Roof high vacuum flat type solar thermal collectors for high temperature outlet fluid for solar heating and cooling (by double stage absorption chiller)

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For installations

BISTS Location: *Naples (Italy), longitude 14°16'36"12 E, latitude 40°51'46"80 N*
Climate Type: *Köppen climate classification = Csa*
Building Use: *Non-residential building (offices, expo space, conference room)*

Level of BISTS integration
Classifications: Rush = 2 and Reijenga = 3.

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

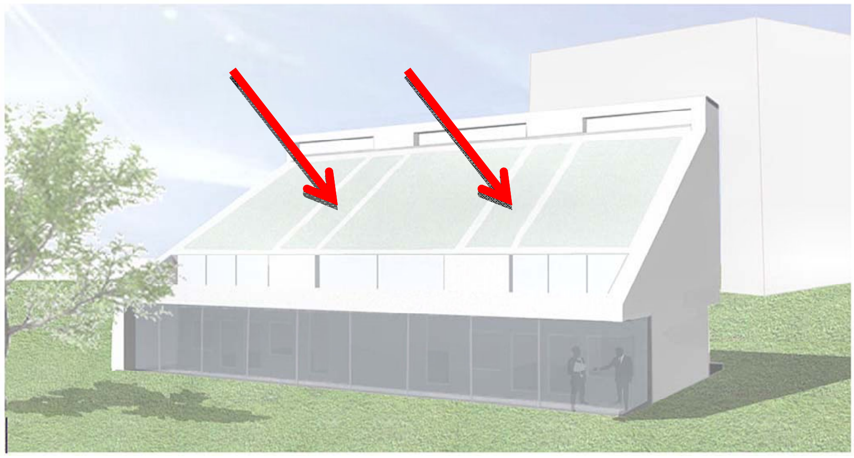


Figure 1. NZEB prototype of the Municipality of Naples (South-Italy)

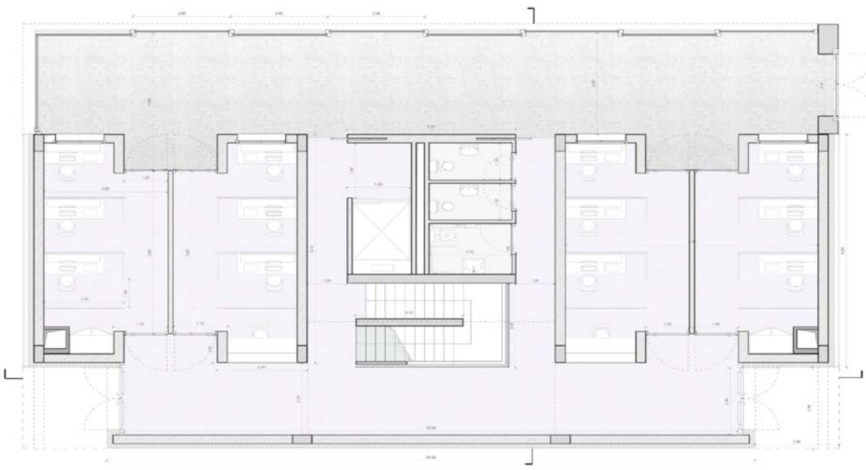


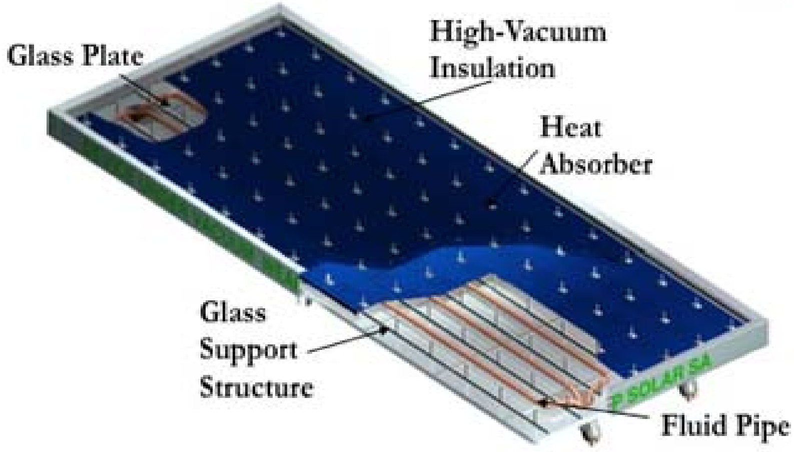
Figure 2: Plant view (offices) of the NZEB of the Municipality of Naples

Type of BISTS: hybrid

Function(s):

- ✕ Water heating
- ✕ Combi-system
- ✕ Cooling/ventilation/shading
- ✕ linked to double stage absorption chiller for solar cooling

This BISTS is active and passive, simultaneously. The active-mode regards the space solar heating and cooling obtained by the produced hot water. The system can be also considered as passive since it decreases the heating load (by the high efficient thermal insulation obtained by the deep vacuum into the collector).



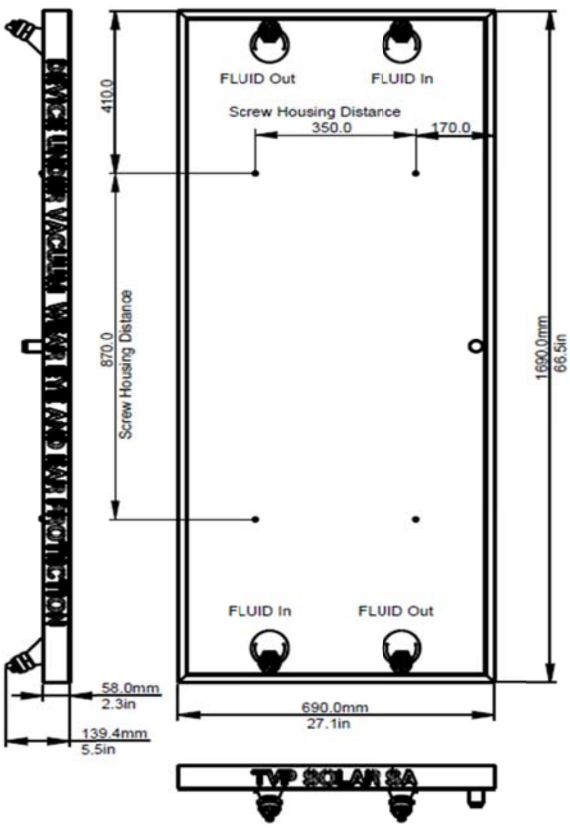


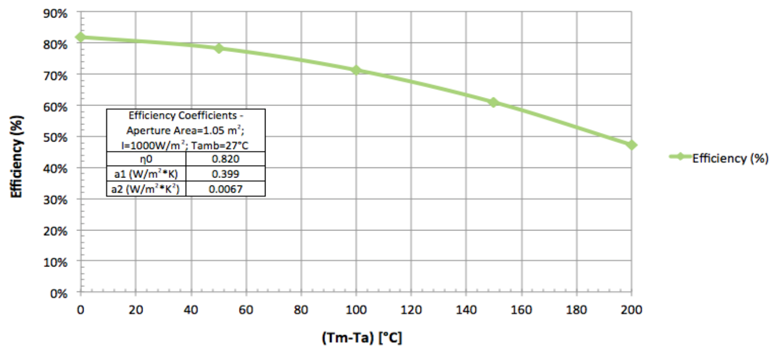
Figure 3. High vacuum, high temperature solar collector (TVP Solar – Tresol)

Building element:

✕ Facade

✕ Roof

O Other: ……………………..



Incidence Angle Modifier (IAM) Coefficients								
Einfallswinkel θ *incident angle θ*	0	20	30	40	50	60	70	90
$K_{ab}(\theta)$:	1	0.99	0.98	0.95	0.91	0.84	0.70	0.00

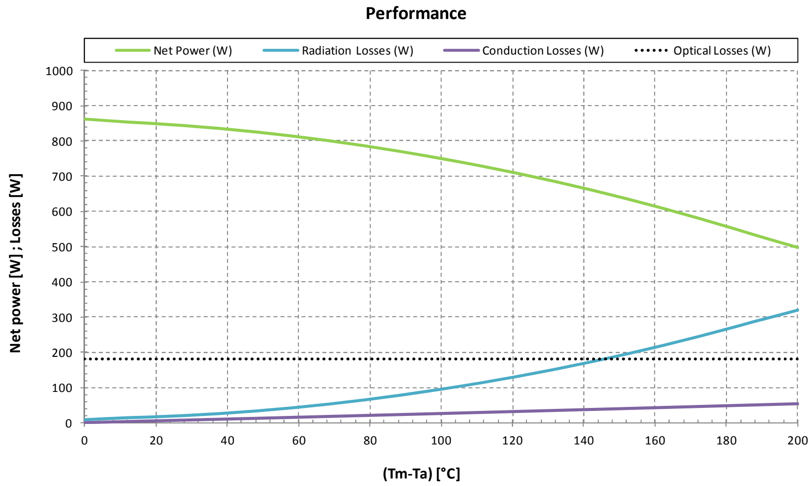


Figure 4. Efficiency and performance parameters (TVP Solar – Tresol, HT-Power panels v. 4.0)

BISTS characteristics:
Technology: high vacuum (10^{-4} - 10^{-9} mbar) flat type solar thermal collector for high temperature outlet fluid (up to 250°C) for solar heating and cooling and DHW preparation, Figure 3
Collection area: 58 m^2(total), each module is 1690 mm length x 690 mm width
Inclination/Orientation: 30º/South roof
Peak power installed: 29 kW (@ 180°C); 37 kW (@ 130°C)
Produced Energy (heating): 7.56 MWh/y
Produced Energy (cooling): 13.6 MWh/y
Contribution to building load: 90% (heating); 93% (cooling)
Pre-fabrication off-site: Yes

The South oriented tilted roof is designed with a slope of 30° in order to maximize the yearly energy performance of the solar field. Here, solar thermal collectors (two vertical narrow rows in Figure 1) are integrated in the building roof. The modules efficiency and performance curves are reported in Figure 4. The BISTS is utilized for both winter and summer seasons.

- *Heating season* - The thermal energy released by the solar collectors is suitably exploited for space heating (supporting the building HVAC system) and for domestic hot water preparation.
- *Cooling season* - The outlet hot fluid released by the solar thermal panels is suitably exploited for space cooling (supporting the building HVAC system). In particular, the obtained hot water (up to 250°C) supplies a 26 kW H_2O/LiBr double stage absorption chiller.

Stage of Development:

× Idea/Patent
× Prototype
× Demonstration
O Integral building element
× Commercially available

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BISTS description and context

The building project initiative stems from the action ED6 of the Sustainable Energy Action Plan (SEAP, Covenant of Majors of the European Community, August 3rd 2012) and from an explicit Resolution (n. 517 on April 21st 2011) of the Municipality of Naples. The building is designed on three levels and at this moment is the first Italian non-residential NZEB project. The building will be built up on three floors (two of them above the ground level) and it will host offices (ground floor), expo spaces and a conference room (first floor), Figure 1.

In order to meet passive heating and cooling criteria, the building is conceived with a rectangular shape (15.0 × 24.5 m, East-West oriented longitudinal axis) and without windows on the eastern, northern and western façades. The floor area of the conditioned spaces is 554 m^2. The building roof slope is 30°, the S/V ratio is 0.38. The window to wall surface area ratio is low (about 15%), while it becomes high (about 70%) when referred to the southern façade (for maximizing the winter solar heat gain). The first floor terrace windows are equipped by external horizontal variable tilt solar shadings, while horizontal overhangs are modelled on the top of the roof windows. At the southern side of the ground floor, a sunspace is designed in order to maximize the winter passive heating gain (suitable absorptive dark surfaces are considered for the related opaque elements). In summer, such space becomes (by completely opening the external sliding windows) a shaded open porch (S/V ratio decreases to 0.36). The porch ceiling width and height are conceived in order to avoid the indoor space superheating. The building envelope is designed with a high thermal capacitance and insulation (high superficial masses of the opaque building elements as well as suitable thicknesses of thermal insulation are taken into account).

The main features of the NZEB envelope are reported in Table1. The external opaque envelope is designed as remarkably reflective (reflective cool paint). The building shape and the interior design are conceived in order to maximise the natural ventilation. The porch width and height, as well as other design and operating parameters are optimized for the maximum NZEB energy efficiency. More details are reported in [1].

Building element	**Density** [kg/m^3]	**Transmittance** U [W/m^2K]	**Embedded PCM layer**	**Note**
Vertical walls	800 (brick layer)	0.23	Yes (3 cm)	
Tilted roof	1050 (concrete slab)	0.23	Yes (3 cm)	
Sunspace (exterior), East office, conference room windows	-	1.6	No	Emissivity = 0.10. 6/13/6 glazing filled by Argon. SHGC = 0.58
Other windows	-	0.9	No	Emissivity = 0.10. 6/8/6/8/6 glazing filled by Krypton. SHGC = 0.46

Table 1. NZEB envelope features

Modelling and simulation tools developed/used

In order to analyse the BISTS performance and to design the NZEB from the energy point of view a suitable dynamic energy simulation model was purposely developed in MATLAB environment (DETECt 2.2, the code was validated by the BESTEST procedure [1-4]). By such tool the energy analysis of the proposed solutions and their interactions with the building indoor spaces (e.g. BISTS thermal passive effects) can be analysed. DETECt 2.2 was also utilised for the optimization procedure of several building envelope operating and design parameters (for minimising the heating and cooling building energy demand). Such code includes several tools for the energy performance analysis of different BISTS typologies, such as the examined solar thermal collectors coupled to a heating and cooling system (with a 26 kW H_2O/LiBr double stage absorption chiller). The layout for the summer HVAC system configuration is reported in Figure 5. The results of this analysis are reported in Table 2.

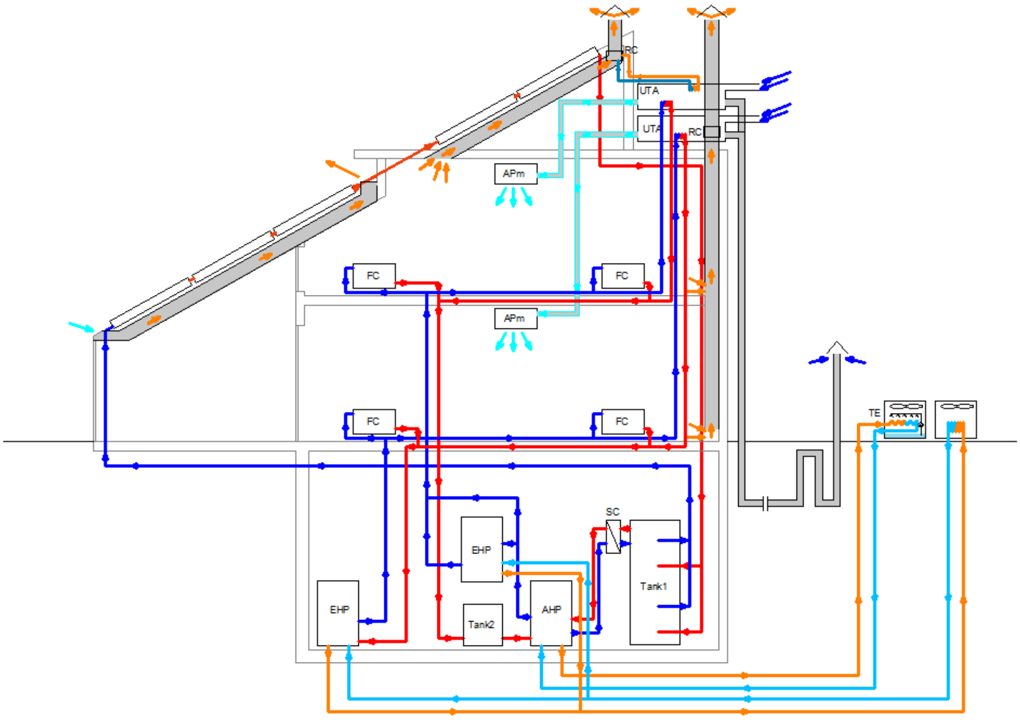

Figure 5. BISTS and solar cooling system layout

Energy demands [kWh/m^2·y]		**Heating**	**DHW**	**Cooling**	**Electricity**				
					Ventilation	**Light**	**Appliances**	**Fans, pumps and cooling tower**	
Total		3.90	1.85	6.70					
Carrier	**Electricity**	0.13	0.21	0.19	2.50	3.51	5.96	2.18	
	Solar	3.47	1.21	5.62					
Renewable energy [kWh/m^2·y]		**Thermal**			**Cooling**				
Produced on site		38.9			30.9				
Exported		30.4			30.6				
Primary energy [kWh/m^2·y]		**Produced on site**		**Produced and consumed on site**			**Exported**	**Imported**	**RESs**
		153.9		45.9			108.0	32.0	235%
Energy needs and class (Italian guidelines)		**Methodology**		**Primary energy for heating** [kWh/m^3·y] (Class)			**Energy for cooling (not primary)** [kWh/m^2·y] (Class)		
		UNI TS 11300 (Italian release of EN 13790)		1.92 (A+)			9.39 (I)		

Table 2. BISTS performance calculated by DETECt

BISTS Performance data Based on: O Estimation × Detailed simulation by DETECt (in-house developed dynamic simulation code for the building-plant energy performance analysis) O Measurement/testing O Long-term monitoring **Performance parameters** *For integrated systems:* *key performance indicators -* *Solar savings fraction: 0.90% (heating); 0.93% (cooling)* *BISTS U-value: 0.23 (roof), 0.40 W/m^{2}K (solar collector only without additional underlying thermal insulation)* *BISTS Ms: 27 kg/m^2 (solar collector only)* For separate collectors: performance rating coefficients (EN12975, EN12976, η0,a1,a2 – Figure 4).	

Additional information
The contribution on the overall balance of renewable energies is remarkable (given the need to provide electricity, heating and cooling to an existing large public building adjacent to the examined NZEB).

System viability
The technology of the adopted solar thermal collectors is the foundation of the high-vacuum flat solar thermal panels, providing high efficiency, low cost and long durability. Using a patented, inorganic and flexible glass/metal seal, such panels combine the advantages of a traditional layer layout (e.g. minimum dead space and maximum diffuse light capture) and a complete suppression of convection losses due to high-vacuum insulation. Built up with commonly available, inexpensive materials qualified for long-lasting high-vacuum products (i.e. light bulbs and cathode ray tubes), this technology is specially engineered for mass manufacturing. These panels harness the full power of solar thermal technology-providing unrivalled performance for any thermal applications in any climate condition, without concentration.

Sources and references
[1] Buonomano A., De Luca G., Montanaro U., Palombo A.. Innovative technologies for NZEBs: an energy and economic analysis tool and a case study of a non-residential building in Mediterranean climate. Energy and Buildings; 2015. http://dx.doi.org/10.1016/j.enbuild.2015.08.037
[2] Buonomano A., Palombo A.. Building energy performance analysis by an in-house developed dynamic simulation code: An investigation for different case studies. Applied Energy 113, 788-807, 2014
[3] Buonomano A., Palombo A.. NZEBs design and simulation: a new tool for dynamic energy performance analyses. ECOS 2014 - 27th International Conference on Efficiency, Costs, Optimization, Simulation and Environmental Impact of Energy Systems, Turku, Finland; 06/2014
[4] Buonomano A., Calise, F., Palombo A.. Solar heating and cooling systems by CPVT and ET solar collectors: A novel transient simulation model. Applied Energy, 103, 588-606, 2013