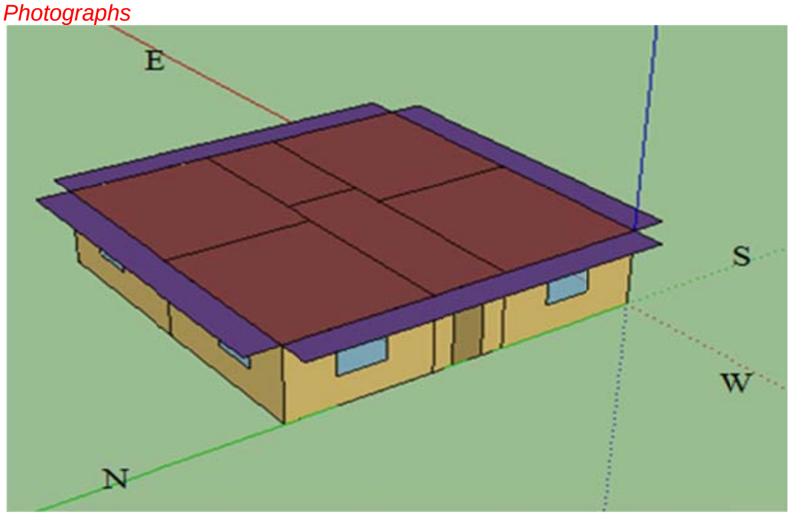
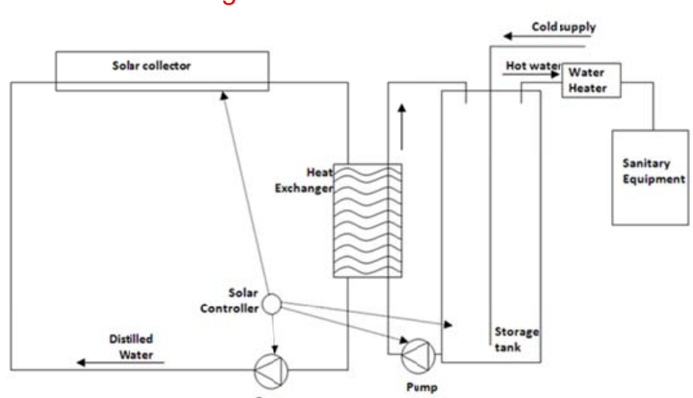
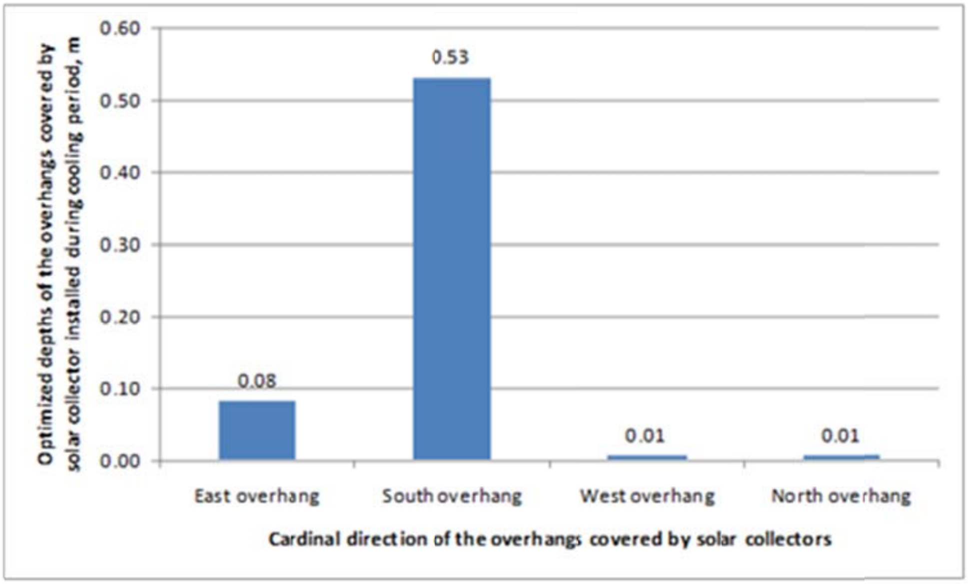
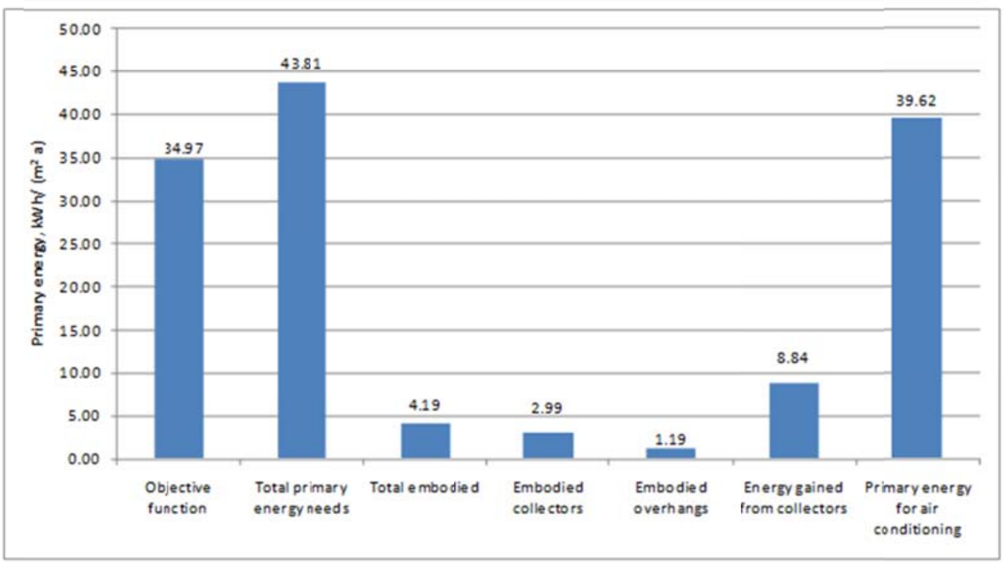
Example name: Overhangs by using Solar Collectors for summer houses

Template completed by: *Milorad Bojic, University of Kragujevac, bojic@kg.ac.rs*	*Photographs* 
For installations BISTS Location: *place=Kragujevac, Serbia, longitude=20.92^0East, latitude=44.02^0North.* Climate Type: *Köppen climate classification=Dfb* Building Use: *Residential summer house* Level of BISTS integration Level 3. Visible, surface change Ox New Build O Refurbishment O Other: ……………………	
Type of BISTS: Active/Passive Function(s): Ox Water heating Ox Cooling/ shading	At the same time, BISTS is active and passive. It is active as the roof overhang is solar collector producing hot water. It is also of passive type as it can decrease space cooling due to shading, and it may influence the use of natural light and electricity due to a need for artificial light. 
Building element: Ox Roof overhangs	

BISTS characteristics:

For example…..Collection area 4 m^2, Orientation (see below) /inclination (horizontal), Energy output, Contribution to building load (see below), Material/colour/texture (that of solar collectors), Pre-fabricated off-site? (yes) Structural load (taken care about by pre-calculation), Other





Stage of Development: **Responsible:** *Faculty of Engineering, University of Kragujevac, Serbia.*

Ox Idea/Patent ……………………………………..
O Prototype ……………………………………..
O Demonstration ……………………………………..
O Integral building element ……………………………………..
O Commercially available ……………………………………..
tick all that apply

BISTS description and context

For example….Building size, form and function, project motivation, particular features, architectural attributes

The investigated house is located in Belgrade, Serbia. The house has a plane roof. The house is used by one family, and has the living area of 117m^2. The house has 4 air-conditioned rooms. Each air-conditioned room has the exterior walls, external windows, interior walls, ceilings, and floors of the same size and composition. In each room, all windows are set to the identical geometrical position relative to the boundaries of room. The exterior walls are made (from inside to the outside) by using 0.02 m of plaster, 0.19 m of porous brick, 0.05m of polystyrene (as a thermal insulating layer), and 0.02m of plaster. They have U-value of 0.57 W/(m^{2}K). The windows are double glazed with the air gap of 15mm having U-value of 2.72 W/(m^{2}K). The overall area ratio of the windows to the entire envelope walls is 0.14, where the total area of the envelope is 112 m^2 and the total area of the windows 19 m^2. The roof is made (from top to bottom) by using 0.08 m of mineral wool (as a thermal insulation layer), 0.04 m of cement screed, 0.16 m of porous brick, and 0.015m of plaster. It has a U-value of 0.40 W/(m^{2}K). The floor has a U-value of 0.47 W/(m^{2}K). The installed windows and doors on the building envelope provide the infiltration of 0.5 ach.

The project motivation is to mount the solar collector with the optimal dimensions when the house is erected.

System viability

Economic viability (capital and running costs)-not calculated, maintenance-not calculated, embodied energy-taken into account (for concrete 1.92 MJ/kg, for solar collectors 1720 MJ/m^2), environmental impact and sustainability-calculated through the energy ratio (2.68) and energy payback period (3.81a). Wider social context was not researched.

Modelling and simulation tools developed/used

Design tool is developed that uses simulations to obtain the overhang dimensions, direction, and inclinations and the effect of the overhang installations. For simulations, EnergyPlus is used with OpenStudio while the optimisations are done by using Genopt software. The new code is developed and Hooke Jeves optimization algorithms are usedThe simulation results are taken from EnergyPlus, and overhangs depths are changed in Genopt and their new values are sent to EnergyPlus. New simulation results are compared with old one, and new depths of the overhangs are automatically given by Genopt according to previous simulation results.

1. EnergyPlus

To simulate heating, cooling, lighting, ventilation, water network, and other energy flows in a built environment, EnergyPlus software can be used. This software can model energy use in a residential building. EnergyPlus takes into account all factors that influence thermal loads in the building, such as electricity devices, lighting, pipes in the building, solar radiation, wind, infiltration, and shading of open rooms [24]. This software enables us to simulate energy behaviour of the residential buildings for defined period. EnergyPlus software enables modelling of space heating of residential buildings taking into account all heat losses and gains. This software enables modelling of different scenarios of the building heating.

2. OpenStudio

For the purpose of the simulations house models are created in Google SketchUp and then implemented in EnergyPlus by using OpenStudio plugin [25].

3. Genopt

GenOpt is an optimization code used for the minimization of a function that is evaluated by an external simulation program, such as EnergyPlus, TRNSYS, SPARK, IDA-ICE or DOE-2. It has been developed for the optimization problems where the cost function is computationally expensive and its derivatives are not available or may not even exist. GenOpt can be coupled to any simulation program that reads its input from text files and writes its output to text files. The independent variables can be continuous variables (possibly with lower and upper bounds), discrete variables, or both. Constraints on dependent variables can be implemented using penalty or barrier functions [26].

3. Optimization Algorithm

In this investigation using GenOpt, the depths of the overhangs are optimized. A minimum depth of the overhang is taken to be 0.001m. A maximum depth of the overhang is set to 10m. The optimization method is that of Hooke-Jeeves [27]. The initial depth for all simulations is set to 1m and the optimization step is 1. The number of step reduction is set to 7. So the precision of the results is better than the 0.01m (1cm). The maximum number of iterations is set to 2000, but it is not reached (the maximum number of iterations is lower than 200 in all cases).

How optimum was found is shown in Fig.5.

4. New code modules

New code modules are created for established simulation programs

(1) The embodied energy, used when a building is specified, designed, and constructed for overhang and collectors.

(2) The annual primary energy consumption for cooling.

(3) The annual total primary energy consumption is the sum of the primary energy consumption for cooling and the annual embodied energy.

(4) The objective function presents the annual total primary energy consumption minus the annual energy of hot thermal water from solar collector which is gained for the time of simulation.

(5) The energy ratio is presents the ratio between saved energy for cooling and embodied energy during lifecycle for the house with overhangs covered with solar collectors.

(6) The energy payback period for the house with overhangs covered by solar collectors.

5. Model outcomes are the overhang dimensions, energy ratio and energy payback period.

6. Validation and accuracy will be done in the future.

BISTS Performance data

Based on:
O Estimation
Ox Detailed simulation
EnergyPlus, OpenStudio, Genopt, Optimization algorithm, New code
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: %
Light transmittance: %
Solar transmittance: %
Total solar energy transmittance: %:
Solar heat gain factor: %
Building fabric U-values: W/m^2K
Noise, fire, etc ratings
Other:

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

Graphs for collector efficiency, seasonal energy gains, diurnal/seasonal solar fraction, etc.

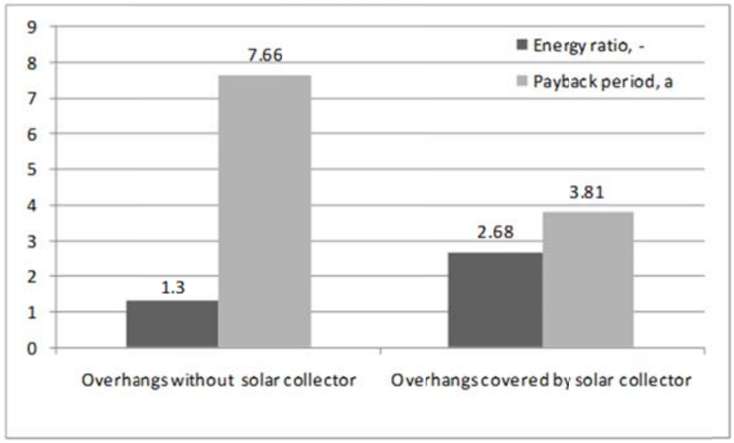


Fig. 10. Energy ratio and payback period for the inspected cases

Additional information:

Sources and references:

[1] D. Crawley, L. Lawrie, F. Winkelmann, W. Buhl, Y. Joe Huang, C. Pedersen, R. Strand, R. Liesen, D. Fisher, M. Witte, J. Glazer, EnergyPlus: creating a new-generation building energy simulation program, Energy and Buildings. 33 (2001) 319-331.

[2] Website – http://en.wikipedia.org/wiki/SketchUp, [accessed 18.3.2012].

[3] Website – http://simulationresearch.lbl.gov/GO/, [accessed 8.8.20121].

[4] Hooke, R.; Jeeves, T.A. (1961). "'Direct search' solution of numerical and statistical problems". Journal of the Association for Computing Machinery (ACM) 8 (2): 212–229. doi:10.1145/321062.321069.

INSTRUCTIONS

Please fill in as much information as possible.

Tick where appropriate.

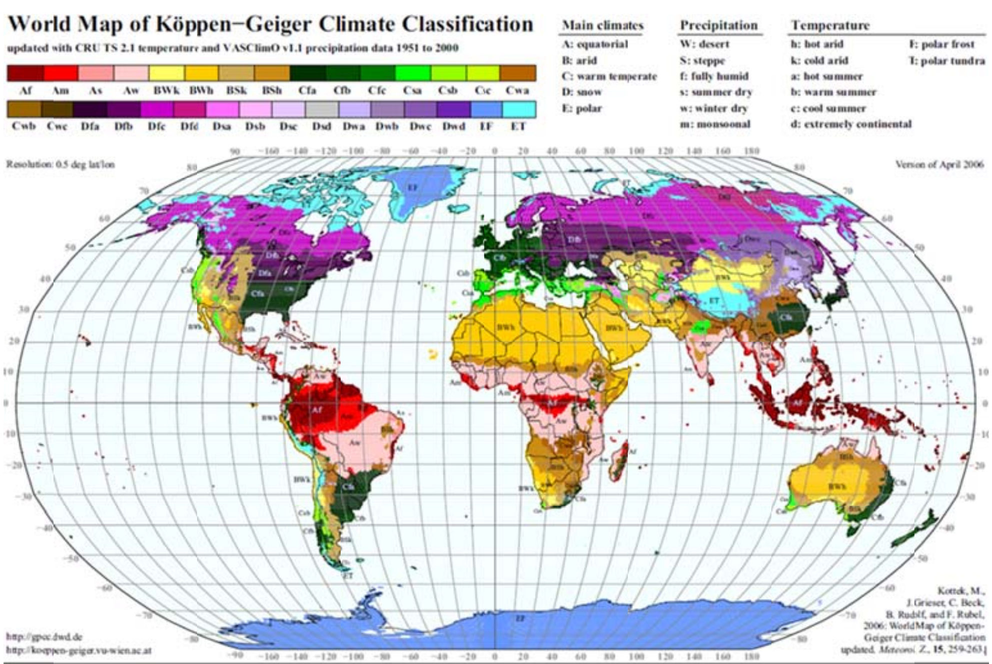
Text in red is suggested guidance. Insert information in provided space, removing red text as appropriate

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'