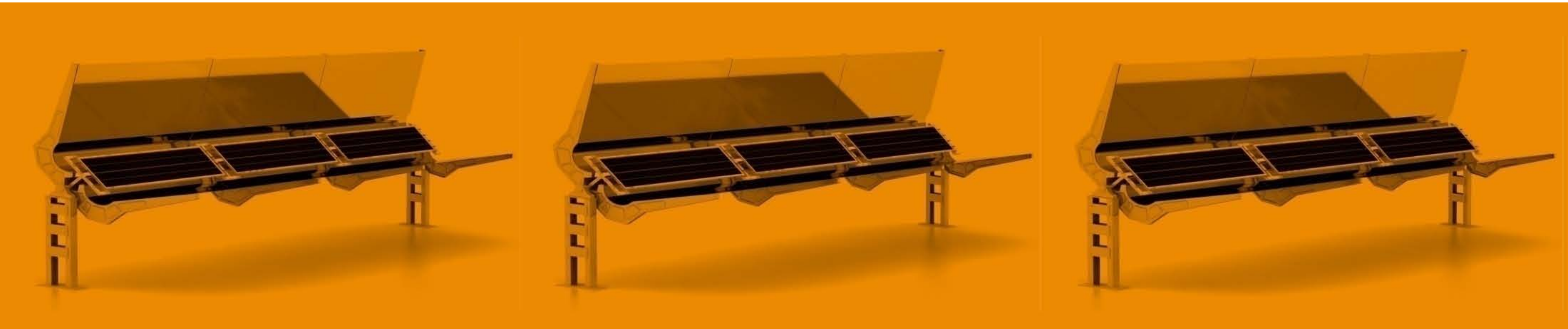
A NOVEL TECHNOLOGY FOR SOLAR APPLICATIONS

Cristoforo BENVENUTI

SEEC’2009
Trento 8-9 October 2009



It is generally assumed that:

- Flat panels collectors are only adequate for low temperature application
- High temperatures may be obtained only by light focusing

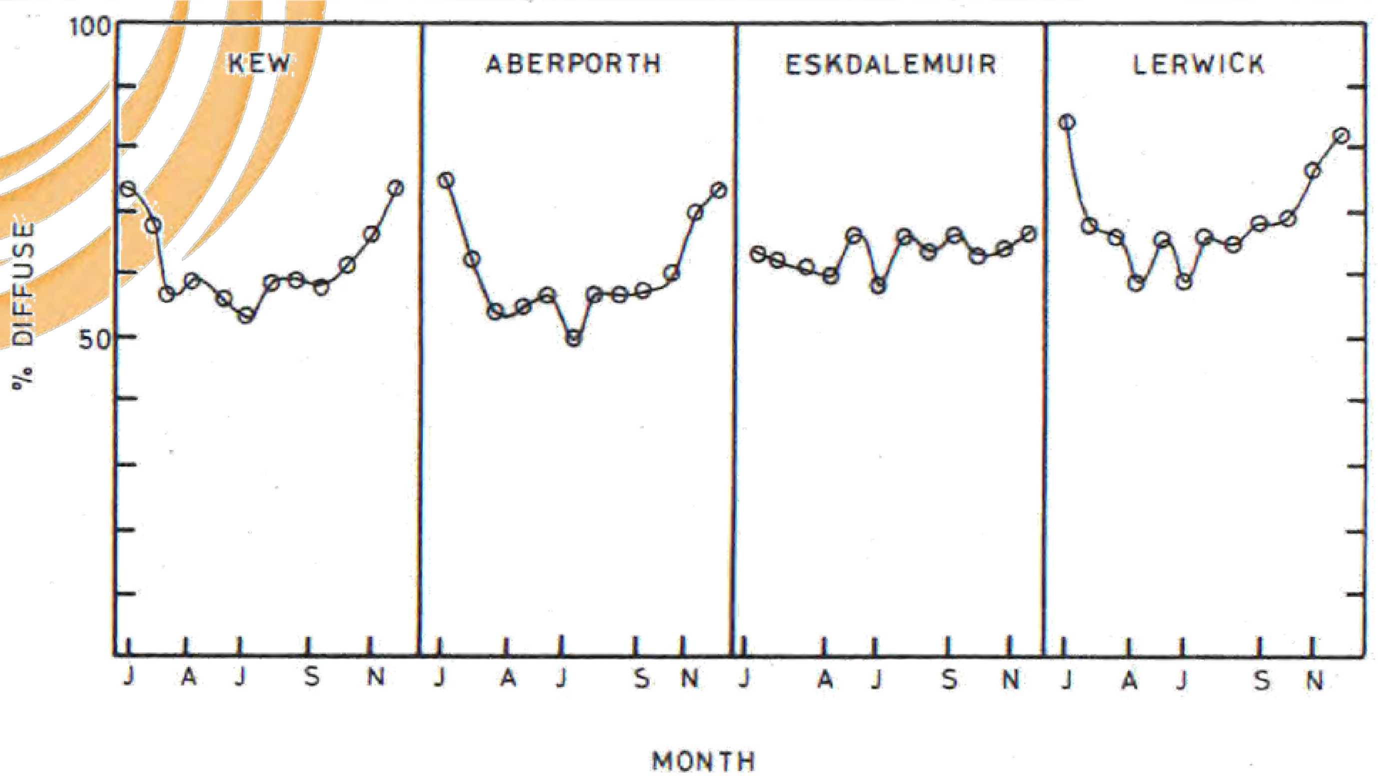
Alternative route to high temperature : Decrease thermal losses!

Very low thermal losses may be achieved thanks to:

- Vacuum
- A selective coating on the light absorbers

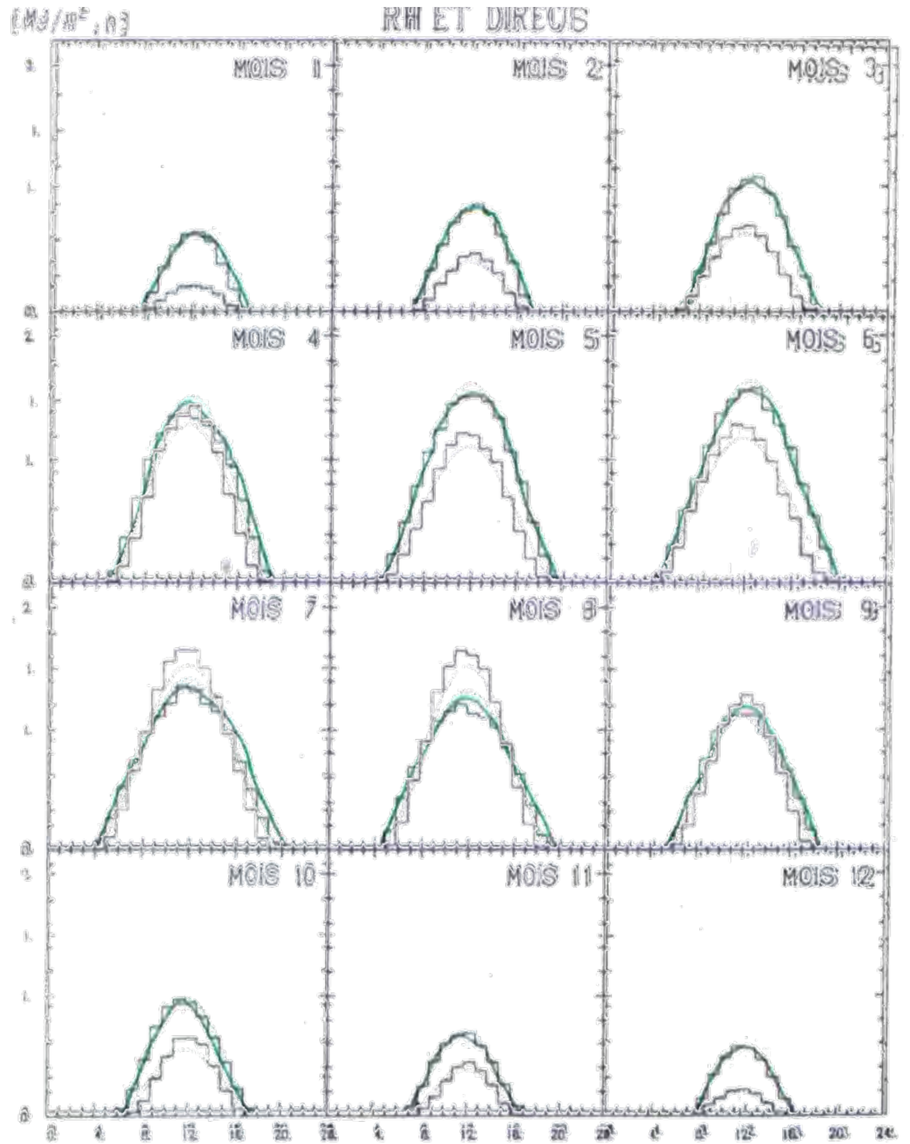
In this way 300°C are at reach without mirrors

- Also the diffuse light is collected, which cannot be focused
- The diffuse component of solar light amounts to about 30% in the best solar areas, and exceeds 50% in Central Europe



Mean monthly diffuse radiation as percentage of mean monthly global radiation for four UK stations for each month

Direct and diffuse light components in Geneva (CH)



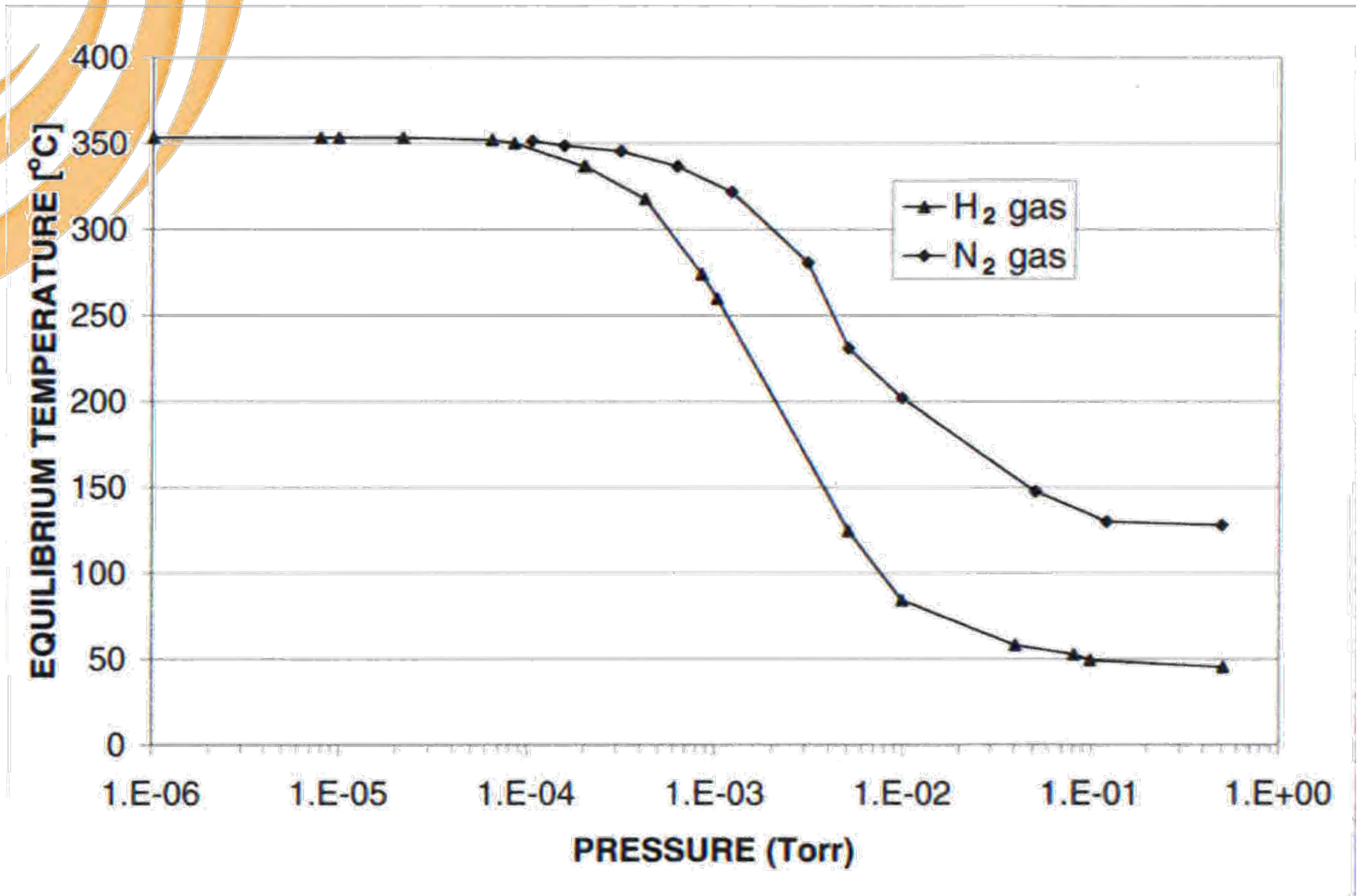
Total and direct component of solar light at different locations

	Phoenix, AZ		Albuquerque, NM		Fort Worth, TX		Omaha, NB		Nashville, TN		Blue Hill, MA	
	Total	Direct	Total	Direct	Total	Direct	Total	Direct	Total	Direct	Total	Direct
Fixed, horizontal	1.00	0.72 (1.02)	1.00	0.73 (1.05)	1.00	0.61 (1.31)	1.00	0.60 (1.31)	1.00	0.55 (1.47)	1.00	0.52 (1.55)
Fixed, L-5° tilt	1.09	0.83 (1.16)	1.11	0.85 (1.19)	1.07	0.70 (1.46)	1.11	0.72 (1.58)	1.08	0.64 (1.68)	1.09	0.64 (1.86)
Tracking, E-W axis	1.16	0.90	1.20	0.93	1.14	0.77	1.18	0.79	1.12	0.70	1.16	0.71
Tracking, N-S horizontal axis	1.29	1.03 (1.35)	1.33	1.07 (1.39)	1.25	0.89 (1.74)	1.30	0.92 (1.72)	1.21	0.79 (1.93)	1.23	0.79 (2.03)
Tracking, polar axis	1.38	1.12 (1.58)	1.43	1.18 (1.62)	1.33	0.97 (1.99)	1.40	1.03 (2.17)	1.28	0.87 (2.31)	1.32	0.89 (2.55)
Tracking, normal (two axes)	1.42	1.17 (1.62)	1.47	1.23 (1.67)	1.36	1.01 (2.09)	1.44	1.08 (2.26)	1.31	0.90 (2.40)	1.36	0.93 (2.67)

Issues

- Vacuum => 10 tons per m^2 of glass window, the glass must be properly supported
- The joint between the metal frame and the glass must be vacuum tight
- All materials inside the panels must fulfill UHV specifications (low degassing, cleanliness)
- A built-in pump is needed to maintain the vacuum for 20 years
- This pump must preferably be powered by sun

Is vacuum really useful?



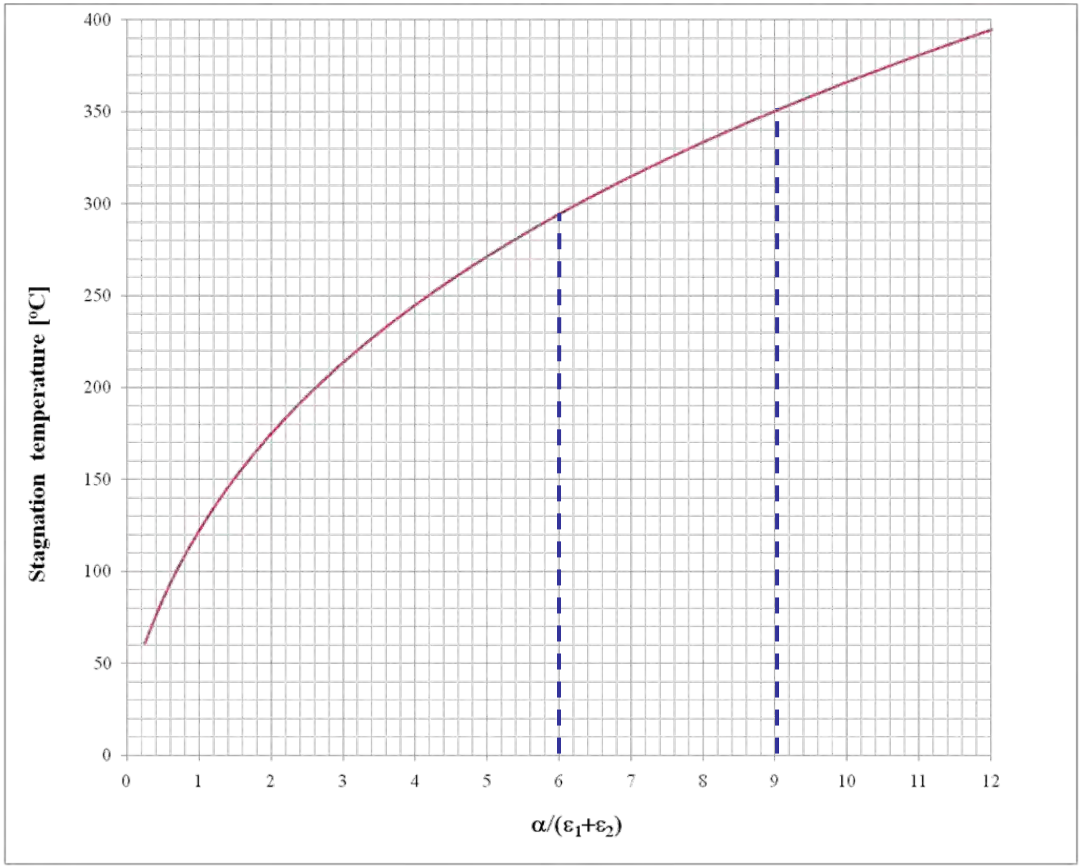
Variations of the absorber temperature as a function of the panel pressure

How important is the absorber selectivity ?

Selectivity:

- High absorption (α) of solar (visible) light
- Low emission (ε) of infrared radiation

For α values of 0.9 and ε values of 0.07 (at 300°C), temperatures of the order of 300°C may be obtained for absorbers blackened on both sides, and of the order of 350°C for single side blackening

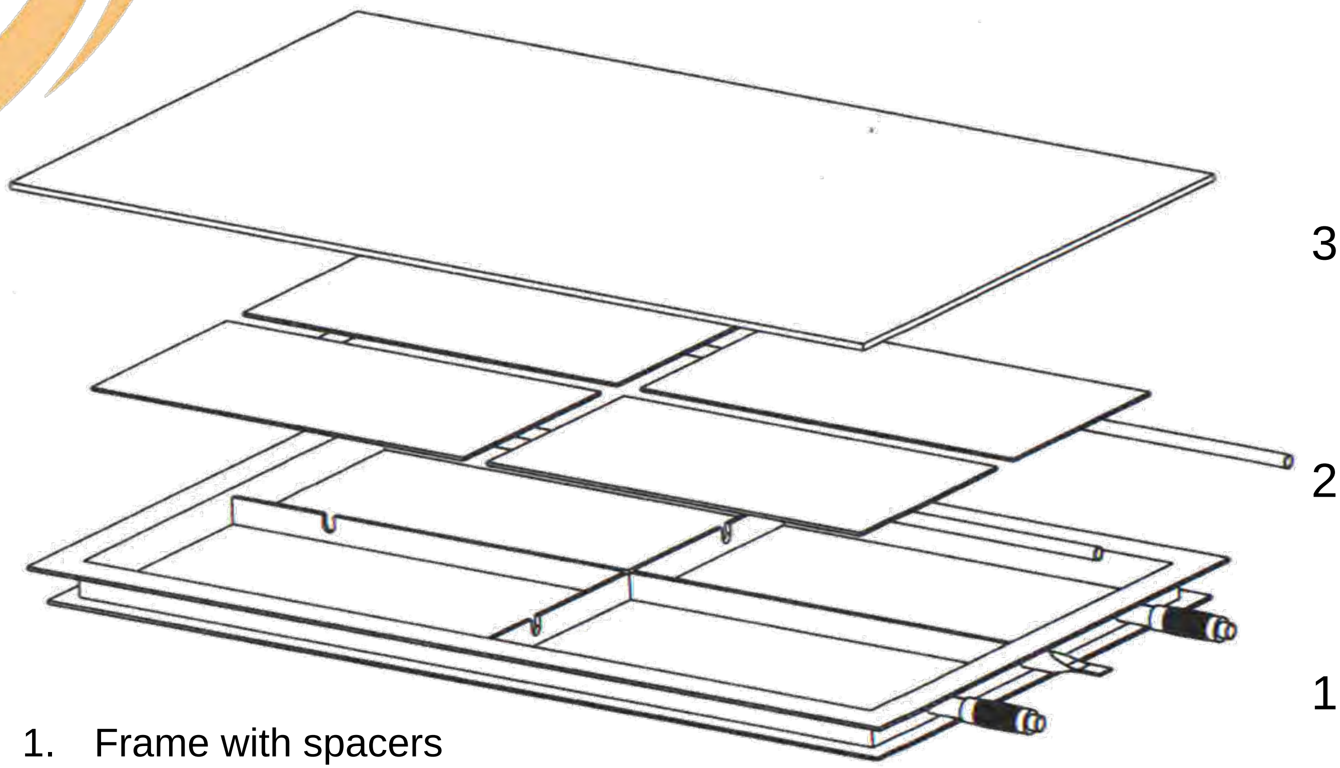


Calculated variation of the peak stagnation temperature as a function of the α/(ε1+ε2) ratio

History

On the ground of these considerations evacuated flat plate solar panels were built and testes in the 70s.

Global view of the 1st panel



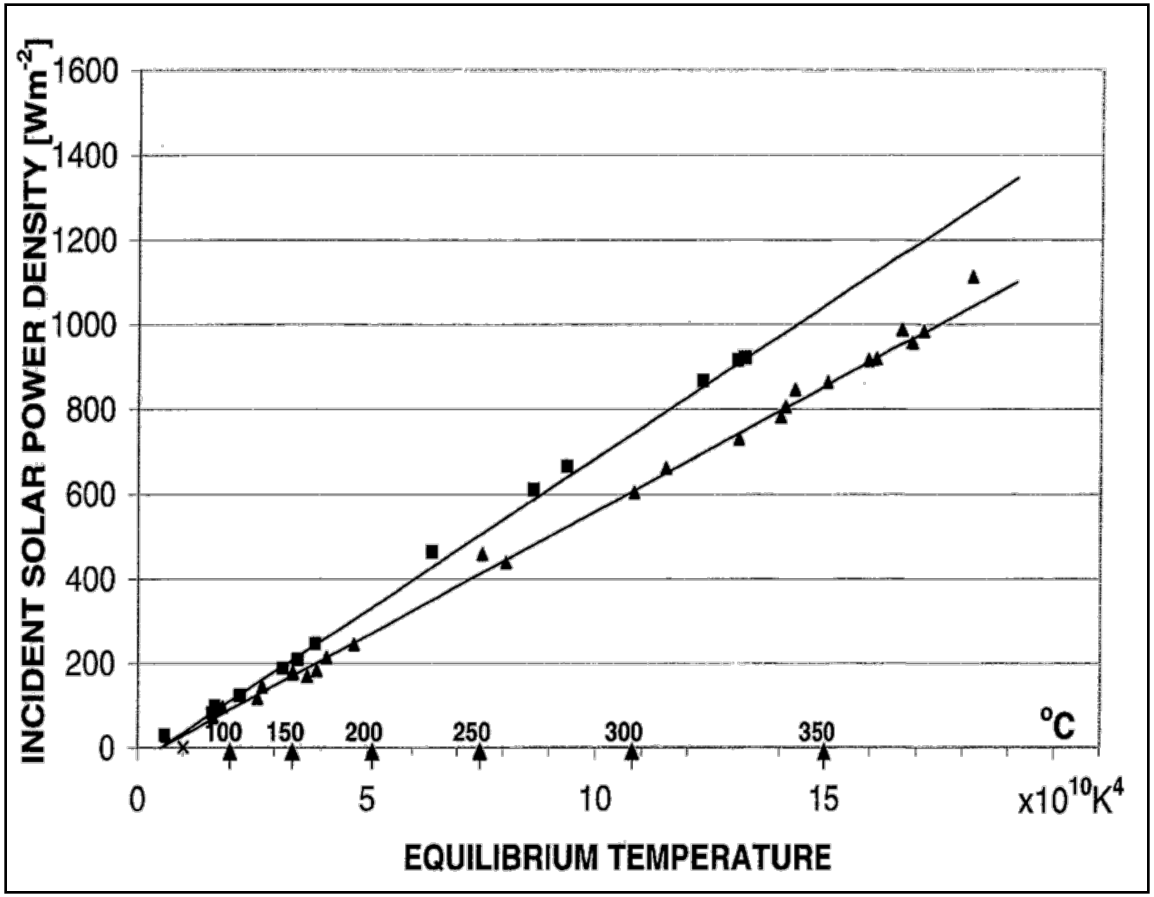
1. Frame with spacers
2. Absorbers with coating pipes
3. Glass window

The flat plate evacuated solar collector

The flat plate evacuated solar collector

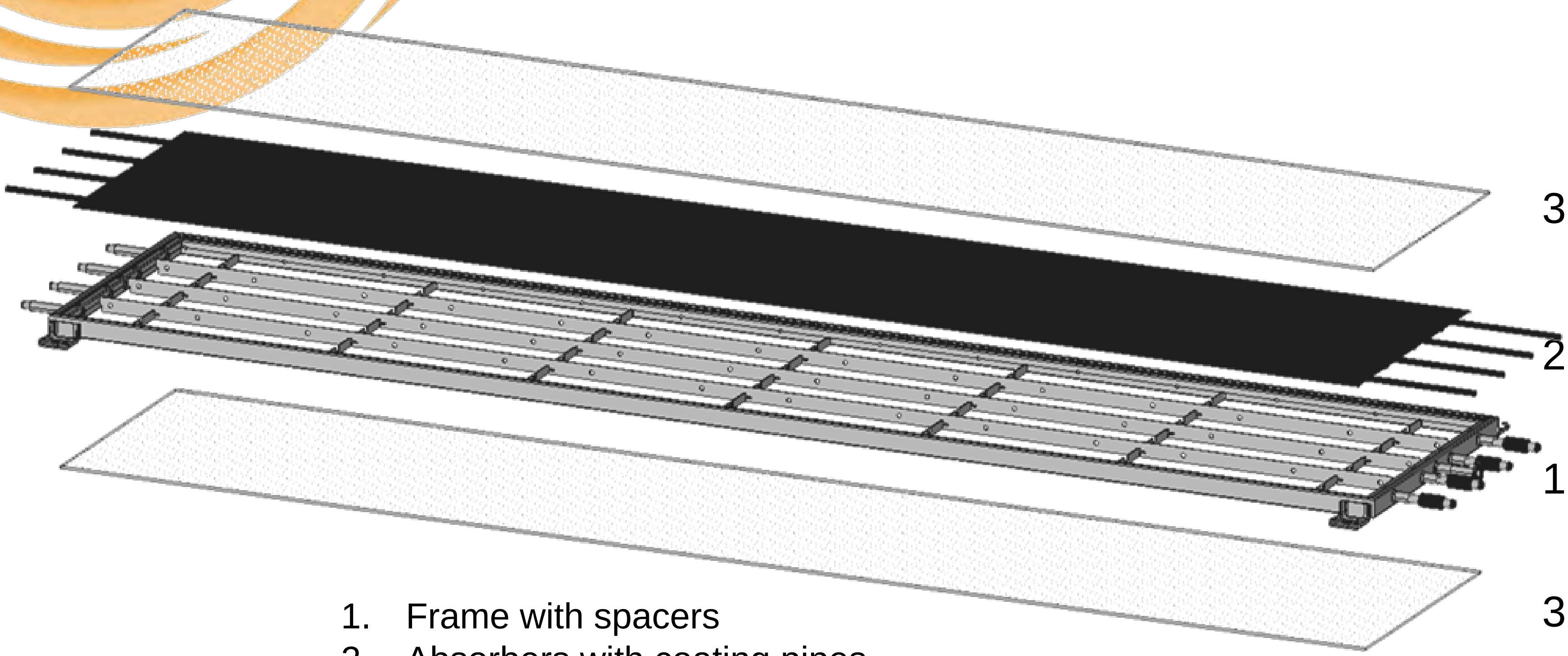
Results

These prototypes were exposed to real environment conditions on the roof of a CERN building for about 9 years.



Stagnation temperatures of the best and worse absorbers of a panel prototype

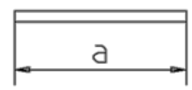
Global view of 3m panel



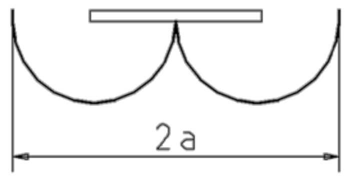
1. Frame with spacers
2. Absorbers with coating pipes
3. Glass windows

Mirors

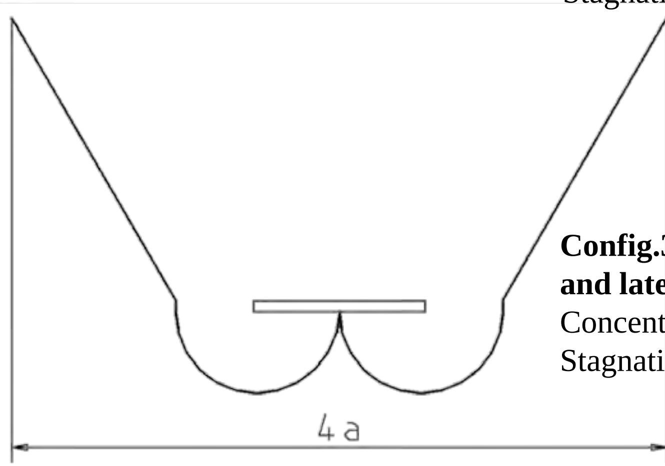
In spite of the good thermal performance of the panels, the addition of mirrors helps gaining on cost effectiveness and increasing the useful operating temperature, so as to cover, with the same panel, all the possible solar applications



Config.1 - Bare panel
Stagnation temperature ~ 320°C



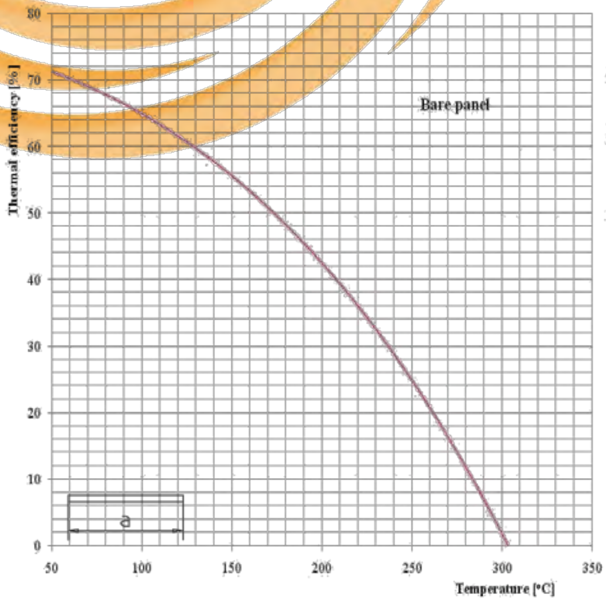
Config.2 - Panel with cylindrical mirrors
Concentration factor 1.9
Stagnation temperature ~400°C

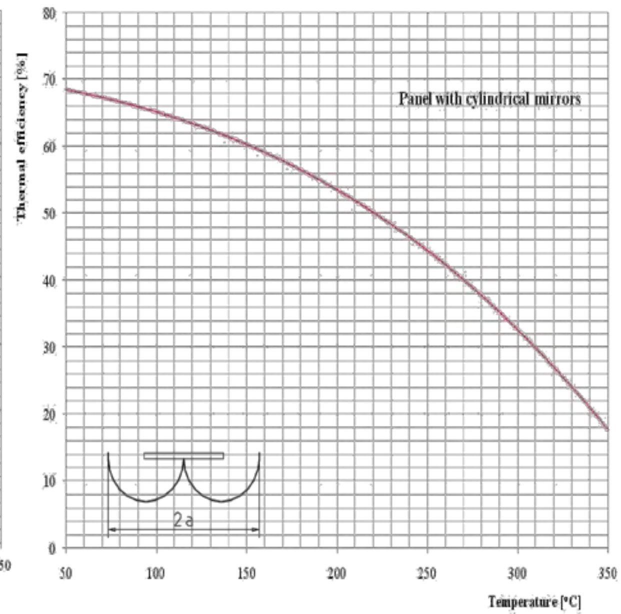


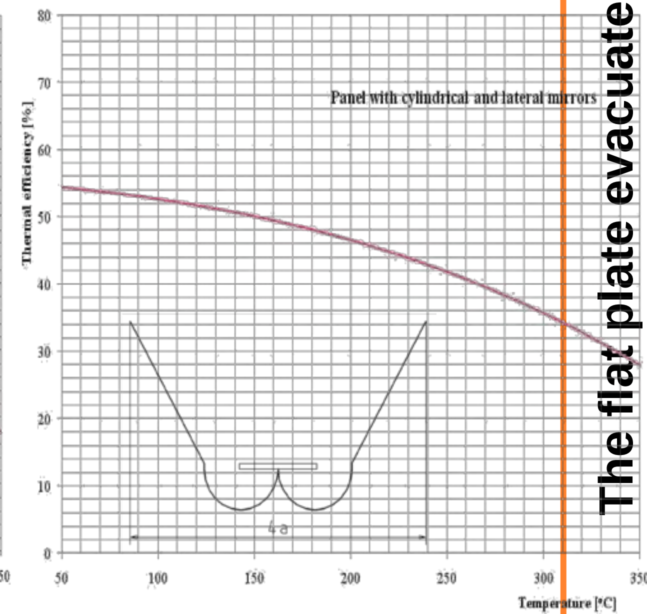
Config.3 - Panel with cylindrical mirrors and lateral mirrors
Concentration factor 3
Stagnation temperature >450°C

Different panel configurations

Thermal efficiencies of the 3 possible panel configurations

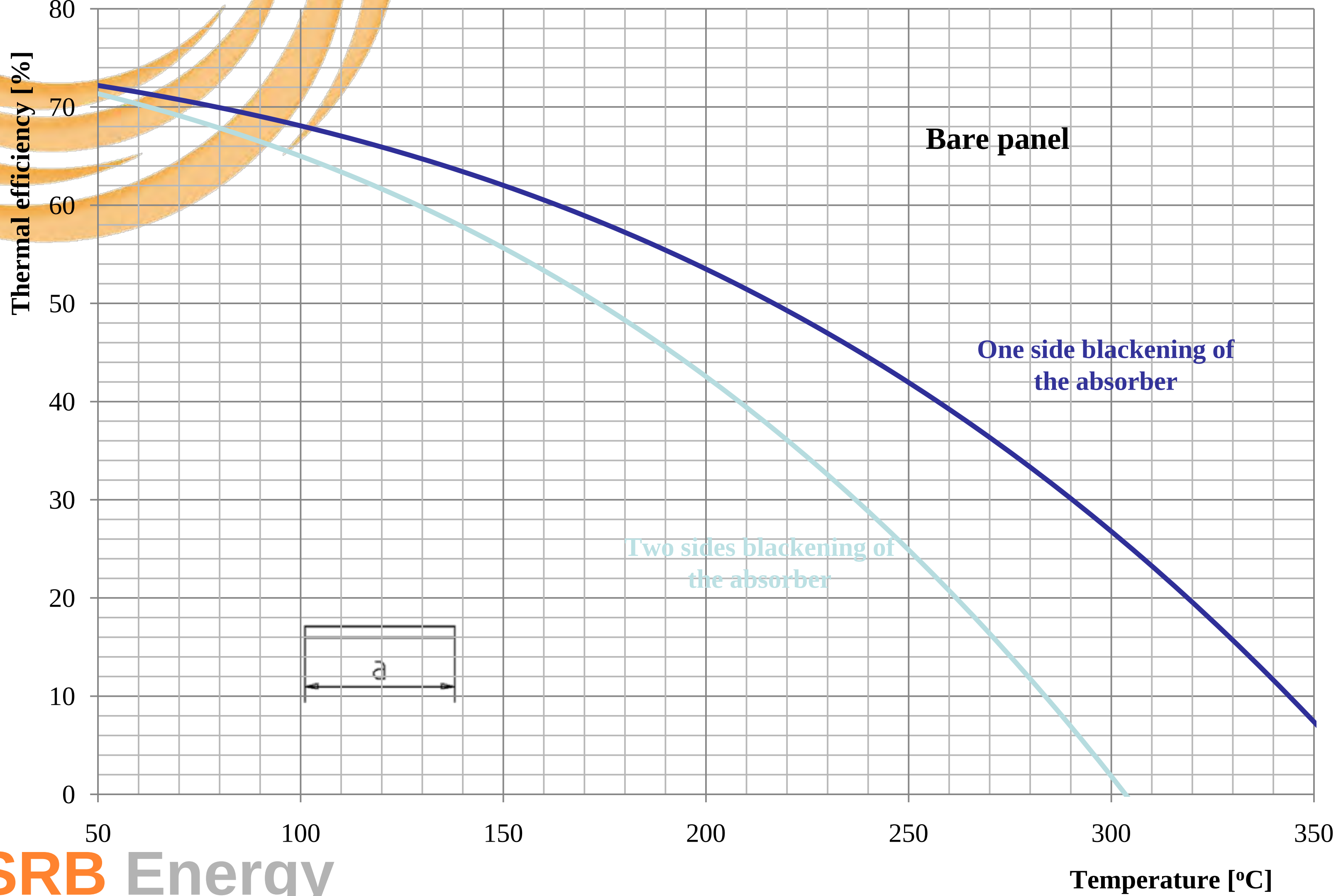




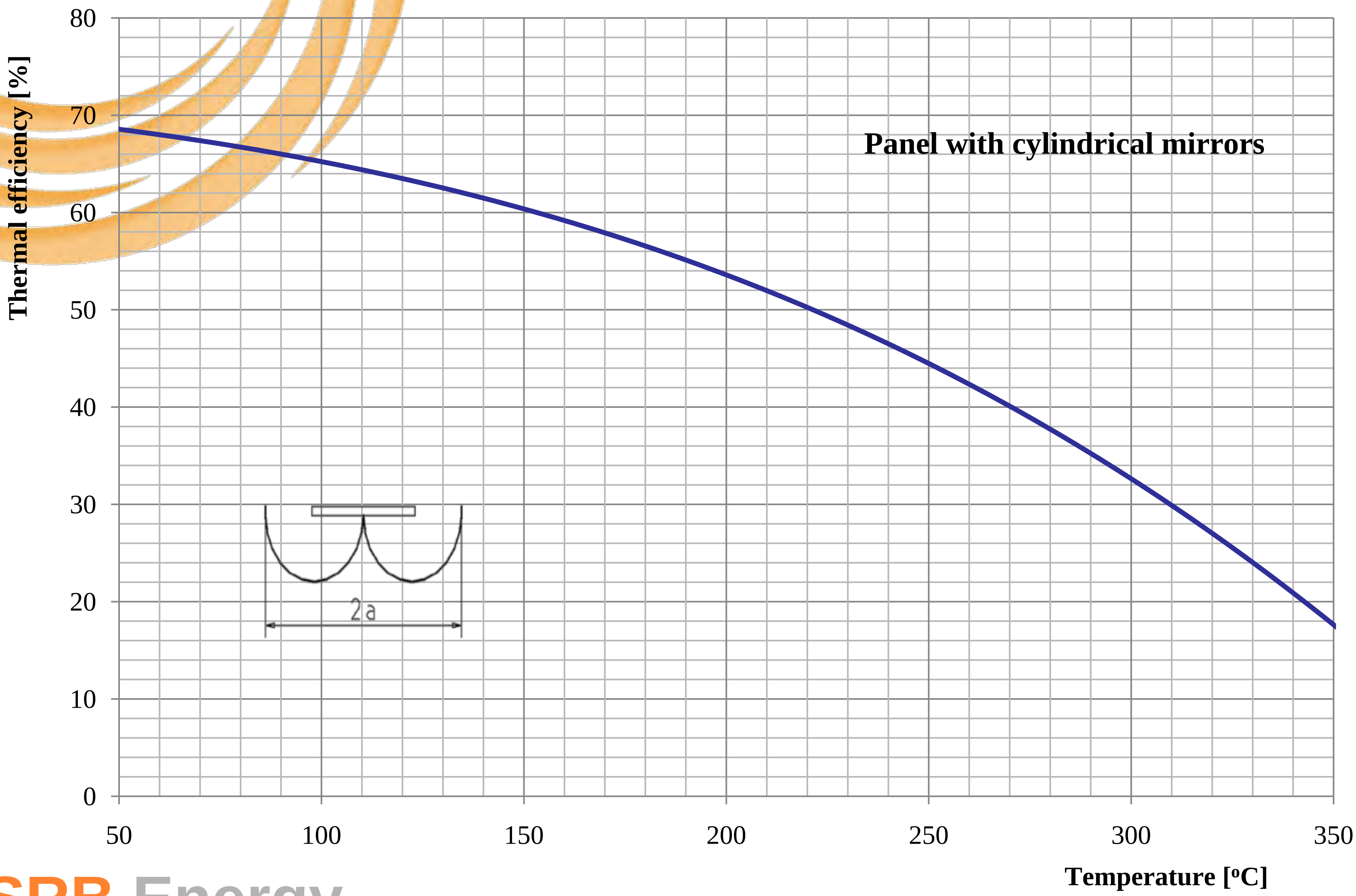


These figures represent the performance which could be obtained by implementing certified improvements. The estimate is carried out for an incident power of 1000W/m^2 and a glass temperature of 30°C.

Thermal efficiencies as function of the temperature

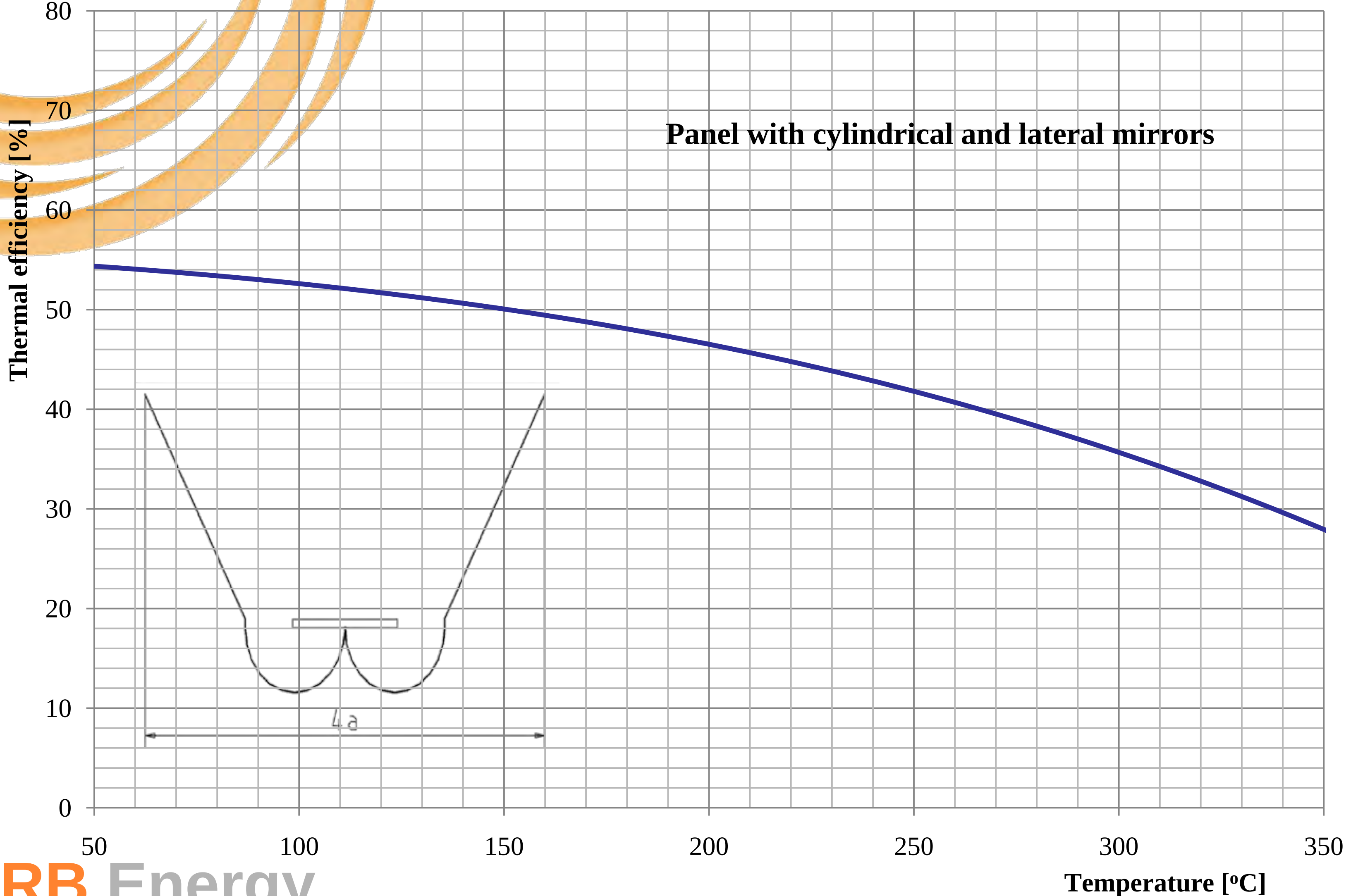


Thermal efficiencies as function of the temperature



SRB Energy

Thermal efficiencies as function of the temperature

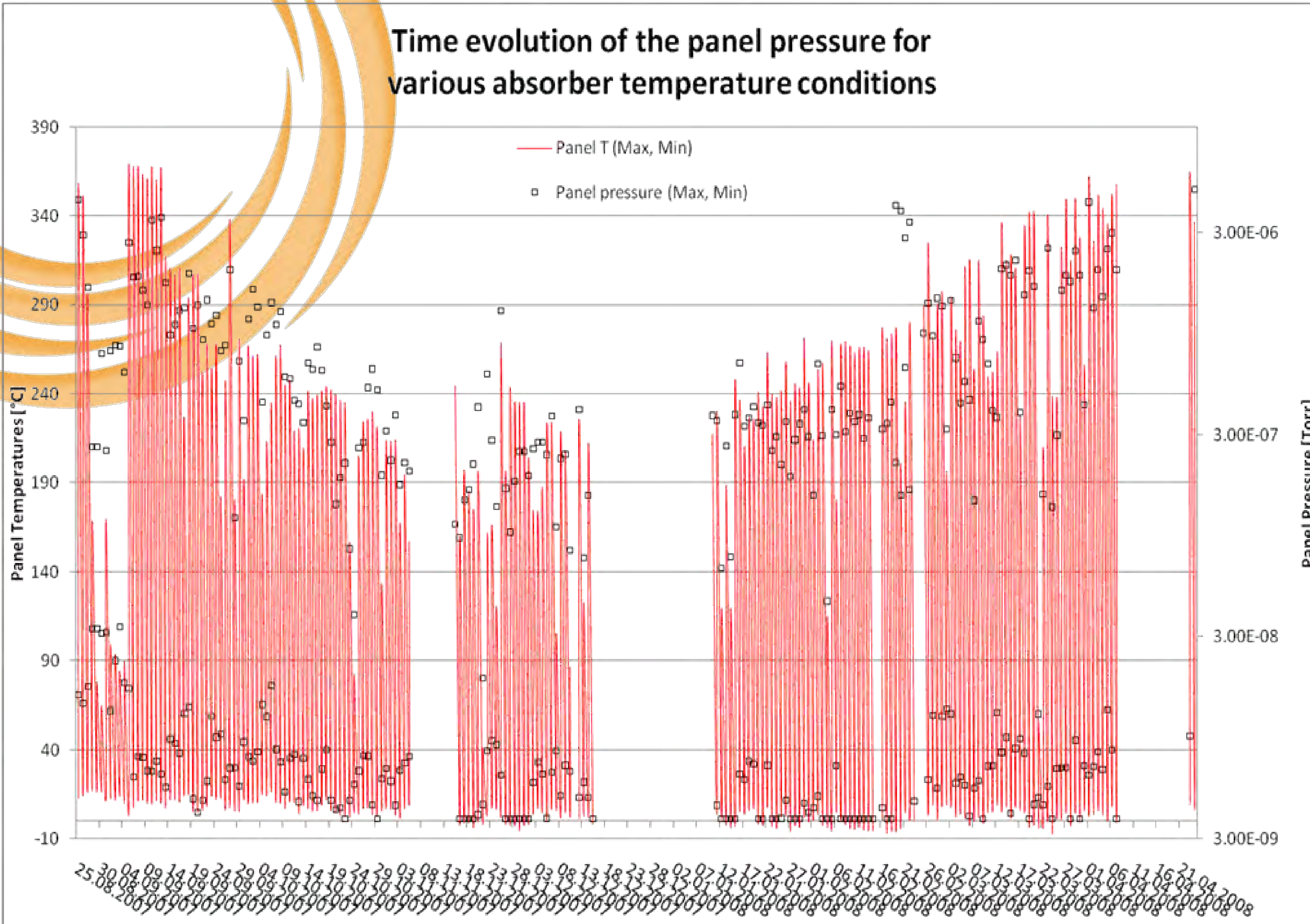


SRB Energy

Vacuum performances

- After evacuation the pressure inside the panel is in the low 10^{-7} Torr range.
- Due to the progressive decrease of the surface outgassing, the pressure decreases with time to the 10^{-8} Torr range, and increases to the 10^{-6} Torr when the absorbers are heated by sun to 300°C
- The temperature dependance and its evolution over about 6 months for a recent panel prototype is illustrated in fig.

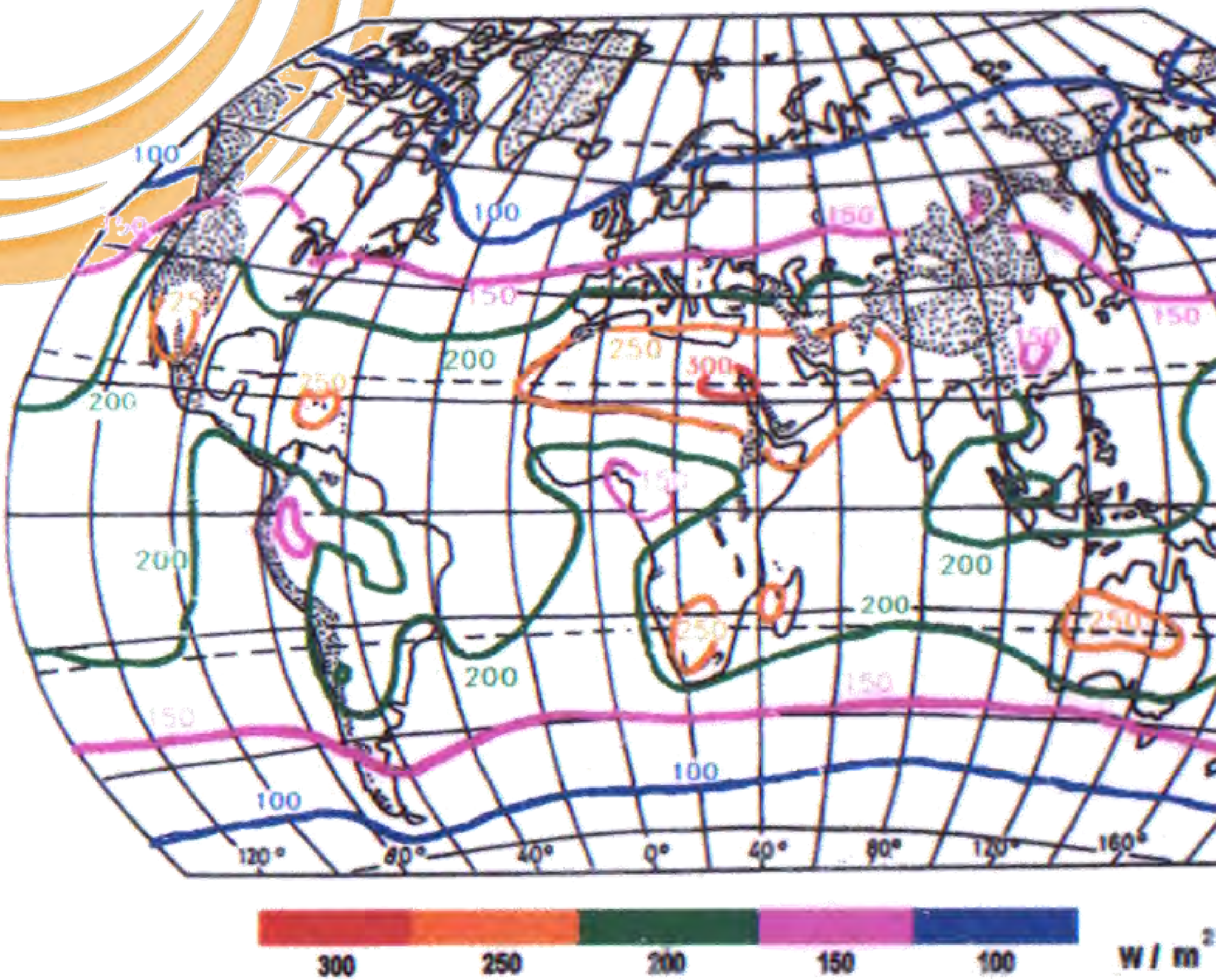
The flat plate evacuated solar collector



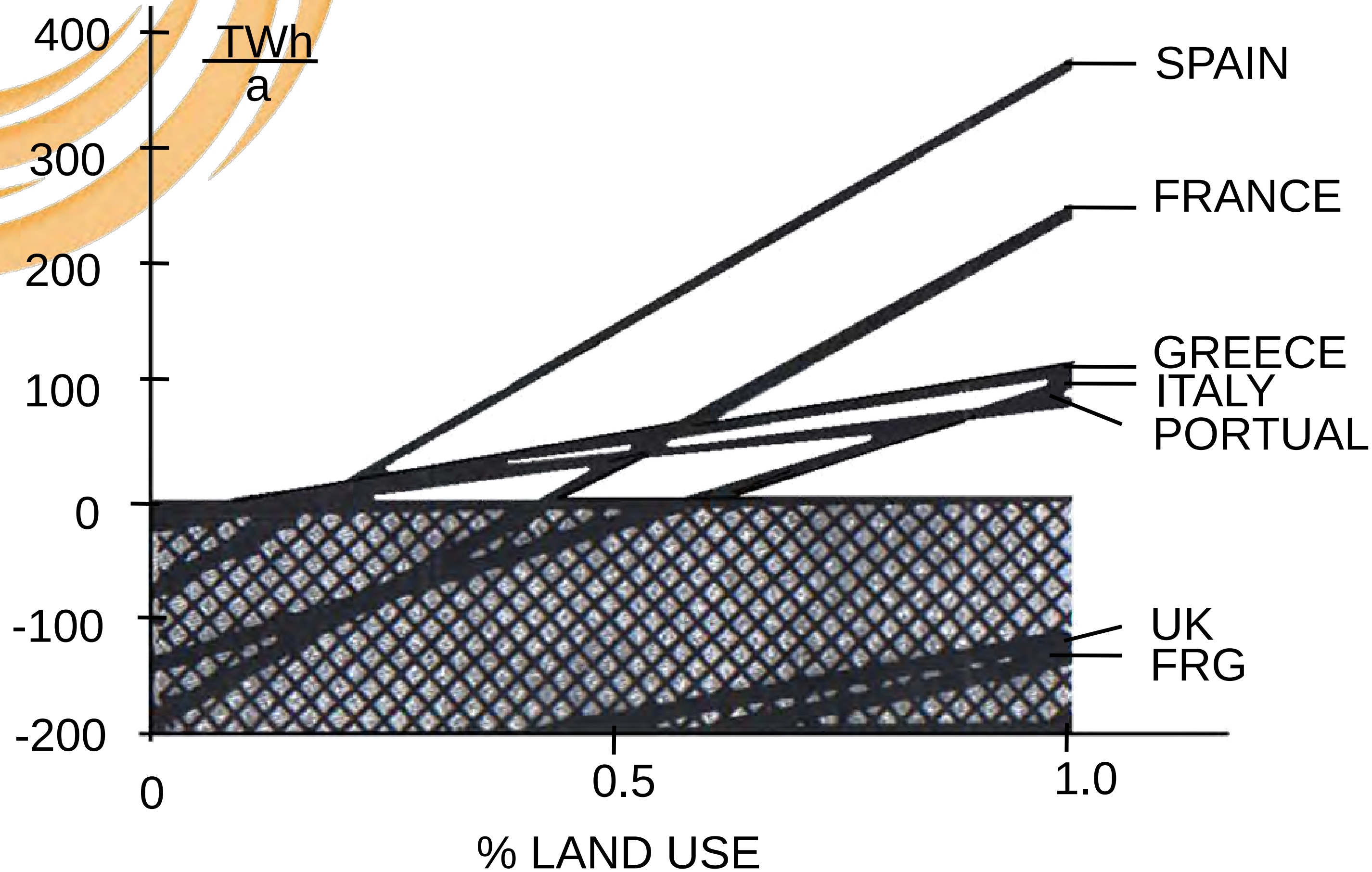
Applications

- The unique feature of the SRB solar panel is that it may be used for all the Solar Energy applications, a field now covered by products of different design
- The SRB panel is particularly suited for applications in the temperature range 150-250°C (for instance for industrial heat production and cooling / air conditioning) for which the panel performance is outstanding.
- For the production of electricity the SRB panel efficiency is similar to that offered by parabolic through solar fields, but the mirror geometry is much less critical and the maintenance for cleaning much reduced
- For low temperature applications (<100°C, domestic water heating) the SRB panel provides higher efficiencies than the existing flat panels in regions as Central Europe, where the available solar energy is reduced.

Solar power repartition



Potential for thermal electricity



Potential solar thermal electricity generation vs. present electricity demand as a function of land use

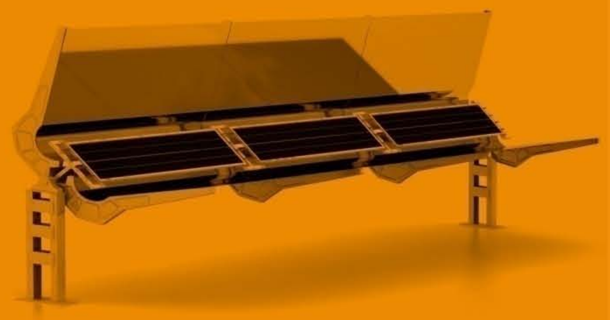
The flat plate evacuated solar collector

Key general information

Solar Energy Input $KWh(th)/m^2.year$	Typical Options and outputs	Estimates of Attainable Systems Efficiencies		Typical Regions
		Thermal	Electric	
2300 and above	Electric power generation and/or hydrogen production	0.60	0.20	Desert regions of North Africa, Southwest USA, Australia, etc.
1200 to 2200	Electric power generation ; Industrial process heat; Heating and cooling	0.40 to 0.55	0.10 to 0.18	Moderate regions of North and South America, Asia, Australia, and primary regions of Southern Europe, etc.
1000 to 1100	Water and/or air heating for resindential buildings and low grade process heat	0.30 to 0.40	0.08 to 0.10	Secondary regions of Europe, Asia, Africa, North and South America, etc.

Facilities in Spain

SRB Energy

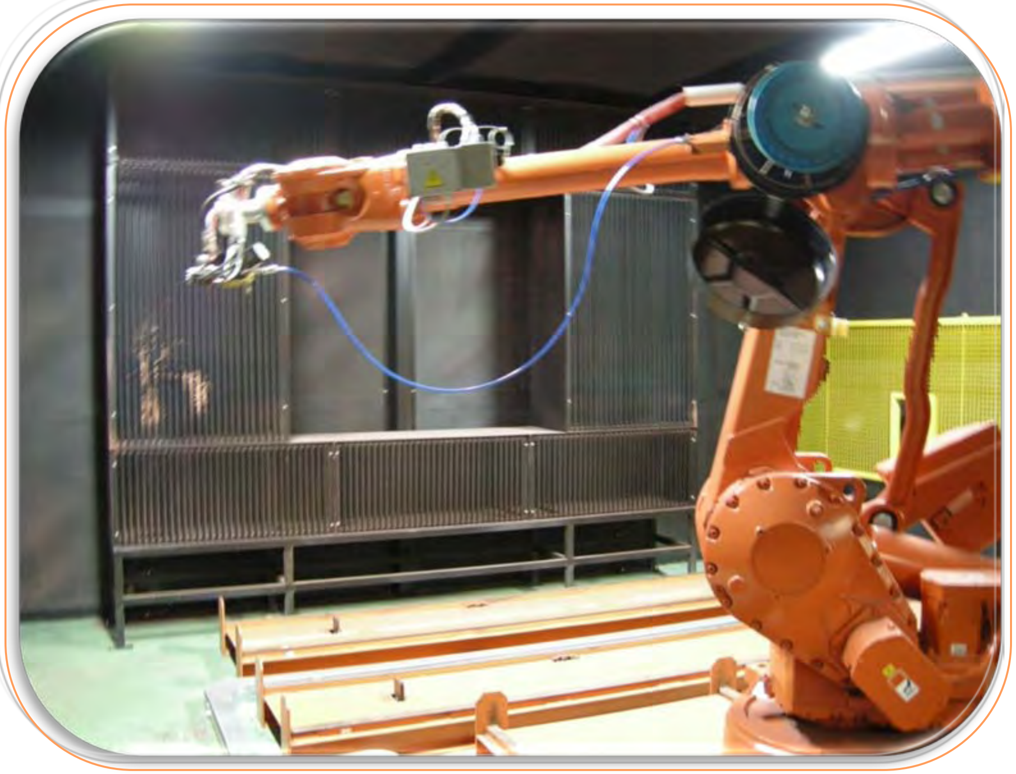




General view of the plant

Frame welding

Glass metallization

Plasma gun



Global view

SRB Energy

Glass soldering

Glass washing machine

Frame chemical treatment

SRB Energy

Chemical plant for absorber treatment

Assembly line

SRB Energy

Assembly process

Software

General view

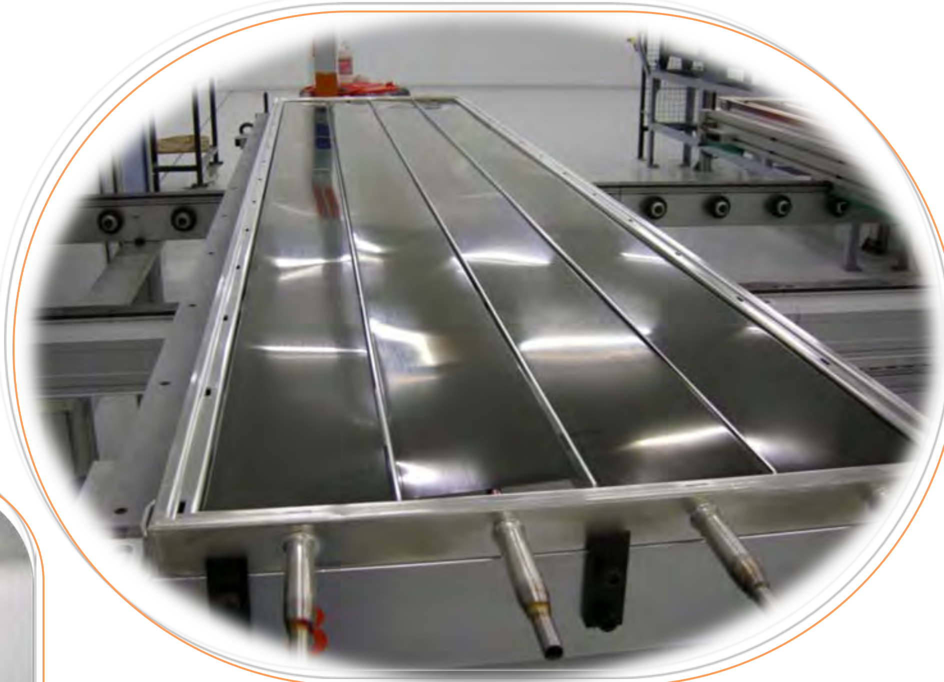
SRB Energy

Tubes welding

Bellows welding

Sleeves welding

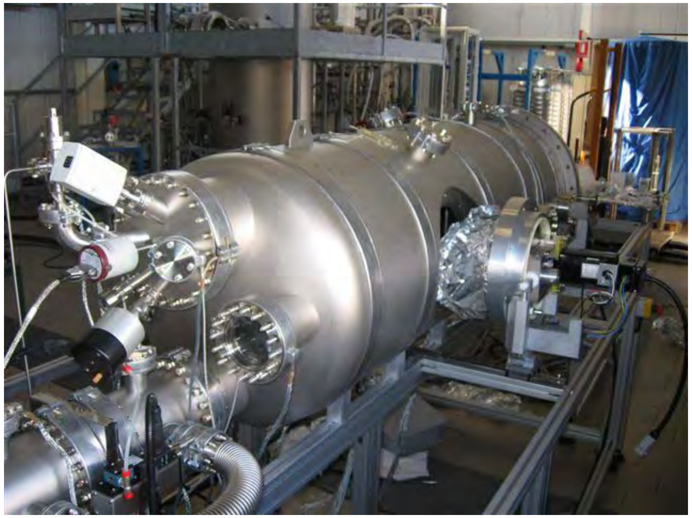
Absorbers

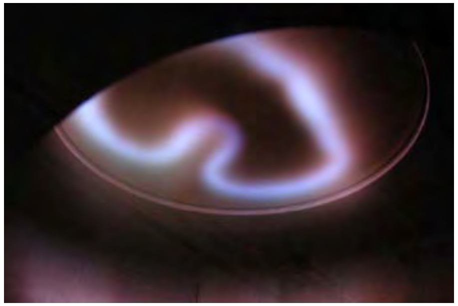


Absorber cutting

Laser welding

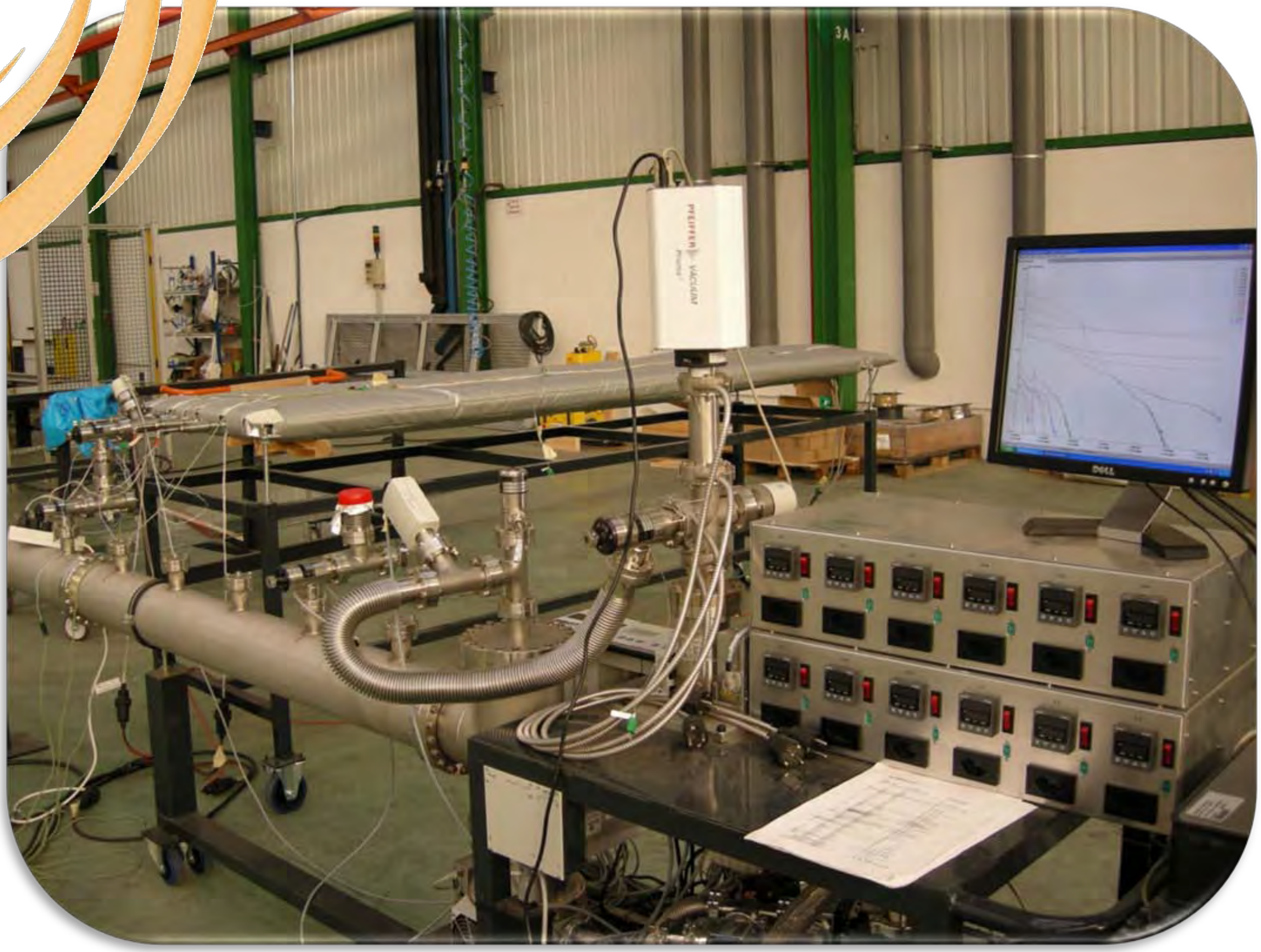
Roll to roll system for Getter





SRB Energy

Baking system prototype



Vacuum testing bench

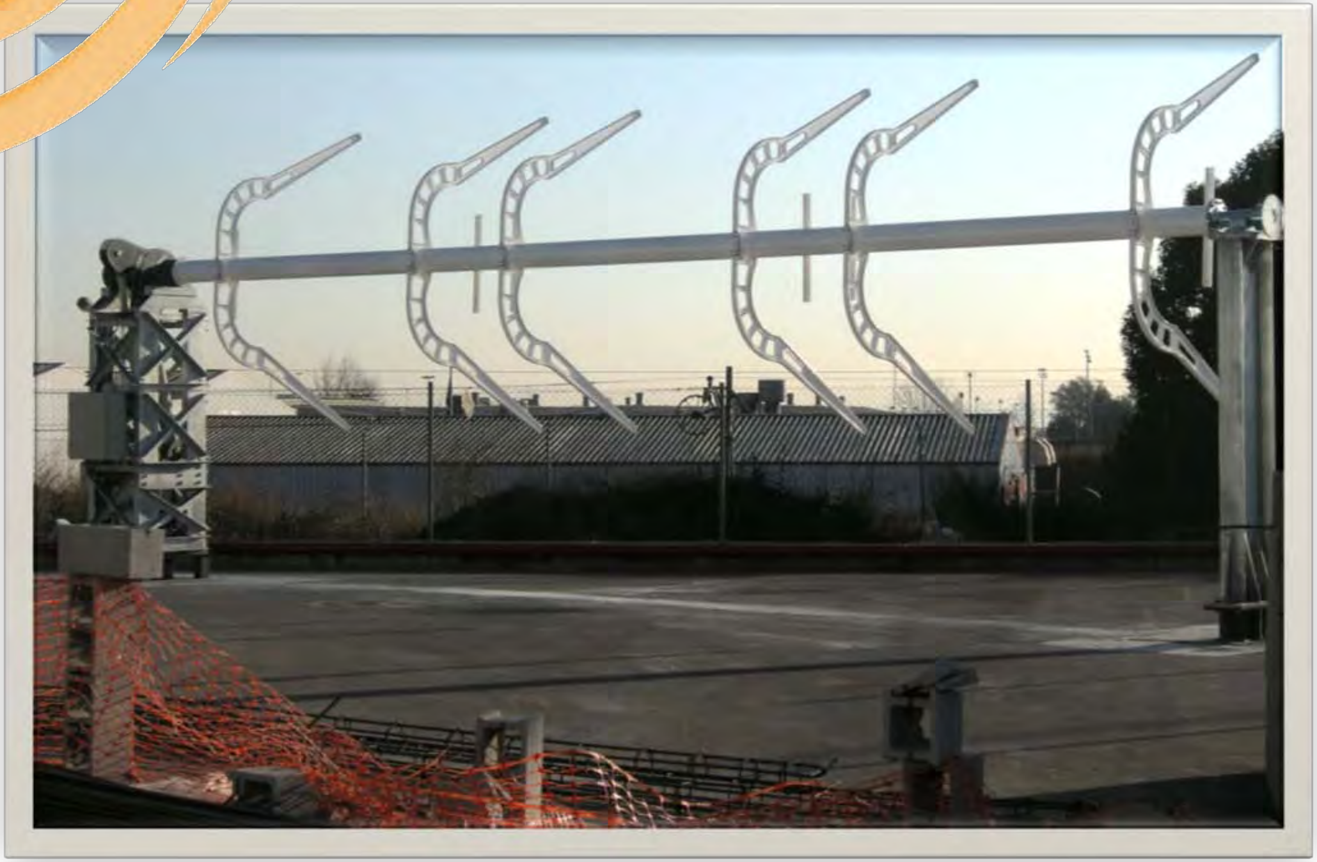
Vacuum

Panel of 3m

Sun tracker for the homologation

SRB Energy

Sun tracker



c/o CERN
CH-1211 Genève 23
Tel. +41 22 767 89 77
Fax. +41 22 767 17 80
geneva@srbenergy.com
www.srbenergy.com

References

1. Evacuable Flat Panel Solar Collector
   PCT / EP 2004 / 000503 (18.08.2005)
   Inventor: C. Benvenuti
   Applicant: CERN
   CH-1211 Geneva 23
2. Protective device for a solar collector
   PCT / EP 2006 / 006142 (26.06.2006)
   Inventor: C. Benvenuti
   Applicants: SRB ENERGY RESEARCH SARL
   rue de Candolle,9 CH-1205 Geneva
   CERN
   CH-1211 Geneva 23
3. Solar panel collector with cooling conduits comprising thermal expansion means
   PCT / EP 2006 / 001141 (26.06.2006)
   Inventor: C. Benvenuti
   Applicants: SRB ENERGY RESEARCH SARL
   CERN

References

4. Device for vacuum tight soldering an evacuated flat panel solar collector
   PCT / EP 2006 / 006140 (26.06.2006)
   Inventor: C. Benvenuti
   Applicants: SRB ENERGY RESEARCH SARL
   CERN

5. High efficiency evacuated solar panel
   PCT / EP 2008 / 057286 (11.06.2008)
   Inventor: C. Benvenuti
   Applicants: SRB ENERGY RESEARCH SARL
   CERN

6. Evacuated solar panel with a non evaporable getter pump
   PCT / EP 2008 / 057281 (11.06.2008)
   Inventor: C. Benvenuti
   Applicants: SRB ENERGY RESEARCH SARL
   CERN

7. Sealing mechanism for an evacuated solar panel
   PCT / EP 2008 / 057283 (11.06.2008)
   Inventor: C. Benvenuti
   Applicants: SRB ENERGY RESEARCH SARL
   CERN