INTEGRATION OF PV MODULES IN EXISTING ROMANIAN BUILDINGS FROM RURAL AREAS

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5. Solar energy and built environment

ABSTRACT *The paper is based on an on-going national research project focused on the promotion of new architectural concepts i.e. BIPV systems, which include active solar systems (PV generators) and solar tunnels. The advantages of using the distributed solar architecture are more remarkable in the case of large network-connected PV systems, such as the PV systems in the rural area, installed on building's façades or roofs. Thus, in contrast to other EU states, in Romania there is no photovoltaic building construction branch, the limited number of isolated cases being not enough to argue the start if a photovoltaic market in the building industry. The major purpose of the project is to demonstrate the efficiency of integrating various PV elements in buildings from rural areas, to test them and to make them known so that they can be used on a large scale. To do this, the new products will be installed on three pilot buildings (two in Bucharest and one in Timisoara) and the PV modules will be integrated in consonance with their architecture. One of them will be a historical building and the other two will be new buildings; they will have different typologies and they will be located in different areas, inclusive in rural areas. The installed power for each building will be of approximately 1.000 Wp, including some technologies with PV modules integrated in the architecture of the buildings.*

Keywords: PV-modules, BIPV Systems, building facades, flat rooftops, rural areas

1. INTRODUCTION

1.1 RES Policy

In Romania the main policy instrument to support RES-E at national level is the quota system based on tradable green certificates (TGC) as introduced in 2004. The mandatory quota for electricity suppliers increases from 0.7% in 2005 to 8.3% in 2010. Wind, solar, biomass or hydro power generated in plants with less than 10 MW capacity (new or refurbished since 2004) are eligible for certificates. A minimum and maximum price for the TGCs is determined annually by the Romanian Energy Regulatory Authority (ANRE). A supplier who fails to fulfil his quota has to pay the maximum price – at least in theory. Arguing with the large imbalance between supply and demand for RES-E, it is the common practice of ANRE to adjust the quota at the end of each year to the amount of offered TGCs. This means for example that the quota for 2008 was modified from 5.3% to 0.32% ex-post. Consequently, almost no penalties are paid. Obviously this reduces the effectiveness of the penalty and destroys the proper functioning of the overall RES trading scheme.

In 2008 a new law was introduced, which stated important improvements on the existing regulations of the RES trading regime. However, no secondary legislation has yet been approved by the Government in order to make the law operational. An entry into force is expected for 2010. A key element of the new law is to establish technology-specific weighting factors in the RES trading system. Estimated development of electricity production from photovoltaics in Romania: for 2005 (0MW/0GWh); Average for 2011-2012 (26MW/30GWh); Average for 2013-2014 (61MW/69GWh); Average for 2015-2016 (102MW/116GWh); Average for 2017-2018 (169MW/192GWh); 2020 (313MW/357GWh).

At this moment, the necessity of the use of new forms of energy in Romania is politically stated. According to the proposal for a Directive of the European Parliament and of The Council on the promotion of the use of energy from renewable sources, given in Brussels in January 2008, there is an aim "to establish an overall binding target of a 20% share of renewable energy sources in energy consumption to be achieved by each Member State, as well as binding national targets by 2020 in line with the overall EU target of 20%".

Since 2005, a number of laws were elaborated and released by the Ministry of the Environment and Sustainable Development. The most recent Order, emitted in 2008, states that up to 90% of the costs of a solar system that is installed by a Local Authorities can be taken over by the Government. It is expected that the Order will stimulate the increase of the interest for solar systems. During the last few years, the users that have been emphasizing the possibilities opened by alternative energy sources increased. However, although we have regulations rIn Romania the main policy instrument to support RES-E at national level is the quota system based on tradable green certificates (TGC) as introduced in 2004. The mandatory quota for electricity suppliers increases from 0.7% in 2005 to 8.3% in 2010. Wind, solar, biomass or hydro power generated in plants with less than 10 MW capacity (new or refurbished since 2004) are eligible for certificates. A minimum and maximum price for the TGCs is determined annually by the Romanian Energy Regulatory Authority (ANRE). A supplier who fails to fulfil his quota has to pay the maximum price – at least in theory. Arguing with the large imbalance between supply and demand for RES-E, it is the common practice of ANRE to adjust the quota at the end of each year to the amount of offered TGCs. This means for example that the quota for 2008 was modified from 5.3% to 0.32% ex-post. Consequently, almost no penalties are paid. Obviously this reduces the effectiveness of the penalty and destroys the proper functioning of the overall RES trading scheme.

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Regarding energy efficiency in buildings and methodologies to evaluate the buildings, the actions that have been taken are mainly aiming to increase the thermal insulation of the envelope and to work on the installations within the building. A number of pilot projects have been carried out, during the past decade, alongside with building regulations that support the interventions. Not much has been done so far in terms of implementing solar energy systems. No building regulations regarding the use of PV systems exist so far.

1.2 Solar Architecture

Solar Architecture is a general term which implies the integration of photovoltaic system into classical building design (Technical Report Project No. 21039/2007). The key concept here is represented by the photovoltaic modules, which substitute some façade or roof components. For the design and construction of solar/PV systems it is necessary to have information about the solar energy collectable on tilted surfaces. In Romania, the meteorological stations have no such databases and do not perform such measurements. During the past 20 years the building activity has flourished in Romania. Along with the construction of new buildings – mainly residential parks and office buildings - the activity of retrofitting the existing stock of buildings is intense. Taking advantage of the necessity to up-grade the structural system of the buildings - as we are a country with severe seismic activity - the owners of the buildings are trying to improve the living conditions also from the hygro-thermal, acoustic, functional and (more in a declarative manner, still), environmental point of view. While the state is getting more involved in the activity of structural consolidation and thermal rehabilitation of the mass dwellings that were built mainly before 1990 (some of them dating since the thirties), owners of individual houses are more and more interested in the use of alternative energy sources (sun and wind based) as complementary measures to decrease the energy costs while using the energy their equipment requires.

Although in Romania the building market is rapidly developing, the building contractors do not promote PV technologies and new materials used for high performance day lighting, either because of their ignorance or their conservativeness, or the high costs related to importing such systems from the European market. Though during the last years more private companies in Romania offered to merchandise and install PV systems, one can not discuss of a proper PV market. Thus, in contrast to other EU states, *in Romania there is no photovoltaic building construction branch*, the limited number of isolated cases being not enough to argue the start if a photovoltaic market in the building industry although many other possibilities exist for utilization of BIPV in rural areas (Fara, L. *et. al*, 2008).

In general, the design of such buildings one should pursue the optimization of the processes of dimensioning and orienting the surfaces on which the components collecting solar energy are to be placed in order to obtain a maximum of collected energy, satisfying at the same time the quality with regard to destination of the building, the designing and aesthetics rules. Therefore, the data regarding the solar energy collectable on tilted surfaces represent a vital prerequisite for architects and engineers who have to size the PV or thermo-solar systems, for the specialists who have to elaborate feasibility studies associated to the implementation of solar installations (Šúri, M. *et. al*, 2007).

Compared with other European countries, Romania has an above-average solar irradiation in the summer, comparable to the one of Greece, country in which the solar/photovoltaic technology is highly developed. *Stand-alone* private PV systems and the ones supplying energy also into the grid can be an attractive investment solution. A key element for the promotion of these renewable energy sources is the education for the sustainable development of the economic and social life of the population, especially young people; future inhabitants of houses designed and built using the new concepts of solar architecture. The effort to carry out a project of such a span requires human resources highly qualified in different areas of study such as urban/rural architecture, the physics of photovoltaic devices, the physics of atmosphere (solar radiation), applied electronics (electrical measurement methods), data transmission, informatics, database administration.

2. PROJECT DESCRIPTION

2.1. BIPV systems

The PV architecture is a new concept for Romania. Consequently, the project aims to achieve demonstrative designs of ecological solar buildings containing in their structure photovoltaic elements, passive solar elements, and modern systems for day lighting. These are available on-line on the web-site of the project (http://renerg.pub.ro/pasor) and, additionally, will be presented to building contractors and to the public. For users who desire to access the meteo data by WUT station they can work with site http://solar.physics.uvt.ro/srms. In this section of the project we have in view the practical construction of three BIPV (building integrated PV) systems which are integrate in the structure of buildings. The two systems were equipped with monitoring systems and the necessary infrastructure for transmitting the data to the web-site. A computer-based displaying system placed in public domain will permit real-time visualisation of the parameters of the installation and, additionally, will transmit technical and economical information referring to the solar/ photovoltaic architecture to the large public (Promotion of Solar Architecture in Romania (PASOR), Reports of Project No. 21039/2007).

A holistic analysis of the building has been before introducing a BIPV system (Harvey D., 2006). The main criteria of such analysis would be as follows:

- opportunity of the BIPV utilisation;
- involvements of the built environment (urban, rural, industrial) towards the building;
- involvements of the BIPV placement towards the building itself (these criteria are linked with volumetric analysis, style, general and particular look of the building envelope);
- specific requirements of the building envelope based on the type of selected BIPV;

- optimum action type and place (analysis of the BIPV systems corresponding with the envelope parts where it would be intended to act and not shading the modules);

- technical and operational involvements on the envelope components;

- efficiency of the agreed system;

- financial and payback period involvements of the investment;

- type and way of the produced electrical energy management.

2.2 The project partners:

IPA SA (Project coordinator), West University of Timisoara (WUT), Polytechnic University of Bucharest (PUB), Polytechnic University of Timisoara (PUT), University of Architecture and Urbanism "Ion Mincu" (UAUIM) in Bucharest

2.3 .Present project results in July 2010*:*

<u>1. Quantitative results:</u>

- Centre for measuring the solar energy that can be collected from tilted surfaces (unique in Romania) at WUT;

- Modernization and installation, by applying the project's energy concepts, at the roof of WUT, and at the roof of the UAUIM –Bucharest. Additionally, mounting of solar windows in the solar PV Laboratory from PUB;

- Project website, containing: software and guide, accessible online, for: estimation of the solar energy that can be collected from tilted surfaces; PV system design; architectural solutions;

- Database containing measurements of solar energy collectable from tilted surfaces;

- Submission to the authorities of the legal requirements

related to the authorisation of the operation of distributed electric power sources;

- Organisation of a thematic competition („Solar house") for students;

- Organisation of workshop for discussing the results of the project with representatives of the target groups;

- Brochures, guidelines, bibliographies for the different target groups

<u>2. Main results:</u>

- Development of a database regarding the measurement of solar radiation on tilted surfaces in various points on Romania's territory, with the involvement of the National Institute for Meteorology and Hydrology;

- Specialisation of young architects (students in the last years or studying for the master's or doctor's degree) in the problems specific to solar architecture within the Universities in Bucharest and Timisoara;

- Raising the awareness of local authorities and building contractors with regard to the benefits of using solar architecture;

- Increasing the level of information of the population regarding distributed photovoltaic systems.

<u>3. Estimated profits and profitability:</u>

- Development of specialization in solar architecture, with great opportunities within the EU market;

- Achievement of important steps in the development of the photovoltaic industry in Romania;

- Possibility of capitalization of the results obtained by the project in Romania's neighbouring countries;

-Easy to install: Our attractive, flexible solar roof panel literally rolls right on. We manufacture the solar roofing systems in easy to handle modular rolls to allow for rapid installation at our customer's sites. We employ experienced roofing professionals to install our products, with no disruption to your business.

-Light weight: The solar panel weighs only 3.7kg/m2 allowing installation on existing facilities without exceeding roof loading limitations.

-Powerful: The amorphous silicon panels enable maximum kilowatt-hour output, producing electricity using a wider spectrum of light than traditional crystalline technology. This feature enables the panels to produce electricity all day long, even when it is cloudy.

-Rugged and durable: Durability to cope with challenging weather conditions, and stability to handle changing light and shade conditions, have been built into all our roofing products. In addition, our roof is sealed and bonded, providing a weather-tight, long-lasting roof that has no penetrations. All our roofs are backed by a 20 year guarantee and an operations & maintenance program.

-Attractive appearance: Our unique electrical engineering integrates the solar array within the roofing assembly providing a neat and uncluttered roof surface.

3. SHORT DESCRIPTIONS OF THREE PV DEMO SYSTEMS

3.1 PV Demo System at UAUIM

Four PV modules composed of mono-crystalline silicon SRP (270Wp, 26 kg, 1047 x 2028 x 89 mm) were mounted on a roof versant of the historical building of UAUIM –Bucharest. In order to find the optimal location for the PV modules one carried out a study of the building's solar irradiance for each season. One analyzed several possibilities in terms of location and types of constructive assemblies. Along with the reconsolidation process an architectural and functional conversion of the attic took place, through setting up new office spaces. Illumination of the hall resulted on the axis of the attic, was achieved through solar tunnels. For night lighting one installed lamps in each terminal space covered by natural light through the solar tunnels. The reconsolidation and rehabilitation process also implied the replacement of both the roof framing and the roof covering, making it easier to integrate the PV modules in the roof (Harvey,D., 2006; Šúri, M. *et al*.,2007).

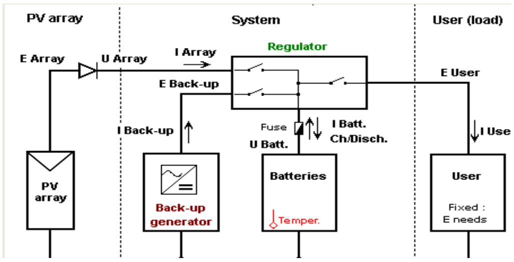

Figure 1. Electrical scheme of the PV system

The versant on which the PV modules were mounted is south-west oriented, with a tilt angle of around 150. The solar irradiance study showed that there were no objects that could shade the respective versant.

Figure 2. PV modules mounting

The Velux solar tunnel has a fixed tube (35 cm in diameter) with an inner reflector surface with 98% degree of reflection; it ends up with an internal lighting fitting with 4 mm thick heat insulation glass.

Figure 3. Solar tunnel: the glass covers on the roof, and the lighting fittings in the hallway working during the day

Figure 4. Image of the roof, before and after mounting the PV modules

This is probably, the first building in Romania to have a hallway illuminated exclusively form renewable energy sources: solar tunnels for day lighting, and the photovoltaic energy stored during the day for night lighting.

3.2 PV Demo System at WUT

WUT planned and achieved two objectives: the Solar Irradiation Monitoring Station (SIMS) and the Photovoltaic Laboratory (PVL) that compose the Solar Platform in WUT.

At the end of 2009, one obtained the first series of annual data from monitoring the solar irradiance and the meteorological parameters. The data acquired on the SIMS platform, are accompanied by the data obtained from monitoring the mobile and the fixed PV subsystems.

The monitoring system currently uses 21 channels, while another 15 channels are available for future developments. Data acquisition is done simultaneously at a frequency of 4 samples per minute (Jurca, T *et. al*, 2009).

1. The Platform for Monitoring Solar Irradiation on tilted surfaces. For a good design of the BIPV systems, one has to know the quantity of solar energy that can be collected on surfaces with different spatial orientation. These data are used at developing the numerical algorithms and at integrating them in computer applications used by architects and engineers developing solar energy projects in Romania.

2. The data base resulting form the monitoring of solar irradiation on tilted surface. The fine sampling of the data base, the entries for tilted surfaces, the simultaneous registration of the solar irradiation data and of the electrical parameters of the photovoltaic generators, are attributes of the data base that makes it unique in Romania. It represents the basis for developing numerical algorithms for estimating solar irradiation.

3. Experimental stand for studying the power delivered under load, in the case of installing photovoltaic modules with different fixed spatial orientations. This is the most common situation in urban photovoltaic architecture.

4. Facilities for characterizing the operation of photovoltaic modules and systems under concrete ambient conditions. Under real atmospheric conditions, temperature and solar irradiance change continuously and in such non-standard situations, the characteristics of the modules are unknown. Despite the many models that translate the parameters of the modules listed in the catalogue, under concrete environmental conditions, a problem still occurs in selecting the adequate model, which works with highest accuracy in the given location. The experimental development in the project creates the prerequisites to answer these problems.

Figure 5. Total view of the PV system on the roof of WUT

Figure 6. Station for measuring the meteorological parameters at WUT

The photovoltaic system is made up of two subsystems, one fixed and the other mobile, both of them being fitted with identical batteries and loads. The main function of the PV system monitoring is to compare the data obtained from the two subsystems (collectible solar energy, energy delivered, etc).

The solar tracker system is SunTracer SM33PMCBL that combines tracking the sun on its trajectory with the load control feature (max. wind speed:130 km/h; lifecycle: 20.000 complete rotations □10 years).

The modules are ISP90 (ISTAR SOLAR) composed of mono-crystalline silicon (125 x 125 x 10 mm; 90Wp). The batteries used for storage have 110 Ah/12V.

At each of the systems, the following parameters are measured: the current delivered by the module (Imodule), the current consumed by the load (Iload) and the battery voltage (Vbattery).

The data acquisition equipment is a PXI platform (National Instruments). The data acquisition board NI PXI-6259 disposes of 32 analogue inputs, of which 16 are reserved for the SIMS and 16 for monitoring the demonstrative PV system. The data are read after 15 seconds. The LabVIEW application for acquiring and storing the data was developed and maintained by PUT.

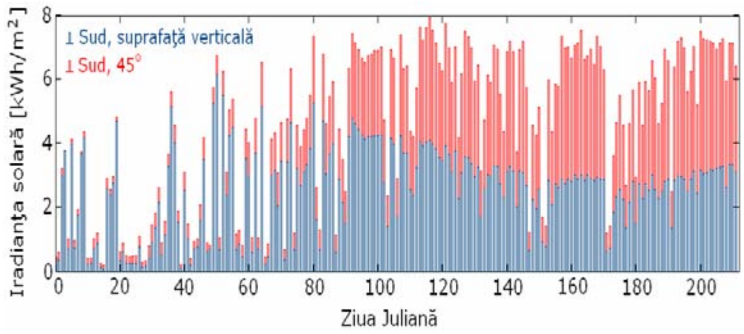

Figure 7. The total solar energy per day, registered in the first seven months of 2009 on two surfaces with different spatial orientation.

3.3. BIPV Demo System at PUB

A grid-connected BIPV demonstrative system was developed at the Polytechnic University of Bucharest. It was put into service in July 2008, and is made up of 6 PV panels, an inverter, equipment for monitoring and storing the data, as well as a station for monitoring the meteorological parameters. The power delivered by the PV modules is 615Wp. These are KORAX semitransparent modules: 3 modules of 120Wp and 3 of 85Wp (mono-crystalline silicon; anti-reflector layer; 1550 x 800 x 6 mm //1050 x 800 x 6 mm; 14 kg//9kg) they are mounted on the existing structure of the window of the BIPV laboratory in PUB (Fara, L. *et. al*, 2008).

Figure 8. The photovoltaic system at PUB – seen from outside (a), seen from inside (b)

The main components of the monitoring system are the weather monitoring station and a data logger, together with two computers for taking over the data and a web server for processing and presenting the data in a useful format for the end-user.

The Sunny Boy SB700 inverter operates at high conversion efficiency, using a MOSFET bridge for converting direct current. The current supplied to the grid is perfectly sinusoidal, with a very low rate of distortion of the grid harmonic (Fara, L. *et. al*, 2009).

The inverter transmits data to the monitoring equipment through electric line communication, and data signal modulation at 100 kHz.

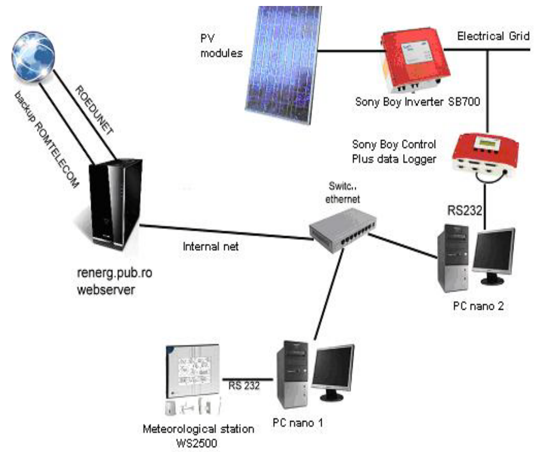

Figure 9. Basic schema of the monitoring system

The monitoring equipment, Sunny Boy Control Plus, offers many features for storing (up to one year of measurements) and processing the data from the inverter. It is connected to a computer through a serial null-modem RS232 cable (www.sma-america.com). Sunny Boy Control Plus can display the energy supplied to the grid in one day, the total energy supplied to the grid, and the energy that is generated at the moment by the solar modules. Besides that, it can display in real time the operation parameters of the inverter. One can also establish the data to be archived:

- voltage generated by the modules (VPV),

- energy generated by the modules (PAC) and

- total generated energy (Et).

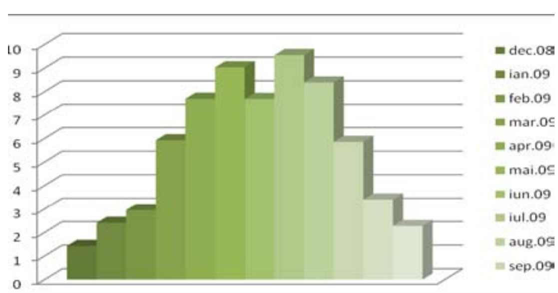

Figure 10. Energy supplied to the grid by the BIPV system from PUB between december 2008 – november 2009 (in kWh)

LaCrosse Weather Station WS2500 is the station used to measure the meteorological parameters. It has, in the basic package, six outdoor sensors for wind (speed and direction), temperature, humidity, atmospheric pressure, solar irradiation and rainfall, and another 2 indoor sensors that measure temperature and humidity in the room in which the station is mounted. The data are taken over from the sensors through a radio connection, on the frequency of 433 MHz, from a maximum distance of 100 m (if no interferences exist). All the sensors have an internal battery together with a PV mini-module for supply, reaching autonomy of minimum 10 years. The data are read from the sensor at every 5 minutes.

The software for monitoring the weather station allows registration of the meteorological data for any period of time and can generate graphs for any parameter that the user might want to visualize. It takes over the sensor data by accessing the weather station through a serial connection. The time interval at which the access is done can be set up between 3 to 30 minutes. The data are then stored in an internal binary file of the software, but they can be exported in known formats, for any further processing of the data.

One can also automatically generate the graphs for a certain period, and these will be displayed on a PC.

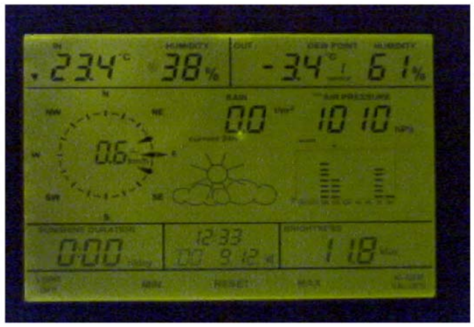

Figure 11. Station for monitoring the meteorological parameters / screen

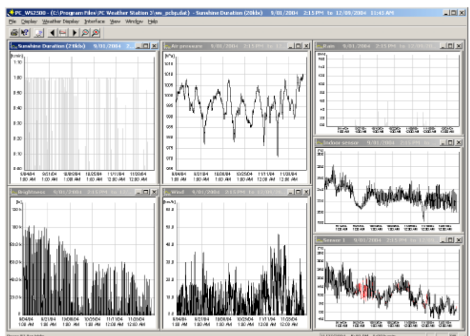

Figure 12. Screen with meteorological data at PUB

4. CONCLUSIONS

There is growing interest in highly glazed building facades, driven by a variety of architectural, aesthetic, business and environmental rationales promoted both in rural and urban areas. The environmental rationale appears plausible only if conventional glazing systems are replaced by a new generation of high performance, interactive, intelligent façade systems, that meet the comfort and performance needs of occupants while satisfying owner economic needs and broader societal environmental concerns. The challenge is that new technology, better systems integration using more capable design tools, and smarter building operation are all necessary to meet these goals. The opportunity is to create a new class of buildings that are both environmentally responsible at a regional or global level while providing the amenities and working environments that owners and occupants look for.

Although the energy efficiency is much reduced in the case of facade modules, their application on the vertical component of the envelope, on large surfaces, may attenuate this inconvenient and increase the energy they deliver. On the other hand, these modules bring their own contribution to the architectural and technological definition of the buildings.

The flat rooftops, on which arrays of photovoltaic panels can be installed at the optimum tilting angle, can be considered to have maximum efficiency and are highly suitable for isolated rural farms. They might be combined with rooftop terrace-gardens that would further increase the reliability of the PV system (preventing panel overheating and improved dusting) (Prasad, D. and. Snow, M. 2005; http://buildingsolar.com/technology.asp).

Obviously, one can combine these integration techniques – facade and rooftops – resulting in a unitary building from the point of view of architectural expression of the envelope.

At the moment we are at the phase of finalizing the technical studies and analyzing the behaviour of the demo systems with the different integrated modules. The local PV market of PV is not very large and it needs to be stimulated through attractive incentives from the Government.

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