

## General information:

- Technology developer:
  - Shap s.p.a. – Solar Heat And Power (Italy)
  - University of Florence - CREAR (Italy)
  - Tel Aviv University (Israel)
- Demonstration project developer:
  - CRR – Consorzio Roma Ricerche (Italy)
  - Shap s.p.a. – Solar Heat And Power (Italy)
  - Besel (Spain)
  - Di.S.P. – Distributed Solar Power Ltd. (Israel)
  - Tel Aviv University (Israel)
  - University of Florence - CREAR (Italy)
  - Fraunhofer Institute of Solar Energy (Germany)
  - Colleferro Town (Italy)
- Location of demonstration project: Colleferro (Italy)
- D Project starting date: June 2007
- D Project status: in progress

## Summary of project

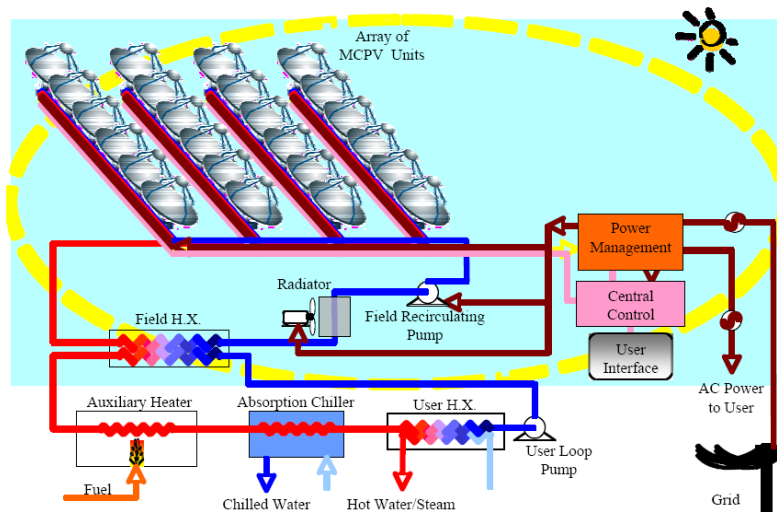
Photovoltaic technology produces electricity from solar radiation, but the cost of this electricity generation is typically 2 - 4 higher than the cost of power generation from conventional fuels' combustions. Two reasons contribute to this high cost: the need to use large amounts of expensive semiconductor material, and the low electricity conversion efficiency. The first issue can be resolved by concentration: collecting solar radiation over a large area with a mirror or lens, and concentrating it to a small target where only a small area of semiconductor cells is needed. Several types of concentrating systems have been proposed and tested in recent years with varying sizes and levels of concentration. The second issue is the electricity conversion efficiency: silicon PV cells convert only 10–20% of the collected radiation to electricity, while the more sophisticated (and very expensive) multi-junction cells are capable to reach efficiency less then 40%.

Most of the collected solar energy is then rejected to the environment. A way to achieve a better overall efficiency is to capture the rejected heat as well, and use it as an additional energy product. This is possible today with Photovoltaic/Thermal (PV/T) flat collectors; but these provide heat at relatively low temperature, about 40–60°C. This is suitable only for the limited applications of domestic water heating or space heating. According to available end-use statistics, thermal energy for heating and cooling accounts for 50–70% of the total energy use in many types of buildings. However, in sunny regions much of that requirement is for air conditioning and refrigeration that cannot be provided by low-temperature heat.

## Description of project

Concentrating photovoltaic (CPV) systems can achieve the synergy that addresses both the above-mentioned issues. CPV systems can greatly reduce

Figure 1



European Project "Eco-Building International Club for advanced European sustainable energy technology dissemination in Europe and China"

Project partners:

ENEA (IT), ISNOVA (IT), FINCO (IT), ADEME (FR), AIMCC (FR), DTI (DK), DI (DK), CRES (GR), EBHE(GR), GPPEC (GR), SEC(B), ZERI (CN), CBEEA (CN)



the needed area of cells, and they can operate at higher temperatures than flat collectors. The result is the CPV/Thermal (CPVT) system as proposed in the UPP-Sol project (Figure 1), which provides both electricity and medium-temperature heat. The collected medium-temperature heat is therefore suitable for a wide range of thermal applications, including absorption cooling and air-conditioning, steam production, desalination, and industrial process heat.

A schematic of a typical CPVT system, including an array of small collectors and the electrical and thermal components, is shown in the Figure above. The CPV array heat exchanger can be easily adjusted to provide a wide range of temperatures by regulating the flow rate of the coolant. Therefore, a CPVT system can be used as polygeneration system - providing electricity, heating, cooling, and possibly other products such as steam or desalinated water.

An important requirement for a CPVT polygeneration system is the location of the solar collectors. Since heat cannot be transported over long distances, the collectors have to be installed close to end-users, and therefore have to be small enough to be integrated into an urban living context, for example on the rooftop of the building where the end-user is located. Small units can be arranged in a modular way, even in irregular spaces that may be available in many buildings. Examples of small CPVT collector arrays on typical rooftops are shown in Figure 2. Another advantage of the location at the end-user site is the fact that the solar energy replaces conventional energy purchase at retail cost, which is much higher than the utility's of production cost. As a result, the same solar technology may be non-competitive at the utility's power station, but competitive at the end-user site. In addition, the end-user may enjoy government incentives given to renewable energy systems, making the system even more competitive.



Figure 2



Figure 3

## A Short Description of the Technology

The collectors used by project Upp-Sol are small, about 1 m in diameter, which permits easy integration and installation in buildings. The concentration is only in a factor of few percentages, so the needed area of PV cells is much smaller than the collector's area. Triple-junction cells with nominal efficiency of 35% are used to obtain the highest possible system efficiency. This type of cells is capable of operating at higher temperatures with respect to silicon cells.

Two Building Integrated Spherical Collector (BISC) versions with different geometries have been produced for applications in various types of buildings. One is a roof-integrated stationary collector, and the second is a freestanding tracking parabolic dish type collector.

The BISC device, developed through the Project BISC supported by Italian Ministry of Environment in cooperation with Israel, represents a new concept of collecting solar power that is based on the following principles (Figure 4 - 5):

- **Stationary spherical primary reflector:** to reduce tracking requirements
- **Small collector unit:** (about 1 m) suitable for rooftop installation

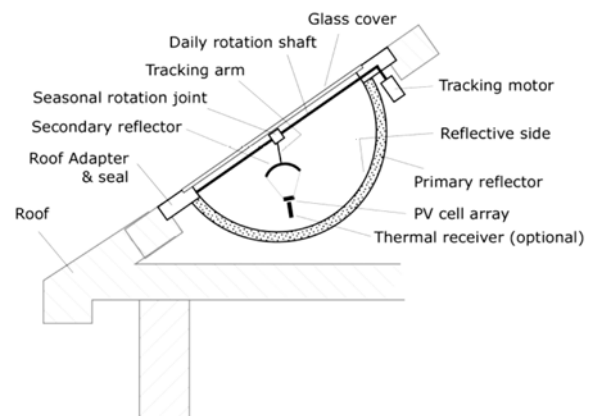


Figure 4

The project aims at promoting and widespread disseminating EU innovative Research and Technology Development and Demonstration results, as well as eco-sustainability criteria in building sector, which include:

- energy efficient building materials, components and systems not yet introduced into the building market or in their first market phase;
- innovative applications of heating/cooling and power supply technologies, combined with the use of renewable energy sources, in building sector;
- best EU demonstration eco-building projects.

- **Collector structure contained below aperture level:** permits installation flush with roof or façade
- **Secondary reflector:** to correct spherical aberration and provide high concentration
- **Co-generation** of electricity and medium-temperature heat using advanced PV cells
- Collector components suitable for **low cost mass production**

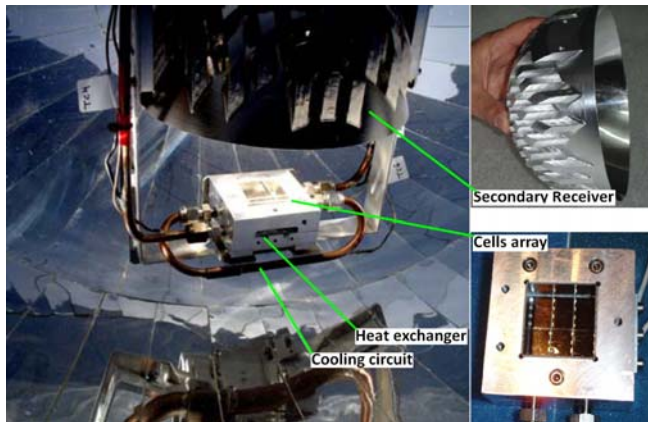


Figure 5

In particular, Non-tracking primary reflector: solar concentrating systems need to track the apparent motion of the sun. This involves both high complexity and high cost. The BISC can track the sun by moving the receiver rather than the reflector. This enables streamlined integration within a roof structure without disturbing the roof contour and without moving external elements. The reflector and tracking mechanism can be protected from the environment.

Receiver: a array of special concentration PV cells is placed on a substrate integrated with a heat exchanger, which provides the electrical connections and cooling. Spaces among the cells are minimized (Figure 5). The electrical and coolant connections are located at the back of the receiver to minimize shading.

Cooling system and Co-generation: the cooling system supplies cold fluid to cool the PV array, the secondary reflector (if actively cold), and the thermal receiver if installed. The system will consist of a pump and at least one heat exchanger for heat rejection. The coolant may be water or another heat transfer fluid. The system includes a variable speed coolant pump, a liquid-to-air heat exchanger to reject the heat to the environment, a flow control valve, and a flow meter. Temperatures, pressures, and flow rate are measured by computer-controlled data acquisition modules installed on the coolant system.

BISC units can also be installed on flat roofs as stand-alone units. In this case, the primary reflector is installed permanently in the roof structure and an internal tracking system that moves the CPV receiver and a smaller secondary reflector. This is possible due to the symmetry of the spherical geometry: the optics is the same regardless of the direction of the incident solar radiation. Movement of the sun shifts the location of the focus, and tracking requires moving the receiver along the trajectory of the focal point. The secondary reflector corrects the spherical aberrations of the primary, thus allowing high concentration on the CPV receiver. A BISC collector developed at Tel Aviv University is shown in Figure 6. A similar collector with some variations in design details has been constructed at University of Florence -CREAR.

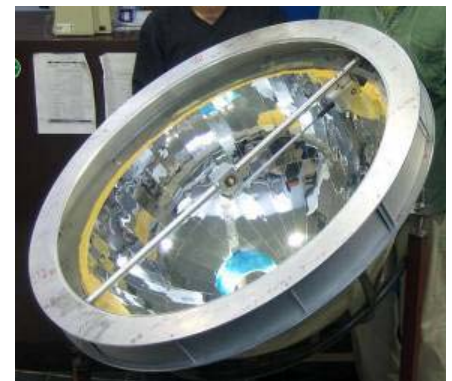


Figure 6

## Results and Achievements

A single collector will produce about 70 W of electricity and 160 W of thermal energy under nominal conditions. The amount of solar radiation collected and converted by the stationary collector is smaller than for a fully tracking collector of the same aperture area, since only a part of the reflective area is active at any given time. However, the cost of the stationary collector is lower than a fully tracking one of the same aperture area, and therefore the cost of the energy should be similar. In the table below, 2 cases are considered for the estimation of the peak electrical and thermal power.

	Unit	Commercial	Prototype
<b>Geometric concentration ratio</b>	-	405	405
<b>Average incident flux on module</b>	kW/m <sup>2</sup>	254	193
<b>Estimated electrical output</b>	W (DC)	59	48
<b>Peak active area elec. efficiency</b>	%	17.3	14.1
<b>Estimated thermal output</b>	W	152	114
<b>Thermal efficiency</b>	%	44.6	33
<b>CHP efficiency</b>	%	62	47

The first case is for collector which is manufactured in mass production and represents the performance of a commercial collector. The second is the evaluation of the performance of the current prototype which has been developed without standard industrial methods and hence is expected to have limited performance. In both cases the achievement refers to a single collector. The electrical output of the commercial and the prototype unit is estimated to be 59 and 48 W respectively. The thermal output 152 and 114 W respectively.

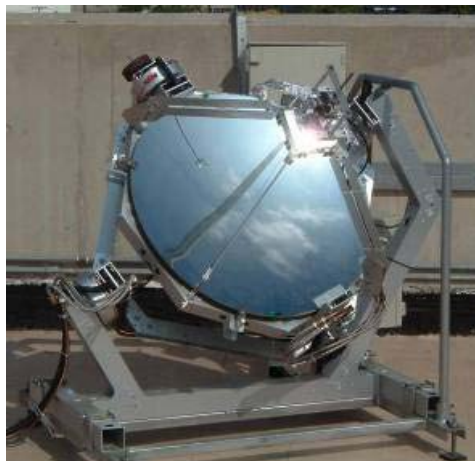


Figure 7

Moreover, the second CPVT solution: Miniature Concentrated Photovoltaic (MCPV) unit, a freestanding dish collector, has been developed by Tel Aviv University and Distributed Solar Power Ltd. (shown in Figure 7). It consists of a concentrating glass mirror, a tracking mechanism that follows the apparent motion of the sun, and a CPV receiver with high-efficiency triple junction cells and a heat exchanger for extraction of the thermal energy. The CPV cells can operate at a conversion efficiency of 32% or higher

Each collector unit, with aperture area of about 1 m<sup>2</sup>, can produce about 200 W of net electrical power and 480 W of thermal power. The thermal power can be used directly as heat, or can be converted, for example, to 330 W of cooling power by the use of an absorption cooler. In a recent analysis, we have estimated the cost of cooling with a CPVT system with electric net metering, coupled to a single effect absorption chiller.

## Cost Analysis

The results of the cost analysis are presented in the table on the right. The estimated manufacturing cost per unit is \$283, or about \$4 per Watt peak when accounting for the electricity only. However, when taking into account the thermal energy as well, the specific cost of the unit is only \$1.3 per Watt. This is a relevant measure in cases where the thermal energy replaces the consumption of electricity. For example, in Israel almost all the backup for water heating systems is by electricity. Therefore energy provided from a solar collector directly replaces electrical energy.

The estimated lower and upper estimates are \$182 and \$367 per unit, respectively. This corresponds to \$2.7 - 5.4/W for electricity only, and \$0.8 - 1.6 for the total energy. The lower estimate is in a clearly competitive range. The upper limit would not be competitive with alternative renewable energy systems, if we compare the specific cost based on electricity only. If we account for the thermal energy then even the high estimate may be attractive. This depends on the type of application and the specific value of the thermal energy, as indicated by the alternative energy source available to the specific customer.

	Nominal	Low	High
<b>Component</b>			
<b>Primary reflector</b>	27.0	19.0	30.0
<b>Secondary reflector</b>	7.0	3.0	9.0
<b>Glass top</b>	10.0	9.0	12.0
<b>Tracking system</b>	80.0	34.0	105.0
<b>PV cells</b>	48.0	41.0	54.0
<b>Control</b>	20.0	14.0	24.0
<b>Structure</b>	50.0	35.0	65.00
<b>Cooling system</b>	15.00	10.0	20.0
<b>OEM total Cost</b>	257.0	165.0	319.0
<b>Assembly</b>	10.0%	10.0%	15.00%
<b>Total manufacturing cost</b>	282.7	181.5	366.9
<b>\$/Wp electric only</b>	4.2	2.7	5.4
<b>\$/Wp total</b>	1.3	0.8	1.6

In conclusion, this innovative system is an attractive candidate for polygeneration, since cooling requirements have a good correlation with the availability of sunlight. The cost of cooling has been compared with a conventional electric compressor, as well as with a solar cooling via flat-plate thermal collectors. The solar thermal cooling is more expensive than conventional cooling, but cooling with the CPVT polygeneration system is preferable when its installation cost is less than \$4.5/Wp (€3.75/Wp).

Several recent analyses have estimated the cost of CPV systems, when produced on large scale, to reach the range of \$1—3/Wp. Therefore the potential for competitiveness against conventional energy sources, even without government incentives, is very promising.

**All market operators are invited to join Eco-Building Club!**

Apart from awareness of most recent EU research results applicable in building sector, the Club offers to market operators:

- an innovative procedure for analysing market potentiality of research results and eco-sustainable building concepts in an international ambit;
- the opportunity for having a qualified and direct contact with worldwide high level experts in building and energy sectors;
- the possibility to promote one's own research results through project dissemination activities;
- the opportunity to assess the feasibility of some specific technology transferring actions.

**Information on project developer:**

CPVT collector technology for urban applications has been developed by the project participants under national and bi-national programs.

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- [www.shap.it/ENG/concentrating\\_photovoltaic\\_systems.htm](http://www.shap.it/ENG/concentrating_photovoltaic_systems.htm)
- [www.uppsol.eu/](http://www.uppsol.eu/)

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