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Urban heat islands and sensitive building design – A study in some French cities' context

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ABSTRACT

This study carried out in late 2013 for the French Ministry of Ecology, Sustainable Development and Energy (MEDDE), aims primarily to make a situational analysis of the awareness and consideration level of the UHI constraints, by organizations that influence on the location and the design of building hosting sensitive people to high temperature (nursery, retirement homes). This assessment was performed by a national survey which was conducted in 10 French cities which are likely to be affected by the phenomenon of UHI, among 75 local stakeholders who were likely to be involved in the choice of construction or location of this kind of establishment. The UHI mitigation and adaptation practices applied in each city have also been analyzed. These practices are mainly vegetation (green spaces, green screens and roofs) and specific coatings on facades and roofs (variation of radiative properties by using different colors and materials). Among the other main conclusions of this investigation, it appears that only 11% of the total panel questioned considers UHI in decisions and only 17% of the influential stakeholders believe that there has been an evolution in their decision making since the introduction of the PNACC plan in France. These most influential stakeholders in the decision-making process are the designers (prime contracting: thermal and design engineering, architect, etc.). To complete this study, some operational suggestions are proposed to improve the consideration of UHI constraints in decision process, concerning the implementation or the refurbishment of the targeted building.

1. Introduction

In France, the 2003 heat wave had disastrous health consequences (a 60% increase in the number of deaths from the 1st to the 20th of August 2003) which led to the establishment of a strong environmental policy. In addition to many risk prevention measures, France has established in 2011 a National Plan of Adaptation to Climate Change (PNACC) including 230 measures within 20 different policy areas including health, urban planning and built environment.

In addition to the greenhouse effect, the increasing heat waves in urban areas, especially in large metropolitan cities, are also due to the urban heat island phenomenon (UHI). These temperature differences' peaks, between urban areas (warmer) and rural areas (cooler), are mainly observed on summer nights. UHI parameters are well known: anthropogenic sources (including increasing use of air conditioning systems), urban morphology, low wind speed, air pollution, etc.

The UHI consequences are numerous, especially for citizens (discomfort, excess mortality) and for building energy demand. Indoor thermal comfort has direct impacts on health and productivity (Seppänen, Fisk, & Faulkner, 2003). Strong heat waves cause an important need for air conditioning in buildings, especially among most sensitive people to heat: elderly and children. As a first approach, the use of cooling systems is a solution which can contribute to release heat outside the buildings amplifying the existing phenomenon of heat island urban (Bozonnet, Allard, Chazelas, Guarracino, & Musy, 2008). Moreover it contributes to increase building energy demand and electricity peaks (network overload). The adverse effect of this vicious circle can be reduced using more renewable energies, designing cooling systems discharging little or no heat outside, and amending the urban geometry or cover materials.

Many solutions exist and are used in the design of cities (see Section 3.4). These are both mitigation measures of climate change, consisting in reducing human impact on the climate system, and adaptation measures to climate change, consisting in making sure that the heat in the city bearable for its inhabitants, in the short and

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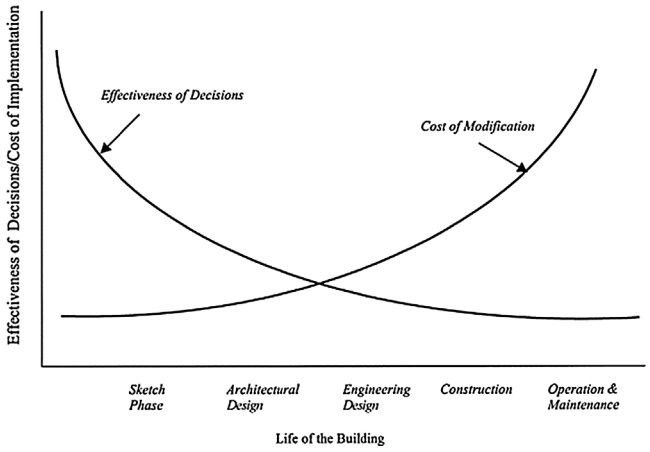

Fig. 1. Costs of decisions and their impact on building performance during the lifetime of a project (Saad AL-Homood, 2001).

long term (IAU, 2010). In the case of the fight against UHI, mitigating urban heat island is an adaptation to climate change. Adaptation measures are often more difficult to define and to implement than the mitigation measures and generally apply to a more local scale. They must also be integrated into a larger argument to avoid the phenomenon of "maladaptation" (OCDE, 2009), that may be contrary to the mitigation of climate change (e.g. the almost systematic use of air conditioning in buildings hosting fragile people), and cause significant costs. Moreover, mitigation measures may be contradictory with adaptation measures (e.g. cities densification). It is therefore necessary to adapt to the impacts of climate change and the potential impacts of mitigation measures.

The effects of the high temperatures occur directly on health as shown in the study of Buechley (Buechley, Van Bruggen, & Truppi, 1972), which highlights a certain correlation between the increase in the mortality rate in urban areas and the ambient temperature. Included in these main causes of death, one can identify: the causes directly related to heat (heatstroke, hyperthermia and dehydration) but also cardiovascular diseases, symptoms and ill-defined conditions, diseases of the respiratory system and the nervous system, endocrine diseases (BEH, 2006). The observed mortality in France during the heat wave of 2003 affected more urban than rural areas. The highest relative to normal seasonal temperature variations were observed in urban areas. The excess mortality rate in France was 40% in small and medium-sized cities, 80–141% for big cities like Lyon and Paris (InVS, 2012).

These impacts of UHI involve an important social and energy cost, which is difficult to assess given the spatial and temporal heterogeneity of the UHI phenomenon by cities, districts, streets or building environment. A better understanding of the physical mechanisms responsible of UHI development, the existing mitigation measures, and the associated costs, are necessary to fight efficiently against this phenomenon. It also requires a strong consideration of these issues by the decision makers and particularly regarding project implying the most vulnerable people to heat. Moreover, for a given project, more the subject will be treated upstream, better will be the efficiency/cost ratio, as shown in Fig. 1.

A 2010 study realized by the Ile-de-France Institute of Planning and Urbanism (IAU) refers to numerous barriers to the adaptation of French cities to climate change and UHI, particularly in terms of city planning. The reasons given include: the novelty of the issue, the lack of background studies on UHI and the specificity of the phenomenon for each city, the problem of the area scale concerned, etc. (IAU, 2010).

New developments on climate change and UHI policies are also developed in California, based on the Global Warming Solution Act (Assembly Bill 32), which requires the state to reduce greenhouse gas emissions to 1990 levels by 2020. To achieve this reduction, but also the UHI effect and thereby co-benefits for residents (such as reduced utility bills, improved air quality and health, fortified climate resilience,), "cool community" strategies including cool roofs, cool pavements, cool walls and urban vegetation, have been identified as voluntary measures. Lawrence Berkeley National Laboratory (LBNL), which worked with state and local stakeholders (officials, non-profit organizations, school districts, utilities and manufacturers) in a recent study, observed that the recipe for success of cool community efforts includes empowered leadership, broad stakeholder backing, support of other policy objectives, and guidance from researchers to ensure sound implementation of promising science (Gilbert, Mandel, & Levinson, 2014). Mitigation and adaptation solutions to climate change exist, real experiences feedbacks exist, scientific understanding of the phenomena is well developed and National Plans are deployed as in France or California. All technical factors are combined to succeed in mitigating and/or adapting to the UHI effects; yet concrete measures are not enough systematically adopted at large scales.

The present study, carried out in late 2013 for the French Ministry of Ecology, Sustainable Development and Energy (MEDDE), try to better know the reasons of this weak integration of cool strategies in decision process, in the particular case of building hosting sensitive people to high temperature (nursery, retirement homes). The first aim was to assess the level of awareness of the UHI constraints during hot season and its consideration by organisms that influence on the location and the design of these building. This study also contributes of the overall assessment of the PNACC plan. The main barriers of the UHI integration in decisions and lines of inquiry to improve its consideration complete this study.

2. Methodology

A survey was conducted in 10 French cities with 75 local stakeholders who were likely involved in the choice of construction or location of the targeted buildings. The survey consisted in an interview of key actors and included a questionnaire with open and closed questions. The objective was to collect, through interactive interviews, qualitative answers in order to well understand the decision-making process in each city and the possible improvements identified.

The selected towns for this study are mainly large urban area in France which are affected by UHI (Paris, Lyon, Lille, Toulouse, Grenoble and Marseille, although the UHI phenomenon is discussed for the latter). There are also medium-sized towns affected by UHI (Nancy and Valence), a French oversea territory city (Saint Denis de La Réunion, Reunion Island) in order to be representative of the entire territory, and an ecological district (called "confluence" district in Lyon) for which, UHI topic is potentially better understood. The geographical location is given by Fig. 2.

The survey is voluntary targeted on various authorities and responsibilities, from public and private sector, including: the different services of the concerned local authorities (cities, urban communities, local and Regional Council), the services of the Environment Agency and the Energy Management (ADEME) and the Regional Health Agency (ARS), architectural offices and thermal engineering firms, services in charge of financial allocations for the construction of buildings for the targeted sensitive populations, and other institutions concerned with the subject. Their areas of expertise are also very diverse (Fig. 3), although they are primarily focused on sustainable development, building energy and public policy.

To process the survey results, actors are clustered into 7 categories, depending on their role in the decision on construction of