In Portugal it is not usual to integrate solar thermal collectors or PV modules in the buildings’ envelope. The most common solution is the installation of the solar thermal collectors on the roof, flat or pitched (see Figure 1).






Fig. 1: Examples of installation of solar thermal and PV collectors in Portuguese buildings

Example name: Case Study 1 – Integrated on a pitched roof

Template completed by:
University of Minho
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Fig.2: Integration of STC in a pitched roof (Caixa Geral de Depósitos, bank headquarters, Lisboa)

For installations

BISTS Location:
Lisbon (38.7138° N, 9.1394° W)

Climate Type: CSA

Building Use: Commercial – Bank headquarters

Level of BISTS integration:
Reijenga classification: Applied invisibly

- O New Build
- ● Refurbishment
- O Other: ……………………

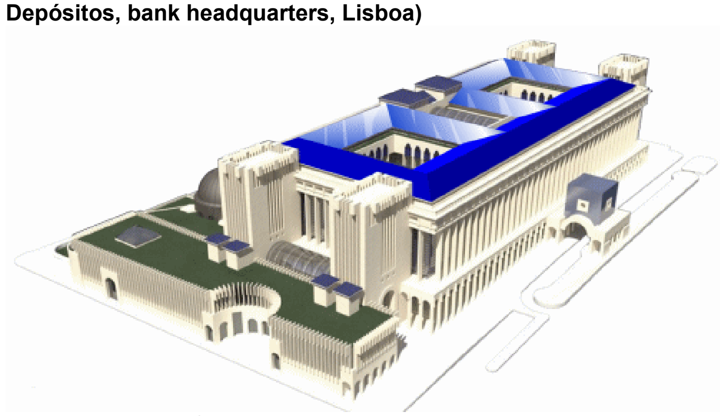

Fig.3: 3D model of the building

Type of BISTS:

Active

Function(s):
- ● Air heating and cooling
- ● Water heating
- O Combi-system
- O Cooling/ventilation/shading
- O PV/T
- O linked to another system (e.g., heat pump)
- O Other: ……………………..

Fig.4: Installation of the STC in the roof

Building element:

O Facade
● Roof
O Other: ……………………..

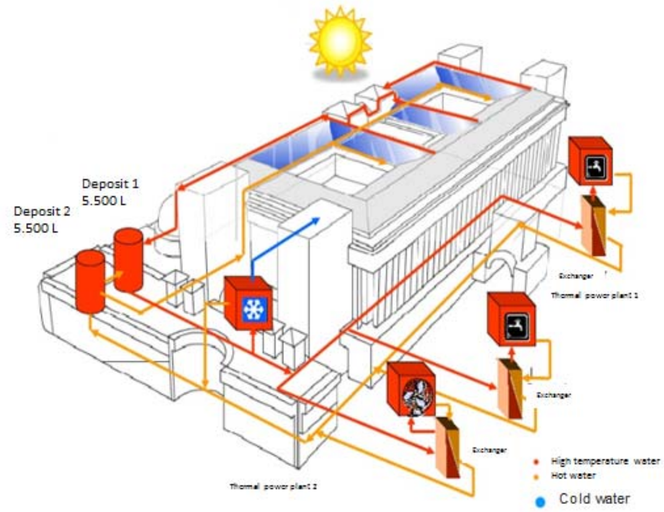

Fig.5: Scheme of the air heating and cooling system

BISTS characteristics:

The solar thermal system used in the CGD central headquarters consists in 158 solar collectors with a total area of 1600 m^2. The panels were manufactured off-site and subsequently placed on the roof of the building over a wooden structure. The roof on the south side would be a prime location, but CGD opted not to use it due to concerns about visual impact. In total, there are energy savings of more than 1 GWh/year, corresponding to 5% of the global building consumption.

Stage of Development: Installed
Responsible: Jayme da Costa
Mecânica e Eletricidade, S.A.

O Idea/Patent …………………………………..
O Prototype …………………………………..
O Demonstration …………………………………..
● Integral building element …………………………………..
● Commercially available …………………………………..

BISTS description and context

The building has a total floor area of 173,600 m^2 with a rectangular shape and consists of 15 floors. This is a building for services, including bank headquarters.

System viability

CGD invested in this project about 1 million Euros, and foresees to recover the investment in 8 - 10 years through the savings made on the electricity bill. With the solar thermal plant, the building annually saves more than 1 GWh of electricity, equivalent to avoiding each minute of operation the emission into the atmosphere of about 1 kg of CO_2.

Modelling and simulation tools developed/used

The building has a system to do a detailed monitoring of the energy produced, that allows a real-time analysis of the performance. This data allows the CGD direction to evaluate the further expansion of this type of system in other CGD buildings. The SolTerm software was used in the modelling and simulation phases.

BISTS Performance data

Based on:

● Estimation

O Detailed simulation

● Measurement/testing

O Long-term monitoring

Performance parameters

For integrated systems:
key performance indicators -

Solar savings fraction: 99,8%
Esolar:37007 KWh
leaning radiation: 1363 KWh/m^2
horizontal radiation:
1649 KWh/m^2

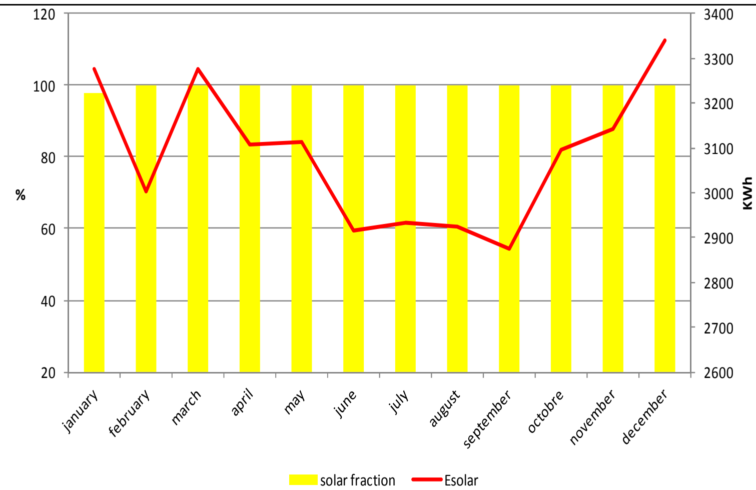

Fig.6: Estimation of the STC performance during the whole year

Additional information:

Sources and references:

https://www.cgd.pt/Institucional/Caixa-Carbono-Zero/Projectos/Pages/Central-Solar.aspx

Example name: Case study 2 – integration on the facade

Template completed by:
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For installations

BISTS Location: Carcavelos, Lisboa (38.709° N, 9.336° W)

Climate Type: CSA

Building Use: service – Operational Coordination Centre

Level of BISTS integration: Reijenga classification: Added to the design

● New Build
O Refurbishment
O Other: ……………………

Fig. 7: Operating Control Centre of BRISA, view of the South and East facade (Carcavelos)

Fig. 8: Aspect of the roof

Type of BISTS:

Active

Function(s):
O Air heating
O Water heating
O Combi-system
● Cooling/ventilation/shading
O PV/T
O linked to another system (e.g., heat pump)
O Other: ……………………

Building element:

● Facade
● Roof
O Other: ……………………..

Fig. 9: Partial view of the East and North façade

Fig. 10: Close view of the solar thermal panels

BISTS characteristics:

The Solar Thermal Collectors are installed on the roof and on the South, East and West facades. In the facades the STC are also used as the cladding of a ventilated wall. The roof has 144 solar collectors, with a 7º angle towards the South (this angle was due to architectural restrictions), with an area of approximately 400 m^2. The south facade has 100 solar thermal collectors with an area of approximately 200 m^2. In the East and West facades 48 solar thermal collectors are installed, with an approximate area of 96 m^2 (in each façade).

Stage of Development: Installed
Responsible: HVAC: Pen Engenharia - Luis Andrade;
Carrilho da Graça, arquitectos

O Idea/Patent …………………………………..
O Prototype …………………………………..
O Demonstration …………………………………..
● Integral building element …………………………………..
O Commercially available …………………………………..

BISTS description and context

The building has an operation room with 450 m^2, and a height of 9 m (occupying the two floors of the building). Adjacent to the operating room, on the lower floor are located the technicians offices, the technical rooms (data servers room) and the archive. In the upper floor are located the offices, an auditorium and a cafeteria. The architecture project was done in a way to integrate a large area of solar collectors, on the roof and on the three facades exposed to radiation, creating an opportunity for the adoption of an efficient cooling solution from the energy and environmental impact point of view. This STC is mainly used for cooling and is a solar absorption cooling system.

System viability

The energy requirements of this building are essentially for cooling, resulting from the heat released from the large amount of equipments. This reality led to the adoption of an absorption cooling cycle solar system. Since the solar radiation is coincident in time of occupation of the building, this system showed to be the most efficient one.

Modelling and simulation tools developed/used

The water circulators, each dedicated to solar orientation, have variable speed according to an algorithm which includes several parameters, especially the temperature of the water out of sewers and water temperatures at the bottom and at the top of the two deposits of hot water. The used modelling and simulation tool was the SolTerm software.

BISTS Performance data

Based on:
- ● Estimation
- O Detailed simulation
- ● Measurement/testing
- O Long-term monitoring

Performance parameters
For integrated systems:
key performance indicators -

South
Solar savings fraction: 93,9%
Esolar:34972 KWh
Leaning radiation: 1094 KWh/m^2
horizontal radiation:
1613 KWh/m^2

East
Solar savings fraction: 77,9%
Esolar:29016 KWh
Leaning radiation: 778 KWh/m^2
horizontal radiation:
1613 KWh/m^2

West
Solar savings fraction: 81,5%
Esolar:30369 KWh
Leaning radiation: 779 KWh/m^2
horizontal radiation:
1613 KWh/m^2

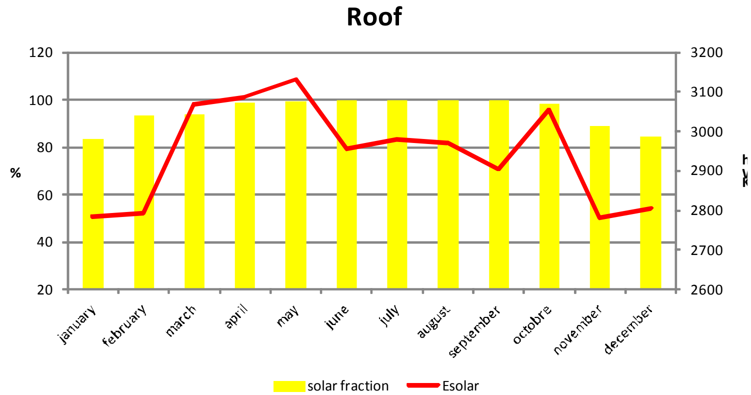

Fig.11: Estimation of the STC (roof) performance during the whole year

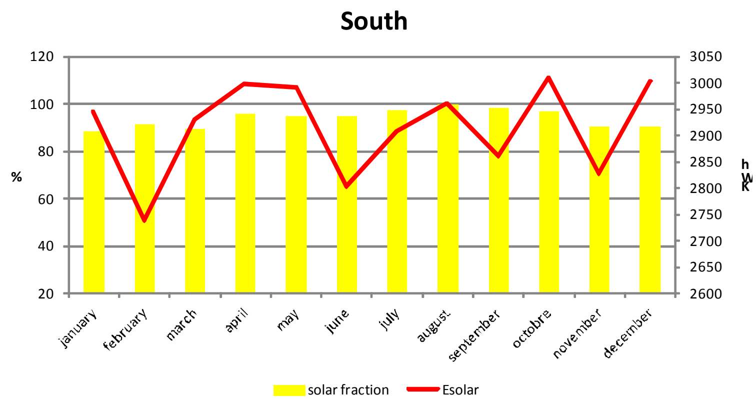

Fig.12: Estimation of the STC (south) performance during the whole year

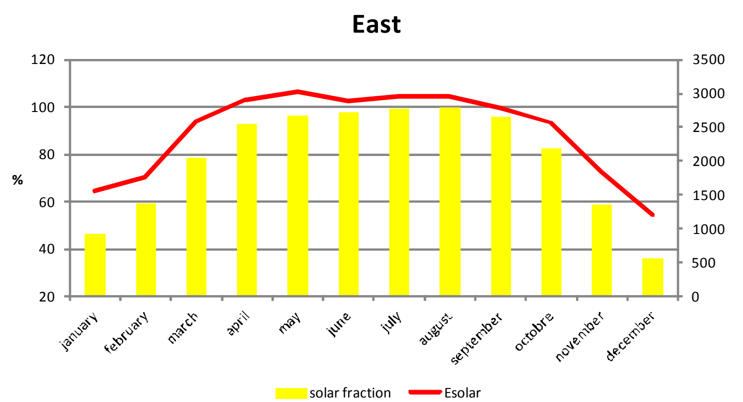

Fig.13: Estimation of the STC (east) performance during the whole year

BISTS Performance data

Roof
Solar savings fraction: 94,8%
Esolar:35312 KWh
Leaning radiation: 1622 KWh/m^2
horizontal radiation:
1613 KWh/m^2

West

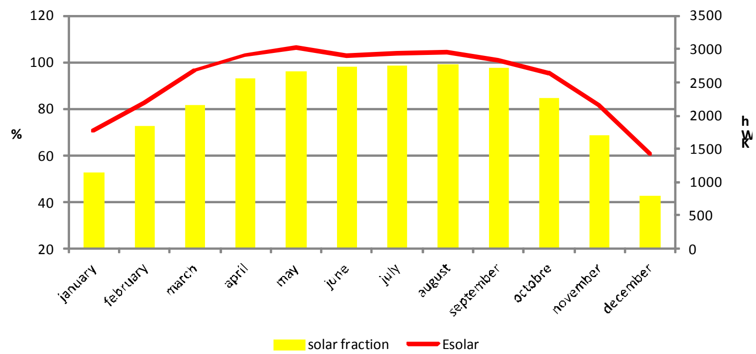

Fig.13: Estimation of the STC (roof) performance during the whole year

Additional information:

The production system and thermal energy storage system consists of the following major components:

- 4 groups of solar thermal collectors (East, South, West and roof);
- One absorption chiller;
- A cooling tower (closed type);
- A chiller / heat pump system backup;
- A primary hot water tank;
- A secondary hot water tank;
- A tank of chilled water.

Sources and references:

http://www.grunfos.dk/web/homept.nsf/webPrintView/78425FD007DFDAF580256F50004CEBE6

http://jlcg.pt/additional_work/brisa

Example name: Case Study 3 – Integration on the facade - balcony

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For installations

BISTS Location: Porto
(41,157° N, 8,631° W)

Climate Type: CSB

Building Use: Residential

Level of BISTS integration

Reijenga: Adding to the architectural image

O New Build
● Refurbishment
O Other: ……………………

Type of BISTS:

Active

Function(s):
● Air heating
O Water heating
O Combi-system
O Cooling/ventilation/shading
O PV/T
O linked to another system (e.g., heat pump)
O Other: ………………………

Building element:

● Facade
O Roof
O Other: ……………………..

Fig. 14: Use of vacuum tubes as balcony rails – example (source: Basnet, 2012)

Fig. 14: Use of flat panels as balcony rails – example (source: Basnet, 2012)

Fig. 15: Use of evacuated collectors as balcony rails (source: Basnet, 2012)

BISTS characteristics:

The apartment complex (still in design phase) is designed as an energy effective, passive house with PV modules on the roof for necessary energy to run the electrical equipment and solar thermal collectors for hot water located on the facade.
The options for the integration of STC analysed were vacuum tubes, flat plate and evacuated collectors.
Vacuum tube solar thermal collectors will be integrated as an architectural element used as balcony balustrades in the south facade. The 90 cm high solar module balustrades that look like normal handrails are a stack of nine long glass tubes. Inside each of these glass tubes, a finger-thick pipe with a metal absorber transports water. The collector as a whole is oriented vertically, but each absorber is turned to an optimum angle towards the sun, to collect the maximum energy in the fall and spring. If the solar collectors were pitched, too much energy would be produced in the summer and too little in the other seasons. Beside the energy advantage and balcony fencing, the solar collectors create aesthetic value by throwing a changing pattern of light and shadow on the floors of the rooms.
Other possibility is the integration of flat pane solar thermal collectors on the balconies, with 90º or 75º tilt, placed on the south facade.

Stage of Development: **Responsible:** N/A

O Idea/Patent …………………………………..
O Prototype …………………………………..
O Demonstration …………………………………..
● Integral building element …………………………………..
O Commercially available …………………………………..

BISTS description and context

The STC will be integrated in a multifamily building located in Porto. The principle was to integrate solar collector not only on the roof, as usually done in Portugal, but to integrate them on elements as sun screening or on balcony surfaces as the balconies usually are oriented toward south and west. Besides the use of STC as cladding multifunctional elements in the facade, they can equally be used as balcony railings. The tubular vacuum collectors as balcony railings, which makes the conventional railing unnecessary; have a good degree of transparency giving interesting shadings on the floors. Most important is that these tubes make solar energy visible.
Other example is the integration of flat pane solar thermal collectors on the balconies, with 90º or 75º tilt, placed on the south facade.

System viability

The STC systems used in balcony railings are better than to photovoltaic systems in terms of installation cost, annual savings, maintenance and return. Normally the return, in terms of carbon emissions, of a solar thermal energy system is 2 years.

Modelling and simulation tools developed/used

The presented results are based in estimations and modelling developed in the SolTerm software.

BISTS Performance data

Based on:
- ● Estimation
- O Detailed simulation

- ● Measurement/testing
- O Long-term monitoring

Performance parameters

For integrated systems:
key performance indicators -

Solar savings fraction: 82,0%
Esolar:1294 KWh
Leaning radiation: 1004 KWh/m^2
horizontal radiation:
1449 KWh/m^2

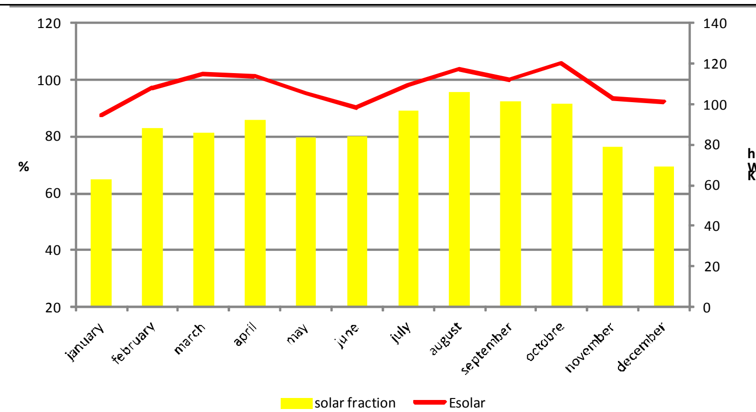


Fig.16: Estimation of the STC performance during the whole year

Additional information:

collectors as balcony railings	
Shape and size	Collector modules with nine evacuated tubes. Each was dimensioned as standard balcony railing
Positioning	the modules are positioned at regular intervals in the facade
Colour	Standard reflecting blue colour is in harmony with the colour of the background glazing
Material and surface texture	The horizontal lines created by the solar tubes characterise the horizontal lines of the timber cladding
Flexibility in integration	Good aesthetics integration was achieved using this approach, since the evacuated tubes are similar to conventional balcony railings.

Solar flat-plate collector	
Shape and size	The height of the module is derived from the floor to floor height.
Positioning	The modules are placed in a checker board style in asymmetrical pattern in the facade
Colour	Blue colour of the modules is in harmony with the reflecting blue colour of the windows.
Material and surface texture	The horizontal lines seen on the absorber of the collector break the verticality of the facade
Flexibility in integration	The flexibility in integration is more prevalent with the used similar sized modules.

Sources and references:

Arjun Basnet (2012). Architectural Integration of Photovoltaic and Solar Thermal Collector Systems into buildings. Master’s Thesis in Sustainable Architecture. NTNU. Trondheim, Norway.

INSTRUCTIONS

Please fill in as much information as possible.

Tick where appropriate.

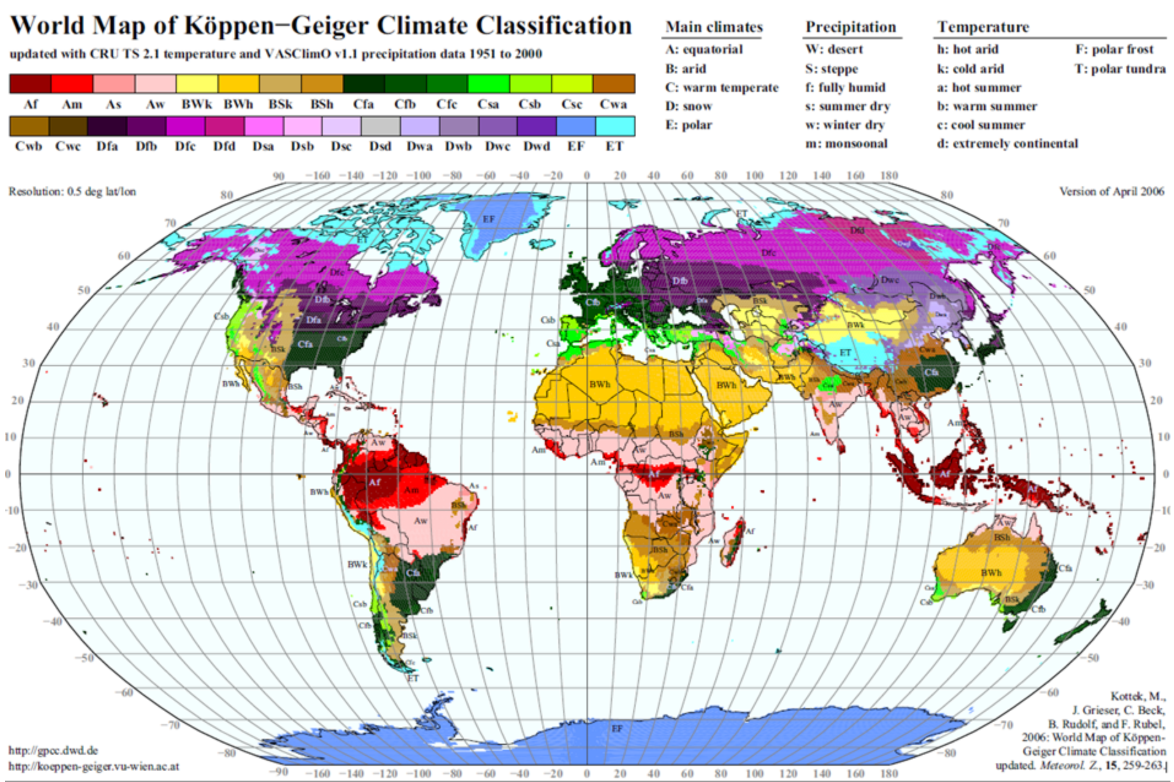
Text in red is suggested guidance. Insert information in provided space, removing red text as appropriate

If possible, use metric values.

If necessary, supply additional information on separate sheets

<u>Reference listing</u>

Köppen climate classification



(Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of Köppen-Geiger Climate Classification updated. Meteorol. Z., 15, 259-263.)

Reijenga classification
The integration of PV systems in architecture can be divided into five categories:

1. Applied invisibly
2. Added to the design
3. Adding to the architectural image
4. Determining architectural image
5. Leading to new architectural concepts.

(Reijenga, TH and Kaan, HF. (2011) PV in Architecture, in Handbook of Photovoltaic Science and Engineering, Second Edition (eds A. Luque and S. Hegedus), John Wiley & Sons Ltd, Chichester, UK)

Rush classification

The architectural/visual expression of building services systems are identified as:

Level 1. Not visible, no change
Level 2. Visible, no change
Level 3. Visible, surface change
Level 4. Visible, with size or shape change
Level 5. Visible, with location or orientation change

(Rush, RD. (1986) The Building systems integration handbook Wiley, New York, USA)

Collector test standards

BS EN 12975-2 2006 'Thermal solar systems and components solar collectors - Part 2 test methods'
ASHRAE Standard 93-2010 'Methods of Testing to Determine the Thermal Performance of Solar Collectors'
ASHRAE Standard 95-1987 'Methods of Testing to Determine the Thermal Performance of Solar Domestic Water Heating Systems'