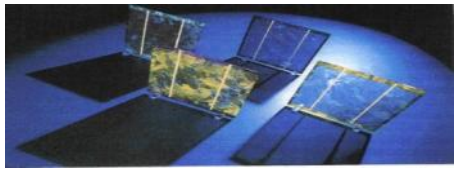
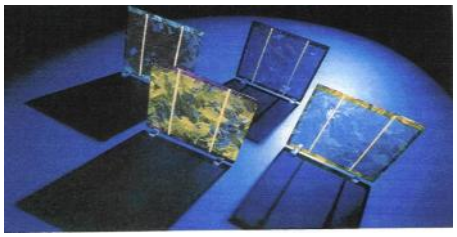
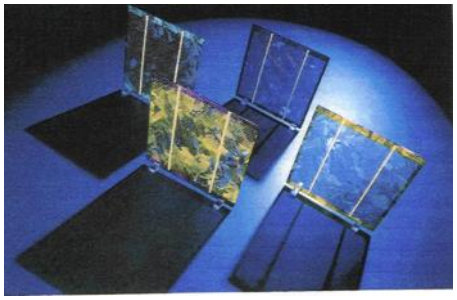
PV+THERMAL SYSTEMS
Design and performance aspects for building integration

Yiannis TRIPANAGNOSTOPOULOS

Assoc. Professor in Physics Department University of Patras, Greece
Tel: +30 2610 997472, e-mail: yiantrip@physics.upatras.gr

Thessaloniki

VERGINA

DODONI

DELPHI

Patra

Athens

OLYMPIA

MYCENES

DELOS

THIRA

KNOSSOS

Patra: The gate of Greece to Europe

Solar Energy Laboratory

Is established at the Physics Department and has an experience in education and research for 35 years

Activities:

Solar collectors
Photovoltaics
small wind turbines
energy and building
greenhouses

ICS Type solar water heaters

Simple and low cost solar water heaters

Efficient in water heating

Satisfactory preservation of hot water temperature

Aesthetical integration on buildings

Booster reflectors to improve energy performance

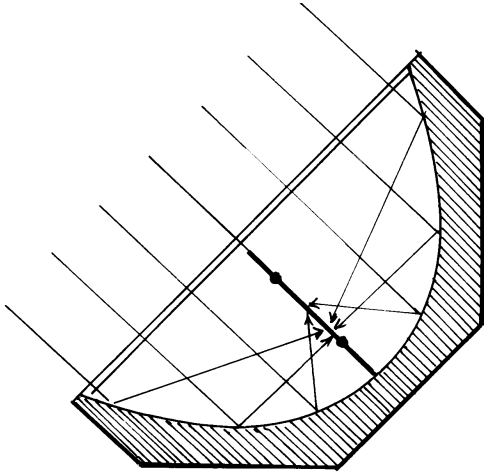
The reflectors increase the solar input achieving higher thermal output at higher operating temperatures.

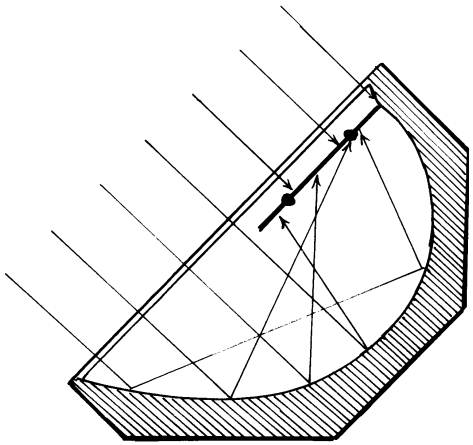
Solar collectors with colored absorbers

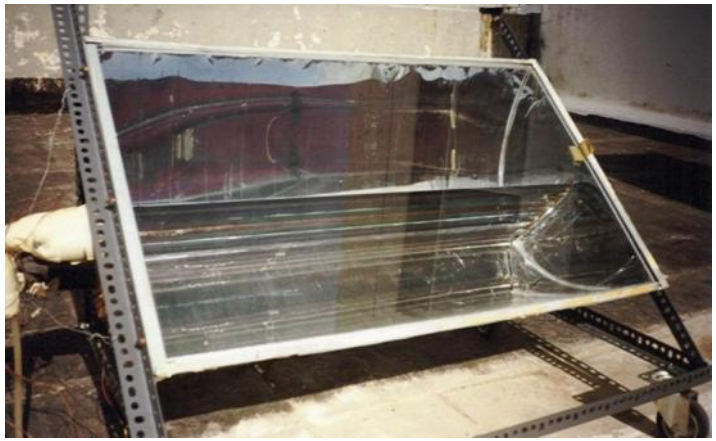
Solar collectors with absorbers of different color than black could be an interesting solution for the wider application of solar energy systems

These collectors are of lower thermal efficiency than that of the usual black collectors because of the lower absorptance

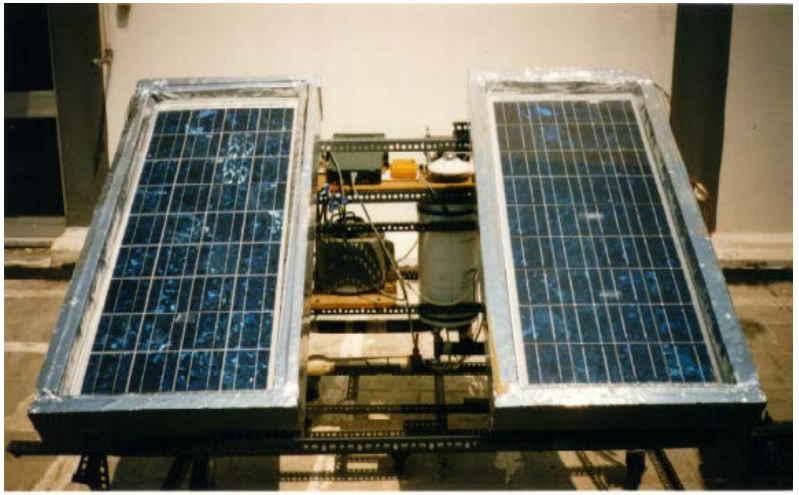
Stationary concentrating CPC solar collectors

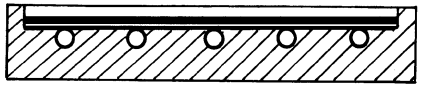




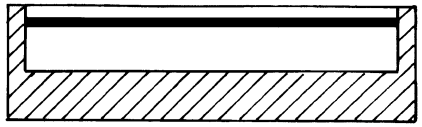


Hybrid PV/T Systems

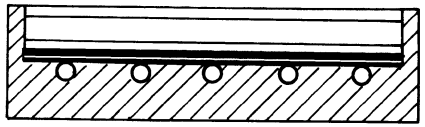




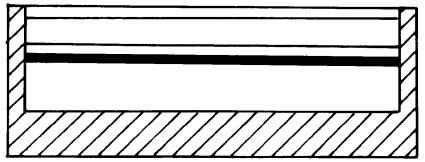
a PV / WATER



c PV / AIR



b PV / WATER + GL

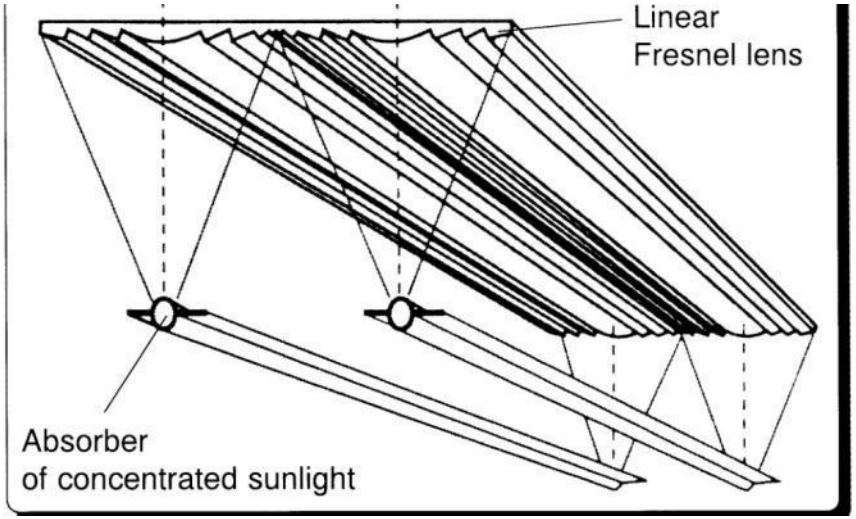


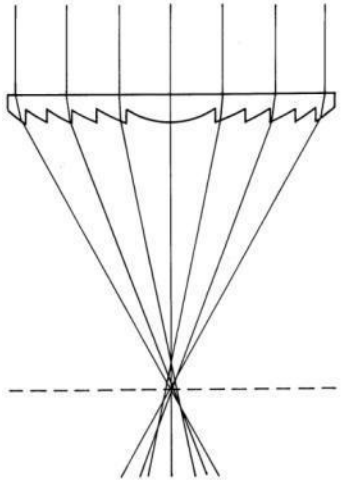
d PV / AIR + GL

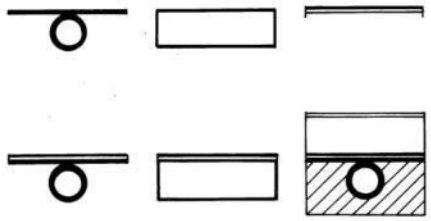
CROSS SECTION OF STUDIED PV/T SYSTEMS

Fresnel lenses for illumination and temperature control

Fresnel lenses are solar radiation concentrators with low volume and weight and low cost. They can separate the direct from the diffuse solar radiation and it makes them suitable for illumination control in the building interior space, providing light without sharp contrasts.



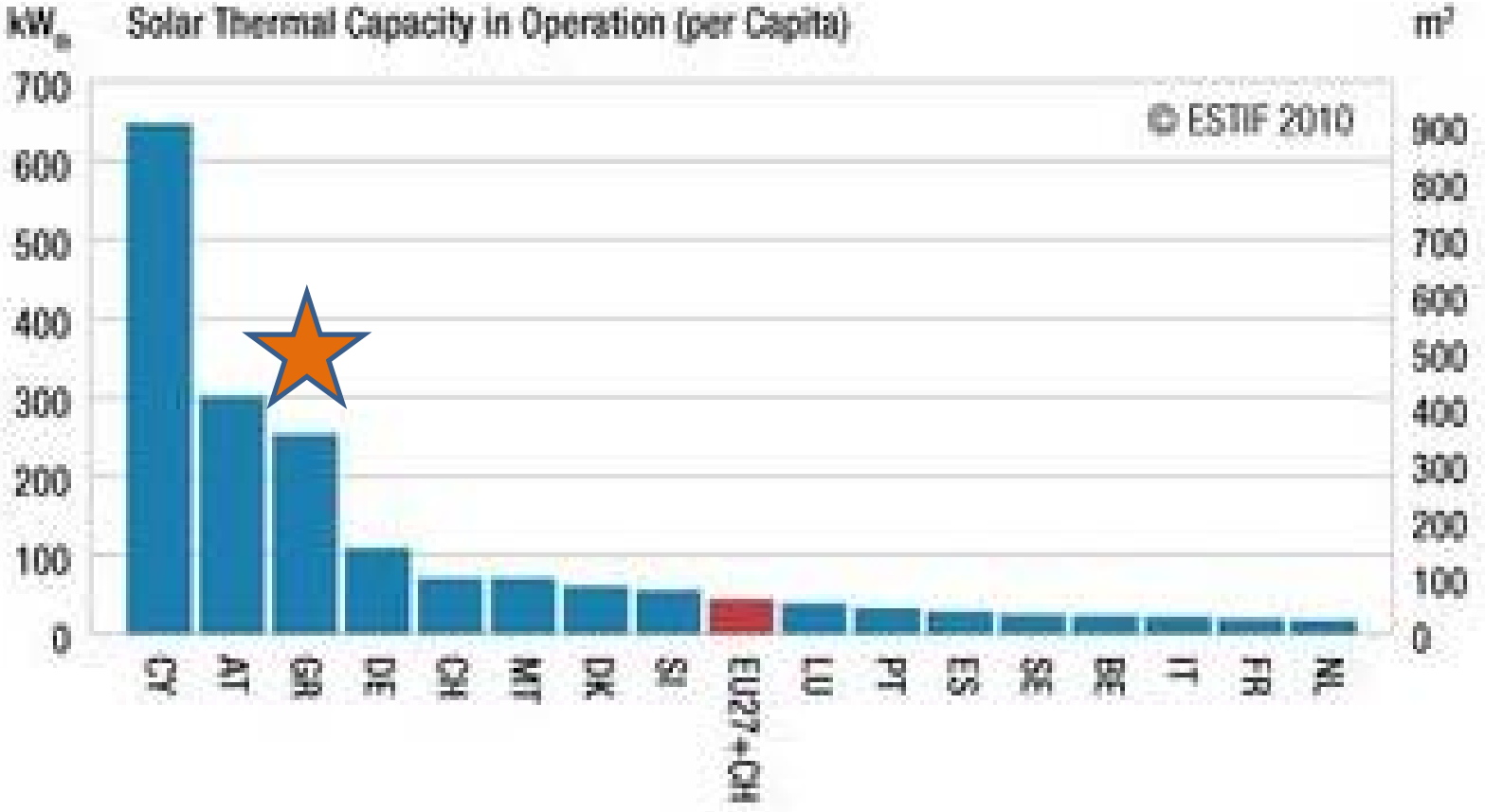




The surplus solar energy can be extracted and used to cover building electrical and thermal needs.

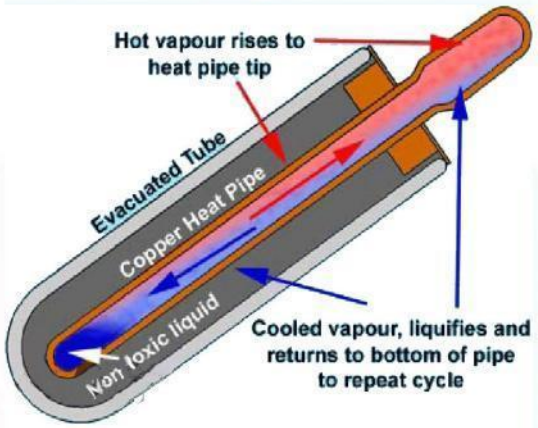
Solar Thermal

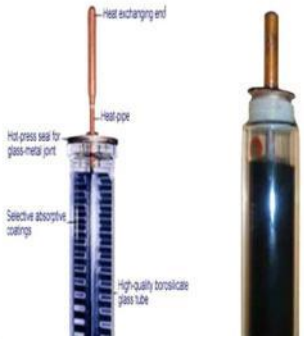
Domestic Hot Water



Installed solar thermal collectors per capita

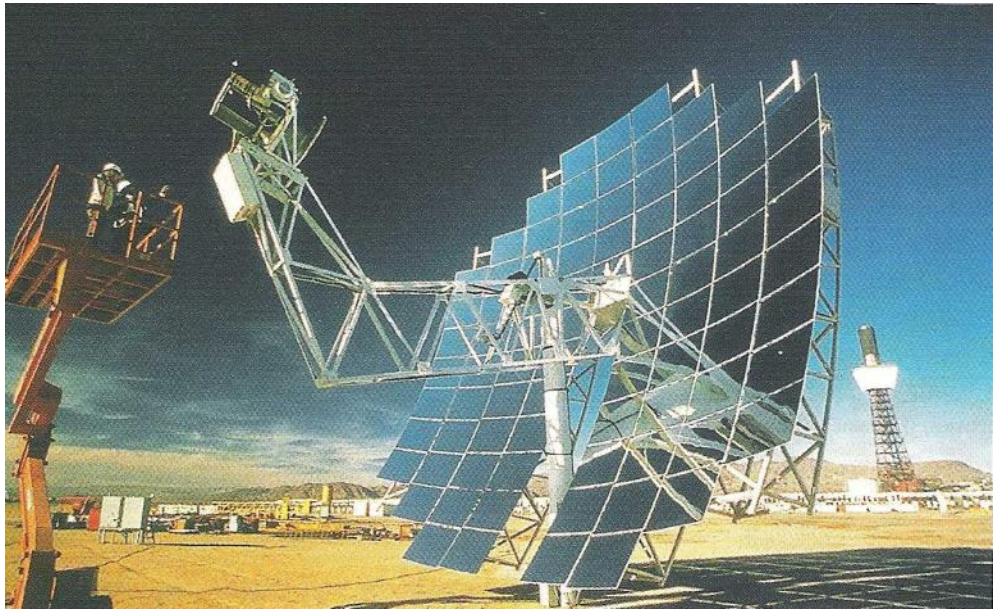
Flat plate collector, vacuum collector, thermosiphonic collector, parabolic trough, Fresnel reflector and Fresnel lens concentrating collector.





Solar Thermal systems

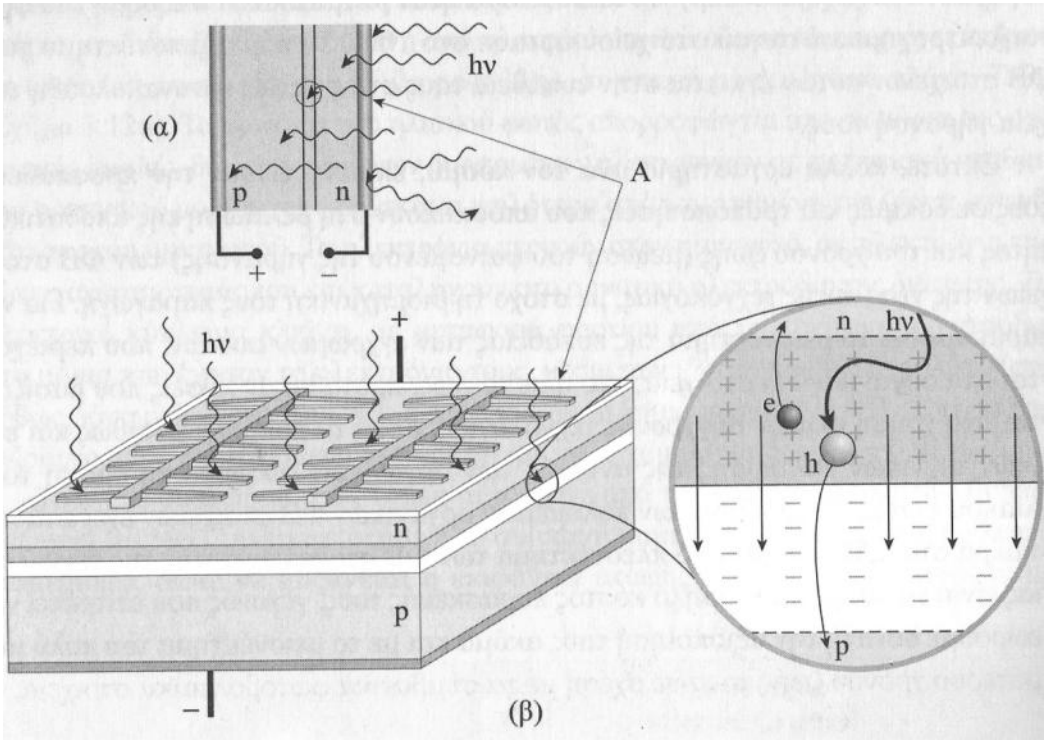
Application examples of solar thermal collectors

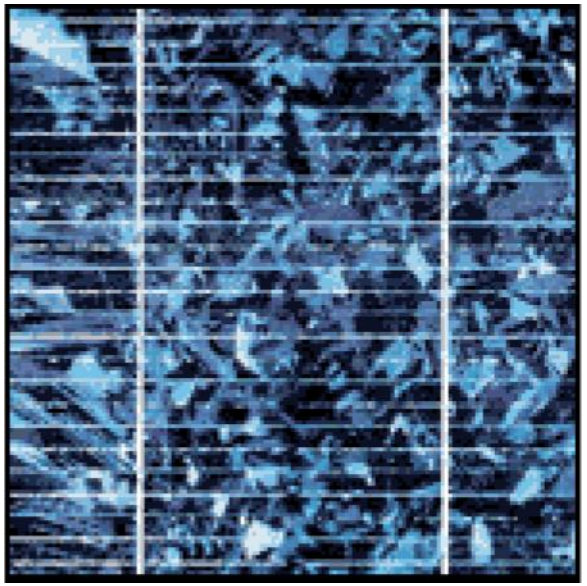


Concentrating solar thermal systems

solar tower

Photovoltaic effect and silicon cells

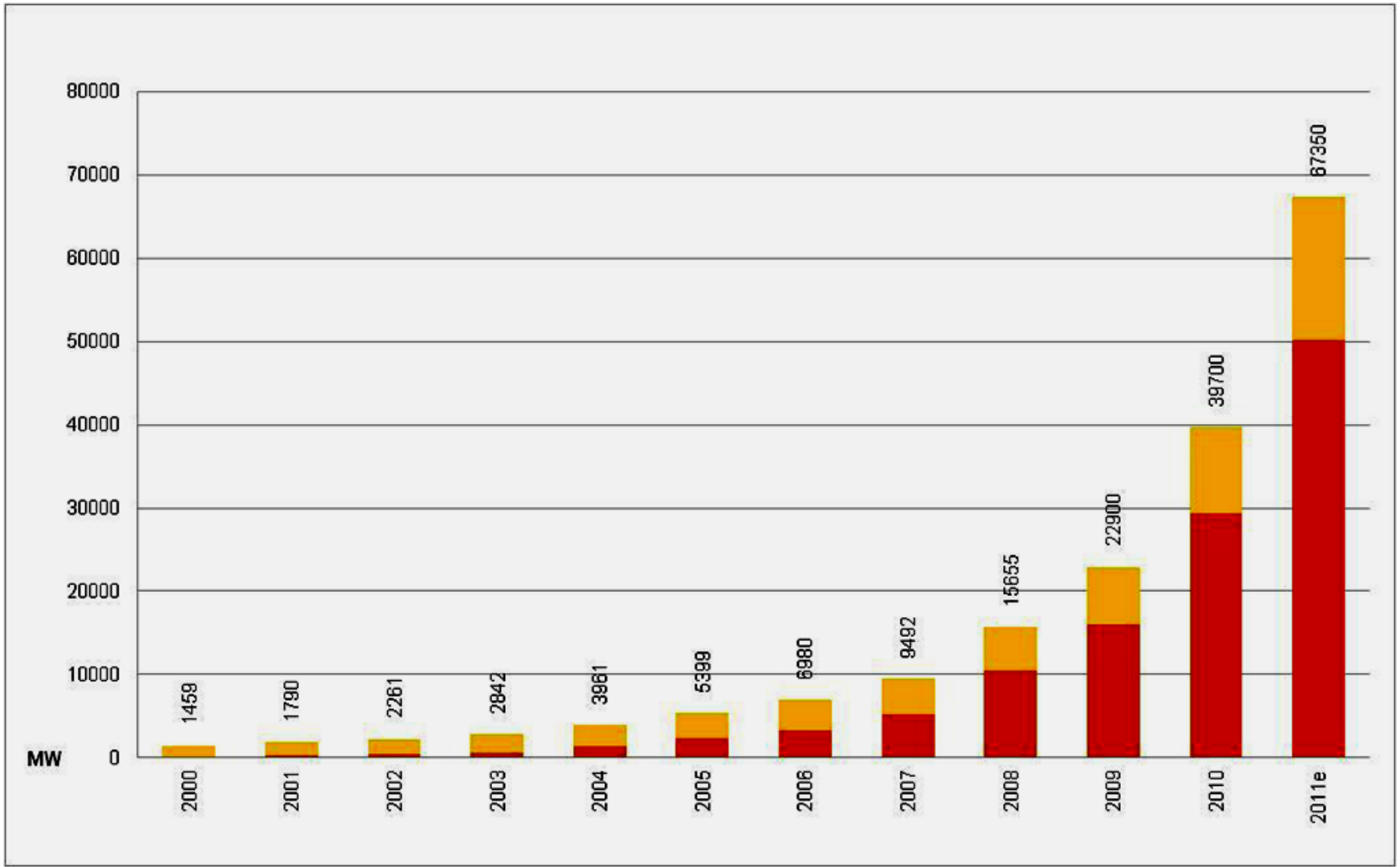




Photons are absorbed by the semiconducting material of solar cells, resulting to the producion of voltage/current

Photovoltaics

Greece: 600 MW-Europe: 50.000 MW-World 67.500 MW

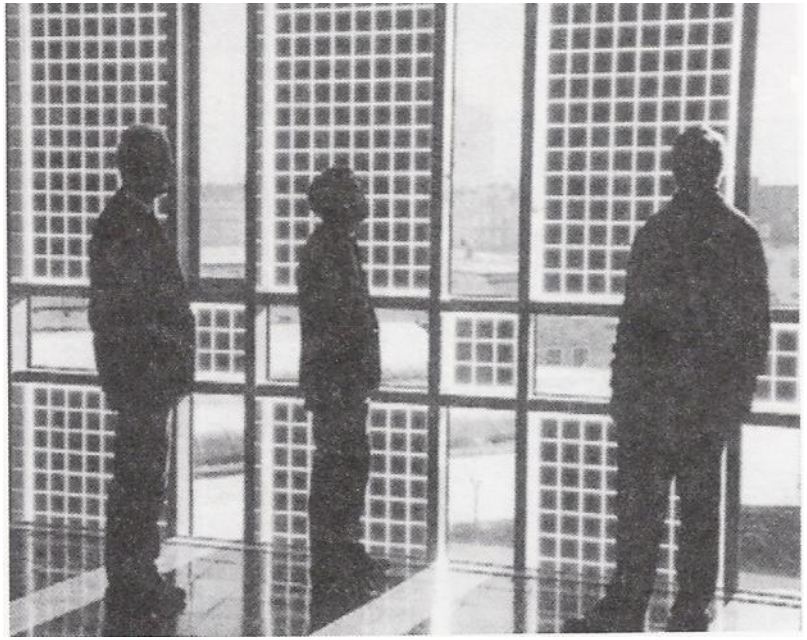


Photovoltaics

Photovoltaic park

Photovoltaics

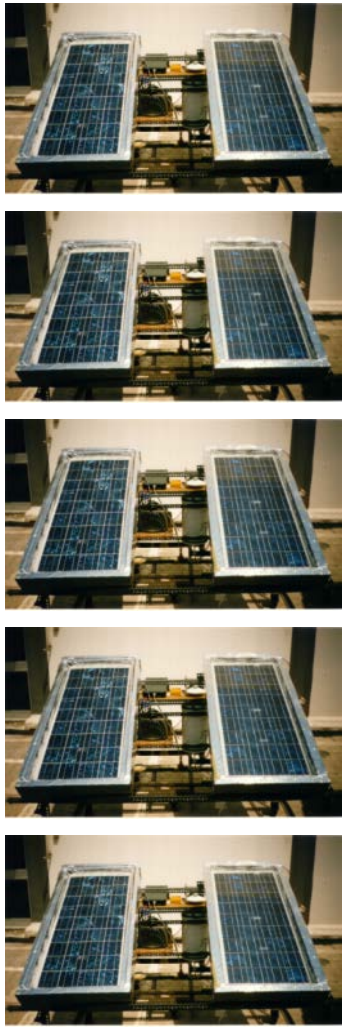
Photovoltaics for Semi-transparent building façades



Hybrid Photovoltaic/Thermal solar systems

The hybrid Photovoltaic/Thermal (PV/T) solar collectors are consisted of mounted together photovoltaic panels and thermal units that extract the heat and provide simultaneously electricity and heat.

Concept of Hybrid Photovoltaic/Thermal solar systems



Photovoltaics convert 5%-15% (depending on the technology) of the solar radiation into electricity and the rest is converted into heat.

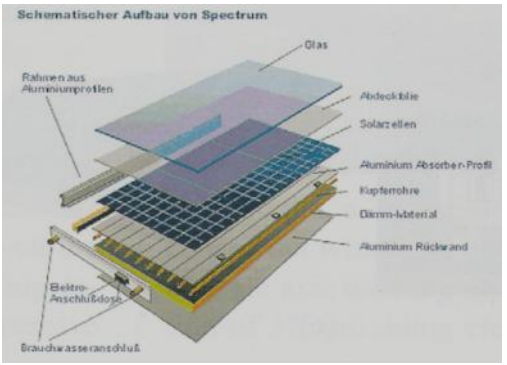
The heat inctreses the temperature of PV modules and this results to electrical efficiency drop.

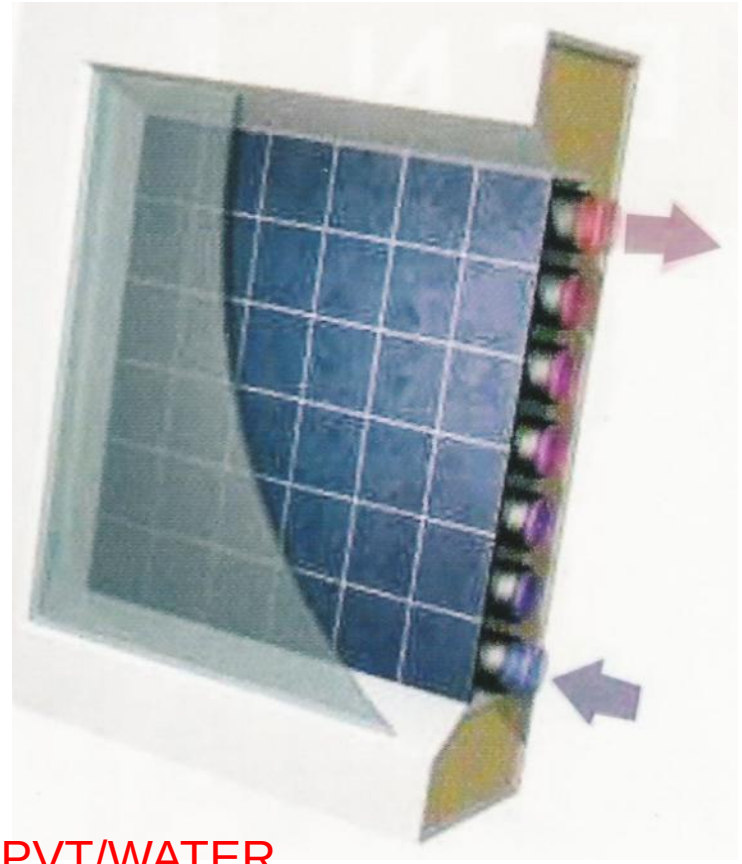
This effect can be partially avoided by applying a suitable heat extraction mode

The PV modules combined with thermal units consist the hybrid Photovoltaic/Thermal (PV/T) systems providing electrical and thermal output.

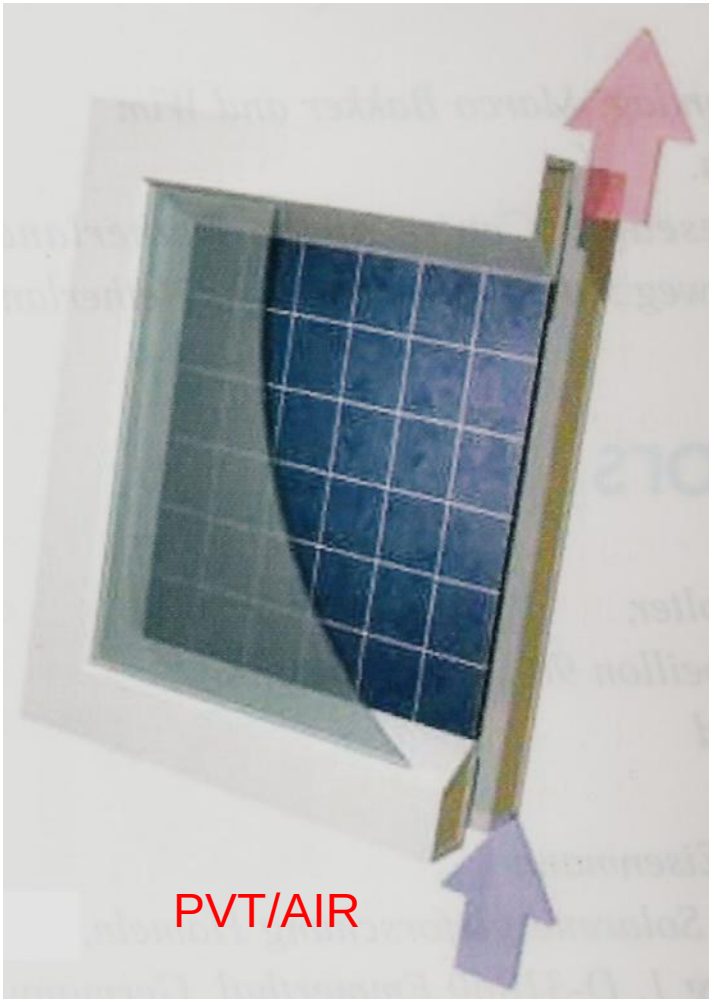
PV/T systems provide simultaneously electricity (5%-15%) and heat (50%-70%).

Hybrid Photovoltaic/Thermal Solar Energy Systems

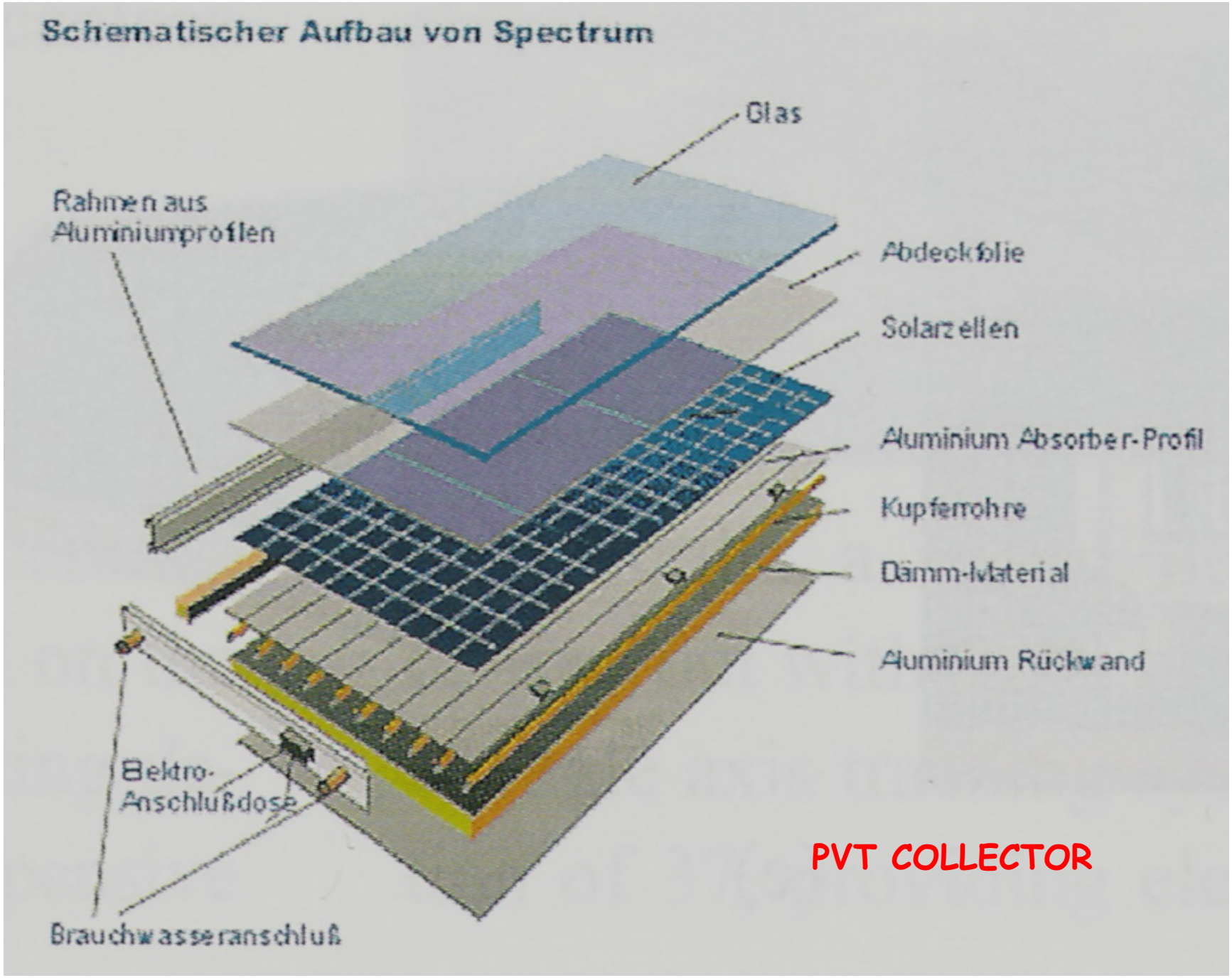




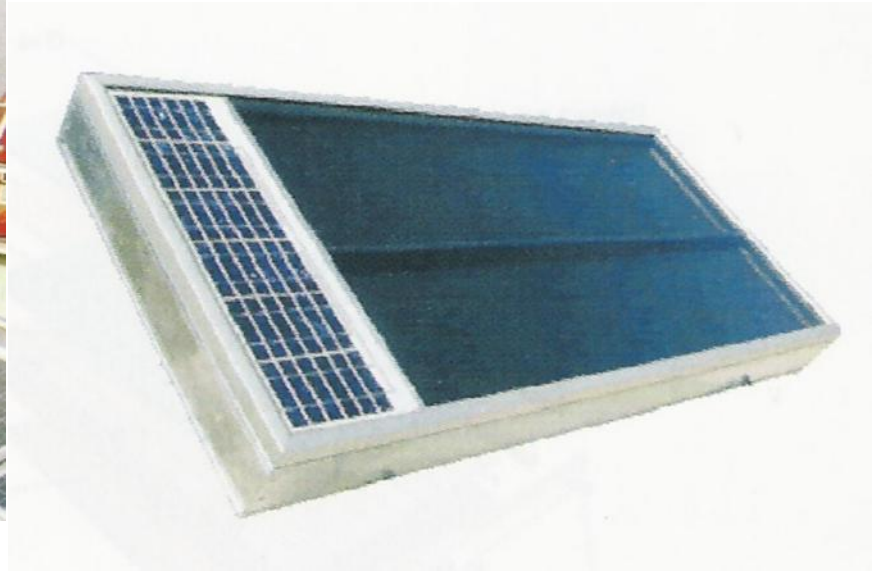
PVT/WATER

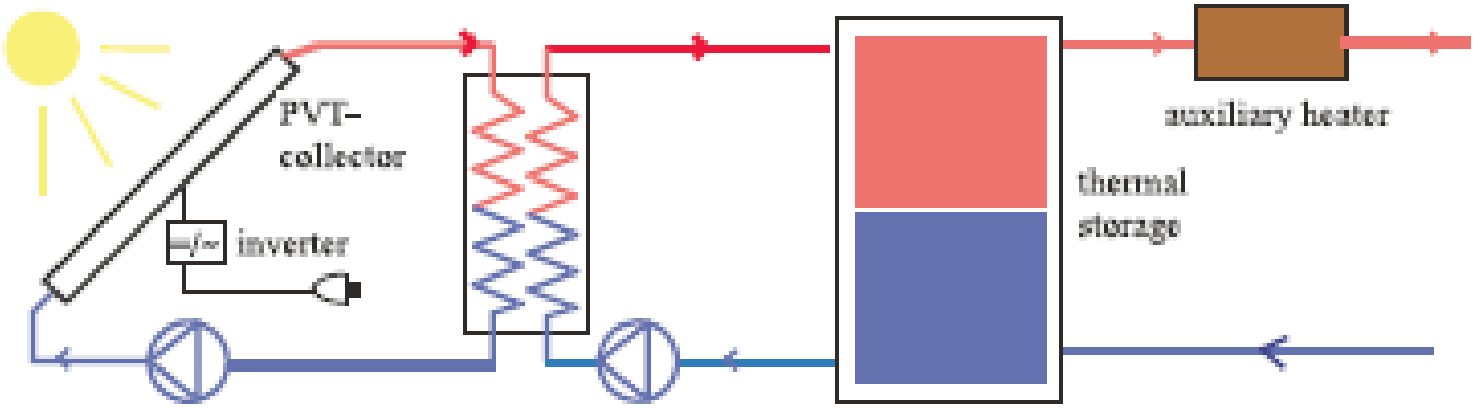


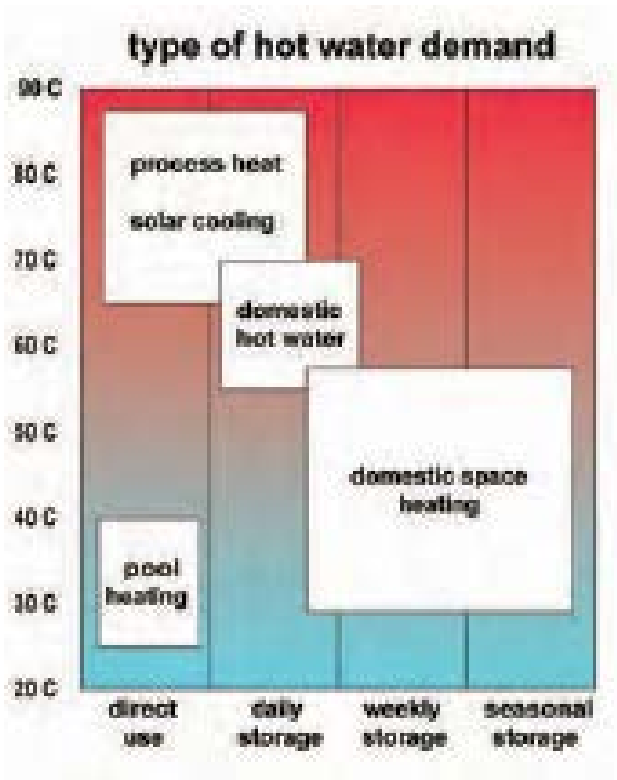
PVT/AIR

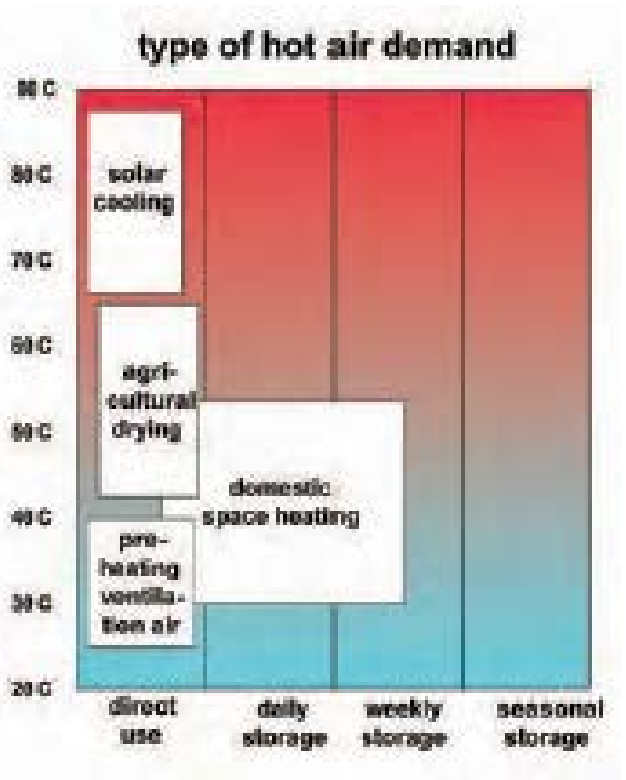

Schematischer Aufbau von Spectrum
Glas
Rahmen aus Aluminiumprofilen
Abdeckfolie
Solarzellen
Aluminium Absorber-Profil
Kupferrohre
Dämm-Material
Aluminium Rückwand
Elektro-Anschlußdose
Brauchwasseranschluß
PVT COLLECTOR

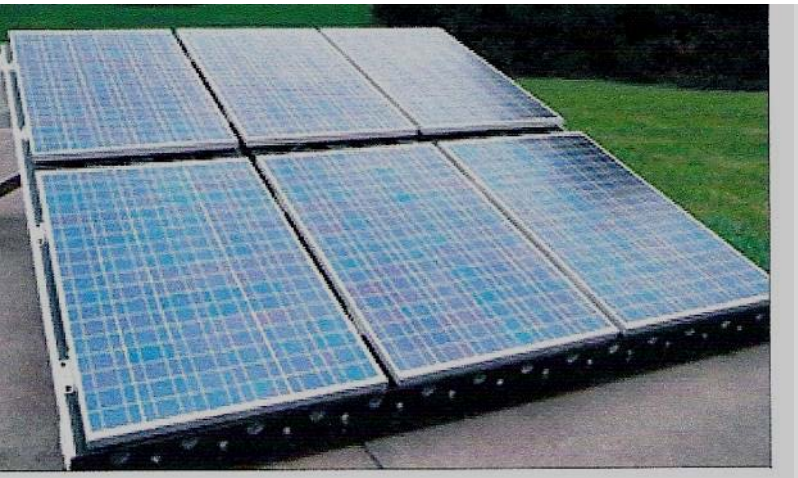
Hybrid Photovoltaic/Thermal Solar Energy Systems

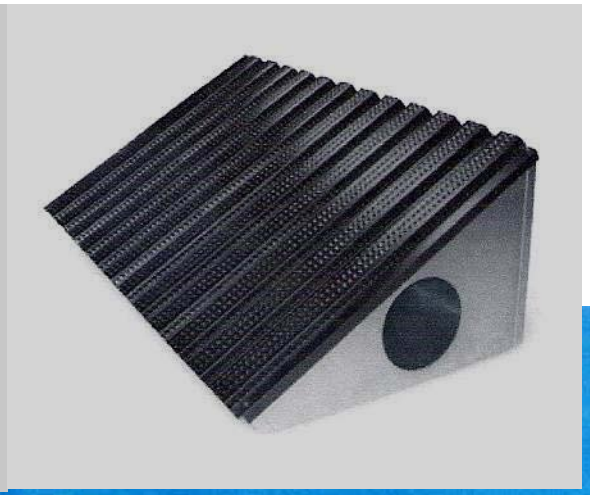



PVT-
collector
inverter
auxiliary heater
thermal
storage


type of hot water demand
90 C
80 C
70 C
60 C
50 C
40 C
30 C
20 C
process heat
solar cooling
domestic
hot water
domestic space
heating
pool
heating
direct
use
daily
storage
weekly
storage
seasonal
storage


type of hot air demand
90 C
80 C
70 C
60 C
50 C
40 C
30 C
20 C
solar
cooling
agri-
cultural
drying
domestic
space heating
pre-
heating
ventila-
tion air
direct
use
daily
storage
weekly
storage
seasonal
storage



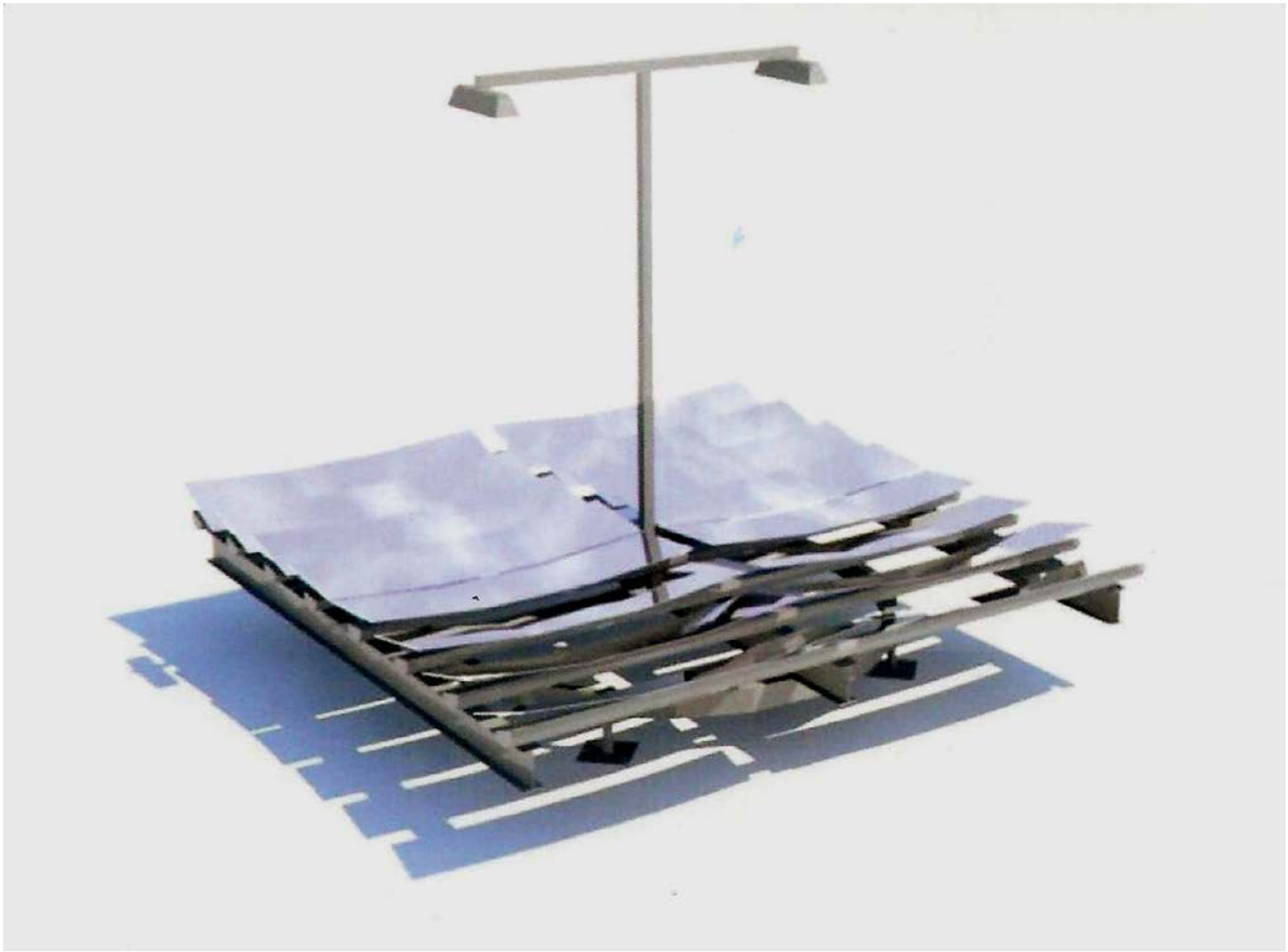


Solar Wall PVT collector

This roadmap was developed as part of the EU-supported Coordination Action PV-Catapult

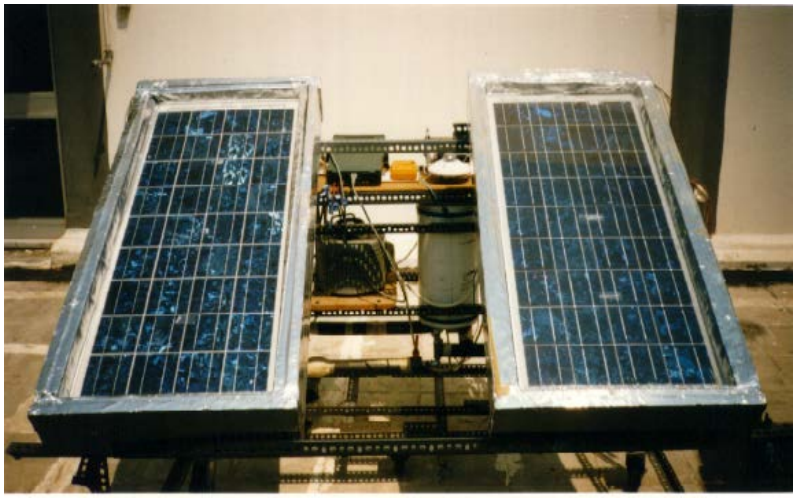
Arontis CPVT collector

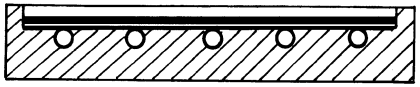
Heliodynamics Fresnel reflector PV/T collector



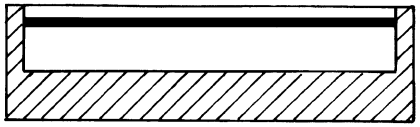
Hybrid Photovoltaic/Thermal solar collectors with Fresnel reflectors (Menova system)

UPatras developed PV/T collectors

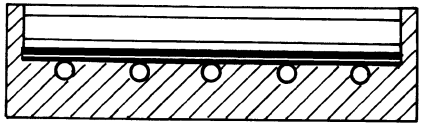




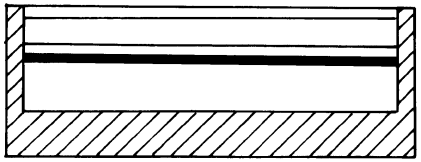
a PV / WATER



c PV / AIR



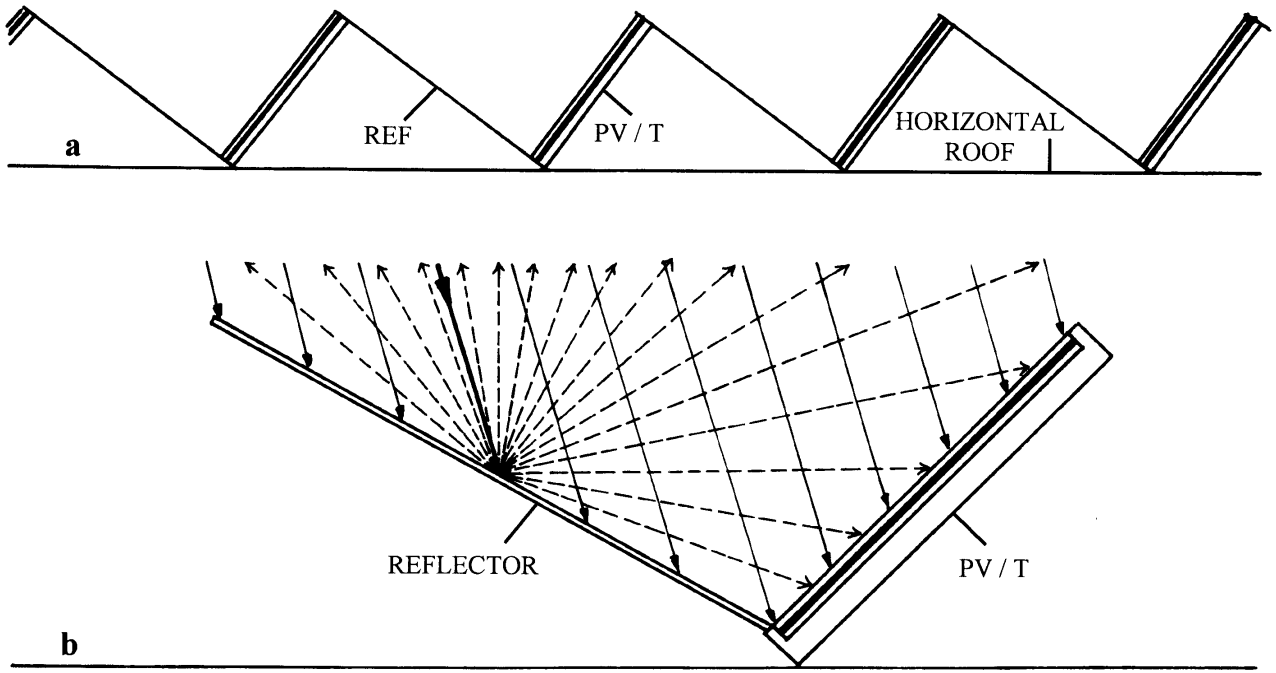
b PV / WATER + GL

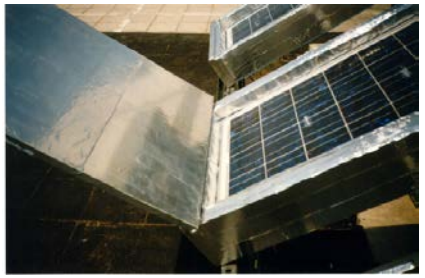


d PV / AIR + GL

CROSS SECTION OF STUDIED PV/T SYSTEMS

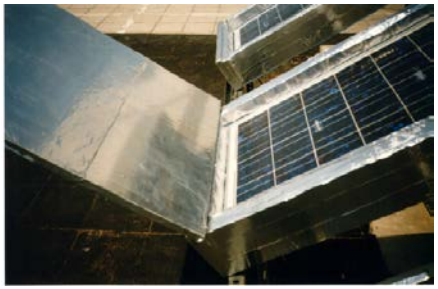
Diffuse reflectors between the parallel rows of the installed PV/T collectors on horizontal roof.

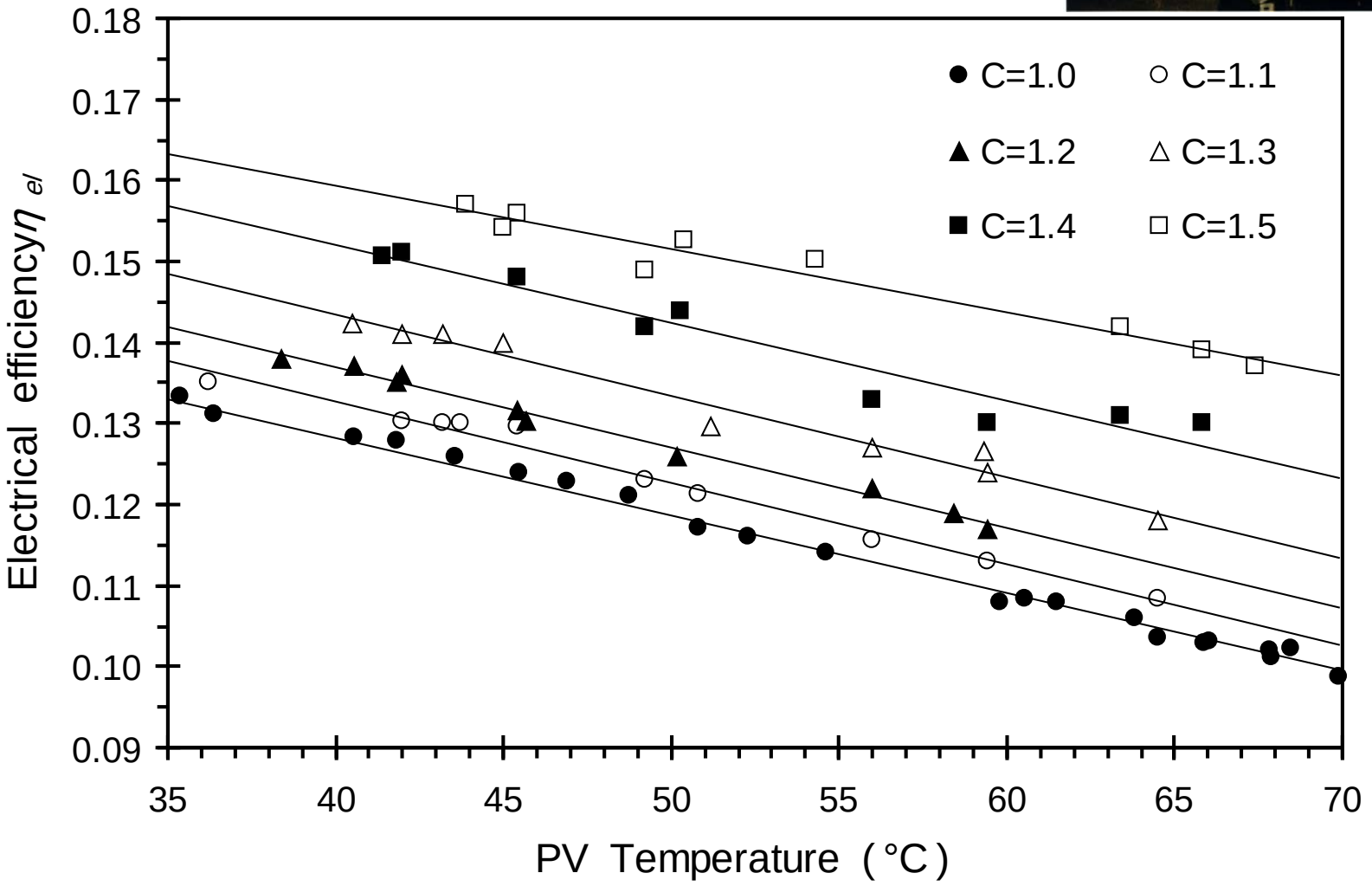




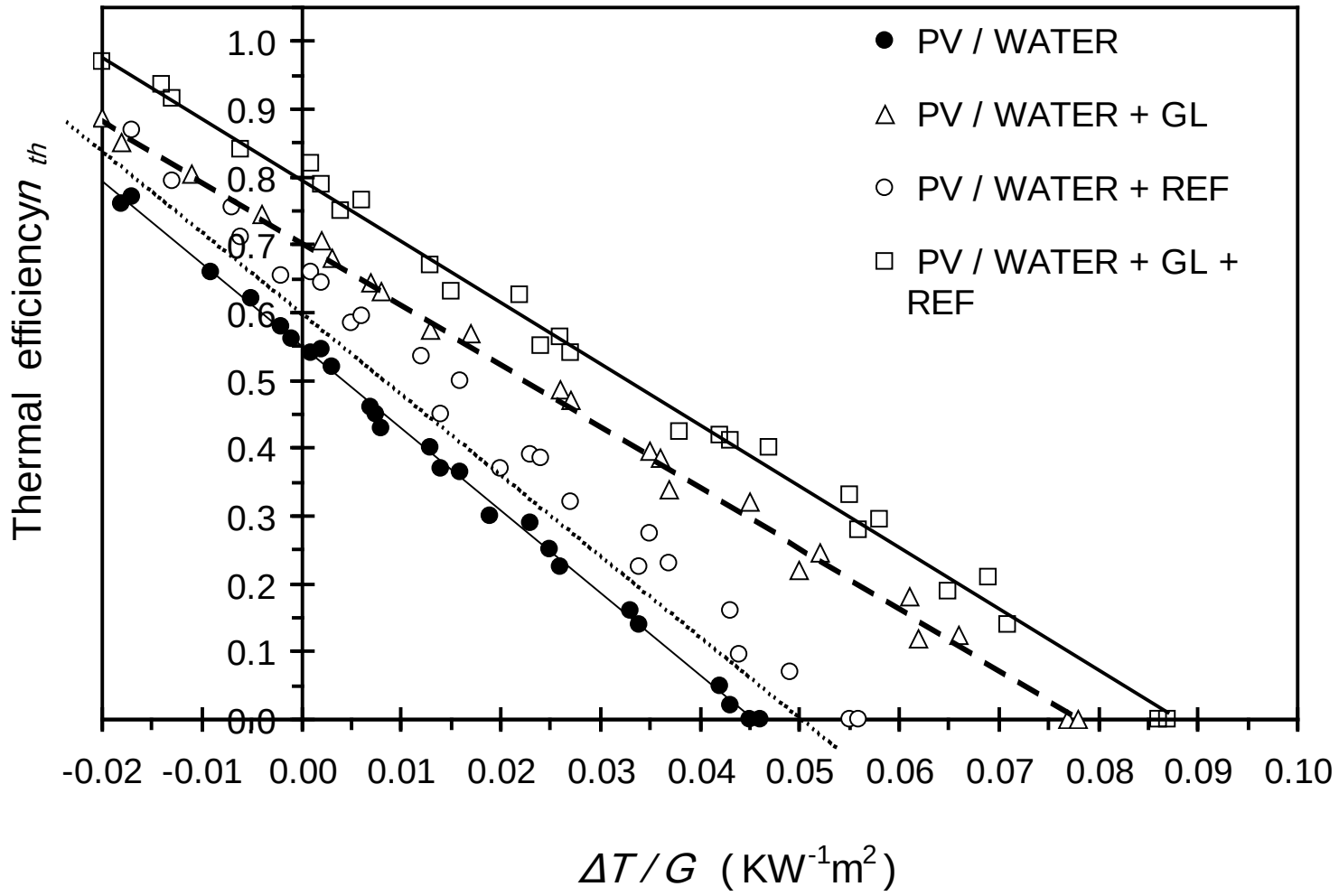
A performance improvement can be achieved by using diffuse reflectors between the parallel rows of the installed PV/T collectors on horizontal roof.

Electrical efficiency for pc-Si PV/T + REF hybrid solar energy systems

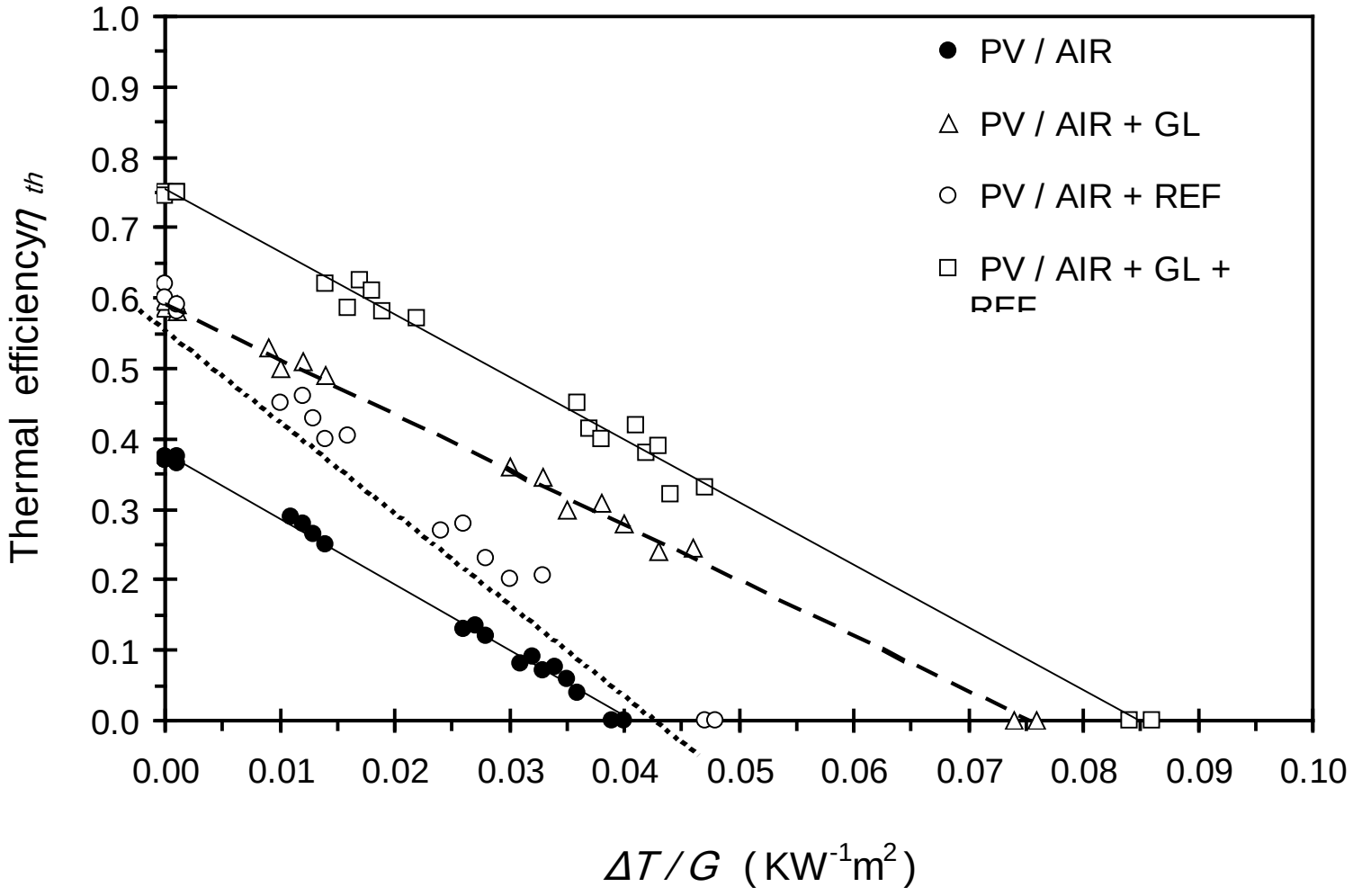




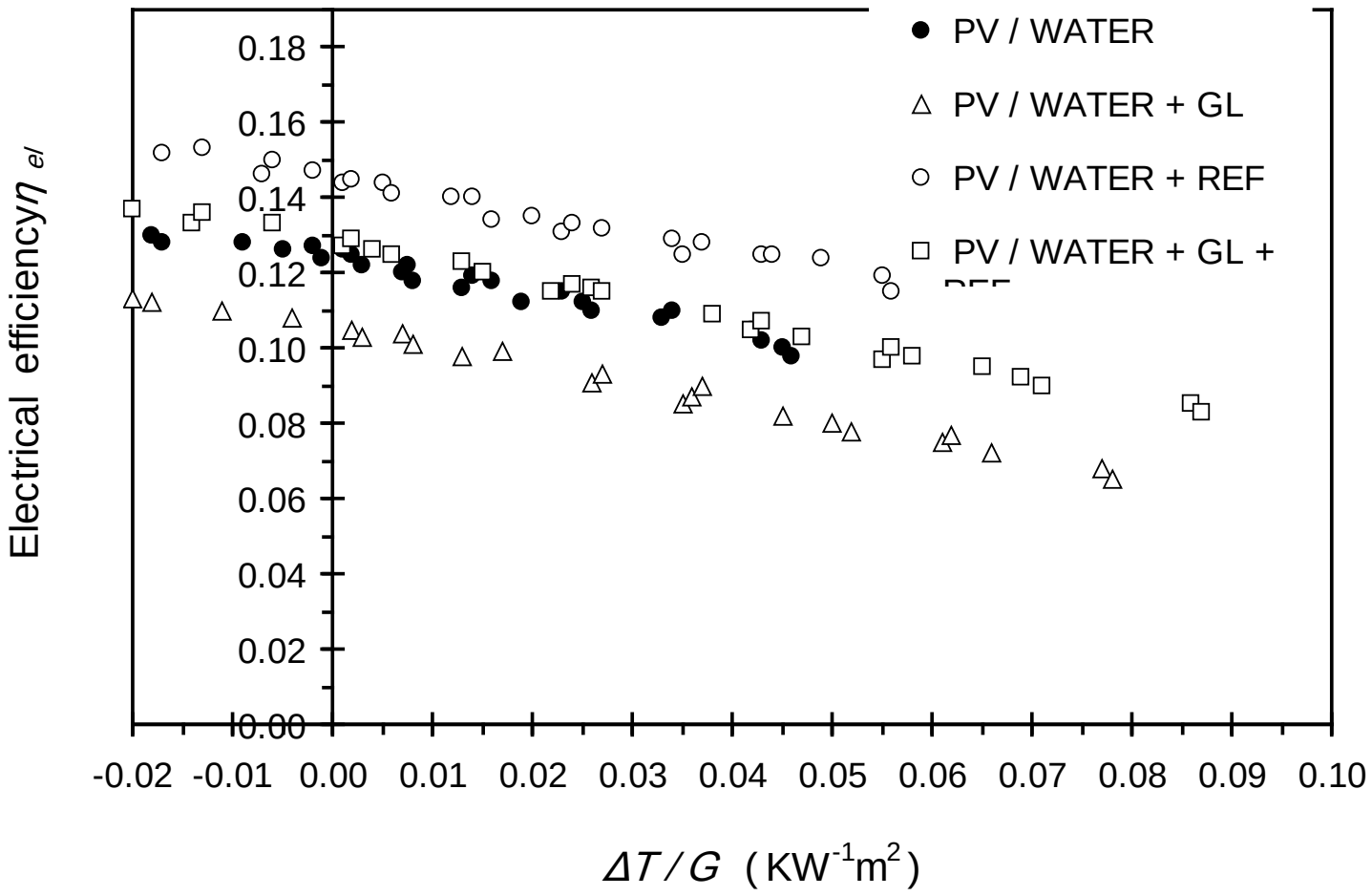
Test results of Thermal efficiency for pc-Si PV/T water system



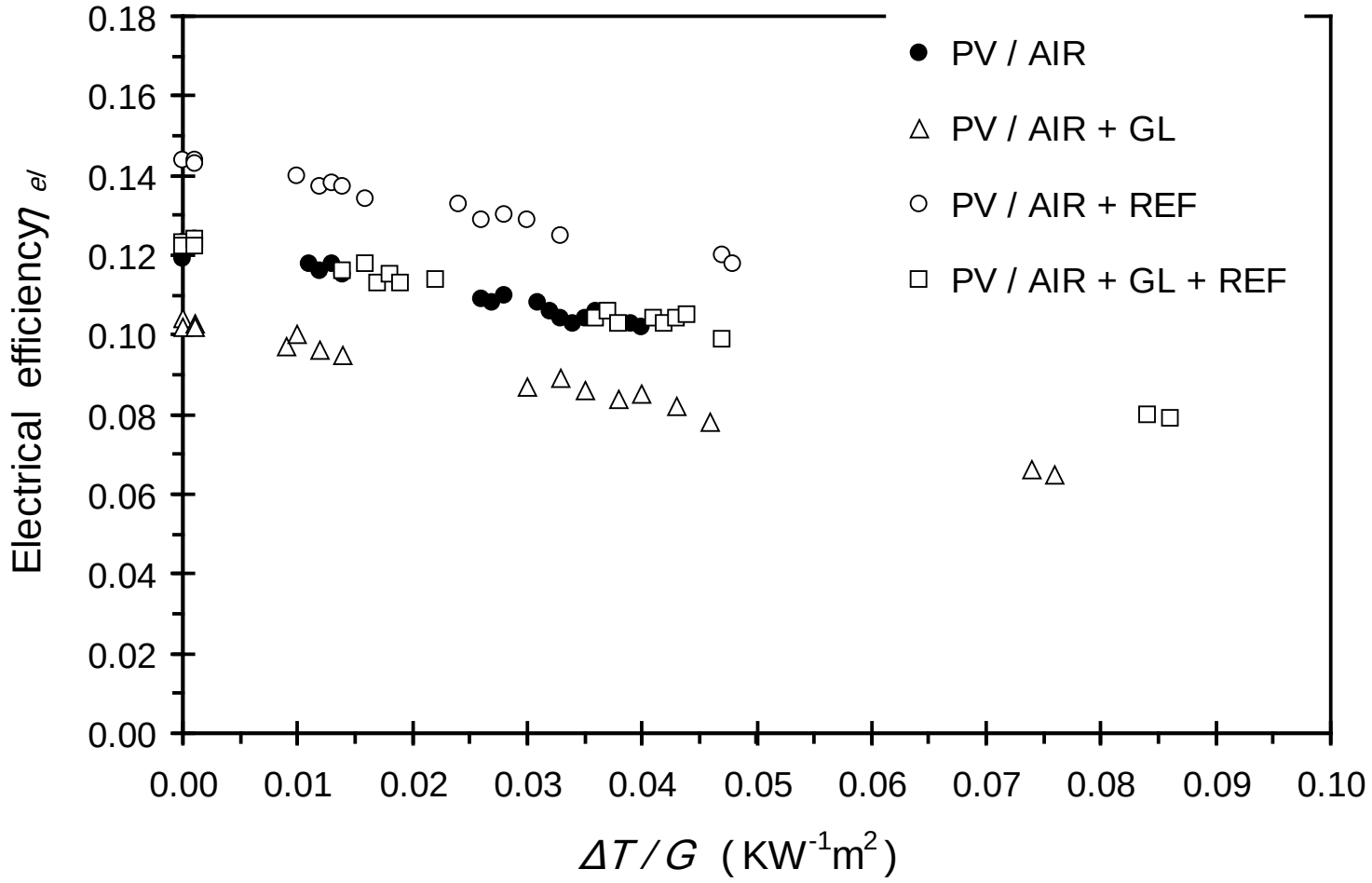
Test results of Thermal efficiency for pc-Si PV/T air system



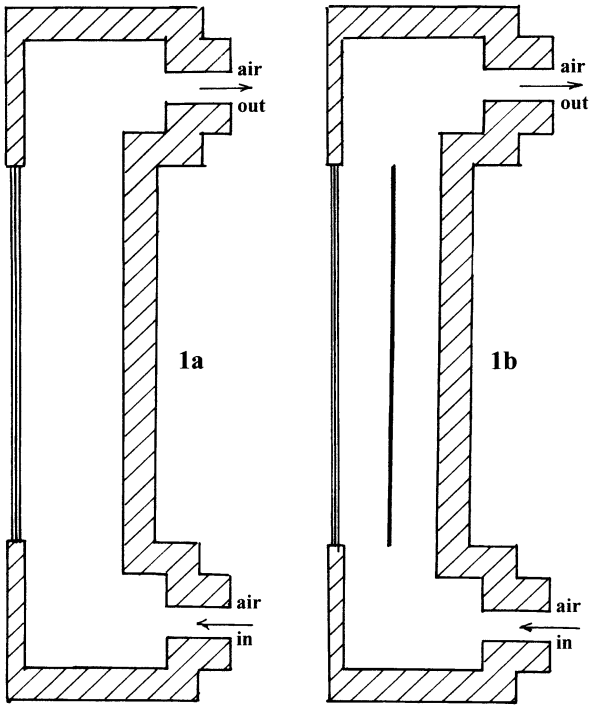
Test results of electrical efficiency for pc-Si PV/T water system



Test results of electrical efficiency for pc-Si PV/T air system

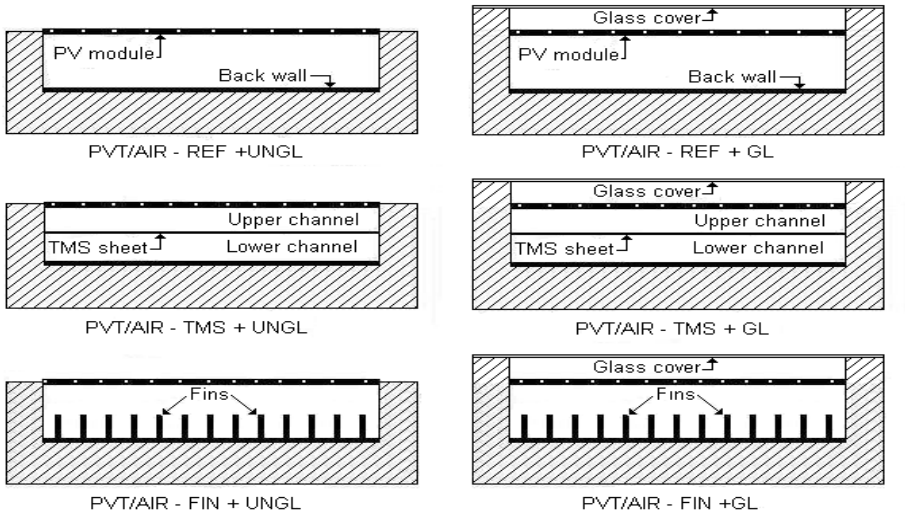


TMS air heat exchanger

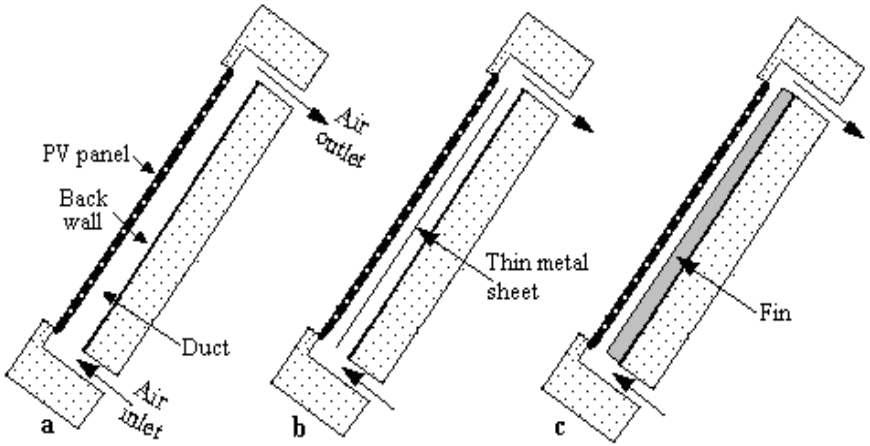


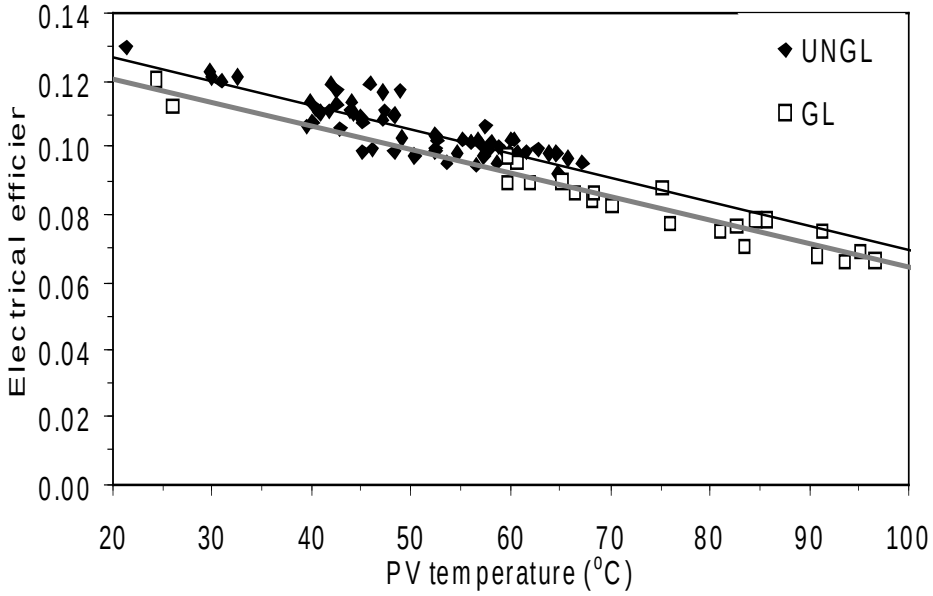
We increase the heat exchanging surface area inside the air channel by using a thin flat metallic sheet (TMS) suspended in the middle of the cavity to improve air heat extraction and prevent building overheating

Hybrid Photovoltaic/Thermal solar systems with air heat extraction

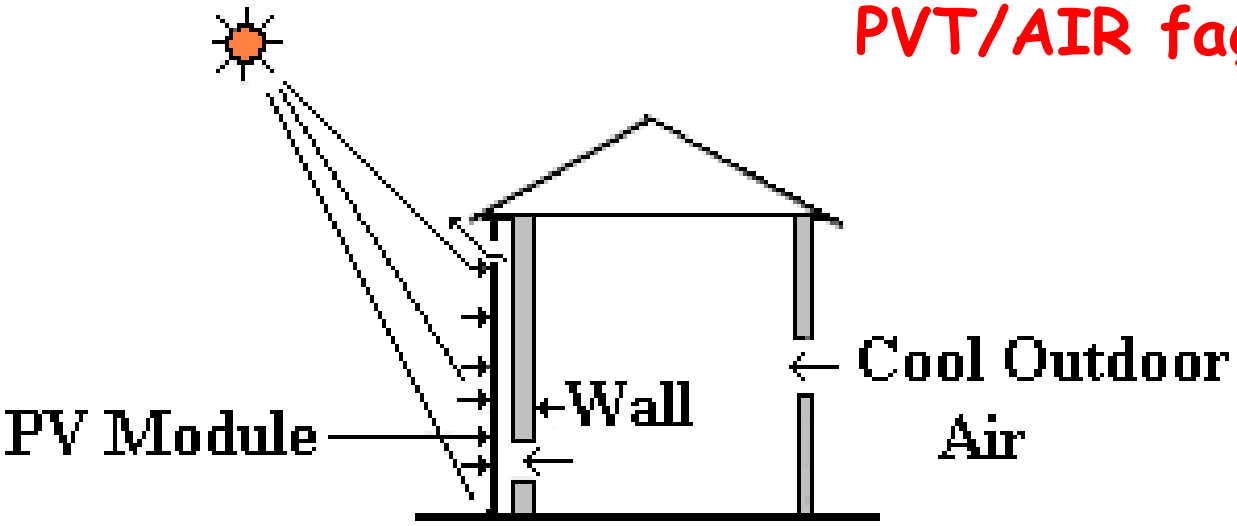


PV/T with air heat extraction
PV/T of glazed and unglazed type
PV/T systems with improvements





PVT/AIR façade integration

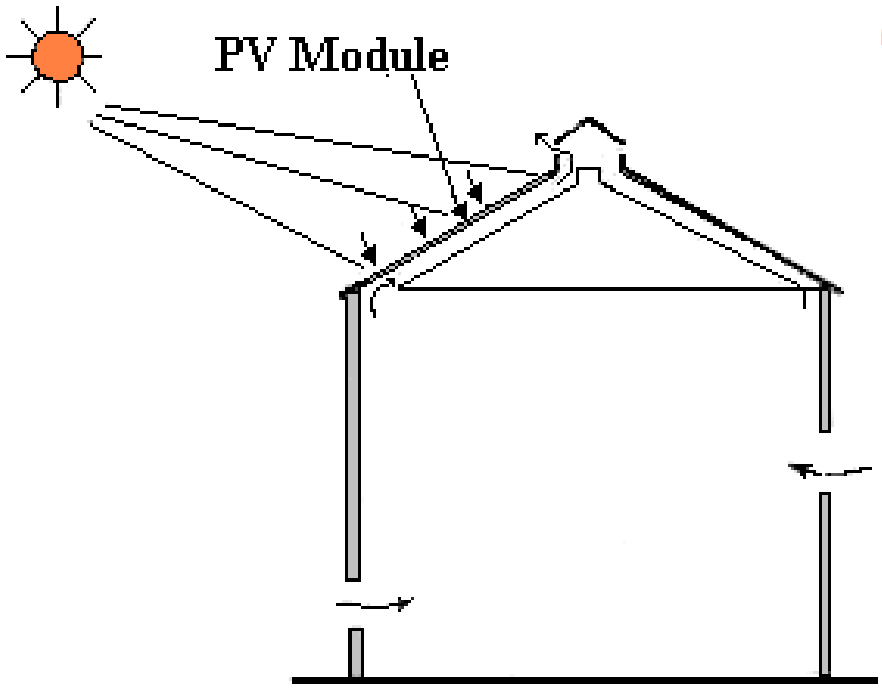


PV mounted on Facade for Ventilation

PV modules integrated on the façade with air gap contribute to a heat flow of circulating air out of the building.

Fresh air enters into the building through open windows and doors or infiltration and achieve natural ventilation.

PVT/AIR Roof integration



PV module mounted
as a Solar Roof Ventilator

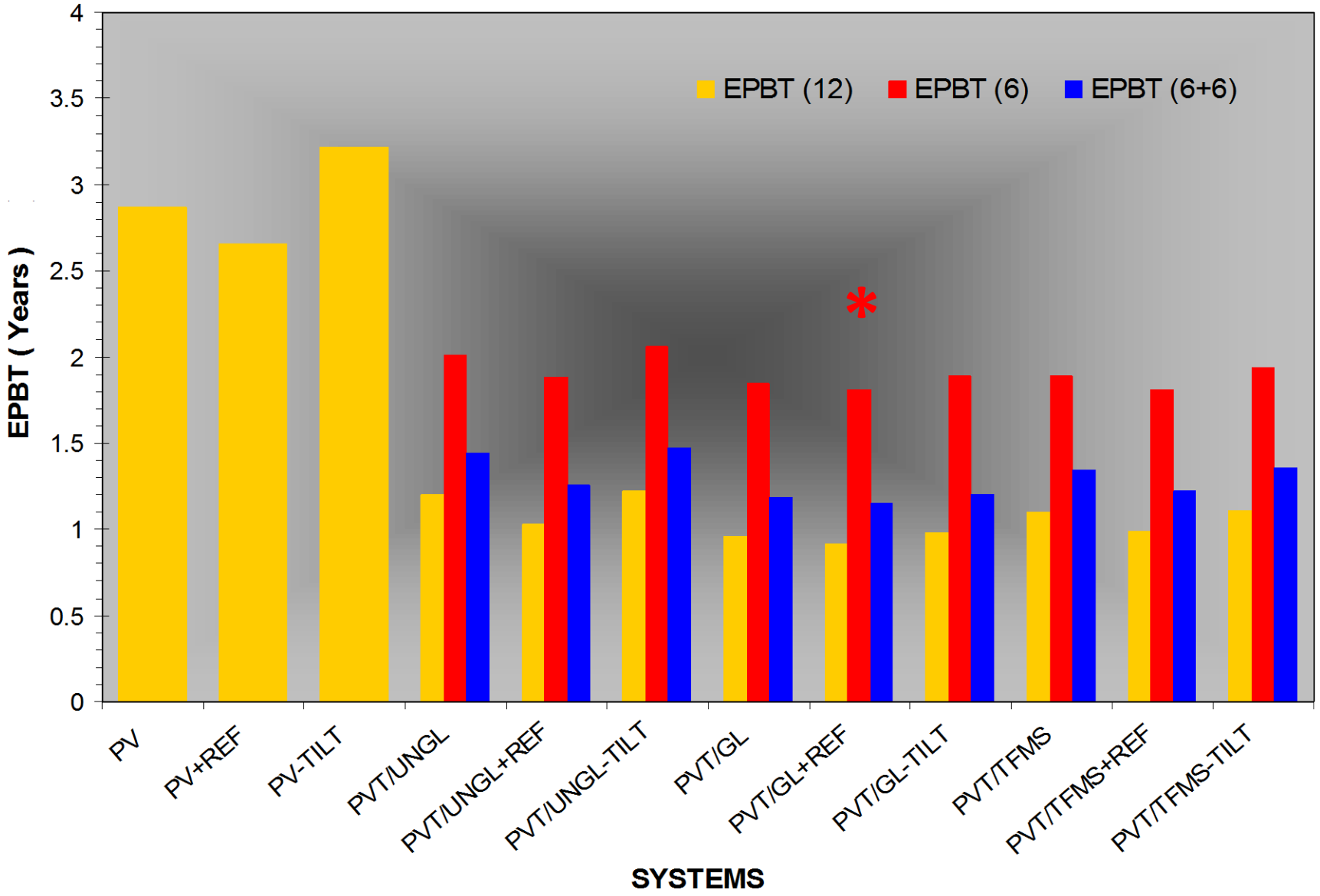
PV module mounted on the roof operates as a roof solar collector.

Fresh air enters into building through open (or infiltration) windows and doors and achieves natural ventilation.

PV/T system can be used as "ventilation driver" for natural ventilation of building creating substantial ventilation rate with air velocity about 1 ms^{-1}.

TMS "shields" the back wall up to about 3°C below that of REF system and reduces building heat load in summer.

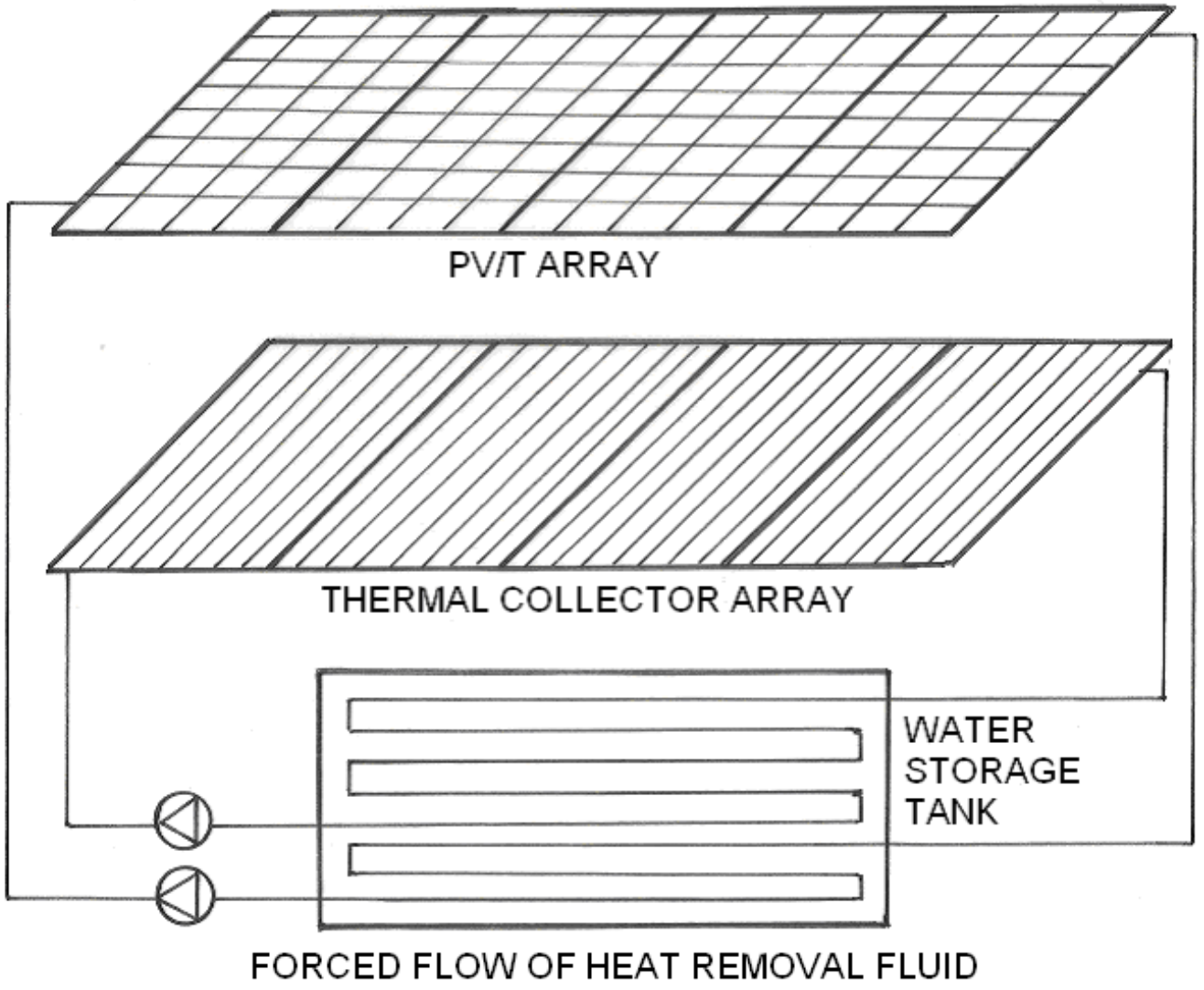
Energy Pay Back Time results



Thermosiphonic PVT/WATER collectors

Multi Solar System, MSS Millenium Electric, Israel

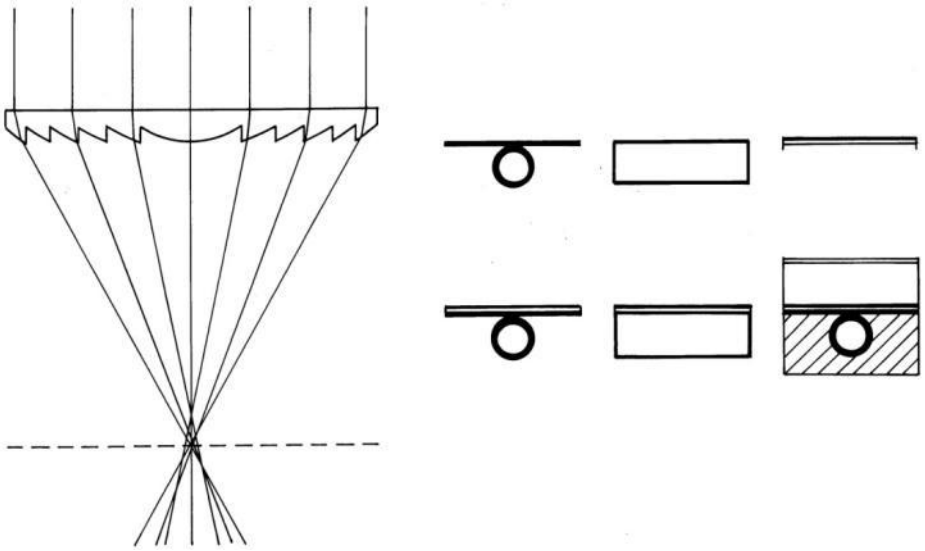
HYBRID PHOTOVOLTAIC/THERMAL SOLAR SYSTEMS



Improved performance with separated thermal collector and PV/T system

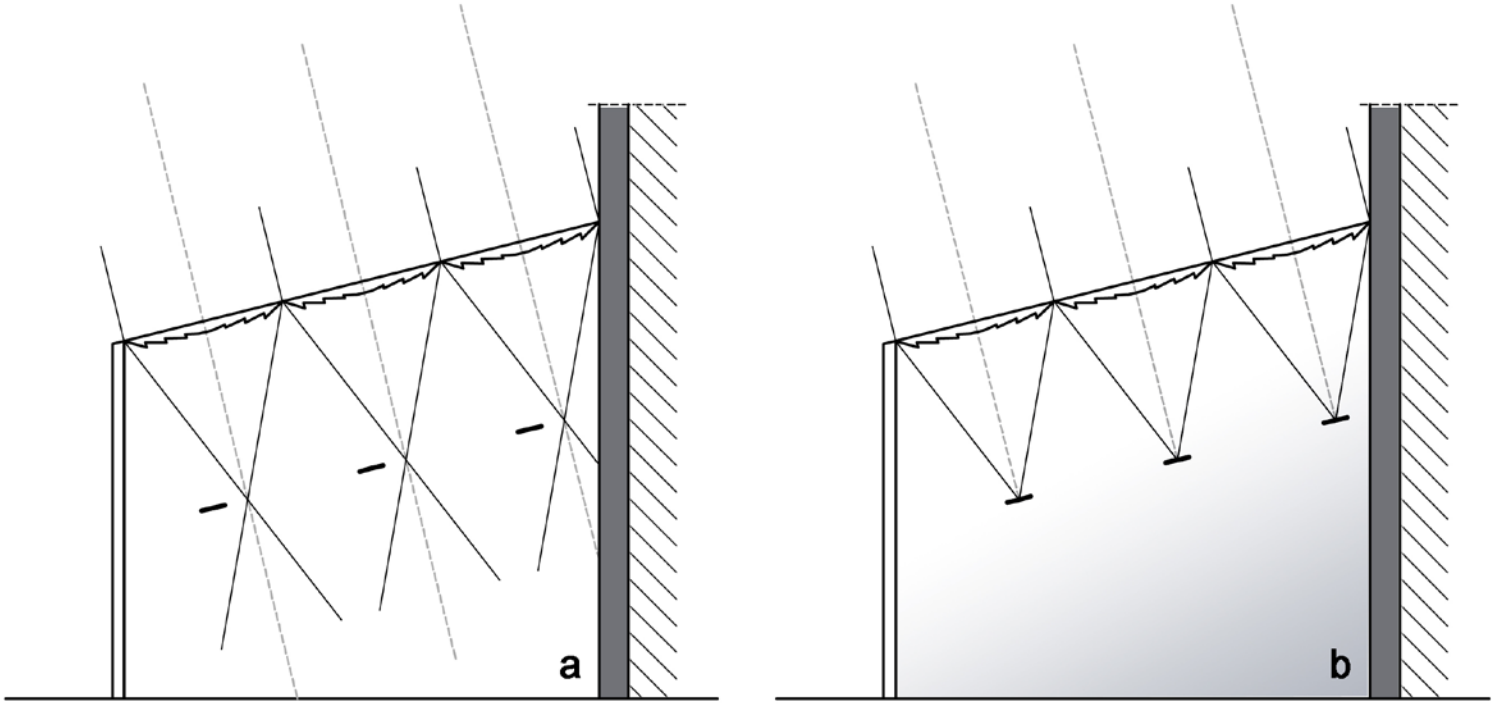
PV/T systems combined with Fresnel lenses

The direct incident solar radiation can be concentrated on an absorber strip, located at the focal position and can be taken away to achieve lower illumination level and also to avoid the overheating of the space.



In low intensity irradiance, the absorber can be out of focus leaving the light to come in the interior space and keep the illumination at an acceptable level.

The operation concept of the fresnel lenses with tracking absorbers

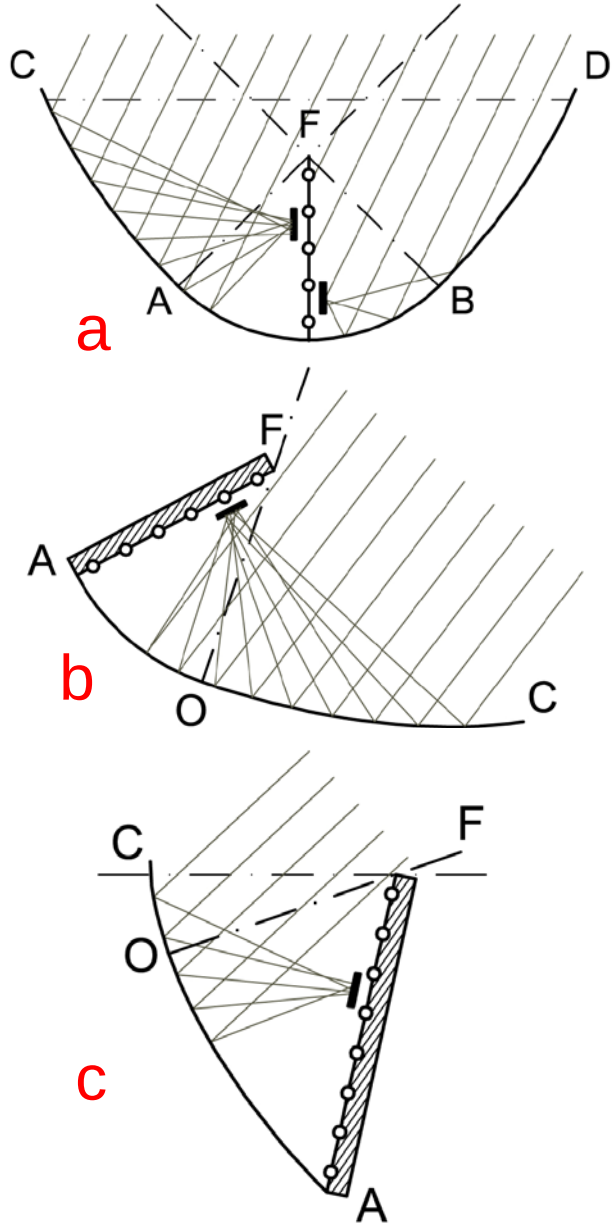


Absorbers out of focus

Absorbers at focus

To control the illumination and the temperature of the transparently covered internal spaces of buildings (atria, sunspaces) the tracking absorbers play a significant role.

CPC reflectors combined with linear PV and PVT absorbers

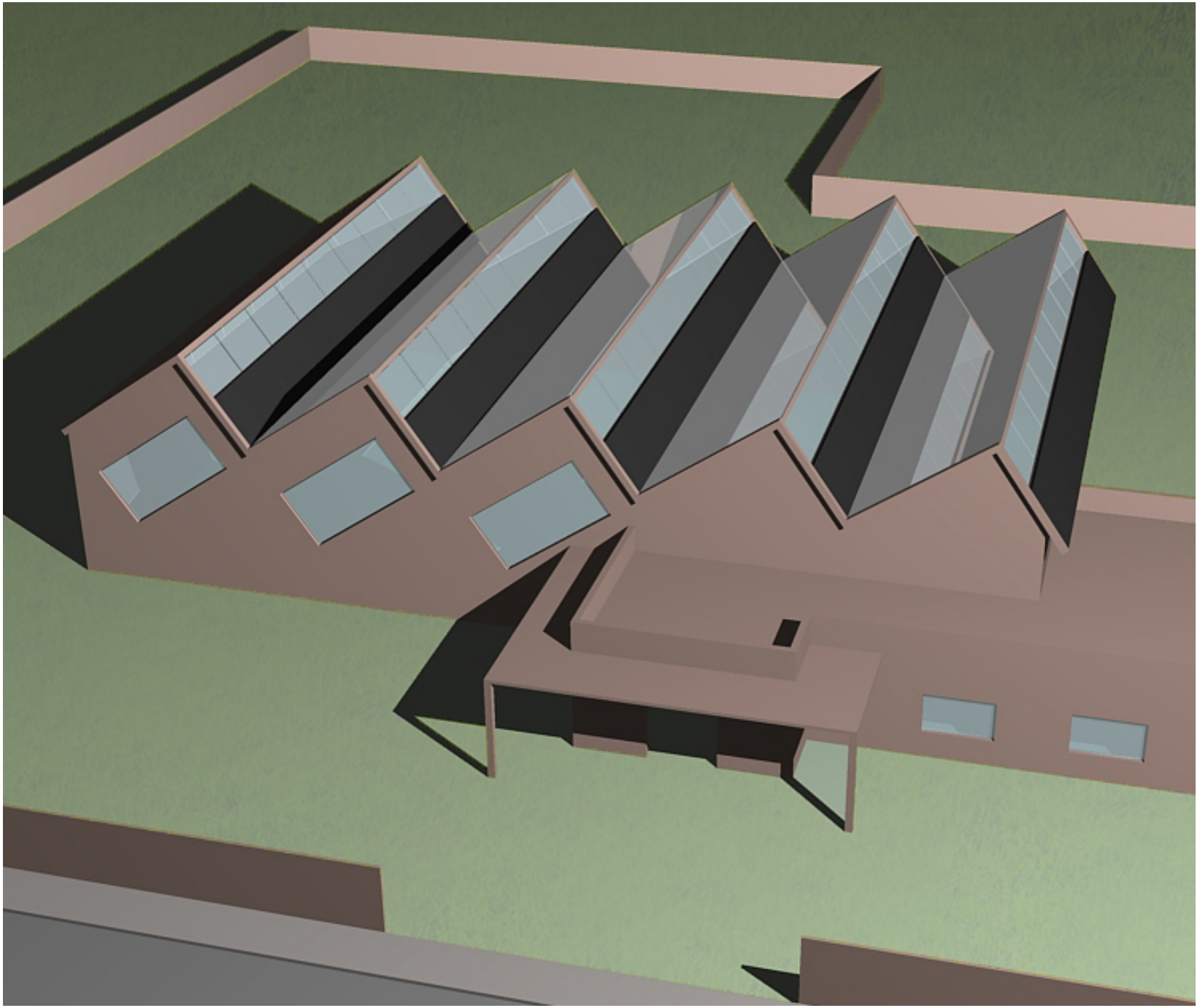


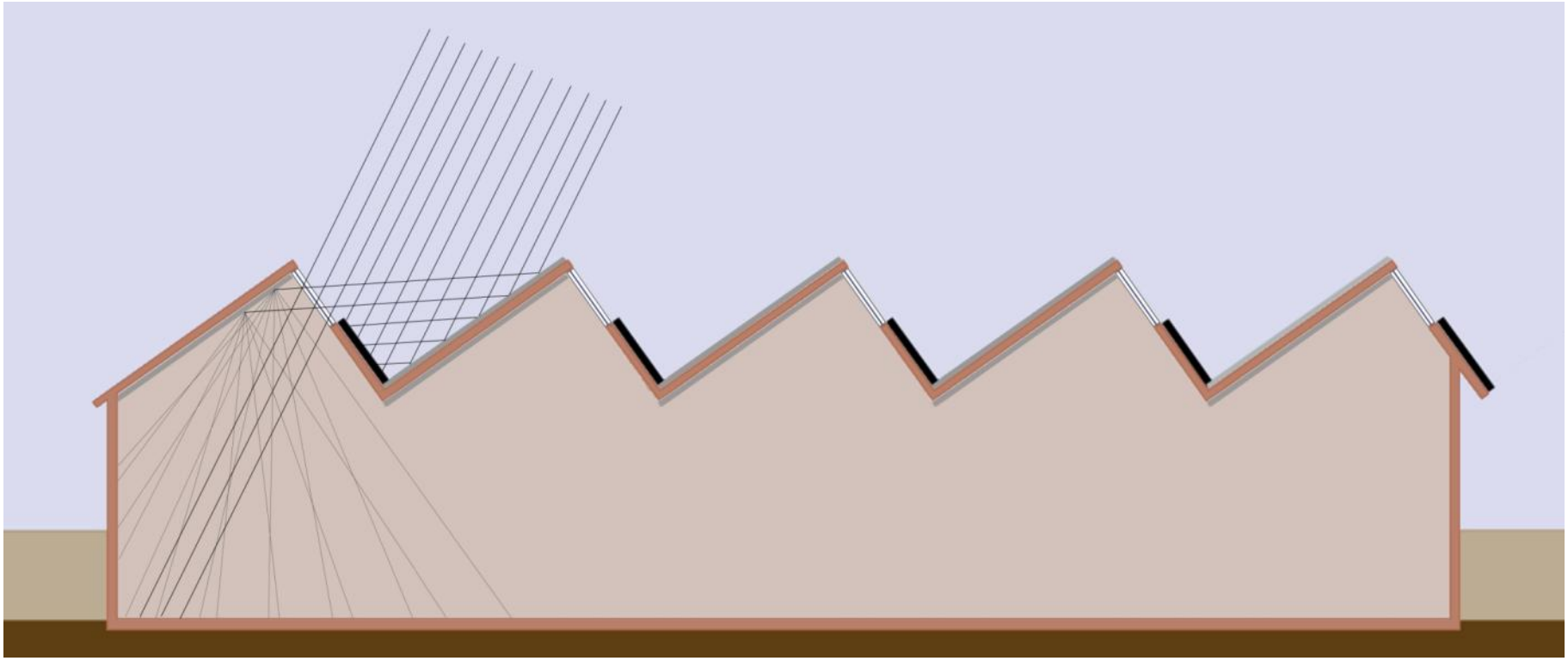
Stationary CPC reflectors with flat bifacial absorber (a) can be combined with PV strips that track the converged solar radiation and absorb the concentrated solar radiation.

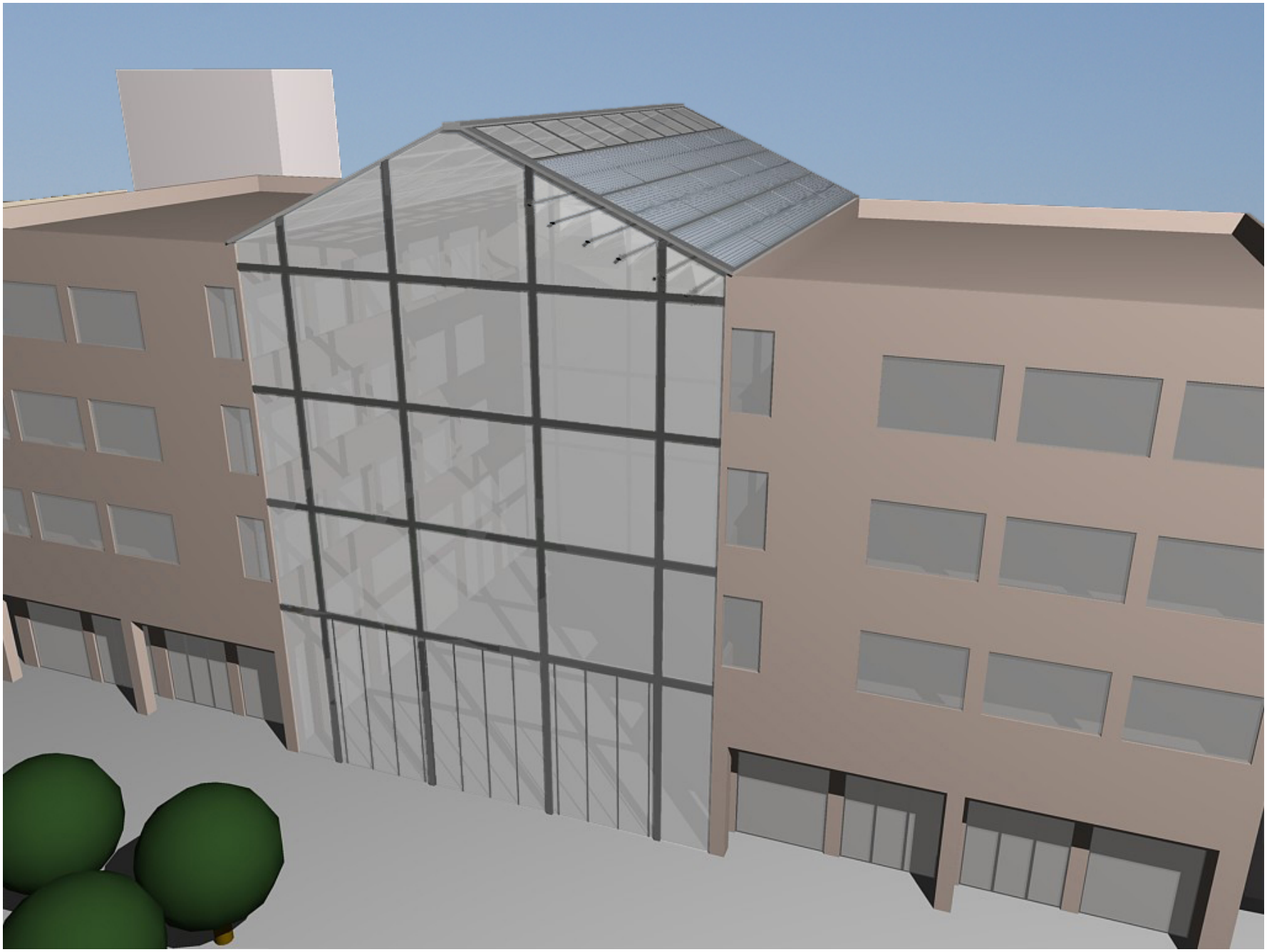
The non-absorbed beam solar radiation and the diffuse solar radiation are absorbed by the flat bifacial thermal absorber and can be taken away by the circulation of a heat removal fluid.

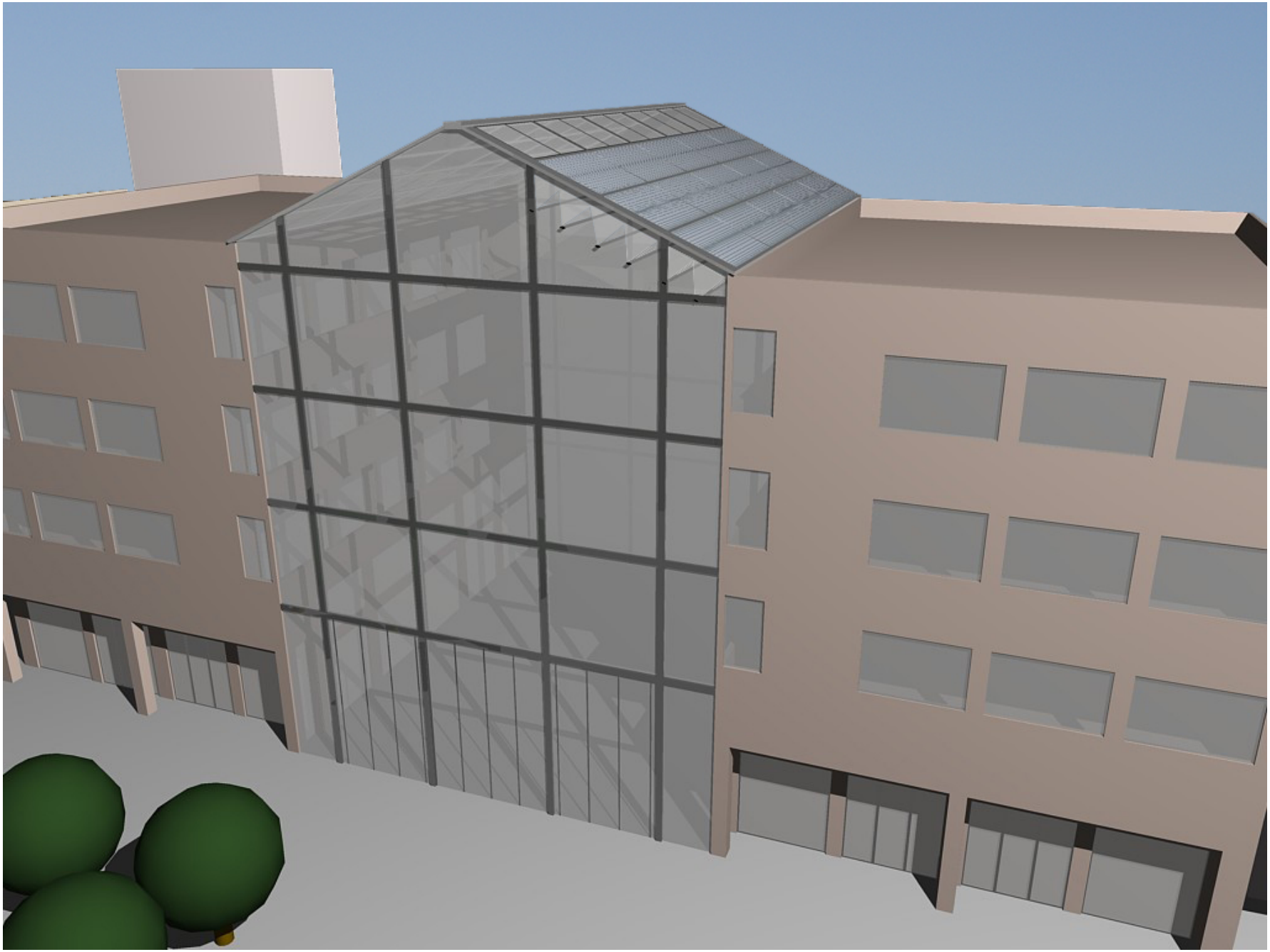
In asymmetric CPC reflector, the PV strip is moving in front of the thermal absorber, tracking the converged solar radiation.

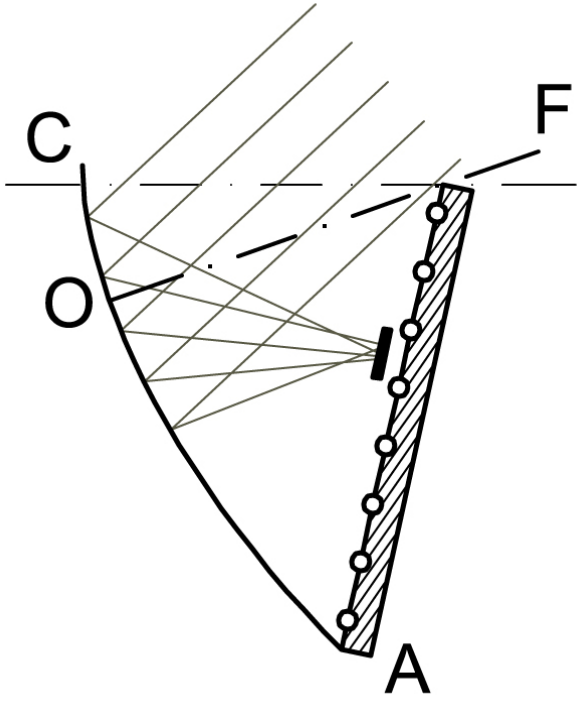
The parabola axis is directed to:
(b) the higher altitude of sun (summer) or to
(c) the lower sun altitude (winter).

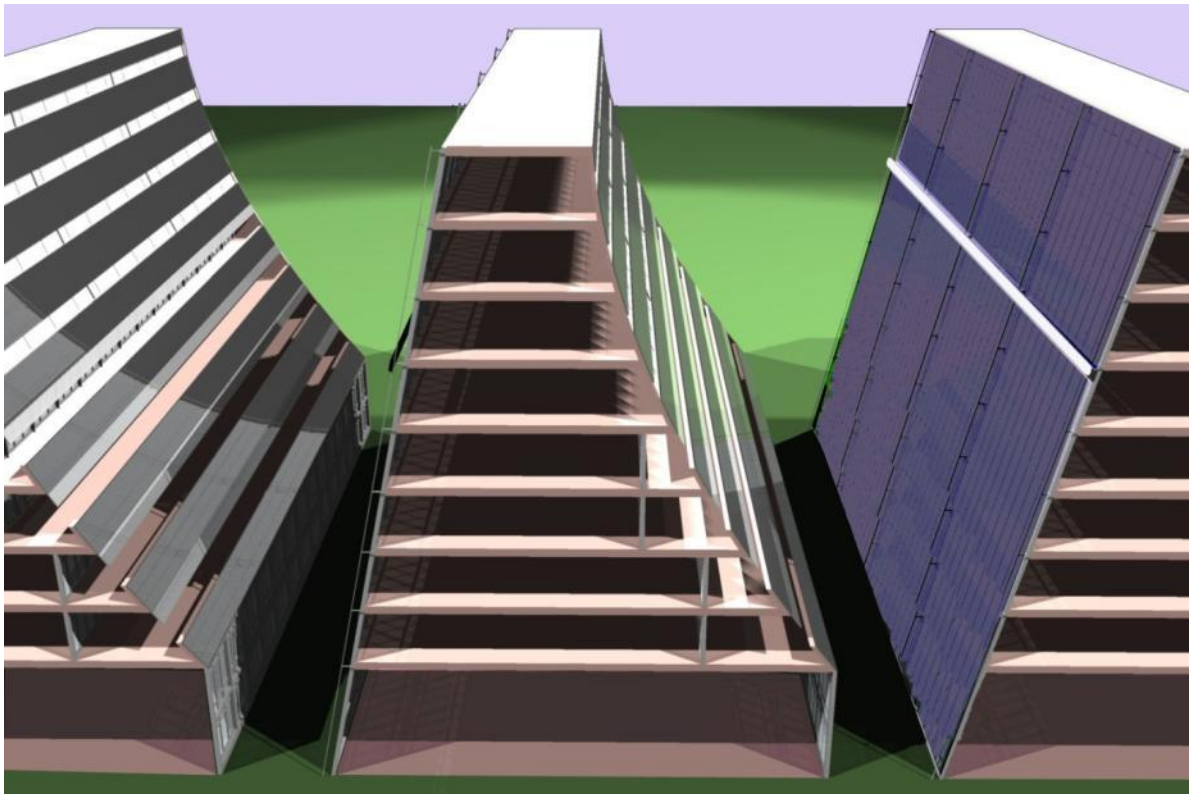




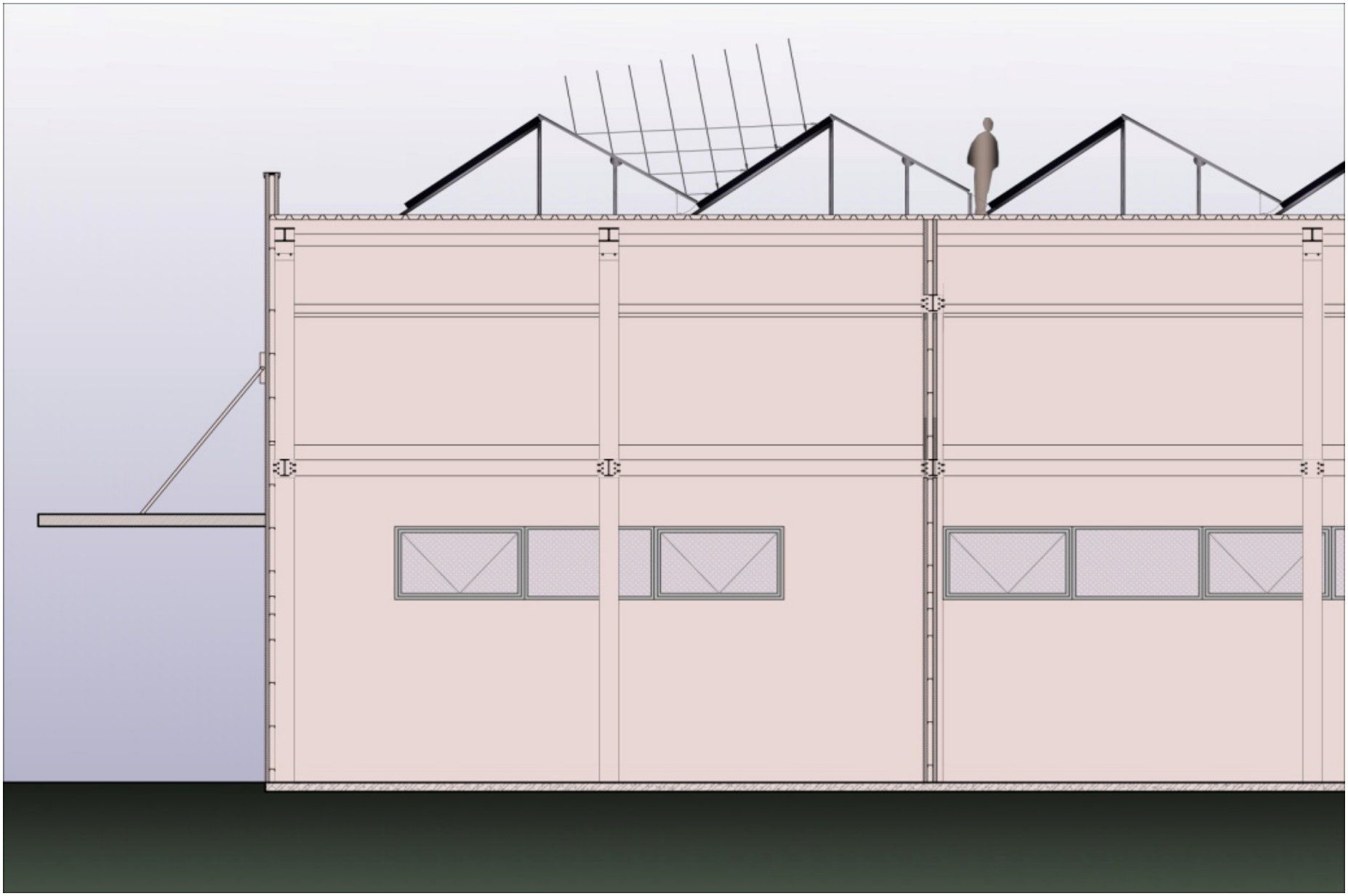


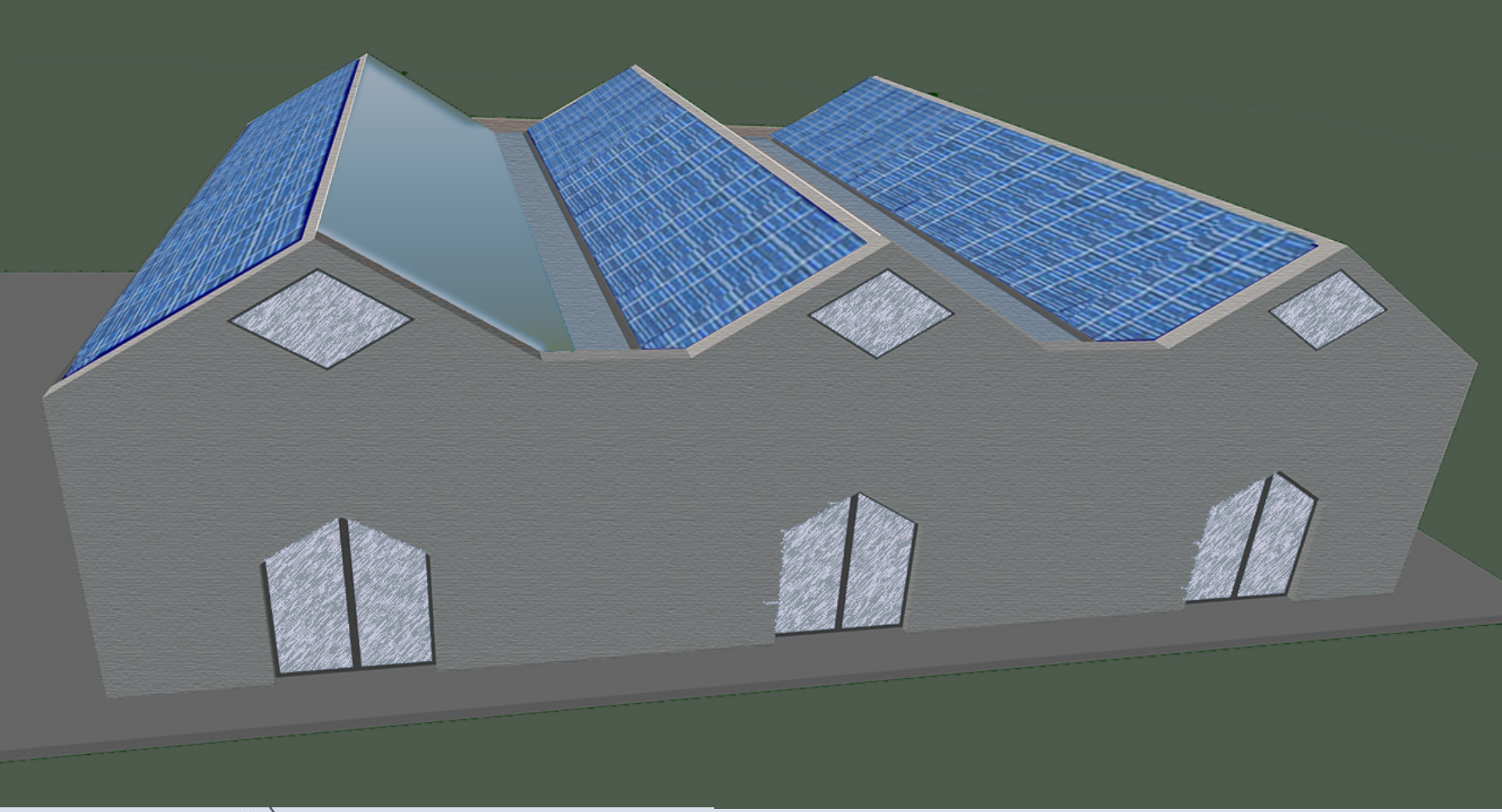


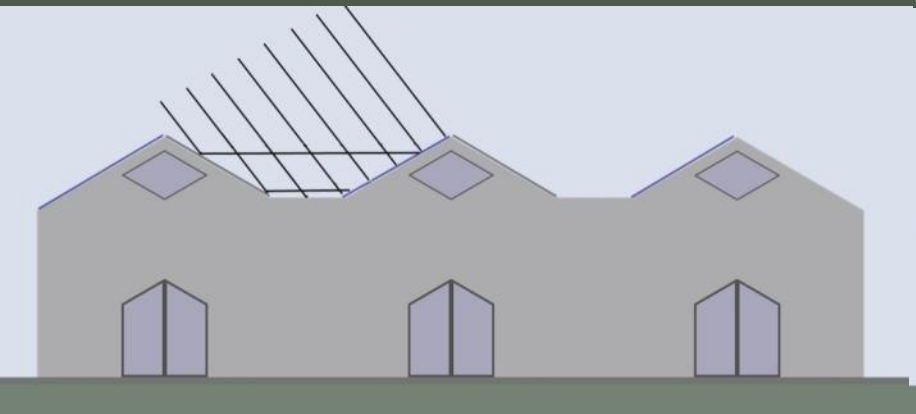


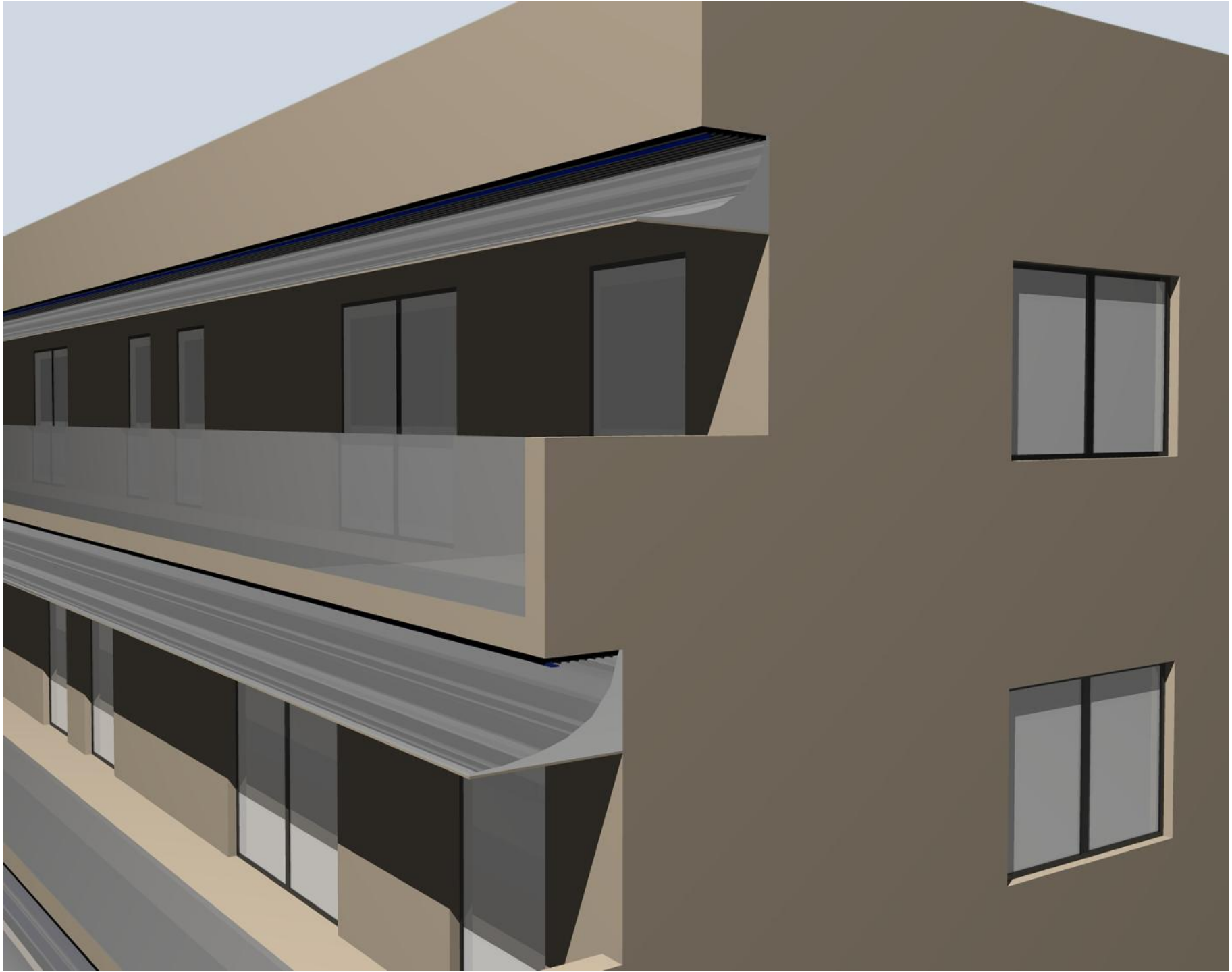


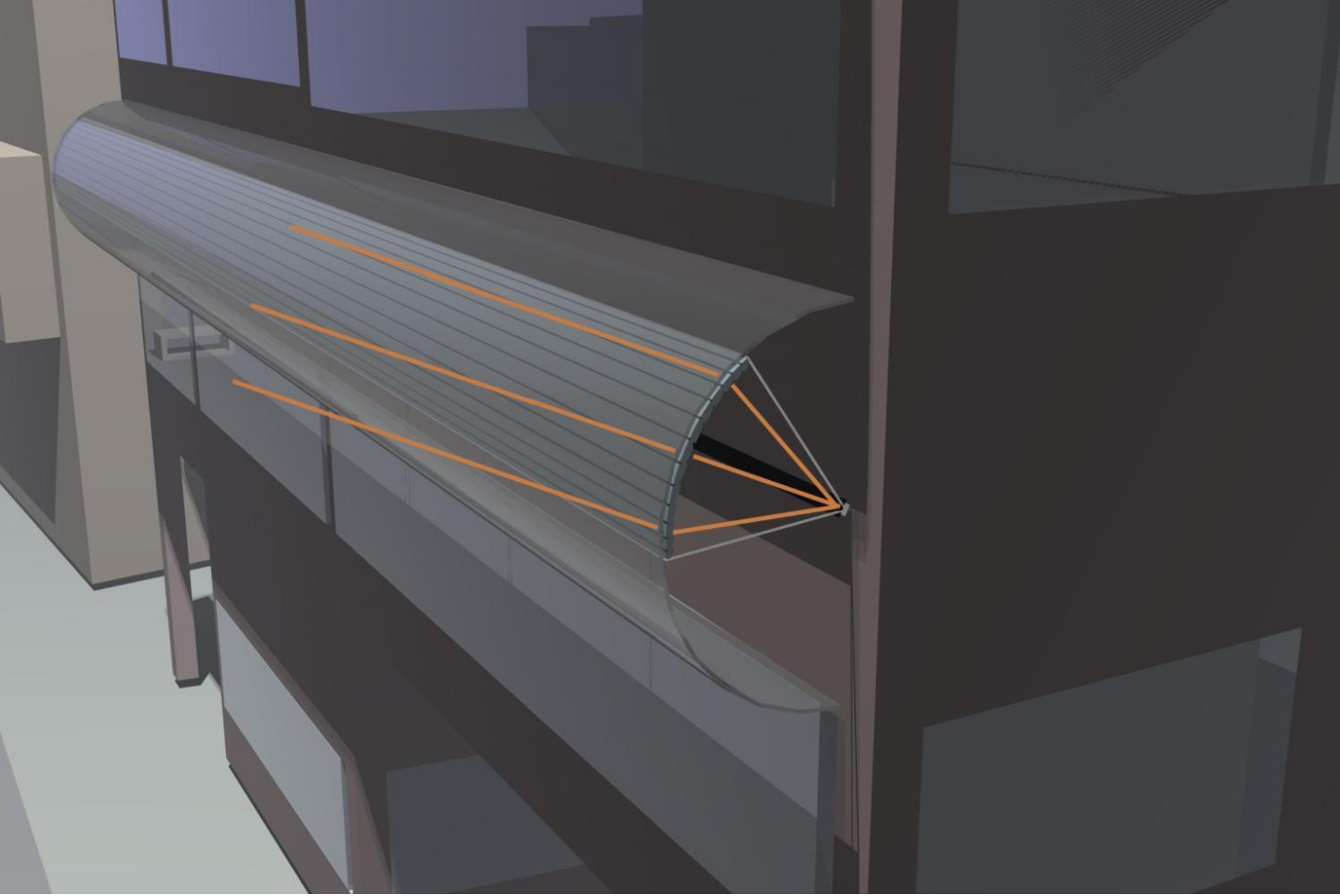
Architectural design of CPC-PVT building integration



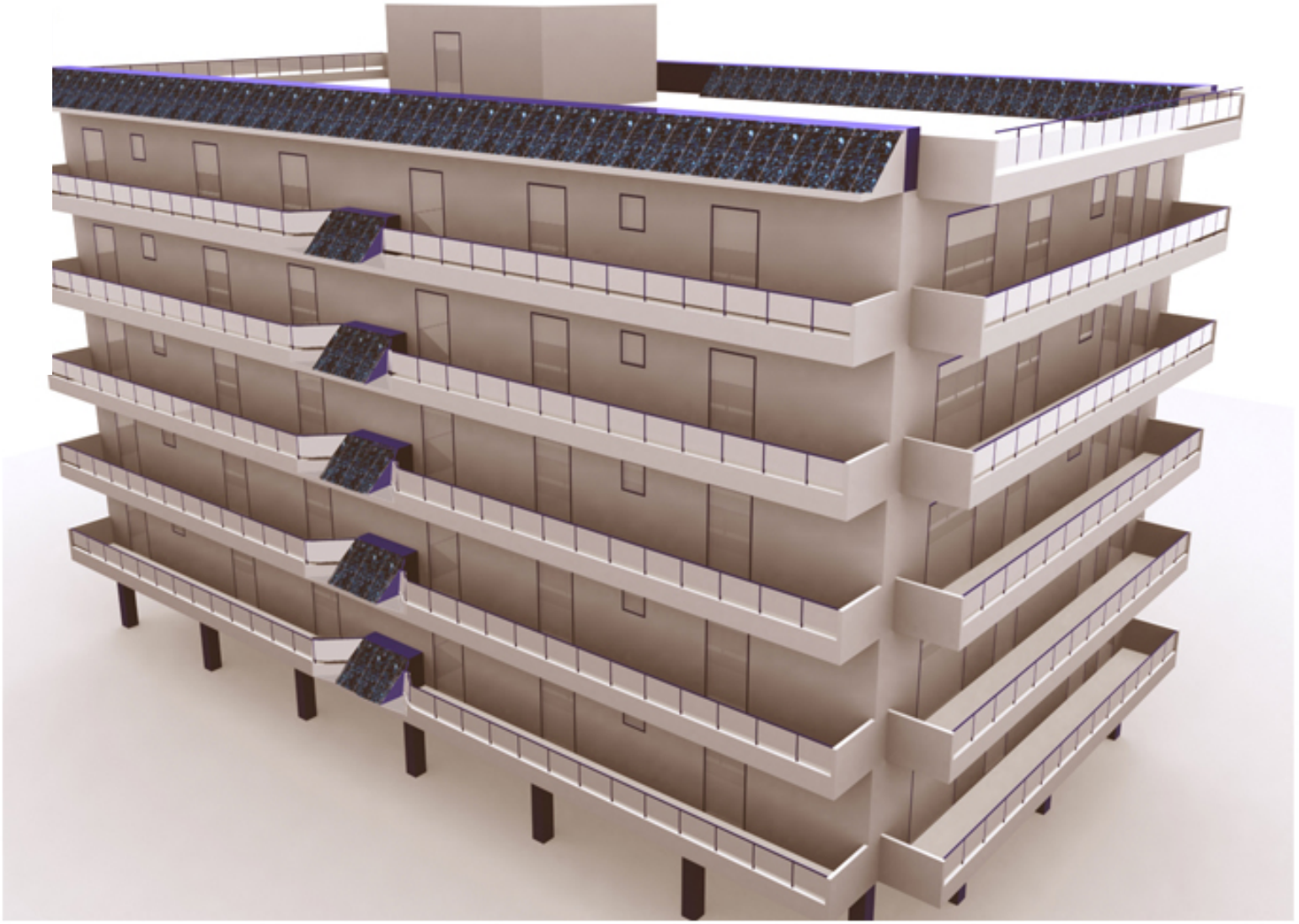


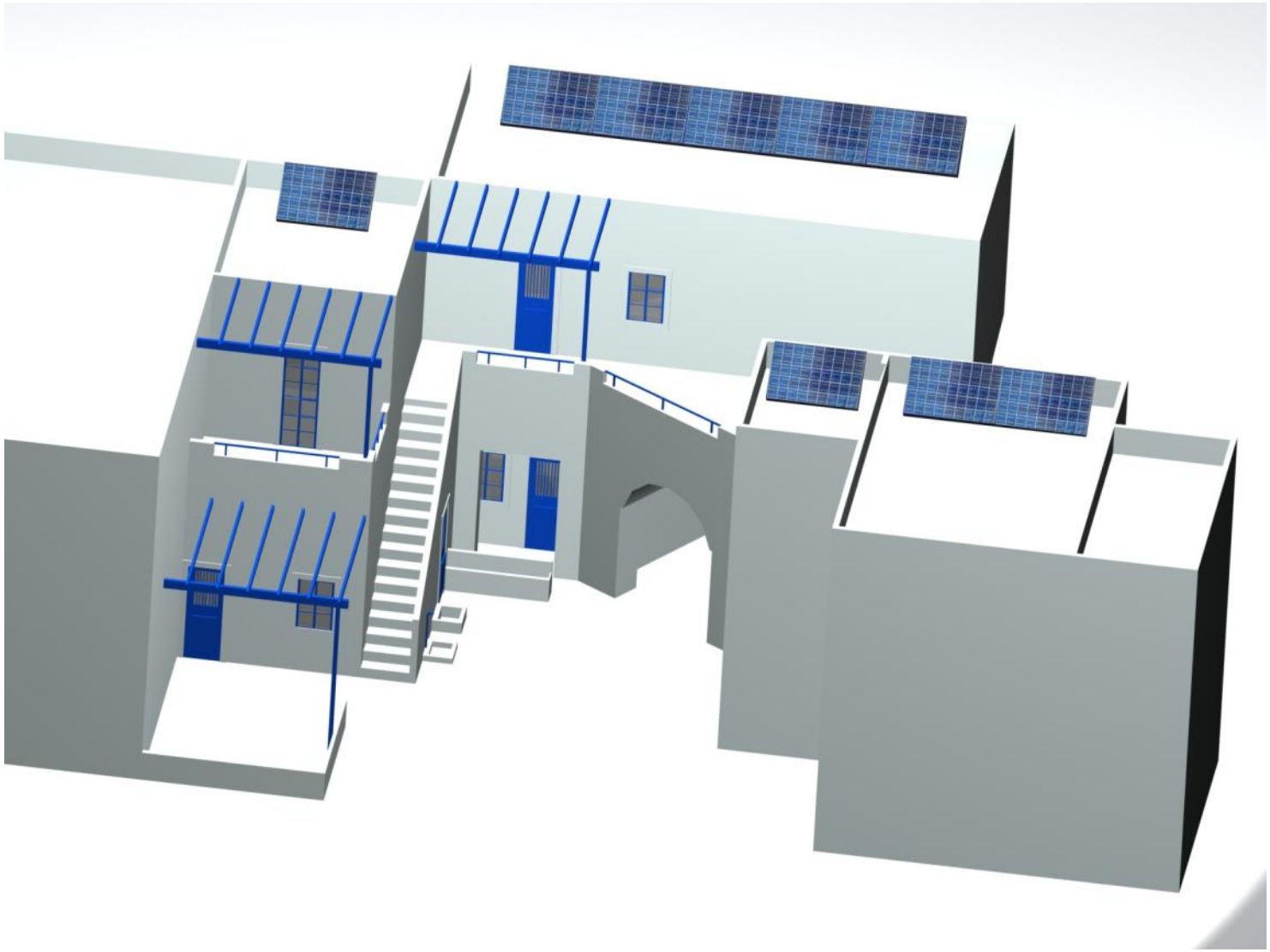






block of flats in Greece





HYBRID PV/T COLLECTORS ON CYCLADIC HOUSE ROOF

UPatras architectural design for cycladic island houses

Thank you for your attention

Ευχαριστώ για την προσοχή σας