ENEA Activities on CSP Technologies

ENEA Programme Main Strategic Choices

Since 2001, a vigorous ENEA programme has been launched, following a government directive on research and demonstration of concentrating solar technologies, on two main subjects. Both activities were suitably funded, by a specific law, and organized as large projects:

- Medium temperature (about 550°C) heat collection and storage, primarily intended for electricity production.
- High temperature (greater than 850°C) heat collection for direct hydrogen production.

Actually 75 researchers are involved in the program, the budget until now has been 17 Ml €.

The innovations in trough technology introduced by ENEA

In the past five years the R&D activities on the first line of research were pointed out primarily on:

- Design and realization, in strong conjunction with domestic industries, of innovative components (Solar Collector Assembly, Receiving Tube, etc.)
- Issues related to the usage of molten salt in trough systems
- Design, realization and operation of lab scale and full scale testing facilities for the characterization of the component and materials developed

Systems, components and technologies developed with Italian industries

- Linear parabolic collector
  - Supporting structure
  - Reflecting panels
  - Tracking system
  - Heat Collecting Element (HCE)
- Molten salt technology
  - Heat tracing components and systems
  - Circulating pumps, valves and heat exchangers
  - Specific sensors (mass flow rate, pressure, level,...)
  - Operating experience (filling, draining, accident recovery, …)
  - Auxiliary systems (melter and solidifier)

Supporting structure design concepts

Main beam: single tube

Supporting arms: precise parabolic shape

Simple on field regulation

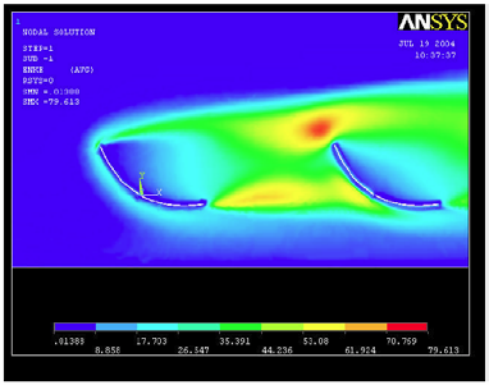
Design suitable for COR-TEN steel

(no hot deep galvanization required)

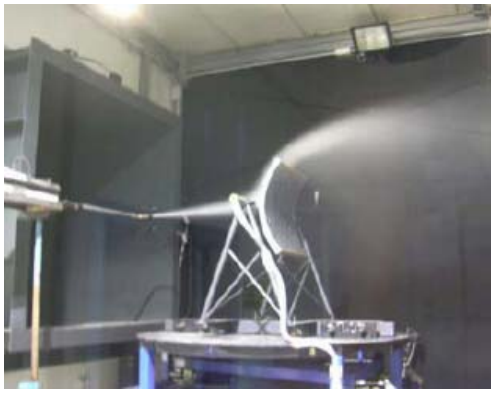
Limited number of assembling parts

(Manufacture and installation reduced costs)

Supporting structure: wind loads

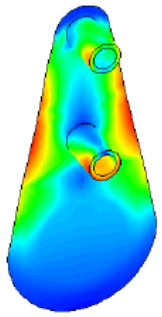


CFD Analysis



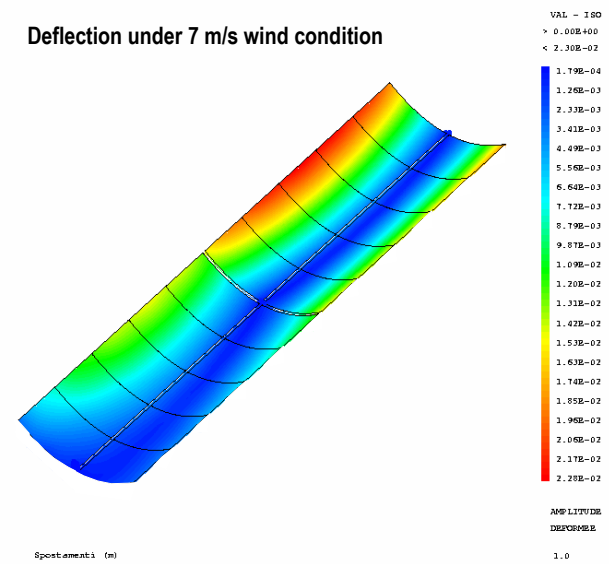
Tunnel tests

Supporting structure: Structural Analysis



Von Mises distribution
on module end-plate

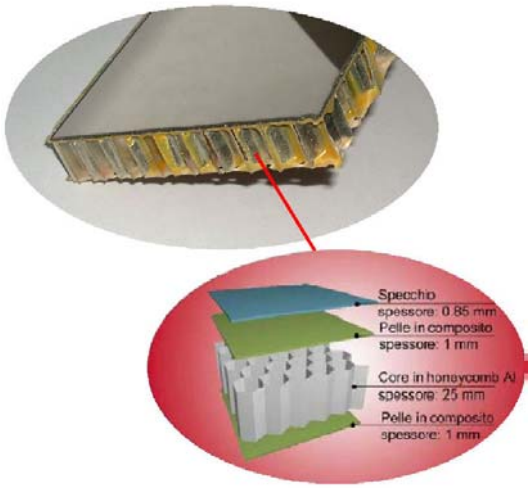
Deflection under 7 m/s wind condition



Reflecting panels

- Composite material panels
  - Large size (an half parabola each)
  - Easy to assemble
  - Excellent mechanical properties
  - Very good optical performances

Reflecting panels: honeycomb sandwich

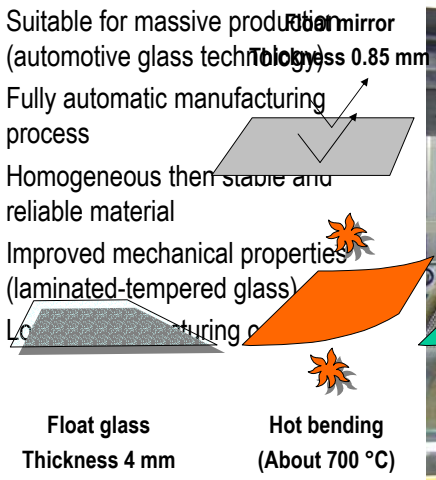


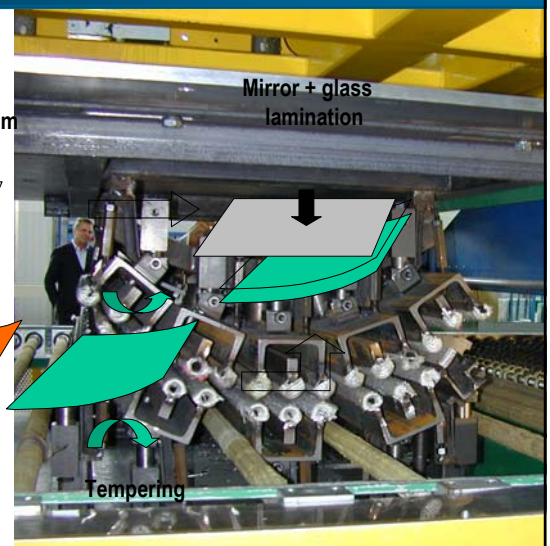
Reflecting panels

- Self sustaining panels
  - Large size (an half parabola each)
  - Simplified supporting structure
  - Excellent mechanical properties
  - Excellent optical performances

Reflecting panels

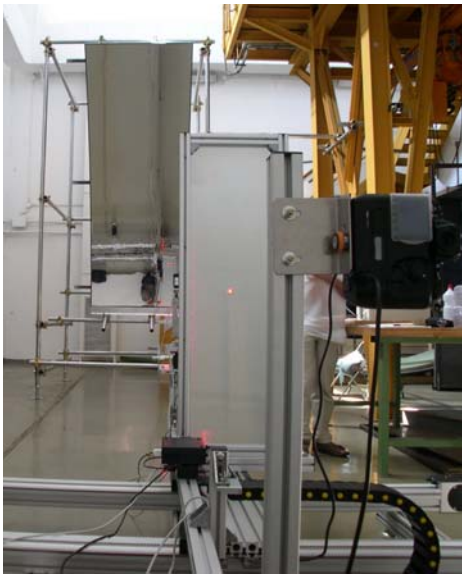
- Laminated glass mirrors
  - Suitable for massive production (automotive glass technology)
  - Fully automatic manufacturing process
  - Homogeneous then stable and reliable material
  - Improved mechanical properties (laminated-tempered glass)
  - Low manufacturing cost

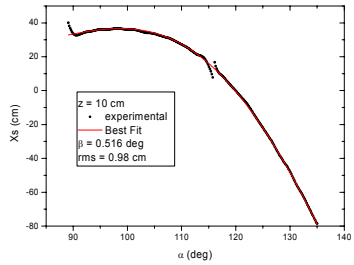


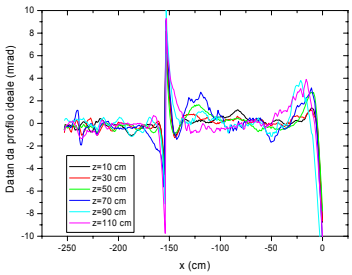


Tempering bending press

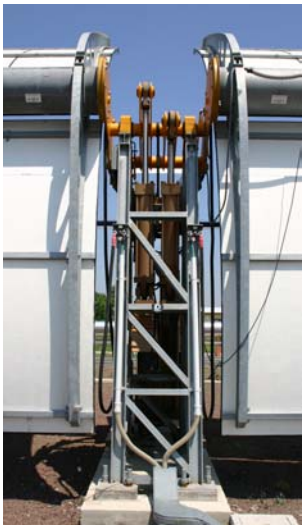
Reflecting panel characterization activities







Tracking system

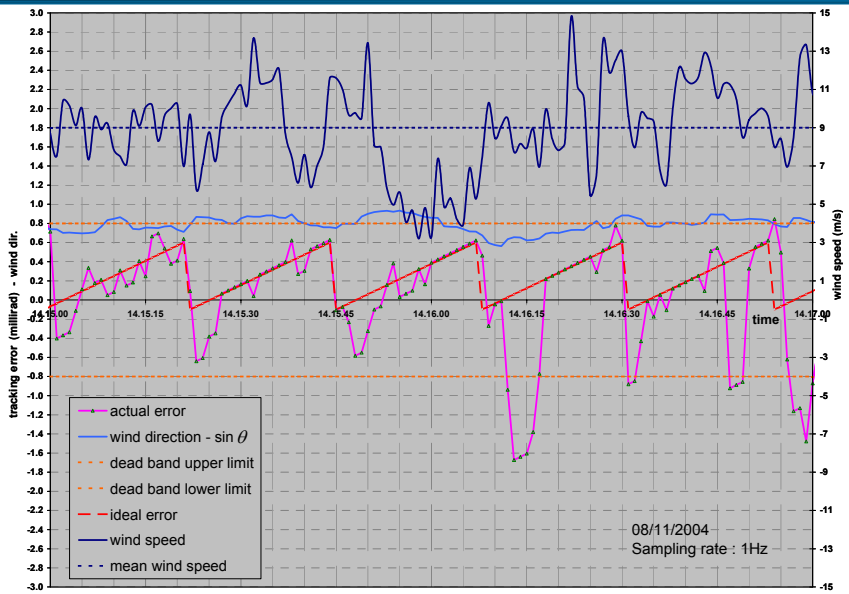


Prototype on field

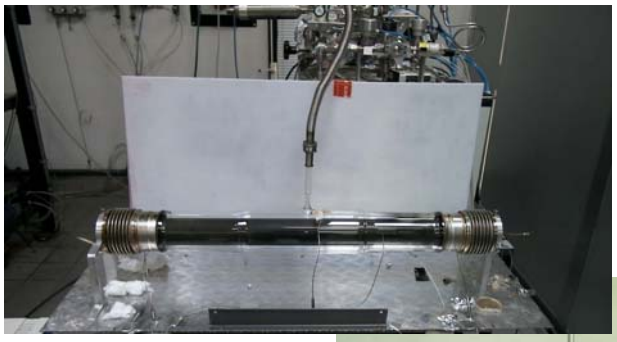
New system under test

- Hydraulic system
- Open loop control (with position feedback)
- Precise positioning (± 0.8 mrad)
- Rotary speed up to 0.5 rad/min
- Fast response time
- Safety blocking system
- Environmental compatible hydraulic fluid
- Hermetically sealed fluid tank

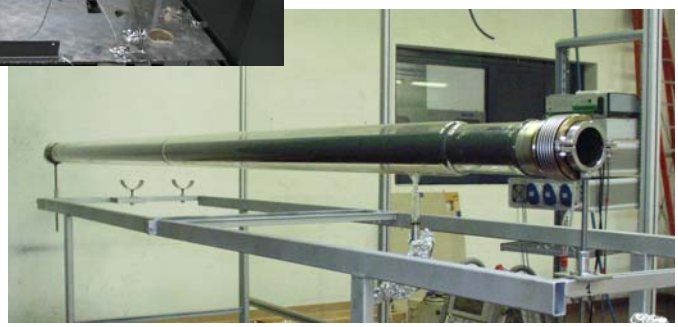
Tracking system: operation under highly windy conditions



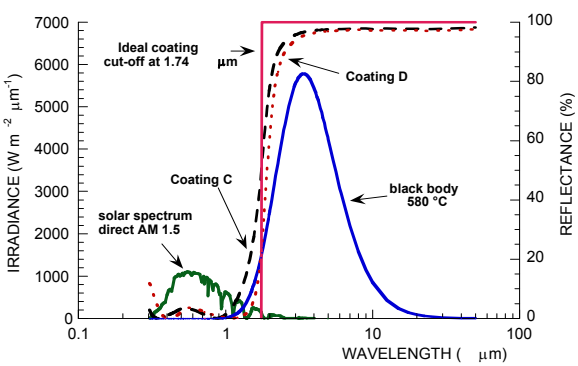
Heat Collecting Element



Designed for 550°C operating temperature



ENEA CERMET coating performances



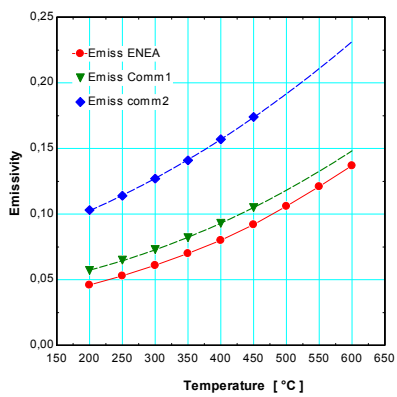
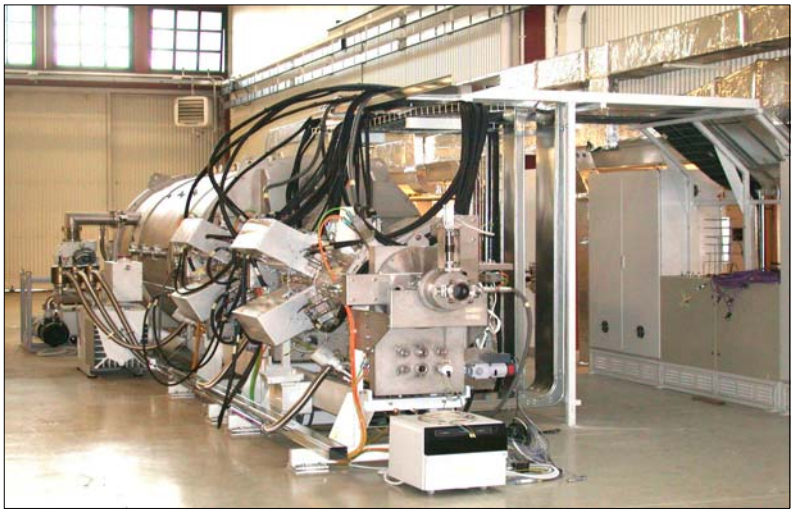


Photo-thermal parameters (Coating C):

α_s (solar absorptance) = 94.5 %

ε (emispherical emittance) :at 400 °C ➔ 8.0 %, at 580 °C ➔ 13.0 %

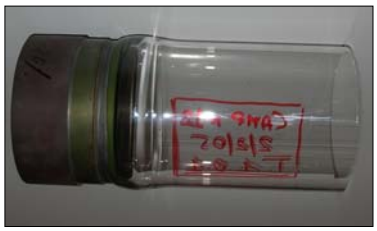
CERMET deposition sputtering plant



Installed October 2005 - Commissioning December 2005 - Full operation March 2006

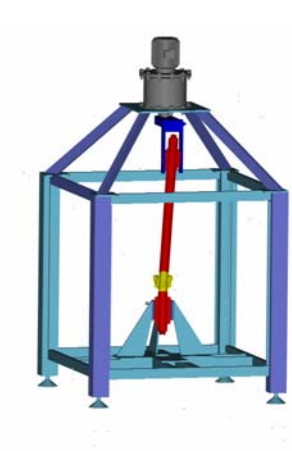
R&D on the HCE fabrication process

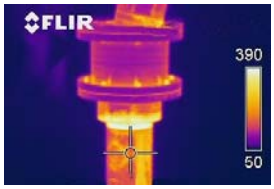
- Development of the glass to metal seal technological process
- Improvement of the bellow design
- Improvement of the system for out gassing the HCE and sealing automatically the glass envelope under vacuum



R&D on collectors interconnections

Cinematic join test facility





R&D on collectors interconnections

Rotating join

PCS: Solar Collector Assembly Test Loop

Experience with molten salt in parabolic trough

PCS: Solar Collector Assembly Test Loop

Main objectives

- Test the optical and thermal efficiency of the new solar collector assembly developed by ENEA
- Analyze the behavior of the process components (pump, valves, piping…) with molten salt as heat transfer fluid
- Verify the instrumentation, control system and operating procedures (molten salt management)

Tests operating conditions (flow, temperature, etc.) are similar to those foreseen in real power plants.

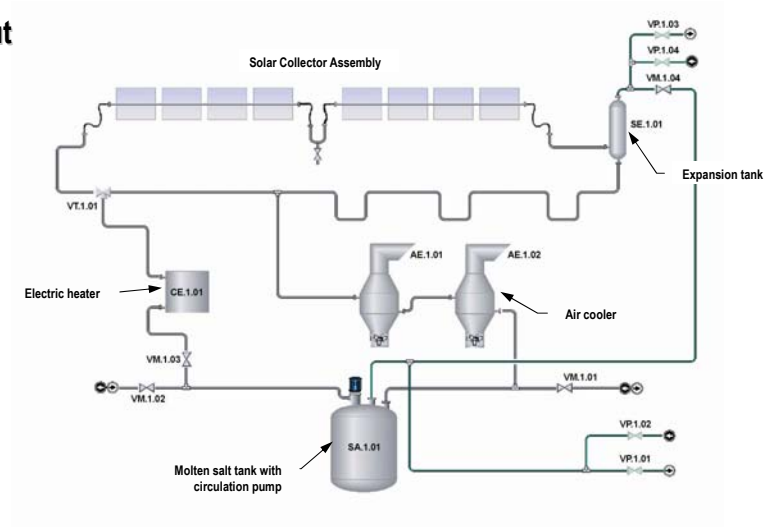
PCS: Solar Collector Assembly Test Loop

Main parameters

- Heat transfer fluid: mixture of molten salt (40% KNO_3 60% $NaNO_3$)
- Normal operating temperature: 270 – 550°C
- Heat transfer fluid flow: 3,0 – 7,5 kg/s
- Design pressure: 8,5 bar
- Molten salt volume: 5 m^3 (9500 kg)
- Maximum thermal power: 500 kW

PCS: Solar Collector Assembly Test Loop

Layout



PCS: Solar Collector Assembly Test Loop

Main components

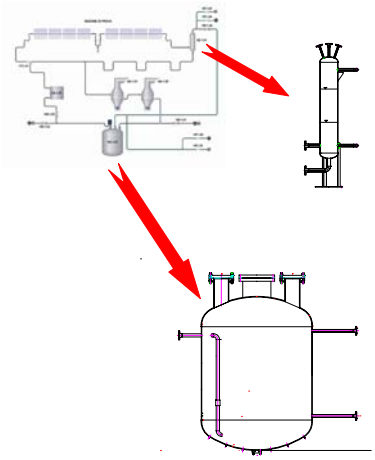
PCS: Solar Collector Assembly Test Loop

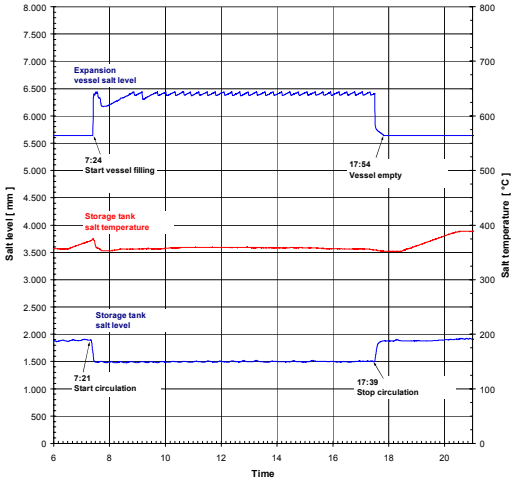
Plant operation

- Start: April 2004 (after the preliminary testing)
- In the first experimental tests tube receivers with black chrome were used. The experimental campaign ended in December 2004.
- In the new experimental tests tube receiver with cermet, supplied from SCHOTT, are used. The experimental campaign started May 2005.
- More than 1700 hours of operation
- About 160 filling and draining cycles

PCS: Solar Collector Assembly Test Loop

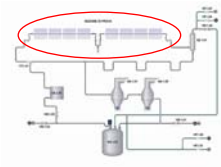
Salt level during the test

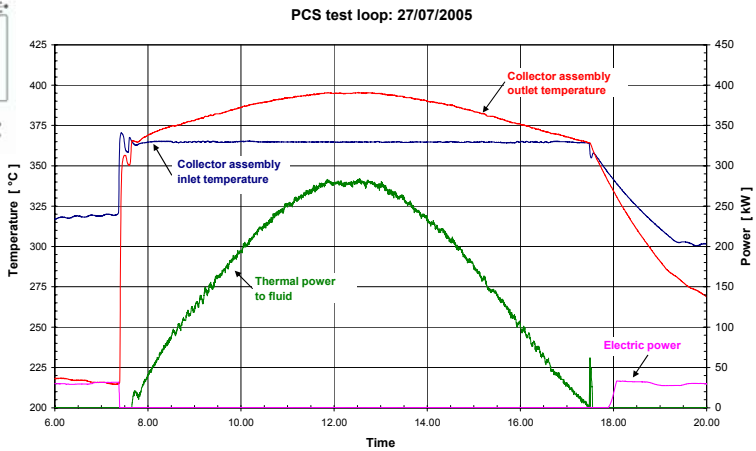




PCS: Solar Collector Assembly Test Loop

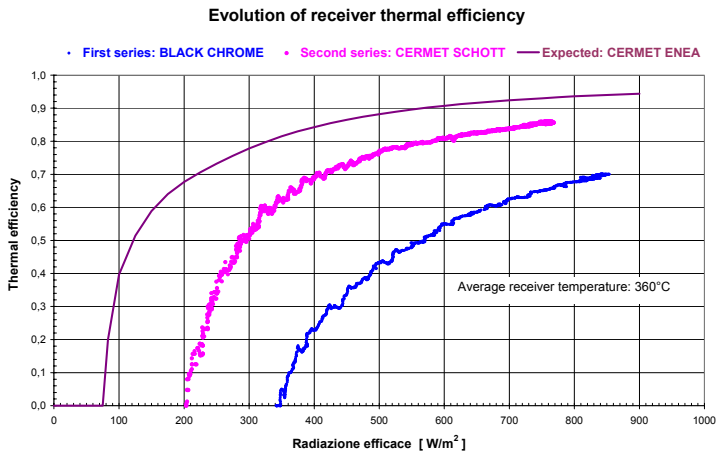
Solar collector assembly





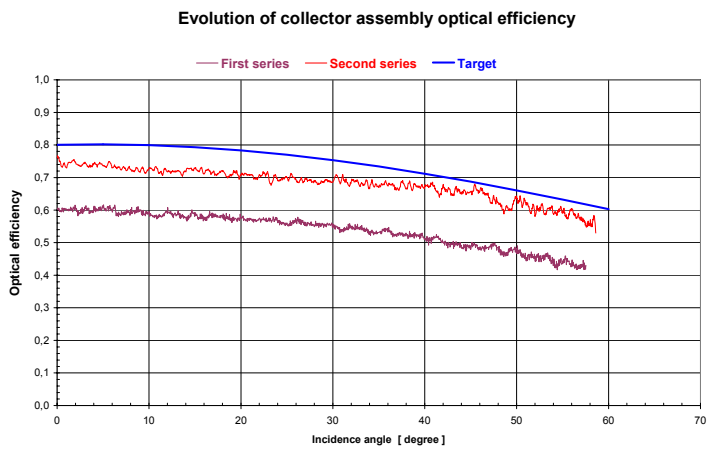
PCS: Solar Collector Assembly Test Loop

Efficiency



PCS: Solar Collector Assembly Test Loop

Efficiency



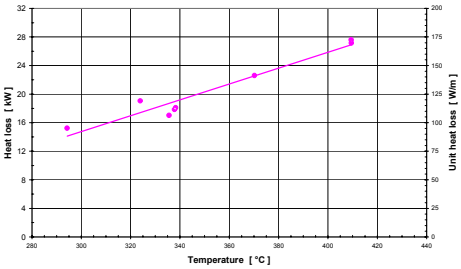
PCS: Solar Collector Assembly Test Loop

Electric heating systems:

- Electric heater: Joule effect (400 kW)
- Piping, valves, flanges: Mineral Insulated cable (26 kW)
- Heat Collecting Element: Joule effect (50 kW x 2)
- Air coolers: Joule effect (50 kW x 2)
- Storage tank:
  - Internal heaters: 100 kW
  - External heaters: MI cable (16 kW)

PCS: *Solar Collector Assembly Test Loop*

Piping

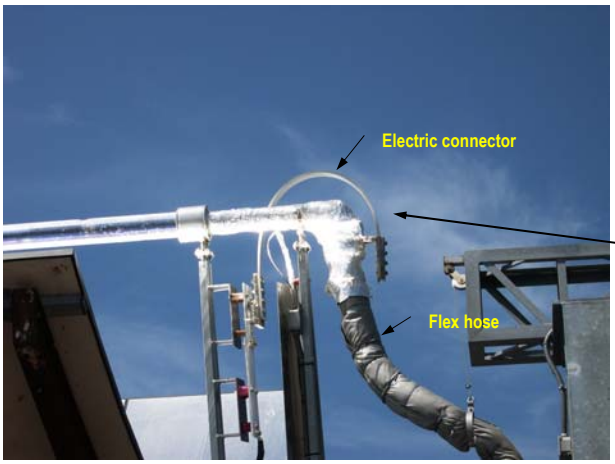


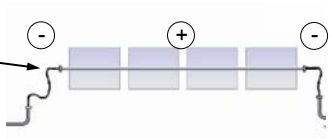
Insulation:

- stainless steel foil
- calcium silicate: 50 mm
- mineral wool: 200 mm
- aluminum jacket

PCS: Solar Collector Assembly Test Loop

Heat Collecting Element





PCS: operation remarks

- In the first 18 months of tests, during the normal operation, with the salt circulating, no problems were pointed out.
- In the beginning, some problems are arisen occasionally at the end of the draining phase, at very low salt flow, for the presence of cold points due to a non perfect insulation and non uniform heating that led to salt freezing.
- These problems, in any case, were easily solved, using the normal heating systems installed on the loop, only increasing the pre heating temperature, to thaw the salt, and caused only a delay in the test execution.

PCS: operation remarks

- The only severe accident occurred during the commissioning phase, with the system operating completely in manual mode by the supplier.
- The accident was due to a wrong indication of a valve position with consequent salt filling in a non preheated zone causing an extended salt solidification.
- With the aim of a very fast recovery of the plant the supplier accelerate the salt thawing, without a real understanding of the phenomena, causing a tube rupture in one of the air coolers.
- After those facts, ENEA technicians were charged of the plant operation and within a week, only using very carefully the heating system, the plant was recovered.

PCS: operation remarks

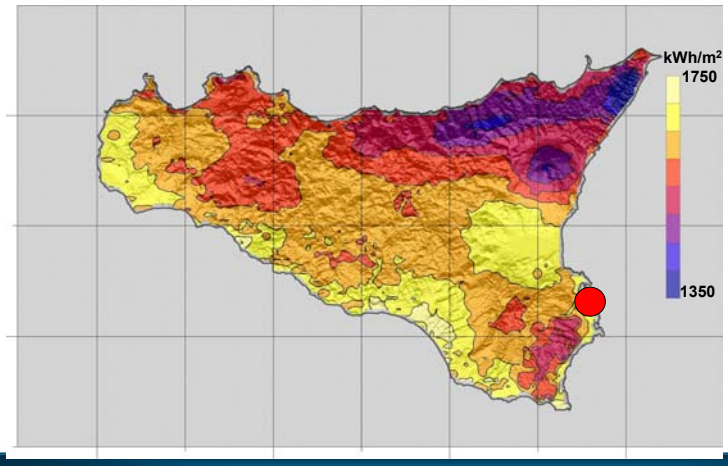
- Attention must be held in the draining and filling phases of the loop, because the low flow and the thermal losses can cool the molten salt down to the freezing point.
- In any case the molten salt freezing is not a critical condition because as the fluid freezes, it contracts, reducing its volume without stress for piping.
- Particular attention must be placed in the thawing phase. When salts melts its volume increases by about 4,6%, it is necessary to control the heating phase in order to allow the fluid expansion and not to exceed the allowable stress on piping.

The design of a molten salt solar trough plant: the "Archimede" project

- An agreement between ENEA and ENEL, the major Italian power generating company, was signed in September 2003 in order to verify the feasibility of the integration of a solar plant, according the ENEA approach, into a recently renewed combined cycle power station.
- A joint working group, constituted by engineers and technicians, was constituted with the aim to investigate all the technical and economical aspects of such project and to produce a preliminary design of the solar plant.
- After one year of work the group produced a design document on which all the critical aspects of the system were evaluated.
- The working group stated the feasibility and the economical validity (considering the forecasted but still not active Italian subsidies on solar thermal power plants) of the project including the use of molten salt as heat transfer fluid and thermal storage media.

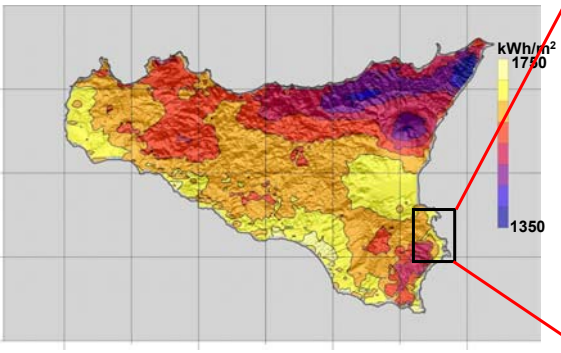
Progetto "Archimede": la localizzazione

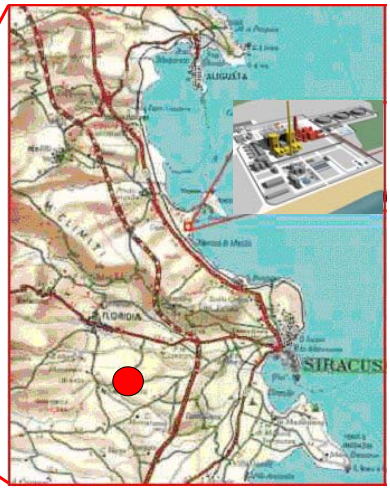
La zona di Siracusa è una delle aree nazionali a più alta insolazione: 1725 kWh/m^2 annui



Progetto “Archimede”: la localizzazione

Presso il comune di Gargallo è stata recentemente riconvertita una centrale ad olio combustibile in una a gas a ciclo combinato





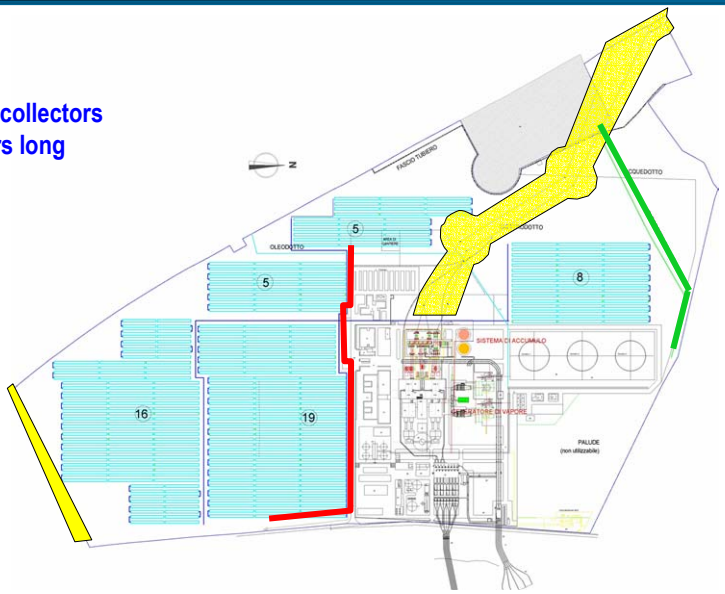
Progetto “Archimede”: la localizzazione

Presso il comune di Gargallo è stata recentemente riconvertita una centrale ad olio combustibile in una a gas a ciclo combinato

Potenza elettrica complessiva 760 MW

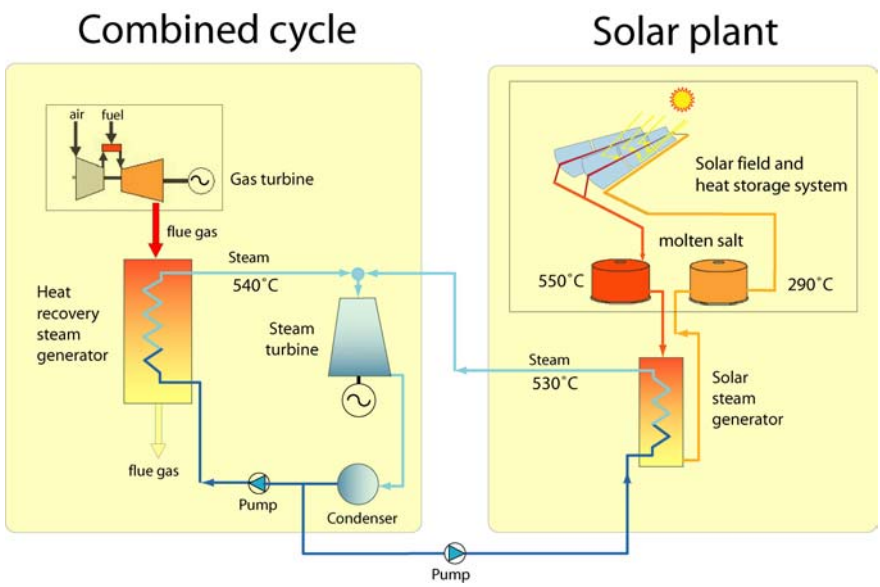
The “Archimede” project: the solar field

318 solar collectors
100 meters long

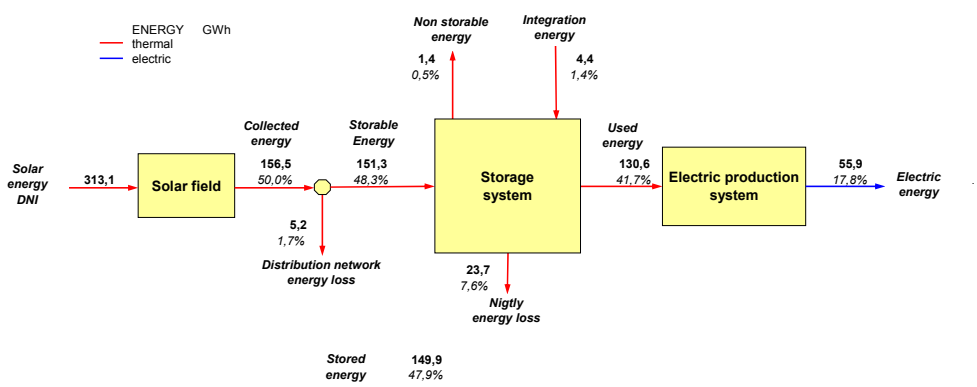


“Archimede” project: photographic reconstruction

The "Archimede" project: the systems integration



The "Archimede" project main parameters



The "Archimede" project main parameters

Collectors orientation		*NS*
Number of collectors		318
Thermal energy collected	GWh/y	156.5
Storage capacity	MWh	500
Thermal energy stored	GWh/y	149.9
Nominal electric power	MWe	28.1
Gross plant efficiency	%	43.6
Delivered electric energy	GWh/y	55.9
Primary energy savings	TEP	11,835
CO_2 emission avoided	ton/y	36,306

The preliminary design document was completed in December 2004 in collaboration with ENEL. The realization phase was postponed due to the delay in the approval of national subsidies on concentrating solar thermal power plants.

Thank you for your attention