Example name: Integration of Solar Thermal Collectors in the Building Envelope at Settlement Konjarnik, Belgrade, Serbia

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Figure 1. BISTS Design Variants

(a) I Design Variant: roof 40˚ (roof and facade layouts); (b) II Design Variant: parapet 90˚; (c) III Design Variant: parapet 45˚; (d) IV Design Variant: sun shading 0˚

For installations

BISTS Location: *Belgrade, longitude 20°28′5″, latitude 44°49′6″*
Climate Type: *Köppen climate classification – the humid subtropical (Cfa) climate zone*
Building Use: *residential*

Level of BISTS integration
Rush classification: Visible, surface change
Reijenga classification: Adding to the architectural image

O New Build
O Refurbishment (marked)
O Other: ……………………

Drawings/Sketches/Cross-sections

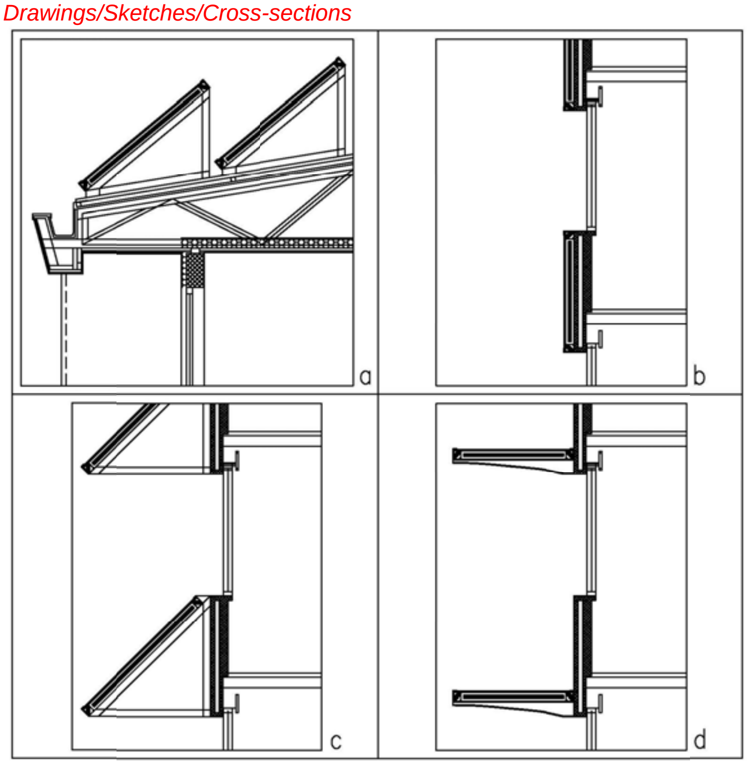


Figure 2. Design Variants I – IV (a - d) cross-sections

Type of BISTS:

Active

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

Building element:

O Facade (marked)
O Roof (marked)
O Other: sun shading (marked)

BISTS characteristics:

For example…..Collection area….m^2, Orientation/inclination, Energy output, Contribution to building load, Material/colour/texture, Pre-fabricated off-site? Structural load, Other

Solar thermal collectors are integrated in the south oriented building facade and roof surfaces, with the deviation to the west about 10° (Figures 1 and 2):

- I Design Variant: solar panels mounted on the roof and tilted at 40°, area of 100 m^2 (Fig. 1a - roof and facade layouts and 2a),
- II Design Variant: solar panels integrated in parapets (vertical position-90°), area of 90 m^2 (Fig. 1b and 2b),
- III Design Variant: solar panels integrated in parapets and tilted at 45°, area of 120 m^2 (Fig. 1c and 2c),
- IV Design Variant: solar panels integrated as sun shadings (horizontal position-0°), area of 55 m^2 (Fig. 1d and 2d).

Flat solar thermal collectors with liquid working medium (Table 1) have been proposed for integration in building envelope and used for the calculations and simulations of solar thermal systems for all design variants, which were done in Polysun 4 Version 4.3.0.1.

Table 1. Characteristics of flat solar thermal collectors with liquid working medium used for integration in building envelope (*the type dimension from catalogue, which can be changed, and is different for different examples)

manufacturer	Institut fur Solartechnik SPF
absorber area (m^2)*	1.8
glazing area (m^2)*	1.8
total area of the foreground of the chasing (m^2)*	2
max temperature (°C)	220
max flow rate (l/h)	2000
heat capacity (J/K)	5000

Stage of Development:

Responsible: *Research institute, Company, etc.*

O	Idea/Patent	Faculty of Architecture, University of Belgrade
O	Prototype	…………………………………..
O	Demonstration	…………………………………..
O	Integral building element	…………………………………..
O	Commercially available	…………………………………..

BISTS description and context

The project motivation is to show different design solutions and benefits of integration of solar thermal collectors in envelope of multifamily housing building in Konjarnik settlement, Belgrade (Figure 3). Considering complexity of integration of active solar systems, the following aspects of integration of active solar systems are analysed: energy, architectural, ecology and economy aspects.

Figure 3. Appearance of housing in Konjarnik settlement

The multifamily housing building (the 8-storey building - ground floor, 6 floors and attic) has rectangular and compact form and consists of 5 blocks. It is located in a semi-closed block, on the south oriented hillside. Its longer, east-west axis is parallel to the isohypses. The neighbouring buildings are sufficiently far to prevent overshading. One of the central blocks, with four one-side oriented flats, is chosen for the analyses. The block has the following characteristic dimensions: width = 13.30m, length = 25m, height = 22.60m, heated floor area = 242m^2, heated building area = 1,938m^2, heated building volume = 5,470m^3. Facades are consisting of rows of windows and parapets, or windows and loggias.

System viability

For example….Economic viability (capital and running costs), maintenance, embodied energy, environmental impact and sustainability, wider social contexts

Analysis and the results will later be entered.

Modelling and simulation tools developed/used

For example….new modules/types created for established simulation programs, stand-alone modelling, use of generalised codes, model outcomes, validation and accuracy. Design tools developed

BISTS Performance data

Based on:
O Estimation
O Detailed simulation
Specify software(s) used
O Measurement/testing
O Long-term monitoring
tick all that apply

Performance parameters

For integrated systems:
key performance indicators -

Solar savings fraction: %

Satisfaction of monthly water heating energy demands (Figure 4):

- Collectors mounted on the roof and tilted at 40˚: from min 19.6% in December to max 84.9% in August;
- Collectors integrated in parapets (vertical position-90˚): from min 23.9% in January to max 47.8% in September;
- Collectors integrated in parapets and tilted at 45˚: from min 22.9 % in January to max 79.3 % in August;
- Collectors integrated as sun shadings (horizontal position-0˚): from min 2.7 % in January to max 45.3 % in August.

At the yearly basis, it is evident that design variants of solar thermal collectors' integration can meet from min 23.4% (Sun Shading 0˚) to max 53.6% (Roof 40˚) hot water demands (Figure 5).

Light transmittance: %
Solar transmittance: %
Total solar energy transmittance: %:
Solar heat gain factor: %
Building fabric U-values: W/m^{2}K
Noise, fire, etc ratings

Other:

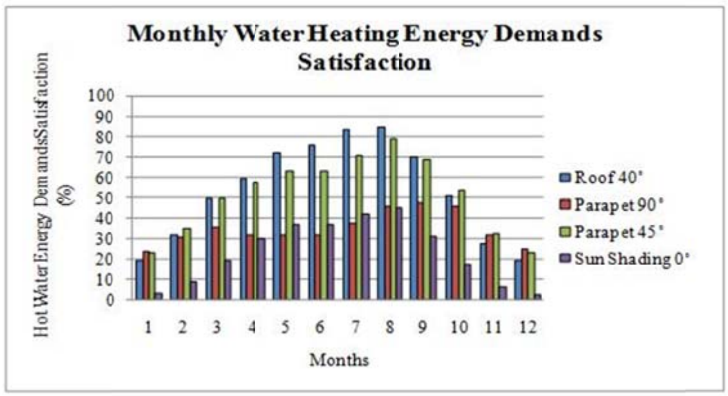


Figure 4.

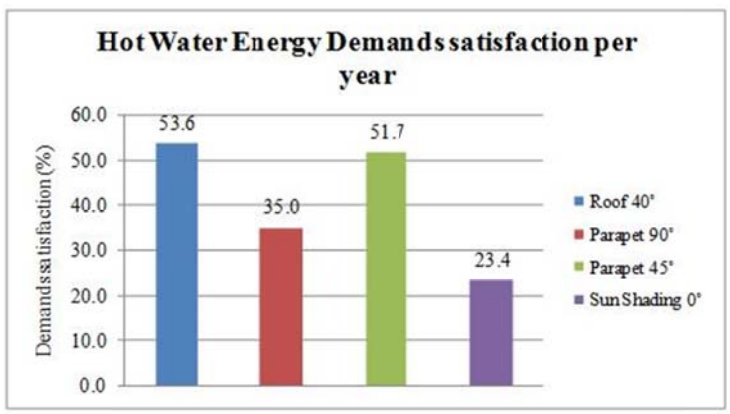


Figure 5.

Monthly thermal energy production (Figure 6 and 7):

- Collectors on the roof and tilted at 40˚: from min 1,492kWh in December to max 6,605kWh in August; per m^2 from min 14.9kWh/m^2 in December to max 66.1kWh/m^2 in August;
- Collectors integrated in parapets (vertical position-90˚): from min 1,858kWh in January to max 3,603kWh in September; per m^2 from min 20.6kWh/m^2 in January to max 40kWh/m^2 in September;
- Collectors integrated in parapets and tilted at 45˚: from min 1,780kWh in January to max 6,169kWh in August; per m^2 from min 14.8kWh/m^2 in January to max 51.4kWh/m^2 in August;
- Collectors integrated as sun shadings (horizontal position-0): from min 208kWh in January to max 3,524kWh in August; per m^2 from min 3.8kWh/m^2 in January to max 64.1kWh/m2 in August.

For comparative analysis of energy performances of collector integration design variants at the yearly basis, calculation of thermal energy production and average thermal energy production per m^2 per year are carried out and shown in Figures 8 and 9.

At the yearly basis, it is evident that design variants with integrated solar thermal collectors can produce thermal energy from min 21,475.5kWh (Sun shading 0˚) to max 49,269.5kWh (Roof 40˚). Thermal energy production per m^2 varies from min 356.8kWh/m^2 (Parapet 90˚) to max 492.7kWh/m^2 (Roof 40˚).

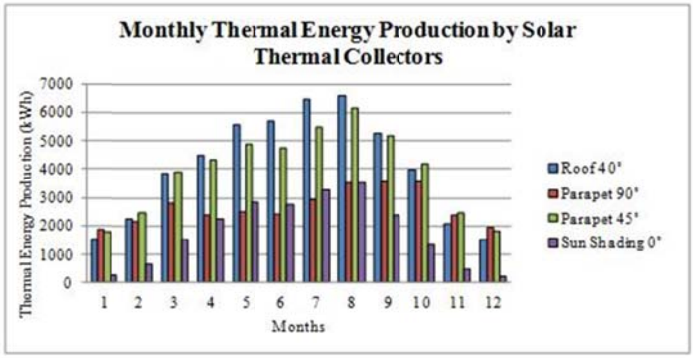


Figure 6.

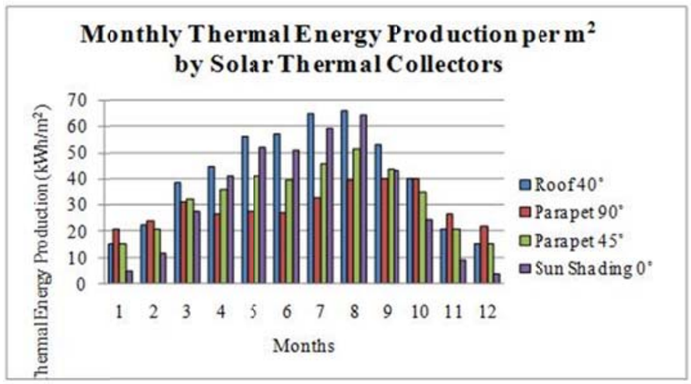


Figure 7.

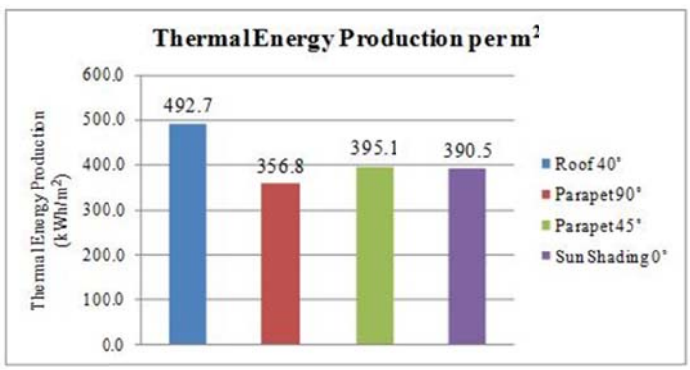


Figure 8.

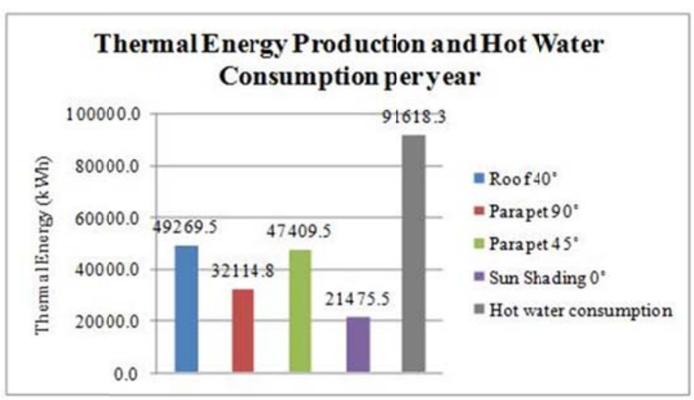


Figure 9.

The problem of CO_2 emissions is analysed with assumption that mentioned consumer heats water by electrical energy when the hot water from collectors cannot be provided. Electrical energy consumption for water heating is shown in Table 2. By using the conversion factor (2.5) for electricity as a heat source for water heating, the annual primary energy consumption for water heating is calculated (according to the Serbian Regulations on energy efficiency of buildings) and shown in Table 3. Estimation of emissions of the electrical power networks is based on the fact that for production of 1 kWh, CO_2 emission amounts 0.53 kg in Serbia (according to the Regulations on energy efficiency of buildings). Values of CO_2 emissions are presented in Table 3 for all proposed design variants of thermal collectors' integration, while CO_2 reduction achieved by solar thermal collectors is shown in Table 4.

Other:

- Needs for hot water are defined on the basis of number of apartments and inhabitants in the block. There are 28 apartments in one block and 90 occupants inside them altogether. Daily need for hot water per person is 50-100ℓ. For the calculation is adopted daily consumption of 80ℓ of hot water per person, therefore in total for one block 90 (inhabitants) x 8ℓ (consumption per person) = 7200 ℓ. Adopted hot water temperature is 50°C. In terms of thermal energy, it is 251 kWh per day, i.e. 91618.3 kWh per year for one block.
- For calculation in the program is adopted additional water heating by electricity (to meet the 100% of hot water needs, because it is impossible always to satisfy all needs by solar energy).

For separate collectors:
performance rating coefficients - (EN12975, a0,a1,a2), ASHRAE, etc

Table 2. Electrical energy consumption for water heating

	Existing building	Building with solar thermal collectors			
		Roof 40°	Parapet 90°	Parapet 45°	Sun Shading 0°
kWh/a	**91,618.3**	**42,348.8**	**59,503.5**	**44,208.8**	**70,142.8**

Table 3. Primary energy consumption for water heating and CO_2 emissions

	Existing building	Building with solar thermal collectors			
		Roof 40°	Parapet 90°	Parapet 45°	Sun Shading 0°
kWh/a	**229,045.75**	**105,872**	**148,758.75**	**110,522**	**175357**
CO_2 emissions kg/year	**121,394.25**	**56,112.16**	**78,842.14**	**58,576.66**	**92,939.21**

Table 4. CO_2 reduction achieved by solar thermal collectors

	Roof 40°	Parapet 90°	Parapet 45°	Sun Shading 0°
kg/year	**65,282.09**	**42,552.11**	**62,817.59**	**28,455.04**

Additional information:

Calculations and simulations of solar thermal systems for all design variants were done in Polysun 4 Version 4.3.0.1. In calculations, the existing water heating system fully based on electricity was substituted with the new system – solar thermal collectors (AKS Doma – manufacturer), with the auxiliary system powered by electricity.

In the calculation, the heating of the water from 20° to 45°C is conceived by the system with solar thermal collectors with the auxiliary system powered by fuel oil. Losses of solar system are assumed as included into 40ℓ/person daily consumption.

Sources and references:

Golic, K., Kosoric, V., Krstic-Furundzic, A. (2011) General model of solar water heating system integration in residential building refurbishment-Potential energy savings and environmental impact. Renewable&Sustainable Energy Reviews International Journal, Volume 15, Issue 3, Elsevier, pp. 1533-1544.

Krstic-Furundzic, A., Kosoric, V. (2010) Reduction of CO2 emissions through solar thermal collectors’ application on student housings in Belgrade. In: Vincent Buhagiar (Ed.) Strategies for a Low Carbon Urban Built Environment. Malta: Institute for Structural Engineering, Bundeswehr University, Munich, Welsh School of Architecture, Cardiff University, Faculty for the Built Environment, University of Malta, Msida, Cost Office, Midsea Books Ltd., pp. 12-21.

Krstic-Furundzic, A., Kosoric, V., Golic, K. (2012) Potential for reduction of CO2 emissions by integration of solar water heating systems on student dormitories through building refurbishment. Sustainable Cities and Society International Journal, Volume 2, Issue 1, Elsevier, pp. 50-62.

Krstic-Furundzic, A., Kosic, T., Grujic, M. (2010) Energy, ecological and economic aspects of improvement of the dwelling housing in Belgrade. In: Installation&Architecture, Thematic conference Proceedings, Belgrade: Faculty of Architecture, University of Belgrade, pp. 39-47.

Regulations on energy efficiency of buildings, Official Gazette RS, No. 72/09, 81/09 – revise, 64/10 and 24/11, pp. 58.

Regulations on terms, content and method of issuing certificates of energy performance of buildings, Official Gazette RS, No. 61/11, pp. 8

INSTRUCTIONS

Please fill in as much information as possible.

Tick where appropriate.

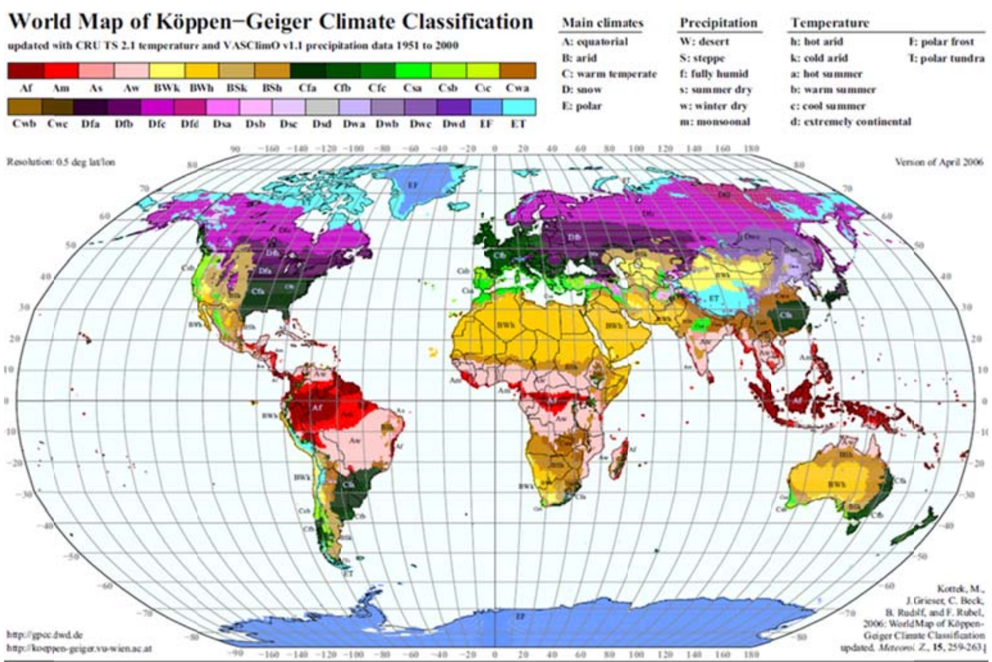
Text in red is suggested guidance. Insert information in provided space, removing red text as appropriate

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’