# Architectural aspects of BISTS

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# Building Integration of Solar Thermal Systems – TU1205 – BISTS

Usage of renewable energy sources in buildings

reduce

consumption of pollutant energy sources and thereby reduce $CO_2$ emissions.

Sun is renewable energy source whose usage exerts influence on architectural design and building concepts.

New building envelope structures and components are developed.

Building envelope becomes a structure which produce – thermal energy and/or
– electric power.

One of the building's components that is involved in thermal energy production is solar thermal collector – STC.

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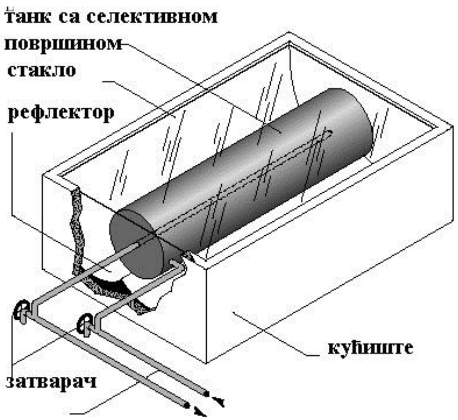
# Building Integration of Solar Thermal Systems – TU1205 – BISTS

## Low-tech solar collectors




## Thermosyphon systems

The store should be located above the collector.

Direct system is one where the tap water is circulated directly through the solar collector.

Indirect system is one that employs a separate fluid circuit to transfer heat from the solar collector to the store.

## Flat and vacuum solar thermal collectors

Interesting from the architectural aspect

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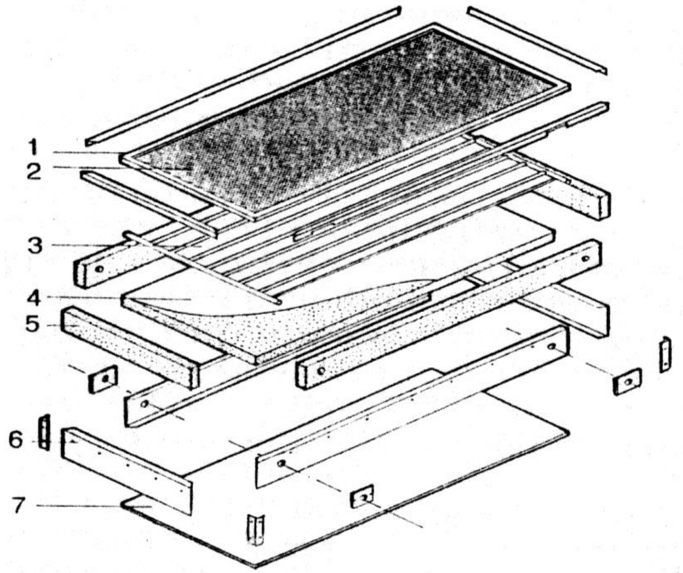
# Building Integration of Solar Thermal Systems – TU1205 – BISTS

## Flat solar thermal collector




**Transparent** (2)– tempered glass, polyethylene, PVC (translucent, resistant to atmospheric precipitation, and temperature oscillation, UV rays); double-glazing where the water is being heated to t > 35° C.

**Absorber plate** (3)– copper, aluminum or steel plate bonded to the waterways

**Thermal insulation** (4)– prevents excessive heat loss, fiberglass or polyisocyanurate, both of which can withstand very high temperatures (does not absorb moisture, does not react chemically with moisture), bottom side 30-50mm, lateral sides 30-40mm.

**Casing** (1,5,6,7)– weather-tight enclosure, usually metal (aluminum owing to its weatherability), rarely of plastic or wood.


“Stand-off”


Building integrated

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# CONTENTS OF THE PRESENTATION

## Architectural aspect includes following subjects:

1. Location/Application possibilities
2. Function possibilities
3. Light permeability
4. Dimensions and form
5. Color, material, texture, joints
6. Construction possibilities

   (Recycling)

affect the building appearance

[Krstic-Furundzic, A. PV Integration in Design of New and Refurbishment of Existing Buildings: Educational Aspect, JAAUBAS-Journal of the Association of Arab Universities for Basic and Applied Sciences, Volume 4 (Supplement), University of Bahrain, 2007, pp. 135-146.]

# 1. LOCATION/APPLICATION POSSIBILITIES refer to:

**1.1. climatic conditions** (specific for each location)

**1.2. position on the building envelope,**

**1.3. orientation and inclination; shading effects.**

# Location of Solar Thermal Collectors-STC

**Position besides the building** – no influence on building appearance

**Position on the building envelope**

- **on the roof**
  - “stand-off” → flat roof, sloping roof, saw tooth roof, curved roof
  - **“building integrated”** → balcony railings, sunshades, sunscreens, awnings, overhangs
- **on the facade**
  - “stand-off” → vertical facade surface, tilted facade surface, curved facade surface
  - **“building integrated”** → vertical facade surface, tilted facade surface, curved facade surface

→ semi transparent surfaces

→ opaque surfaces

**influence on building appearance**

[Krstic-Furundzic, A. PV Integration in Design of New and Refurbishment of Existing Buildings: Educational Aspect, JAAUBAS-Journal of the Association of Arab Universities for Basic and Applied Sciences, Volume 4 (Supplement), University of Bahrain, 2007, pp. 135-146.]
[Krstic-Furundzic, A., Lectures on the course ”Contemporary facades and roofs”, Faculty of Architecture, University of Belgrade]

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# POSITION ON THE BUILDING ENVELOPE/APPLICATION POSSIBILITIES

The application of solar thermal collectors to a building envelope enables **zero land consumption.**

Regarding location on building **"standoff" and "building-integrated" ST collectors** are available. In a different way they strongly influence building appearance.

In the first case they are independent devices applied on roof or facade structure.

In the second case, **building-integrated solar thermal systems /or PV modules/ are building components which can substitute for usual roof or facade cover materials.**

Stand-off collectors placed on an angled collector supports on flat roofs or walls.

Collectors, as building components, integrated into building envelope – facade and roof.

[Krstic-Furundzic, A., “ *PV Integration in Design of New and Refurbishment of Existing Buildings: Educational Aspect* “, *JAAUBAS-Journal of the Association of Arab Universities for Basic and Applied Sciences*, Volume 4 (Supplement), University of Bahrain, 2007, pp. 135-146]

# Building Integrated Solar Thermal Collectors

Taking into consideration building envelope structure and geometry, solar thermal panels can be integrated into:

* **facades –**
  - vertical walls,
  - sawtooth wall (vertical or horizontal direction),
  - sloping wall,
  - curved/flexible facade surfaces.
* **roofs** – pitched roof, skylights, sawtooth roof, curved/flexible roof surfaces.
* **facade and roof shading devices** – horizontal, vertical, tilted,
* **overhangs** – horizontal and sloped,
* **balcony railings** – vertical and tilted.

**Position and geometry exert influence on integration design and construction solutions.**

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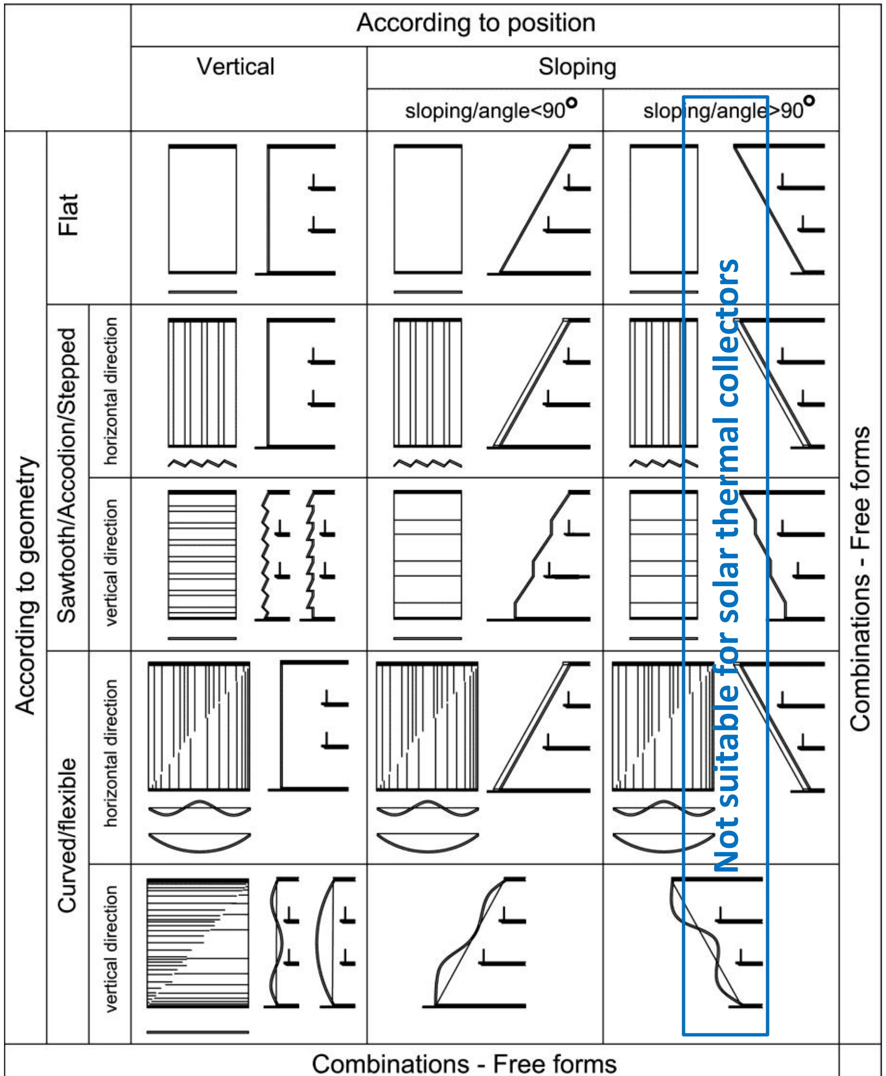
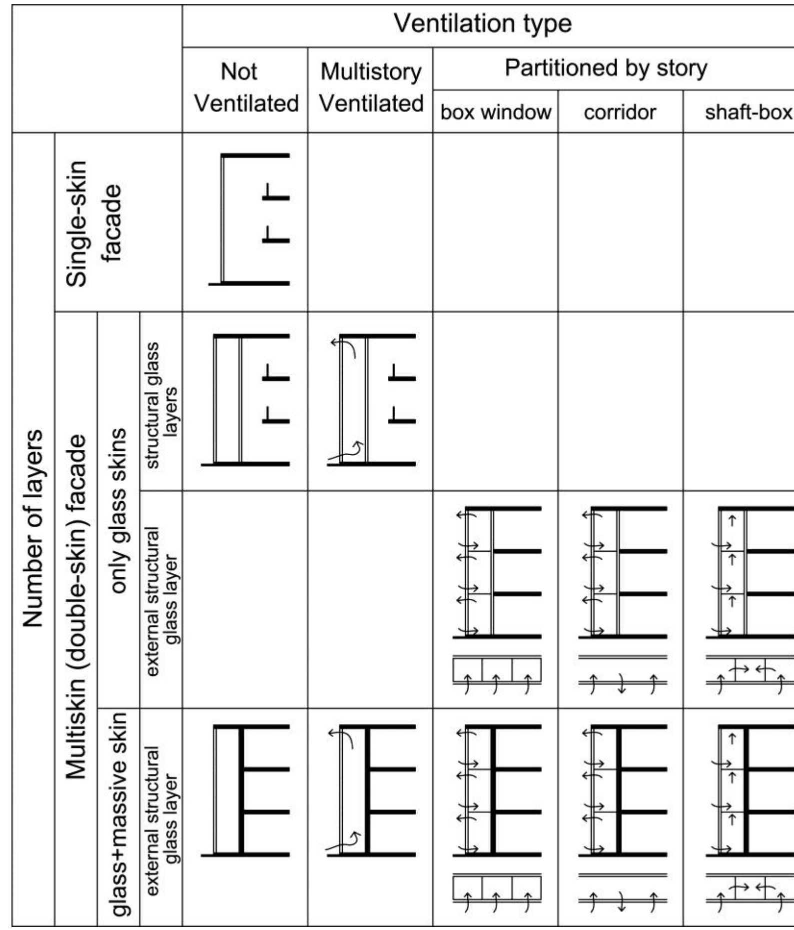



Single skin facade - BISTC can be integrated into parapet or wall structure as specific building component.

Ventilated double skin facade can be treated as solar thermal collector.




[Krstic-Furundzic, A., Kosic, T., Terzovic, J., "*Architectural Aspect of Structural Design of Glass facades/Glass Skin Applications*", in Challenging Glass 3, Proceedings of the Conference on Architectural and Structural Applications of Glass, Editors: Bos, Louter, Nijsse, Veer, Faculty of Civil Engineering and Geosciences, Delft University of Technology, IOS Press BV, The Netherlands, 2012, pp. 891-900]

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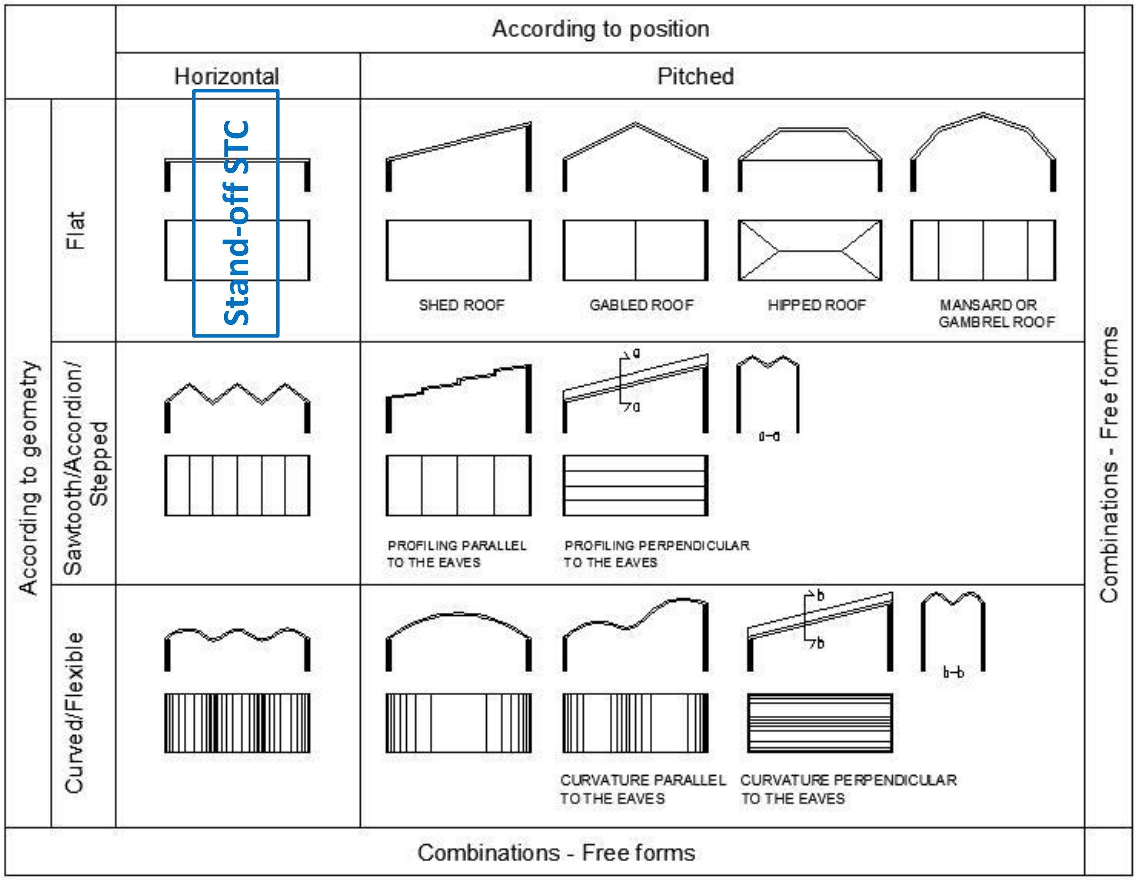


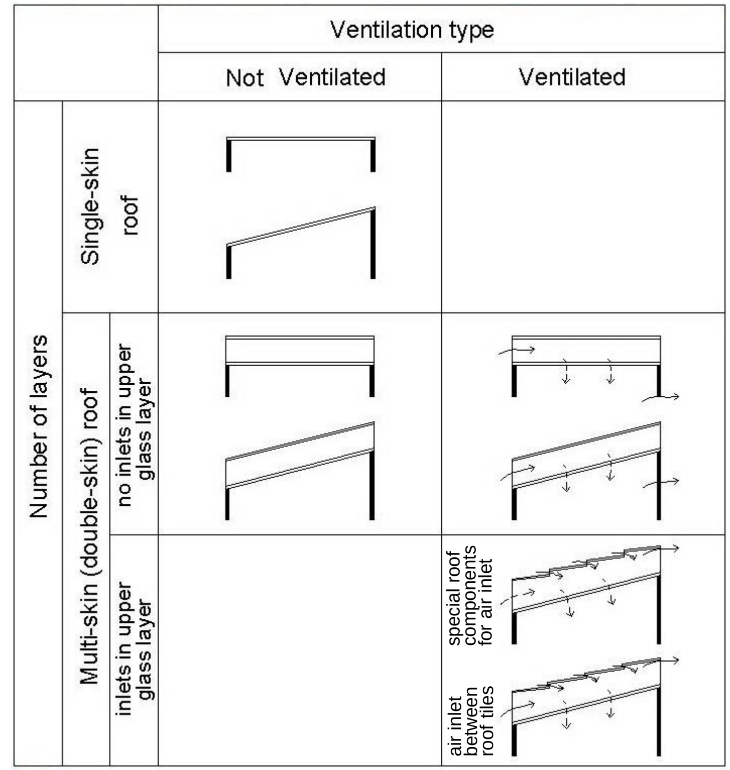


Single skin roof - BISTC can be integrated into roof structure as specific building component.

Ventilated double skin roof can be treated as solar thermal collector.

[Krstic-Furundzic, A., Kosic, T., Terzovic, J., "*Architectural aspect of structural glass roof design*", Proceedings of the Conference on structural glass, Editors: Jan Belis, Christian Louter, Danijel Mocibob, Taylor&Francis Group, London, UK, 2013, pp. 45-52]

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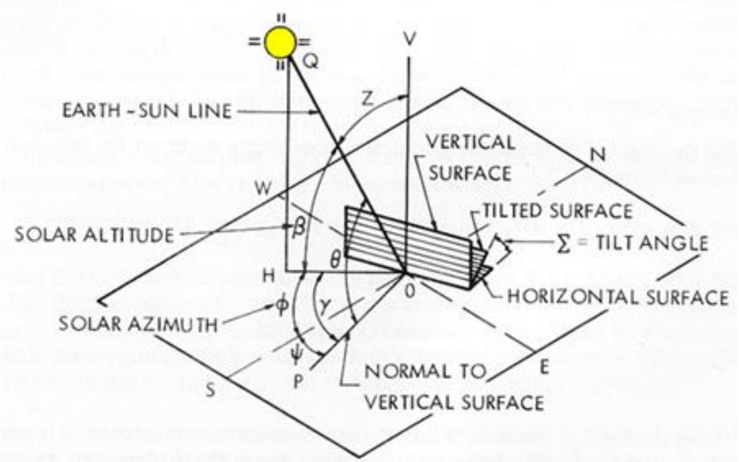
# ORIENTATION AND INCLINATION, SHADING EFFECTS

In the northern hemisphere preferable orientations of STC :

- in higher latitudes directly towards the sun (south),
- 45° either side of south will make little difference,
- near the tropics, the higher availability of sunshine makes their orientation less important, they can even face east or west [Roaf, S., Fuentes, M., Thomas, S., 2003].




***Altitude** is the vertical angle the sun makes with the ground plane (0° < alt < 90°).*

**Azimuth** - By convention, azimuth is measured from north towards the east along the horizon (in a clockwise direction).

The collectors should be inclined at an angle equal to the site's latitude, from the horizontal [Roaf, S., Fuentes, M., Thomas, S., 2003].

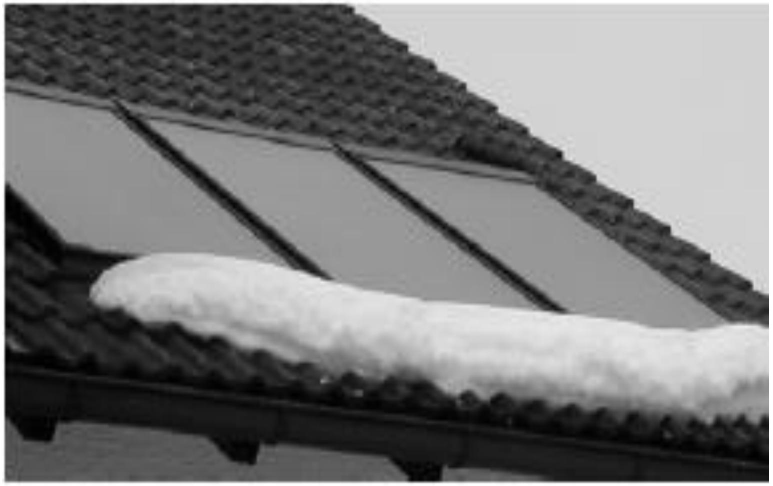
In the winter it is recommended that the flat-plate collectors be tilted at the angle of latitude plus 15° and in the summer at the angle of latitude minus 15° [Appleyard and Konkle, 2007].
Some authors recommend ± 10°

Solar thermal collectors-modules can be placed in:
- horizontal,
- vertical or
- inclined position.

Most experts consider that a 30° pitch is necessary to ensure that snow slides.

Evacuated tubes, because of their shape take longer to shed snow [Appleyard and Konkle, 2007].

evacuated tubes



flat plate collectors

Snow shedding of the evacuated tubes and flat plate collectors .

It is not recommended to put the collector in a positioned shaded from the sun by building or adjacent trees [Roaf, S., Fuentes, M., Thomas, S., 2003].

Neighborhood drive-thoughts have to be conducted in order **pitch and shading to be verified**.

Neighborhood mapping

(Key: full sun=optimal orientation, no shade; green tree=good orientation, little to no shade; yellow tree=medium orientation, some shade; red tree=east-west facing orientation, some shade; red octagon=no exposure)

A sample GIS photograph with the symbols indicating solar potential is shown in the Figure, which provides a database that would verify the solar potential of neighborhoods and individual residences in case of Ann Arbor settlement, Michigan [Appleyard and Konkle, 2007].

# 2. FUNCTION POSSIBILITIES

Building integrated systems are characterized by **FUNCTIONAL COMPLEXITY.**

As **external layer** of building envelope, solar thermal collectors/PV provide: **thermal, acoustic and humidity insulation, wind protection**, in some cases **fire and security protection, protection from sunrays and produce thermal energy/electric power**

which determines

functional and technical performances of modules and thereby building envelope, influencing AESTHETIC POTENTIALS AND POSSIBILITIES [Krstic-Furundzic, 2007].

Both PV and STC systems can be used in place of normal building components with their multifunctional potential as external skin [Fuentes, 2007].

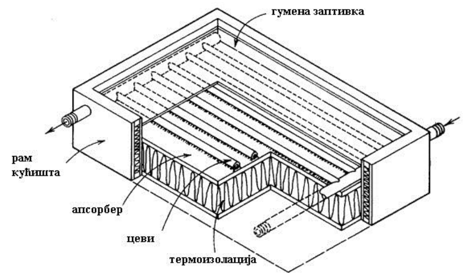
Application of building integrated solar thermal modules removes the need for conventional cladding materials which will be reflected in investment costs.
Cost of cladding is replaced with cost of STC which stimulates selection of BISTS.

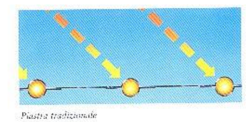
## Flat solar thermal collector

APPEARANCE of solar thermal collector is influenced by type of fluid (function):

**liquid fluid** – solar water heating systems for domestic water or space heating

**tubes of absorber layer are visible** clearly manifesting the facade specific function.



Absorber plate bonded to the waterways

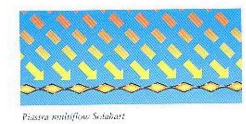
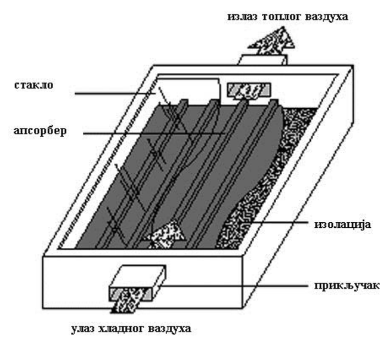
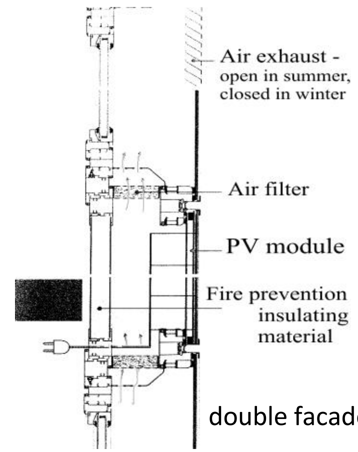


Plate to plate absorber type

**gaseous fluid** – solar air heating systems for space heating

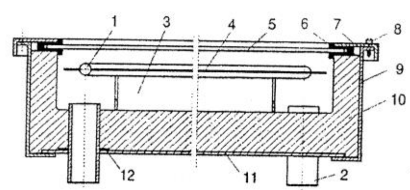
**vision of glass facade prevail** and mislead about facade concept can appear, particularly in case of double facades.




double facade

**combine – liquid and gaseous fluids**

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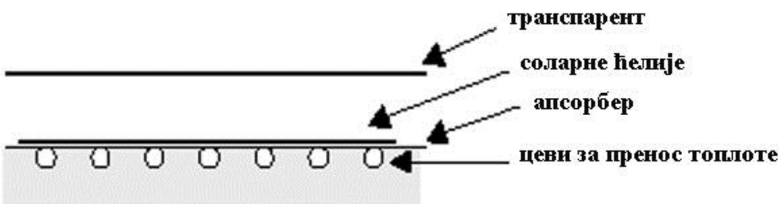
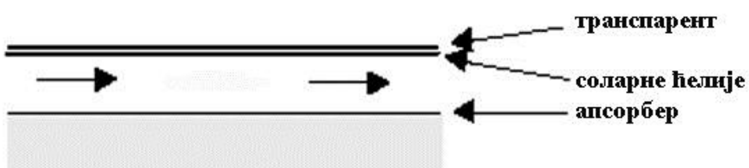
## Flat solar thermal collector with PV cells

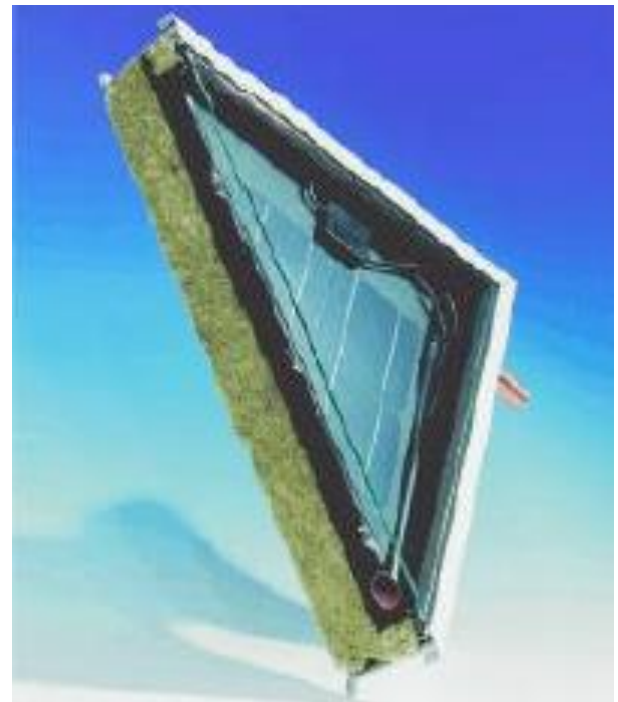
Presence of PV cells influences collector/building appearance making impression of photovoltaic facade or roof.

**- with liquid fluid**




**- gaseous fluid**



# Building Integration of Solar Thermal Systems – TU1205 – BISTS

| Aspects | | Criteria function groups | Individual criteria functions |
|---|---|---|---|
| Functional and Aesthetic aspects | Class of Criteria for Building Aesthetics | Compatibility of physical characteristics of STCs in relation to building envelope | Compatibility of dimensions of STCs in relation to building envelope |
| | | Compatibility of material appearance of STCs in relation to building envelope | Compatibility of color of STCs in relation to building envelope |
| | | | Compatibility of surface characteristics (texture, fracture, surface relief, warmth to touch) of STCs in relation to building envelope |
| | | | Compatibility of glossiness – reflection of STCs in relation to building envelope |
| | | | Compatibility of transparency level in relation to building envelope * refers only to glazed STCs |
| | | Compatibility of physical and aesthetic characteristics of STC sealing-joints in relation to building envelope | Compatibility of physical and aesthetic characteristics of STC sealing-joints in relation to building envelope |
| | | STCs' fitting in building envelope | Naturalness of STC integration |
| | | | Relationship between composition of STC colors and materials and colors and materials on building envelope |
| | | | Design harmony |
| | | | STCs' fitting in building context |
| | | | Design innovation |
| | | Success of visualization concept of STC integration | Success of visualization concept of STC integration simultaneously in relation to building and in relation to building context |
| | Class of Criteria for Building Physics | Physical–mechanical characteristics | Mechanical characteristics of STCs (material strength, friction resistance, resistance to force impact) |
| | | | Behavior in relation to liquids (water absorption, capillary absorption, moistening/non-moistening, permeability of water, frost resistance |
| | | | Behavior in relation to air – steam of STCs |
| | | | STC characteristics in relation to deformations and destruction (behavior in relation to wind, fire, earthquake; deformations caused by changing of moisture level, temperature change, dynamic loads) |
| | | | Thermal characteristics of STCs (size modifications caused by temperature change, thermal capacity of materials, thermal resistance, thermal insulation in winter and summer) |
| | | | Acoustic characteristics of STCs |
| | Class of Criteria for Mounting | Ease of STC mounting and joint quality | Easy for mounting |
| | | | Joint quality (construction stability aspect, building physics aspect, maintenance aspect) |

**Aesthetic requirements fulfillment!**

Consideration of aesthetic and functional aspects simultaneously,

taking into account

- aesthetics criteria,
- building physics criteria and
- STC mounting criteria

Connection between functional and aesthetic aspects (authors Krstic-Furundzic, A. and Kosoric, V.)

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# 3. LIGHT PERMEABILITY

In terms of functional requirements, demand for **light permeability** also may be given. Various light permeability and interesting light effects inside a building can be produced through the use of semitransparent and non-transparent solar thermal collectors.

**Semitransparent panels**

variation of the profiles, arrangements and distances between the tubes

different effects achieved by shadows and light.


Semitransparent collector encapsulated into a double skin facade, Social housing, Paris, France, www.iea-shc.org

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# 4. DIMENSIONS AND FORM

## 4.1. Dimensions
## 4.2. Form

**Variation in dimensions and forms of glass STC is dependent on glass characteristics asking for their development.**

In case of conventional roof and facade claddings various systems are available and designer must fit the dimensions and form of the existing range of products.

PV and STC systems that are architecturally pleasing within the context of the building, good material and colour composition, that adapt well to overall modularity, the visual aspect of the grid which is in harmony with the building and creates a satisfactory composition will result in good integration and renders high architectural quality

[Roberts and Guariento, 2012].

# DIMENSIONS

Talking about dimensions some **problems** can be noticed.

The suppliers in the BISTS industry produce their modules in individual, non-standard sizes.

Architect is forced to design its application in favor of a certain product before the call for tender.

We need "open" PV systems, the production of not just standardized modules but modules that will fit in with other industries that use – or could use – PV modules [Nordmann, 2005, Built-in future]

Key question in development of BISTS → creation of "**open**" **BISTS**

As standardized products are often not applicable, the situation calls for innovative **approaches with custom made products** [Hermannsdorfer and Rub, 2005].

Certain manufacturers have an interest to fit specific project requirements as Norman Foster calls "design development".

# FORM

Following solar thermal panel form types can be selected:

- Flat – orthogonal, triangular, …
- Curved
- Evacuated tubes (vacuum tubes)
- Dummy elements

In order to achieve a comprehensive architectural expression of the building, there is a need for the dummy elements.
The use of dummy elements also becomes relevant on the non-exposed surface of the facade or roof according to the design [Probst et al., 2007].

Manufacturers aware of the problem that characteristics of the collector have to be imitated. To have an appearance compatible with the system, dummies would require a glazing and an added metal sheet similar to the absorber used in the proper collectors.

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With regard to form, flat modules are mostly in use, but concave and convex shapes are also available and very frequently present in contemporary architecture.

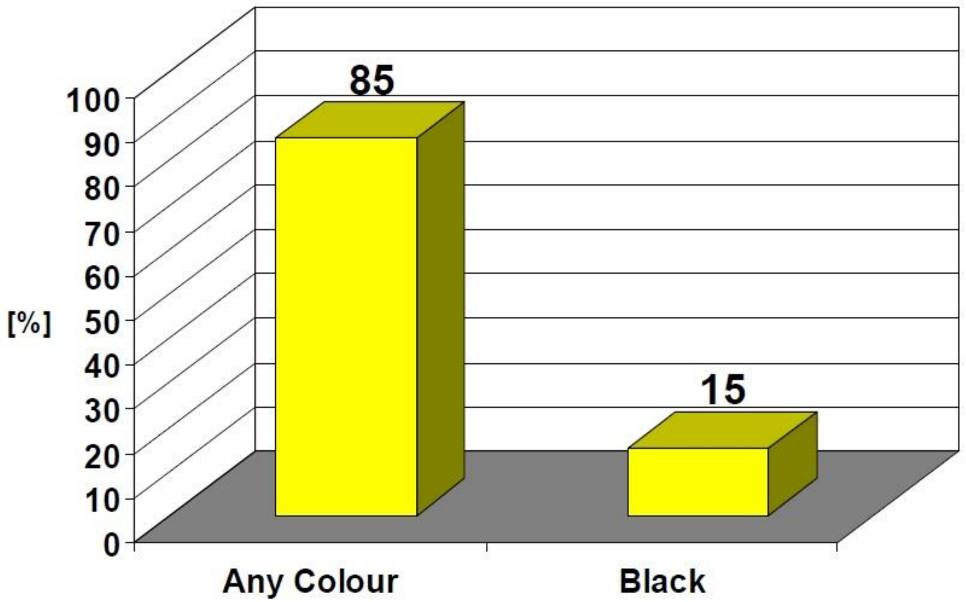
The curved surface of the building envelope covered with solar collectors.

Typically, the curve is formed by an appropriate number of flat plate collectors.

Werner Weiss, Building integration of Solar collectors, AEE-Institute for Sustainable Technologies (AEE INTEC), Austria, www.aee-intec.at

# 5. COLOR, MATERIAL, TEXTURE, JOINTS

The appearance of solar thermal collector, as a building component, is determined by the material, surface texture, color and type of jointing.




Werner Weiss, Building integration of Solar collectors, AEE-Institute for Sustainable Technologies (AEE INTEC), Austria, www.aee-intec.at

Despite an Austrian survey showing that 85% of architects would like to dispose of colored collectors, even at the cost of a slightly reduced efficiency, many well rated examples integrate black collector modules [Probst, 2008].

Integration issues are much more complex than just choosing an appropriate collector color.



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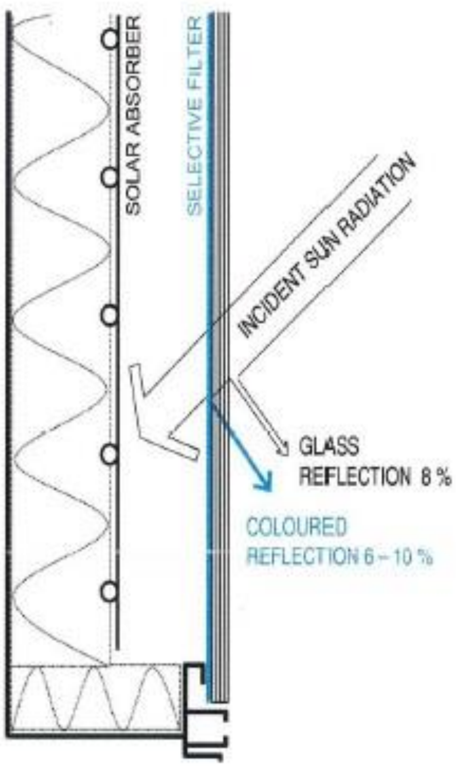
# COLOR and APPEARANCE

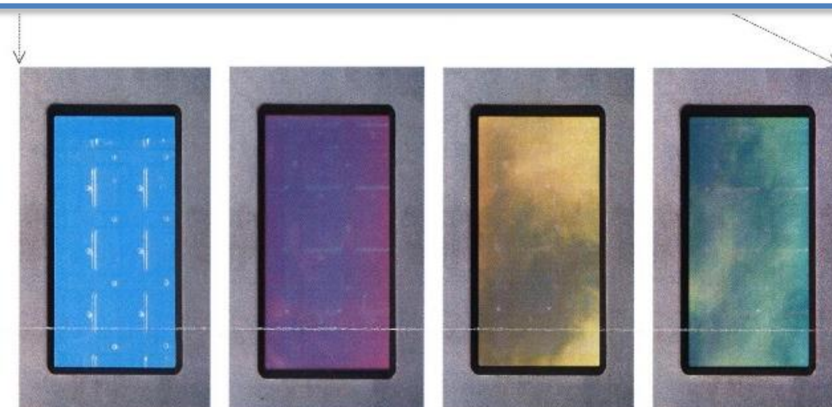
Color of solar thermal collector depends on absorber color or selective filter color.




Colored absorber

Selective filter

Standard extra white solar glass with different selective filter colors (inner side) in front of black solar absorber.



Werner Weiss, Building integration of Solar collectors, AEE-Institute for Sustainable Technologies (AEE INTEC), Austria, www.aee-intec.at

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# COLOR

Color of BIST collector depends on absorber color.

monotony of the black color

Flat plate solar collectors are of **black appearance** because of the black color of the absorber

high thermal efficiency

To avoid the monotony of the black color **absorbers of blue, red–brown, green** or other color.

lower thermal efficiency

challenge for architects

advanced building appearance

We notice that the increase in cost by using larger area of collectors to overcome the lower efficiency of the colored absorber is balanced by the **achieved aesthetic harmony with the building architecture** [Kalogirou et al, 2005].

# MATERIAL, SURFACE TEXTURE AND FINISH

The absorbers of the STC also have variations in terms of surface texture and finish. These are available from **corrugated, embossed, perforated, regular and irregular in terms of surface geometry.**

Evacuated tube collectors have exposed glass tubes. The surface is matt or glossy [Probst and Roecker, 2011].

The glazing above the absorbers in case of glazed STC systems may shine when sunlight falls on the surface and glare could be a problem.
The variations in the surface texture and finish inside the glass covering may not be visible from the outside.

In case of unglazed STC, the absorber surface texture and finish is clearly visible.

Flat plate solar thermal collectors with their opaque nature can only be integrated into the opaque parts of facade and roof [Probst and Roecker, 2011].

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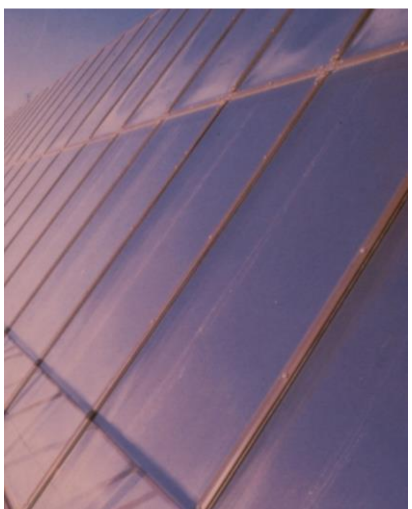
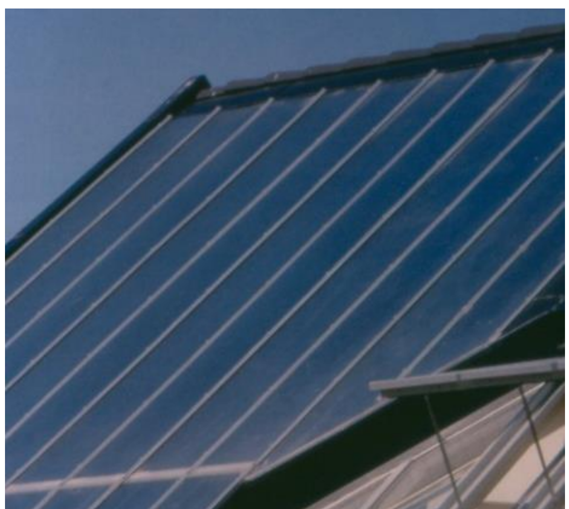
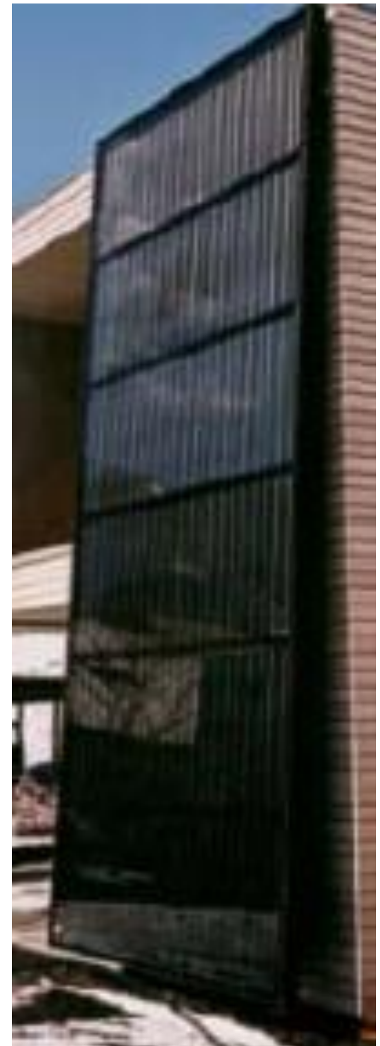
# JOINTS - JOINTING

A problem is still the total lack of adequate jointing options.

Alternative to the standard rubber jointing, a continuous, quite wide, aluminum frame is appropriate and suitable solution (mostly in use in practice).







# 6. CONSTRUCTION POSSIBILITIES

**Integration into building**

- 6.1. Solar thermal integrated facades
- 6.2. Solar thermal integrated roofs
- 6.3. Solar thermal shading devices, overhangs, balcony railings

**Construction possibilities for integration**

- **as glazing layer – glazed flat STC**
  - Application on: semi transparent surfaces; opaque surfaces
- **as conventional roof and facade cover – unglazed STC**
  - Application on: opaque surfaces
- **as vacuum (evacuated) tubes**
  - Application on: semi transparent surfaces; opaque surfaces

**influence on building appearance**

[Krstic-Furundzic, A., Lectures on the course ”Contemporary facades and roofs”, Faculty of Architecture, University of Belgrade]

# SOLAR THERMAL INTEGRATED FACADES 6.1

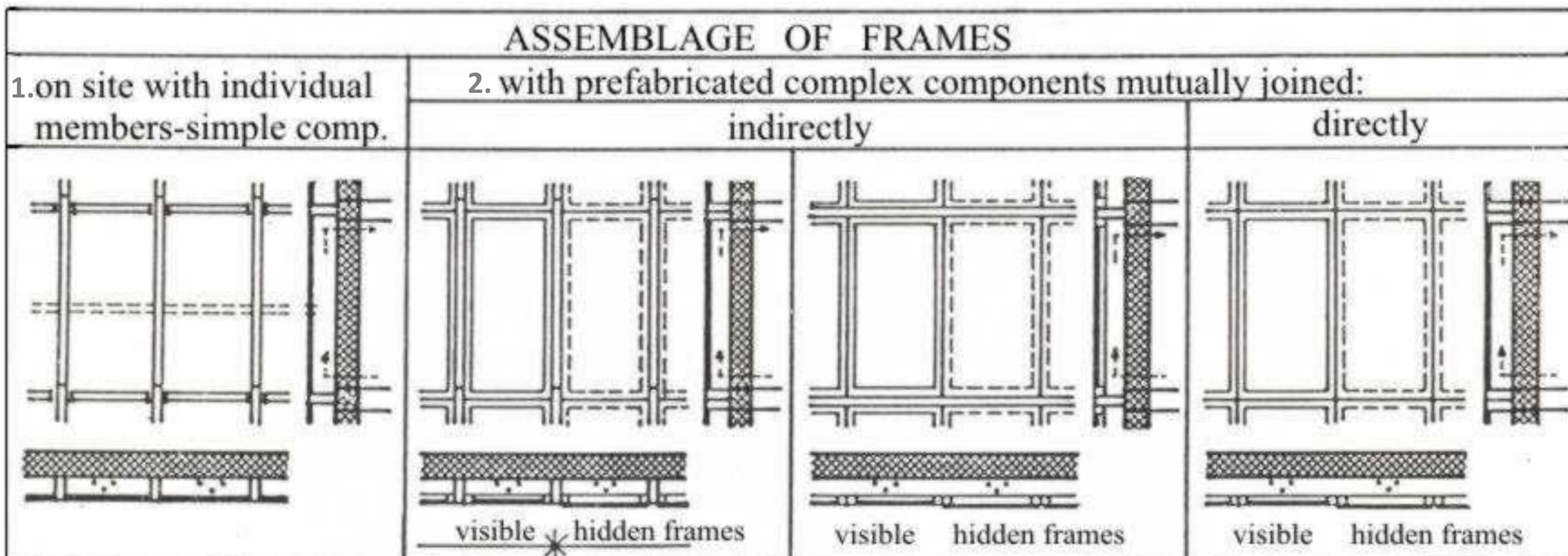
## Construction as glazing layer – glazed flat STC

**Glazed solar thermal integrated facade is type of curtain wall.**

Glazing layer consists of two kinds of structural components: **- sections and - glass sheets**.

If they are treated as individual components that are assembled on site the glazing is made by simple prefabricated components and needs scaffold for its erection (Figure: Assemblage of frames - Type 1).

When the structure is formed as frame with glass plates filling, glass partitions - panels as prefabricated complex components (Type 2) are present that can be mutually directly and indirectly joined.




[Krstic-Furundzic,A., 2007].

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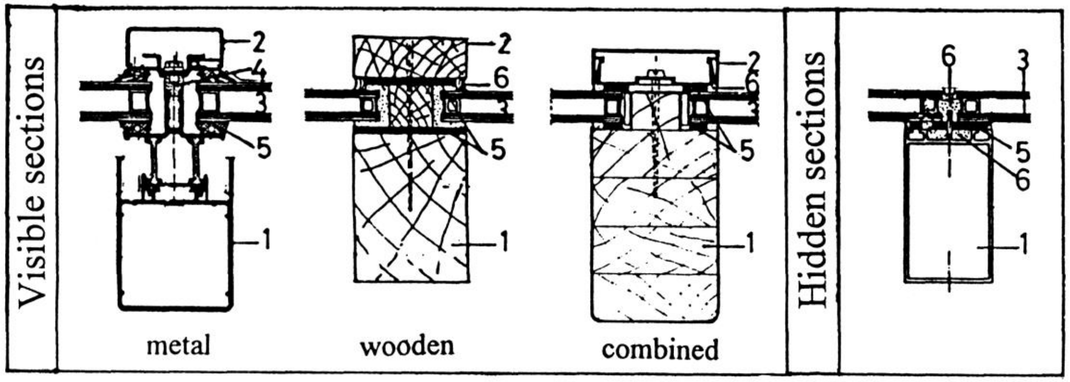
Wooden, metal and plastic sections can be used.

Metal and plastic sections are light and have smaller measures than wooden sections. Metal sections, which are customary in use, have to be constructed of two parts in order heat-thermal bridge problem to be solved and condensation prevented.




1. Supporting section
2. Covering sections
3. Double-glazing (or single)
4. Heat-bridge break
5. Rubber profile
6. Putty or silicone

Types of sections regarding material and appearance [Krstic-Furundzic, A., 2007].

By diversity of dimensions, shapes, colors and materials (wood, plastic or metal) of sections and frames it is possible to make different facade designs.

But, they can be hidden by glass, which makes new appearance [Krstic-Furundzic, A., 2007].

# Building Integration of Solar Thermal Systems – TU1205 – BISTS

Architectural aspects of BISTS, Krstic-Furundzic, A., Faculty of Architecture, University of Belgrade, Serbia

## Prefabricated facade integrated STC

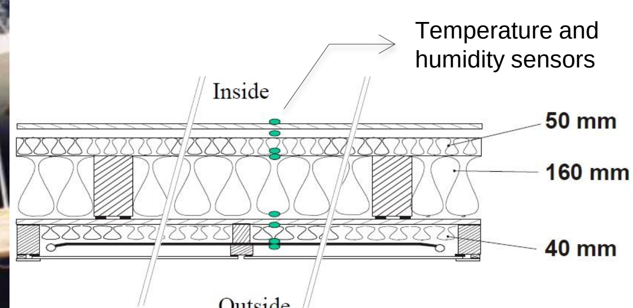
Unique quality of prefabricated facade wall panels with BISTC achieved by production at the factory.

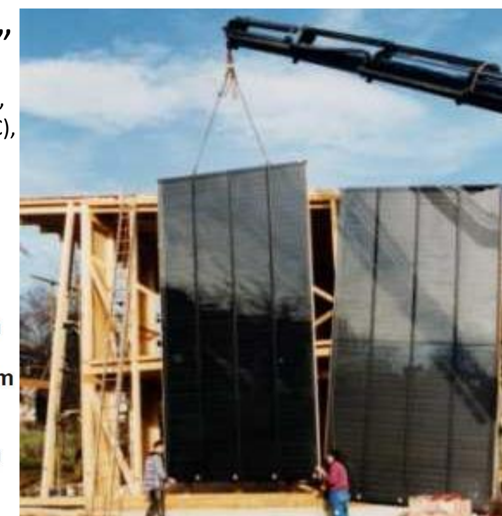
Mounting is easier and less time is needed.

Dimensional (modular) coordination is essential.

"Test facade"

Werner Weiss, Building integration of Solar collectors, AEE-Institute for Sustainable Technologies (AEE INTEC), Austria,
www.aee-intec.at



# Building Integration of Solar Thermal Systems – TU1205 – BISTS

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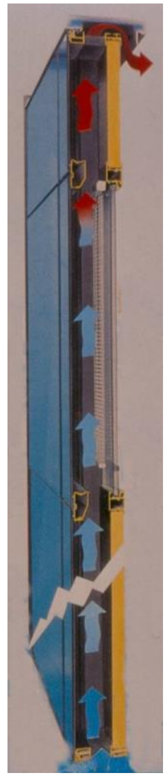
Development of **hybrid PV/T solar facades** that produce electrical power and thermal energy, and provide protection against inclement weather, light and noise is actual and interested in industrial production.

Hybrid Photovoltaic/Thermal facade constructed of prefabricated glass modules.



*Solar House 1,* Eds: Fitzgerald, E. and Owen Lewis, J., Energy research group, School of Architecture, University College Dublin

## Double facades

Solar module consists of three layers:

- external glazed layer, in which PV modules are encapsulated,

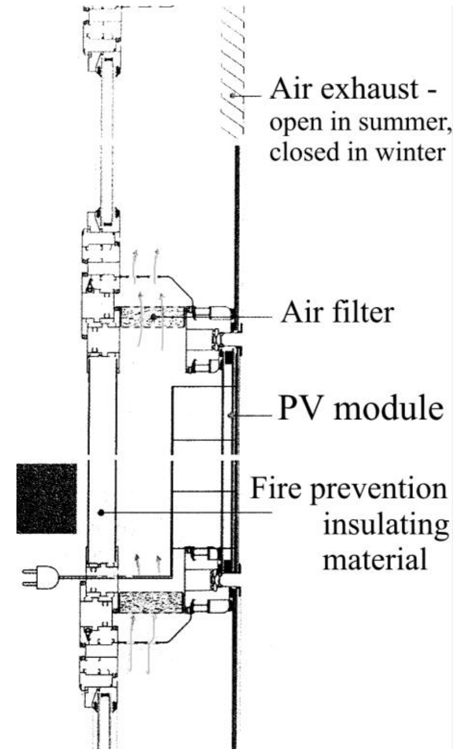
- internal layer, as insulating partition,

are separated with

-middle layer intended for air flow.

The thermal energy – hot air supplied in the middle layer can be used for the heating of the building, using a system based on a ventilated PV wall principle.

Assemblage of multifunctional modules (M-modules) by using curtain wall technologies is acceptable and usage of frame structures is favorable .




“Environmental facade” Alumil Milonas S.A.

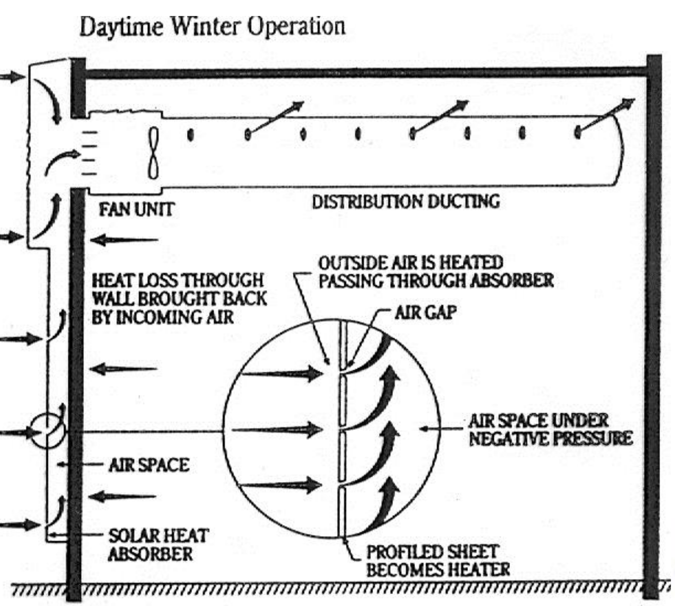
# SOLAR THERMAL INTEGRATED FACADES 6.1

## Construction as conventional facade cover – unglazed STC

Sunlit ventilated facades → air that is warmed in the air gap is usually ejected and thus a significant amount of heat is lost.

Such structure can function as solar collector → solar wall although a conventional building appearance is preserved.

Construction as conventional facade cover, SolarWall




Various metal panel profiles are available. Aluminum panels have the best properties regarding corrosion resistance. They can be styled, shaped, and designed in a variety of colors.

Dark colored vertical corrugated metal cladding is applied which becomes the solar absorber. It is perforated to allow outside air to travel through thousands of tiny perforations/holes on the metal surface. Air picks up the heat and rises to the top of the wall by the stack effect, where it is collected in a canopy plenum and ducted to the nearest fan.

In summer period gap layer is ventilated, the air is exhausted into outer space preventing the main wall to be overheated.



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Beijing Olympic Village, 2008.

Construction as conventional facade cover, SolarWall

Building appearance influenced by different colors of metal sheets (absorber layer).

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## Historic building retrofit

**Werner Weiss, Building integration of Solar collectors, AEE-Institute for Sustainable Technologies (AEE INTEC), Austria**
www.aee-intec.at

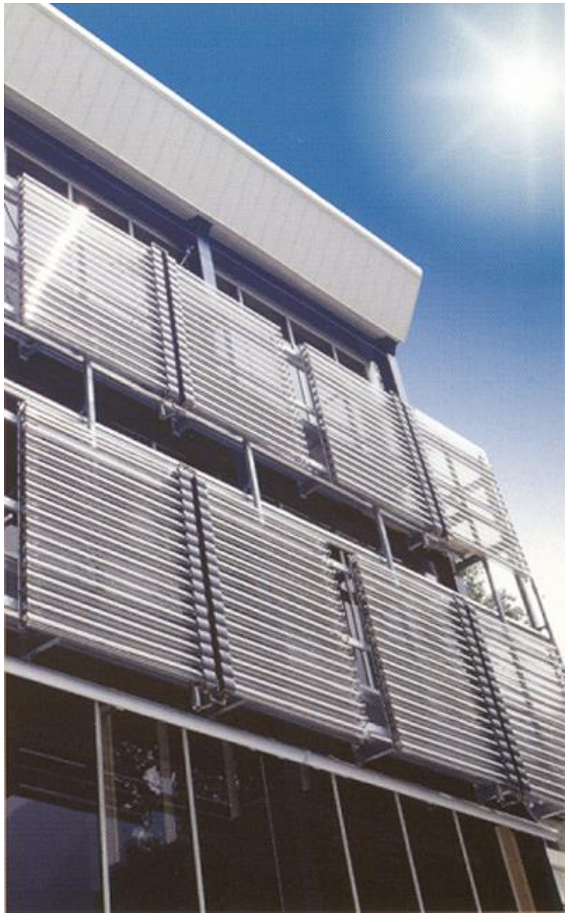
Residential building refurbishment,
**Fred Douglas Place, Manitoba, Canada**
**SolarWall System**

# SOLAR THERMAL INTEGRATED FACADES 6.1

## Vacuum tubes

STC with vacuum tubes are usually applied on opaque facade walls by specific substructure over the wall final layer.

Facades with vacuum tubes



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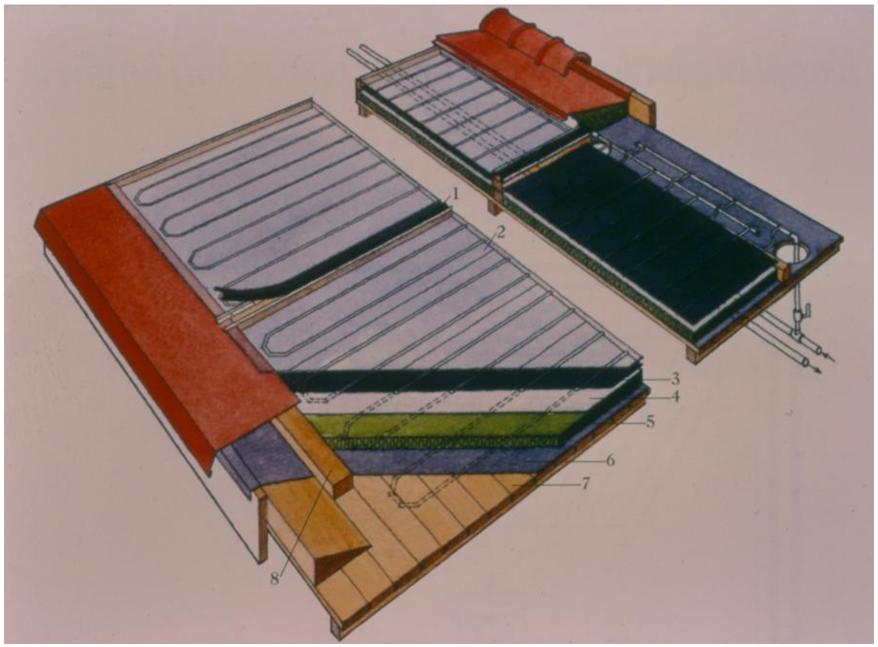
# SOLAR THERMAL INTEGRATED ROOFS 6.2

## Construction as glazing layer – glazed flat STC

Fabrication on sight

Solen – en aldrig sinande källa, A-sunergy, A-hus, Veddige



Solar thermal collectors can cover roof surface on the whole or partly substitute roofer. If partly substitute roofer, they have to be harmonized regarding dimensions-design grid, form, color, joints.

Prefabricated STC panels

The mounting system consists of frameworks of extrusions (which provide support for the modules), a watertight seal, and tubes or air channels.

Air gap is placed between external glazed layer and internal solid, light or massive, roof construction which have to be well insulated to prevent heat losses.

Structure with opaque modules is customary solution in case of solid, not transparent, roof.



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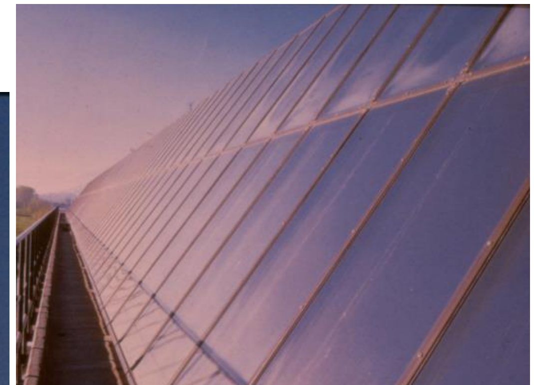
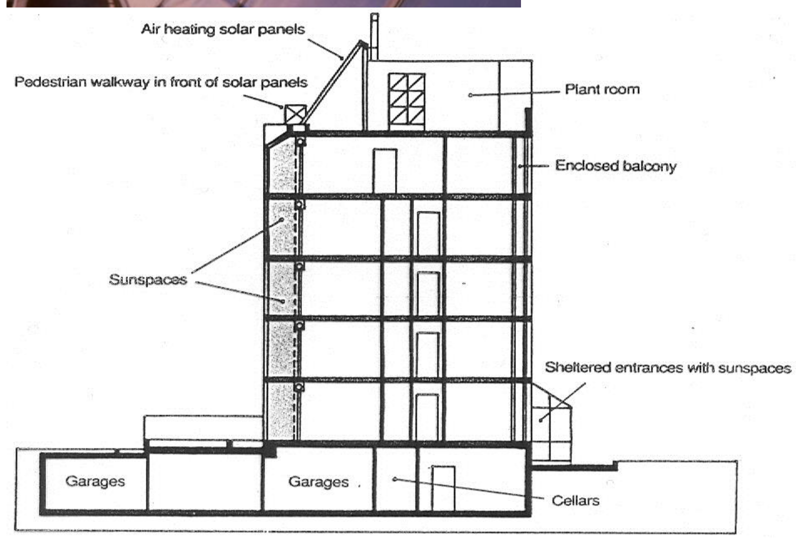
In order to maintain the efficiency of the system, a solution for the maintenance and cleaning of the collector must be predicted allowing cleaning dirt and snow removal.



Rainwater gutter serves as the access for roof maintenance.



**Prefabricated solar thermal collectors** are excellent solution for application on roof surfaces. Mounting is easier and less time is needed.

Unique in quality of the collector can be achieved in production at the factory.

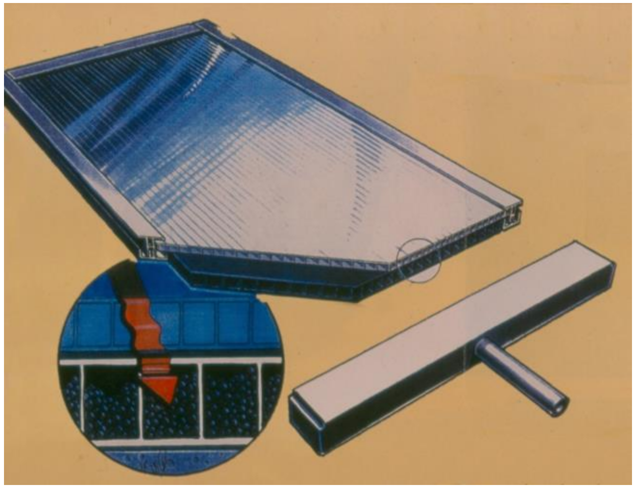
Usually it is necessary to plan storage space on building site.

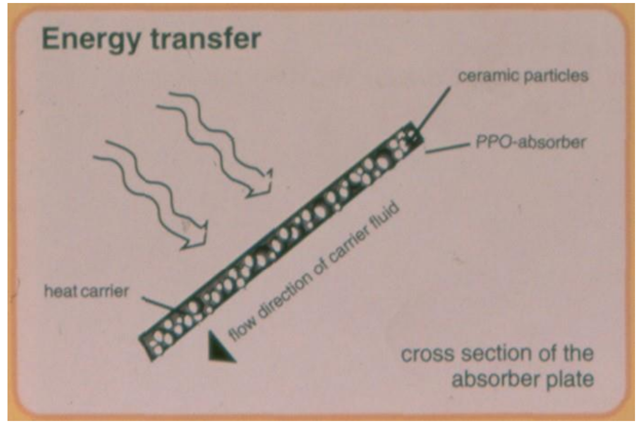
Residential Complex in Gardsten

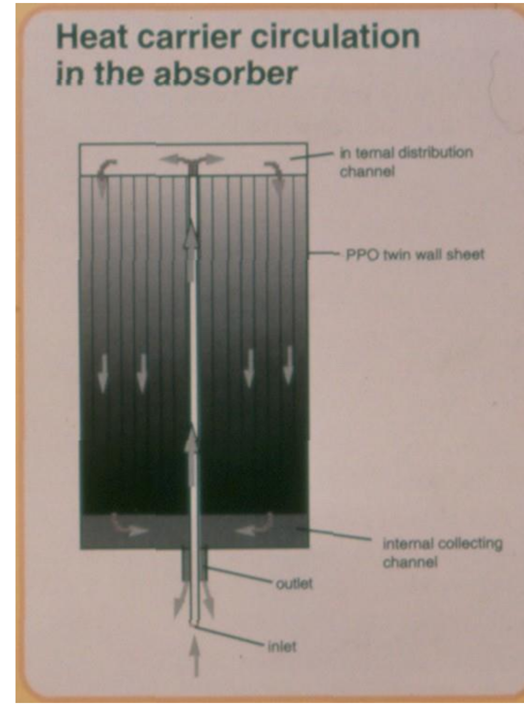
# Prefabricated solar thermal collectors

Werner Weiss, Building integration of Solar collectors, AEE-Institute for Sustainable Technologies (AEE INTEC), Austria
www.aee-intec.at

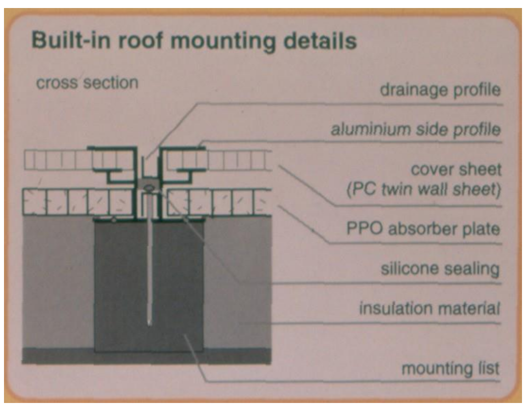
# Building Integration of Solar Thermal Systems – TU1205 – BISTS






## Polycarbonate cover sheet




SolarNor AS advertising material, Integrated Solar Systems, Blindern, Norway.

**A transparent polycarbonate (PC) twin wall sheet** or hardened glass can be used as cover sheet.

Advanced plastic material, as polycarbonates, sustains itself at high temperatures and retains excellent properties under humid conditions. This property is often called the greenhouse effect.

**The twin wall absorber sheet contains a large number of channels filled with ceramic particles**.

Its thickness is 10cm. The function of the ceramic particles is to provide good thermal contact between the carrier fluid and the energy absorbing surface of the absorber plate. This is obtained by means of the capillary effect .

The water is lifted to the top of the collector by means of pump power, while the drain-back to the storage is provided by gravity. Safety mechanism is built-in providing damages, due to boiling and freezing, to be avoided.

Collector width is 60cm, and standard lengths are 170, 255, 340, 510cm.

Specific appearance is obtained by color of the ceramic particles and structure of transparent layer.

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## Polycarbonate cover sheet

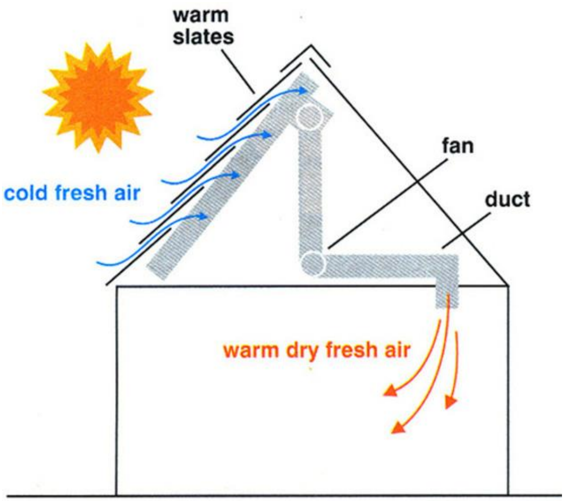
SolarNor AS advertising material, Integrated Solar Systems, Blindern, Norway.

# SOLAR THERMAL INTEGRATED ROOFS 6.2

## Construction as conventional roof cover

Contemporary roofing technology refers to placement of roofer over the substructure and the air gap between the roof tiles and underlay is ventilated.

Air that is warmed in the air gap is usually ejected and thus a significant amount of heat is lost.




Such roof structure can function as solar collector – with conventional roof appearance .
Dark colored roofer becomes the solar absorber. Air picks up heat and rises to the top of the roof by the stack effect, where it is ducted to the nearest fan and preheated fresh air is distributed into the building. In summer period gap layer is ventilated, the air is exhausted into outer space preventing the roof to be overheated. (*Berwickshire, Scotland)*



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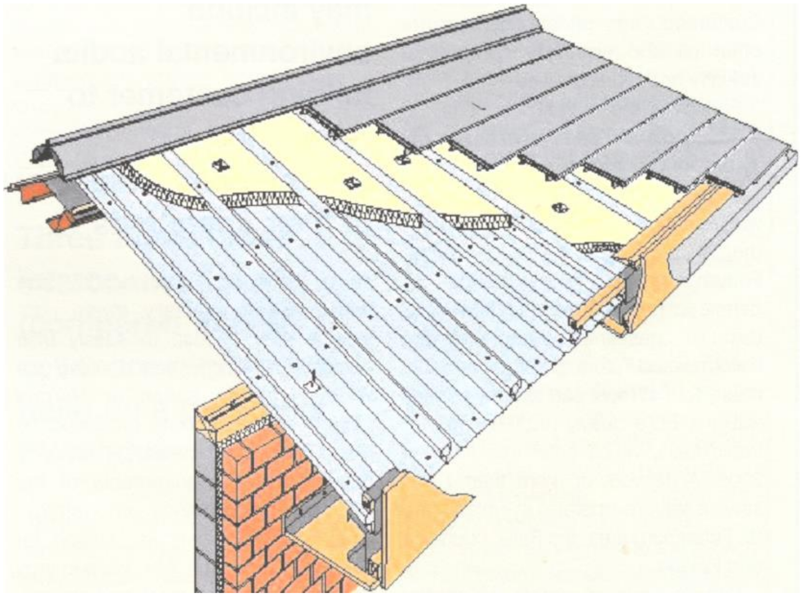

Construction as conventional roof cover with metal sheets with integrated tubes.

Roofing tile elements in which the tubes/channels are integrated. They can be mounted directly on the battens and overlap each other at the top and bottom. (*Energy Centre, Binfield, UK)*

They resemble and replace normal roof tiles, providing weather protection.
The assembly can be simplified to such an extent that it can be mounted by regular craftsman. The roof does not give the impression that it is a solar thermal collector.

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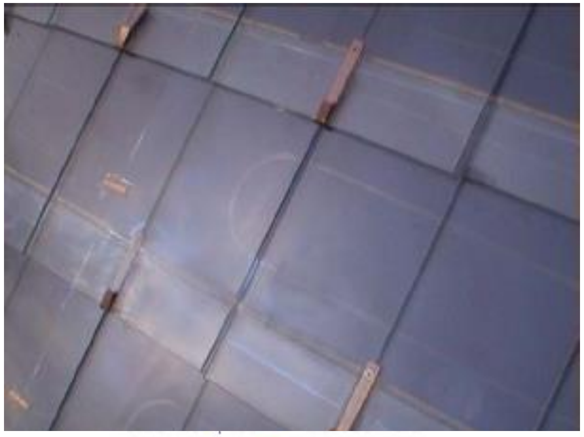
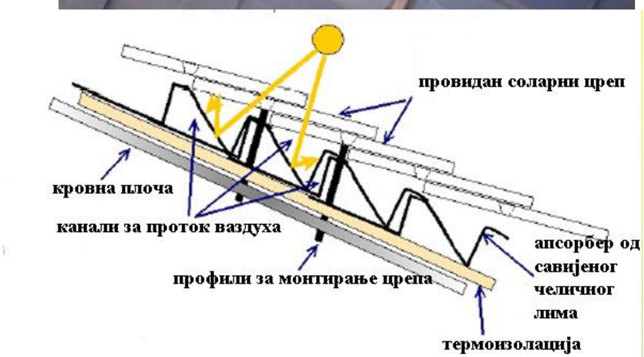
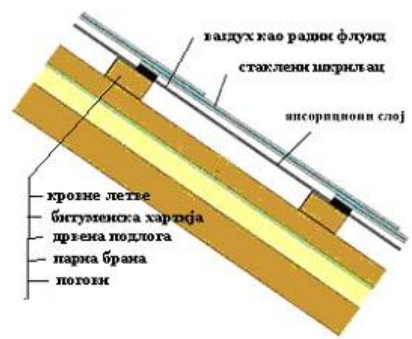
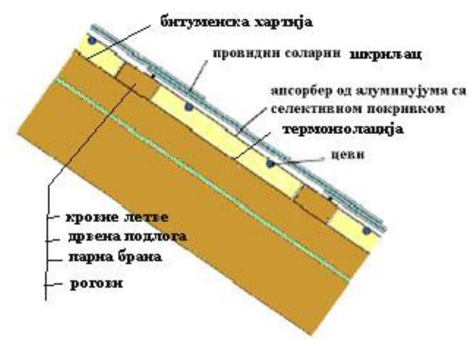





Construction as conventional roof cover with glazed roof tiles under which the tubes/channels are integrated.




They resemble and replace a normal roof tiles, providing weather protection.
The assembly can be simplified to such an extent that it can be mounted by regular craftsman.

Construction as conventional roof cover with glazed roof tiles under which the tubes/channels are integrated.

## Construction as conventional roof cover

Roof ceramic tiles as solar thermal collectors. Techtile Therma STC systems on the roof.

http://www.remenergies.it/



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# Building Integration of Solar Thermal Systems – TU1205 – BISTS

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Refurbishment of
the commercial building

**Building Integration of STC in a pitched roof,**
**Caixa Geral de Depositos, bank headquarters, Lisbon**
(data obtained from Sandra Monteiro da Silva, Ricardo Mateus, Manuela Almeida, University of Minho)

# SOLAR THERMAL SHADING DEVICES, OVERHANGS AND BALCONY RAILINGS 6.3


STC as shading device


Flat STC are preferable for overhangs as they can protect from rain and snow.


For balcony railings construction both types are suitable, but vacuum tubes enable better view of the surroundings.

**Shading devices with integrated STC** convert solar energy into thermal energy and at the same tame prevent admittance of sun rays and overheating of a room in summer.

BISTCs as shading devices are placed in front of the glazed surfaces in such a manner to provide sufficient lighting of the room, operable windows and ventilation and according to need to allow passing of sun rays into room in winter.

Regarding structure and geometry following solar thermal shading devices can be selected:

- flat STC as sloped or horizontal overhang above window,
- vacuum STC as horizontal overhang above window or like shading screen with horizontal, vertical or sloped arrangement of vacuum tubes.

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# SOLAR THERMAL SHADING DEVICES, OVERHANGS AND BALCONY RAILINGS

Shading is provided by opaque flat STC or by semi-transparency of vacuum tubes arrangement. For south orientation the most effective are horizontal overhangs, while for east and west orientation vertically placed shading elements are suitable. Building appearance is strongly influenced by the type of solar thermal shading devices. In the case of movable shading elements building envelope becomes changeable structure adaptable to day and season changes - "alive" structure.

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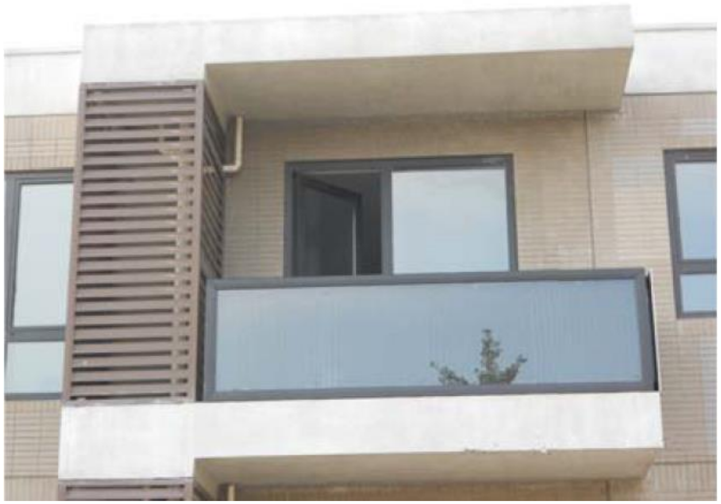
## SOLAR THERMAL BALCONY RAILINGS



**Beijing, China, flat STC as balcony rail**

**Balcony rails, Porto, Vacuum and flat STC**

(data obtained from Sandra Monteiro da Silva, Ricardo Mateus, Manuela Almeida, University of  Minho; Source: Basnet 2012.

# NEW ARCHITECTURAL DESIGN OPTIONS

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**Integration of STSs into building envelopes produce a constant provocation and challenge to architects and engineers for creation of new architectural design options which refers to:**

**- Functional possibilities-multifunctional concepts.**

**- Structural complexity.**

**- Light permeability and transparency.**

**- Adaptability - changeable appearance and function.**

**- Architectural attractiveness – variety of forms, shapes, dimensions...**

**- Prefabrication.**

**Multifunctional Concepts and Structural Complexity**

**- heating and cooling potentials, production of thermal and electrical energy, (case study a.),**

**- shading potential with light permeability and production of thermal and electrical energy (case study b. and c.),**

**- transparency,**

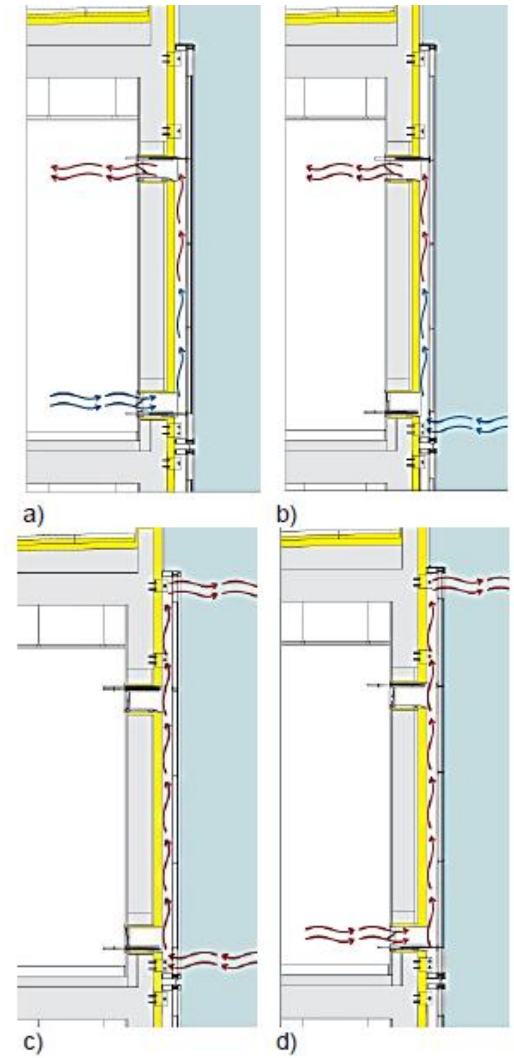
## Case study a. Double facade as hybrid PVBI/T system

Office building, Lisbon (data obtained from Laura Aelenea, Ana Rute Ferreira, LNEG)

Cooling description: During cooling season is important to extract the heat from the modules to the environment. Therefore, the most used functional situation is the extraction of the heat to outside through the two external vents (case c), in this situation the internal vents are closed. Another possible situation in terms of functional use, is the evacuation of the hot air from the room through the lower internal vents, and use the “chimney effect” released to the outside (case d).

Heating description: The heat released in the process of converting solar radiation into power is successfully recovered (natural convection) and insufflated into adjacent room, as a heating strategy for the improvement of the indoor climate during heating season in the day time hours (case a).

In the mid-season months, the system can function as a fresh air pre-heating system in which air is admitted from outside through the lower vents, which heats thereafter in the air gap of BIPV-T before insufflated directly into the room by natural convection through the upper internal vents (case b).

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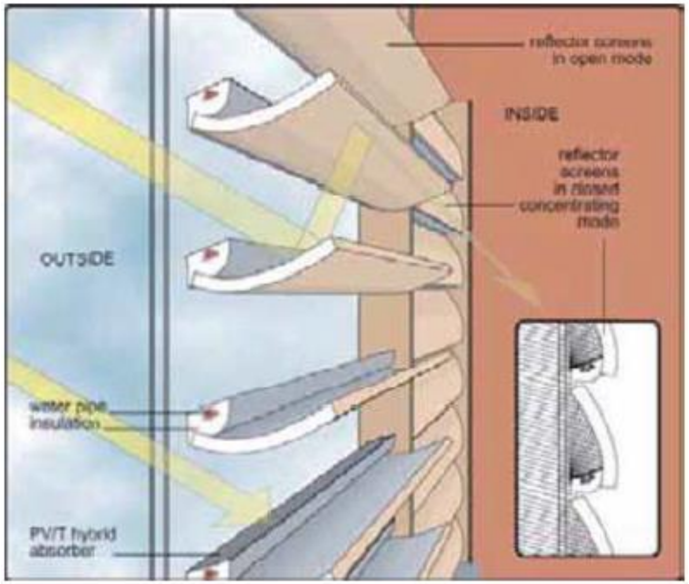
## Case study b. Solar Window, Lund, Sweden (Information obtained from Dr Mervyn Smyth, Uni of Ulster)




The presence of the hybrid PV/T system inside a window makes it highly visible from the exterior as well as the interior. One of the basic ideas behind the design was to express the building integrated solar energy system architecturally in an attractive, maximally exposed way. The curved concentrating geometry is decorative and expresses the capturing nature of a solar energy system. The backside facing the interior could be covered with any surface material suitable for the interior context. The modular nature of the reflectors, with no connection to the energy distribution, makes it possible to exchange them for alternative surface, thickness or reflecting geometry. The concave front facing the window will be highly visible from the exterior, and the mirror like surface might be the most critical aesthetical property for a wider acceptance. However, the curved mirror can generate interesting optical expressions in the façade. The overall impression of the façade will hence change when approaching it. The mobility of the reflectors also contributes to a dynamic façade expression.

**House on Durand DR, Hollywood, CA** (data obtained from Contantinos Vassiliades)

*With the integration of passive and active solar technologies, the house offers thermal comfort all year round without the need for air conditioning. In the southern side of the building, the building integrated solar thermal system, functions both as blinds for shading of the building, as well as solar thermal system that provides hot water used for household needs in the water and on floor heating. The thermal solar collector is invisible, fully integrated and does not distract from the clean architectural lines of the building.*

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# ARCHITECTURAL PLANNING/INTEGRATION

**Design of multifunctional building envelopes is particularly complex task asking for a multidisciplinary approach. From the architectural viewpoint the design process of building integrated solar thermal systems (BISTS) should include the following research steps:**

- **Prediction of amount of energy demands that should be covered by STC.**

Predicting the amount of energy demands to be covered by solar thermal collectors, indicates the required area of building envelope surfaces appropriate for STC integration.

- **Evaluation of building potential for STC integration based on climatic data, urban layout and building technology system characteristics.**
- **Discussion of location and position of STC on the building envelope taking into account functional and aesthetic aspects, as well as mounting options (creation of design scenarios).**
- **Calculation of energy benefits of different design scenarios.**
- **Estimation of environmental benefits of different design scenarios.**
- **Multi-Criteria comparative analysis of different design scenarios (aesthetic, energy, ecological, economic, etc. criteria).**
- **Selection of optimal STC integration scenario.**

# Building Integration of Solar Thermal Systems – TU1205 – BISTS

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## CONCLUSIONS

Facades and roofs with BIST systems present type of **energy efficient building envelops** that convert solar energy into thermal energy and at the same time protect from atmospheric influences.

**BISTS contribute to nature and environment protection.**

BISTS can be used in construction of new and refurbishment of existing buildings.

BISTS influence on buildings and settlements appearances is significant resulting in **visual identity of buildings and settlements.**

The integration of STCs into building envelopes is **challenge to architects**.

Production of BISTS is new **provocation and orientation for building industry**.

**Apartment buildings, "Utopia Garden" project, Dezhou, China.**

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# Thank you for your attention

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