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Integration of adaptation to climate change within the design process of urban planning projects: new tool(s) and new methodology(ies)

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1. Introduction

This article summarizes some of the results of the research project ADAPTATIO which addresses the integration of adaptation to climate change within the design process of urban planning projects. During this project, financed by the French ministry for ecology and sustainable development, EIVP (a French engineering school), the City of Paris, CSTB (the French Scientific and Technical Centre for Building), CDC Climat research (think tank supported by Caisse des Dépots dedicated to research in the field of climate economics) and EGIS Concept (an engineering firm) have cooperated to propose new ideas on adaption to climate change both in terms of tools and methodologies.

2. Built environment and climate: a long interaction re-examined by the evolution of energy prices and climate projections

The built environment, with buildings and networks (surface, underground and overhead) connecting them, is inherently exposed to climatic agents. A key function of the buildings is the protection of the human group against climate vicissitudes, isn't it? Storms, thunderstorms, flooding, flood runoff, heat and cold have been, are and will be the common lot of cities according to their geographical location. These very old and unstoppable relationships have led to constructions adapted to climatic characteristics (Colombert et al., 2012): igloos, patio houses, compact buildings with sloping roofs, or underground areas are some of the many examples confirming the link between local climate and the built environment. Furthermore, climate impacts often exceed the scale of the concentrated built environment (urban area) or dispersed (rural) to affect entire regions.

Until the late nineteenth century, the construction of building was based mainly on the use of locally available materials. The coming of new construction processes and new technologies and equipment from the late nineteenth century and during the twentieth century (reinforced concrete, float glass, air conditioners, elevators, etc.) opened the field of possibilities and profoundly changed the built environment (especially urban) with the arrival of high buildings, sometimes with almost completely glazed facades.

Traditional and modern buildings are suitable because they provide the primary function of protecting people and property from the hazards of climate-induced effects. With the enrichment of society, new functions are expected. Maintaining an equal indoor climate in buildings at every time of the year became possible due to an energy expenditure easily granted because of the modest cost of energy in the twentieth century.

The likely emergence of a new climate in the short term (to scale of the previous secular periods during which the built environment has been adapted to the local climate) and changes in energy prices carry with them the factors which can lead to new changes, new developments.

3. Current consideration of climate change in urban development projects

On the scale of urban design and urban planning, actions may be engaged and allow to adapt to climate change (CC) without display this ambition. This is what we wanted to check through the tools now used on this scale. We have analyzed the following tools: "HQE aménagement", LEED ND, BREEAM Communities, sustainable planning framework of the City of Paris, urban development framework called AURA (in French: "Améliorer l'Urbanisme par un Référentiel d'Aménagement") - Sustainable development Guide of Montpelier, HQE2R method and ISDIS system, RST02, environmental approach to urban planning (AEU), Eco-district French approach (Ecoquatier), @d aménagement durable® and CBDD®2013.

This analyze has helped to highlight or reinforce a number of points:

- First, the importance or, at least, the strong presence of the theme 'climate change' and its various issues (mitigation & adaptation) - particularly through the emergence of international climate policy, national and local - influenced the methods used by urban design professionals to describe, analyze their projects. Nevertheless, if the issue of mitigation, including energy efficiency, is strongly present, adaptation to CC is more discrete and / or indirectly included. Adaptation is nevertheless still present. This presence is based primarily on bioclimatic architecture and urbanism items (local and climate data, like soil, wind, rain, sun, etc., are taken into account to improve outdoor and indoor comfort at a lower energy cost) where adaptation of an urban planning or a building to its environment and its climate are a key element. There are also references and objectives for the reduction of the urban heat island, for the management, the preservation or the restoration of water (rainwater, water bodies, etc.) and green spaces, the climate risk management, or limiting the cooling requirements.
- The most likely methods to take account of the adaptation to CC and to develop meaning are also the latest methods (Ecoquartier approach, CBDD®2013) or those developed by local authorities themselves (sustainable development Guide of Montpelier, sustainable planning framework of the City of Paris). A more complete analysis of all the methods developed today would nevertheless be necessary to confirm this. The inclusion of territorial features (urban heat island, Mediterranean climate) and latest European or French strategic documents on the issue of adaptation to CC may come partly explain this finding.
    - The 16th commitment of the "Ecoquartier" approach is thus "Reduce greenhouse gas emissions, adapt to climate change" and specifies actions like: "Anticipate and adapt to climate change (see French national climate change adaptation plan came out in June 2010 and Territorial climate Plans; specific actions for the reduction of the phenomena of urban heat island; Prevention of risks of flooding and submersion; Action for the comfort of buildings (bioclimatic architecture) in context of increased temperatures; Taking into account the behavior of soils and subsoils; Arrange the green and blue network; Work on the porosity, shapes, colors and materials, air movement, the vegetation and evapotranspiration to help limit urban heat island and improve the thermal comfort of outdoor spaces and control their exchanges with outside areas, etc.). "
    - The CBDD®2013 guide has also a specific issue dedicated to adaptation to CC that specifies: "The prospective scenarios predict a high increase of average temperatures in 2030 and 2050. In a sustainable development perspective, it comes to search, today, scalability and adaptability of structures (buildings and infrastructure) to those risks. These climate change phenomena could lead for example to: an amplification of heat wave/ cold wave/ drought phenomena; floods; an increase in the intensity and / or frequency of storms; moisture; weakening or lesser strength material, due to temperature changes; changes in the landscape, vegetation and soils. We need to try to estimate the potential effects of climate change on the project. These effects can influence: the building itself; users; local residents. We must understand the needs and desires of future generations to a quality of life without paying an excessive tribute to climate change and without having to suffer the effects. To achieve positive results in terms of sustainable development, it is important that future generations are involved in the right choices, starting today. Take it into account will also promote the economic and social aspects of sustainable development. "
    - Sustainable development Guide of Montpelier clearly highlights the following challenge: "preservation of water resources and the strengthening of the green belt in order to fight against the phenomenon of urban heat island and thus adapt our living environment to foreseeable climate change by fifty years, which the city of Montpellier will be very exposed "and binds it to criteria such as waterproofing coefficient, canopy and summer climate comfort, water resources, vegetation integration, potable water consumption.
    - The sustainable planning framework of the City of Paris questions the adaptation of buildings to global warming - "Improving building comfort in extreme temperatures. How to do? Replace, when necessary, external joinery by efficient double or triple glazed windows. Insulate from the inside or outside roofs and facades of buildings, according to their characteristics. Install a motorized or natural ventilation system. Revegetate facades or roof terraces. "- and focuses also on the fight against the urban heat island.
- Actions to adapt urban planning to future climate warming may be similar to those for address today the issue of summer comfort. It appears that summer comfort is one of the main themes in the analyzed guides and methods. Indeed, the issue of summer comfort or the problem of heat islands is addressed in all the studied documents. The relationship between comfort and thermal vegetation is also an element highlighted in most methods. Water is addressed as resources rather than as a climatic comfort element.
- The relationship between mitigation and adaptation to CC is never explained, despite the need to think jointly these two issues. This is also the case of mal-adaptation.

- Most methodologies are more interested in climate adaptation (present situation) than in adaptation to climate change (future situation). In addition, some methods such as “HQE aménagement” will prefer to talk in general of adaptability and scalability, thereby addressing the environmental changes but also socioeconomic changes: "The 21st century will experience a series of changes, some of which are already initiated: technology transition, ecological transition, aging population, proliferation of networked communications, ... The planning will have to adapt to these changes. "

Current tools do not therefore all encourage reflection on the adaptation to CC during the design of a new urban development.

4. Approach and results of the project ADAPTATIO

4.1 Project background

The project ADAPTATIO examines the medium-term consequences of a new climate and of an increase of energy prices. It helped to think about the means available today to address in the design of urban projects the issue of both adaptation to CC and mitigation. For this, the fact to be adapted has been defined with two key resources for tomorrow - water and energy - and on the economic evaluation of these two needs. Indeed, today, the calculation of energy consumption is based solely on the current temperature data. That means that the energy quality of urban planning is evaluated with the past climate and not with the future climate. In the project ADAPTATIO, the reflections enabled both developing a simple tool for representing energy and water consumption of an urban project under different climate scenarios and discuss a new organization of reflection on energy issues during a project by involving all the stakeholders of a project in the innovation process (cf. Nassopoulos et al., 2015).

To develop our methodology, we choose a real urban project: the Tolbiac Chevaleret sector which is on the ZAC Paris Rive Gauche in the 13th arrondissement of Paris and occupies about 12 hectares. A literature review and the meeting with the project manager of the city of Paris has helped to highlight the fact that different urban and architectural choices have not been designed with a view to adaptation to CC. Nevertheless, the project takes into account the concern of current climate adaptation including implementation of regulations, and special attention is given to interactions of urban development project with its components (buildings, green spaces, etc.) and its environment, and the environmental impact of Tolbiac Chevaleret sector.

To complete this analysis focuses on the Tolbiac sector and to understand if adaptation to climate change is taken into account or not in the design and operation of urban projects, and directly or indirectly, we also interviewed several Project Managers of Parisian urban development. Overall, the findings are similar to those on the Tolbiac sector: adaptation to climate change in itself is not treated, but the bio-climatisme, the fight against urban heat islands, or more generally energy issues and climate, are among the issues included in the urban design.

4.2 Evaluation of energy, water and economic vulnerabilities for the case study

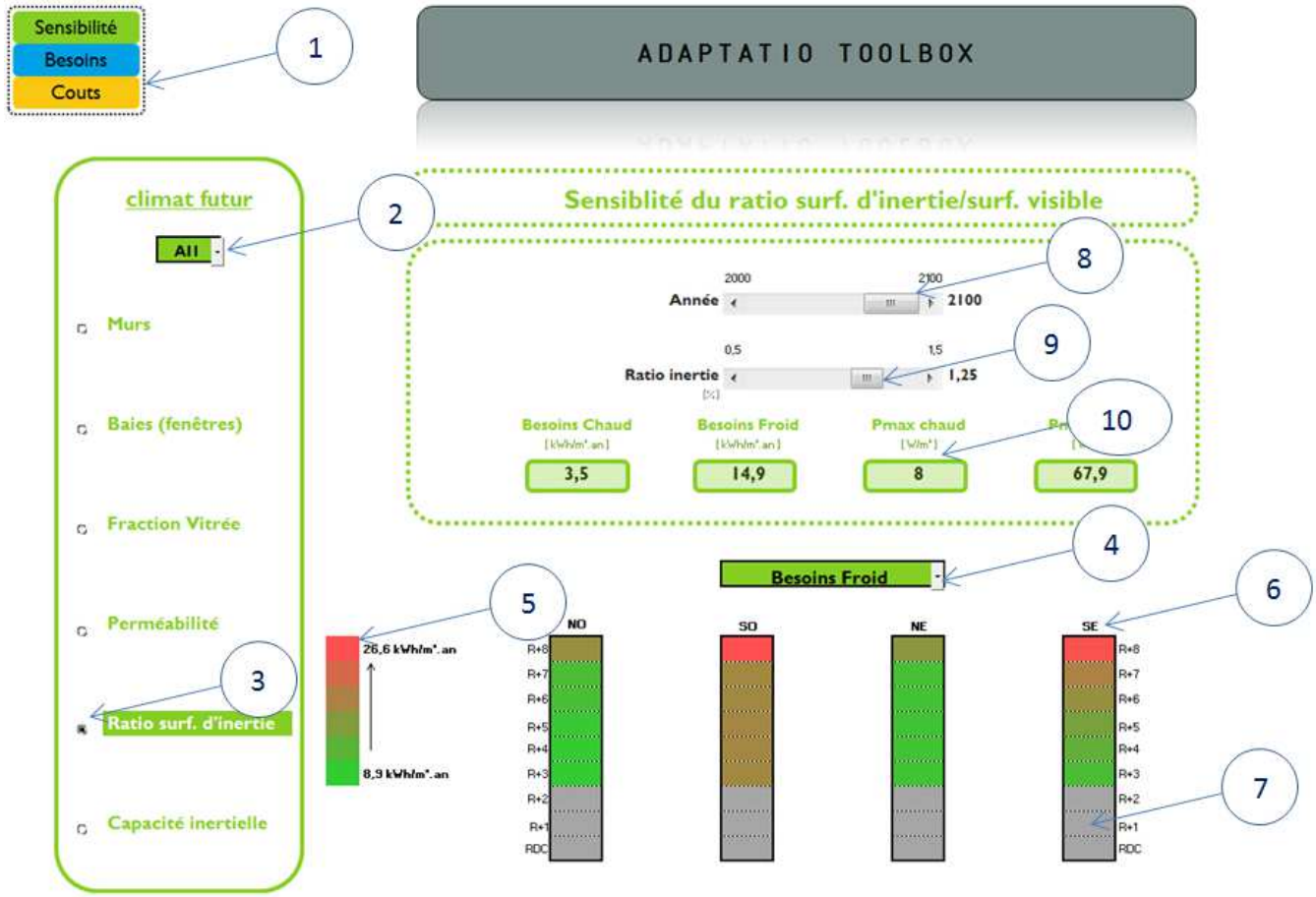
To analyze the vulnerability of a urban development to CC, and provide tangible information to the actors of urban planning during the design of a project, we proposed several simulations and analyzes applied to Tolbiac Chevaleret. The model developed by Egis Clim'Elioth Concept for the scale of the building has been modified to respond to the needs of ADAPTATIO project. The ENVI-met model allowed to approach the issue of micro-climatic changes related to urban form and materials. Economic impacts related to energy and water needs were also assessed. We cross these analyzes with the construction of a toolbox to highlight by simple manipulations effects of CC as of adaptation solutions[1].

Three types of solutions were analyzed and compared to a reference case of Tolbiac Chevaleret with a "very high" performance (from an energy point of view):

- Sensitivity tests on the performance parameters of the building,
- Tests on scenarios needs under different bioclimatic principles "building" or "urban space" solutions,
- And the choice of production systems (heating / cooling) with the calculation of consumption and associated costs.

The first series of tests were on building’s performance. The aim was to test the impact of changes in key performance parameters of the envelope on energy demand of buildings (impact on energy needs). We have assumed that for these tests, thermal comfort strategy was a complementary use of air conditioning and natural ventilation.

[1] This tool processes the results of simulation software on the one hand at the scale of the building (CLIM'ELIOTH. Ecodesign tool developed by Egis Concept and addressing energy issues and comfort of buildings), on the other hand to the neighborhood level (ENVI-MET: simulation tool of urban comfort particularly taking into account the evapotranspiration of vegetation phenomena). This software uses meteorological data for 2050-2100 provided in the project by Meteonorm.



• 1: generic links to "click" to access one of 3 results publishers
• 2: Choice of the "desired future climate" scenario (A1B and A2).
• 3: Scenario Selection "sensitivity parameters to test." When choosing a parameter, the others are automatically fixed to the median value.
• 4: Choice of the scenario "type of needs to test" (heating needs or cooling needs).
• 5: Scale Indication of needs (Scale adjusts automatically when scenario changes)
• 6: Display of the results depending on the floor and orientation of inside spaces.
• 7: The gray levels indicate (for information) the floors of shops and activity programs (not studied in our project).
• 8: Cursors to compare results for different year (2000, 2050 or 2100).
• 9: Cursors to compare different values of performance parameter chosen according to the climate target year (2000, 2050 or 2100). As seen above, the cursor has 5 graduations which describes a value-performance center, one extreme to + 50% and another 50%.
10: Indicator results displayed on average for the entire building program.

Figure 1: Manual of the toolbox

The results of this sensitivity analysis are available through the toolbox (Figure 1). It allows to instantly view the impact of any change in simulated settings on the following output indicators: heating needs, cooling needs, heating and cooling Pmax. Each of these indicators is given in total annual average value, in kWh / m².year for the needs and W / m² for maximum powers, but also by a color scale indicating an average for each direction and each floor.

The impact of these indicators on the basis of the current climate can then be visualized and compared to future (2050 and 2100) according to the two selected climate scenarios (A1B and A2).

The instructions in Figure 1 show how to use the results tab "toolBox_Sensibilité" of the toolbox. All results are displayed in real time on the test page when the user selects scenarios.

Using the toolbox allows to show, for a same building, increasing cooling requirements due to climate change, but also the reduction of heat requirements; and this more or less pronounced depending on the selected scenario (A1B and A2)[2].

4.3 Results

The tab "toolBox_Besoins" of the toolbox represents the changing needs depending on choice of climatic equipment (air conditioning + natural ventilation, or exclusive air conditioning (without possibility of natural ventilation), or air conditioning + natural ventilation + Canadian well) or modification of the urban planning.

If we change climatic equipment (but without urban planning changes), we see with climate change a slight increase of total consumption (heating and cooling) except if the choice of an exclusive air conditioning is done

[2] Water consumption has been restricted to public use (watering green spaces, ponds feeding).

(with no possibility to ventilate naturally) then in this case consumption increases significantly. It also highlights the most efficient solution for energy: to couple air conditioning, natural ventilation and Canadian well.

Regarding the scale of urban planning four scenarios were modeled:

- Greening scenario where vegetated surfaces are increased and watered optimally (scenario S2)
- Reflecting scenario where the physical properties of roofs are changed without touching the walls (S3 scenario)
- Reflecting scenario where the physical properties of the opaque walls and roofs surfaces are changed (S3 bis scenario)
- And finally, a story addition on building (S4 scenario).

All scenarios are tested to assess their impact in terms of energy. Only the scenario S2 "maximized vegetation" is tested to assess impacts in terms of water needs in the Tolbiac Chevaleret sector. The results of these tests on the energy needs were also integrated within the "toolBox_Besoins" tab of the toolbox.

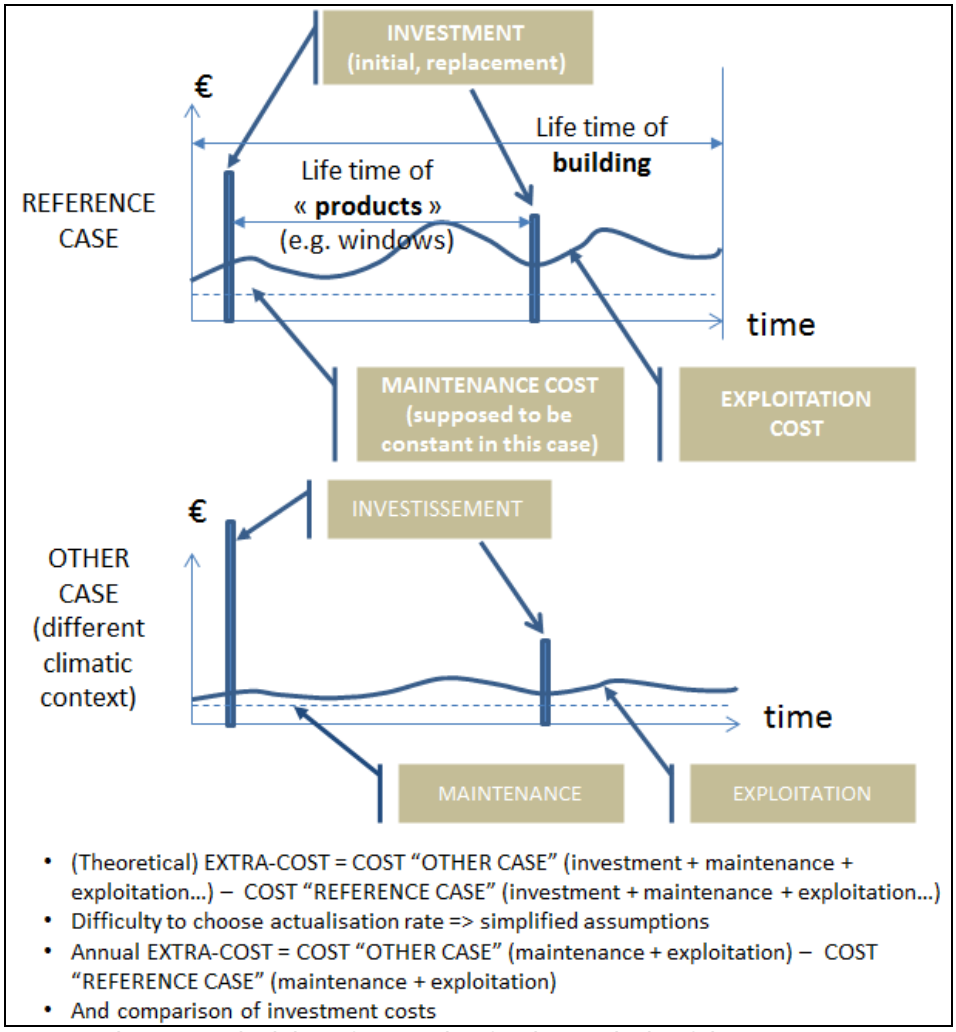


Figure 2: Principles of reasoning for the analysis of the extra cost

To evaluate associated costs, many simplifying assumptions have been made (no discount rate, no rebound effect, changes in energy prices in connection with the modeling of the European commission, a constant flat-rate subscription cost, etc.), we consider the cost difference between the "adapted" situation and "not-adapted" situation, so regardless of the remaining costs. We therefore consider the additional costs due to water or energy consumption, installation and maintenance of a not adapted situation compared to the level of these costs in an adapted situation.

For each studied solution we have analyzed the cost of installation, maintenance costs, costs related to water and energy consumption and the required number of rotation of the installation. Our analysis for each pair of tested solutions to have the information is explained in Figure 2.

The toolbox allows you to compare two by two situations making choices in both:

- Air conditioning and natural ventilation
- Production systems (heating / cooling)

A priori no solution allows to minimize all costs throughout the project lifetime. It is thus necessary to make choices between time and the amount of costs to be supported (excluding the entity that supports these costs and other considerations such as social or political acceptability).

5. Conclusion

In summary, the project ADAPTATIO had not ambition to understand in their entirety the systemic issues raised by the process of adaptation to climate change. The available resources were devoted to the examination of two topics: the impact of a new climate on water and energy consumption especially in a warmer climate.

The exploration of contrasting futures was preferred to show the consequences, including economic, of those choices. We proposed different solutions: actions on the building envelope, on equipment and on the immediate environment of the buildings. For each solution there are an investment, operating costs and maintenance, and a very specific lifetime.

In the defined limits, the reflections with urban professional have led to two observations:

- First, the adaptation to CC is not listed in the specifications of current or planned in the short term projects, the course and the daily follow up are already very complex. The uncertainty surrounding the intensity of future climate change does not facilitate their consideration during projects.
- Second, this relative distance from adaptation, due to the significance of the operational aspects of the conduct of operations, however, is accompanied by an appetite to have tangible factors, including quantified, to appreciate the scale and urgency of possible adaptation measures. The toolbox developed under ADAPTATIO is designed to meet the wishes of professionals to have synthetic indicators associated with the qualification of indoor and outdoor comfort at the neighborhood level. An approach of the associated cost is also available to complete the analysis.

Various workshops and discussions with operators confirmed that the scope of the toolbox ADAPTATIO lies in its ability to raise awareness of the issues associated with a new climate. It allows creating the conditions for an exchange without pretending to substitute for detailed study and simulation tools operationally mobilized by the actors of urban development. Special care will have to be made to the interface that further tests will lead to improvement. His current limits are to require a complete new data entry (geometry and description of buildings and their environment) for each new district studied.

The objective under ADAPTATIO was however reached: to make possible an exploration by professionals in the incidence of future climate on water and energy consumptions of a group of buildings actually made in the Tolbiac Chevaleret sector.

This project opens up many perspectives:

- Organizing the exchange between scientists and professionals to develop an operational approach of adaptation to climate change,
- Refine the economic approach on adaptation in exploring contrasting scenarios of influential factors,
- Integrate other indicators such as greenhouse gas emission level associated with the technical solutions,
- Open the possibility of involving future users of the district to the choice of adaptation options through enhanced visualization capabilities and an educational effort on presentation of simulation results,
- Create the conditions for the mobilization of "design-thinking"[3] methods by enhancing tools like ADAPTATIO toolbox as a support to the intervention of specialized designers that help facilitate discussion and innovation.

Acknowledgment

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[3] Design thinking is a participatory process based on the collective creativity, empathy of stakeholders, and abductive reasoning encouraged to think outside the box. The margin for error is recognized and seen as a success factor to reach innovation that lies at the crossroads of user needs, the possibilities offered by technology and its viability in the marketplace.