

# Architectural Integration of Renewable Energies in Historical Cities

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## 1. Introduction

The principal aim of the project that we present, developed in collaboration with the *Consortio de Santiago* [1] and the IDAE [2], is to investigate the possibility of application of sustainable technologies in buildings inside the historical centre of Santiago de Compostela. The idea is try to obtain technologies, designs and components as standard as possible for the application of the solar power in catalogued buildings, analysing diverse particular solutions in order to adjust to the architectural specific requirements of the historical center of the city [3,4,5] and to implement the ideal opposing solutions, as well as the development of a plan of medium-term action for the city.

We present an ambitious project, with a double slope: To foment global actions of sustainability in zones of historical interest and realizes an interesting project of research and development in the field of Renewable Energies orientated by his proper nature towards decentralized and local applications, this differential characteristic in the field. The use of renewable energies is not reserved exclusively for the companies, that try to give service to big facilities or to produce electricity for the supply of the general network. On the contrary, a good number of applications can take place in the own housing, turning into quality parameters for his enormous environmental advantages and of improvement into the comfort.

**Keywords:** solar energy, PV architectural integrability, sustainability.

## 2. Aims and Benefits

The principal benefits of the project can be summarized in:

- Reduction of consumer expenditures energetic.
- Better thermal, visual conditions and of comfort in housings and places of work.
- Reduction of the pollution and improvement of the environment.

It is necessary to recognize, nevertheless, that in view of the current state of the technology, some technologies

turn out to be, today per today, faces and slightly applicable. With this type of projects it is a question of assuring the applicability of the same one, then evaluating real situations that allow to advance in the field, and with application in case of the historical centre. It is a question of assuring the applicability them evaluating with this type of projects to real situations that allow to advance in the field.

## 3. Structural and Chronogram

The idea is to raise a modular project subdivided in different subprojects of related them among if and that could be developed in parallel. A possible scheme shows itself in the figure 1.

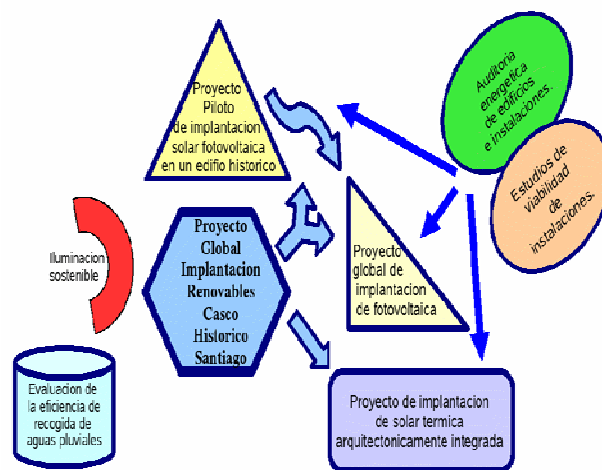


Fig. 1. Diagram of the global actuation.

An efficient design of any application in the field of the renewable energies and the sustainability is unfailingly tied to evaluations and energetic audits, so much individual for every action as global in the environment. We perform two subprojects:

- **Subproject I: Energetic Audits** of buildings and facilities that can be summarized as studies on energetic consumption in the old part of town.
- **Subproject the IIrd: Studies of viability** of facilities or said differently valuation of possibilities of utilization of solar power in a building. The thickness of the project, and the one that can have major impact to level of a city is the use of the solar power in the buildings and that we englobe in 3 subprojects:
- **Subproject the IIIrd: Pilot of solar photovoltaic implantation** in a building always integrated to the architecture.
- **Subproject the IVth: Generalization** previous subproject to the major possible number of buildings of the Historical Centre once obtained results of the previous subproject.
- **Subproject V: Implantation of solar thermal arquitectory integrated**, that constitutes a challenge of improvement of the aesthetics of this type of facilities.

In more advanced stadium, we will tend to both global and ambitious solutions of application of criteria of sustainability, studying possible actions as reutilization of rain waters or utilization of alternative energies in the civil lighting. This type of studies that we include in an only one subproject the VIth of global actions, will have, in the first stadium, a low priority.

I subproject them I, the IInd III and V the rest can be begun in an immediate way while will could go delayed in the time. A tentative chronogram can be the showed one in the figure 2.

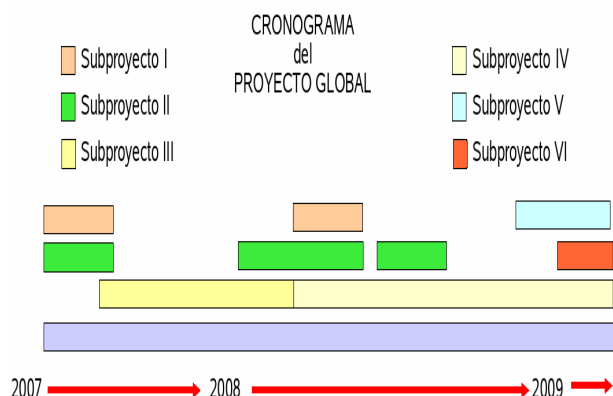


Fig. 2. Chronogram e of the global actuation

#### 4. Energetic Audits

An energetic audit is a tool that studies the energetic state of a building and supplies a technical and economical evaluation of the means of energy saving, always looking

for an improvement of the comfort and confidence of the installations.

The energetic audit is necessary since the implantation of alternative energetic systems is being aimed, using it as a reference when making a decision because, in every energetic audit, the shortages of the building should be showed, allowing to make the appropriated measures to obtain a better performance and optimise the functioning timetable.

Before beginning to do the field work, we obtained climatic information about the city, with the aim of getting an idea of the conditions it will undergo to. To do it, we have to our disposal the meteorological database of MeteGalicia. Furthermore, at this stage we have carried out the building plan to know how many rooms there are, taking into account what every of them are devoted to, and verify that there are concordance to the architectural plans. The functioning timetable is a piece of information to be considered in this first stage, since they are official buildings, not housing.

In a second stage, we carried out the data collection on site. We use a multimetre four-in-one (thermometer, hygrometer, luxometer and a tool for measuring the sound) as a data acquisition system. At the same time, we measure the temperature outside it. These data is compared to that MeteGalicia provides us with.

The measuring instruments were placed in the first and second floor. This last one is placed near the skylight. The data taken, in which there is bank holiday period, will surely lead us to extract information about the conditions of isolation of the building.

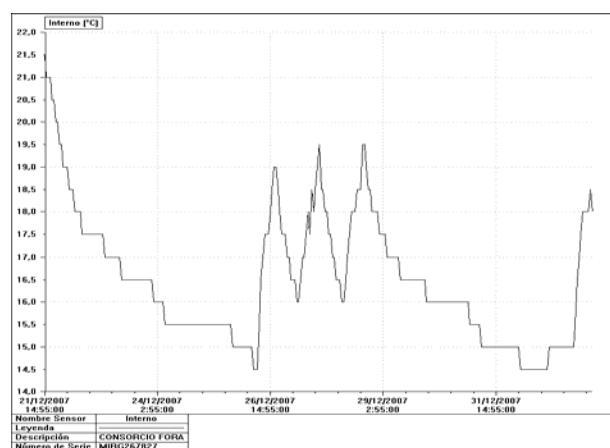


Fig. 3. Temperature distribution within the first floor

In Figure 3 and 4 the temperature distributions of both thermometers are shown. There can be observed some facts:

- *Skylight effect*: the temperature distribution under it shows a daily peak, independently of the using of the warming system (the 25<sup>th</sup> of December 2007 is included). This effect is caused by the natural warming that the solar energy produces under the skylight.

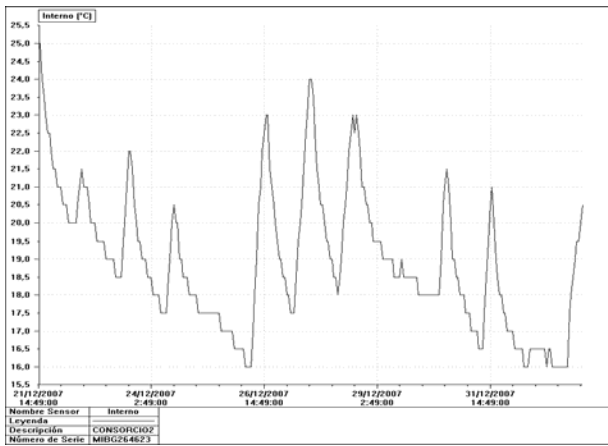


Fig. 4. Temperature distribution in the second floor.

- *Thermal inertia of the building*: The difference between distribution's width of a holiday day and that of a working day shows the thermal inertia of the building (defined as the number of hours that takes the internal temperature to reach the external one). A first study indicates that the thermal inertia in the first floor is approximately three hours whereas the second floor's one is best of six hours. If one needs that the first floor has comfortable temperatures (19°C), the second floor suffers temperatures between 24 and 27 degrees. In fact, throughout the measuring period, we ascertained that the users had to open the windows during the full operation heating.

#### 4.1.1. First structural measures suggested

Given the impossibility of improvement of the building's isolation, we suggest improvements in the heating service system:

- Differentiate the heating levels between the floors by using thermostats.
- Diminish the amount of light that reach the building's inside through the skylight, mainly in summer (see as an example the section 4.2).

#### 4.1.2. Possible energetic measures

Once optimised the heating system, where we look for a method for reaching optimal temperatures of functioning (between 21 and 23°C in winter and between 23 and 25 in summer), we propose the convenience of the using of support renewable energies, which involve a great energetic saving at long and medium term. To do so, a simulation based on actual data of a similar system has been carried out, using a thermal solar system as a mean of co-generation.

In Figures 5 and 6 we show the expected energetic supplies in two spring/autumn-like conditions and winter one. Not including the system's constants, in the most difficult condition and with a conservative sizing, the solar supply is near to 20%. Since the implementation of this kind of systems is not easy in such an historical building, we think that the best alternative is the co-generation with options related to energetic efficiency (geothermic, biomass, etc.)

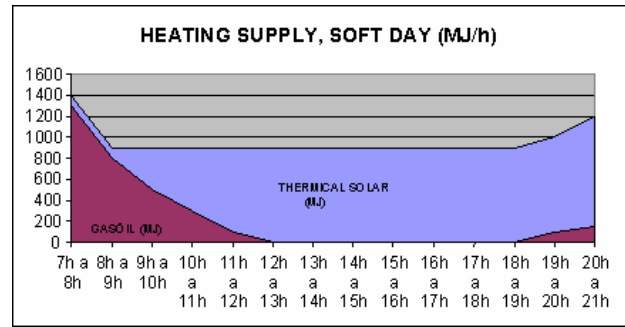


Fig. 5. Energy supply (MJ) as a function of the hour for a normal day.

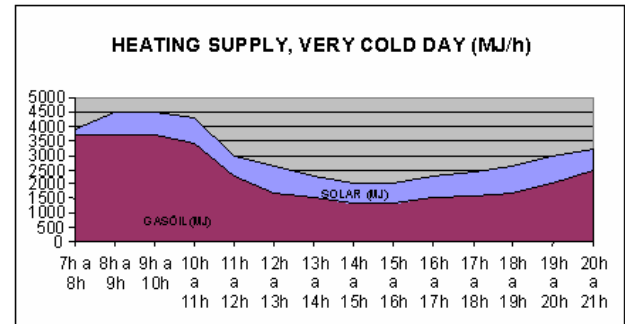


Fig. 6. Energy supply (MJ) as a function of the hour for a cold day.

## 4.2- Example: photovoltaic system (IIIrd)

Within the pilot project of photovoltaic modules, improved for the "Consortio of Santiago de Compostela", the idea is to implement these systems in the historical centre.

### January:

Module's Percent.	Power	Light's Watts	"Lucernaria"'s Percentage	Lumen
100	1100	2332	0	0
80	880	1865.6	20	$2.9 \cdot 10^5$
60	660	1399.2	40	$5.8 \cdot 10^5$
40	440	932.8	60	$8.7 \cdot 10^5$
20	220	466.4	80	$1.2 \cdot 10^6$
0	0	0	100	$1.4 \cdot 10^6$

### July:

Module's Percent.	Power	Light's Watts	"Lucernaria"'s Percent.	Lumen
100	1100	5368	0	0
80	880	4294.4	20	$6.7 \cdot 10^5$
60	660	3220.8	40	$1.3 \cdot 10^6$
40	440	2147.2	60	$2 \cdot 10^6$
20	220	1073.6	80	$2.7 \cdot 10^6$
0	0	0	100	$3.3 \cdot 10^6$

Tab. 1.

We will treat the case of the "lucernaria" (kind of high skylight) that is placed in the building we treated in the previous section. The first problem is to reach a compromise solution between the amount of light that can go through the module location (to illuminate the place under them) and the light that can be used to

produce electricity. To do the comparison, we use the solar peak hours<sup>1</sup> during a year (see Tab. 1.) and, as an example, a 100Wp photovoltaic module of 1m<sup>2</sup>. If we modify the percentage of skylight (it is 11m<sup>2</sup>) which is covered with solar cells for the best and worse month (with regard to the amount of available light), we obtain the Tab. 1 and Fig. 7.

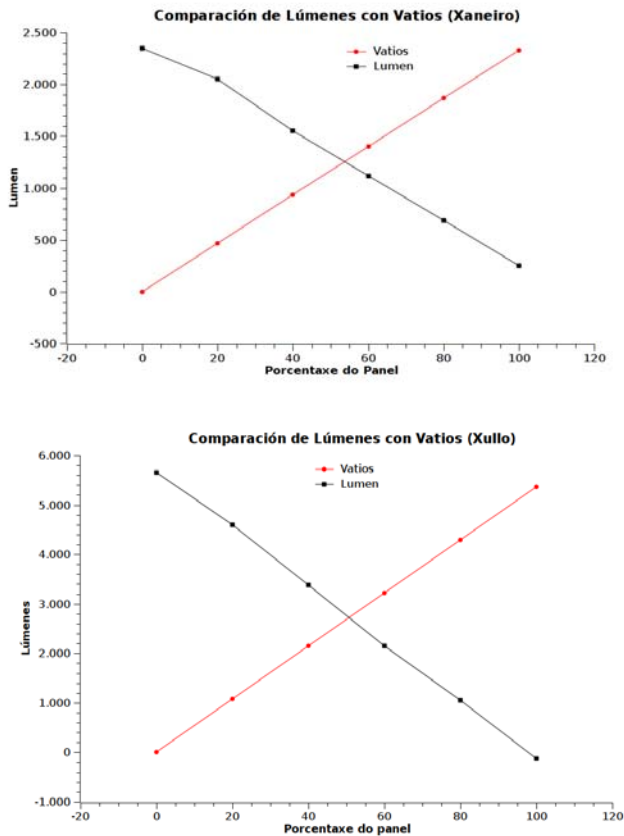


Fig. 7. Upper: relationship between the panel's percentage which covers the "lucernaria" and the light that go through it (black line) and the produced electricity (red one) in the worst month regarding the light. Bottom: the same for the best month.

The choice of the best configuration should take into account this factors and the final decision will be taken between the architects and us.

## 5.- Conclusion

In the paper we present an overview of some evaluations of the first 12 months of actions on that we will centre on the application of sustainable energies in the Santiago de Compostela's historical centre (Subprojects I, the II, IIIrd and the first stadium of the subproject V) with the following scheme:

- There will be studied all the aspects related to the consumption of energy in the historical hull and his distribution in the different uses: warm water, heating, refrigeration, lighting, etc.

- There will be realized a pilot experience of photovoltaic installation of lot in the "lucernaria" of the building of the Consorcio de Santiago de Compostela. The viability of the project will be evaluated so much in economic as technical terms.

The first results we have obtained with respect to the building of the "Consorcio de Santiago de Compostela" are shown. This includes the effect of its skylight (placed in the second floor) in the gradient of temperature between its two floors, the simulation of a possible alternative for the energy supply (based on thermal solar energy) and the pilot project of the implementation of a photovoltaic system on the skylight, which could be mixed with a geothermic co-generator.

The process is being now carried out, so the full work will be shown in the congress.

## References

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<sup>1</sup> Equivalent irradiation at 1000 W/m<sup>2</sup>