A CURA DI
PASQUALE MIANO
BRUNA DI PALMA

PAESAGGI A RISCHIO

FRAGILITÀ, VULNERABILITÀ E PROGETTO

15
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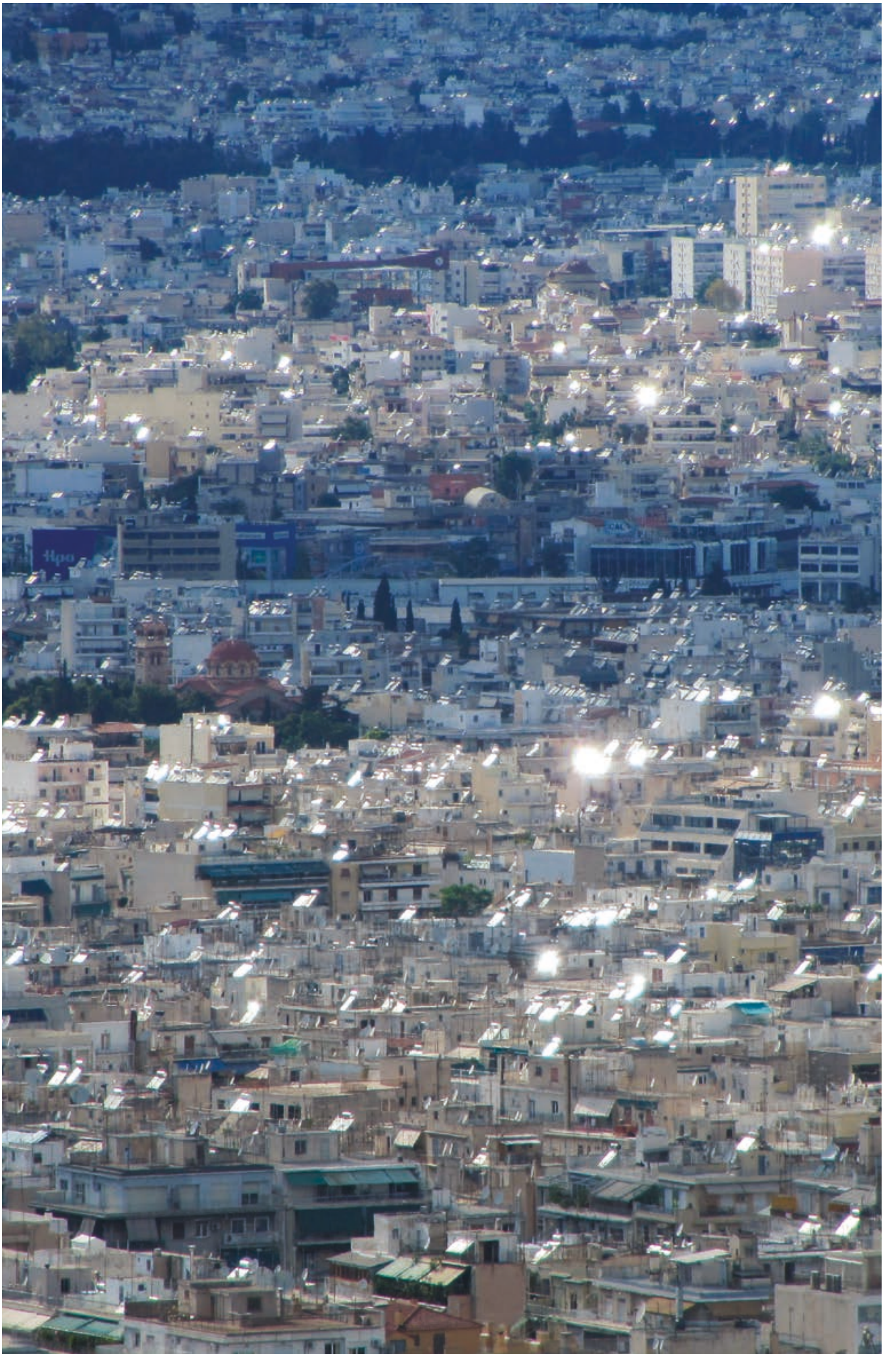


Photograph of Athens captured from the Acropolis by the first Author.

Renewable energy sources in the city

Benoit Beckers, Jairo Acuña Paz y Miño, Inès de Bort

Introduction

In a little over two centuries, the human population of our planet has multiplied by 8 and the urban population by 200. Cities are spreading out much faster than they are being populated, and a few percent of the land area is already covered with concrete or asphalt. The majority of towns have been built amidst the most fertile farmlands, and their sprawl is jeopardizing food self-sufficiency in many corners of the world.

The most dynamic cities today are between the tropics[1], these cities need to be limited and, therefore, densified. Thus, there are more and more compact, impoverished cities in hot climates, with amplified heat waves due to climate change and the immoderate use of air conditioning, which in turn intensifies the Urban Heat Island often with dramatic consequences, as in northern India in July 2022.

The only viable solution is buoyancy-driven ventilation, which works best when the sun is strong, thus leading to large differences in surface temperatures between sunlit and shaded windows. Maximizing this ventilation in a dense and complex urban environment is challenging, yet it is the only way to make our cities sustainable, by reducing peak electricity consumption during the hot season, when the lack of wind and low water levels lower the production of wind, hydro, and even nuclear energy.

Should we continue to produce electricity outside the cities, with endless fields of wind generators, mirrors turned towards a turbine sitting on top of a tower, or photovoltaic panels lined up in rows? Should we continue to scrape and drill the ground to extract from the earth's crust its last seams of coal, its last deposits of gas and oil?

In February 2022, following the Russian invasion of Ukraine, the price of gas soared unexpectedly. By the fall, the Russian army began to systematically bomb power plants and thermal power stations, hoping both that the Ukrainians would flee their cities in the winter, and that the Europeans would convince their governments that it was better to lose a war than to freeze to death. It was finally on February 6, 2023, that in southern Turkey and northern Syria, an earthquake buried tens of thousands of people under the ruins of poorly constructed buildings, leaving injured survivors without shelter in the freezing Anatolian winter.

A city capable of producing the energy it consumes would be more resilient, and more self-aware. Limited to no more than two or three million people – this is already much more than the population of the largest cities before the Industrial Revolution, which never exceeded one million inhabitants – the ideal city of our time would be surrounded by farmland that would provide a significant portion of its food whilst preventing sprawl. There would be no room in the countryside for huge warehouses and truck parks, instead, a rail network would provide the essential transportation of goods and people. Inside the city, the only energy available at all latitudes with sufficient density is solar energy, which can be transformed into electricity by the photovoltaic effect.

The historical city

To ensure sufficient roof space, the city's buildings should not exceed five or six stories, with the added benefit of limiting the use of elevators. This is the model of the European city before 1900 (Rome, Naples, Turin, Paris, or Barcelona), with its heavy and opaque facades offering both thermal inertia and small windows that balance natural light, solar gain, and heat loss. Towards the middle of the 20th century, urban planning, which had composed remarkable urban ensembles according to principles dating back to the Renaissance perspective, the Baroque mastery of light, and the hygienic concerns of the early Industrial Revolution, lost the scales of its physical model to skyscrapers, automobile traffic, and large glazed surfaces.

The historic city is a role model, yet it cannot be adapted to photovoltaic production. No point in disfiguring neighborhoods together constitute a negligible portion of today's cities. However, it is possible to improve comfort and reduce consumption with well-known urban devices whose effect can be accurately simulated today, to optimize their layout for a given urban configuration in a given climate. For example, mirrors placed above lightwells bring more daylight to lower floors[2], textile canopies covering streets in summer protect inhabitants and passers-by from excessive sunlight[3], glazed balconies allow, thanks to the greenhouse effect, to greatly increase buoyancy-driven ventilation in summer.

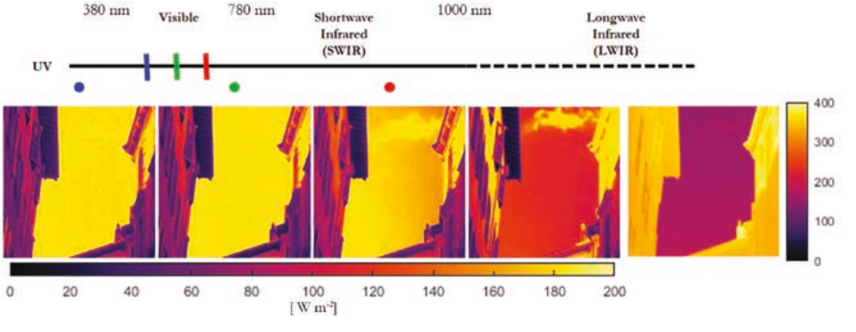
The modern city

Figure 1 shows the roofs of Athens, seen from the Acropolis, sprinkled with Chinese-made thermal solar panels (they are very common in the cities of the Middle Kingdom, for example in Xi'an). Their glittering under the sun enhances the chaotic aspect of the Greek capital, which grew way too fast – its population doubled in 1921, after the Greek-Turkish war – and which its inhabitants call *Tsimentopolis*, the concrete city. If the thermal panels swarm, it is certainly because they bring an appreciable benefit to the inhabitants. However, they occupy a space that might have been used for the deployment of another technological solution – photovoltaics – which is certainly far more expensive to install, but whose long-term benefits would have, perhaps, largely vindicated the initial investment. By working adequately on its terraces, we could convert *Tsimentopolis* into a showcase worthy of its sublime Acropoli.

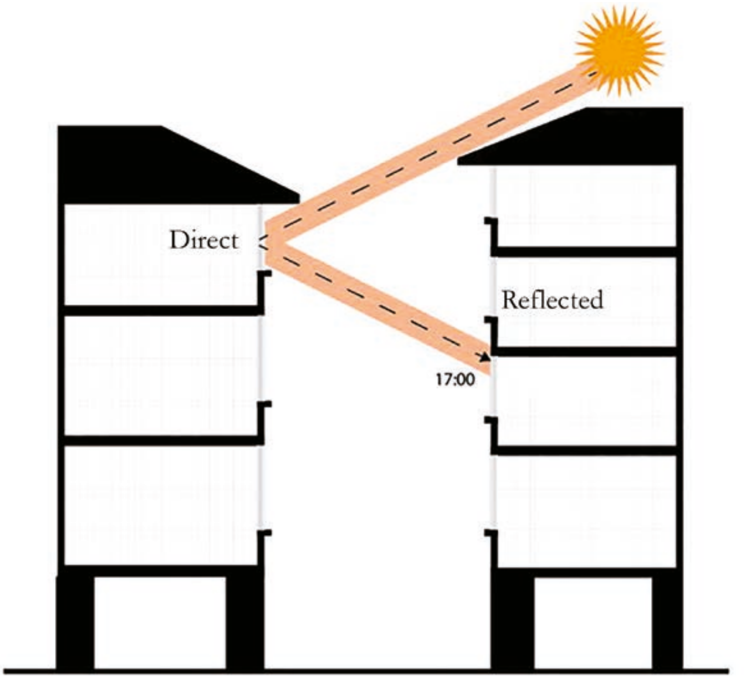
For the installation of photovoltaic panels to be justified, the city's buildings must consume a low amount of energy, both for heating and cooling. To ensure that an urban renewal plan will achieve a satisfactory thermal result, it is necessary to be able to calculate all radiative balances in the city very accurately, taking into account multiple reflections of electromagnetic radiation. In the best case[4], current simulations distinguish between shortwave (below 4 microns, this is solar radiation) and longwave (above 4 microns, this is radiation from the scene, as shown by the thermal camera). In shortwave, we distinguish between specular reflection (on glass and polished metal surfaces) and diffuse reflection (on matte surfaces).

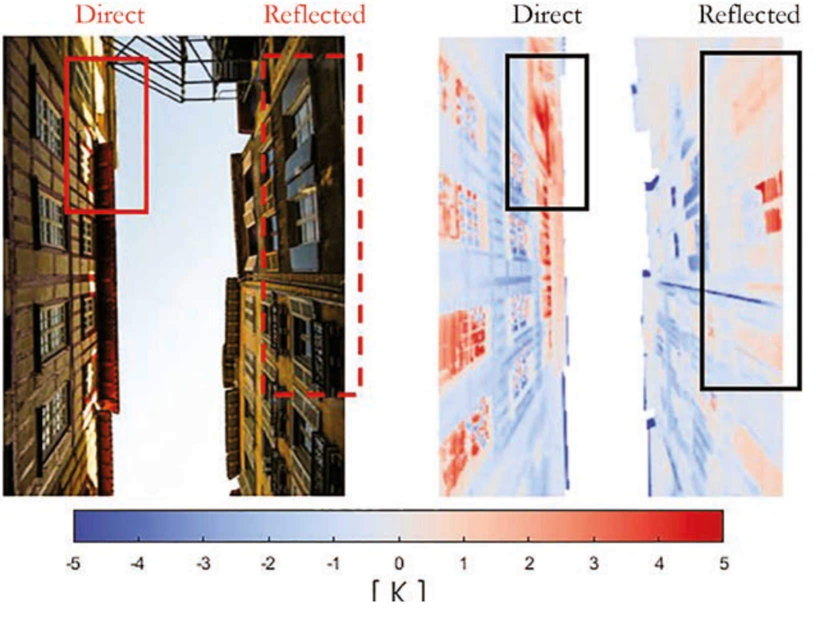
Figure 2 shows a street in Bayonne, southwestern France, photographed with different cameras equipped with different filters. From left to right, increasing wavelength ranges show first the visible light (in the blue, green and red bands), then the near-infrared (which constitutes nearly half of the solar spectrum, but is not visible to the human eye), and finally the thermal infrared. The imperfections of the walls are large enough to randomly scatter the reflections of the shortest waves, but these same walls become increasingly smooth for longer wavelengths. If we go through the figure to the right, we can see that some surfaces become practically mirrors from the near-infrared band. From one wavelength band to another, it is not only the reflection coefficient that changes but the type of reflection itself. Specular reflection does not distribute light in the same way as diffuse reflection.

Figures 3, 4 and 5 show the same phenomenon on another street in Bayonne. Figure 3 shows two images captured at 17pm.: a photograph of the scene and a thermograph relative to the air temperature[5]. On February 20, the moment of the measurement, the sun has an elevation angle of 24.4°[6]. The diagram shows the area of the facade directly illuminated by the sun and its reflection on the opposite *façade*. The observation of these two spectral bands shows the interest in including a third one to better understand the passage from diffuse reflection to specular reflection.

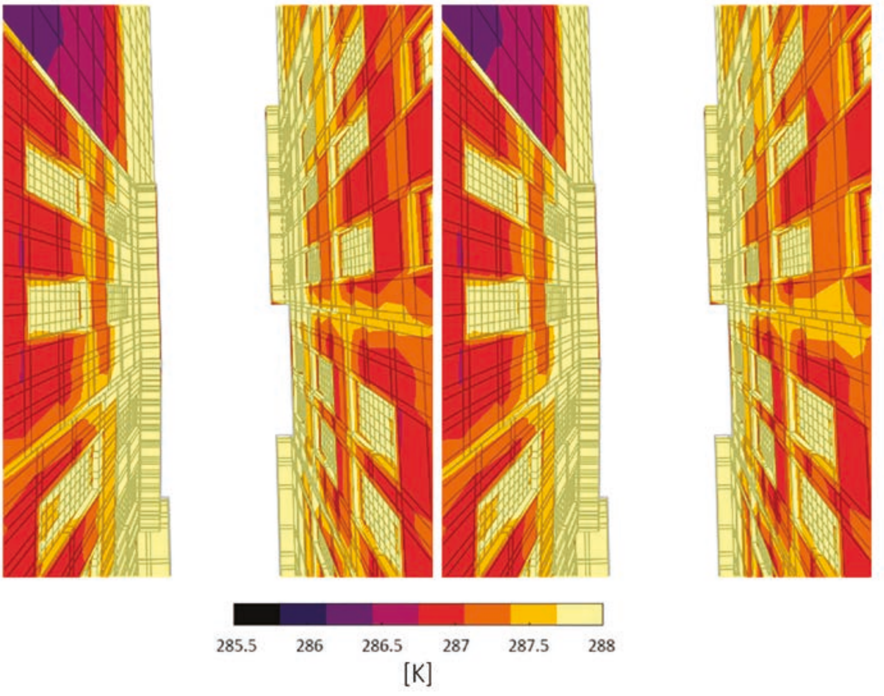


2. Multifrequential imagery of an urban canyon.

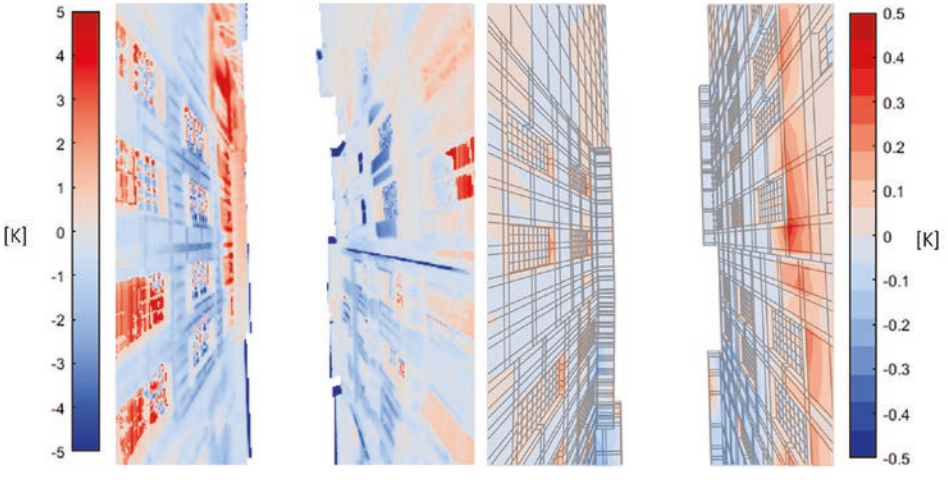




3. Photograph and Thermograph relative to the air temperature.



4. FEM thermal simulation considering: a) perfectly diffuse walls; b) perfectly specular walls.



5. a) Thermograph relative to air temperature; b) FEM thermal simulation considering three spectral bands.

To include, in a simplified way, a third spectral band, we performed a finite element simulation where the short waves are calculated twice: the first assuming specular surfaces and the second assuming diffuse surfaces. The windows were considered specular in both cases.

The sunlight that reaches the surface of the Earth is composed of about 55% infrared (above 700 nm) and 45% visible and ultraviolet (below 700 nm). The two results were therefore combined in the same proportions.

Figure 5 shows the near-infrared influence on surface temperatures. To observe it, we use the representation of the temperature difference. The calculation of the irradiance absorbed by the surfaces shows a distribution similar to that observed in the measurement.

The city to come

For a new city, excluding the most extreme climates, it is undoubtedly possible to achieve energy autonomy. This requires designing the urban form while considering, from the first draft of the mass plan, the different interactions that will occur between buildings and energy fields[7]. For example, the profile of a street must optimize at the same time ventilation, natural light, and solar gain in winter[8]. The solar potential should be split between a sufficient area of photovoltaic panels on rooftops[9] and facades with well-sized windows that are protected from the summer sun and street noise[10], yet providing access to sky light[11]. The window ratio of the facades, the effect of arcades and balconies on the sound field, the use of the greenhouse effect for better ventilation, motorized solar panels to better track the sun and possibly its reflections on the glass towers[12], and many other equally complex aspects should be calculated interactively, as a first approximation, to guide the urban project. Longer and more precise simulations would then allow confirming – or "nuancing" – the first intuitions[13].

Twenty years ago, we developed the first interactive software to help design the acoustics of a theater or concert hall[14], and then a very intuitive software to design a building by controlling the solar paths[15]. In both of these cases, we found that the key was to offer synthetic representations of information[16] – respectively, the polar diagram[17] and the solar diagram[18] – combined with other representations appearing simultaneously on the computer screen, and then to post-process these graphs in such a way that the author of the project could demonstrate to a wider audience his mastery of the various physical aspects under study.

Advances in computer science now make possible much more comprehensive simulations, using methods such as ray tracing[19], radiosity[20], and even finite elements[21], nearly in an interactive manner. In parallel, the development of photographic, thermographic, acoustic, and even aeraulic cameras allows the architect to visualize the energy fields once the project is built[22].

It remains for the professionals of the 21st century to seize these tools and, with their help, finally create cities whose form follows function.

Note

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