SOLAR ENERGY: HARVESTING THE SUN
An architectural approach through Le Corbusier's groundings

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Abstract: Roughly, all through history of mankind, solar solutions in constructions always have been purchased fiercely during periods of energy crisis, mostly when non-renewable energy sources were endangered in some way.
For this paper an architect of the 20th century was chosen, Le Corbusier, as a good example of how to design and build with the sun. Not only he knew how to harvest the sun for comfort issues, balancing wisely natural light and heat (gathering and storing heat for cold periods, or protecting openings from harsh sun beams), but he also dominated the light to valorize shapes and volumes. Here one of his famous project: the "*Unité d'habitation de Marseille*" is analyzed to show a well conceived architecture in urban area. Le Corbusier teach us awesome lessons on how to take sides of so called "passive" solutions and fully merge them in architecture, creating not only energy efficient buildings but an astounding architecture. This study focuses on a particular building to point out comparatively simple solutions in architecture and looks forward to the possibility of sprawling such solutions with a huge potentiality in energy savings. It also tries to demonstrate that good design must consider architecture ruling an ensemble of fields, including urban inclusion and respect to local social and geographic peculiarities. Harvesting solar energy in architecture doesn't mean necessarily adding technical devices to buildings but certainly depends on designers' postures and abilities to integrate technical solutions into an artistic and aesthetical whole.

Keywords: Architecture, solar energy, urban design.

INTRODUCTION

"*Wouldn't it be nice to die while swimming in the Sun?*" is presumed to have asked once Le Corbusier alluding to his peaceful holidays at Cap Martin as he enjoyed the magnificent view over the Mediterranean sea from his summer hideaway: "*Le Cabanon*". Whether this sentence is true or not, it underscores a certain premonition or betrays a staggering coincidence as the architect died on august 27, 1965, of a raging heart attack while he was lying on the beach after swimming, right in front of his cozy little shelter. Premonitions and chronicles aside, this thought also expresses brilliantly Le Corbusier's concerns and *penchant* for Phoebus' light and heat he knew so well to deal with in almost all his designs. In other words, he had mastered the sun and knew how to take advantage of its energy in architecture by achieving astounding solutions to lighten, heat or protect internal surroundings and arrange *wisely, properly and magnificently*, as he says, *volumes and shapes under the sun light*. (LE CORBUSIER, 1927)[3].

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[3] Le Corbusier – Vers une Architecture, 1927.

Figure 1 – My castle on the French Riviera' Le Corbusier at window in his Cabanon in Cap Martin (Alpes Maritimes – France).

Font: Fondation Le Corbusier and http://www.architecture.com/WhatsOn/Exhibitions/At66PortlandPlace/2009/Spring/CorbCabanon.aspx

However, Le Corbusier's ideas about how to harvest sun's light and heat and use it in architecture weren't new. Most of them were retrieved from traditional or vernacular building solutions, some even from as far as the ancient Greeks time. Xenophon (ca. 430-354 BC), for instance, wrote in his Memorabilia (Book III, Chapter VII), citing Socrates describing the advantages of solar orientation of an ideal Greek house: "Now *in houses with a southern exposure, the sun's rays penetrate the porticos in winter, but in summer, being less inclined, they afford shade. If, then, this is the best arrangement, we should build the south side loftier to get the winter sun, and the north side lower to keep out the cold winds. To put it shortly, the house I which the owner can find a comfortable retreat at all seasons and can store his belongings safely is presumably at once the most pleasant and the most beautiful.*" (apud Boyce, 1993). This very first registered concept of a solar house was indeed a judicious one and has been followed by countless architects and builders since then all over the western world (according to sunbeam angles, i.e. local latitude), looking forward to more comfortable dwellings.

Nevertheless, Le Corbusier's merit certainly was to adapt such solutions to contemporary and modern architectural expressions, as did many architects and builders through the 20th century. He first understood the benefits of sun rays on human health and the advantages of natural lighting. He advocated the requirement of at least two hour of direct sun beam inside new buildings as "*medicine had proved that tuberculosis usually settles where the sun doesn't sink in …thus, a minimal number of direct sun beam should be fixed for each home*[4]..." (LE CORBUSIER, Athens Charter, Item 26, 1933). He also learned to control heat and light, creating wealthy spaces and energy efficient buildings as well as amazing atmospheres. Notre Dame du Haut in Ronchamp (1954) gives an outstanding example of this last assertion.

Search for light was an utmost precept to modern architecture. "Licht" became the Bauhaus architects' rallying cry ad was heard far and wide. Most of Le Corbusier's European designs clearly attest this quest for lavish natural lighting, a conceivable attitude considering the scarce luminance of some high latitude countries. It was not, at the time, an energy saving issue but a genuine intent to bring more health, welfare, comfort by aesthetic means as it can be well perceived in *Vila Savoye* at Poissy (1929 – Figure 2).

[4] Le Corbusier – La Charte d'Athènes, Éditions de Minuit, Paris, 1957. P. 50.

Figura 2 – Villa Savoye, Le Corbusier. Photo: Adam

Font: internet. http://picasaweb.google.com/adam.caruthers/ParisFrance. Accessed in 22/02/2009.

New building materials and methods, such as concrete that was worshipped and broadly employed by modern architects, provided independent structures that freed the façades allowing wide openings and much more light entrance in the insides.

Concrete structures, walls and floors are also suitable to store heat. When correctly sized and oriented they can provide comfort during the winter days. Aware of those properties Le Corbusier also was committed to technological advances and rather chose building systems and materials that clearly proclaimed the expression of modern industry. Colors, textures and shapes were bound to reflect the refinement, the lean sense of efficiency avoiding all surpluses just like the industrial machine components. Natural resources should be employed in a rational and organized way, through technical proceedings.

Energy issues as regarded in our days are seldom approached by Le Corbusier in his writings. He oppositely seems rather enthusiastic about technical solutions he discovered during his travel in the United States of America in the late 1920. In his book "*Quand les cathédrales étaient blanches*" (1937), he is bewildered by the successful actions achievable in the "*Pays des Watts*" [sic] and claims that architecture should seize all new techniques available.

> ... No windows anywhere... silent walls... Air conditioning is everywhere: pure, dustless and temperature is constant. Am I in the 5th or 40th floor, secured within a glazed aquarium?…[5]
> … all modern technical devices must be incorporated to architecture, but willing to transcend their simple utility. Such an indispensable goal intends to offer the joys of the heart and of health to the mechanical civilized men[6].

Although Le Corbusier's concern were guided by functionality, aesthetics, health and a certain "*joie de vivre*", when it comes to sun reckoning, most of his projects display the basis of passive solar techniques suitable for energy efficiency. Shapes, structures, materials, openings and its eventual protection seem to have been conceived with this particular purpose.

In the early 1930' he designed a building for the Salvation Army, bound to shelter homeless: the "*Cité de Refuge*". He proposed a glass façade of 1.000 square meters in order to "enlighten the rooms from floor to ceiling, from wall to wall, bringing free and ineffable light and sunshine" (LE CORBUSIER, 1937). As the glassed curtains were sealed, internal comfort was ensured by a central coal heating system during winter times and an electric air conditioning system for the hot summer days. The facilities were open officially in December 1933 and showed off a perfect internal temperature despite the harsh weather conditions. Unfortunately, the building was to be closed by the Police Department, notwithstanding the medical reports and the technical studies bestowed by the ventilation company.

Both postures, on the one side harnessing local natural resources and in the other side using the leading techniques and incorporating them in buildings, may appear self-contradictory. Nevertheless, they are present in all Le Corbusier's buildings as he looked forward to transform architectural housing into "*dwelling machines*" by means of using simple and rational building solutions arranged with refinement of shapes, always interacting with environmental strengths.

[5] Le Corbusier, Quand les cathédrales étaient blanches, Edition Plon, Paris, 1937. P.42.

[6] Idem. P 44.

UNITE D'HABITATION IN MARSEILLE: LA *CITÉ RADIEUSE* OR HOW TO DESIGN WITH THE SUN

The concept of the "*Unités d'Habitation*" (Housing Units) as modules was achieved by Le Corbusier after World War II, issued from the French Government Reconstruction Program that forecasted large multifunctional buildings sheltering habitations, shopping areas, school, theater and assistance accommodations. The very first unit was built in Marseille and was intend to shelter sinister people. Known as *Cité Radieuse*, the project was achieved between 1947 and 1953. It displays all the fundamental elements of modern architecture preached by Le Corbusier: *pilotis*, free levels, garden terrace and façades free from the structure. Those principles will answer for Le Corbusier's concerns about health and comfort.

The building insertion in the middle of the area and its orientation obeyed judiciously to local sun paths. Such a concern fixed the consequência postures for the whole design. All important dimensions were deduced from the *Modulor*[7], evidencing another major care with human proportions. A figure of this *Modulor* is printed on concrete at the entrance of the building (Figure 6).

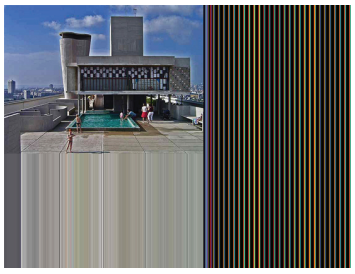


Figure 4 – Pilotis
Photo: Panoramio. Google Earth. Accessed in november 2008

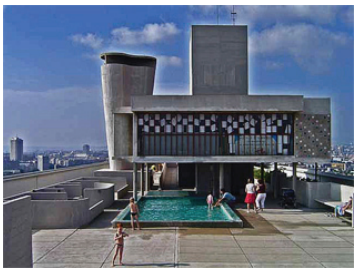


Figure 5 – Roof
Photo: Mike T., Google Earth. Access in november 2008

[7] The *Modulor*, published in 1950, is a regulating system conceived by Le Corbusier willing to find "elegant proportions" in architecture and is established according to measurements of a 6 feet tall man.

Figure 6 – Modulor figure
Photo Dominique Fretin. January 2005

The housing sector within the building displays fifteen different kinds of apartments according to fifteen "*Modulors*" corresponding to different types of families (from 1 to ten individuals).

The primary apartment is 24 meters long (same as the building width) and 4 meters wide. It is a duplex in two levels enabling to interlock 2 of them in a single unit that are meshed together in a concrete structure just like "bottles in a shelf" [sic] (HOBDAY, 2007), as shown in figures 7 and 8. Such an arrangement allows two opposite façades (east and west) to receive sun and light, as it provides an interesting cross ventilation within each apartment. Verandas in each façade (East and West) protected the huge glass wall from the high summer sun, but allowed the sun rays in winter to get through during a longer period, acting as a greenhouse. Besides, from the verandas, one could enjoy outstanding views over the gardens as well as mountains and Mediterranean sea in the distance.

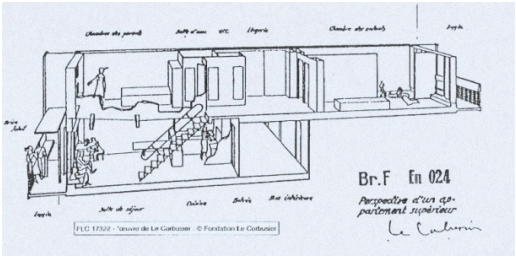
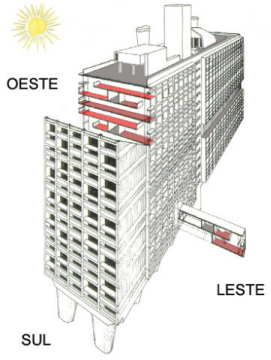


Figure 7 – Sketch of a duplex apartment
Font: http://www.marseille-citeradieuse.org.
Accessed in July 2008



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http://www.marseille-citeradieuse.org.
Access in July 2008

Figure 8 – Perspective view of the building

The 3d and 4th floor shelter "*aerial streets*" designed for meeting sites and services: there, are a hotel, a restaurant, a bookstore, offices, a bakery, a small market, a butcher shop, a local post office, a hairdressing salon and a delivery system service.

As the 3d floor has no verandas, its eastern and western façades are protected by vertical louvers (*Brise-soleils*). Besides protecting from the direct Sun beam, this solution helps to compose and balance the whole façade of the building that could not be achieve by an array of verandas.

Thanks to its extraordinary exposition to the sun, HOBDAY (2007) remarks that the building looks like a Heliotherapy clinic, particularly the terrace on the roof, set aside for leisure: swimming pool and small amphitheater as well as a nursery school where children could get their daily dose of sun in great security.

Figure 9 – Detail of the façade with vertical louvers at the 3d floor

Photo: http://www.trekearth.com/... /Marseille/

Figures 10, 11 and 12 – Photos from the roof of the Cité Radieuse in Marseille: Chimney duct for ventilation, swimming pool and mini amphitheater

Photos: Panoramio. Font: www.googleearth,com. Accessed in november 2008

Access corridors are dark on purpose in order to avoid permanency and thus talking and inconvenient or unnecessary noises. Privacy was reinforced by special acoustic treatment isolating the apartments from the corridors.

The ground level, under "*pilotis*", and thus completely free, is linked to the garden open space that separate the building from the avenue and from neighbors.

ANÁLISIS OF "LA CITÉ RADIEUSE" BUILDING

Marseille, second major French city and country most important harbor, shelters more than a million inhabitants. It lies on the shore of the Mediterranean sea and close to the Rhone delta, at latitude 43º27' North, longitude 5º14' East and altitude 6 m. Climate is temperate and rather dry. Winters are moderate and summers hot. Temperature ranges from 3º Celsius in January to 30º Celsius in July, the hottest month. There is plenty light and little cloudiness.

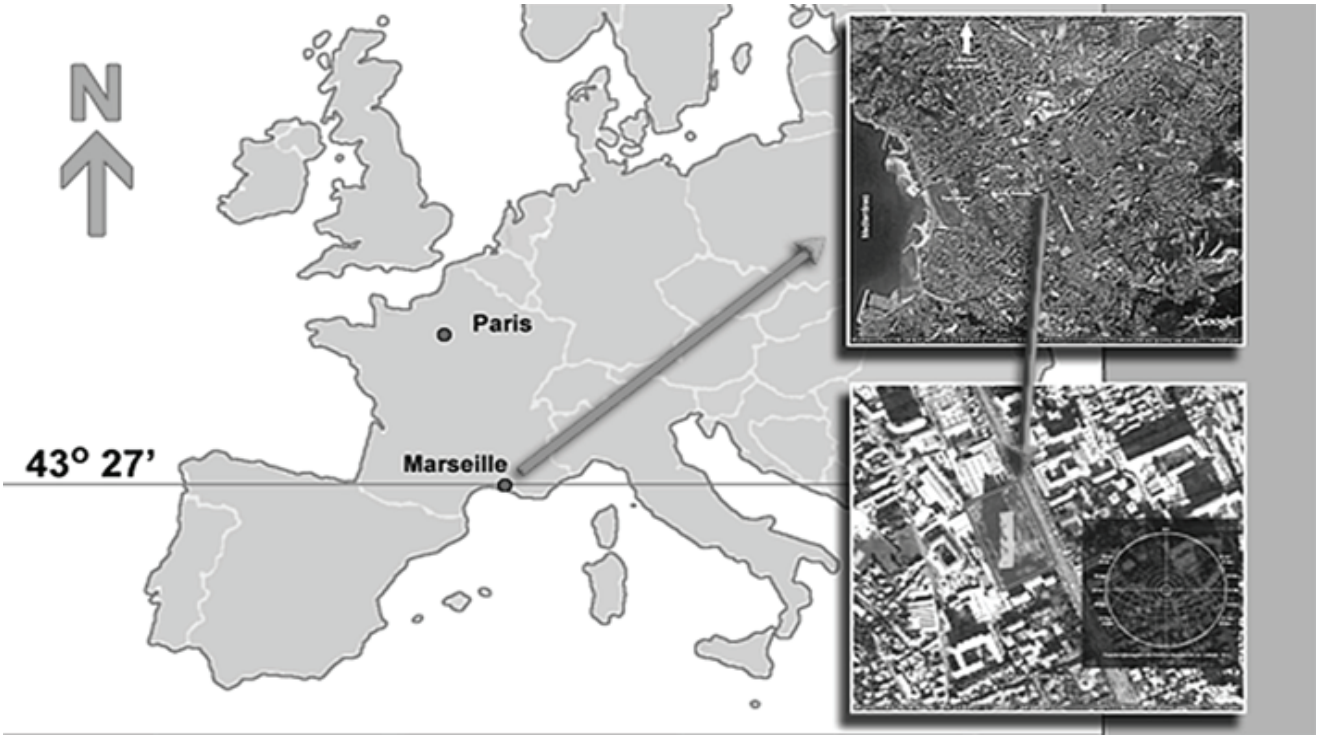

Figure 13 – Locations: Marseille, área and building "La Cite Radieuse"

Fonts: Google Maps. www.googleearth.com. Accessed in march 2009.

1. The area where La Cité Radieuse was built lies along a great avenue crossing Marseille's suburb toward downtown, from south-eat to north-west in the middle of a high densely built zone. In the 50", the area was occupied by low structures, but today high blocks of flats surround the building along the avenue.

2. The lot has generous dimensions, and being surrounded by low construction, allows inserting a high building in its middle, wisely far from the avenue, thus avoiding painful noises. High buildings also enable better sunstroke in each unit.

3. The accurate and careful orientation of the building, along a North-South axis denotes the clear intention to profit from the sunlight as it obviously disobeys to the existing streets logical tracing. "*L'axe Héliothermique est l'armature du tracé urbain". (LE CORBUSIER, 1956*). It also disobeys to a common sense practice, learned from the Greeks, by which the biggest axis of a rectangular building should follow the East-West direction, in order to expose one of the largest façade to the south (in the northern hemisphere) and thus enable a longer sunstroke on this façade. Such a practice obliged to locate long permanency rooms to the south and protect the North façade from the cold winds.

4. In this case, each apartment has two façades, one facing East, the other toward sunset. It receives sun the whole day. Verandas on both sides protect from the high sun, near noon, but let the sun rays penetrate deep in the apartment during winter months. The vertical louvers or *brise-soleils* installed in the 3d floor create a harmonious composition accentuating the horizontality of the whole ensemble.

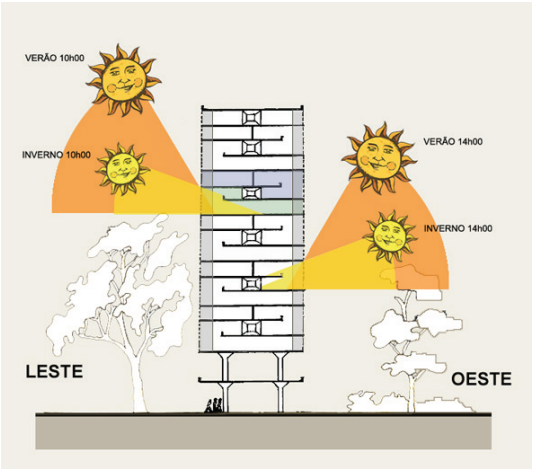

Figure 14 – Façade orientations and dimensions of the verandas. Sketch from Dominique Fretin from a Le Corbusier's croquis

Font: Unité d'Habitation – Le Corbusier – Marseille: http://www.marseille-citeradieuse.org/. Access in February 2009.

5. The nursery school on the roof allows children to enjoy a maximum sunshine, protected (and confined) from the dangers in the ground level, i.e. from the temptation to escape to the avenue. A fundamental health issue, says le Corbusier.

6. Sporting areas and swimming pool also allows every inhabitant to enjoy the sun. Such a design posture denotes le Corbusier's convictions about sanitary and therapeutic qualities of the sun. He also gives a great importance to the children, reminding of those constrained to live enclosed in urban flats where, sometimes, sunrays seldom penetrate.

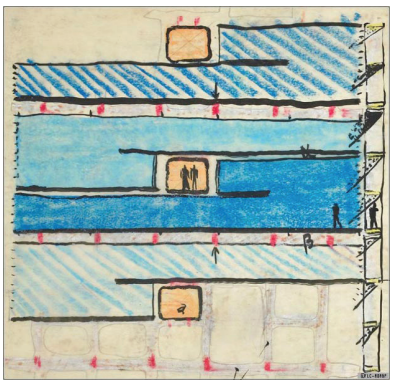

Figure 16 – Sketch for the interlocking system of two apartments, showing the shading devices.

Font: Unité d'Habitation - Le Corbusier - Marseille: http://www.marseille-citeradieuse.org/ . Access in February 2009.
Font: Unité d'Habitation – Le Corbusier – Marseille: http://www.marseille-citeradieuse.org/. Access in February 2009.

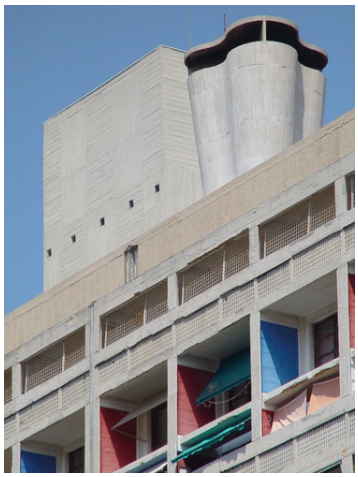

Figure 15 – Chimney for ventilation and view over the last floor verandas

Photo: Panoramio, in www.googleearth.com, Access in March 2009.

7. Concrete used for the construction has thermal qualities that suit well to the local climate. Its thermal capacity permits to capture heat during the cold winter days, store it and release it later when air temperature lows.

8. Glass walls in each apartment stand back the façades, protected by verandas, They provide great natural lighting in the rooms and, besides, the glass acts as a greenhouse during winter days, Sun rays penetrate deeply in each room, heating the floor and creating an agreeable atmosphere.

Figure 17 – West façade detail. Shadows patterns suggest that the photo was taken around 2:00 PM in summer

Photo: http://www.marseille-citeradieuse.org/. Accessed in February 2009.

CONCLUSIONS

The « *Cité Radieuse* » is still an important architectural reference in our days. Concrete is its foremost material and its design intend to purchase the aesthetic ideals of a "dwelling machine" ("*machine à habiter*"), thanks to modulation and pre-fabrication of most of its elements. The largest façades (eastern and western) composition results from spatial arrangements and repetition of simple elements disposed in series as well as explicit intentions to control the sun and natural ventilation. This was the first important project of Le Corbusier where he brought into operation many theoretical ideas. Passive solar architecture techniques are unmistakable and evident in this particular case. The duplex conception enabled to expose opposite façade to the sun and wind and thus, bring heat to the rooms in winter days and a bright light the whole year. The verandas added to the façades were calculated in the same way the Greek porches were. The array of vertical "brise-soleil" on the 3d floor protected the interior from direct sunrays while ensuring a decent natural light. The great difference, however, in this particular case is that Le Corbusier subverted the rules and teaching advocated by Socrates by which the largest façades should be oriented toward South, favoring the long permanency rooms. In such an attitude rests the major innovation in terms of solar building or solar architecture, as it goes against the common sense and conventions that dictates a greater exposition of the sun on South façades, i.e. orientate the largest axis of the building in the east-west direction. In fact, Le Corbusier answers for such option in orientating his building along a North-south axis and thus turning each apartment façade either to sunrise or to sunset, to reach an ideal dwelling able to reintegrate man with Nature, connecting him to daily rhythms punctuated by the sun's movement. Something that has been lost in actual cities (Le Corbusier, 1957).

This simple solution also allows opposite openings sub serving natural cross ventilation and a "chimney effect" desirable for indoor comfort and air renovation, without needing air conditioning equipments. There is a smart balance between protection and deliberate heat, generous ventilation a natural light in each apartment. It appears that those typical passive solar solutions weren't chosen for energy efficiency means or even energy saving purposes, as such worries weren't prior in that time. Air conditioning systems were rare for domestic use and almost inexistent. There were, nevertheless, Le Corbusier's concerns in bring man back to Nature, making easier a direct exposition to the sun, for comfort, pleasure and for health.

A high building, on another hand, allows freeing more ground for contemplation and for leisure as it also enables more units exposed to direct sunlight. At that time, transforming sunlight into electricity was still a dream, although photovoltaic effect was already known but restrict to scientific experiments or researches and far too expensive for practical applications. But Le Corbusier would have certainly considered the possibility as a technology worshiper and as an architect concerned with people welfare and happiness. And he would he have definitely found ways to incorporate photovoltaic systems in his architecture.

Figure 18– "Sun bath on the roof of the Cité Radieuse". Photo: Bophi

Fonte: Panoramio / www.googleearth.com. Acessado em março 2009.

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