Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology

Innovative technologies towards Zero Energy settlements: the Zero Plus experience

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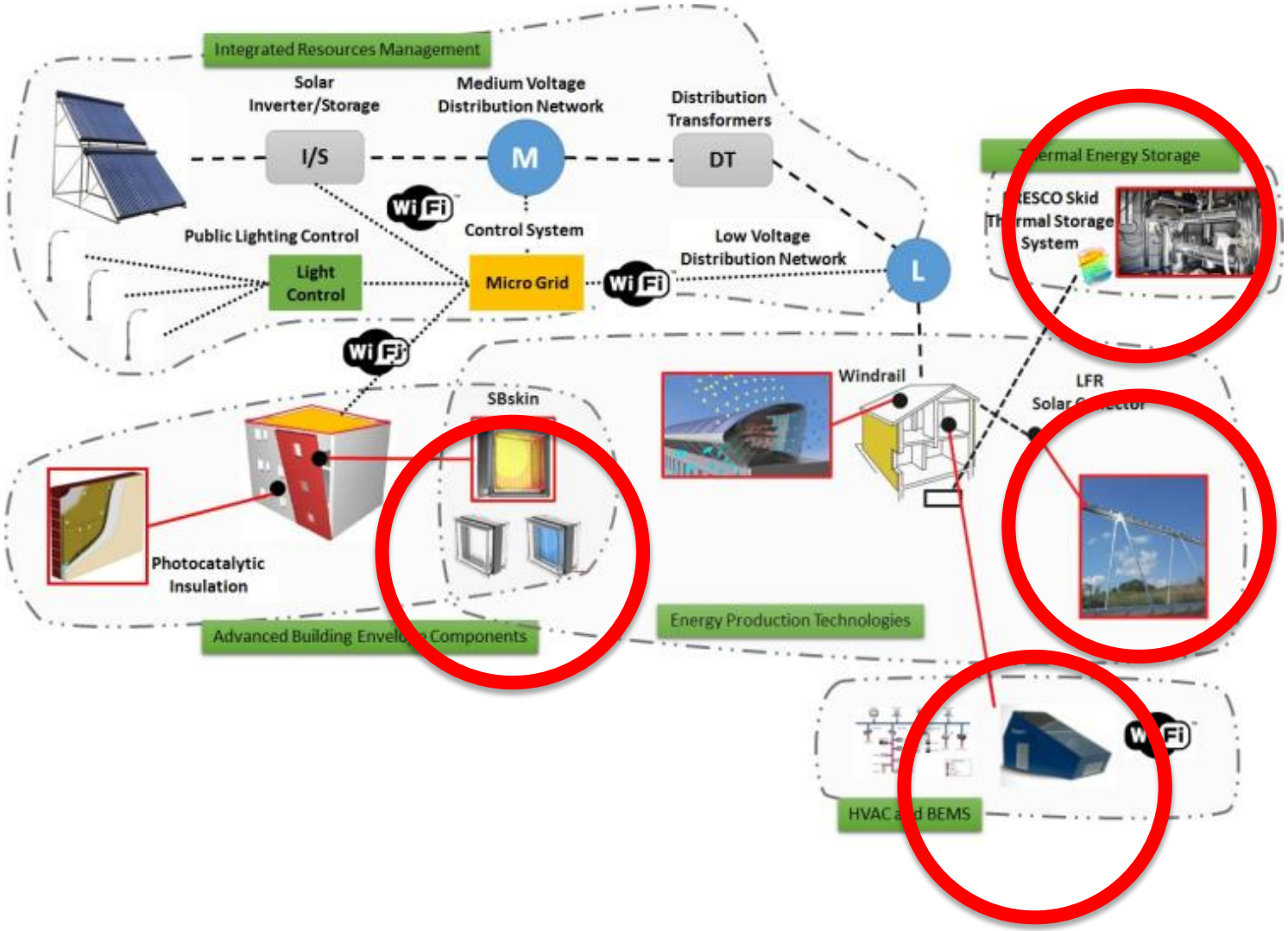
6th Jeffrey Cook Workshop on Zero Energy Settlements
Ben-Gurion University of the Negev, Beer-Sheva - 26th Nov. 2019

Zero Plus technology ecosystem – contribution from ARCA



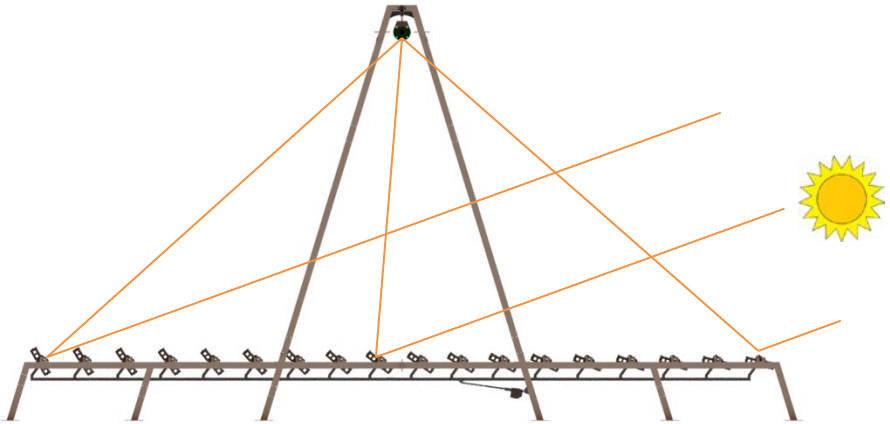
Building integrated Linear Fresnel Reflector

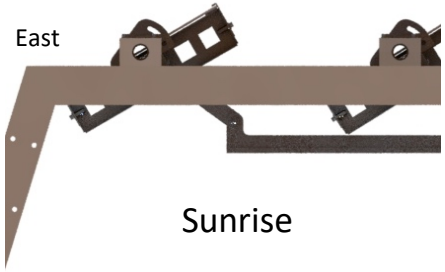
Linear Fresnel Reflectors (LFR) can be used to concentrate solar radiation on the absorber tubes transferring the heat to a circulating heat transfer fluid.

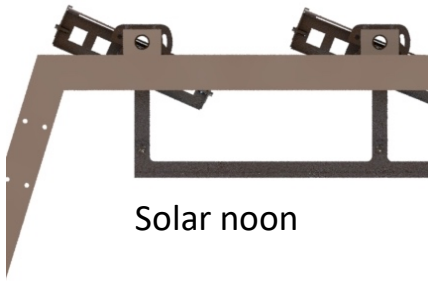
T_{range} 250˚C- 400˚C

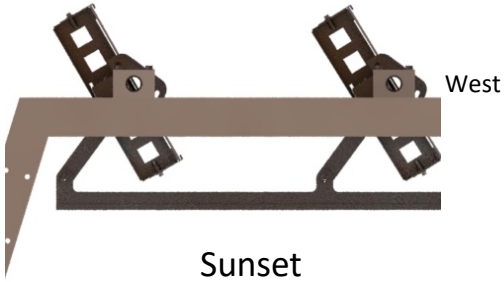
Each module of IFC1832 is composed by 18 mirrors rotating their position in order to reflect sun rays on the absorber tube surface

Characteristics of LFC IFC1832 module	
Net mirror surface	22 m2
Tracking system	Sigle axis
Dimension	4 x 8.7 m
Materials	
Mirrors	Ultraclean glass with silver coating Reflectivity > 95%
Absorber	Vacuum glass/steel pipe CERMET coated
Structure	Galvanized steel
Weight	950 Kg









Building integrated Linear Fresnel Reflector

- ❑ Modular & cost effective
- ❑ Easy to mount and “roof ready”
- ❑ High temperature (up to 300°C), it can drive double effect absorbtion solar cooling

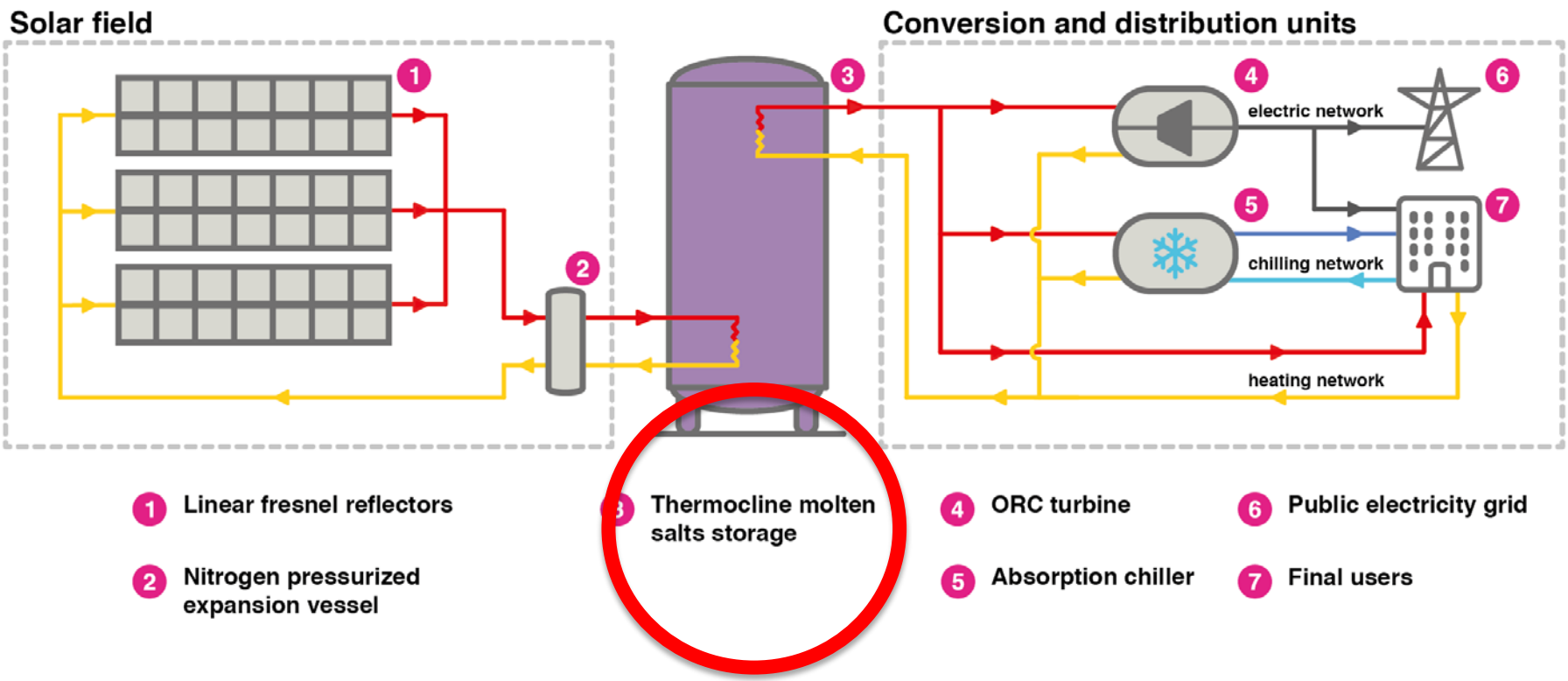
Designed for

- ❑ Settlement Heating&Cooling
- ❑ Industrial thermal processes
- ❑ Food logistics
- ❑ Small CSP plants

A unit is installed at The Cyprus Institute to provide cooling and heating to the Novel Technologies Lab. (NTL), a near to zero energy building.

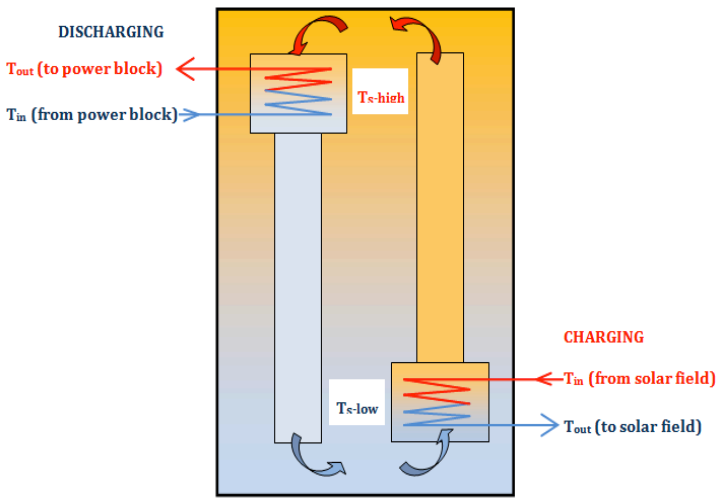
Location	Aglantzia, on the roof of a school, next to the NTL
Latitude Longitude Elevation	35°08'28.1"N 33°22'50.7"E 176m
DNI per year (SolarGis)	2142 kWh.m^{-2}
Type of collector	LFR
Aperture area	184.32 m^2
Thermal oil	Duratherm 450
Peak power	80 kW
Receiver length	32 m
Working temperature	170°C

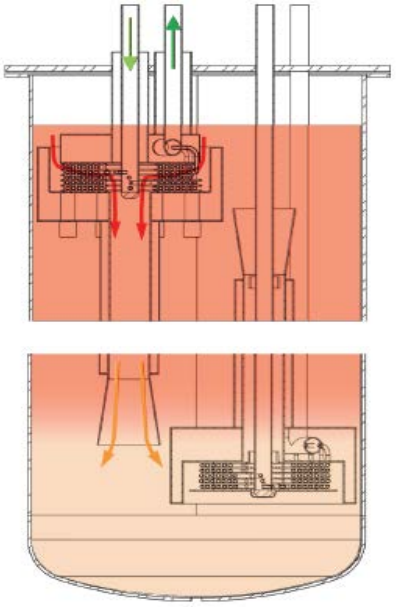
The LFR collector as part of a Distributed Energy System

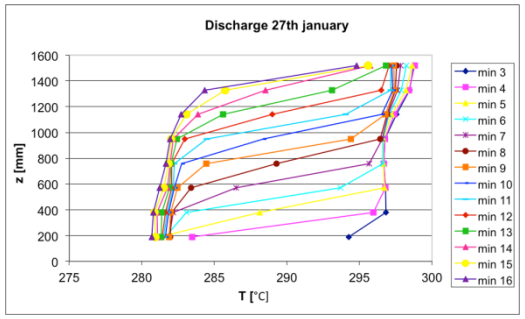


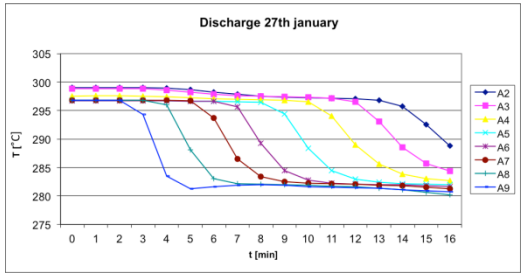
Innovative Thermocline Molten salts Thermal Storage

Two helicoidally heat exchangers are placed on the top and bottom of the tank, immersed in the molten salt.
The heat exchangers are integrated within two corresponding oil loops, designed to remove and supply the heat in the temperature range of 150-400°C.
The working principle is based on the thermal stratification of the molten salt resulting from the heat exchange in the two coils during the charge and/or discharge phases.









Study for integration in built area (dual land use)

Unfortunately the LFR system couldn't be applied at the ZP scale due to budget restriction and characteristics of the case studies.

Another concentrating solar system, for hybrid generation of electricity and heat has been introduced into the technology mix.

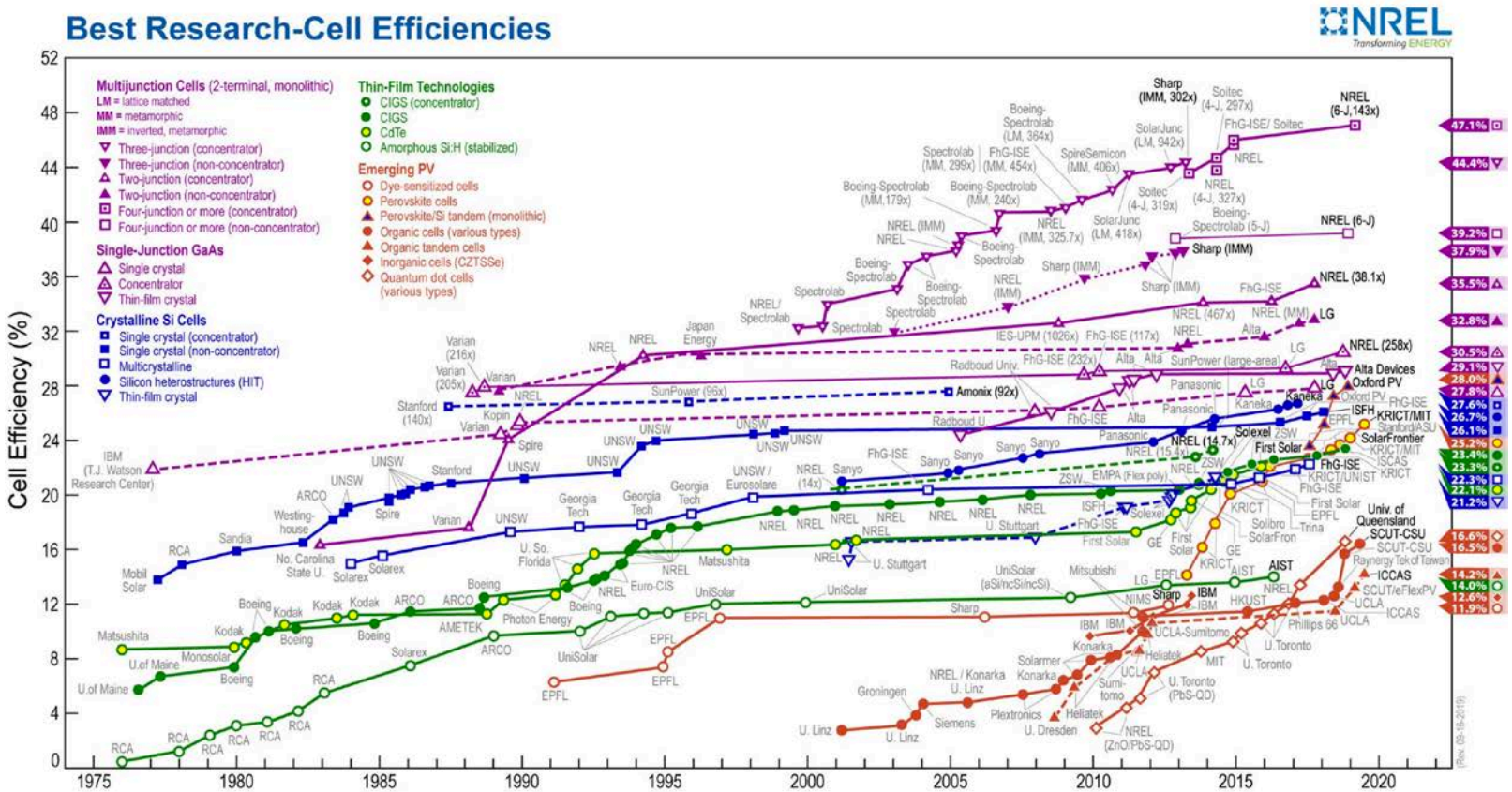
HCPV/T can provide an unbeatable global efficiency **electricity + thermal energy**.

As T_{out} can be raised up to 100°C, solar cooling and water treatment services can be integrated to PV/T generation.

Electric efficiency ≈ 30%
Thermal efficiency ≈ 45%
Overall efficiency ≈ 75%
Module peak electrical power ≈ 1.000 W_{ep}
Module peak thermal power ≈ 2.000 W_{thp}

Why CPV?

- The most efficient solar cells are MJ cells based on III-IV compound semiconductor materials.
- In locations with **high DNI**, by concentrating the solar radiation onto these high efficiency cells, we can get an **higher energy density** per square meter than by traditional PV.
- The latest generation of multi-junction solar cells **already converts 47%** of the solar light into electrical power. **The 50% target should be reached soon.**



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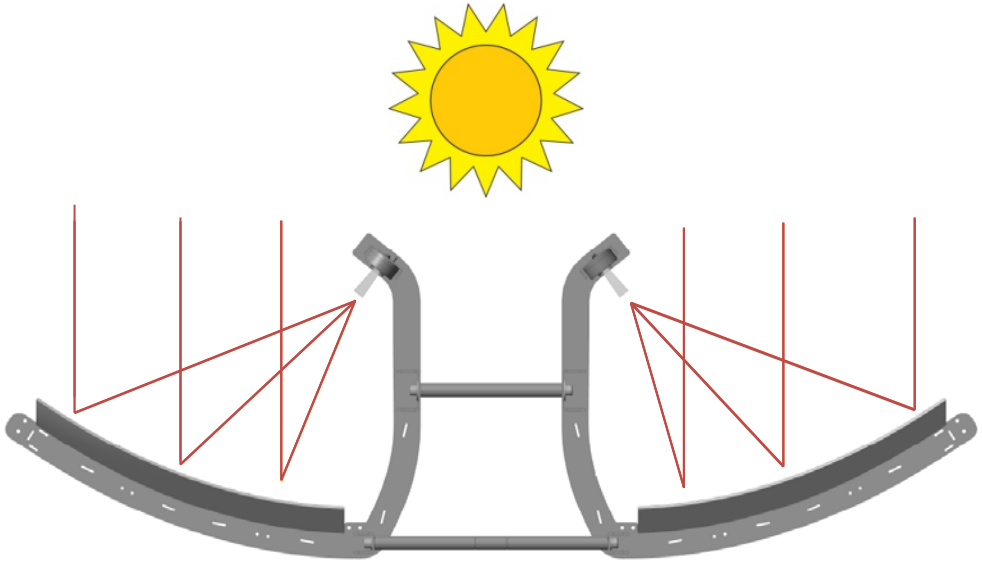
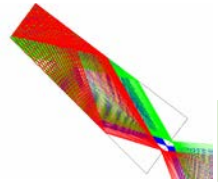
IHC2025 - UHCPV system – primary and secondary optic

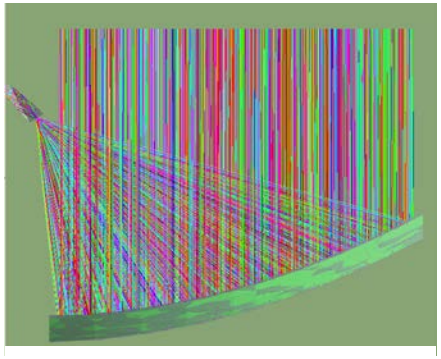
Solar light is concentrated by double curvature parabolic mirrors 45x45 cm into a secondary optic.

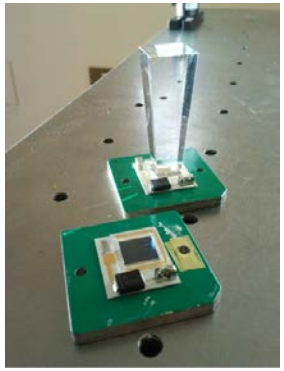
Solar beams are focused from an area of 2.000 cm^2 to 1 cm^2, i.e. with a concentration factor of 2,000 suns.

Optical losses in reflective and refractive transmissions are reduced using solar glass with Ag reflective coating, pure glass materials for secondary optic light pipe and high transmission glues for optical connection between components

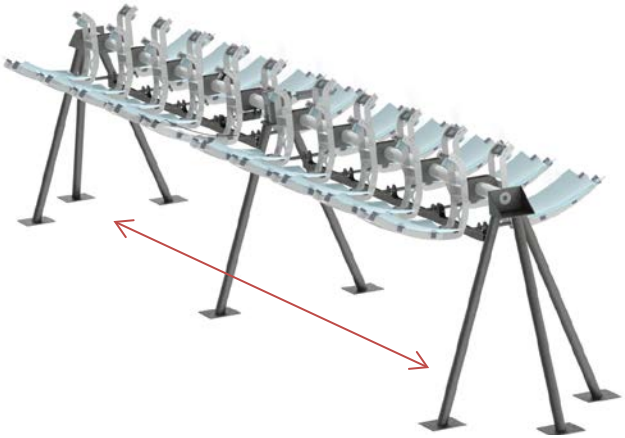


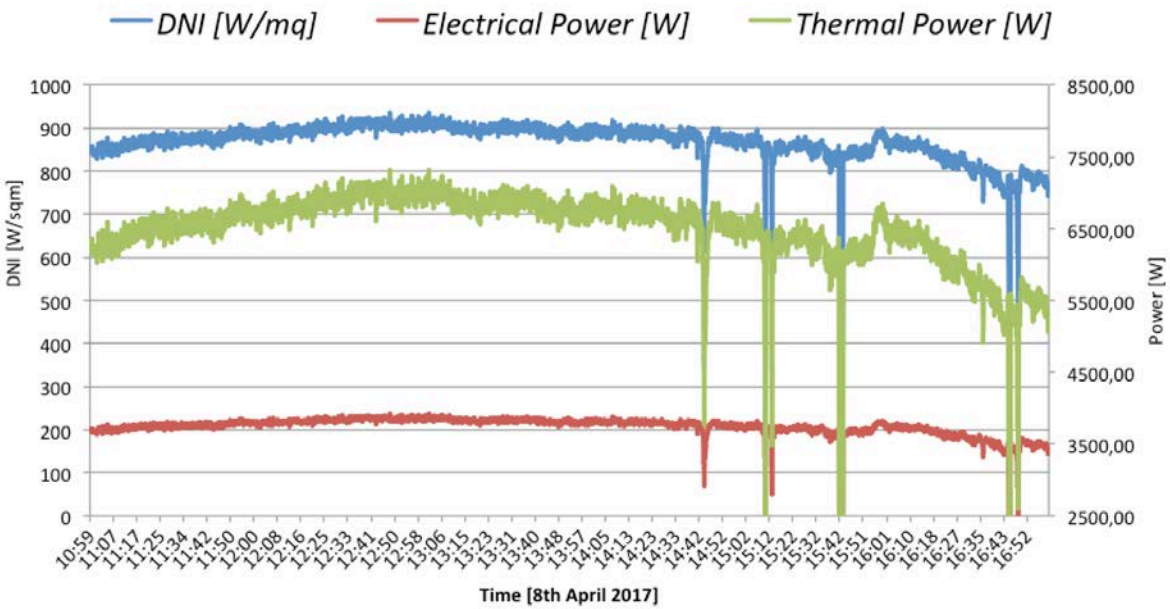




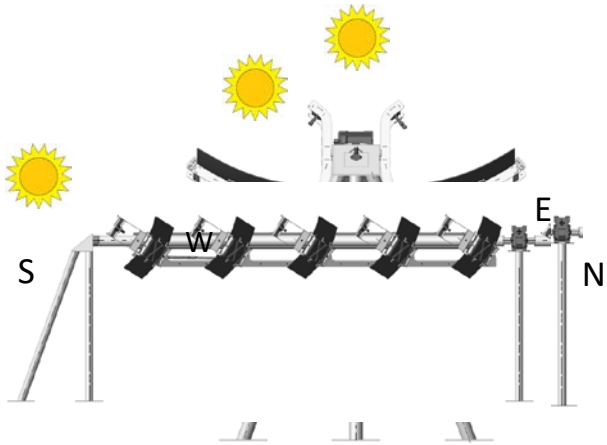


Tracking configuration and performance



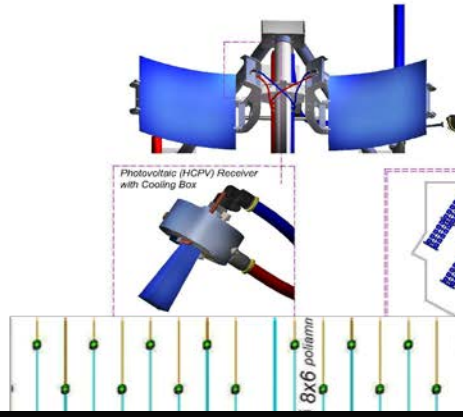


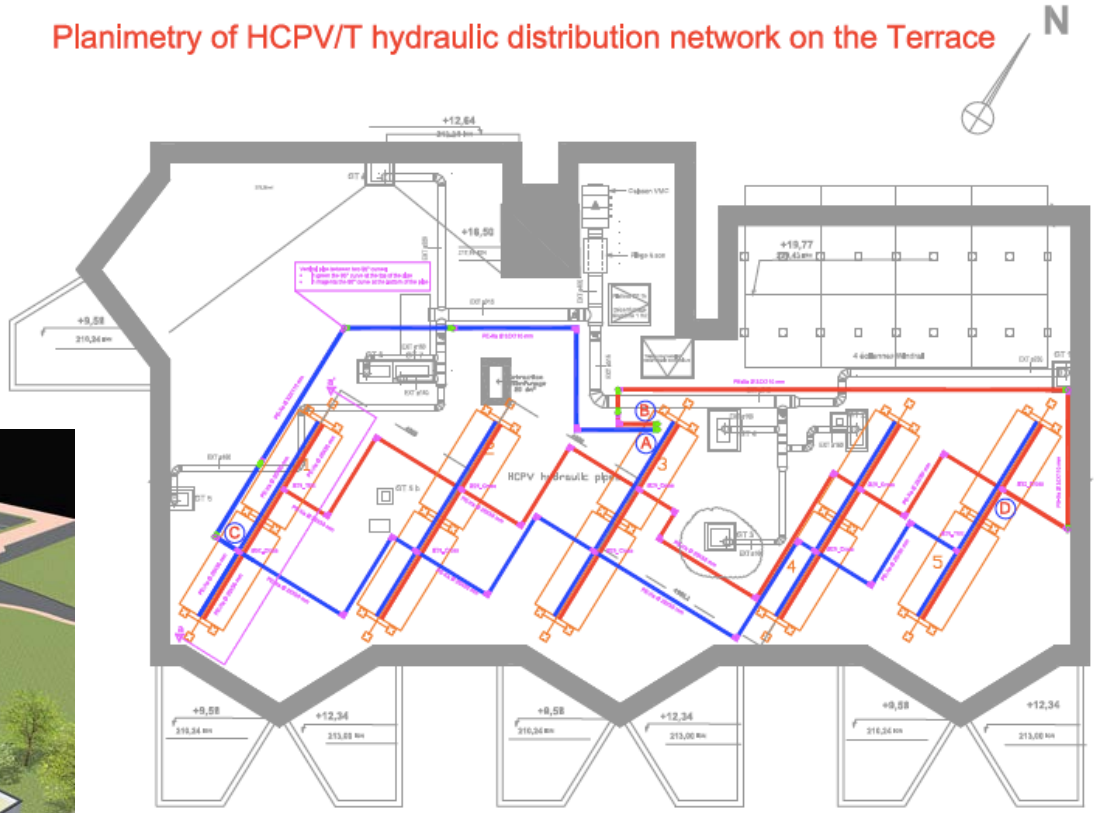
North - South orientation

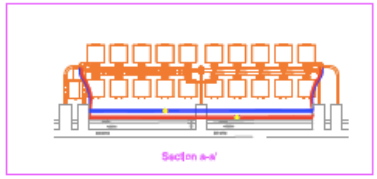


Layout for home PV and DHW generation

Grenoble (France)



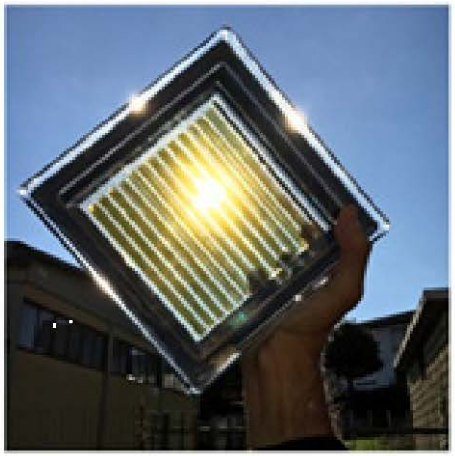




Scale 1:50

Redesign of the whole system and implementation of a small scale manufacturing process

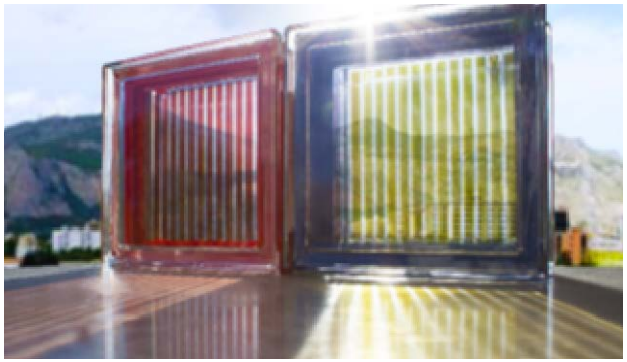
Solar Glass Bricks



SBskin
smart building skin

Solar Glass Bricks, achievements and troubles

- Highly insulating configurations of glass blocks with third-generation Dye-sensitized Solar Cells (DSC). Patented dry assembly system for the construction of translucent panels.
- Significant optimization of products design has been completed for the improvement of energy performance, miniaturization of the electric connections, reduction of production costs.
- It has been reached an optimal balance between the requirements linked to the mechanical resistance, thermal insulation, water and air tightness, durability and integrability of the sub-components.



This technology has been selected for the France case study.
Nevertheless, due to internal controversies among the shareholders, the company suspended its operations in 2018.

Freescoo HVAC

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freescoo

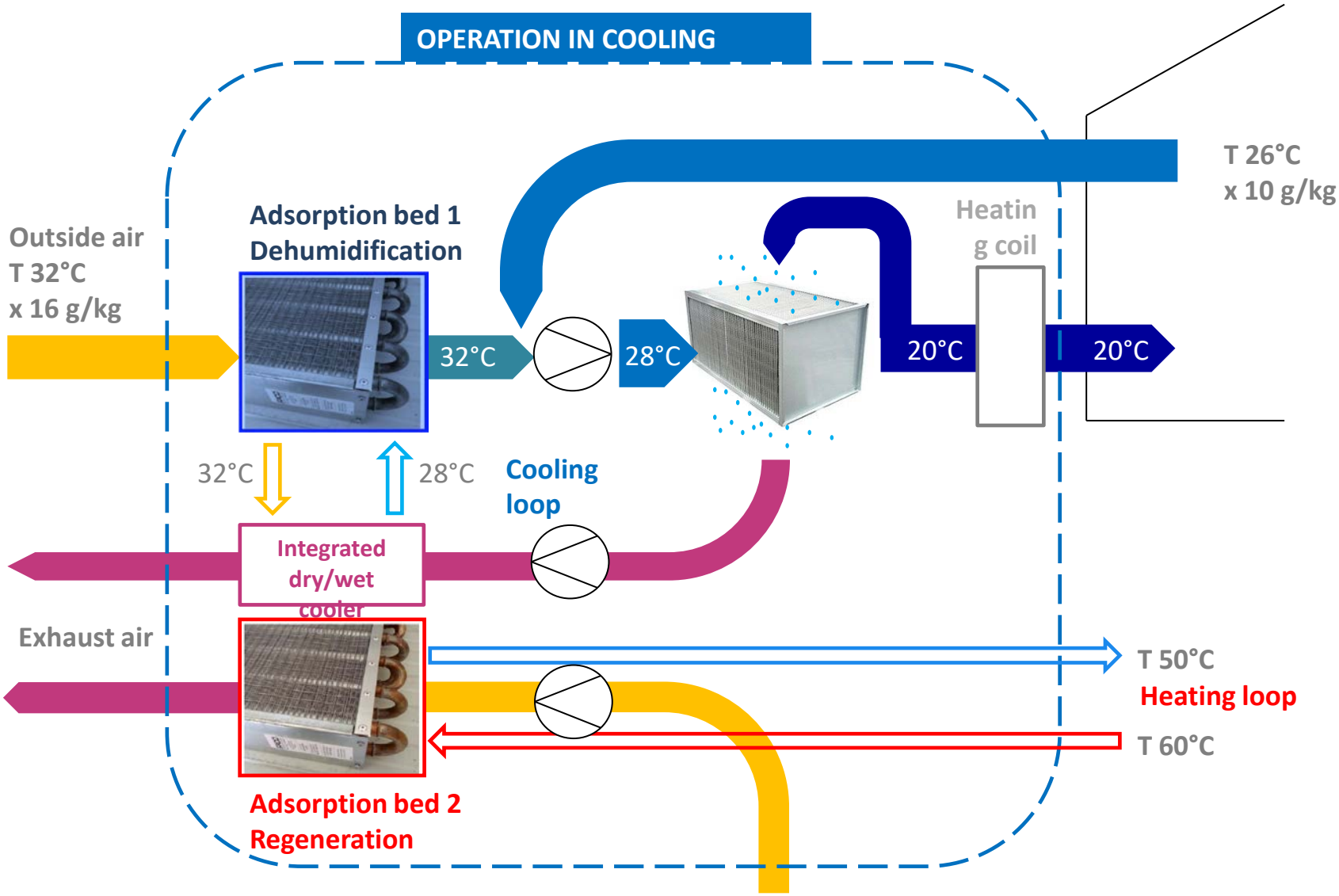
Freescoo is an innovative solar DEC air conditioning concept designed for **ventilation, cooling, dehumidification and heating of buildings** in residential and tertiary sectors.

By using **low enthalpy heat and water evaporation**, Freescoo treats directly external hot and wet air to obtain a conditioned stream typically at 18-20°C and 50-60% of relative humidity, reducing drastically electrical demand

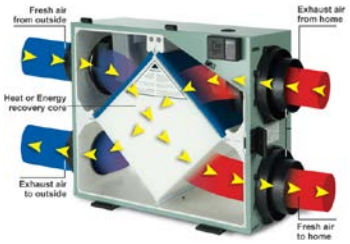
Main features of the concept are:

- Use of water as refrigerant and heat as main energy input
- Use of the Cooled Packed Bed (CPB) technology and high efficiency evaporative cooling concepts
- Low grade solar heat (50-60°C) is used to drive the cooling process (Solar PVT air collector or traditional FP collector, HCPV collectors)
- High electric efficiency (Typical EER >13)
- Simple plug & play
- Several system configurations possible

Freescoo - Cooling cycle



Freescoo vs conventional HVAC

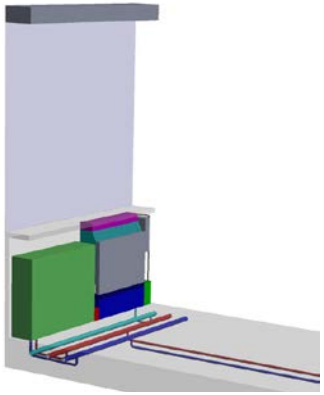


Model (Company)	ELFOFresh 300 (Clivet)	FREESCOO (SolarInvent)
Technology	Heat recovery ventilation system	**DEC + advanced evaporative cooling**
Functions	Cooling, Dehumidification, Ventilation, Heating	**Cooling, Dehumidification, Ventilation, Heating**
Driving Power	Electricity	**Heat (T>55°C)**
Installation type	Roof mounted	**Integrated in building facade**
List Price	€5500	**€5000**
Refrigerant / GWP	R410A / 2088	**Water / 0**
Cooling capacity	2,1KW	**2,5 KW**
Cooling power input	0,714KW	**0,2 KW** (electricity needed to operate the fans)
Seasonal EER	2,94 (average)	**10h per day - From 8,5 (Berlin) to 18,1 (Palermo)** **24h per day - From 7,2 (Berlin) to 19,8 (Palermo)**
Heating capacity	2,31KW	**3 KW**
Heating power input	0,624 KW	**0,08 KW** (electricity needed to operate the fans)
Seasonal COP*	3,70 (average)	**10h per day - From 5,1 (Berlin) to 10 (Marrakech)** **24h per day - From 5,4 (Berlin) to 8,9 (Marrakech)**

New configurations developed in ZP

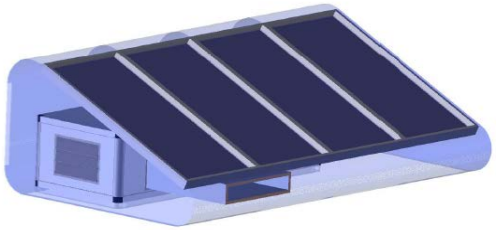
Compact stand alone rooftop unit

This complete unit provides cooled, dehumidified or preheated air to the building with the necessary air change



Compact facade system

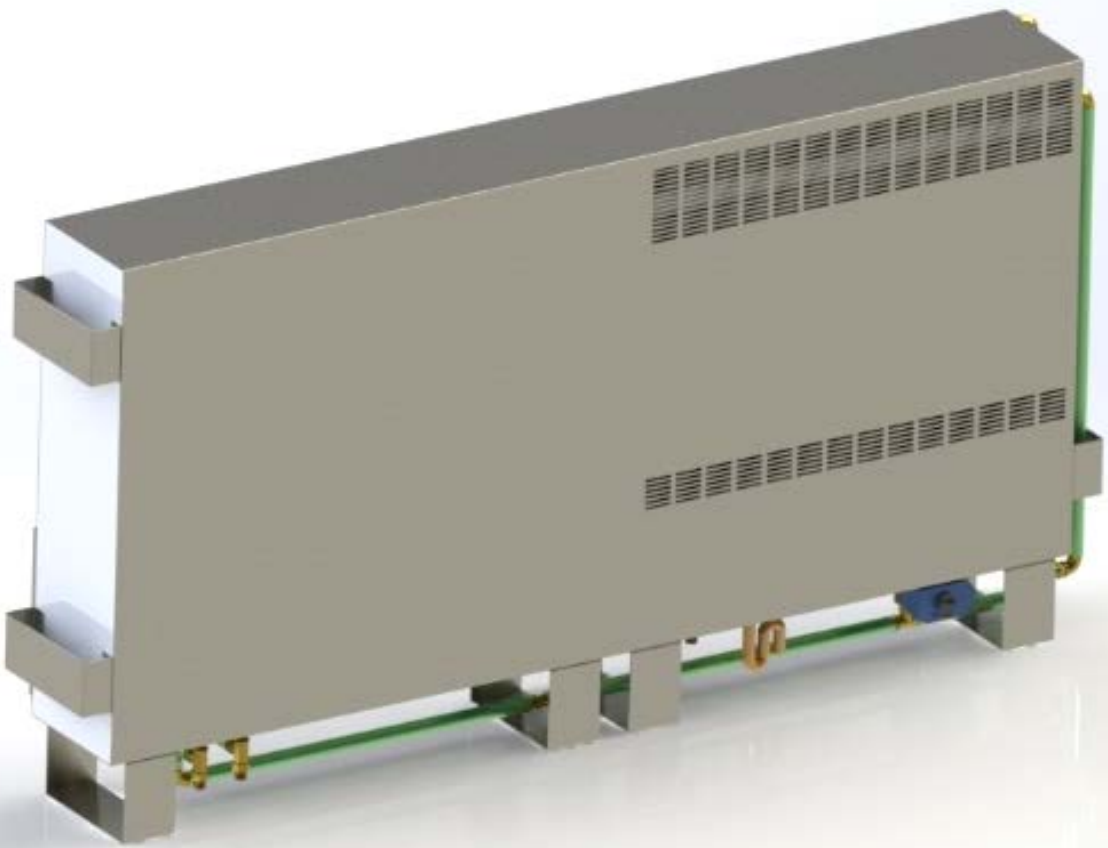
This version can be installed on the external walls of the building, powered by liquid solar thermal or from any other heat source also operating at low temperature (50-60 ° C).



Air handling units

The system provides a complete air treatment and cover the needs of ventilation and air change. It is suitable for users requiring a treatment of an air flow > 1000 m3/h. The air handling unit can be installed in a remote position from the solar collectors

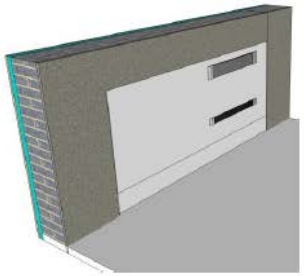
Freescoo for in-wall integration



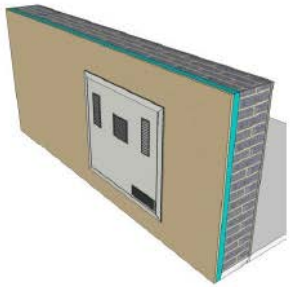
Integration strategy from TUM

Connection proposals

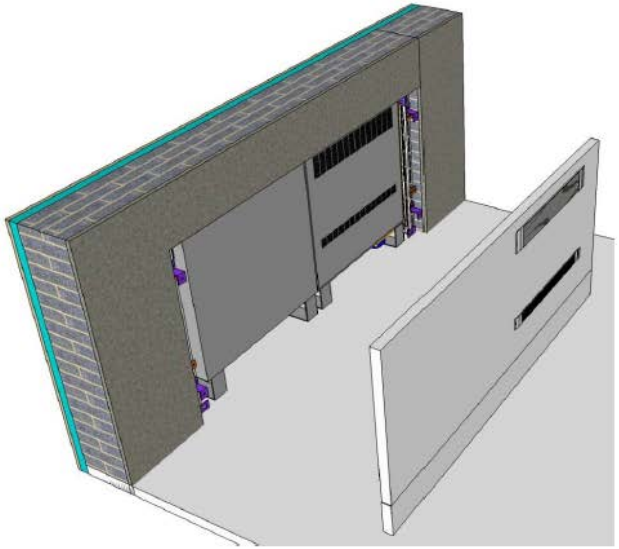
1 Completely embedded into the wall

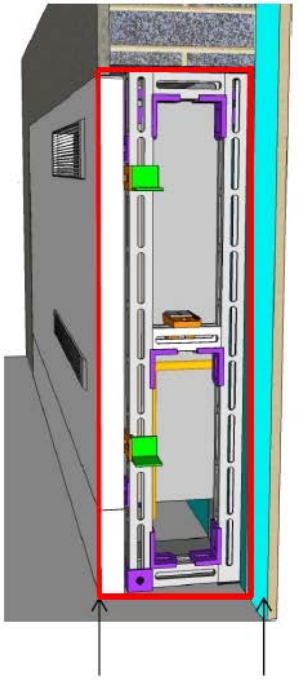


Interior View



External View



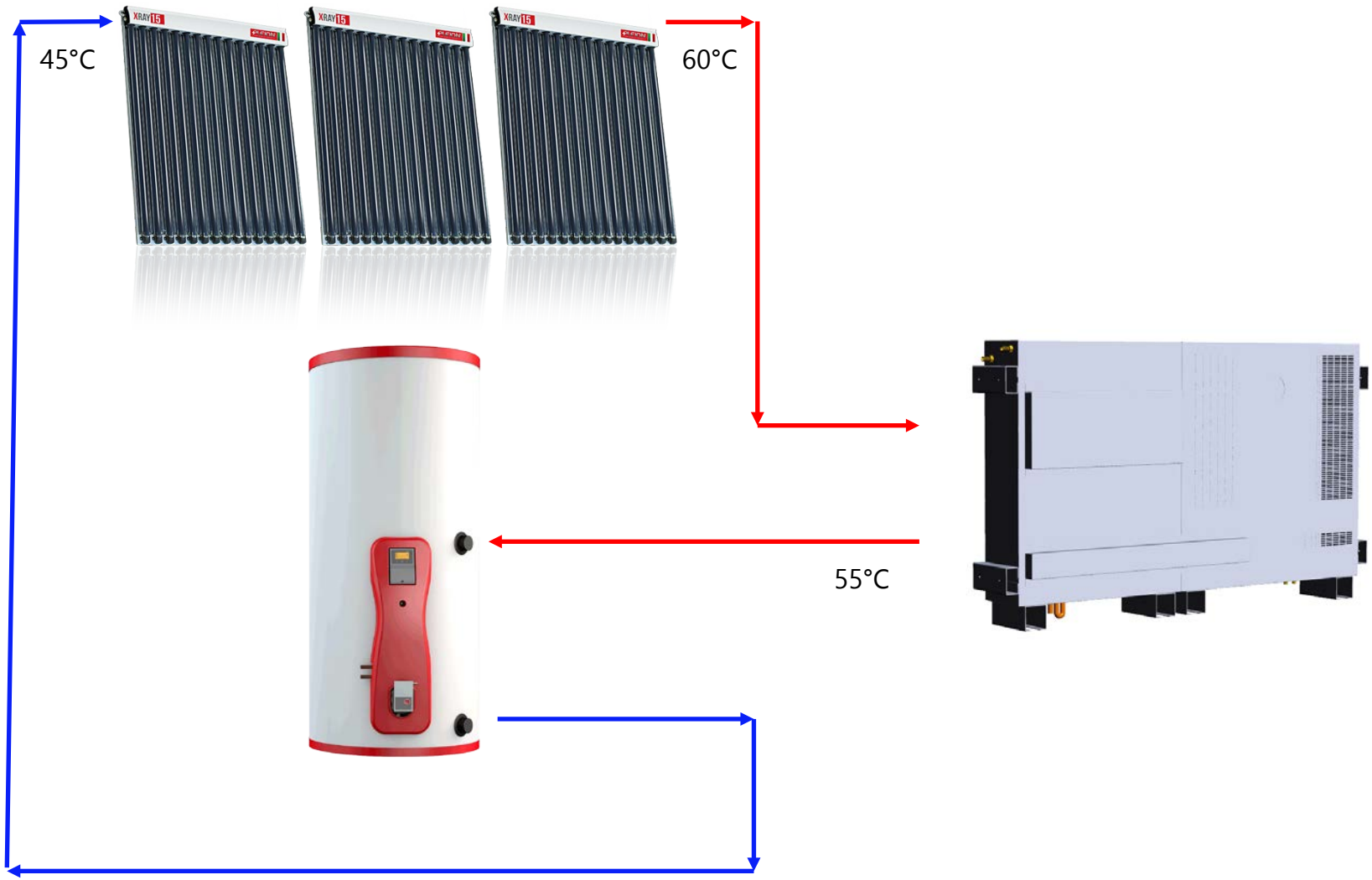


The frame system and Freescoo system

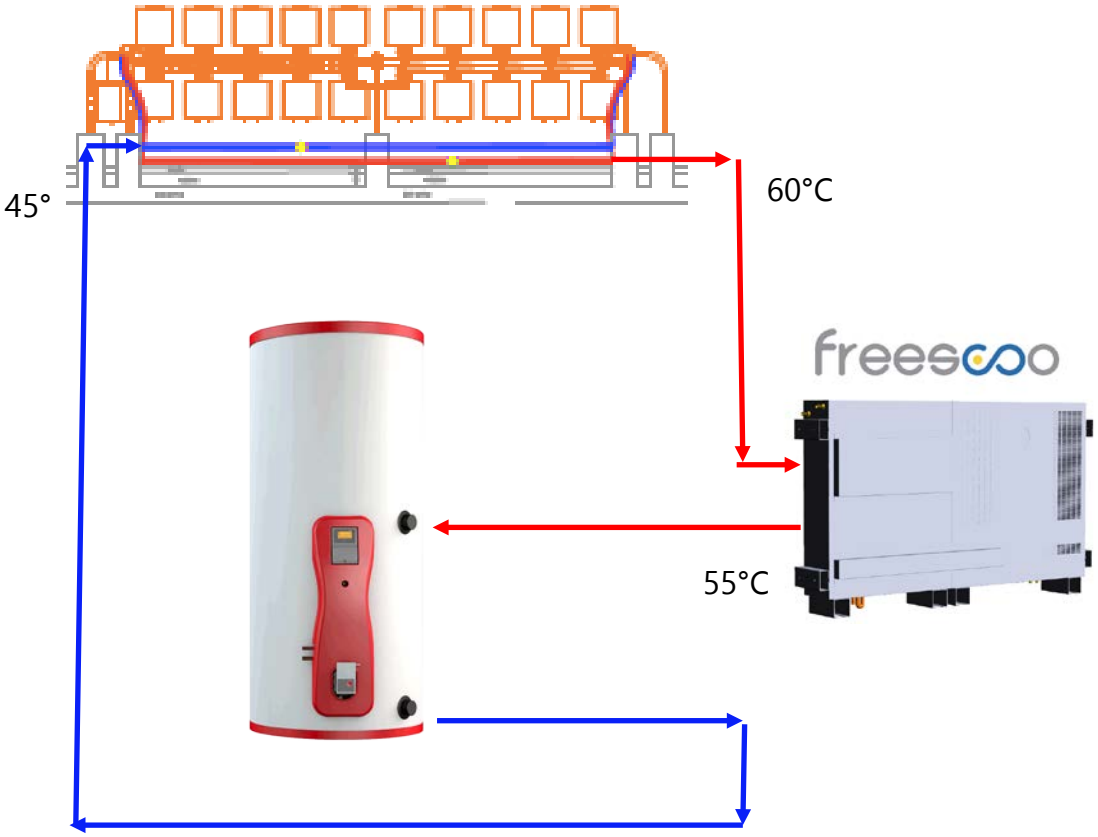
Fibran wall insulation product

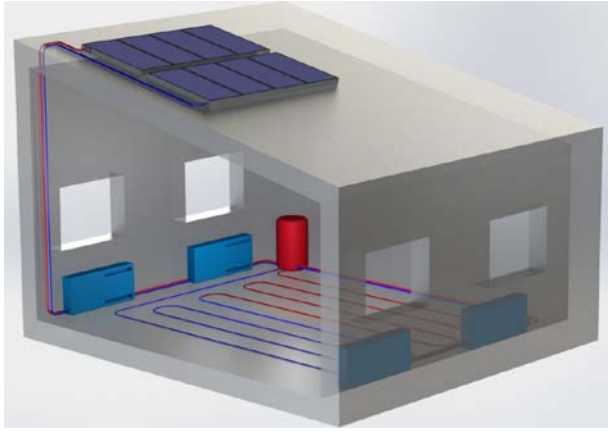
Solar thermal for Domestic hot water

Solar thermal for Domestic hot water + FREESCOO



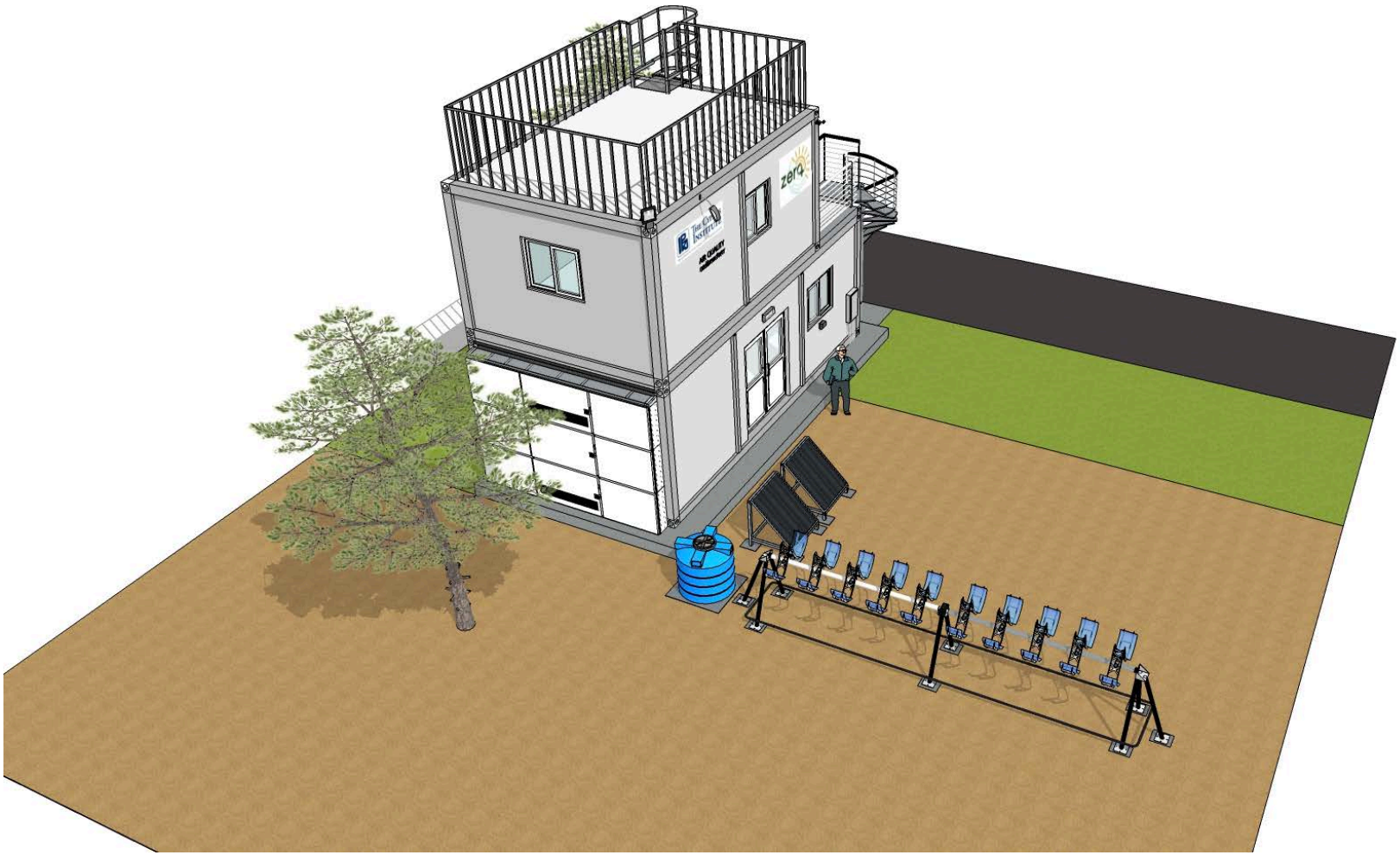
Integration of HCPV modules with Freescoo





- Air change
- Dehumidification
- Cooling
- Heating
- Heat recovery

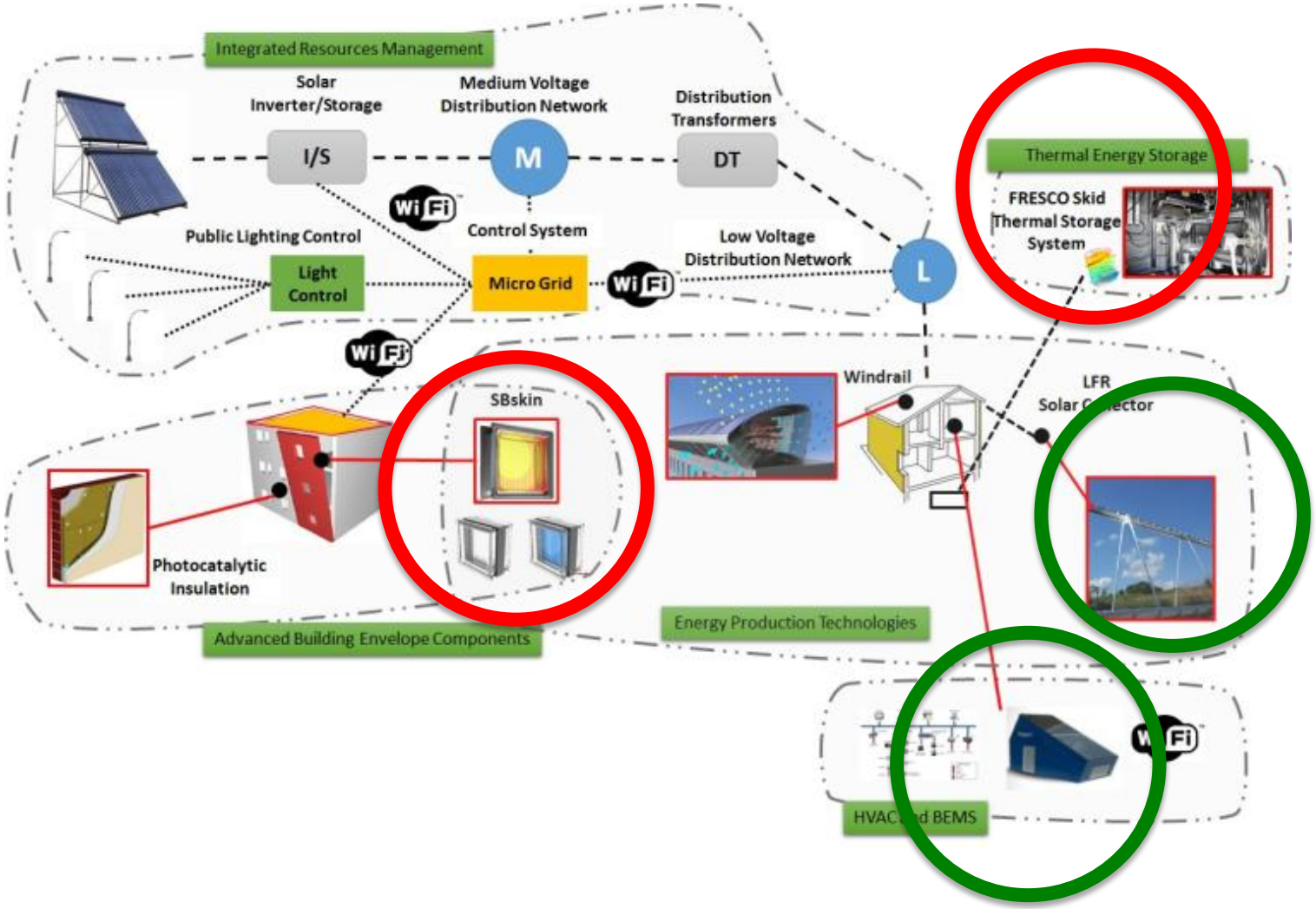
Configuration at the demo site in Cyprus

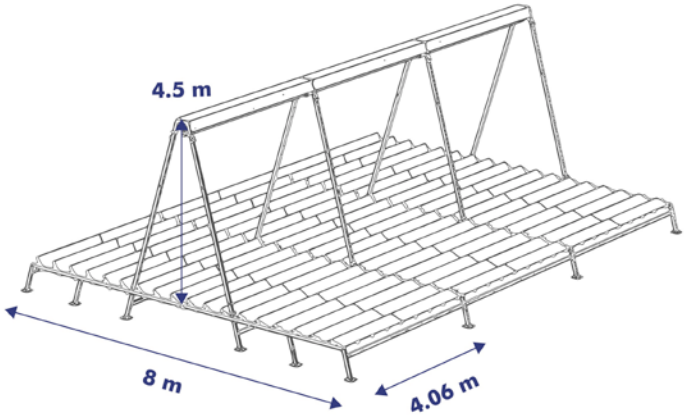


…work in progress.

…the HCPV is the last component just arrived in Cyprus

Zero Plus technology ecosystem – lesson learned



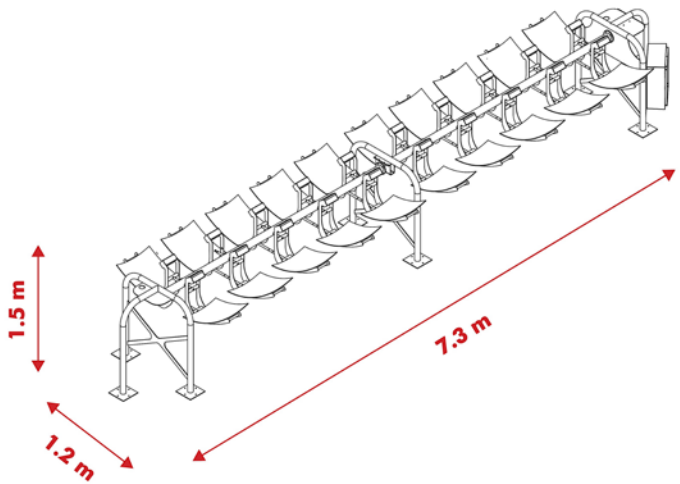


2018
EeB PPP Promising Technologies

Energy building system

Concept validated, but:

- It is not easy to introduce the system in existing buildings or settlements (space requirements, orientation).
- Integration at the early stage of design is required.
- Minimum scale is required.



2018
EeB PPP Promising Technologies

Energy building system

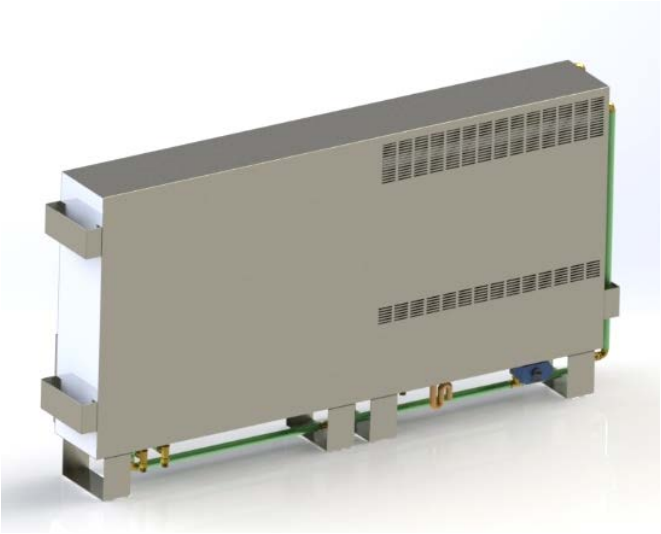
- **Concept validated, TRL improved from 5 to 8, but**
  - **Competitiveness against PV+ST (or hybrid flat PVT) requires a further reduction in industrial cost.**
  - **Requirements in space and orientation are a barrier.**
  - **New services (lighting) can expand the range of application.**

Concept validated, advancements in product design and TRL improved from 5 to 7.

Nevertheless,

- **The company suspended the operations and the system couldn't be installed into a real case**
- **Glass bricks give a limited flexibility to architects and designers.**

-> high interest in the community for active facade elements is triggering new projects around this concept.



2018
EeB PPP Promising Technologies

Energy building system

- **Concept validated, TRL improved from 6 to 8, strong improvement in terms of compactness, flexibility and readiness for installation.**
- **Acknowledgement as a key component of zero energy buildings in hot climates.**
- **Better understanding of possible applications and market potential (heat recovery).**

…nothing new under the sun!

Solar heating and cooling: untapped energy put to use

With diminishing fossil fuel supplies and concern about clean energy, solar heating and cooling is especially attractive today. Use is economically feasible now—with wider use, it will be competitive. A look at some current applications.

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THE IDEA OF BUILDING a home heated by solar energy is not new. As long ago as 35 years the first significant solar space heating project had been initiated. Since then almost two dozen buildings have been designed and built utilizing solar energy for heating. During the years 1958-1960 alone, eight different buildings were constructed, four of which were designed as laboratories, and four destined to be used as residences. Now, with the energy crisis demanding new alternatives, there is another surge of interest in solar buildings.

There is enough sunshine in this country—an average of 4 kilowatt-hours of solar energy per square meter per day—to supply twice the energy need to heat and cool every building. A solar energy system does not require clear days, but also collects diffused solar radiation. Deciduous trees do not interfere with collection. The National Science Foundation predicts that in/by the year 2020, 35% of our buildings will use solar heating and cooling at a savings of $12 billion at present electricity rates.

While the prospects of using solar energy for power generation are still in the stages of considerable uncertainty, the heating of buildings by solar energy is now technically feasible and nearly economically competitive. Locations of successful solar heated buildings in the United States range from Arizona and New Mexico to Colorado and Massachusetts. Techniques have varied with the use of air or water as the heat transfer medium, use of crushed rock, water, or heat of fusion of certain salts for heat storage, widely varying configurations of a solar collector, and a wide range of percentage load carried by the system. But technical feasibility must have an economic counterpart.

Economics

Richard A. Tybout, Professor of Economics at Ohio State University and author Löf made an extensive cost analysis in eight U.S. cities on a solar climate control system. Conclusions were that solar heating is becoming competitive with fossil fuel heating systems and is, in general, already cheaper than electricity. The economics could be improved even more by adding cooling to the load on the solar systems; thus using the same equipment all year long at very little extra cost.

Author Löf's house in Cherry Hills Village near Denver, Colorado is an example of a solar heated building which has been operating over a long period; in this case fifteen years. (See photo.)

The building utilizes a heating system with air as the heat transport medium and crushed rock as the heat storage material. The system consists of two solar collector banks, two vertical heat storage cylinders, hot water preheater, blower, conventional natural gas furnace, central equipment, and the necessary air ducts. The two collector banks on the roof are surrounded by a four ft (1.22 m) parapet wall. They are 50 ft (15.25 m) long, six ft (1.83 m) high, and face south at an angle of 45° with the horizontal. Each

The author's home in Colorado. For fifteen years the two banks of solar collectors have provided a fourth to a third of the heating load.

Pioneering solar cooling plant in a real built environment designed by George O.G. Löf at Colorado State University.

(report of 1974)

zero+

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