms, focusing on each phase of the extended life cycle is a first step towards establishing frameworks for action for the adaptation of buildings to climate change.
- ***Changes in procurement policies***: climate change risk should be attributed to the contracting party best able to manage the impacts.

Need for an enabling regulatory framework: Governments have a central responsibility to act and reduce current and future climate risks.

- ***The technical and urban planning regulatory framework for buildings must evolve*** to strengthen reporting requirements, broaden the concept of safety in buildings to include resilience and social dimensions (e.g. add rules for degraded operation and rapid repair of basic services), and develop performance-based standards.
- ***Integrating adaptation into codes and standards***: This process is already underway, as can be seen with the new European (revision of the 2013 mandate for “Adaptation to climate change in infrastructure standards”) and international standards (ISO 14090 “Adaptation to climate change”) that are being put in place to address the adaptation and resilience of buildings and civil works.

Need for stakeholder engagement: Improved reporting on exposure to climate risks is a climate adaptation measure. Various tools and recommendations are available, often not specific to the RBC sector. In addition to reporting, certifications help assess adaptation measures.

- ***General reporting frameworks on climate and sustainable development***: public (TCFD, European action plan for sustainable financing, French law on energy transition) or private (GRI and CDP).
- ***Declaration frameworks specific to real estate***. The GRESB assessment and reference framework includes a module on resilience that reports on climate risks as well as the state and management of resilience.
- ***Green building certification systems*** such as LEED, BREEAM, HQE, DGNB, are beginning to include requirements for the adaptation of buildings to climate change. There are also specific certifications focusing only on resilience, including natural risks related to climate change.



1. Who is concerned ?

Climate adaptation is at the crossroad of sustainability, risk management, and finance affairs. In line with this, policymakers overseeing the three following areas must work together to adapt the RBC sector.

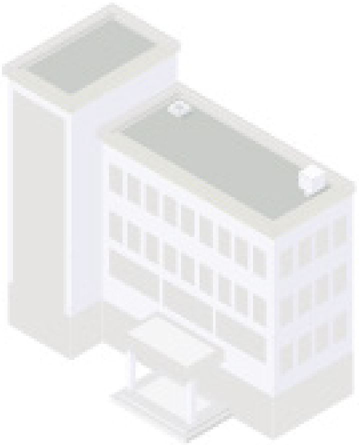
- **CO_2 emissions and energy reduction** are major targets of sustainability in the RBC sector. Designing and implementing both adaptation and mitigation measures simultaneously is beneficial, as they are, like many in the RBC sector, interdependent. The social and organisational dimension of the adaptation process should not be underestimated: involving stakeholders and following methods traditionally used in sustainability approaches offers multiple benefits.
- **Risk management** nowadays includes climate-related risks. Climate change exacerbates climate-related disasters and adds these challenges to other existing risks such as earthquakes, terrorism, cyber security, etc.
- **ESG (Environmental, Social, Governance) reporting** and monitoring increasingly include climate risks since the introduction of the TCFD (Task Force on Climate-related Financial Disclosure Recommendations). But beyond reporting it is also necessary to implement actions to reduce the exposure and vulnerability of buildings and real-estate assets to climate risk. Choosing appropriate adaptation upgrade works or selecting well-rated assets are examples of measures having a positive impact in this field.

Key Responsibilities for Integrating Climate Change Adaptation into the Building Process

Organisations in the building value chain (manufacturers, contractors, owners), influencers (engineering firms, developers, brokers, finance, insurance, modelers), and regulators (state, local authorities) have a responsibility in the adaptation process.

- **Engineers and contractors**: to assess and design climate-proof buildings to decrease loss and reduce the cost of damage and recovery measures, based on the estimated frequency and intensity of the expected risks.
- **Developers**: to justify the market value of adaptation measures.
- **Brokers**: to provide information on climate-related risks.
- **Owners**: to build in safe locations and implement reasonable reinforcement measures to reduce the impacts of climate change.
- **Regulators**: to update building codes and planning rules while reinforcing code compliance, and supplement insurance in case of large-scale climate change events.
- **Government investors**: to offer grants and incentive programs.
- **Local authorities**: to implement and verify the compliance of urban planning.
- **Finance actors**: to preserve the security of loan assets, as mortgage, and finance the initial cost of adaptive investment.
- **Insurance actors**: to monitor risks and losses related to the current climate and cover risk at an affordable price (risk retention, reinsurance, catastrophe bonds, and others).
- **Modelers**: to evaluate the future climate-related risks with appropriate granularity and develop models that can make climate projections, with a particular focus on extreme events versus average climate predictions.
- **Certifiers**: to assess buildings and provide certification for them.
- **Manufacturers**: to certify and inform their customers about the "climate resistance" of their buildings or systems.

This list is a preliminary overview which will be looked at in greater detail in Part III of this report.



2. Raising Risk and Vulnerability Assessment Capacity

To deal with the consequences of climate change the first step is assessing the risk, or vulnerability. Risk studies are cross-sectional and require three-dimensional analysis based on the study of the nature of the hazard, the exposure, and the system sensitivity. The conclusion gives an understanding of the vulnerability and is supplemented by two other dimensions: the value of the property and the life cycle.

Hazards and exposure are location-dependent: climate hazards differ from region to region.

a) **Hazards** are climate change-related events to which the building will be exposed (floods, storms, heatwaves, etc.). Knowing the nature of the hazard is a prerequisite for assessing risk and evaluating vulnerability.

b) **Exposure** varies across world regions, countries, and land plots, since each geography will not be equally impacted by climate change. Frequency, or probability, and intensity of hazards vary according to IPCC scenario trajectories. Parameters such as elevation, impervious or permeable surfaces, distance to water courses also have an impact on local climates. Exposure therefore includes criteria that affect the resilience of the surroundings of the building.

c) **Vulnerability** of the buildings largely depends on the choices that are made during the construction or renovation stages (e.g. large glazed surface, presence of a basement, high-rise structure), and which increase or decrease the vulnerability of a building. The technical conditions that a building must satisfy vary according to the use of said building (e.g. as a hospital, offices, etc.).

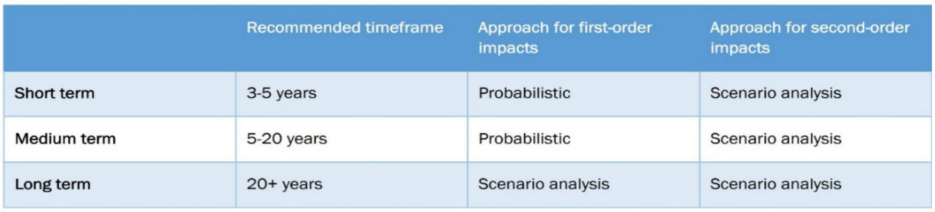
An assessment of the value of the property may complement this three-dimensional risk analysis, since the inability to use a property or its bad technical condition can seriously decrease its value. The level of financial risk also increases according to the nature of the damage, and a building may in addition have cultural, heritage or strategic value (e.g. when it plays a role in maintaining public health or safety). In such cases the risk goes beyond simply the financial.

d) **Timescale** is another dimension to be included in the analysis.

- **In current assessments all risks are not equal, with chronic hazards evaluated less than acute hazards** (UNEP FI, 2019): “*This is likely to be linked to the different temporal nature of these hazards: acute climate shocks are likely to have short-lived effects on a business, for example through temporary business interruption, while chronic changes in the climate lead to longer-term impacts and more fundamental changes in the nature of the business.*”

- **The methodology used to assess the risks depends on the timeframe.** When assessing future risks, the use of historical data is insufficient, as hazards increase in intensity and frequency over time. Exposure to physical climate risks cannot be assessed using historical data alone. The methods used for risk assessment depend on the timeframe and the hazard in question, and the nature of the impacts. The following graph, produced by the European Bank for Reconstruction and Development, proposes an approach for assessing physical climate risks.

Figure 12: Timeframe and recommended approach to assessing physical climate risks (Source: European Bank for Reconstruction and Development)



	Recommended timeframe	Approach for first-order impacts	Approach for second-order impacts
Short term	3-5 years	Probabilistic	Scenario analysis
Medium term	5-20 years	Probabilistic	Scenario analysis
Long term	20+ years	Scenario analysis	Scenario analysis

First-order impacts are acute and chronic hazards from climate change, measured in physical terms (e.g. property damage). They are relevant for all economic and human activities. Second-order impacts refer to the impacts of climate change on economy, humans, and ecosystems, such as productivity, employment, or the availability of natural resources. Traditional approaches to risk management are more difficult to apply to second-order impacts: probabilistic approaches are not adapted for second-order impacts, regardless of the timeframe.

Methods have been developed to assess risk at both the physical (building) and decision-making levels. ULI for instance defines the following method to assess risks generating risk-curve for each event and asset.

STEP 1

Identify the types of relevant hazards.

The first step is identifying the hazards relevant both today and in the future for a given location.

STEP 2

Two or three scenarios are designated for each event.

The most extreme events have the lowest probability, and the mildest versions have a higher probability of occurring. Relying solely on probability and historical data may not be enough as climate change is fundamentally altering the probability of extreme event. The timescale is also important: long-term chronic conditions may be as bad as hazardous, short-term conditions.

STEP 3

Identify affected assets.

Assessing both direct (e.g. damages to property) and indirect (e.g. higher insurance rates, lost services) impacts.

STEP 4

Financial assessment.

The following figure ranks estimated damages according to probability and severity of events. It shows that overall, events with a very low probability and very high severity will tend to generate very high damages, while events with a high probability and low severity will tend to create lower damages.

STEP 5

Calculate annual risk exposure values

For each event type and each asset, create a risk curve, then calculate the annual risk exposure by estimating the area under the curve.

STEP 6

Calculate cumulative risk exposure values

Calculate the net presence value of all future annual-risk-exposure values to understand the total risk a city and the assets face.

Figure 13: The process to assess climate risk exposure (adapted from ULI 2019)

Several assets, vulnerability curves or damage depth curves are used when defining a model: they describe the amount of damage expected as a function of the severity of the events.

The total risk, or cumulative risk exposure, for a given type of event is determined by calculating the net present value of the future annual risk exposure value.

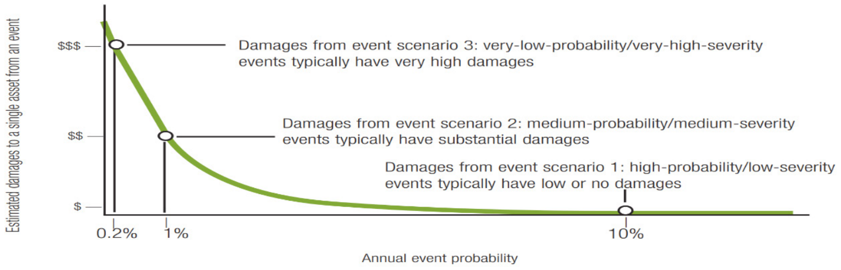


Figure 14: Risk curve of damages according to events (Source: ULI 2019)

Numerous methods exist to make risk assessments. The ISO 31000 standard “risk management” includes useful guidance for assessing and managing risks once they have been identified.

Its new 2018 version places more emphasis on the importance of governance (e.g. involvement of top management and integration into organisational decision-making processes).

Adaptation and the Buildings' Life Cycle

Adaptation must be integrated in each of the building's life cycle phase.

Inception

Assess climate risk

Share targets and challenges of adaptation

Develop tools to make adaptation-related decisions

Planning

Integrate reuse

Conceive with resilient landscaping and nature-based interventions

List and evaluate adaptation measure

Contracting

Integrate an adaptation action plan

Select solutions for a sustainable construction with the lead contractor

Include uncertainty in O&M protocols

Construction

Set up regular reporting on the delivery of adaptation targets

Mitigate the impacts of construction activities on pre-existing adaptation features

Operation & maintenance (O&M)

Update occupants on climate-related risks

Assess the impact of adaptation measures

Review reporting and monitoring procedures and users' guides

End-of-life

Assess the impact of adaptation measures on the lifespan of the asset

3. Developing a Lifecycle Approach in the Building Fabric

Associating the whole value chain and integrating long-term issues is necessary. All actors of the value chain are concerned by adaptation issues. The stakes of each actor will be studied in the following part on the frameworks of action.

3.1 THE EXTENDED PROJECT LIFECYCLE

Integrating climate change adaptation in buildings requires a systemic approach that goes beyond current practices that are often limited to short-term issues and contractual relationships.

A project to construct, renovate or adapt a building is generally carried out for a limited period and according to a temporary organisation mode (project mode) in order to meet specific requirements. To maximise the benefits for stakeholders, the project needs to achieve an optimal combination of time, cost, and quality performance in terms of allocating and exploiting resources while integrating wide-ranging social and environmental life-cycle considerations. These considerations have historically **tended to be limited to the project itself and to short-term issues and contractual relationships, without accountability for impacts and performance over the long-term**.

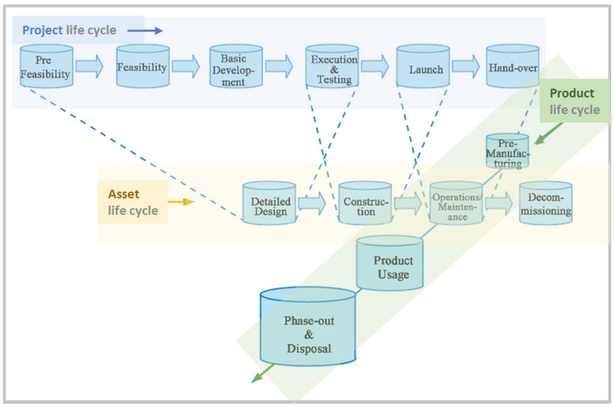


Figure 15: The extended project life cycle.

However, the impact that a project has on society, the environment, and the economy as well as its performance with respect to climate change, extends well beyond a project's execution. Consideration should be given to the **extended life cycle** of a project that includes not only the **life cycle of the building itself, but also the life-cycles of the result of the project, namely the building as an asset and as a provider of services** (see the figure above).

- The building's life-cycle is mainly concerned today with delivery and management of the project, while **the asset and service life-cycles include the long-term deliverables** that the project realizes, including the increasingly important deconstruction or renovation phase of the asset life cycle that is required for circularity.
- A building's extended life cycle therefore recognizes that **the planning and life-cycle assessment of adaptation are determined at both the building-level, including the products incorporated into a building, and at the asset and service levels**, namely the benefits and loads beyond the boundary of the building. In practice, the extended life-cycle excludes the pre-manufacture of products, while the various design phases are included in the planning phase. Testing and commissioning is included in the construction phase, and decommissioning and disposal (or phase-out) is included in the end-of-life phase.

Focusing on each of the extended life-cycle phases is a first step towards establishing action frameworks for the adaptation of buildings to climate change. This is because this approach helps identify the main issues and opportunities that stakeholders must coordinate on in order to provide seamless integration while balancing their own responsibilities with those of the construction process and that of the building.

- Without this focus, owing to the **lack of direct benefits, established concepts, clear drivers and easily understood incentives**, stakeholders tend not to be motivated to account for impacts, constraints, and opportunities that arise throughout a building's lifetime.

A) EMBEDDING ADAPTATION

The two main approaches for embedding climate-change adaptation into activities in the course of a building's life-cycle are:

- implementing a stand-alone, parallel adaptation plan, management system or management process in which the various actors engage at different phases
- inclusion of adaptation into normal business-as-usual processes at each phase

The inclusion of adaptation measures on buildings should become the norm. The **business-as-usual approach is preferred** because adaptation should be part of a building suppliers' standard services and not presented as an additional charge that depends on a client's decision. Clients are also unlikely to consider climate change adaptation in isolation from the overall effort to design and construct a satisfactory building.

The more a client can see that adaptation services are a well-established part of the building suppliers' normal service and in-house practice, the greater the **acceptance** of adaptation measures will be. The skills and competence required for delivering adaptation services are seen as extensions of existing practices that are informed by new principles.

B) THE CHALLENGES OF EMBEDDING ADAPTATION

The **traditional project delivery** model for all types of construction is generally sequential, reflecting the input of the project owner, financiers, architects, consulting engineers, contractors and key suppliers at different phases.

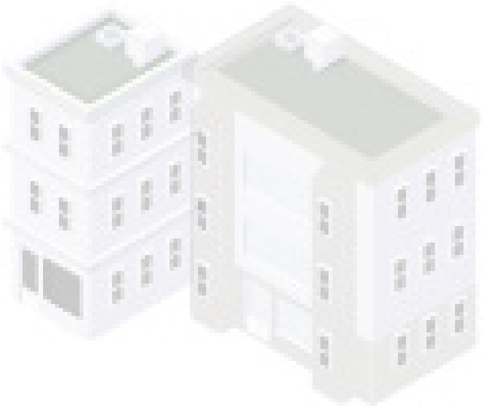
Ideally, the knowledge of all stakeholders involved at all phases should be fully utilised, especially early on in the design and planning phases and at later stages, depending upon the adaptation strategy.

In practice, contractors often work jointly with other partners using the design-build delivery model where some phases, notably planning and construction, overlap (other delivery models such as having a construction manager carry the construction risk are also used, but are less common). Design-build project delivery is increasingly supported by procurement processes enabled by BIM (Building Information Modelling) that provide increased flexibility in project procurement by allowing direct reporting to the client, optimal design input at early stages, early contractor and supplier engagement, and negotiation during tendering.

Similar life-cycle phases are recognisable for most delivery models, and activities at each phase do not depend strongly on the delivery model for most types of buildings.

Focusing on each of the life-cycle phases is therefore valuable and worthwhile, and helps in meeting the main adaptation challenge of developing an effective overall strategy and action framework for the entire life-cycle of a building.

With regard to adaptation, both the strategy and the action framework require effective decision-making and management processes to address the organisational, legal, financial, and information challenges which are summarised in Table 1.



	Challenges & Barriers for Building Adaptation
Organisational	• Fragmentation and a lack of collaboration in value and supply chains. • Essentially linear, step-by-step, on-site production processes involving a large number and variety of resources and knowledge-intensive services. • Wide variety of actors, each with conflicting interests, goals, and values. • Tight couplings between actors in individual projects and loose couplings elsewhere in order to balance the sharing and protection of knowledge, such that coordination is often transacted inefficiently at two interdependent levels, through either personal relationships or permanent networks of partnerships. • Processes, contractual agreements, liabilities, and complex interactions that link many connected but independent and heterogeneous actors. • Actions ranging from incremental changes within current processes to those aimed at a fundamental transformation resulting from either single initiatives or a series of rapid incremental changes. • Adjustment of the level, complexity and expertise requirements of decision-making, implementation and management throughout the building's lifespan. • Consideration of extended life-cycle issues such as adaptive capacity, land-use policies, spatial planning, and the resilience and vulnerability of the system within which a building operates, even if the system is outside the direct control of those managing or occupying the building.
Legal	• Property ownership situation where property rights may be distributed between various parties. • Tenure situation whereby a building's occupiers may be the owner, leaseholders, or tenants. • Land use and zoning plans that determine the extent to which a building or a building's use can change in order to adapt to climate change. • Secure construction permits and meet regulated building codes. • Cross-referenced building codes, standards, and regulations with a long-term perspective so that adaptation provisions agreed at the outset apply throughout the extended life-cycle of a building • Fixed schedules for regulatory and similar requirements. • Complementarity of engineered approaches with nature-based and management approaches through the integration of hard and soft measures while recognising that the complexity of natural and social systems may imply less precision and difficulty in establish legally binding requirements.
Financial	• Secure financing prior to the construction or renovation of a building. • Availability of public funds such as grants and tax advantages which promote the adoption of adaptation measures. • Maximise short and long-term financial returns on investments and minimise risk. • Diverging incentives and benefits between owners and occupiers. • Perceived high cost of project failure.
Understanding	• The more widespread and generalised climate-change impacts develop over the long-term and concern aspects that are often not immediately and easily identified. • Ways to exploit adaptive capacity as the primary strategy for the most efficient use of resources over the extended life-cycle. • Building users are generally unknown during the conception phase, meaning that it can be adjusted quickly to the users' needs. • Building adaptation needs to handle both slow onset ("chronic") impacts and sudden impacts owing to extreme ("acute") events. • Risk analysis for past, present, and future trends in terms of both average and extreme climate conditions, particularly with regard to extreme events. • Variability and seasonality of relevant climatic variables. • Identify climatic variables that are suitable for establishing performance standards. • Responses to be based on evidence-based decisions, with adjustment of risk assessment and management to the level of uncertainty and including both vulnerability and critical thresholds for chronic and acute impacts. • Integrated and synergistic approaches to adaptation that optimise trade-offs with other sustainability priorities. • Upgrading building performance as needed while at the same time reassessing the severity and speed of climate change and taking advantage of improved future technological advances. • Indicators to verify the trajectory of adaptation planning so that monitoring and evaluation can be used to instigate corrective action.

Table 1 : Effective decision making for building adaptation faces many challenges

Developments such as digitisation and the implementation of circular economy principles, modular construction and new methods such as performance-based procurement, mixed-method and value network approaches, science-based targets, and the definition of 'value' in terms of more inclusive non-financial criteria help **mitigate challenges** faced by the RBC sector.

However, given the degree of transformation required and the **urgent need to future-proof buildings,** both demand-side and supply-side actors will face challenges in mitigating climate change. Their contingency plans to drive efficiency and value for owners and users will also similarly face challenges.

3.2 IMPLEMENTING ADAPTATION INTO A BUILDING'S LIFE-CYCLE PHASES

Providing a **succinct appraisal** of adaptation issues and responses for each phase of a building's extended life-cycle is essential since the various adaptation issues can be crystallised at each phase into a limited and practical set of conclusions and outcomes that are carried forward to the next phase of a building's extended life-cycle.

For instance, stakeholders need:

- At inception phase, to agree on overall objectives for a building. For adaptation, as discussed below, they will ideally share their understanding of the issues by conducting a risk assessment and then agree on priorities and an overall strategy.
- At planning phase, to include feasibility studies, design (concept, detailed, technical) and documents on adaptation targets in the project and final brief and to explore a range of solutions according climate and economic scenarios. There is no one perfect solution that outclasses the others, but instead a set of possible solutions depending on the uncertainties and the choice of scenario.

Inception	Planning	Contracting
Activity		
• Sharing challenges and benefits of targets • Setting realistic parameters • Drafting a Strategic Brief	• Project team • Roles & responsibilities • Further dev. of strategic assessment • Brief (project, final), feasibility studies, design (concept, detailed, technical)	• Deployment of financial resources • Statutory & Planning • Warranty • Information for tendering • Tendering
Process		
Share Understanding • Agreed targets for adaption • Liability with respect to taking reasonable account of CC • Duty of care: inform stakeholder about integration of CC in the process • Life-cycle approach (i.e Level(s)) • Tools to help make adaptation-related decisions **Realistic Approach** • Materiality of risk, measures reasonable and good investment **Strategic Brief** • Strategic risk assessment including limitations	**Project Brief** • Include adaptation targets • Detailed climate resilience analysis • Reuse potential of the materials and systems • Choice of material climatic variables **Final Project Brief** • Assessment of impacts • Recognition of chronic and acute impacts on building • Weather file validity • Verification of significant climate vulnerability and risk **Adaptation Plan** • Include adaptive management • Allocative efficiency of hard and soft measures • Designs that allow reuse • Resilient landscaping and nature-based interventions **Design** • Test robustness of critical design components • Explore a range of solutions (best and worst scenario) • Description of seasonal control strategies and system • Requirements for systems, appliances, and fixtures **Review & compliance** • of final specifications to agreed adaptation criteria	• Integration of an adaptation action plan • Compliance of contractors and sub-contractors to adaptation criteria • Development with lead contractor of solutions • Integrate future uncertainty for O&M • Specification of building commissioning • Information for post-construction adaptation

Construction	Operation & Maintenance	End-of-Life
Activity		
• Site handover to the lead contractor • Mobilization of resources • Physical construction process • Handover to the client	• Assistance to occupants and users • Monitoring of O&M • Maintaining and improve maintainability	• Plan deconstruction and demolition • Transport and treatment of Waste and demolition material • Circularity
Process		
• Conformity with respect to adaptation targets • Regular reporting on delivery of adaptation targets • Monitoring and testing **Site** • Mitigation of construction activity impacts on preexisting nature based on site adaptation features **Handover** • Assessment at Handover **Review** • Information and assessment of adaptability (as O&M information)	**Occupants & Users** • Satisfaction surveys • Regular communication on assessment of climate-risks **Adaptation plan** • Long-term monitoring the adaptation plan • Evidence based Impact assessment of adaptation measures • Opportunities for further adaptation measures • Assessment of repair & maintenance **Review** • Follow-up procedures, guidelines	• Assessment of adaptation measures on life span of the existing asset

Table 2: Table: synthesis of detailed checklist (see appendix) to integrate adaptation into the building process.

3.3. CHANGES IN PROCUREMENT POLICIES

Climate risks are being increasingly integrated in procurement policies. This section on the building life-cycle can illustrate the importance of considering climate risks in the entire value chain.

Fievet (2013) stresses: “Four predicted changes to climate are likely to have the greatest implications for procurement decisions: rising sea level, higher temperatures, increased precipitation, and increased frequency of intense storms.”

The following actions can be taken to integrate climate change into the procurement process:

- Estimate the cost of installing, financing, maintaining, and replacing an added component because of climate change.
- **Reduce exposure to risk through contractual risk allocation and warranty negotiation with service providers.**
- Evaluate alternative technologies and favour the one with the lowest life-cycle cost estimate
- Favour no-regret options.

Scottish Sustainable Procurement Guidance on Climate Change

The sustainable procurement guidance on climate change adaptation provided by the Scottish Procurement and Commercial Directorate advises that "contracting authorities must consider carefully: the procurement stages at which adaptation is considered; the extent to which the contracting authority can prescribe adaptation measures; the extent to which the contracting authority can evaluate potentially diverse and even conflicting submissions from bidders" (Scottish Procurement and Commercial Directorate 2018). The guidance offers wording to be included in the contract notice:

- *"a requirement of this contract is that the supply or products and services is as climate resilient as is practicable, reflecting known or anticipated climate change impacts that may affect their supply during the lifetime of this contract", or:*
- *"The Contracting Authority has included obligations within the specification and contract conditions relating to adaptation to known or anticipated climate change, which are relevant to the products/services to be delivered."*
- *In the specification development phase, the contractor may be expected "to provide a method statement setting out how it has assessed risks associated with climate change, what those potential risks are and how they will be managed in the delivery of the contract/project."*

For Bennett and Collin (2018), in performance-based contracts "**the risk of climate change must be allocated to the contracting party best able to manage the impacts**". Five steps are proposed to manage the risks:

- Determine the criticality of the asset.
- Determine its vulnerability (including the exposure to hazards and the adaptation measures available).
- Determine the climate threat (future climate exposure).
- Determine the consequences in terms of costs.
- Identify adaptation measures.

Recommendations include:

- Treating excessive cost overruns associated with recovery from climate-induced extreme events as part of the history of non-performing contracts, and thereby penalising tenderers in future tenders.
- Mandating the use of climate projections to inform the design parameter.
- Realistically estimating potential emergency works on the basis of risk allocations.
- Providing asset owners with the maintenance history, as a means to identify trends in climate-change risks, so that increasingly accurate resilience considerations are addressed in future bids.
- Incentivising long-term climate change risk mitigation and adaptation by having longer contract periods.

4. Need for an Enabling Regulatory Framework

4.1 ADAPTING BUILDINGS TO CLIMATE CHANGE: GOVERNMENTS HAVE A RESPONSIBILITY TO LEGISLATE

Climate change has significant impacts on the economic, social, financial, and cultural life of a community and on the safety of its citizens. As such, governments have the responsibility to act on the reduction of current and future climate risks.

Government Engagement on Adapting Buildings to Climate Change

There are multiple reasons for the intervention of governments in the buildings' adaptation process:

- **The need to reduce the vulnerability of buildings is recognized at the international level**. The Sendai Framework offers a common vision for catastrophe-related risk reduction and recognizes the need to reduce the vulnerability of buildings.
- **Protecting people and properties is a key function of governments**. More precisely, protecting the built environment against risks is crucial to the functioning of human groups and is at the basis of existing regulations on buildings. As climate change increasingly stresses the built environment and threatens human safety, adapting buildings should be a high priority for governments and one of their primary responsibilities.
- **Climate change could have a significant social cost for governments**: Investing in buildings' adaptation can be seen by governments as a way to prevent some societal problems (e.g. violence, delinquency), that will be exacerbated if living conditions deteriorate.
- **The stakes are also financial** for governments: the earlier they invest in adaptation the lower the costs will be in terms of social and societal problems and also crisis management.
- Climate change also calls into question the measures currently in place to protect **cultural heritage** sites that may be threatened by climate

  resent another challenge, one that would allow governments to tackle poverty and better protect their vulnerable populations.

Adaptation measures are by nature location-specific and require the involvement of national and local governments. National governments define National Adaptation Plans which are then adapted at the local scale.

4.2 THE TECHNICAL AND PLANNING REGULATORY FRAMEWORK ON BUILDINGS MUST EVOLVE

Integrating the current and future climate in the regulatory framework is a complex endeavour.

- **The climate of reference is essential** for establishing construction norms and zoning. However, often the current climate is used as reference even though it is not an adequate reflection of what the climate will be like in the future.
- **Producing and sharing reliable information on the climate is required** to improve risk management and adaptation, yet governments face challenges in producing such information.
- **Risk management and sustainability efforts converge** as climate change disrupts businesses and challenges green goals.
- **Integrating adaptation policies in mitigation and development policies is crucial** to ensure that these policies do not contradict each other.

At the inter-ministerial level, the main ongoing changes are the following:

- **Requirements on reporting** for private actors regarding their extra-financial performance. Authorities often use these requirements to measure how the private sector is contributing toward climate change adaptation, as well as its awareness of the inherent risks involved.

- **The current approach to safety in buildings needs to be broadened** to include resilience and the social aspect of the issue, both of which at present are rarely considered. The current approach focuses on increasing a building's sturdiness, while its security is based on the ultimate limit state (ULS). An approach to safety incorporating resilience and social dimensions could involve for example the functioning of a building in "degraded mode" or the quick repair of basic services.
- **The future-proofing of buildings is hampered by the absence of codes, regulations and standards.** Certain countries and cities have recently decided to use **performance-based standards** that do not require climate criteria to be defined. Such standards make revision easier, since the base set of climatic data can be modified depending on future climate change without affecting the parent code. New initiatives looking at cities and infrastructure standards have been established to develop performance-based infrastructure standards.

The EU Taxonomy for Sustainable Activities

The EU Taxonomy is a tool for understanding whether an economic activity is environmentally sustainable or not. It sets performance thresholds for economic activities that make a substantial contribution to an environmental objective, avoiding significant harm to others (e.g. climate change mitigation and adaptation, pollution, waste and circular economy, water, biodiversity) and complying with minimum social safeguards. ***The taxonomy presents screening criteria on eight economic activities, including construction and real estate activities.***

The Taxonomy is included in the European Commission's Action Plan on Financing Sustainable Growth. In 2018 the Technical Expert Group on Sustainable Finance was established to help develop the technical details of the Taxonomy and make recommendations on climate disclosure, low carbon, bechmarks and an EU Green Bond Standard.

A political agreement was reached in December 2019, creating a legal framework for the Taxonomy and its governance. Climate change mitigation and climate change adaptation are core environmental objectives treated by the taxonomy, and technical screening criteria for both these objectives were published in March 2020. In the near future the taxonomy's principles could be integrated into countries' legislation.

4.3 INTEGRATING ADAPTATION INTO CODES AND STANDARDS

Governments have identified important standards to guarantee the resilience of buildings to climate change and are currently seeking to identify which standards need to be adapted to better take into account the current and future impacts of climate change in investment decisions.

New European and international standards are currently being put in place to help deal with adaptation and resilience for buildings and civil engineering works: standardisation supports regulation and stakeholders in their approach to climate change.

- **The RBC sector is one of the three priority sectors involved in the review process of the Eurocodes, according to the 2013 mandate "adaptation to climate change in standards for infrastructures"**. The revision concerns the thermal performance of buildings and building components (EN ISO 15927-4), ventilation for buildings (EN 16798), Sustainability of Construction Works, calculation methods for buildings (EN 15978 series) and for civil engineering works (EN 17472). As Eurocodes are being used by non-UE countries, the impact of this reviewing process will be significant (more information here).

- **ISO 14090, Adaptation to climate change — Principles, requirements and guidelines, is the first in a range of ISO standards in this area.** It was released in June 2019.
- Other standards are currently being developed including ISO 14091, *Adaptation to climate change Vulnerability, impacts and risk assessment* and ISO 14092, *Adaptation to climate change — Requirements and guidance on adaptation planning for local governments and communities.*Some standardisation guides also deal with adaptation to climate change, like ISO Guide 82 *Guideline for addressing sustainability in standards*, ISO Guide 73:2009 *Risk Management – Vocabulary*, CEN-CENELEC Guide 32 *Addressing climate change adaptation in standardization* and the to be published ISO Guide 84 *Guidelines for addressing climate change in standards.*

Copernicus Climate Change Services, in cooperation with NEN and BMGI, is developing a methodology to upgrade standards for the adaptation of infrastructures to climate change.

5. Need for Stakeholders' Engagement

Due to regulations and voluntary initiatives, organisations are increasingly communicating their exposure to climate and ESG (Environmental, Social and Governance) risks (UNEP FI 2019). Improving reporting on climate risk exposure is a climate adaptation measure. However, forward-looking disclosure is barely required, as regulation focuses mostly on current and short-term exposure. Different tools and recommendations are available, often not specific to the RBC sector.

5.1 GENERAL REPORTING FRAMEWORKS ADDRESSING CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Banks and financial institutions play a major role in real estate markets, providing loans and services to home buyers and asset investors. Finance is also exposed to climate risks, because linked to the real-estate industries, fo instance to keep property value as collateral of a mortgage.

Frameworks led by public authorities include:

- At the global level, the **TCFD** (Task Force on Climate-related Financial Disclosures) proposed, in June 2017, recommendations on the disclosure of clear, comparable and coherent information on the risks and opportunities of climate change. The Task Force aims at improving transparency for investors on the climate risks they are exposed to.
- At the regional level, improving transparency on climate vulnerability is one of the objectives of the European **action plan for sustainable finance.**
- At the national level, for example in France, **The French Article 173 of the Energy Transition Law of 2015** requires investors to report on how ESG and climate are integrated in their investment strategy. This includes measures implemented to adapt to climate change.

TCFD TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES

*The objective of the **[Task Force on Climate-related Financial Disclosures (TCFD)]** is to develop voluntary, consistent climate-related financial risk disclosures to be used by companies in order to provide information to all their stakeholders. It considers the physical and transition risks associated with climate change and what constitutes effective financial disclosures across industries.*

The work and recommendations of the Task Force help firms understand what financial markets want from disclosure in order to measure and respond to climate change risks and encourage firms to align their disclosures with investors' needs. Adaptation to climate change can be anchored in the four climate-related disclosures pillars.

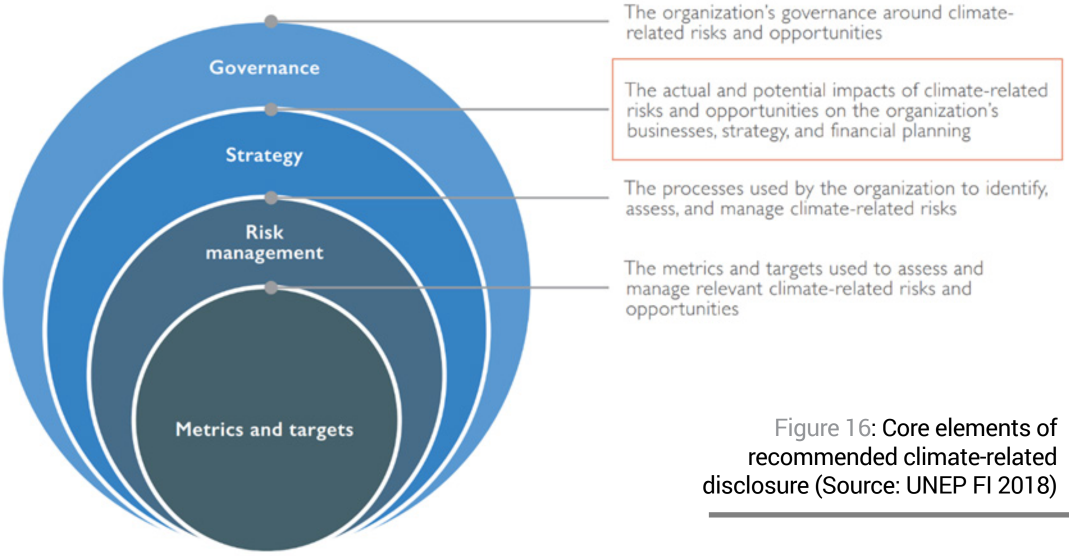
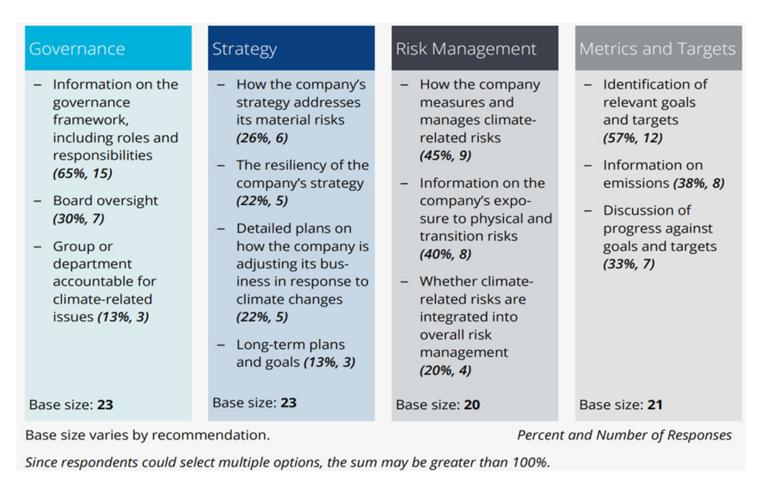


Figure 16: Core elements of recommended climate-related disclosure (Source: UNEP FI 2018)

***The 2019 status report of the TCFD reveals that the materials and buildings industry** has high levels of disclosure on strategy (impact on organisation) and metrics and targets (climate-related metrics and climate-related targets).*



Governance	Strategy	Risk Management	Metrics and Targets
– Information on the governance framework, including roles and responsibilities *(65%, 15)* – Board oversight *(30%, 7)* – Group or department accountable for climate-related issues *(13%, 3)*	– How the company's strategy addresses its material risks *(26%, 6)* – The resiliency of the company's strategy *(22%, 5)* – Detailed plans on how the company is adjusting its business in response to climate changes *(22%, 5)* – Long-term plans and goals *(13%, 3)*	– How the company measures and manages climate-related risks *(45%, 9)* – Information on the company's exposure to physical and transition risks *(40%, 8)* – Whether climate-related risks are integrated into overall risk management *(20%, 4)*	– Identification of relevant goals and targets *(57%, 12)* – Information on emissions *(38%, 8)* – Discussion of progress against goals and targets *(33%, 7)*
Base size: **23**	Base size: **23**	Base size: **20**	Base size: **21**

Base size varies by recommendation. *Percent and Number of Responses*

Since respondents could select multiple options, the sum may be greater than 100%.

Figure 17: Key themes of useful elements of climate-related disclosures (source: TCFD 2019)

Frameworks led by the private sector include the GRI (Global Reporting Initiative) and CDP (Carbon Disclosure Project). Companies are also encouraged to integrate reporting on ESG stakes into financial disclosures (including climate-risks adaptation strategies) and follow standards such as the "*Sustainability Accounting Standards Board" and the "UN Principles for Responsible Investment.*"

The GRI Sustainability Reporting Standards (GRI Standards) are the first and most widely adopted global standards for sustainability reporting. 93% of the world's largest 250 corporations now report on their sustainability performance using these standards.

CDP is a not-for-profit charity that runs a global disclosure system for investors, companies, cities, states, and regions to measure and manage their environmental impacts (e.g. climate change, water security and deforestation).

5.2 REPORTING FRAMEWORKS SPECIFIC TO REAL ESTATE

The Global Real Estate Sustainability Benchmark (GRESB) assessments, covering real estate, infrastructure funds, and infrastructure assets, assess and benchmark ESG performance for real assets. For the past three years, GRESB has offered a Resilience Module, designed to improve reporting and benchmarking for climate risk and resilience by property and infrastructure companies. In 2021, the Resilience Module will be integrated into its core assessments, making climate risk and resilience reporting mandatory for its participants.

GRESB assesses and benchmarks the Environmental, Social and Governance (ESG) performance of real assets, providing standardised and validated data to the capital markets. The 2019 real estate benchmark covers more than 1,000 property companies, real estate investment trusts (REITs), funds, and developers.

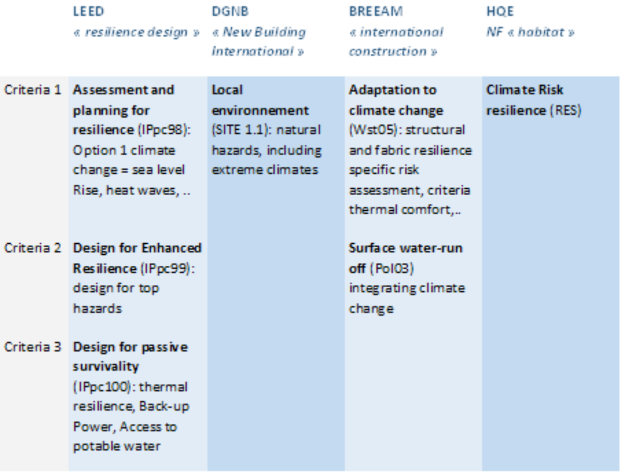
GRESB has an optional Resilience Module addressing the vulnerability of business operations and of assets to social and environmental shocks and stressors. This Resilience Module addresses the two fundamental dimensions of climate risk and resilience identified by TCFD : transition and physical risks. After 2020, resilience indicators will migrate into the core Real Estate and Infrastructure Assessments.

According to GRESB, in 2019 "participants reported having systematic risk management processes for all three issues with 92% reporting on physical risk management, 84% reporting on transition risk management, and 72% reporting on social risk management. Practices within these broad categories varied widely, and only a small minority of companies reported comprehensive programs." Results from the 2019 GRESB Resilience Module support several practical recommendations for real asset investors, for example not assuming that all companies are effectively managing climate risk and promoting resilience, asking for more information, having well-defined climate governance relevant risk assessment processes, coordinated business strategies, and aligned targets and operational measurement.

5.3 VOLUNTARY CERTIFICATION SCHEMES FOR BUILDINGS

Green Certification Schemes are starting to include requirements on the adaptation of buildings to climate change.

- **LEED** has released a Climate Resilience Screening Tool to provide a framework to prioritise opportunities for resilience rewarded in LEED credits (more information available here).
- For the **BREEAM** certification, a number of issues within the Refurbishment and Fit-Out scheme contains assessment criteria to support the mitigation of the impacts of extreme weather events arising from climate change (more information available here).
- **HQE** includes the identification of climate risk in the site analysis (more information available here).



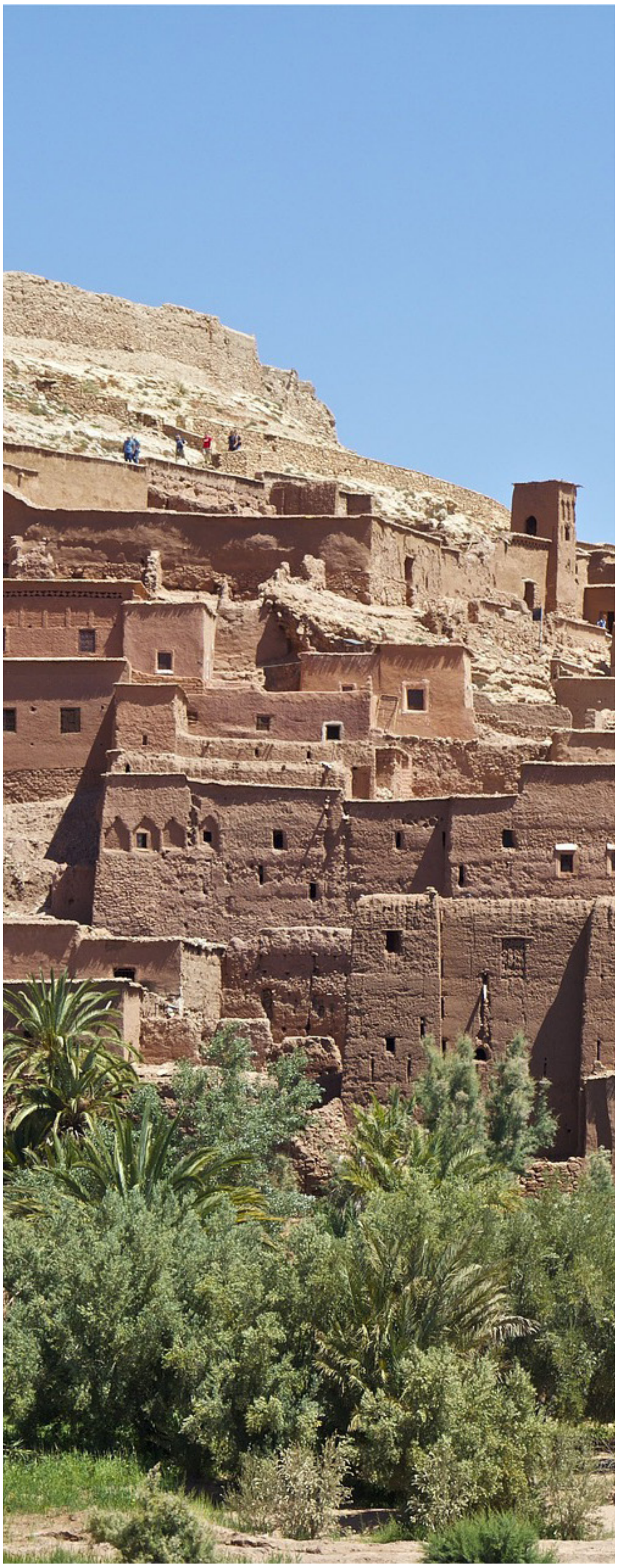
	LEED *« resilience design »*	DGNB *« New Building International »*	BREEAM *« international construction »*	HQE *NF « habitat »*
Criteria 1	**Assessment and planning for resilience** (IPpc98): Option 1 climate change = sea level Rise, heat waves, ..	**Local environnement** (SITE 1.1): natural hazards, including extreme climates	**Adaptation to climate change** (Wst05): structural and fabric resilience specific risk assessment, criteria thermal comfort,..	**Climate Risk resilience** (RES)
Criteria 2	**Design for Enhanced Resilience** (IPpc99): design for top hazards		**Surface water-run off** (Pol03) integrating climate change	
Criteria 3	**Design for passive survivality** (IPpc100): thermal resilience, Back-up Power, Access to potable water			

Figure 18: Example of climate resilience criteria in green Certification schemes

Although green building ratings and standards historically have prioritised climate change mitigation activities over adaptation, many of these ratings and standards can also be used to adapt buildings to climate change by considering specific issues, such as using LEED to reduce negative health outcomes following exposure to climatic events.

Some specific resilience certifications exist, such as:

- **Fortified** in USA (from Insurance Institute for Business and Home Safety, IBHS) for reinforcing natural hazard requirements
- **RELi** (from GBCI) which has a 360 degree approach of risk management (including natural hazard)



6. Adaptation of Non-Engineered Buildings

Non-engineered buildings need a specific approach.

It is estimated that *non-engineered* construction (either “traditional“construction based on local materials or construction that misuses industrial materials) **count for more than half of the buildings in most of the cities of the developing world.** These buildings account for most of the collapses and fatalities during natural disasters. Lack of integrity of a building’s structural elements, improper detailing of a building’s structural elements and low quality of construction materials are typical problems found in many of these structures due to misconceptions and a lack of guidelines and skilled technicians.

6.1 LOCALLY-DRIVEN

Beyond the building-specific specifications the need to strengthen, develop, and incorporate local knowledge and capacity within the community is of equal importance. It is often assumed that markets in developing countries lack access to appropriate materials for construction, and that this is why buildings fail when facing hazards. However, often this is not the main reason for the vulnerability of the built environment in these countries.

The vulnerability of the built environment in developing countries is frequently due to failure in knowledgeably monitoring and inspecting the construction phase; the misuse or misapplication of tools, materials, and techniques; or even a lack of sufficient time given to a process (e.g. allowing concrete to fully cure before proceeding with construction). Coupling international support (e.g. knowledge, materials, technologies) with local resources, knowledge, and skills builds capacity, lowers vulnerability, improves resilience, and maximises benefit for donor investments.

As underlined by IIED, global climate finance needs to develop the institutional channels through which to encourage and support hundreds of locally driven upgrading initiatives, within which resilience enhancement is embedded. This means that global funds for adaptation will have to establish how to work with local governments, and also with grassroots organisations and federations formed by the inhabitants of informal settlements.

6.2 GUIDANCE FOR DEVELOPING COUNTRIES

In many parts of developing countries, the most suitable approach for governments is to work with the inhabitants of informal settlements and their community organisations in improving housing quality and providing needed infrastructure and services. Owner-driven construction or upgrading can offer an alternative to a more formal method of governing building design and construction, such as through building codes and formal permitting processes.

Integrating adaptive and resilient approaches in owner-driven construction or slum upgrading projects could help to unlock greater capacity and action among at-risk populations, leading to an overall reduction in vulnerability. UNEP issued a “Guidance note on adaptation and the built environment” that presents a range of approaches and technologies tailored to a developing country context and a built environment that is largely self-constructed.

Identifying design ideas and potential technical approaches to reduce vulnerability according to local context is a crucial first step for any building and construction project. To address adaptation and resilience in owner-driven construction or slum upgrading initiatives, the UNEP guidance note encourages government officers, adaptation specialists, and development practitioners to consider the following points prior to undertaking a new project.

SUGGESTED LIST OF KEY QUESTIONS

UN environment programme

According to UNEP's "Guidance note on adaptation and the built environment," governments and project developers in developing countries should aim to identify the adaptation needs of their buildings and construction project and corresponding solutions.

1) What are the current local climatic conditions and the expected future conditions triggered by global climate change? Knowing how a building's design or use addresses the current and expected future climate conditions is of high importance.

a) Is the area in a hot and humid, hot and arid, temperate, or other type of climate zone?
b) What are the daily temperatures and expected future change (cooling-degree days)?
c) What are the current and expected changes in precipitation (increased or decreased rainfall, water shortages, flooding, etc.)?
d) Are there impacts expected from sea-level rise (flooding, storm surge, and availability of fresh water)?

2)What are the climate change-related risks (both current and future) at the project site?

a) Is there a better site for the project? One that has fewer expected hazards?
b) If the site cannot be moved or the hazard avoided, what is the magnitude of the hazard (e.g. top wind-speeds, flood line, etc.)? Knowing this will be critical in selecting a more appropriate building design approach.

3) Is the building location optimised?

a) Is the site and building designed to minimise flood or other climate risks (e.g. heat wave, sea-level rise etc.)?
b) Has the site taken full advantage of available nature-based solutions for solar gain, shading, and natural ventilation or drainage?
c) Does the building's design approach fully utilise tools for mitigating flood risk?
d) Is the building facing the proper orientation in order to minimise unwanted heat gain and take advantage of shading and natural wind flow?

Note: Ensure the design is appropriate for the hemisphere and distance from the equator (e.g. north-facing or south-facing)!

4) Do the key building design elements (such as walls, roofs, internal layout of spaces) adequately respond to current and expected future needs (e.g. warming, precipitation, etc.) and expected hazards, such as high-winds?

a) Is the roof optimized for shading? Reducing heat-gain? Resisting or mitigating damage from strong winds? (Reminder: this can include the shape and materials used but also construction methods).
b) Are the walls adequately designed for minimising unwanted heat loss or gain? Resisting or mitigating wind and water damage?
c) Is the layout (placement of rooms) optimised for natural ventilation and managing the heat or cold? What about for safety (e.g. bedrooms above flood elevation)?

5) Are the most appropriate materials and methods selected?

a) Is there sufficient local capacity for the installation and maintenance of the materials and/or construction practices, or is more knowledge and training needed?
b) Does the building utilise materials or methods that can mitigate or reduce risk (e.g. wet-dry construction)? Does it utilise a design for reconstruction? Does it employ frangible or triage design approaches?
c) Are the materials sustainably and locally sourced? Are the chosen materials most appropriate for the local climate (e.g. thermal performance, strength, recyclability)?

PART 3

Frameworks of Action

>> INTRODUCTION

The following part of the report focuses on Frameworks of action. Each of them will illustrate the challenges and current state of practice on building adaptation to climate change of a stakeholder of the Real estate, Building and Construction (RBC). Case studies and recommendations will also be presented in the frameworks of actions.

The **list of stakeholders covered in this part** has been defined with the Steering Committee of the project.

The **five challenges, the context and the state of play presented in each framework of action** rely on a literature review, an online survey and interviews with professionals during the period March 2019 to June 2020 (see methodology). Recommendations were inspired by the literature review and contributions from professional organizations. Case studies were identified in the literature review and interviews.
Before diving into each of the frameworks of action, five points need to be raised:

- Each stakeholder will be presented separately so as to facilitate reading. Of course, adapting buildings to climate change requires the mobilization of many actors, and they need to **work in an integrated, holistic manner**.
- **Both adaptation and mitigation** need to be pursued by RBC actors. Although some measures may contribute to both actions, as with the example of passive cooling systems, some adaptation measures, such as air conditioning, result in GHG emissions.
- The adaptation of buildings needs to be considered in a **lifecycle approach**. Even if some actors are involved only at a specific stage, considering the whole lifecycle of the building is important. For instance, choices made during the conception phase may limit the possibilities to improve the adaptation of the building in the operation phase.
- All actors should develop a **culture of risk management including the understanding of resilience.**
- Climate risks should be included in **financial decision-making**.

POLICY MAKERS		INVESTORS	DEVELOPERS	INSURERS
Governments	Local authorities			
Challenges				
Which data on climate risks and vulnerability is available? How to establish climate models at national and local scale? Which security margins to include in planning regulations and construction norms to face climate change by 2070? How to link adaptation, mitigation and development policies? What training and knowledge-sharing to provide to officials and private actors?	How to implement resilient, low-carbon and inclusive urban planning? What data and competences are required for risk-prevention policies? Which assessment methods for climate risks are available? How to improve community involvement and resilience? What financial subsidies can be developed and how to communicate on them (energy renovation, green procurements, uses, etc.)?	How to identify and quantify the current and future physical and financial impacts of climate change on assets? How to assess the level of risk of a building before acquisition? What is the cost of adaptation at the asset and portfolio levels? How to quantify the part of investment needed nowadays to avoid future higher costs of non-adaptation? How to address the difference in timeframes between short-term hold period and long-term climate impacts? How can adaptation to climate change be included in decarbonisation strategies?	How to deal with lack of data on climate modelling? Which are the vulnerability criteria for buildings? What is the pedagogic role towards clients that can be endorsed to raise awareness on the climate issue? How to reconcile environmental imperatives and innovation while staying within the allocated budgets? How to develop integrated and coherent projects within regulatory constraints such as allotment?	What are the possibilities to insure buildings in highly vulnerable locations at a bearable cost? How to encourage insured parties to set up adaptation strategies and invest in adaptation measures for their buildings? Which efforts by insured parties in adaptation strategies can be recognized and how? How can climate previsions be included in insurance models? How to cross and share data concerning risk assessment? How to limit rising insurance costs?
Recommendations				
INVOLVEMENT Set the institutional framework for risk prevention and management **DATA** Establish an open-source database on climate risks and vulnerabilities and model climate change at the local level **POLICY** . Define adaptation options focusing on priority sectors, including catastrophe management, and implement adequate financing . Implement, monitor and evaluate the adaptation actions in policies and projects **NORM** Include climate previsions in the construction norms that apply to both recent and vernacular methods of construction	**INVOLVEMENT** Engage with different stakeholders from local communities to investors **DATA** Identify buildings and infrastructure at risk **STRATEGY** . Anticipate urbanization to come in urban planning (including informal housing), and potential hazards that will become more frequent with climate change . Adapt urban planning to urban heat islands mitigation . Set up policies that value responsible approaches (by financial subsidies, or regulatory framework adaptation)	**INVOLVEMENT** Engage with policymakers on city-level resilience strategies and with the insurance industry **DATA** . Map physical risk for current portfolios and potential acquisitions . Incorporate climate risk into due diligence and other investment decision-making processes . Report on climate adaptation strategies at the portfolio level and integrate the TCFD recommendations **STRATEGY** Implement physical adaptation and mitigation measures for assets at risk	**INVOLVEMENT** Set up an upstream collaboration with architects Dialogue with other real estate actors in order to set up new levers **DATA** Establish a list of vulnerability criteria for buildings **ACTION** Limit the density of buildings **RESEARCH** Include social sciences in projects development	**INVOLVEMENT** . Engage with public authorities and investors on climate research and information . Encourage customers to adapt to climate change and reduce their greenhouse gas emissions through insurance products and services . Help policymakers identify the appropriate areas in which public-private cooperation can be beneficial **STRATEGY** . Recognize investments made by asset managers in resilience or mitigation measures with better premiums or more coverage . Divert from fossil energies and enhance investments in low-carbon technologies and renewable energies

DESIGN		MATERIAL MANUFACTURERS	PROPERTY & FACILITY MANAGERS
Architects	Engineering		
Challenges			
How to ensure that climate change adaptation is considered on every project? How to ensure that site-specific risks and potential benefits are sufficiently well analysed and addressed? How to ensure we reduce reliance on mechanical systems? How to address lack of awareness together with a fragmented design chain? How to tackle lack of regulation and market drivers?	How to harmonize climate risk assessment methods along the building value chain? How to integrate the adaptation as a business-as-usual approach of building process stakeholders? How to promote solutions robust to uncertainty? How to secure adaptation responsibility between building-process stakeholders? How to integrate hard and soft adaptation measures?	Which construction materials will be needed by 2050, considering the rising temperatures and increased frequency of climatic hazards? How to deal with climate change impacts on building materials' durability regarding existing buildings as well as future constructions? How to limit the environmental impact of the solutions produced? How to optimize energy consumption and reduce greenhouse gas emissions? How to conciliate imperatives of comfort, resistance and energy performance in the development of materials? What are the adaptation solutions to the depletion of natural resources?	How to measure the adaptation of buildings to climate change? Which data can be collected to encourage adaptation? Which type of awareness needs to be improved and which actions of owners and tenants related to resilience needs to be addressed? Which compromises can be found between user comfort, building security and energy performance? How to encourage owner's investments in innovation and resilience?
Recommendations			
INVOLVEMENT . Increase inter-disciplinary, cross-sector collaboration . Promote advocacy and awareness around the importance of climate adaptation **STRATEGY** . Embed climate resilience and adaptation into existing methodologies . Promote passive design and nature-based solutions **TRAINING** . Integrate climate resilience and adaptation into existing curriculum for both existing professionals and students	**INVOLVEMENT** Train engineers to these issues **DATA** Collect Data on adaptation measures **STRATEGY** . Extend the life-cycle approach, including not only life-cycle of the building project itself but also the life cycles of the result of the project, namely the building as an asset and as a provider of services -.At each phase of the building project (inception, planning, acquisition, construction and operation) integrate clear adaptation management requirements (see table below) **POLICY** Implement an effective decision making for building adaptation to address organization, legal, financial and information issues	**INVOLVEMENT** Raise awareness on climate change issues among the different actors and spread good practices **STRATEGY** Adapt ranges and productions to different habitat types **RESEARCH/STRATEGY** . Engage in circular economy approaches by limiting waste materials and enable better recycling and material reutilization . Observe practices in geographical areas where regular extreme weather conditions already exist . Orient Research & Development towards direct adaptation issues by promoting eco-innovation approaches	**INVOLVEMENT** . Engage with local stakeholders, especially local elected leadership . Consider psychological factors in energy management **DATA** . Use available data on environmental hazards from national and international sources . Promote and propose EPC (energy performance contracting) **ACTION** Identify gaps in building protection

Contributors and/or reviewers :

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE

1. Governments

5 MAIN IDENTIFIED CHALLENGES

Which data on climate risks and vulnerability is available?

- Assessing vulnerability requires data on socioeconomic factors. Even when data is available, relying on it may not be that easy as it may be complex to access, to understand and to use. More information is available in the context section of the report.

How to establish climate models on a national and local scale?

- Climate change will have very local impacts. Impacts at the local scale may be derived from global models or models may be established on a local basis. More information is available in the annex to the report.

Which safety margins to include in planning regulations and construction norms to face climate change by 2070?

- Using a technical approach alone to avoid risk by reinforcing robustness is reaching its limits when the evolution of climate and extreme events is uncertain. It can be too costly or may lead to mal-adaptation measures. The management of the coastline is a specific issue for national government: if the long-term trend of sea-rise is certain, level and speed remain uncertain. In this context, how to take into account long-term forecast?

How to link adaptation, mitigation and development policies?

- Adapting to climate change should not mean renouncing to mitigate climate change. Vulnerable populations will be most at risk. Adaptation, mitigation and development policies should be linked, but they depend on different actors.

What training and knowledge-sharing to provide to officials and private actors?

- Drafting and implementing adaptation measures for buildings require contextualised knowledge and training for all the actors, public and private, involved along the lifecycle of the building. Tailor-made training programs are considering the climate, topography, land-use, etc.

CONTEXT & BIBLIOGRAPHY: NATIONAL ADAPTATION PLANS

Floods and droughts are often identified as major hazards. In terms of national plans, the need for National Adaptation Plans (NAPs) was first agreed upon in 2011 at the CO17 in Durban South Africa. Since then, adaptation planning has become integrated into development planning. National Adaptation Plans have contributed to engage stakeholders with a framework for collective action (GlobalABC 2018).

Developed and developing countries are not facing the same level of risk, although flooding remains the most threatening risk for both.

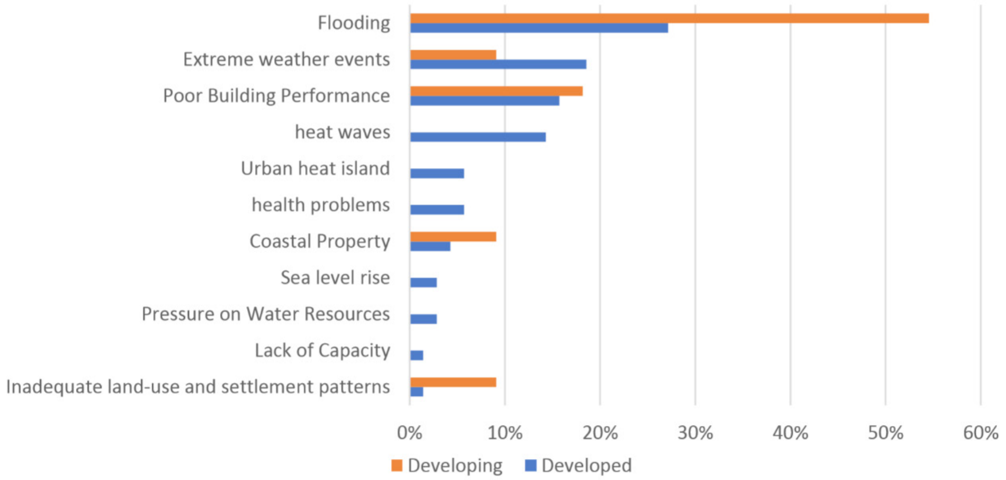


Figure 19: Variation in common issues of concern between developed and developing countries (Source: GlobalABC 2018)

Improving the adaptation of buildings in the informal sector is particularly challenging. One of the main issues being the lack of ownership titles.

The **Sendai Framework for Disaster Risk Reduction** 2015-2030 under the UN Office for Disaster Risk Reduction addresses the impacts of climate change through the lens of climate risk management (ecbi 2019). It aims at reaching “substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries”. The challenge for governments is also about how to find enough resources to be able to prioritize long term planning over short term needs.

STATE OF PLAY

By the end of 2018, 43 countries had submitted a National Adaptation Plans that included some building sector actions (GlobalABC 2018). Eight of them also included adaptation actions in their NDCs, while four countries included building sector adaptation actions in their NDC. Among African countries, 17 states include actions for the building sector within their **National Adaptation Plans**. Some countries, like Senegal, also included adaptation actions in NDCs.

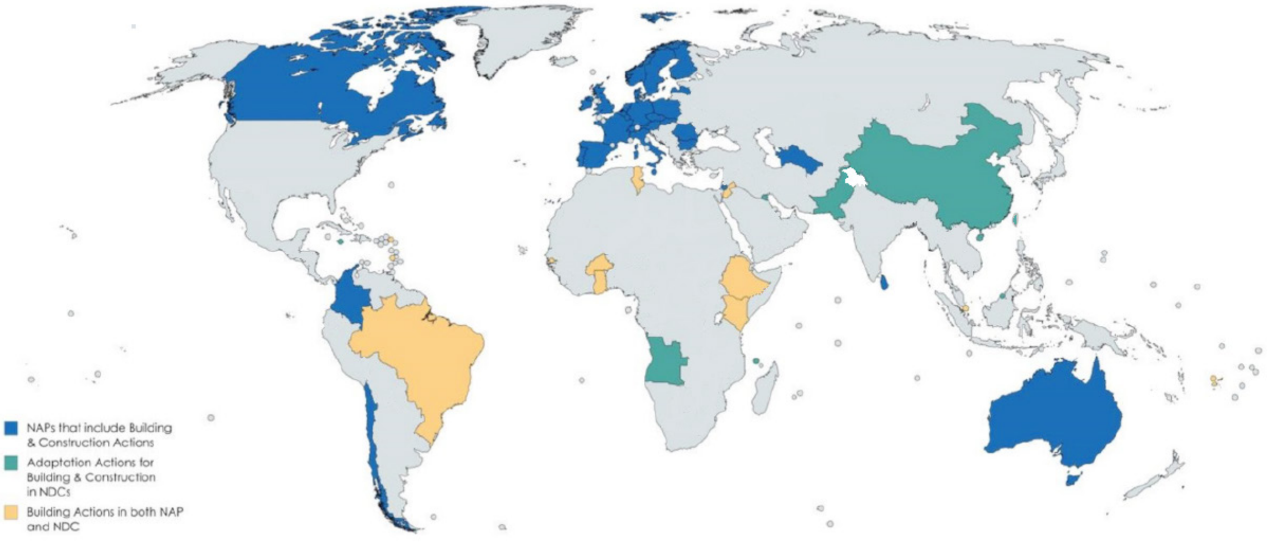


Figure 20: Global coverage of Building Sector Climate Adaptation Actions (Source: GABC 2018)

this map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area

The main measures presented in the adaptation plans for buildings concern:

- The integration of Urban Land-Use Planning to protect vulnerable populations and essential infrastructure.
- The creation of regulations and standards.
- The improvement of the energy efficiency and thermal comfort of buildings.
- The Promotion of research and development.
- Awareness-raising & capacity-building activities.

Framework laws and policies often include adaptation plans, information generation and sharing, regulation and early warning systems, but gaps remain on investment and economic incentives (Nachmany, Byrnes and Surminski 2019). In most developed countries, building codes are up-to-date and enforced. Hazards such as floods, tsunamis and fires are now fully addressed. Most buildings built in the last decades can resist in the face of natural disasters (100 Resilient Cities 2019). **However, many policy instruments focus on current risk and not future trends.** Only 7% of the flood laws analysed by Nachmany, Byrnes and Surminski (2019) contain a focus on climate change. They include the UK Flood and Water Management Act of 2010 and the Indonesia Act on Meteorology, Climatology and Geophysics of 2009. A quarter of the countries studied have adaptation-related building code requirements and around a third have land-use planning requirements.

A significant part of government-driven regulatory instruments and financial incentives focus on energy efficiency, whereas there should be a focus on adaptation as well. For example, India is planning to make the Energy Conservation Building Code mandatory in the near future, while Malaysia is aiming for stricter energy standards for buildings. Malaysia, and Thailand have several control and market-based instruments in place to promote green buildings. Comparatively, Philippines and Vietnam have limited incentives. Demand for green government's buildings and public buildings is also likely to increase. In India, several government buildings have incorporated green design. In the Philippines, new mandates from the Government Energy Program require increased water and energy efficiency for public buildings.

5 RECOMMENDATIONS

Involvement – Set the institutional framework for risk prevention and management

- Risk management policies usually involve emergency services (ministries of internal affairs and of health) and prevention (ministries in charge of environment and construction, ministry of health). Fires were one of the first risks to be dealt with by the public services. As risk management involves different ministries, one administration should be in charge of it and rules for cooperation should be defined.

Data – Establish an open-source database on climate risks and vulnerabilities, and model climate change, both at national and local level

- When available, databases may be scattered, thus requiring an assessment of available knowledge. Climate risks at the local level are often barely known. Evaluating climate vulnerability also requires access to socio-economic data. Many countries rely on general circulation models or on statistical and dynamical down scaling. They do not have national models ad dressing their specific context. The adaptation of buildings to climate change involves many different actors from different disciplines who need to work together. Capacity-building for the use of climate related data concerns government officials as well as private actors, for example through training and certification programs.

Standards – Include climate previsions in the construction norms that apply to both recent and vernacular methods of construction

- For buildings, in many places, increasing temperatures will lead to an increasing need for cooling. If this is not anticipated in the conception phase, relying on cooling systems will lead to a strong increase in GHG emissions. Construction codes and standards should address both contemporary and vernacular methods of construction. [...]

Passive measures including insulating and shading should be implemented so that occupants can use buildings even if energy services are not available. Also, the increasing frequency and intensity of extreme events calls for increasing sturdiness. Norms should target safety but also functional recovery. The average of the 30 last years, used to define the climate of reference, is not adequate anymore. A better option would be to refer to the maximum and minimum parameters of a climate hazard over an unfavourable period. A particular attention should also be paid to limiting urbanization where climate risks are high. Some areas will be affected by flooding. Other risks include withdrawal: swelling of clay soils under the effect of drought. Codes and standards tend to apply to new builds only, measures beyond codes and standards are needed to ensure the most vulnerable populations have access to adaptation and resiliency measures.

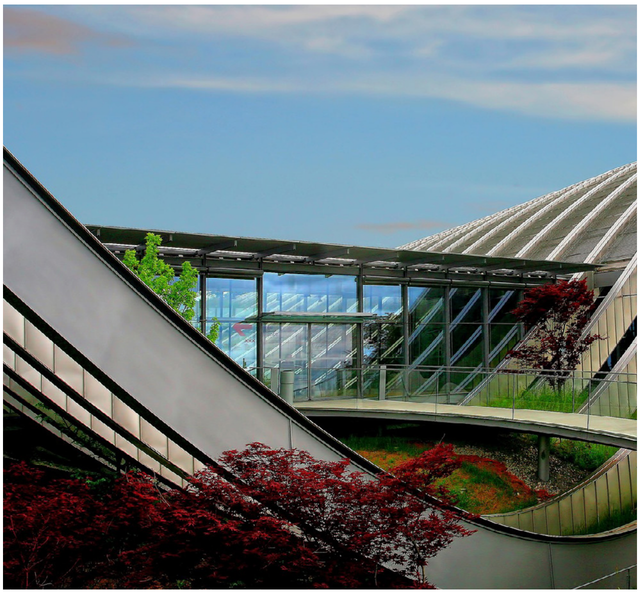
Policy – Define adaptation options focusing on priority sectors, including catastrophe management, and implement adequate financing measures

- Prevention is key to avoid and mitigate risks, and activating the solidarity to deal with low frequency risks. Governments should develop a culture of risk mitigation and resilience: policy should not be based only on hard engineering (protection infrastructure and reinforcement of robustness of assets) but also on social engineering (early warning, manage the decrease of the service level, recovery preparedness). The adaptation fund and GCF should be mobilized for the adaptation of buildings and the real estate sector. Improving adaptation will require mobilizing different sources of financing, such as central-government funds, public-private partnerships, institutional investors, insurance and, in developing economies, international financial institutions (Goldman Sachs 2019).

Policy – Implement, monitor and evaluate the adaptation actions in policies and projects

TOOLS

- **Copernicus Atmosphere Monitoring Service**: the CAMS provides consistent and quality controlled information related to air pollution and health, solar energy, greenhouse gas emissions climate forcing, everywhere in the world. More information available at this link.
- **Cordex**: Part of the World Climate Research Programme (UNESCO, WMO) the Coordinated Regional Climate Downscaling Experiment (CORDEX) serves as a catalyst to progress on Regional Level of Climate Change information challenge through the development of regional climate models (RCMs).
- **Drias**: or Data on French Regionalized climate scenarios and Impacts on the environment and Adaptation of Societies, is a programme providing free downscale information of future climate in France. More information in French available at this link.
- **Sendai indicators**: the “Sendai framework” provides indicators to track progress in disaster prevention and management. Ten of those indicators concern the built environment (ex: B3 dwellings damaged (B3) or destroyed (B4), economic loss in housing (C4) or in critical infrastructure (C5) or to cultural heritage (C6), number of damages or destroyed Heath (D2) or educational (D3) Facilities). More information available at this link.
- **GlobalABC roadmaps**: the GlobalABC develops regional “roadmaps for buildings and construction 2020-2050” based on a common framework including “resilience” (see pages 77-83, more information available at this link).



CASE STUDIES AND BEST PRACTICES

Climate Resilient Buildings and Core Public Infrastructure Initiative (CRBCPI), National Research Council Canada and Infrastructure Canada

- CRBCPI is a CAN $42.5M Canadian initiative to update building and infrastructure codes and standards to consider climate change and extreme events. By the end of the 5-year initiative in March 2021, CRBCPI will have produced a number of important outputs including: future climatic design data including climate change considerations for use in infrastructure/building codes and standards; national guidelines on flood-resistant buildings and wildland urban interface design for preventing the spread of wildfires; guidelines on the prevention of overheating of indoor spaces during heat waves; guidelines on the durability of building envelope and materials; guidelines on coastal risk assessment for buildings and infrastructure; pilot studies on the impact of climate change on LCA; and suites of standards including climate change adaptation considerations. More information is available here.

Schools resilience, Saint Lucia and Antigua & Barbados

- CTCN provides Technical Assistance to governments in order to improve climate change resilience in local communities by assessing and implementing available technologies and designing adaptation options for schools, also used as shelters. More information here.

Strengthening summer comfort in the future RE2020 regulation, France

- This is a very important objective of the national policy of adaptation to climate change (action P&R-8 of the NCCAP-2). It aims to protect the population (users of new buildings) from future heat waves, which will become more frequent and more intense whatever the GHG emission scenario is. RE2020 will integrate:

  . a level of exposure to “heat waves” in degree-hours (a threshold without air conditioning at 350 DH or 1 week at 2°C of the adaptive comfort temperature, and a threshold with fictitious air conditioning in order to take into account the energy needs following the installation of air conditioning after construction) based on a “reference heat wave scenario” (replace August climate data by the “heat wave” month of 2003)

  . different thresholds of energy demand or consumption in the summer period (BbioFr, CepFr) calculated according to the classical scenario. These thresholds are based on simulations and real measurements of pilot operations (see E+C-). The economic impact of each assumption is also evaluated.

Sea level rise for coastal risk prevention, France

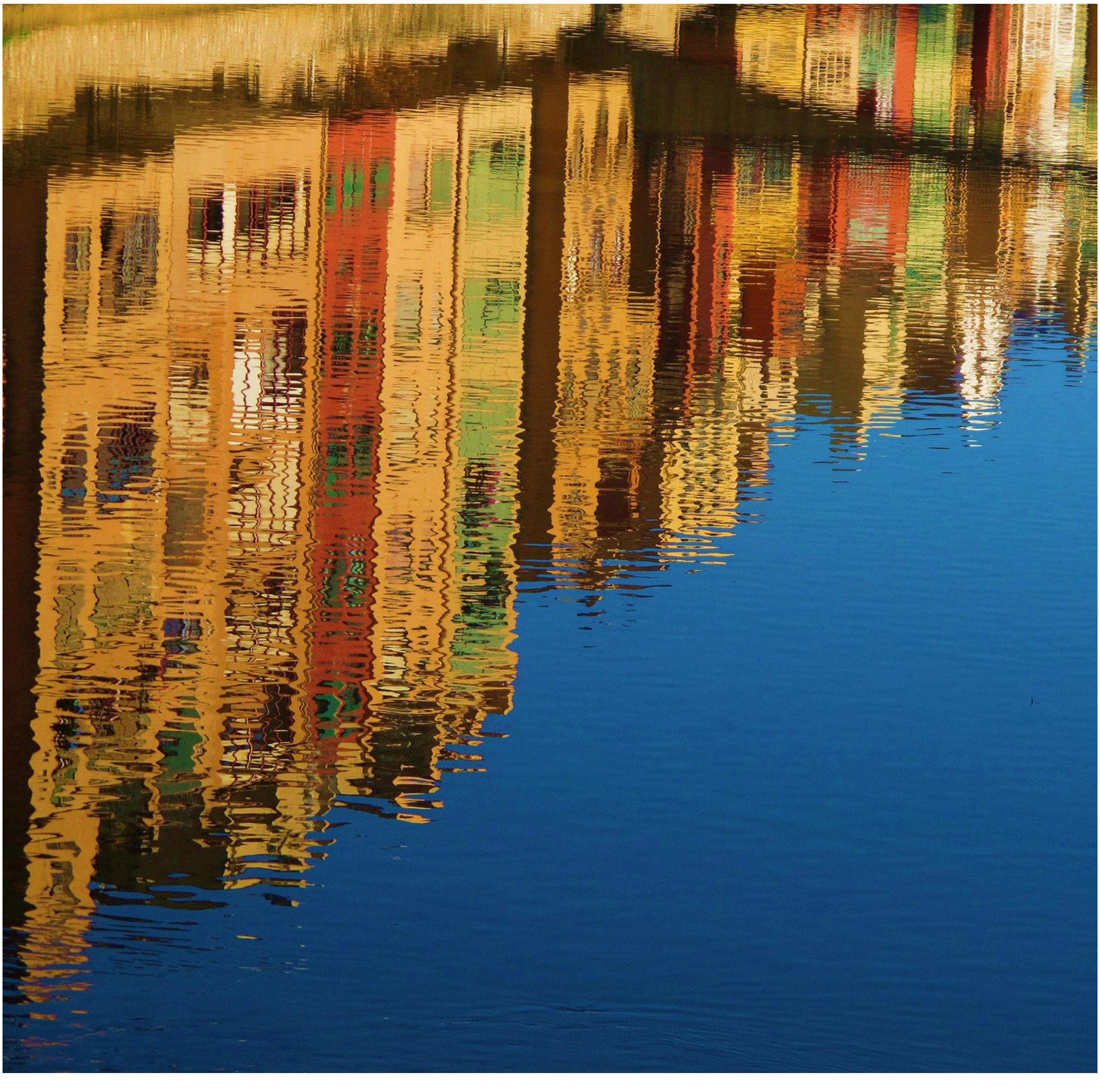
- Regulation to prevent coastal risk (submersion, etc.) called “Plan de Prevention des Risques Littoraux” takes the current sea level +20 cm as reference, and +60 cm for 2100. The zoning is based on +20cm level. These levels can change according to new scientific knowledge.

The Climate change adaptation in Built environment, Morocco

- Morocco has included in its national adaptation plan 2020-2025 a series of measures to be undertaken in the Housing sector both at building and urban area level. Adaptation is also included in the National Plan to Combat Climate Change by considering it as a vector of social and spatial solidarity (particularly in terms of flooding and water management).
- The climate change adaptation plan in the housing sector developed by the Ministry of National Land Management, Urban Planning, Housing and Urban Policy (Tangier Tetouan Al Hoceima region): a climate change vulnerability study has been carried out at the regional level and an adaptation plan is proposed (2020-2030). The proposed measures concern :

  - Construction methods adapted to floods and sustainable drainage systems;
  - Rational land use to adapt to sea level rise;
  - Taking into account the risk of landslides for new constructions;
  - Controlling the effects of urban heat islands and setting up green infrastructure;
  - Managing water demand and reusing waste water;
  - Limiting the development of new housing in areas vulnerable to fire.

- The implementation of a "programme for the sustainable development of Morocco's ksour and Kasbah (an age-old traditional form of housing) threatened by the impacts of climate change: Launched in 2015, this programme affects sixteen (16) pilot sites (nine in rural areas and seven in urban areas) located in the oasis areas of the Kingdom. It has made possible to improve the living conditions of 21400 inhabitants while preserving the authentic architectural and urban character, to strengthen the capacities of local actors and to finance 26 income-generating activity projects for the benefit of the target populations;
- The implementation of rehabilitation programmes for old medinas, a built heritage generally threatened by the intensity of the rains; The implementation of re-housing programmes for populations whose homes are located in sites at major risk and threatened by flooding;
- The implementation of programmes for the sustainable development of oases, particularly in Tafilalet (2006-2011), Drâa (2009-2012), and financial support for the Guelmim-Tata-Assag-Zag programme (2009-2011), programmes including the fight against desertification and silting, as well as the preservation of natural resources.
- Taking into account vulnerability maps in the examination of investment projects and in urban extensions.



Contributors and/or reviewers :

ICLEI Local Governments for Sustainability

2. Local authorities

5 MAIN IDENTIFIED CHALLENGES

How to implement resilient, low-carbon and inclusive urban planning?

- Urban planning impacts in several ways the resilience of buildings to climate change. Buildings face climate risks due to intrinsic factors (construction methods, technical equipment, uses, etc.) and extrinsic factors (infrastructure, urban heat islands, etc.). Adaptation and mitigation both need to be pursued.

What data and competences are required to design and implement risk-prevention policies?

- Extreme events such as floods and heatwaves will be more frequent and more intense. To prevent and manage them, local authorities will need to collect data (weather forecasts, buildings and population at risk, etc.) and coordinate different actors.

Which assessment methods for climate risks are available?

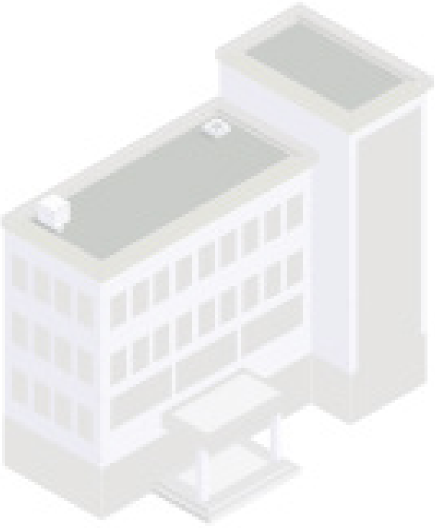
- Evaluating climate risks at the local level may be complex and it needs to rely onspecific methodologies. Questions arise on the level of detail required for urban planning in the climate models.

How to improve community involvement and resilience?

- Recovering from disasters depends on local actors. Local actors may also help identify vulnerable areas and populations and adaptation solutions. Simple tools for risk assessment and adaptation planning are needed, that don’t require immense amount of expertise. Often larger communities are more easily able to adapt than smaller ones, thanks to their resources.

What financial subsidies can be put in place and how to communicate on them (energy renovation, green procurements, uses, etc.)?

- The adaptation of buildings will be costly. Improving the adaptation of buildings to climate change requires mobilizing different sources of financing.



CONTEXT AND BIBLIOGRAPHY

The leeway of local authorities can differ according to their **geographical context, the type of entity** (city, region) they are, and the **type of mandate** (centralized or decentralized authorities) they received. The **city-scale** is an appropriate level for the development of urban resilience and/or adaptation plans, which must come from **urban development policies and community participation** (UNISDR 2012).

Local authorities are also the driving force behind the **production and sharing of information**, as well as the **deployment of financial mechanisms** to support the various actors in implementing their adaptation and resilience strategies (USAID 2018, Western Cape Government 2017). The **support of local economic actors** by public authorities is a key element of the adaptation process. By **adapting regulatory frameworks**, developing policies in **favour of energy renovation, revegetation** (100 Resilient Cities 2018) or by **communicating on the practices conducive to resilience**, local authorities play an essential role.

Thomas Tanner, Tom Mitchell, Emily Polack and Bruce Guenther (2009) highlight an urgent need to improve the understanding of climate vulnerability and adaptation in urban areas, **particularly where poverty levels and population growth rates are the highest**.

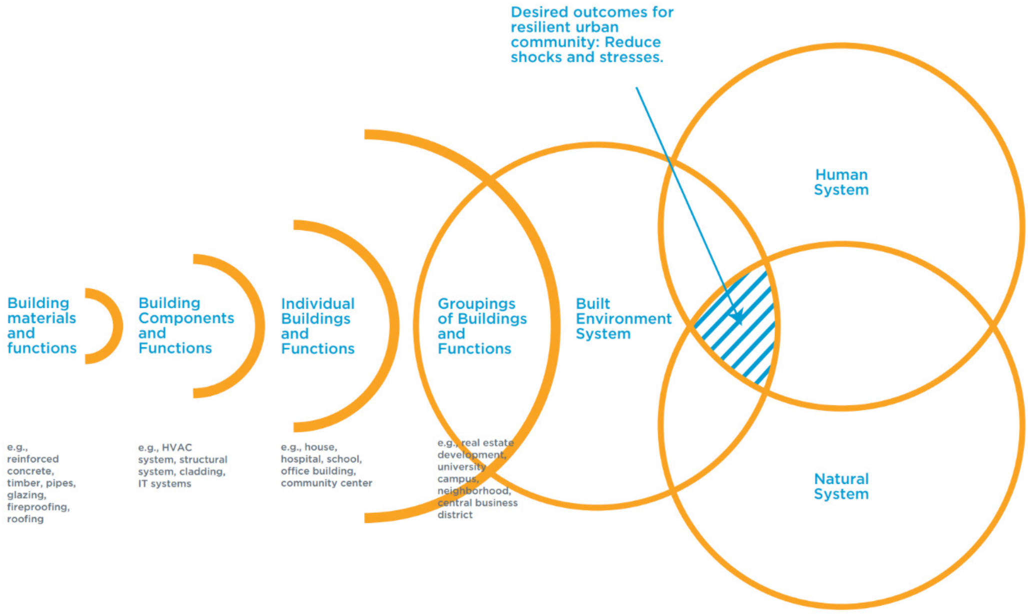


Figure 21: Global coverage of Building Sector Climate Adaptation Actions (Source: GABC 2018)

STATE OF PLAY

Data compiled in the Carbon Climate Registry (cCR) provides a snapshot of the state of climate adaptation at the local and subnational level (ICLEI and C40 2019). Managed by CDP and ICLEI, it allows local authorities to report climate mitigation and adaptation policies through a single-entry point. 1066 entities are registered, representing 9% of the global population. 295 local and regional governments (henceforth “entities”) have contributed to the adaptation section of the cCR within the mentioned timeframe. More than half (58%) of the entities which contributed to the adaptation section of the database have completed or are currently making a climate risk or vulnerability assessment, while 19% do not have or are not making provisions to take such step in the reporting period. The top 6 climate hazards reported globally as representing the highest risks for cities and regions are:

- Flood and sea level rise, including coastal erosion and submersion, river, groundwater and flash/surface flood
- Extreme precipitation, including rainstorm, monsoon, and hail
- Water scarcity and drought
- Extreme hot temperature, including heatwaves and extreme hot days

- Biological hazards, including vector-borne and water-borne diseases
- Storm and wind, including cyclone (hurricane/typhoon) and tornado

A total of 162 reporting entities (with 54% entities being from the Global South) have reported that they have either "completed" or are "in progress" of completing their Climate Adaptation Plan (these are "climate adaptation / resilience plans" and "integrated climate plans"). A total of 2,046 "adaptation-relevant actions" ("adaptation actions" and "adaptation actions with secondary focus on low emission development / mitigation") were reported. Adaptation plans are more frequent in large cities than in smaller cities (Climate Chance & Comité 21, 2019).

According to the 2019 annual report of the Global Covenant of Mayors (GCoM), the three main risks across GCom regions are flood, extreme heat and storms; colour intensity reflects cumulative population of GCoM cities within each region reporting each hazard type and does not equate hazard exposure.

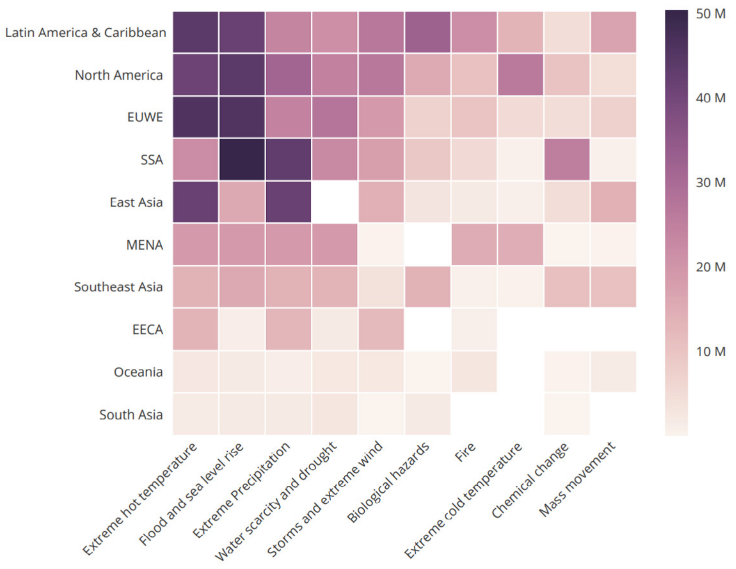


Figure 22: Distribution of hazards identified by reporting cities across Global Covenant of Mayors Region (source: GCoM 2019)

Abbreviations: SSA (Sub-Saharan Africa), MENA (Middle East & North Africa), EECA (East Europe & Central Asia), EUWE (European Union & Western Europe)

For the "Climate Chance" and "Comité 21" associations (2019), **cities struggle to go beyond the assessment phase and do not go to the planning and implementation phases**. Policies implemented often focus on visible hazards, including those linked to water risks. Adaptation actions include "green" actions, or nature-based, "hard" actions, including infrastructures adaptation to resist extreme events, and "soft" actions focused on governance, management and information. Planning and providing information are the most cited actions taken by local authorities: flood mapping, crisis management and education (Climate Change & Comité 21 2019). The report stresses that this is only part of the approach: other actions led by cities may contribute to climate adaptation but are not framed as such. Not all measures result from voluntary commitments: some measures on adaptation require enforcement by the law.

5 RECOMMENDATIONS

Involvement - Engage with different stakeholders from local communities to investors

- Engaging with the real estate industry would help to identify assets at risk and solutions to improve the adaptation at building, neighbourhood and city levels. It is also essential to identify buildings that can be used as shelters in case of emergency. Vulnerable populations should be included in the planning phase. Every actor should understand their role in risk and disaster prevention. Local authorities should also install early warning systems and emergency management structures in the city and organize public awareness raising exercises on a regular basis.

Data - Identify buildings and infrastructure at risk

- Some buildings and infrastructure are critical, they include vulnerable buildings, hospitals, schools, etc. Data on hazards and vulnerabilities need to be collected and updated frequently.

Strategy - Anticipate future urbanization in urban planning (including informal housing), and potential hazards that will become more frequent with climate change

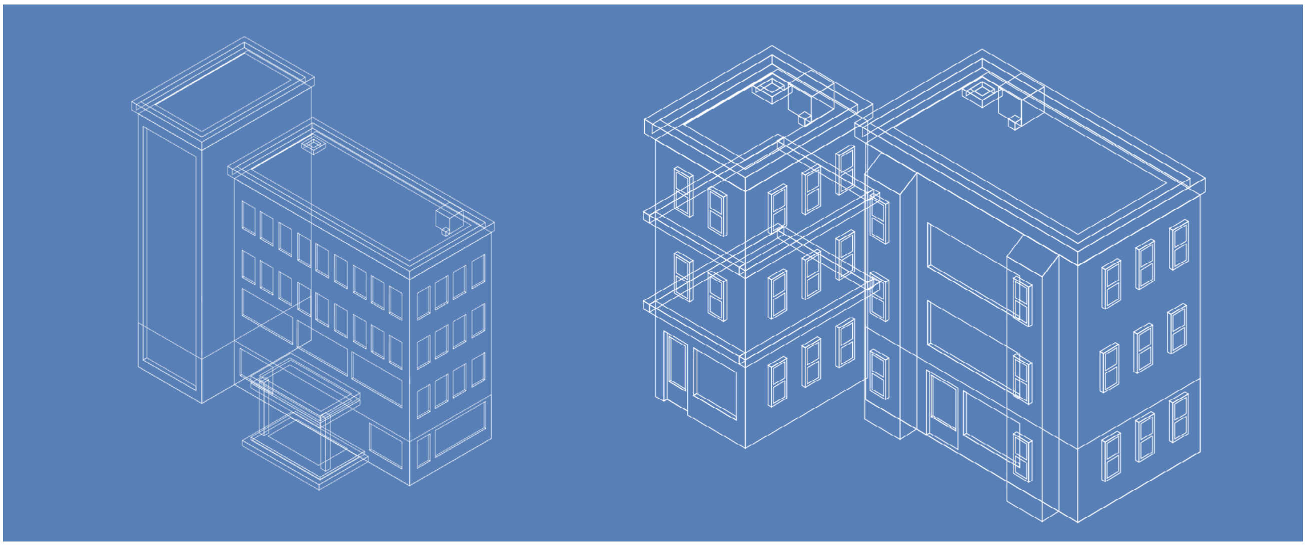
- This recommendation implies enforcing land-use planning principles that are realistic and that consider risks. Local authorities can identify low-risk lands for low-income citizens and improve informal settlements where possible. They should protect ecosystems and natural buffer zones to mitigate floods, storms and other hazards.

Strategy - Adapt urban planning to mitigate urban heat islands

- Measures include increasing the share of vegetated surfaces; limiting the density of building allowed in regulations (LUP); developing mixed neighbourhood; and implementing airflows (natural air ventilation in the city that limits the impacts of heat waves by regulating the temperatures felt).

Strategy - Set up policies that value responsible approaches (by offering financial subsidies, or adapting the regulatory framework)

- Local authorities can promote the use of local construction materials when possible, in order to limit the emissions due to the importation of materials (especially in developing countries where the local market may need to be supported). Other measures include providing grants and insurance incentives to homeowners, low-income families, communities, businesses and the public sector to make investments to reduce disaster risk; promoting passive systems (materials, building orientation, solar protections) in order to reduce the use of climatization; and promoting green procurements through financial subsidies and valuation policies (Western Cape Government, 2017).



Increasing tree cover and green spaces to battle heat island effect

Community gardens help increase water retention while encouraging community-building and local conservation

Greening rooftops to reduce summer heat, provide winter insulation, and reduce stormwater runoff

Increasing permeable surfaces and wetlands to increase natural infiltration of rainwater and reduce stormwater runoff

Toronto and **Montreal** are significantly expanding tree coverage, improving urban biodiversity and ecosystem connectivity

Dresden is building an urban gardening network to help with district-level regeneration efforts

Chicago's green rooftops have helped slow stormwater runoff by 36%

China's sponge cities pilot aims to capture, reuse or absorb up to 80% of stormwater runoff in urban areas by 2030

Figure 23: Urban Planning with Nature-Based Solutions for Adaptation (source: Global Committee for Adaptation 2019)

TOOLS

- **Covenant of Mayors technical materials**, reporting templates and guidelines including climate change adaption, are available at this link.
- **100 Resilient Cities**: the website of 100 Resilient Cities proposes tools to assess risks and to improve resilience at the local level, including but not only to climate change. More information available at this link.
- **ICLEI**: the website of ICLEI contains publications available at this link. ICLEI also organizes congresses on Resilient Cities and monitors the carbon Climate Registry, a voluntary reporting platform for local and regional governments, on climate mitigation and adaptation commitments, plans, actions and performance. Since 2016, the cCR has incorporated a new expanded adaptation section.
- **UNDRR resilient cities campaign**: Disaster Scorecard for cities is available at this link.

CASE STUDIES AND BEST PRACTICES

City of Toronto Green Roof bylaw, Canada (more information at **this link**)

- Part of its strategy to mitigate heat waves impacts and the UHI, Toronto was one of the first city (in 2009) to adopt a bylaw to require and govern the construction of green roofs and cool roofs.

Involving stakeholders through education and training in the Accra Resilience Strategy, in Ghana (100 Resilient Cities, report available at **this link)**

- One measure of the Resilience Strategy is to design a green building certification program to raise awareness and encourage the adoption of green and energy efficient construction in Accra. As part of this initiative, trainings for building inspectors and other officials focused on the rationale and importance of energy code compliance have been developed. This was led by Ghana Geological Survey Authority, Ghana Institution of Engineers, Architectural and Engineering Services Ltd, and the National Disaster Management Organisation. The Department of Works and the Spatial Planning Department have developed an education toolkit. It lays out the codes, the energy savings, and the business cases for adhering to them. Moreover, an incentive program for developers has been formalized to integrate renewable and energy efficient technologies.

Promoting resilient urban development in the Ramallah Resilience Strategy, Palestine (100 Resilient Cities, report available at **this link**)

- One of the goals of the Ramallah Resilience Strategy is to prioritise urban and economic development that supports resilience. To implement it, an action focuses on developing and promoting resilient urban design guidelines. The guidelines will support the strategic development of residential and mixed-use schemes covering issues such as public space, earthquake vulnerability, onsite water capture and reuse, and passive design solutions. This is led by the Ramallah Municipality, in partnership with the Association of Engineers, development and social sectors, universities, developers and the surrounding municipalities.

Promoting resilient urban development in the North of Ivory Coast (more information at **this link**)

- This project is an agroecology partnership between "La Voûte Nubienne" NGO and national institutions. In order to establish ecological habitats in vulnerable areas, agroecology patches are being put in place as front gardens for housing and schools. This method is used to fight against high temperatures thanks to the vegetation photosynthesis, and produce food without a high need of water. It is also a solution to maintain the stability of the soil and to reduce erosion.

3. Investors & Asset Managers

Contributors and/or reviewers :

UNEP FINANCE INITIATIVE

GRESB

5 MAIN IDENTIFIED CHALLENGES

How to identify and quantify the current and future physical and financial impacts of climate change on assets?

- Costs include maintenance costs, destructions, possible higher insurance premiums and the potential income impacts (e.g. reduction in rent due to the ways climate change affects buildings' desirability and lettability). They depend on the exposure of assets to the different hazards.

How to assess the level of risk of a building before acquisition?

- It is essential to know how climate risk exposure on given locations will evolve and to be aware of the risk factors for the buildings (basements, networks, glass areas, etc.).

What is the cost of adaptation at asset and portfolio levels? How to quantify the part of investment needed nowadays to avoid future higher costs of non-adaptation?

- To assessing the cost of adaptation it is important to understand the climate risks, including the evolution of climate hazards for selected scenarios and the vulnerability of assets. The different existing models (currently available or being developed) are listed in the Tool section of the report.

How to address the difference in timeframes between the short-term hold period and the long-term climate impacts?

- Long-term climate impacts are insufficiently included in investment and management strategies, which are defined over a much shorter period of time.

How can adaptation to climate change be included in decarbonisation strategies?

- Decarbonisation strategies may contribute to adaptation, for example if buildings are equipped with natural ventilation. However, as some mitigation measures will not directly contribute to adaptation, it is important to articulate both objectives.

CONTEXT & BIBLIOGRAPHY

For now, awareness of climate **risk is growing, but climate risks are not considered as a sufficient criterion to rule out investments** (ULI and Heitman 2019). Insurance remains the most commonly used method when facing climate-related risks, not arbitration. However, if it covers damages, it **does not protect against the depreciation of assets** that may occur from climate change.

STATE OF PLAY

In 2017, **74% of the institutional investors indicated seeing climate change as a major trend to deal with on the long term** (Novethic, PRI 2017). Investors who are not thinking about climate-related risks for their assets may need to re-evaluate their predictions. Indeed, financial actors tend to underestimate risks that appear uncertain and distant, in part because of a lack of tools and data, leading to short-sighted policies. However, in this case long-sighted policies and strategies would be needed.

In terms of processes, **most leading real estate companies are not establishing new policies and processes in relation to climate risk**. They are, however, modifying existing decision-making and management processes to add climate and extreme weather-related factors among the risks and opportunities to consider (ULI and Heitman 2019). UNEP-FI (2019) provides a **mapping of current physical risk assessment methodologies**.

Regulators are usually more concerned about solvency than risk-reduction from asset owners.

We can observe two major trends: there is more information about climate risks being transmitted to governance bodies, and climate risks are being integrated into the existing risk management framework.

5 RECOMMENDATIONS

Data - Map physical risk for current portfolios and potential acquisitions

- Mapping physical risk can help identifying assets which may be more likely to suffer losses in income or increases in costs. It should cover both incremental changes as well as extreme events, which are expected to be more intense and more frequent.

Data - Incorporate climate risk into due diligence and other investment decision-making processes

- Assessing risks may conduct to renouncing to acquisition, or to select the asset for another portfolio if the exposure of the initial portfolio to a given risk is too high (ULI 2019).

Strategy - Implement physical adaptation and mitigation measures for assets at risk

- Adaptation measures may contribute to the mitigation of climate change, such as passive cooling systems. Adaptation measures include technical and organisational actions. Technical actions can include strengthening the building's structure (to make it less likely to suffer damages), and organisational actions include for instance risk-preparedness for tenants.

Data - Report on climate adaptation strategies at the portfolio level and integrate the TCFD recommendations

- Improving transparency on the climate adaptation measures implemented is important to inform stakeholders about adaptation capacities and the involvement of investors in this issue.

Involvement - Engage with policymakers on city-level resilience strategies and with the insurance industry

- Preparing communities to react in case of disasters is an important part of resilience strategies. In addition, adaptation measures at the buildings level is not enough: the use of buildings requires networks to operate properly. Addressing challenges of ensuring buildings in risk-prone areas and accounting for the cost of adaptation measures requires to involve the insurance industry (which includes insurers of assets as well as those being insured).

TOOLS

- **CRREM [Carbon Risk Real Estate Monitor]** Risk Assessment Tool: This free, publicly available tool may be used to assess building performance against science-based decarbonisation pathways, allowing users to plan real estate portfolio composition and asset-level retrofitting to mitigate transition risk. It is available at this link.

- **LEED Climate resilience screening tool**: available in Excel format, it provides a practical framework to identify climate sensitivities and to prioritize opportunities to increase resilience through the green building outcomes rewarded in LEED credits. It is available at this link.

- **OID cartography of climate risks**: the Observatoire de l'Immobilier Durable (OID) developed a mapping tool to help owners and tenants of buildings in France identify buildings facing climate hazards. It is available at this link.

- **RELi Resilience Action List**: this package of resiliency criteria aims at being a source of design inspiration for more resilient communities, buildings, homes and infrastructure, available at this link.

- **IFC's [International Finance Corporation] Building Resilience Index**: This freely available tool verifies the building information, associated hazards, and risk mitigation strategies, and assigns a score to the building based on the hazard exposure and any residual risk. It identifies risks based on a project location, helps to manage risks and discloses risks by presenting buildings' letter grade resilience level. It is available at this link.

CASE STUDIES AND BEST PRACTICES

Heitman collaboration with Four Twenty Seven to map physical risks (more information at **this link**)

- Climate-risk assessment usually relies on insurance models and public data sets, where historical occurrences are the basis for modelling the risk of natural disasters, though data availability, accuracy, and transparency vary globally. Institutional investors in property must consider longer-term risk that spans over longer holding periods. Heitman turned to scientific climate models that project long-term, global climate change impact and help clarify changing exposure of assets to both extreme weather events and chronic, industry-disrupting fluctuations, such as rising sea levels. However, scientific models can be challenging to access and apply to a large portfolio of real assets. Heitman selected Four Twenty Seven to screen assets and potential new acquisitions and map climate risks around the world. The tools enabled Heitman to screen the current portfolio of Four Twenty Seven and the potential new acquisitions of the company.

AEW's adaptation plan:

- AEW has been implementing an adaptation strategy since 2016 that goes beyond simply reporting on physical and transition risks, but aims to reduce the vulnerability and increase the resilience to climate change of its assets under management. The main steps in implementing this strategy have been: 1- identification of climatology and meteorology experts to assess future exposure to climate-related hazards; 2- selection of an engineering consultant to assess the sensitivity of building components, uses and its surrounding environment; 3- testing of the assessment method and recommendations on a few assets before systematic use. This phase also includes an economic assessment by a real estate expert to understand the impact on the value of the assets according to three scenarios: no action, prevention against worst-case changes, and a balanced approach between resilience and return on investment.

Resilient infrastructure committee, Private Sector Alliance for Disaster Resilient Societies (ARISE) in the UAE (more information at **this link**)

- Within the UAE resilience strategy, UAE launched in 2020 the first ARISE initiative in the Arab region gathering private sector stakeholders which plan to institutionalize risk reduction management in UAE built environment using the 10 essentials of UNDRR. Two members, real estate companies (one, "Danube Properties", in development side and another one, "**Eltizam**", in physical asset management), were mandated in first board meeting to lead resilient infrastructure committee. Key points for the built environment are the followings:

- Having resilience plans for all buildings in Dubai that address all kinds of risks (including Climate Change related) is an important part of it. A process that includes central focal point for all internal and external stakeholders with clear responsibilities and roles are part of it.

- Understanding risks and hazards: natural, man-made and combined risks facing the building now and in the future
- Financial plan to meet resilience needs and making sure that there is funding for maintenance and upgrading of emergency systems.
- Making sure that building managers have the skills needed
- Readiness and emergency systems
- Plan post recovery and learning from experience and access to funds are necessary for faster recovery and building future capabilities.

GRESB Climate Risk Platform

Due to the chaotic nature of climatic patterns and increasing weather extremes — combined with the long lifetimes and limited mobility of real assets — more uncertainty must be taken into account when making investment and development decisions. Understanding physical climate risks, from the asset level up, is crucial to implementing well-informed risk management practices and increasing the resilience of real estate portfolios. The first step is to understand the portfolio's exposure to physical climate risk factors, where "exposure" is used to describe whether a hazard or climate pattern of a particular severity will occur at a specific location with a given probability or frequency.
The GRESB Climate Risk Platform gives asset managers a clear picture of portfolio exposure to a wide variety of physical climate risks at the asset level. Its database of geo-coded assets is mapped onto climate risk exposure outputs provided by external data providers to provide highly resolved geospatial intelligence on risk exposures to individual assets, across multiple climate scenarios and time frames. The first data provider on the platform is experienced reinsurance and risk solutions provider Munich Re.

- ***TCFD Reporting**: The Task Force on Climate-related Financial Disclosures recom-mends that companies identify, assess, and manage risks and opportunities related to both physical climate change and the transition to a low-carbon economy. The GRESB Climate Risk Platform allows companies to better understand what physical climate risks they are most exposed to, and on which assets to focus improvement efforts to increase resilience.*
- ***Due diligence**: The GRESB Climate Risk Platform allows users to assess the exposure of locations for potential asset transactions. Understanding the exposure of locations to physical climate risk ensures that potentially material risks are included in asset valuations.*
- ***Benchmarking**: Based on the exposures of all 100,000+ assets reported to GRESB, GRESB is able to benchmark the exposure of a portfolio against that of peer group portfolios by property type and region. Asset managers can use these benchmarks to compare their assets against their peers, getting a detailed picture of performance to guide strategic decision making.*
- ***GRESB** assesses and benchmarks the Environmental, Social and Governance (ESG) performance of real assets, providing standardized and validated data to the capital markets. Its ESG data covers USD 4.5 trillion in real estate and infrastructure value and is used by more than 100 institutional and financial investors to make decisions that are leading to a more sustainable real asset industry.*

More information at this link.

4. Property developers

Contributors and/or reviewers :

ICADE Bouygues Immobilier nexity

5 MAIN IDENTIFIED CHALLENGES

How to deal with the lack of data on climate modelling?

- Data on climate modelling is necessary to assess current and future risks (considering the variety of scenarios to analyse and interpret in real estate projects). Questions may arise about whether available data is precise enough or additional modelling is necessary. Education on climate models, data, and the use of that data is important in achieving a culture of resiliency in the design community. It is important to explain how to express the uncertainty in climate design data, and how to address this uncertainty in design.

What are the vulnerability criteria for buildings?

- Vulnerability criteria depend on technical and social factors. They are specific to each climate hazard and to the location of the building.

What role can property developers play to educate clients on climate issues?

- Even if projects parameters are defined by contracting authorities, property developers can play a role in encouraging them to take climate risks into account.

How to reconcile environmental imperatives and innovation while staying within the allocated budgets?

- Integrating adaptation into project development contributes to managing risks, and therefore maintaining the value of the building. Such benefits will be felt by the investor over the lifetime of the building. How do we justify the investment in adaptation when there is so much uncertainty in the future? This is difficult to justify when the benefits may not be seen for years (if ever - say a building is never hit by a hurricane). More work on the benefits of investing in adaptation (including economic, social, health) is needed to help investors make smart science-based decisions.

How to develop integrated and coherent projects within regulatory constraints such as allotment?

- Many solutions for the adaptation of buildings to climate change and for developing low-carbon emission projects require an integrated approach to real estate projects. They also should be planned from the early stages of the project.

CONTEXT & BIBLIOGRAPHY

The increasing frequency and intensity of **extreme weather events have raised awareness** on climate risks among property developers (ULI, 2015). However, when it comes to adaptation issues, developers must deal with multiple constraints: the **dependence on restricted budget envelopes** and on **regulatory frameworks** are often brakes to adaptation strategies, especially under **competition models**. While developers and their service providers recognise a **shift towards greater levels of responsibility and cost sharing for adaptation**, the operational ambiguities and financial risks hinder progress in this area (Urban Policy and Research, 2012). Still, property developers have a major role to play in adapting buildings to climate change, insofar they decide ofn the technical ways to make a project **resilient and adapted to the climatic changes to come**.

They are also important interlocutors for both public and private actors to get **operational feedbacks**, especially to improve **the regulatory framework and insurances practices**.

The report published by the Urban Land Institute in 2015 describes different interesting strategies used by developers in the US to adapt to climate-related risks (ULI, 2015).

STATE OF PLAY

Real estate developers cite regulation and expectations from investors as drivers to integrate climate adaptation into project development. There is however a lack of data on the state of play on climate adaptation of real estate developers at the global level.

5 RECOMMENDATIONS

Involvement - Set up an upstream collaboration with architects

- Collaboration is necessary to anticipate the project’s specificities concerning adaptation, for instance revegetation or natural ventilation (reducing the needs for AC).

Data - Establish a list of vulnerability criteria for buildings

- Criteria depend on the understanding of each climate hazard by the meteorological offices or climate services companies. They may include construction materials, networks, glass area, etc. This list should be established with architectural, building science and construction engineering researchers in collaboration with building managers and their teams in the field. It implies having a long-term approach on climate risks and considering the whole lifecycle of the building.

Action - Limit the density of buildings

- The objective is to reduce heat islands and soil sealing. This also implies to respect a certain biotope coefficient per area to limit soil artificialiation.

Involvement - Dialog with other real estate actors in order to set up new levers

- Developers should adopt a prospective role towards public actors (e.g. at the LUP level), in order to guide the evolution of regulatory frameworks. Another action is to communicate with insurers to promote building insurance premiums regarding adaptation strategies.

Research - Include social sciences in projects development

- Social sciences will help to have a better understanding of perceptions, uses and behaviours. This involves taking the psychological dimension into account to ensure, for instance, that energy sobriety is not perceived as a social downgrade (as it is often the case in developing countries) and making sure that the building is user-friendly and flexible for occupiers.

TOOLS

- **RELi Resilience Action List**: this package of resiliency criteria aims at being a source of design inspiration for more resilient communities, buildings, homes and infrastructure, available at this link.

- **THIS (Tool for Heat Island Simulation)**: a GIS extension model used worldwide to calculate urban heat island intensity based on urban geometry. More information at this link.

- **Urban Flood Management in a Changing Climate**: a tool that addresses the needs of practitioners concerning floods and allows them to easily access relevant guidance materials, available at this link.

- **EDGE Buildings (Excellence in Design for Greater Efficiencies)**: a green building certification that makes it faster and easier to build green, with free software to verify the resource efficiency of designs. In link with the IFC evaluation tool Building resilience Index. More information at this link.

- **Geospatial Decision Support System concerning soil sealing**: an operational instrument aiming to mitigate soil sealing. Integrated geospatial quantitative data and procedures on Europe are available and can be freely used by planners and developers. More information at this link.

CASE STUDIES AND BEST PRACTICES

Urban biodiversity for adaptation, with “Bocage Urbain”, by Icade and Elodie Stephan (more information at **this link**)

- In Aubervilliers (France), the project Bocage Urbain (Urban Grove Project) aims to use urban biodiversity to absorb runoff and limit the risks of flooding (it can also improve air quality), using the hedgerow model and adapting it to urban environments.

Facing drought and heat at the Residences at La Cantera (more information at **this link**)

- In San Antonio (United States), La Cantera is a residence designed to resist and recover from droughts, with water conservation and recycling, cistern to capture stormwater runoff and condensate, and native and drought-tolerant landscape. The resilience returns are estimated as follows: protection of $1.4 million parks, rental premiums, enhanced asset value of $500,000, $8,840 in annual water savings, and marketing advantages.

Low-carbon and low-energy buildings at the Prince’s Terrace (more information at **this link**)

- In Adelaide (Australia), the Prince’s Terrace is a residential project with an emphasis put on local, low-carbon materials and trades. It integrates passive design to drive greater thermal comfort and to maximise natural daylight and natural cross ventilation. As a result, the building uses 50% less energy and 50% less potable water than a typical urban townhouse.

A hospital resilient to wind and flooding from coastal storms (more information at **this link**)

- The Spaulding Rehabilitation Hospital is located on the Boston waterfront because water activities are key to its rehab program. It however faces risks of storms and sea-level rise. $1.5 million out of the $225 million program were dedicated to improve the resilience of the building, but the savings amount to $500,000 per year. Measures include the following: the first floor is 30 inches above the 500-year flood level to safeguard against projected sea-level rise over the life of the building; all mechanicals - boilers, chillers, air handlers for ventilation -were installed on the roof or in a penthouse.

Contributors and/or reviewers :

insurance europe

5. Insurers & reinsurers

5 MAIN IDENTIFIED CHALLENGES

What are the possibilities to insure buildings in highly vulnerable locations at a bearable cost?

- In places exposed to significant climate hazards, insurance premiums may become too high to be supported. New models need to be imagined.

How to encourage insured parties to set up adaptation strategies and invest in adaptation measures for their buildings? Which efforts by insured parties in adaptation strategies can be recognized and how?

- Premiums have not yet been affected by climate risks and are largely levied based on the historical analysis of climate hazards (ULI 2015). Such analysis does not correspond however to the climate of the coming decades and premiums might not be enough to cover losses.

How can climate previsions be included in insurance models?

- Models are often based on historical data while climate risk exposure and associated damages are expected to significantly increase in the coming years, as presented in the context section.

How to cross-reference and share data concerning risk assessment?

- The objective would be to establish a common set of standards to assess the exposure of buildings to climate risk. This would contribute to increasing awareness of climate risks among insured parties.

How to limit rising insurance costs?

- Limiting the rise in insurance costs will be a challenge especially for people with low incomes who are often also the most vulnerable to climate hazards. Not all of them however are covered by an insurance scheme.

CONTEXT & BIBLIOGRAPHY

Climate change can impact the different determinants of premiums: available insurance capital, returns on insurers' assets, risks and demand for insurance (ULI and Heitman 2019). Moreover, climate change is expected to lead to a higher volatility of prices. Insurers calculate risk premium each year, based on the past three years' tendencies, meaning that if extreme events occur more frequently, premium will likely rise on the long term. Considering the greater accuracy of extreme events, insurers will set up higher insurance premiums or decreased insurance coverage.

The insurance industry is more advanced on climate risks than investors and asset managers and they are used to resorting to stress tests. Given this expertise, the insurance industry has a significant part to play in helping to promote societal resilience (ClimateWise 2016). Measures must now be taken to help minimise future climate-related losses, and to ensure affordable and sustainable insurance cover in the years to come (Insurance Europe 2016).

STATE OF PLAY

A study conducted by ACPR (2019) showed that among French insurers, 43% had developed both an internal definition of the risks associated with climate change and an analysis process. About half of them reported having established proper tools to improve the recognition and effective integration of climate change risks into their risk management policy. The French Article 173 of the Energy Transition Law of 2015 requires investors to report on how ESG and Climate are considered in the investment strategy. According to the 2019 follow-up report, 3 years after this obligation, 36% of the structures, representing 94% of the total market value, had reported on how ESG and climate were tackled in their investment strategy.

Among the insurance industry, if there is agreement on the definition of climate risk, tools and methods to evaluate the exposure to climate risks remain different and will evolve over the coming years (ACPR 2019).

5 RECOMMENDATIONS

Strategy - Recognize investments made by asset managers in resilience or mitigation measures with better premiums or more coverage

- As proposed by ClimateWise (2016), this could include the development of new types of insurance cover or the evolution of existing ones to support the monetisation of returns on investing in resilience. Also, long-term incentives could be provided to policyholders through multi-year insurance policies.

Involvement - Engage with public authorities and investors on climate research and information

- It includes implementing or joining data-sharing initiatives to cross-reference data, improve risk assessment (notably the assessment of future risks) and support to adaptation measures.

Involvement - Encourage customers to adapt to climate change and reduce their greenhouse gas emissions through insurance products and services

- This could mean offering new options to policyholders who invest in resilience (ClimateWise 2019). It would reduce risk exposure.

Strategy - Divest from fossil energies and enhance investments in low-carbon technologies and renewable energies

- Although not directly targeting adaptation, this recommendation answers to the objective of addressing simultaneously adaptation to and mitigation of climate change.

Involvement - Help policymakers identify the appropriate areas in which public-private cooperation can be beneficial

- This could be done by providing research, encouraging prevention measures, delivering financial solutions and applying their expertise to track trends, and define problems posed by climate change (Insurance Europe 2016).

TOOLS

- **Open source models (such as the Oasis Loss Modelling Framework)**: The Oasis Loss Modelling Framework is an open source catastrophe modelling platform, free to use and constituted as a not-for-profit company. Its development is largely driven by the global insurance and reinsurance community. In 2018, 80 models were covered. Information is available at this link.

- **ClimateWise principles**: The ClimateWise Principles aims at providing a comprehensive reporting framework for the insurance industry. More information is available at this link.

- **Climada**: developed in Switzerland, Climada is an open-source economics of climate adaptation assessment model that uses state-of-the-art probabilistic modelling to estimate the expected economic damage, the incremental increase from economic growth and the further incremental increase of damage resulting from climate change. More information at this link.

- **ZÜRS Geo (Zonierungssystem für Überschwemmungsrisiko und Einschätzung von Umweltrisiken)**: developed in Germany, provides an online risk assessment tool for the insurance industry to assess flood risk and offer risk-related premiums. More information at this link.

- **Swiss Re's Catnet**: gives a general understanding of flood risks and explains how to manage and insure them. It also explores different types of flooding and the challenges involved in making them insurable. More information at this link.

CASE STUDIES AND BEST PRACTICES

“Blue Marble”, a start-up to provide insurance to low-income populations (more information at **this link**)

- In places exposed to significant climate hazards, insurance premiums may become too high to be supported. New models need to be imagined.

Insurance and reinsurance for damages from natural catastrophes (more information available at **this link**)

- In France, part of a Natcat’s surcharge on premiums goes to a public fund for investments (around €200 m). This investment goes towards the implementation of risk-reduction measures for insured, as is required in their local risk prevention plan, and for local authorities, so they may act as climatic/flood risk prevention project managers at river basin level.

A data-sharing initiative on climate risks (more information available at **this link**)

- The Federation of Finnish Financial Services (Finanssialan Keskusliitto) created a joint flood insurance data-sharing initiative with the Finnish Environment Institute. This is an example of a data-sharing partnership that other insurers in the world could introduce in their country.

Including aggressive physical scenarios by Aviva (more information available at **this link**)

- Aviva initiated a project to create best-in-class climate-related scenario analysis capability to enhance our disclosure. The project covers the identification of appropriate climate-related scenarios, assessment of those scenarios, and development of reporting formats for the results of the scenario analysis. The introduction of a more aggressive physical risk scenario, expecting an increase in temperatures of up to 6°C by 2100, enables the potential impact of more extreme physical risk outcomes to be assessed over a decision-useful, consistent and comparable time frame with the one used for transition risks.

Contributors and/or reviewers :

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6. Architects

5 MAIN IDENTIFIED CHALLENGES

How to ensure that climate change adaptation is considered on every project?

- Climate change adaptation should be considered on all projects. IPCC SR 10 recognises climate change adaptation as a critical component of disaster risk reduction, yet the need for climate change adaptation and mitigation strategies is not routinely considered as part of the design process and/or not undertaken methodically.

How to ensure that site-specific risks and potential benefits are sufficiently well analysed and addressed?

- Successful adaptation strategies require an understanding of anticipated climate change risks coupled with a rigorous assessment of site-specific characteristics such as orientation, elevation, slope, micro-climate etc, yet local climate projections may not always be readily available or potential long-term impacts clearly understood.

How to ensure we reduce reliance on mechanical systems?

- An over-reliance on mechanical systems increases vulnerability and reduces resilience. Passive design is crucial in thermal comfort to assure both adaptation and mitigation goals in the building sector.

  Vernacular design is often seen as a social devaluation in favour of so-called "modern" designs, less adapted to the present and future climatic conditions of the countries concerned. But both should go hand in hand to make buildings more resilient.

How to address lack of awareness together with a fragmented design chain?

- Successful climate adaptation strategies rely on integrated design solutions and effective collaborative working practices across different disciplines in which the hierarchy of risk is understood so that it can be progressively reduced throughout the entire design process, from planning through to construction.

How to tackle lack of regulation and market drivers?

- Greater advocacy is required about the need for clear guidance and coherence around policy and standards in relation to climate change adaptation and mitigation. Closer cross-sector collaboration is also required between built environment professionals, insurers, and funders. This includes sharing knowledge on different geographical areas, in order to compare different ways of solving common problems.

CONTEXT & BIBLIOGRAPHY

While attention among built environment professionals is increasingly focused on the urgent need to reduce carbon emissions, the growing frequency of extreme w, floods, and wildfires etc, is a reminder of the need to also focus on the matter of climate resilience and adaptation. An association of architecture organizations summarized the challenges posed by climate change and the solution to solve them in a guide aiming to lead architects towards the achievement of UN sustainable goals (UN, 2018). In its report, 'The business case for adapting buildings to climate change', Innovate UK published seven key messages together with a number of recommendations.

SEVEN KEY MESSAGES

o The market for design services to adapt buildings to future climate change remains very limited

o At present, the construction and property industries have no adaptation plan to tackle climate change

o The limited market is not an excuse for building design professionals to do nothing

o Clients and professionals urgently need educating in climate change adaptation for buildings

o Construction clients risk procuring stranded assets if they do not heed climate change risks

o There is a need for a programme of monitoring and evaluating the performance of climate adapted buildings.

o The Government must signal that adaptation in the built environment is a critical issue

Table 3: Seven Key Messages from 'The business case for adapting buildings to climate change'

STATE OF PLAY

- **Failure to address climate adaptation is recognised as a key risk**: In June 2020, the Commonwealth Association of Architects published its 'Survey of the Built Environment Professions in the Commonwealth' in which respondents from 33 countries rated 'Climate Change' and 'Resilience to disaster and the need for adaptation' as two of the biggest challenges facing the built environment in their countries. Respondents also cited 'Rapid urbanisation', 'Urban sprawl', 'Outdated planning policy and building code' together with 'Lack of enforcement of existing regulations' among their top 10 challenges.
- **More research is necessary**: A scoping study published in February 2020 by the Norwegian University of Science and Technology identified that there is a notably small body of literature on climate impacts and adaptation measures for buildings. In particular, there is a lack of material concerning the implication of climate change and relevant adaptation measures in cold climates

- **Architects have a key role to play**: In April 2019, the International Union of Architects (UIA) SDG Commission, together with Arcasia and the Institute of Architects Bangladesh, signed the 'UIA SDG Dhaka Declaration', calling on architects to actively contribute to the achievement of the UN Sustainable Development Goals. The Declaration notes that "Architects can take action to reduce or eliminate the climate changing emissions associated with the construction and operation of the buildings they design and make their designs adaptable to anticipated changes in climate".

- Specialist courses are available. **The Quebec Observatory for Adaptation to Climate Change**: Launching in Spring 2021, the Quebec Observatory for Adaptation to Climate Change will offer a 22 hour short course aimed at educating architects and other built environment professionals about the need to consider resilience and adaptation in relation to their projects.

- An increasing number of environmental frameworks exist which are intended to help building designers to engage with the subject of sustainability, and recognise the importance of climate resilience, e.g.: BREEAM, HQE, IFC EDGE and LEED.

5 RECOMMENDATIONS

Strategy - Embed climate resilience and adaptation into existing methodologies

- The preparation of formal evidence-based climate assessments and adaptation strategies should become an integral part of the designer's workflow and jointly owned by all members of the design team.

Involvement - Increase inter-disciplinary, cross-sector collaboration

- Effective adaptation relies upon each member of the design team recognising the importance of their contribution at each stage in the process, , i.e., planning, design, engineering and construction.

Strategy - Promote passive design and nature-based solutions

- Successful climate adaptation begins with the application of comprehensive passive design strategies which draw upon natural characteristics such as shade and ventilation and work with, rather than against, natural systems.

Training - Integrate climate resilience and adaptation into existing curriculum for both existing professionals and students

- Develop programmes to ensure that built environment professionals understand the importance of and are equipped with the necessary skills to engage with the challenges of climate resilience and adaptation.

Involvement - Promote advocacy and awareness around the importance of climate adaptation

- Professional bodies need to promote advocacy and help raise standards around climate adaptation with policy-makers, clients and their members.

TOOLS

- **Climate_ADAPT**: The European Climate Adaptation Platform Climate-ADAPT is a partnership between the European Commission and the European Environment Agency (EEA). Climate-ADAPT is maintained by the EEA with the support of the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA). Climate-ADAPT aims to support Europe in adapting to climate change helping users to access and share data and information on (more information at this link) :

  o Expected climate change in Europe
  o Current and future vulnerability of regions and sectors
  o EU, national and transnational adaptation strategies and actions
  o Adaptation case studies and potential adaptation options
  o Tools that support adaptation planning

- **Climate Just** is a web-based information tool designed to help with the delivery of equitable responses to climate change at the local level in the north-west of England. Its focus is to assist the development of socially just responses to the impacts of extreme events, such as flooding and heatwaves, as well as supporting wider climate change adaptation, (more information at this link)

- **UKCIP**, formerly known as the UK Climate Impacts Programme, based at the University of Oxford, produces guidance and tools for use in the development and implementation of planning adaptation strategies, (more information at this link).

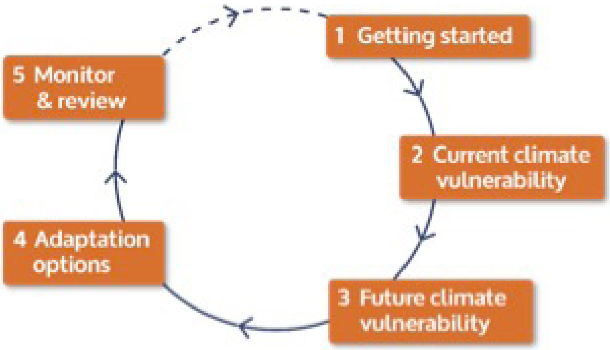


Figure 24: UKCIP Adaptation Wizard

- **The Green Studio Handbook, Environmental Strategies for Schematic Design**: provides a resource for designers seeking guidelines to integrate green design strategies into the conceptual and schematic design stages, (more information at this link).

- **Local Climate Zones classification scheme**: a global approach aiming to describe and characterize the physical nature of cities. The scheme comprises 17 zones based mainly on properties of surface structure (e.g. building and tree height & density) and surface cover (pervious vs. impervious). More information at this link.

CASE STUDIES AND BEST PRACTICE

Climate change impact assessment, Red Hill Primary School (more information at **this link**).

- This case study was developed by Worcestershire County Council using the UKCIP Adaptation Wizard (Version 1.0). The Adaptation Wizard was used by the County Council's architect to assess the impacts of climate change on a new school and to provide an initial outline adaptation strategy for the design and construction phases, and throughout the design life of the building.

Private sector firms are taking a lead (more information at **this link**).

- Engineering firm Cundall is among those demonstrating leadership with the publication of its 'Sustainability Roadmap' which identifies how the firm intends to maximise its impact under six key target areas: Climate positive action, Zero carbon energy, Health & Wellbeing, Materials and Supply Chain, Ethics and Equity, and Climate Adaptation. Its Climate Change Adaptation strategy aims to mitigate the impacts of predicted climate change scenarios by providing evidence-based design solutions and advice while improving how the firm's design advice responds to climate change scenarios by commissioning research and collaborating with others to investigate the effects and solutions of climate change on building and infrastructure design.

Thermal comfort in the Czech National Library of Technology (more information at **this link**)

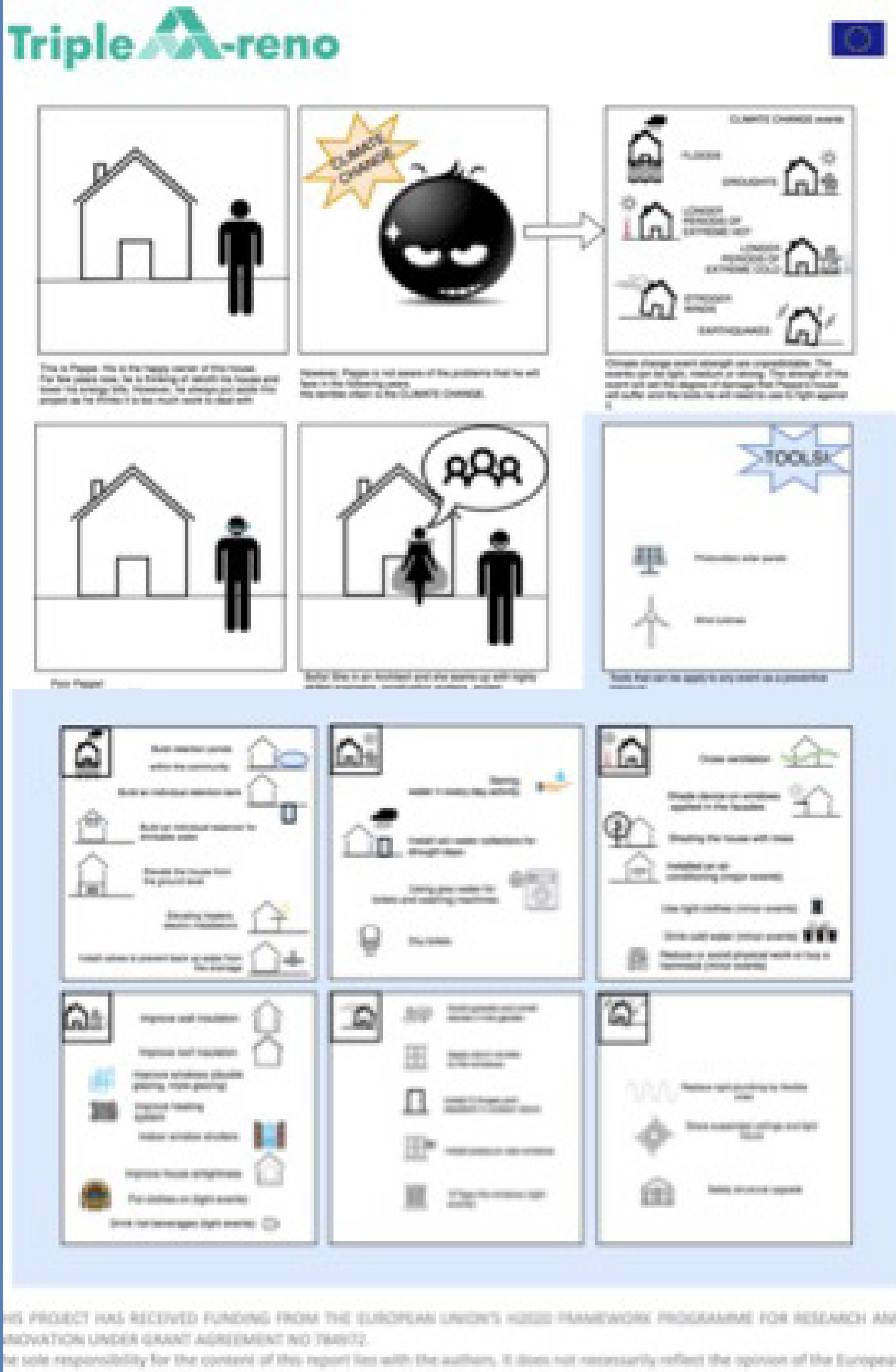
- The Czech National Library of Technology can be pre-cooled during summer months via natural ventilation through operable windows. A concrete core activation system is used to heat and cool the building. The façade is divided into glazed and solid segments in a near 50/50 ratio to minimise solar heat gains. The roof is covered with plants, for water-retention, slowing down roof drainage during heavy rains.

Water management at the Kärcher Visitor Center (more information at **this link**)

- The site has a rainwater retention basin with a capacity of 220m3. Woodchip heating with an output of 850 KW provides the buildings with energy. About 160 tonnes of old pallets can be processed in the pallet chipper per year and fed into the heating system. This covers about 40% of the total heating energy requirement. Outside, a biotope with two ponds was created, one of which can be used as an extinguishing water pond. Local animals and plants are to be settled here.

Academic education and continuous professional development of architects, EU-funded project

The European Union's H2020 Framework Programme for Research and Innovation financed a project, led in partnership with ACE (Architects' Council of Europe) to produce and spread some visuals illustrating how to integrate new climate change problematics into building conception.



More information at this link.

6. Engineering companies

Contributors and/or reviewers :

RESALLIENCE Consulting / Modelling / Business Strategy

FIDIC International Federation of Consulting Engineers
The Global Voice of Consulting Engineers

5 MAIN IDENTIFIED CHALLENGES

How to harmonize climate risk assessment methods along the building value chain?

- The assessment of the adaptation are determined at building-fabric level, but also at the product and at the building service level, along the building life cycle.

How to integrate the adaptation as a business-as-usual approach of building process stakeholders?

- Clients are unlikely to regard climate change adaptation in isolation from the overall effort to design and construct
- A clear and effective decision making for building adaptation is needed

How to promote solutions robust to uncertainty?

- Solutions designed for a certain climate condition should also be valuable if the condition in the future doesn't change the same way as forecasted

How to secure adaptation responsibility between building-process stakeholders?

- There is no prescribed industry standard on adaptation

How to integrate hard and soft adaptation measures?

- Necessity to articulate technical and social/behavioural dimension of adaptation

CONTEXT & BIBLIOGRAPHY

Climate change will highly impact buildings' structures and engineering companies working on a construction or renovation project will need to adapt their practices to develop a future-proof project. The impact a project has on society, the environment and the economy, and its performance with respect to climate change, extend well beyond a project's execution. They call for consideration of a building's **extended life cycle** that includes not only the delivery and management of the project but also the impact of deliverables that the project realises, including those arising at deconstruction or renovation. Engineering companies include all these parameters into the project. The tension created in considering a building's extended life cycle often calls for more complex and costly approaches, frameworks or processes. For adaptation considerations, all actors will share their understanding of the issues and then agree priorities and an overall strategy that can be carried forward to the next phase. Specific organisation, legal, financial, and information challenges are raised by adaptation.

STATE OF PLAY

In contrast to climate mitigation involving, for example, greenhouse gas emission during operation and energy efficiency, the methods and tools needed to implement adaptation strategies and planning lack established concepts, clear drivers and easily understood incentives. **The construction sector** is anchored by the difficulty to establish a common perspective for decision making to be able to introduce and implement practical solutions that provide adaptation to climate change. But the conventional building and construction process is generally sequential and fragmented.
However, given the degree of transformation that is needed and the urgency to future-proof buildings, it is wise to expect that **the ability of both demand-side and supply-side actors to mitigate climate risks will be challenged**. Providing a succinct appraisal of adaptation issues and responses for each life-cycle phase is therefore essential for engineering companies.

The consulting engineering industry represented by **FIDIC**, the international federation of consulting engineers with a member association grouping consulting engineering companies in over 100 countries, is a major actor on each phase of a building's life cycle from inception through to planning, design, construction, operation and eventual deconstruction or renovation. Engineering companies are encouraged to integrate adaptation issues at each phase of a building's life cycle. A similar life-cycle has been adopted for dealing with several complex, multifaceted aspects of buildings other than adaptation, such as embodied carbon, carbon pricing, resource efficiency, circularity, and taxation.

5 RECOMMENDATIONS

Extend the life-cycle approach, including not only life-cycle of the building project itself but also **life cycles of the result of the project**, namely the building as an asset and as a provider of services.

At each phase of the building project (inception, planning, acquisition, construction and operation) **integrate clear adaptation management requirements** (see table below).

Implement an effective decision making for building adaptation to address organization, legal, financial and information issues (see...).

Collect Data on adaptation measures.

Train engineers to these issues. Training is key, as well as the development of guidance documents, standards and codes, sharing of best practices, risk assessment and design tools, and certification programs for professionals. A 'learning needs' assessment should be conducted before the design and delivery of (both basic and advanced levels) training and capacity building programs.

BUILDING CYCLE	REQUIREMENTS
Inception	**Agree and document the general principles** that strategically align each of the stakeholders' expectations.
Planning	Ensure that a fully representative project team briefed by the client **delivers a final project brief that meets established industry** best-practices for identifying and implementing adaptation measures.
Acquisition	Ensure that **adaptation planning, management, monitoring, review and reporting are fully incorporated into a building project's acquisition phase** that involves finalising the legal and financial processes needed to deliver the project according to agreed requirements.
Construction	**Ensure that project and contract management procedures monitor, test, certify, adjust where necessary and communicate adaptation requirements**, impacts and outcomes.
Operation	**Recognise the importance of comprehensive reviews of evidence-based impacts** in monitoring and adjusting planned and specified adaptation measures.

TOOLS

- PIEVC Engineering Protocol: the "Public infrastructure engineering vulnerability committee" protocol based on an "engineers Canada" initiative is a five step process (1-Project definition setting boundaries, 2-Data gathering and sufficiency including identification of the features of the infrastructure and of the applicable climate, 3-Risk assessment including identification of components' sensitivity to particular climate parameters, 4-Engineering analysis including assessment of total projected load and capacity, 5-Recommendations) to analyse the engineering vulnerability of an individual infrastructure (e.g. a building or an infrastructure system such as a potable water treatment and supply system) to current and future climate parameters such as extreme heat or extreme rainfall.

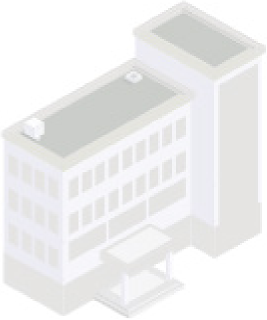
- Weathershift: is a tool, from an ARUP led initiative, using data from global climate change modelling to produce EPW weather files adjusted for changing climate conditions (i.e. FTMY data). Projected data can be produced for any location in the world where weather data files in EPW format are available for shifting under three future time periods (2035, 2065, 2090) across a range of climate scenarios.

- CCWorldWeatherGen: "Climate Change World Weather File Generator for World-Wide Weather Data – CCWorldWeatherGen | Sustainable Energy Research Group" 2015.

CASE STUDIES AND BEST PRACTICES

Nanaimo regional general hospital –climate change vulnerability assessment, Canada

- A climate change vulnerability assessment was conducted by the Vancouver Island Health Authority for Nanaimo Regional General Hospital (NRGH) using the PIEVC protocol. The work consisted of identifying the potentially vulnerable infrastructure systems, determining possible climate change induced effects on relevant climatic parameters, and developing a risk rating for each possible interaction. More information at this link.



Numerical modelling for a better adaptation of buildings to climate-change induced urban heat islands – RESALLIENCE

RESALLIENCE delivered two numerical modelling projects of Urban Heat Islands simulations through the quantification of vegetation evapotranspiration under hot and uncomfortable meteorological conditions. The objective of this type of study is to evaluate the cooling potential of an urban development project. Both presented case studies are in Île de France and under the same climate hypothesis, however.

- *The first case study concerns a listed Haussmann-style building whose capacity to adapt to climate change is constrained by the urban context, architectural heritage and regulations;*
- *The second case study concerns a study in the design phase constrained by carbon neutrality objectives in a new urban environment involving other building projects.*

Case study 1: Evaluation of the cooling potential of a train station requalification project.

*This case study allowed the promoters of a train station requalification project to **evaluate and map the impact of evapotranspiration from the different vegetated zones** on project area and its close environment under conditions of high heat. For the modelling, the choice of a hot weather situation has been chosen in coordination with the client, as well as the hypothesis related to the irrigation conditions of vegetation areas, including green roofs, roof gardens, trees and green facades.*

The results of the simulation with the cooling potential are presented with:

- *Air temperature at 1m from surfaces (floors, walls, roofs, etc.);*
- *3D iso-contour for a given air temperature threshold;*

*These 3D envelopes allow to visualize the zone inside which a **gain of 1° or 2° is calculated** by the modelling.*

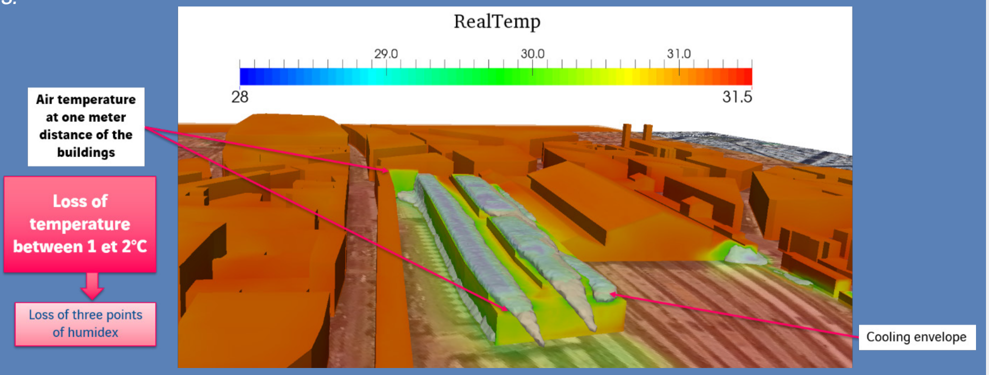


Figure 1: Urban Planning with Nature-Based Solutions for Adaptation (source: Global Committee for Adaptation 2019)

Case study 2: Evaluation of the cooling potential of green roofs and spaces for a real estate project

The purpose of this study was to assess the impact of variable coefficient of evapotranspiration upon surfaces and air temperatures as well as the thermal comfort. The latent flux being directly proportional to the loss of water through evapotrans piration from green areas, it has an impact upon the surface temperature as evapotranspiration is known to have a cooling effect.

*From this assessment, it is also possible to estimate the appropriate irrigation strategy for the maintenance of green areas of the project. In this case study, **the meteorological situation has been defined following a hot period of summer 2050 according to the RCP 8.5 (fig 2). A strong difference on surface temperatures (until 15°C) and air temperatures (until 5°C) can be seen between three scenarios of evapotranspiration.***

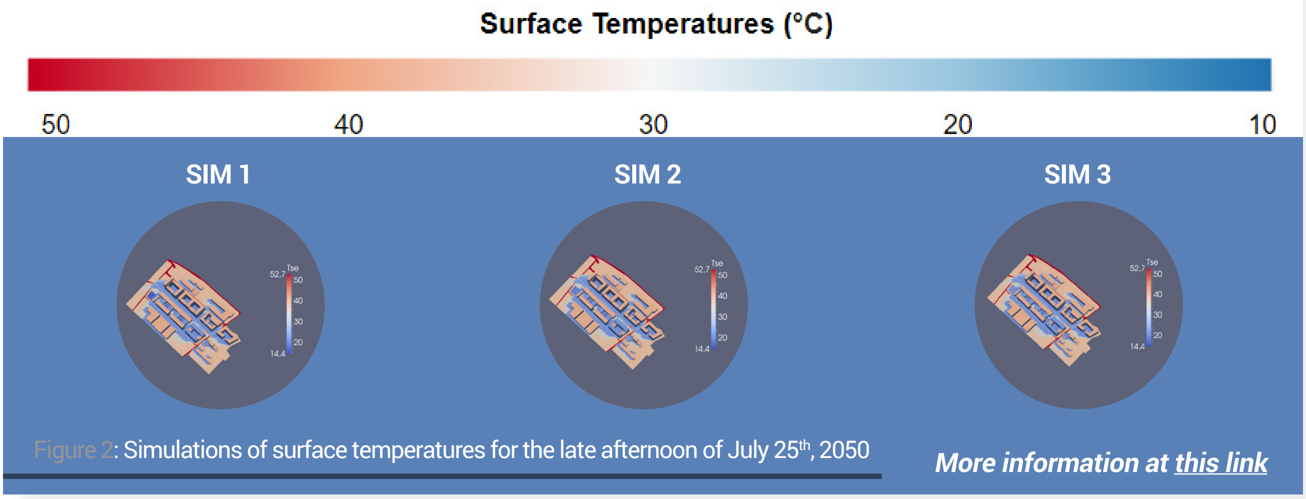


Figure 2: Simulations of surface temperatures for the late afternoon of July 25th, 2050

More information at this link

Carbone 4, a major consulting firm for climate strategy, developed for Icade (under a pilot project launched in 2015) a method and conducted the assessment of climate risks on its portfolio of assets. The risk diagnosis was established at the level of each building to capture the specificities related to its environment and its technical characteristics, faced with climate evolutions. This diagnosis enabled the identification of the adaptation solutions to be implemented at the building level and corporate level to fully integrate the subject into its development strategy. Now used by several French and European real estate companies (Icade, Gecina, Klépierre and Altarea Cogedim), the Carbone 4 method has shown its value and interest and makes it possible to enter into the subject of adaptation in a concrete way. In addition, the method is compatible with labels and technical standards which are starting to offer specific Resilience modules. More information at this link.

7. Material, Equipment & Construction

Contributors and/or reviewers :

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INBAR INTERNATIONAL BAMBOO AND RATTAN ORGANISATION

5 MAIN IDENTIFIED CHALLENGES

Which construction materials will be needed by 2050, considering the rising temperatures and increased frequency of climatic hazards?

- Climatic hazards will impact the structure of buildings, as presented in the context section, but also the value chains of construction materials. Integrating adaptation objectives from the conception phase may also impact the type of materials needed.

How to deal with climate change impacts on the building materials' durability for existing buildings as well as future constructions?

- Chronic hazards as well as changes in conditions may alter materials' characteristics and durability (see the part on climate impacts for more information).

How to limit the environmental impact of the adaptation process? How to optimize energy consumption and reduce greenhouse gas emissions?

- Adaptation to and mitigation of climate change should be pursued simultaneously. The impact is expressed in terms of CO2 emissions, consumption of natural resources and biodiversity.

How to conciliate imperatives of comfort, resistance and energy performance in the development of materials?

- Buildings will face increasing constraints due to extreme events and gradual changes in climate conditions. However, keeping in mind climate mitigation, it should not be forgotten that materials more adapted to climate change may generate higher GHG emissions over their lifecycle.

What solutions can be found to adapt to the depletion of natural resources?

- In the future, some materials may not be available anymore, or become too costly. This concern applies to both industrial processes used to produce materials and to the use of products.

CONTEXT & BIBLIOGRAPHY

Climate change is now a major tendency on the construction market. Materials now have to be hazard-resilient and maintain an optimized insulation. However, building materials companies are dependent on the construction market and regulatory standards that encourage buyers to turn to certain types of materials.

Their leeway is therefore concentrated in **research and development**, in advising real estate developers, and in finding ways to produce materials that have a limited impact on the environment. Indeed, the extraction of natural resources to be used as building materials consumes energy, cause environmental degradation and contribute to global warming (Sagheb, Azadeh & Vafaeihosseini, Ehsan & Ramancharla, Pradeep, 2011).

It is of utmost importance to assess the building materials' durability. In fact, climate change consequences (temperature and precipitation evolution, increased solar radiation, wind loads evolution), considered individually or combined, will impact the durability of the materials used in the building envelope (Nijland, Adan, Van Hees, Van Etten, 2011). These issues will affect the degradation rate of building materials. It is thus necessary to determine adaptation solutions at a materials level, for instance by looking at the performance of key materials in current climates that are close to the projections.

It is also necessary to include more global design solutions that will help enhance the durability of the building materials used. **Mitigation and adaptation should thus both be pursued**. A PBMC report presents the role of bio-based building materials in climate change mitigation, with the example of Brazil (PBMC, 2018). A project commissioned by the Swedish Association of Local Authorities and Regions (Sveriges Kommuner och Landsting 2016) concludes that, based on a large number of LCA studies, "*wood-based buildings are appropriate for long-term strategies for reducing fossil fuel use and GHG emissions when combined with sustainable forestry*". Moreover, considering the impact of building materials from a life-cycle perspective (resource extraction, transport, refinement, manufacturing process, utilization, disposal), it is necessary to reduce the amount of new materials needed. Enabling a circular building industry is a particularly efficient way to achieve this goal by reducing energy consumption (material embodied energy), waste production and virgin resources extraction (reuse, upcycle, recycle building materials). The Cradle to Cradle design concept and the BAMB project (Buildings As Material Banks) are two relevant examples showing how the construction materials' industry can shift from a linear to a circular model.

STATE OF PLAY

In the European Union, the Directive 2018/851 (EU), amending the Directive 2008/98/EC on waste, now includes the construction and demolition wastes as a primary issue to be dealt with. Especially, it aims at redefining the idea of waste recovery in order to "*cover forms of recovery other than energy recovery and other than the reprocessing of waste into materials used as fuels or other means to generate energy. It includes preparing for re-use, recycling and backfilling and other forms of material recovery*". Moreover, to facilitate re-use and high-quality recycling, the Directive enjoins the member states to promote selective demolition.

The **BAMB project** (Building As Material Banks) that was launched in September 2015 as part of the EU funded Horizon 2020 program, aims at "enabling a systemic shift in the building sector by creating circular solutions". In fact, building materials have historically been used as part of a linear model in which they end up as waste when the building is refurbished or torn down. This model, by constantly increasing the need for new building materials, is contributing to the ecosystem destruction, resource scarcity and energy overconsumption. Therefore, the BAMB project intends to turn buildings into banks of valuable materials that can be reused, thus reducing the need for new material production and the amount of waste generated by the building sector.

The BAMB goal to enable a circular building sector will be achieved through three main solutions:

- Materials Passports: "*they are (digital) sets of data describing defined characteristics of materials and components in products and systems that give them value for present use, recovery, and reuse*";
- Reversible Building Design: it consists of a different building construction and refurbishment approach enabling efficient repair, re-use and recovery of building materials by facilitating deconstruction and building parts removal;
- Circular Building Assessment: a decision-making model, declined as a BIM prototype, will be developed in order to assess resource productivity and assist the different stakeholders in "*making better choices and designs in order to enhance reuse potential and transformation capacity*".

5 RECOMMENDATIONS

Research - Observe practices in geographical areas where regular extreme weather conditions already exist

- In these areas, materials are adapted to climate conditions. Following this approach would contribute to adapt materials to future conditions in other areas.

Strategy - Adapt the ranges and productions to the different habitat types

- This recommendation stresses the importance of local practices to adapt buildings to climate change.

Involvement - Raise awareness on climate change issues among the different actors involved in the project and spread good practices

- Material, equipment and construction actors have a role to play in engaging real estate developers and investors in the process of adapting buildings to climate change.

Research - Orient Research & Development towards direct adaptation issues by promoting eco-innovation approaches, as well as partner with industry to enable innovation

- Eco-innovation approaches may include bio-based materials. Indirect adaptation issues concern for instance the expansion of biodiversity in cities. It includes the production of windows visible by birds or roof materials adapted to local vegetation.

Research/Strategy - Engage in circular economy approaches by limiting waste materials and enable better recycling and material reutilization

- This recommendation is also in line with the objective of climate mitigation.

TOOLS

- **The Green Guide (BRE)**: a guide that provides guidance on how to make the best environmental choices when selecting construction materials and components. It can be useful to construction materials companies to anticipate changes to come in the materials market. More information available at this link.

- **Materials Passports Platform (BAMB)**: a "one stop shop" providing the user with information about the value potential of building materials for the whole construction life cycle (planning, construction, repair, renovation, repurposing) and with the ability to track materials' quality and modifications. More information available at this link.

CASE STUDIES AND BEST PRACTICES

Fox Vakanties building (C2C inspired project)

- Beyond using healthy building materials (from occupant and environmental perspectives), this building has been designed with a particularly high potential for disassembly, reconfiguration and recycling. For instance, façade panels are feather edged, instead of being glued in order to be replaced without being destroyed if technology evolves. The steel structure includes minimal welding to be reused or recycled without almost any waste (11% reusable, 88% recyclable, 1% lost). Connections between floors can be changed and staircases repositioned without a need for an energy-intensive demolition process in case of building reconfiguration. This example illustrates how a building can become a bank of material, as defined in the BAMB European project.

Energy efficiency and better comfort in hot climate thanks to Typha material developed by TyCCAO program in Dakar, Senegal

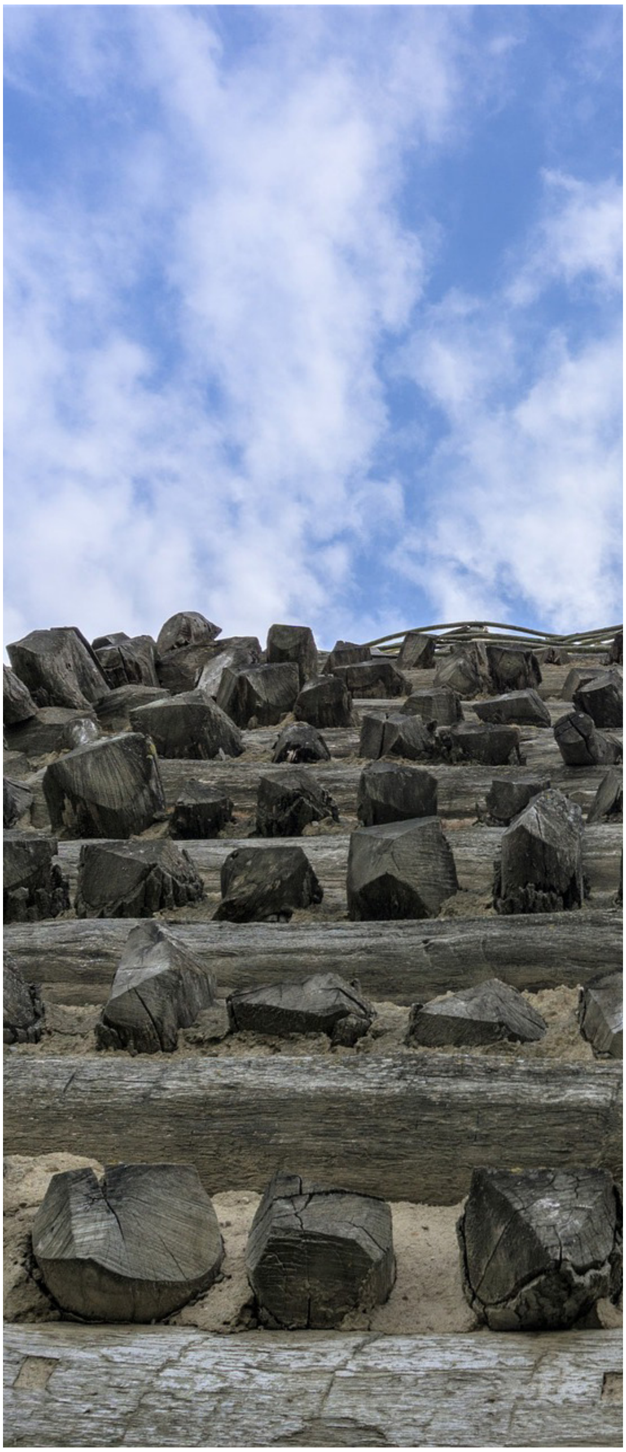
- This project is initiated by various French and Senegalese structures (GRET - Professionals of Solidarity Development, Concept Biobuild, Ministry of the Senegal Environment and Sustainable Development, through its Environment Directorate and supported by FFWE - French Fund for the World Environment). One of the main objectives is to contribute to the development of buildings with low environmental impact through their energy efficiency due to the use of local and biobased building materials, including Typha plant as insulation material. More information at this link.

Cool surface coating promotion in South-Africa

- The South African National Energy Development Institute's (SANEDI) Cool Surfaces Project is the response to South Africa's building need for a quality energy passive, low cost, low maintenance cooling technology that is fire retardant and waterproof. A building that does not have air conditioning is kept at a cooler (i.e. from 34°C to 25°C) and more constant temperature. In a building with air conditioning, the average energy savings range from approximately 7%-15% of total cooling costs. "Whitening 100 m2 of roofing cancels the warming effect of 10 tons of CO2 emissions (or 0.6 tons per year for the life of the roof)" (more information).

Electrochromic glass

- Electrochromic glass (such as "SageGlass" from Saint-Gobain), is now a mature adaptive façade solution providing a dynamic control of daylight (visible light transmission from 60% to 1%) and solar heat (g-value from 0,41 to 0,04) entering the building spaces, and avoiding additional sun-shading equipment, which is often sensitive to strong wind or rainfall. SageGlass provides improved comfort against glare and direct sunlight, as well as a reduction of cooling and lighting loads by up to 20% and peak load up to 26% as demonstrated throughout numerous third-party studies. Access to natural light and views to the outdoors are maintained at all times. This solution is a real asset to improve a building's energy performance and occupants' well-being and health. Moreover, it contributes to achieving green certifications (LEED, BREEAM etc.) along with a thorough smart building design.
- To date, SageGlass helped save energy while enhancing comfort in more than 1'000 projects in 27 countries. A great example is the IATA executive office near Geneva Airport in Switzerland, where the skylight was renovated using dynamic glass, resulting in a reduction of cooling loads estimated at 60%. The benefits on the energy bill, as well as on the occupants' experience, were confirmed by the facility manager of IATA (more details can be found here).



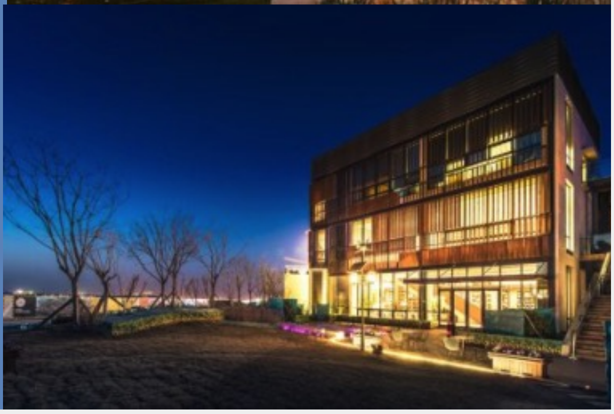
Wood, the renewable resource for a sustainable future - China Academy of Building Research

The Sino-Canadian Ecological Demonstration Area is a community-wide low-carbon and ecological demonstration project located in Binhai New Area, Tianjin, China. It is launched in 2012 by the China National Ministry of Housing and Urban-Rural Development (MOHURD) and Natural Resources Canada (NRCan). The project introduces Canadian best practices in sustainable urban planning, ecological community infrastructure and wood frame building technology to build a sample eco-district for other cities to follow.

The demonstration project covers an area of 1.8 km2, including residential townhouses, office buildings and a science centre. The townhouses, covering 50 000 m^2, were built with light wood frame. They reach the Canadian energy efficient standard Super E®. C-MaRS Office Buildings have prefabricated energy-efficient wood walls (PEEWW) made from Canadian lumber, which greatly increased the building assembly rate and energy saving property. The Wood Science Centre is a two-story building with Douglas-fir glulam clad with western red cedar panels. Together with components like waterproof breathable membrane, OSB board, insulation materials and fireproof gypsum board, it forms a complete waterproof, fireproof, ventilated and energy-saving ecological system.

The application of wood structure in this project offered buildings a better thermal insulation performance, a high rate of prefabricated building components, an excellent seismic behaviour and a green and low-carbon as well as faster construction speed. Moreover, compared to steel and concrete constructions, wood constructions have inherent characteristics that allow them to operate as single units to withstand earthquake forces. Therefore, wood structure is an ideal construction system in areas prone to seismic activity like China who has roughly half of its landmass located in an earthquake zone. Overall, wood construction is a safe, carbon-neutral and sustainable alternative to the incumbent structural materials of urban China.

More information at this link.



Bamboo as a sustainable construction material to tackle global climate change

International Bamboo and Rattan Organization (INBAR)

Bamboo is one of the fastest growing woody plants on Earth and is an important natural resource of the Global South. It can help meet various development goals, including the UN SDGs 1, 7, 11, 12, 13, 15 and 17. Bamboo is a versatile material with over 10'000 uses and applications that has been used since ancient times to build construction. Bamboo is a lightweight material with high tensile strength, flexibility, high load bearing capacity and durability. Once treated, Bamboo makes an ideal green construction material.

- ***Adaptation benefits****: INBAR and its development partners in Africa, Asia and Latin America have developed technologies and construction techniques for modern structures. These have been transferred to about 50 countries, and currently bamboo is widely used as an environmentally-friendly construction material for the construction of: 1) Earthquake or natural disasters resistant houses (Fig 1); 2) Low cost social houses (Fig 2); 3) Post-disaster rehabilitation and reconstruction, since bamboo is a ready-made/easy to construct material. Moreover, it is used for river transportation and as boats in many parts of the world. Bamboo helps improve resilience to climate change as it is a renewable resource (possibility of annually harvesting) without degradation or deforestation, with rapid establishment and a great resistance capacity to climate change impacts (withstand flash floods and fires). It is important to emphasize that houses or facilities built with bamboo, besides boosting local economies and employment, resilience of communities against climate change and natural disasters impacts, also provides enormous climate change mitigation impacts.*
- ***Mitigation benefits****: Compared to other high energy-consumption construction materials such as concrete and steel, bamboo houses can make it easier to achieve thermal comfort, reduce energy consumption, and maintain a healthy environment inside the building. A study shows that during the construction process, a bioclimatic bamboo house generates 75.6 Kg CO2eq /m2. However, it can capture the equivalent of 82 Kg CO2eq /m2, amounting to a negative balance of -6.8 Kg CO2eq /m2. This shows that bamboo could play a very positive role in tackling climate change by reducing the carbon emissions produced by the global construction sector.* ***More information at this link***.

Figure 1: Elevated Bamboo House, INBAR (Ecuador, 2009)

Figure 2: Bioclimatic Bamboo House, INBAR (Ecuador, 2019)

Figure 3: Bamboo Tea House, INBAR (China, 2009)

8. Property & facility managers

Contributors and/or reviewers :

CBRE nexity

5 MAIN IDENTIFIED CHALLENGES

How to measure the adaptation of buildings to climate change?

- Whereas mitigation is easily measurable (in terms of GHG emission reductions), adaptation is by nature more complex to measure, due to the uncertainties concerning overall MRV (Monitoring, Reporting and Verification) challenges (Gaia 2018). Measurement of a building's vulnerability is a issue to know the adaptation capacity of a building.

Which data can be collected to encourage adaptation?

- Being able to have reliable data is difficult as property managers are often between the owner and the operator(s), and do not always have the necessary tools to collect reliable energy data.
- Property and facility managers who can collect data play a key role in monitoring data for safety and proactive adaptation improvements.

What type of awareness needs to be improved and which resilience related actions by owners and tenants need to be addressed?

- Property and facility managers have a key role to play in involving the different actors of the building sector.
- The role of facilities with added resilience is also crucial in providing open spaces for community uses during extreme weather, for example when power or water or any other services are down in the area.

What compromises can be found between the users' comfort, the building's security and the energy performance?

- One of the main examples is thermal comfort: rising temperatures and heatwaves will result in a surge in energy consumption for cooling needs if the standards for comfort stays the same. But, with innovative concepts that focus on eco-conception and natural solutions, such as passive building design, comfort standards may not be altered. Moreover, having less technological equipment in a building can increase the ability to react in case of technological outages (no electricity, heating problems…). Measures for existing buildings should also be studied, because they were not meant to be passive.

How to encourage owners' investments in innovation and resilience?

- This challenge stresses the importance of mobilizing the different actors along the value chain. Property and facility managers can be proactive towards the building owner and they need their support.

CONTEXT & BIBLIOGRAPHY

Property managers are on the front line of increasing a building's resilience, as they are at the crossroad between tenants, investors, contractors and local authorities, and can influence how well a building is prepared for and recovers from a damaging environmental event (CBRE, 2019). Furthermore, investors can require their real estate asset managers to analyse which measures can be taken to improve the energy efficiency and the share of renewable energy in the energy mix of their portfolio, in order to make their buildings more resilient and less polluting (Gaia, 2018). However, being at the crossroad between different stakeholders can also be problematic, as property managers are often torn between different and sometimes contradictory interests, such as the comfort of tenants and the energy performance of buildings. Thus, managers must find compromises, adapt to different points of view, and raise the stakeholders' awareness about environmental issues.

5 RECOMMENDATIONS

Action - Identify gaps in building protection

- This includes for instance the absence of hurricane resistant windows or water pumps. The objective is then to upgrade existing protections features (CBRE 2019).
- Focus on a multi-hazard vulnerability assessment and measurement, which includes adaptive capacity, but also takes into account the physical, social and economic factors that characterise sensitivity (and are easier to assess than pure adaptive capacity).

Data - Use available data on environmental hazards from national and international sources

- With greater awareness of the information available, property managers can be more proactive in responding to risks (CBRE 2019). Monitoring technologies are a core issue for the building sectors. It's important to make available performance-based energy indicators.

Involvement - Engage with local stakeholders, especially local elected leadership

- The objective for property management is to have a stronger voice in local decision-making, and to improve communication with local authorities. This way, managers can for instance receive early warnings of any potential disruption to building services from public works projects (CBRE 2019).

Data - Promote and propose EPC (energy performance contracting)

- Implementing constraints of results makes it possible to put the energetic performance at the foreground, even more so if these constraints are accompanied by premiums when they are respected.

Involvement - Consider psychological factors in energy management

- The objective is to adapt energy consumption to the needs and habits of the tenants. For instance, in office buildings, we could adapt the brightness of the lights depending on the time of the day to reduce energy consumption.

TOOLS

- **RiskMemeter Online**: is a tool for climatic risk assessment. It is a worldwide mapping of natural hazards risks, and building-specific reports. More information at this link.
- **Asset view and Asset IQ are tools to store documentation related to building performance. Asset view** is a tool that can facilitate securely storing documentation relating to building performance for easy reference (CBRE 2019). Asset IQ is a tool developed by CBRE, that can be installed in a building to provide real-time information on its energy consumption and provide recommendations on how to improve this consumption.
- **CIRIA publications**: guides aiming at providing building owners, facility managers and designers with information for benchmarking on water-efficiency. **Water Key Performance Indicators and benchmarks for offices and hotels** is available at this link. **Rainwater and greywater in buildings** is available at this link.
- **MyCris**: a tool based on Climate Risk Impact Screening method to get a company analysis for different climate scenarios, information an all climate hazards and on the climate change impacts for different sectors including real-estate. More information at this link.

CASE STUDIES AND BEST PRACTICES

Metropolitan Transportation Authority (MTA) Headquarters, Lower Manhattan (US)

- Following the Superstorm Sandy (in 2012), that caused a lot of flooding, the MTA moved essential equipment to higher places, implemented movable barriers to keep floodwaters out, and installed pumps in basement areas. In addition, the MTA improved the energy efficiency of the building by introducing more efficient lighting systems and occupancy sensors to turn lights off when spaces are unused. As a result, the building is 10% more energy-efficient and is fitted to withstand a one-in-500-year flood event (CBRE 2019).

Class A office park, New Delhi (India)

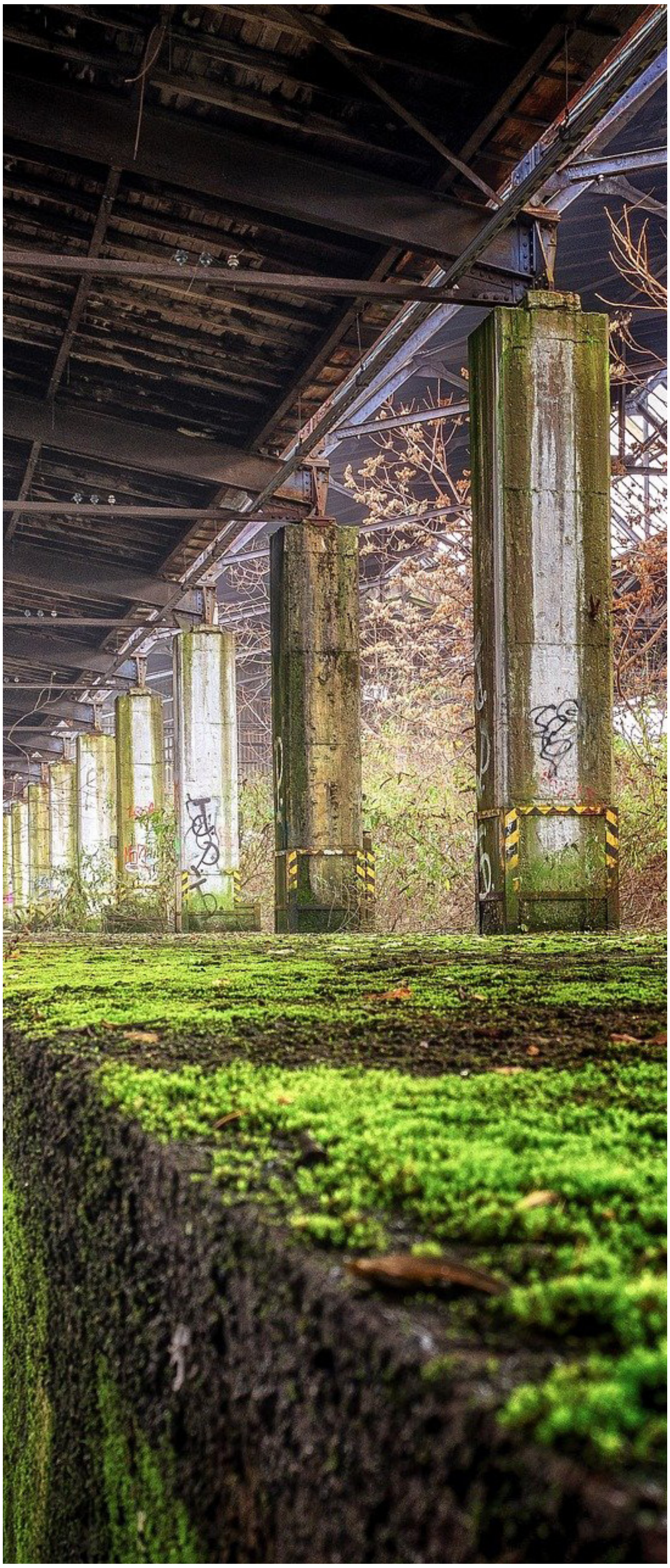
- Considering the heavy rainfalls in New Delhi, property managers "installed standby irrigation pumps to improve drainage, connected electricity supply between buildings on the campus to even out highs and lows in the load, and added an air balancing system to existing air conditioning to ensure that comfortable temperatures are maintained throughout the buildings, especially during hotter periods in summer" (CBRE 2019).

National Trust shop, holiday flats and District Council Visitors Centre (Boscastle, UK)

- After the floods of August 2004, these buildings have been renovated to incorporate adaptation measures which will increase resilience to future events. The removal of impermeable wall finishes, and their replacement with limewash, will allow walls to dry out after an inundation. Internally, a suspended floor was converted to a solid floor to reduce the impact of any future flood inundation, and electrical points were raised off the ground (Land Use Consultants 2006).

Development of Climate-related risk assessment method for Public Buildings, Société Québécoise des infrastructures, Canada

- The project launched in 2019 by the "Société Québécoise des infrastructures" with the "Institut national de santé publique du Québec" and the Consortium Ouranos aims at developing a method to assess the vulnerability to climate change of nearly 350 public buildings scattered over a territory of 1.5 M km2. The method considers eight climate hazards, their physical impacts on buildings and operations, and the potential consequences for occupants. More information here.



Appendix

Technical annexes

1. IMPLEMENTATION OF ADAPTATION INTO EACH BUILDING'S LIFE-CYCLE PHASES

INITIATION PHASE

Buildings aim to meet the needs of people. Wherever there is a mismatch between supply and demand, initiatives are launched to adjust how a building is used, to redevelop or relocate a building, to seek an alternative, or to construct a new building.

Decisions made during the early stages of a long-lived investment such as a building that locks in development patterns for a long time, are best made at the initiation phase to have the greatest impact on a project's ultimate outcome and success.

The initiation phase that enables a client to decide whether or not to proceed with a project therefore aims to align each of the stakeholders' expectations as early as possible.

Activities covered:

- stakeholders sharing their understanding and their awareness of the challenges and benefits of setting and meeting agreed targets;
- setting realistic parameters in terms of scope, location, time and cost that become the basis for briefings, discussions, engagements and undertakings with stakeholders;
- a strategic brief that defines the scope of the project so that project preparation and a briefing process can begin (larger commercial projects may require a business case to be developed).

Processes to ensure that adaptation to climate change is implemented need to address:

- **agreed targets for adaptation** to climate change since stakeholders will favour different adaptation strategies stemming from diverse and conflicting values;
- **liability with respect to taking reasonable account of future climate change**;
- **the duty of care to inform stakeholders** about the extent to which climate change has been taken into account in design and construction;
- the minimum requirement to provide information about the handling of climate risks while seeking a more comprehensive engagement;
- **assurance that risks from climate change are material, and that the measures to address them are reasonable and a good investment** in the absence of regulatory support, formalised competence, established standards, and some measure of proof that future-proof design strategies will work;
- **strategic risk assessment to identify an overall strategy and the limitations to the response to climate change**, recognising that while there are currently no prescribed industry standards, best-practices involve developing scenarios based upon different system boundaries and different reference periods (a practical starting point is an assessment for "cradle-to-completed construction" corresponding to a well-balanced scenario regardless of a building's ownership structure and future tenure);
- the **European Union Level(s) and similar methodologies** to familiarise stakeholders with the life-cycle approach to impact assessment to prepare them for more challenging performance assessment schemes and tools;
- **tools to help make adaptation-related decisions** (e.g., standard ratios of capital expenditure to operational expenditure for different building types to understand the relationship between these expenditures).

PLANNING PHASE

The planning phase allows the client to decide whether or not to proceed with the building project.

Activities covered:

- assembly of the project team by the client;
- definition of each party's roles and responsibilities;
- further development of the strategic risk assessment beyond purely strategic considerations as the project becomes better defined;
- development of an initial project brief and related feasibility studies that adopt a life-cycle approach and specify the desired service outcomes, while allowing value chain freedom as to how these outcomes are achieved to allow for innovation;

- preparation of a final project brief that includes a concept design and takes into account post-occupancy and operational issues and buildability, the environmental impact of key materials, and climate risks associated with the concept design and the selected site;
- confirmation that the final project brief reflects the concept design by specifying: a) measurable outputs; b) design quality evaluation methodologies; c) options for achieving low levels of life-cycle environmental impacts;
- a developed design stage where strategies (e.g. for sustainability, adaptation, buildability, health and safety, and operation and maintenance) are further developed, accurately costed and sufficiently detailed to allow the client to sign them off;
- a possible technical design phase to finalise technical aspects and conclude design work by specialist subcontractors.

Processes to ensure that adaptation to climate change is implemented need to address:

- an initial project brief that include sustainability and **climate adaptation targets**, supported by statements of environmental requirements, building's lifespan and future climate parameters, and the risks associated with the concept design and the selected site;
- a strategic risk assessment that includes a **detailed climate resilience analysis**;
- a specific requirement to consider the end-of-life, disposal or potential for **reuse of the materials and systems** selected;
- **material climatic variables** selected on the basis of exposure and on the sensitivity to changing climatic conditions;
- assessment of the range of impacts associated with the climatic variables identified in the vulnerability assessment in terms of likelihood and consequence of occurrence and a **rating for each impact is established**, taking account of adaptation measures included as part of the concept design;
- recognition in the final project brief that relevant climatic variables must reflect two types of climatic mechanisms which lead to **building failure**, namely background deterioration at the building material level as well as sudden damage from extreme events which affect whole-building elements;
- assessment as to whether the climatic variables selected for climate impact analysis and dynamic building simulations based on standard **weather files**, weather data sets and design-day files are compatible with climate change models and base climatic data (larger projects may require an Environmental Impact Assessment aligned to a Climate Risk and Vulnerability Assessment);
- indication in the final project brief as to whether or not the vulnerability and risk assessments conducted during the concept stage indicate that all **climate vulnerabilities and risks** are insignificant, in which case no climate adaptation measures, other than those required by regulation, need to be incorporated into the building;
- ensuring that the project's terms of reference explicitly demonstrate that current and future climate risks have been assessed, and that resilience measures are to be incorporated where necessary;
- development of a **standards-based adaptation plan** that includes adaptive management based on long-term monitoring and makes use of maintenance and upgrading cycles for timely, effective and proportionate upgrades that are prioritised over the building's life-cycle;
- adoption of a design strategy at the developed design stage based on **'allocative efficiency'**, namely using resources over time in the most efficient way so that hard and soft measure to adjust a building's adaptive capacity allow the implementation of an incremental, phased transition to what will be needed;
- incentives to implement designs that allow the **building and its systems to be reused** through future dismantling and subsequent reassembly;
- demonstration that the phased approach protects a building, its owners, occupants and systems efficiently and effectively and does **not exclude opportunities** to exploit future technological advances to mitigate climate change;
- performance metrics and life-cycle analyses for natural elements and ecosystems, including adaptation **resilient landscaping; and nature-based interventions** which integrate ecosystem conservation and restoration and incorporate passive survivability wherever possible;
- recognition in developed design that some building elements cannot be easily or viably adjusted in maintenance cycles but are nonetheless fundamental to a building's ability to cope with future climate;

- during developed design, the need to undertake further analysis of the critical design thresholds that are the most sensitive to climate and **test the robustness** of critical design components to a range of climate futures;
- recognition that a single developed design solution is often insufficient to understand the complex relationship between climate and building performance (**buildings need to be designed within a framework of possibilities and vulnerabilities** to reflect a range of solutions that address best and worst case climate scenarios);
- for the concept and detailed design, **descriptions of the anticipated internal environment**, of seasonal control strategies and systems;
- performance requirements for resource-efficient and resource harvesting **systems, appliances and fixtures**;
- after developed and possible technical design, the **review** of final specifications and designs against the agreed adaptation criteria and verification of the **compliance** with agreed criteria for contributions by specialist subcontractors;
- a possible **cost-benefit analysis of proposed adaptation measures** which recognises that climate impact and modelling issues will generally lead to a range of solutions with different cost, benefit or risk values that require new tools for decision making under uncertainty, especially with regard to climatic variables.

CONTRACTING

Once the decision has been taken to proceed with the project, usually on the basis of an agreed procurement strategy, delivery model and management plan for procurement, the acquisition or pre-construction phase groups procurement processes.

Activities covered:

- the deployment of financial resources;
- establishing warranty and post warranty obligations for building systems;
- applications for statutory and planning approvals;
- production information providing sufficient detail to enable tendering;
- further information for requirements detailed in the contract for construction;
- tendering, namely the identification and evaluation of potential contractors and/or specialist suppliers, the preparation of contracts and the obtaining and evaluation of tenders.

Processes to ensure that adaptation to climate change is implemented need to address:

- integration of an **adaptation action plan**;
- the monitoring, review and reporting of activity data that inform analysis of the impact of adaptation measures on emissions and resource use;
- for the lead contractor, key subcontractors and specialist suppliers and any eventual replacements, the assessment of their **compliance** with both agreed and legally required adaptation criteria;
- the further **development** with the lead contractor of methods, techniques and procedures for sustainable construction, especially those that enhance adaptation and minimise harmful impacts on existing on-site passive adaptation;
- taking future uncertainty into account, the development of **schedules** and protocols for operation, maintenance, repair, replacement, and refurbishment;
- the specification of building commissioning, **handover** and operation and maintenance phase monitoring processes;
- the collation of comprehensive and accurate **as-built information** as the basis for the implementation of post-construction adaptation measures.

CONSTRUCTION

The construction phase covers all activities relating to the actual building project construction. These activities range from site handover to the lead contractor and mobilisation of resources including transport to the site, through physical construction and installation of plant and equipment at the site to practical completion and handover to the client.

Mobilisation includes establishing the management and review of information that needs to flow between the parties. Commissioning and handover require special attention as buildings and their systems become more advanced. Considerations relate to pre-start-up and system start-up, operator training, the consolidation of designs, drawings, and operating and maintenance documents, functional acceptance, and the testing, adjusting, and balancing of systems.

Processes to ensure that adaptation to climate change is implemented need to address:

- the **conformity** of construction processes with respect to adaptation targets agreed upon completion of the tender process;
- regular **reporting** across the supply chain that includes evidence-based data from site activities to ensure cooperation, the delivery of the adaption targets, and the analysis of impacts arising from changes in construction methods;
- specified **monitoring and testing** of adaptation requirements during construction;
- **mitigation** of the impact of construction activity on pre-existing nature-based on-site adaptation features that are specified in landscaping plans;
- in cases where a fit-out of a building follows construction, an adaptation **assessment at handover** to influence, guide and inform the fit-out;
- a final review of the as-built information and a final assessment of the **adaptability** of the completed project as part of operation and maintenance information.

OPERATION AND MAINTENANCE

The operation and maintenance phase of a building includes assistance for building users during the initial occupation period and the review of a building's performance throughout the phase, possibly making use of a digital twin which is continually updated.

Crucial is the monitoring of operations and maintenance considerations defined at the planning phase and specified at the acquisition phase. The most important considerations relate to resource consumption, waste, maintenance, repair, refurbishment, and replacement of building components, assemblies and systems, and supply of the resources and equipment used for these activities. Preventive maintenance, maintaining and ideally improving the maintainability of the building and replacing and re-siting building systems facilitates these operations. The activities, processes, and workflows required to maintain the operation of a building's supporting infrastructure such as utility systems, parking areas and nature-based drainage structures and landscaping should also be included.

Processes to ensure that adaptation to climate change is implemented need to address:

- user satisfaction and user occupancy **surveys**;
- the regular updating and **communication** to buildings' occupants and users of the assessment of climate-related risks;
- nature-based solutions for passive design and other building features requiring adaptive management based on **long-term monitoring** of the adaptation plan to check that it is providing the expected level of risk reduction and remains flexible and open ended;
- assessment of the **evidence-based impact** from adaptation measures on the performance of the building and its adaptation features with respect to durability, resilience, fitness for purpose to prolong the building's lifespan and to reductions in resource use and operational emissions;
- opportunities for further **adaptation measures** when considering fit out, replacement cycles of plant and materials or major renovation;
- assessment of **repair and maintenance** regimes for adaptation measures that take into account known refurbishment scenarios and planned future changes to the building;
- the **review** of reporting procedures and the sources of data as these will change during the use phase, the updating of user guides and maintenance and repair schedules, and the optimisation of real-time control and proactive condition monitoring and maintenance regimes.

END-OF-LIFE

The extended life cycle of a building includes an end-of-life phase comprising physical processes of deconstruction and demolition together with transport of waste and demolition material. Also included is the treatment of waste by separation, recycling, reuse, re-purposing, and disposal in landfills or by transformation.

Processes to ensure that adaptation to climate change is implemented need:

- to identify, as for new buildings, whether or not adaptation measures contribute to **extending the life of the existing asset** within its current function or extending the life with a new function.

2. CLIMATE MODELS & DATA

Uncertainty on climate impacts is high, due to several factors ranging from climate models to socioeconomic factors. Wilby and Dessai (2010), cited by the European Bank for Reconstruction and Development, presents the following factors of uncertainty. Each step along the chain increases the uncertainties.

Figure 25: Cascade of uncertainty (Wilby and Dessai (2010) in European Bank for Reconstruction and Development)

Factors on the future society cover, among others, demographics and political and economic choices. They include policies to mitigate climate change and thus will cause a certain amount of GHG emissions to be released into the atmosphere. **RCP (Representative Concentration Pathway) scenarios** represent possible evolutions of GHG and ozone concentrations in the atmosphere. The RCP scenarios combine assumptions on future climate policy with climate modelling (UNEP FI 2019). They were proposed by an expert group in the perspective of the 5th report of the IPCC, released in 2014, based on several hundred available scenarios published in the literature. The value (2.6, 4.5, etc.) corresponds to radiative forcing expressed in Watt per square meter by 2100. Concerning CO2 emissions, RCP 2.6 considers the implementation of policies to reduce CO2 emissions until almost zero emissions at the end of the century. RCP 8.5 considers an increase in emissions all over the 21st century. Whatever the scenario, the evolution of climate by 2050 is known overall, but there is leeway left for the second half of the century.

By 2100 and starting from pre-industrial levels, the average global temperature is expected to increase by 1.0 to 3.7°C. This most pessimistic scenario is also the most challenging one in terms of adaptation needs. To put this figure in perspective, Meteo-France recalls that the average temperature in the world has already increased by 0.6 °C over the 20th century. **Overall, the higher the temperatures, the stronger the impacts of climate change, although they will depend on location.**

	Medium term: 2046-2065	Long term: 2081-2100
GHG concentration scenario	Mean and likely range (in °C)	Mean and likely range (in °C)
RCP 2.6	1.0 (0.4 to 1.6)	1.0 (0.3 to 1.7)
RCP 4.5	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP 6.0	1.3 (0.8 to 1.8)	2.2 (1.4 to 3.1)
RCP 8.5	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)

Figure 26: Mean and likely range of temperature increase in the medium and long term depending on GHG concentration scenario (Source: European Bank for Reconstruction and Development)

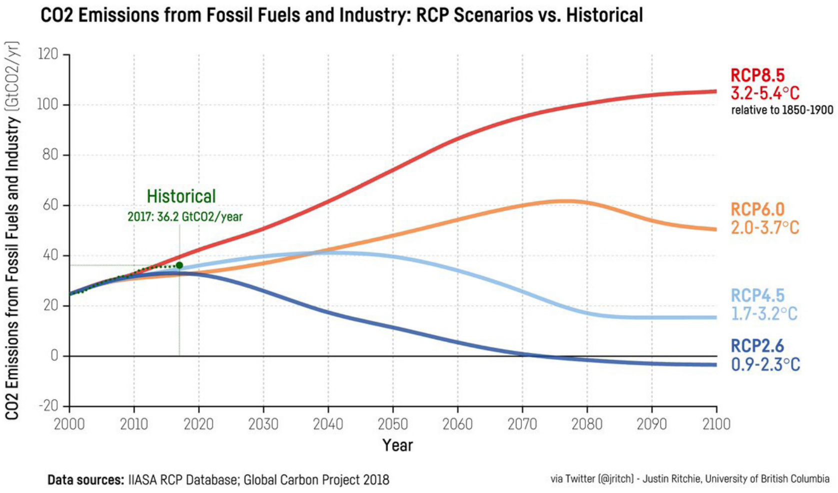


Figure 27: RCP scenarios and their impact in terms of global warming

Climate models, also known as general circulation models, use mathematical equations to characterize how energy and matter interact in different parts of the ocean, atmosphere, and land. The predicted climate results from the adjustment between received energy (solar radiation) and “lost” energy (infrared radiation towards space). Solar radiation received depends on astronomical parameters and is set in the model. Infrared radiation returned depends among other factors on GHG concentrations, which are defined through RCP scenarios. The Coupled Model Intercomparison Project (CMIP) and Atmospheric Model Intercomparison Project (AMIP) are experimental protocols aiming at fostering the improvement in climate models and supporting the international assessment of climate change.

The complexity of models has significantly increased over time, but even the latest simulations cannot address fine-scale processes at the local scale. As explained by the IPCC (2013), regional-scale climate information can be obtained by downscaling, but the resolution is often too low. Downscaling methods are thus used to translate the information required for impact assessment at the regional and local scale (USGCRP 2017). High-resolution AGCMs, variable-resolution global models, and statistical and dynamical downscaling (regional climate modelling) are used to complement Atmosphere–Ocean General Circulation Models, and to generate region-specific climate information. Guidance on the development of regional climate scenarios has been developed in a report by the National Communications Support Programme, UNDP-UNEP-GEF, referenced in the bibliography.

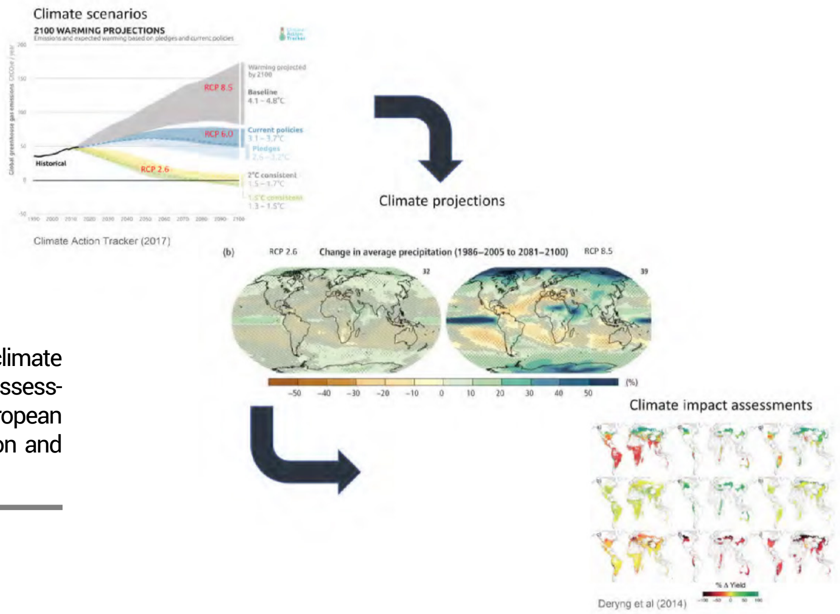


Figure 28: Chain from climate scenarios to impact assessments (Source: European Bank for Reconstruction and Development)

In the figure below, the IPCC raises the level of additional risks and impacts linked to the global mean surface temperature change. **The higher the temperature change, the higher the risk of severe impacts and the lower the ability to adapt. Purple indicates “*very high risk of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited availability to adapt*”.**

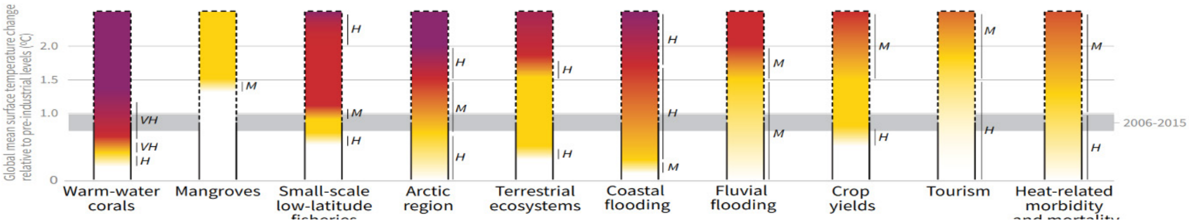


Figure 29: Impacts and risks for selected natural, managed and human systems (Source: IPCC 2018)

Focus on: the Climate Data Store by Copernicus

The CDS provides a single point of access to a wide range of quality-assured climate datasets distributed in the cloud. CDS datasets include observations, historical climate data records, estimates of Essential Climate Variables (ECVs) derived from Earth observations, global and regional climate reanalyses of past observations, seasonal forecasts and climate projections. Access to data is open, free and unrestricted. Along with the data, the CDS includes a set of tools for analysing and predicting the impacts of climate change. Users of the CDS can access these tools to develop their own applications online. More information is available at ***this link****.*

Focus on Climate Change integration in Meteonorm

Typical Meteorological Year (TMY) data including CC scenario data for building design Meteonorm (from Meteotest) includes three IPCC scenarios (B1, A1B, A2 from AR4 update to AR5 ongoing) and allows projections to the year 2100. Meteonorm was updated with urban heat and climate change data (RCP 4.5 and 8.5) for 102 European cities (in the update 7.3.4) based on EURO-CORDEX models combined with urbaclim model (temperature mid-point 2050).

See conference ***https://www.climateservices.biz***

Bibliography

100 Resilient Cities 2019, Buildings and Resilience, Resilience point of view series, http://100resilientcities.org/wp-content/uploads/2019/09/Resilience-POV-built-environment-FINAL.pdf.

ACPR 2019, Les assureurs français face au risque de changement climatique.

African Development Bank, Adaptation Benefit Mechanism, https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/adaptation-benefit-mechanism-abm.

AULAGNIER S. (BURGAP), ALMOSNI N. (BURGEAP), DUPONT F. (FBC), LEFEBVRE-NARÉ F. (WattGo) 2015, Etude prospective sur les impacts du changement climatique pour le bâtiment à l'horizon 2030 à 2050 – Rapport final, ADEME. 115 pages.

Banque de France 2019, Changement climatique : quels risques pour le secteur financier français ?, https://publications.banque-france.fr/sites/default/files/medias/documents/819275_bdf225-8_changement_climatique_vf.pdf.

Bennett, C, and Collin, F 2018, Addressing the risks from climate change in performance-based contracts, https://blogs.worldbank.org/transport/addressing-risks-climate-change-performance-based-contracts.

BOMA Canada 2019, Guide de resilience 2019.
Bernstein, A, Gustafson, M, and Lewis, R 2018, Disaster on the Horizon: The Price E ect of Sea Level Rise.

Carbon Brief 2018, Interactive: How climate finance 'flows' around the world, https://www.carbonbrief.org/interactive-how-climate-finance-flows-around-the-world

Carbon Brief, The impacts of climate change at 1.5C, 2C and beyond, consulted on 11 June 2019, https://interactive.carbonbrief.org/impacts-climate-change-one-point-five-degrees-two-degrees/?utm_source=web&utm_campaign=Redirect#.

CBRE 2019, Global resilience & Property Management, https://www.cbre.us/research-and-reports/Global-Resilience-and-Property-Management--May-2019.

CCR 2015, Modélisation de l'impact du changement climatique sur les dommages assurés dans le cadre du régime Catastrophes Naturelles.

Climate Chance 2019, Observatoire Mondial de l'action climat non-étatique, bilan des actions climat par secteur, https://www.climate-chance.org/wp-content/uploads/2019/11/fr_c1_complet_def.pdf.

Climate Chance & Comité 21 2019, Cahier adaptation – Bilan 2019 des actions d'adaptation, Observatoire Mondial de l'action climat non-étatique, https://www.climate-chance.org/wp-content/uploads/2019/11/fr_c4_complet_def.pdf.

Climate Chance 2018, Report Workshop 5 Sustainable Buildings and Construction in Africa, https://www.climate-chance.org/wp-content/uploads/2018/11/climate-chance-afrique-2018-buildings-eng.pdf.

ClimateWise 2019, Physical risk framework: Understanding the impacts of climate change on real estate lending and investment portfolios.

ClimateWise 2018, Gearing up for regulation: The ClimateWise Principles Independent Review 2018, https://www.cisl.cam.ac.uk/resources/publication-pdfs/the-climatewise-principles-independent-review-2018.pdf.

ClimateWise 2016, Investing for resilience, https://www.cisl.cam.ac.uk/resources/publication-pdfs/Investing-for-resilience.pdf.

DWS 2018, From the front lines of real estate.
E&E News 2019, Climate liability is on the rise. Here's what it looks like, https://www.eenews.net/stories/1060850731.

Ecbi 2019, Pocket guide to adaptation under the UNFCCC.

EU Technical Expert Group on Sustainable Finance 2019, Taxonomy technical report.

European Bank for Reconstruction and Development 2018, Advancing TCFD guidance on physical climate risks and opportunities.

FFA 2015, Risques Climatiques : quel impact sur l'assurance contre les aléas naturels à l'horizon 2040 ?

Fievet 2012, Guidance for City Procurement to Facilitate Climate Change Adaptation Pursuant to the Mayor's 2007 Executive Order, http://clinics.law.harvard.edu/environment/files/2015/08/climate-adaptation-procurement-guidance.pdf.

Gaia, Climatic risks and opportunities in real estate portfolio management, 2018

GeoPhy & Four Twenty Seven 2018, Climate Risk, Real Estate, and the Bottom Line.

GermanWatch 2018, Indice mondial des risques climatiques 2019.

GlobalABC 2019, 2019 Global Status Report for Buildings and Construction: Towards a zero-emissions, efficient and resilient buildings and construction sector, https://wedocs.unep.org/bitstream/handle/20.500.11822/30950/2019GSR.pdf?sequence=1&isAllowed=y.

GlobalABC 2018, Global ABC thematic background paper. National adaptation plans for the building sector.

Global Commission on Adaptation 2019, Adapt now: A global call for leadership on climate resilience, https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf.

Global Covenant of Mayors for Climate and Energy 2019a, Implementing climate ambition - Global Covenant of Mayors 2018 Global Aggregation Report, https://www.globalcovenantofmayors.org/wp-content/uploads/2018/09/2018_GCOM_report_web.pdf.

Global Covenant of Mayors for Climate and Energy 2019b, 2019 Annual Report – Climate emergency: unlocking the urban opportunity together, https://www.globalcovenantofmayors.org/wp-content/uploads/2019/12/2019-GCoM-Aggregation-Report.pdf.

Goldman Sachs 2019, Taking the heat: Making cities resilient to climate change.

GRESB 2019, Resilient Real Assets : Update from the 2019 GRESB Resilience Module, https://gresb-prd-public.s3.amazonaws.com/2020/Resilience_Report.pdf.

Greater London Authority, Adapting to climate change: a checklist for development, 2005

Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S.C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, 2013: Evaluation of Climate Models. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USAIPCC 2018, Special report - Global warming of 1.5 °C, An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_version_stand_alone_LR.pdf.

ICLEI and C40 2018, Data speak louder than words: Findings from an initial stocktake of climate change adaptation and urban resilience efforts, https://resilientcities2019.iclei.org/wp-content/uploads/Data-speak-report-web-final.pdf.

ICLEI 2018, Resilient Cities Report 2018 Tracking local progress on the resilience targets of SDG 11, https://resilientcities2018.iclei.org/wp-content/uploads/RC2018_Report.pdf.

Insurance Europe, Climate change: from words to action, 2016.

International Union of Architects, Arcasia and Institute of Architects Bangladesh 2019, UIA SDG Dhaka Declaration, https://www.uia-architectes.org/webApi/uploads/ressourcefile/264/dhaka_declaration_forpublication.pdf.

IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

ISO 2019, Managing the impact of climate change: first international standard for adaptation published, https://www.iso.org/news/ref2405.html.

Lu, X. (2006), Guidance on the Development of Regional Climate Scenarios for Application in Climate Change Vulnerability and Adaptation Assessments within the Framework of National Communications from Parties not Included in Annex I to the United Nations Framework Convention on Climate Change, National Communications Support Programme, UNDP-UNEP-GEF New York, USA, 42 pp., https://www.uncclearn.org/sites/default/files/inventory/undp22.pdf.

Land Use Consultants in association with Oxford Brookes University, CAG Consultants and Gardiner & Theobald (2006) Adapting to climate change impacts – A good practice guide for sustainable communities. Defra, London.

McAlpine, S, Porter, J 2018, Estimating Recent Local Impacts of Sea Level Rise on Current Real Estate Losses: A Housing Market Case Study in Miami Dade, Florida.

McCarthy Tétrault LLP 2018, Impacts of climate change - foreseeable or unforeseeable? Drafting force majeure clauses in the era of climate uncertainty, https://www.lexology.com/library/detail.aspx?g=ceb2a5db-7952-49a9-9d08-fe1ecb89807c.

Munich Re 2018, Natural catastrophe review: Series of hurricanes makes 2017 year of highest insured losses ever, https://www.munichre.com/en/media-relations/publications/press-releases/2018/2018-01-04-press-release/index.html.

Nachmany, M, Byrnes, R and Surminski, S 2019, Policy brief - National laws and policies on climate change adaptation: a global review, http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/12/National-laws-and-policies-on-climate-change-adaptation_A-global-review.pdf.

NIBS, National Institute of Building Sciences, 2019, Natural hazard mitigation saves: 2019 report https://cdn.ymaws.com/www.nibs.org/resource/resmgr/reports/mitigation_saves_2019/mitigationsaves2019report.pdf.

Nijland, Adan, Van Hees and Van Etten 2009, Evaluation of the effects of expected climate change on the durability of building materials with suggestions for adoption. Heron Journal. https://www.researchgate.net/publication/280016232_Evaluation_of_the_effects_of_expected_climate_change_on_the_durability_of_building_materials_with_suggesstions_for_adoption

OECD, 2020, Common Ground Between the Paris Agreement and the Sendai Framework, Climate Change Adaptation and Disaster Risk Reduction, http://www.oecd.org/env/climate-change-adaptation-and-disaster-risk-reduction-3edc8d09-en.htm

PEEB 2020, Better designs for cool buildings. https://www.peeb.build/imglib/downloads/PEEB_Cool%20Buildings_Working%20Paper_August%202020.pdf

PEEB 2020, overview on Energy efficient building design in hot climate zones. https://www.peeb.build/imglib/downloads/PEEB_Overview%20Building%20Designs%20and%20Climate%20Zones-Master-25.03.2020.pdf

PBMC 2018, Role of Bio-based Building Materials in Climate Change Mitigation: Special Report of the Brazilian Panel on Climate Change. PBMC, COPPE – UFRJ. Rio de Janeiro, Brasil. 20p.

Sagheb, Azadeh & Vafaeihosseini, Ehsan & Ramancharla, Pradeep 2011, The Role of Building Construction Materials on Global Warming. https://www.researchgate.net/publication/269031946_The_Role_of_Building_Construction_Materials_on_Global_Warming_Lessons_for_Architects

Scottish Procurement and Commercial Directorate 2018, Climate change adaptation: sustainable procurement guidance, https://www.gov.scot/publications/procurement-guidance-climate-change-adaptation/.

Setzer, J and Byrnes, R 2019, Global trends in climate change litigation: 2019 snapshot, http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/07/GRI_Global-trends-in-climate-change-litigation-2019-snapshot-2.pdf.

Sveriges Kommuner och Landsting (2016). Climate impacts of wood vs non-wood buildings. https://webbutik.skl.se/bilder/artiklar/epub/7585-377-2.epub

TCFD 2019, 2019 Global Status Report, https://www.fsb-tcfd.org/wp-content/uploads/2019/06/2019-TCFD-Status-Report-FINAL-053119.pdf.

Technology Strategy Board, Design for future climate, 2005

Thomas Tanner, Tom Mitchell, Emily Polack and Bruce Guenther, Urban Governance for Adaptation: Assessing Climate Change Resilience in Ten Asian Cities, 2009

UN, UN architecture guide to the UN 17 sustainable goals, 2018

UNEP FI 2019, Changing course: A comprehensive investor guide to scenario-based methods for climate risk assessment, in response to the TCFD, https://www.unepfi.org/wordpress/wp-content/uploads/2019/05/TCFD-Changing-Course-Oct-19.pdf.

UNEP FI 2018, Navigating a new climate, Assessing credit risk and opportunity in a changing climate: Outputs of a working group of 16 banks piloting the TCFD Recommendations - PART 2: Physical risks and opportunities, https://www.unepfi.org/wordpress/wp-content/uploads/2018/07/NAVIGATING-A-NEW-CLIMATE.pdf.

UNESCO, world heritage center, 2008, Policy Document on the Impacts of Climate Change on World Heritage Properties, https://whc.unesco.org/en/CC-policy-document/

UNISDR 2012, How to make cities more resilient: a handbook for local government leaders

UNISDR 2015, Global Assessment Report on Disaster Risk Reduction.

Urban Land Institute 2015. A Guide for Assessing Climate Change Risk. Washington, DC: Urban Land Institute.

Urban Land Institute 2015, Returns on Resilience: The Business Case. ULI Center for Sustainability, https://uli.org/wp-content/uploads/ULI-Documents/Returns-on-Resilience-The-Business-Case.pdf.

Urban Land Institute and Heitman 2019, Climate risk and real estate investment decision-making.

USAID 2018, Building urban resilience to climate change, a review of South Africa

USGBC 2018, Resilient by design: USGBC offers sustainability tools for enhanced resilience.

USGCRP 2017, Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp.

US GCRP 2018, Fourth National Climate Assessment, Volume II, https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf.

WBCSD 2020, Building system Carbon framework – a common language for the building and construction value chain, https://www.wbcsd.org/Programs/Cities-and-Mobility/Sustainable-Cities/Transforming-the-Built-Environment/Decarbonization/Resources/The-Building-System-Carbon-Framework

Whitehouse 2016, presidential proclamation – national building safety month https://obamawhitehouse.archives.gov/the-press-office/2016/04/29/presidential-proclamation-national-building-safety-month-2016

Western Cape Government 2017, Making better choices: green procurement in state-subsidised human settlements.

World Economic Forum 2019, The Global Risks Report 2019: 14th edition, http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf.

World Health Organization 2018, COP24 special report: health and climate change, http://www.who.int/iris/handle/10665/276405.

World Resources Institute 2010, Surveying risk, building opportunity: Financial Impacts of Energy Insecurity, Water Scarcity, and Climate Change on Asia's Commercial Real Estate Sector, https://wri-indonesia.org/sites/default/files/surveying_risk_building_opportunity.pdf.

Methodology

This publication was coordinated by Laura Georgelin – OID, Régis Meyer – Ministère de la Transition Ecologique - France and Oriane Cébile – OID, with the support of Sakina Pen Point – OID, Mathilde Philippot – OID, under the supervision of Loïs Moulas – OID.

The **methodology** adopted is as follows:

- A Steering Committee defined the objectives, the content and reviewed the different version of the report
- Professionals were contacted for interviews and were asked to answer the online survey
- Institutional and professional organizations were solicited to review the report

The **Steering Committee** has been initiated by the Ministère de la Transition Ecologique & Solidaire – France and by OID. It gathers:

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ADEME – AEW Ciloger - AFD - Afnor – Agence d'Aménagement Foncier et du Logement (Benin) – Architects' Council of Europe – ARISE UAE - Bioarchitek - Bouygues Immobilier – CAA - Carbone 4 – CBRE - CDRI - China Academy of Building Research - Energies 2050 - EU taxonomy subgroup on adaptation – FFB - FIABCI - FIDIC – FPI – GIZ - Global Alliance for Buildings & Construction – GRESB – Icade - ICLEI – ICOMOS – INBAR - Insurance Europe - Ministère de la Transition Ecologique, France - Ministère de l'Aménagement du Territoire National, de l'Urbanisme, de l'Habitat et de la Politique de la Ville, Maroc – National Research Council Canada – Nexity – Resallience - Société québécoise des infrastructures - SOCOTEC – UIA - ULI - UNEP - UNEP-FI – OID - WBCSD

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