

ITALIAN CONTRIBUTION TO CSP WITH FLAT REFLECTORS

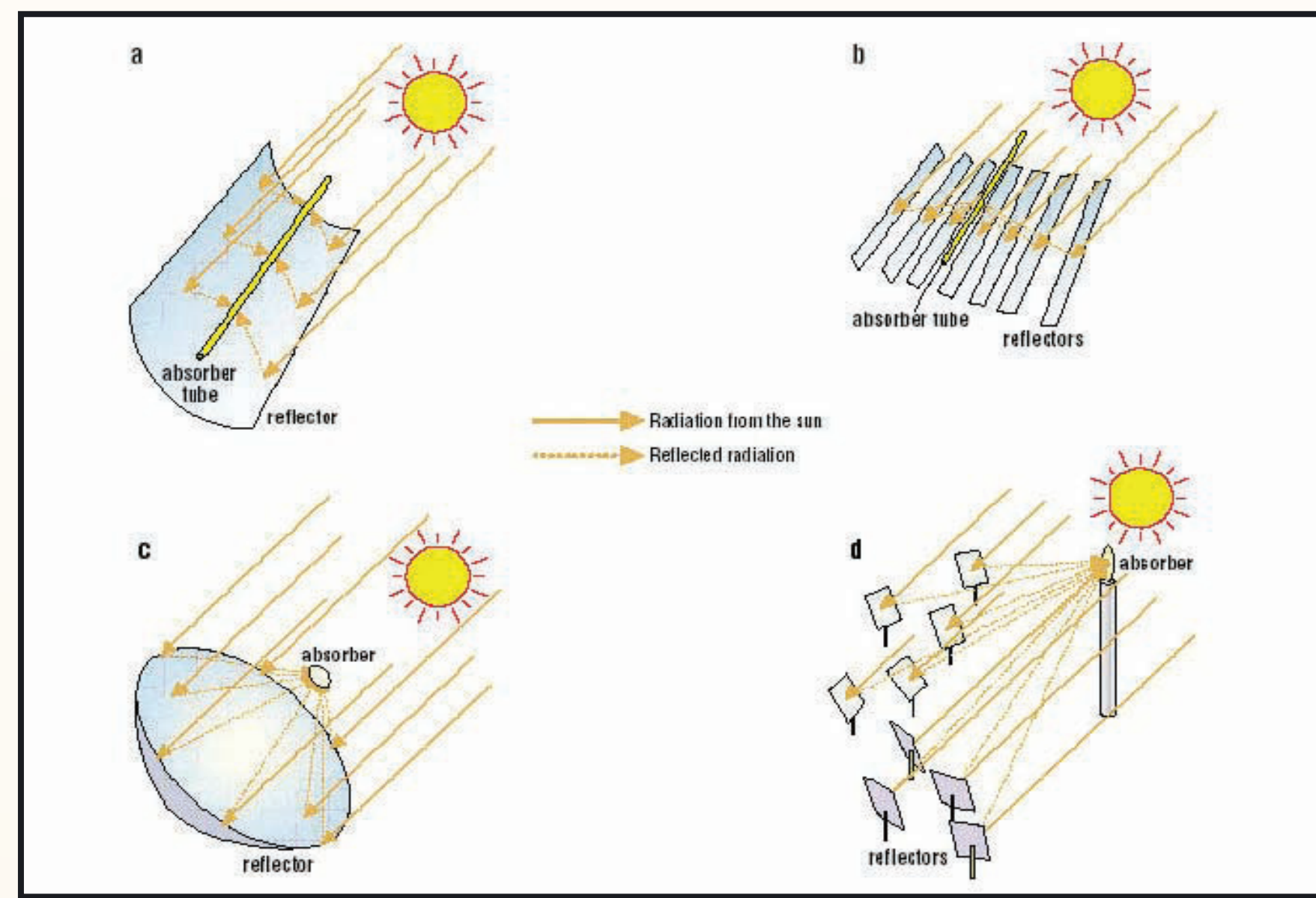
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INTRODUCTION

This poster presentation is about the Italian contribution made over the last 200 years for the development of Concentrating Solar Thermal Power (CSP) with flat or almost flat reflectors. Roughly ten Italian mathematicians, physicists, engineers, and scientists explored in the last two centuries the possibility to produce power from solar heat.

In this poster two such inventors are recalled: Alessandro Battaglia (1842 – n.a.), whose work has been rediscovered by GSES in 2008, and Giovanni Francia (1911-1980), known as the father of solar thermoelectric plants, whose 100th anniversary falls this year.

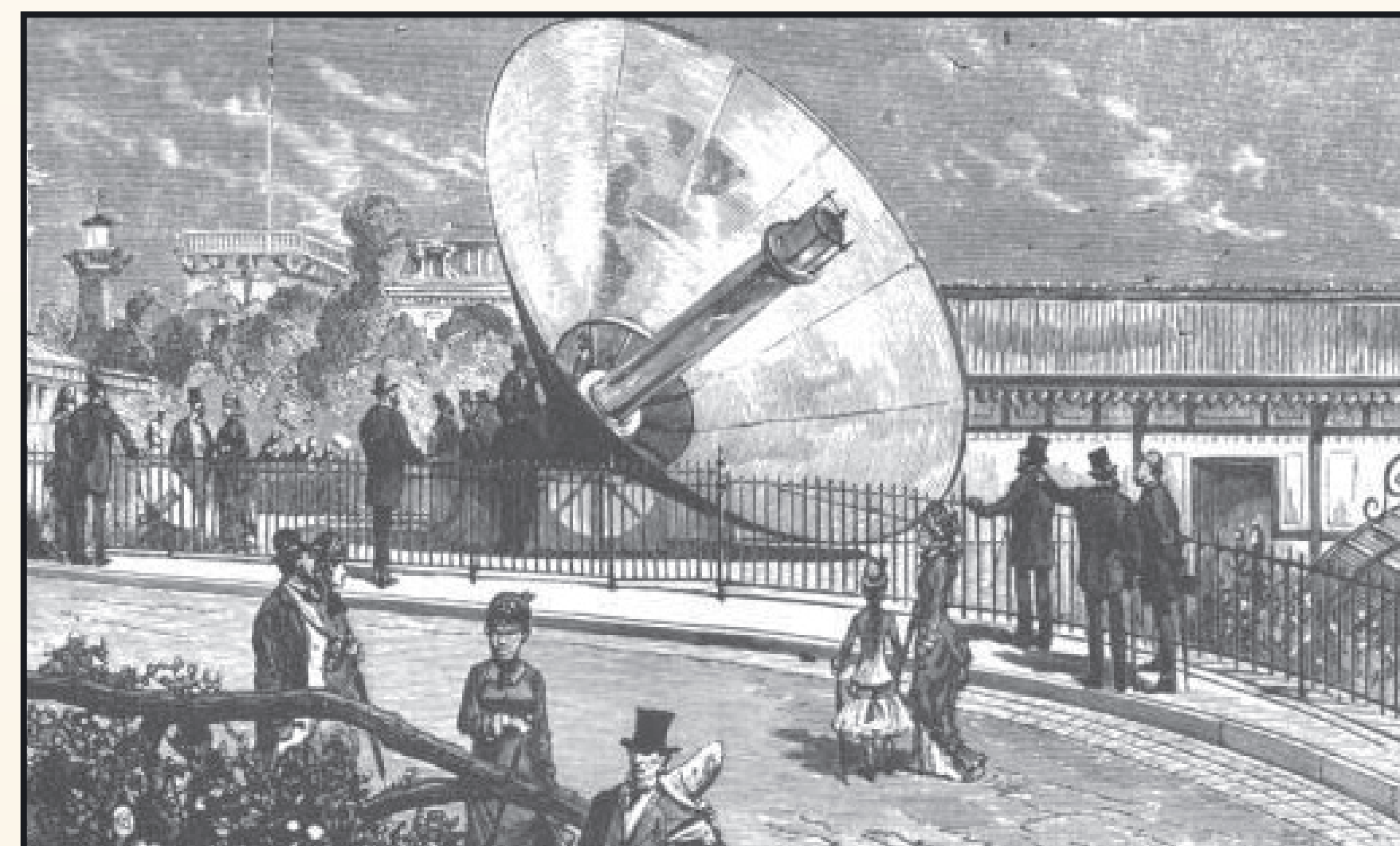


Four common types of CSP today, with curved reflectors - trough (a), and dish (c) - and with flat or almost flat reflectors - linear Fresnel (b), and tower (d) Source: <http://www.solarpaces.org>.

ALESSANDRO BATTAGLIA (1842 - N.A.)

Mouchot's sun machine

The image below shows Augustine Mouchot's sun machine, the largest of its time, on display at the Universal Exposition in Paris in 1878 (Butti and Perlin, 1980).



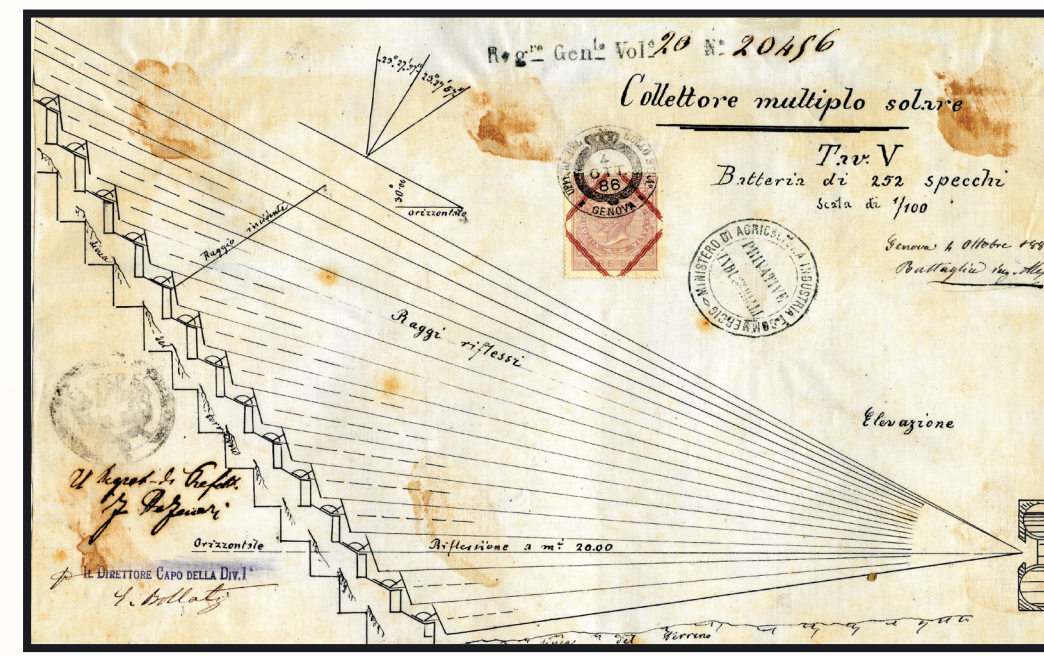
Mouchot's sun machine was noted in Italy by Alessandro Battaglia.

Mouchot's sun machine was noted in Italy by Alessandro Battaglia (1842 – n.a.). Battaglia thought that the Mouchot design had several inherent limitations that he illustrated in 1884 at the Encouragement Institute of Naples:

- It is not possible to build boilers of sufficient capacity to power industrial engines due to the fact that the boiler is mounted on the tracking collector, which limits its size;
- The boiler loses its heat easily because it is exposed to open air and cannot be insulated and protected;
- The tracking collector, as a single surface, is also limited in its total area.

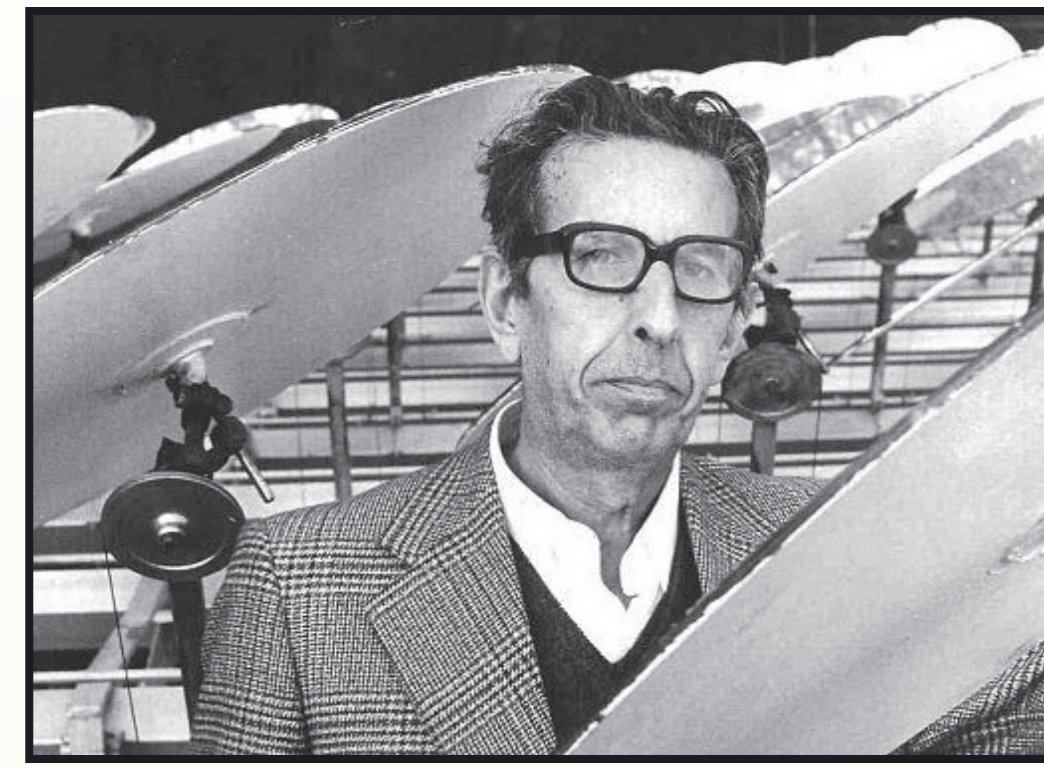
Battaglia's "Collettore Solare Multiplo"

To overcome these limitations, Battaglia proposed separating the boiler from the collecting reflector area and filed a patent registered on Oct. 4, 1886. The Multiple Solar Collector was Battaglia's answer to the challenges of building reflector field capable to collect large quantities of solar energy in order to meet modern industrial energy demands.



Cross section of the collecting reflector area made up of 250 flat reflectors and the longitudinal grounded boiler, one meter in height, installed inside a brick oven, insulating and protecting the boiler, and with an open window facing the reflector area. (Central State Archive, Rome, Italy).

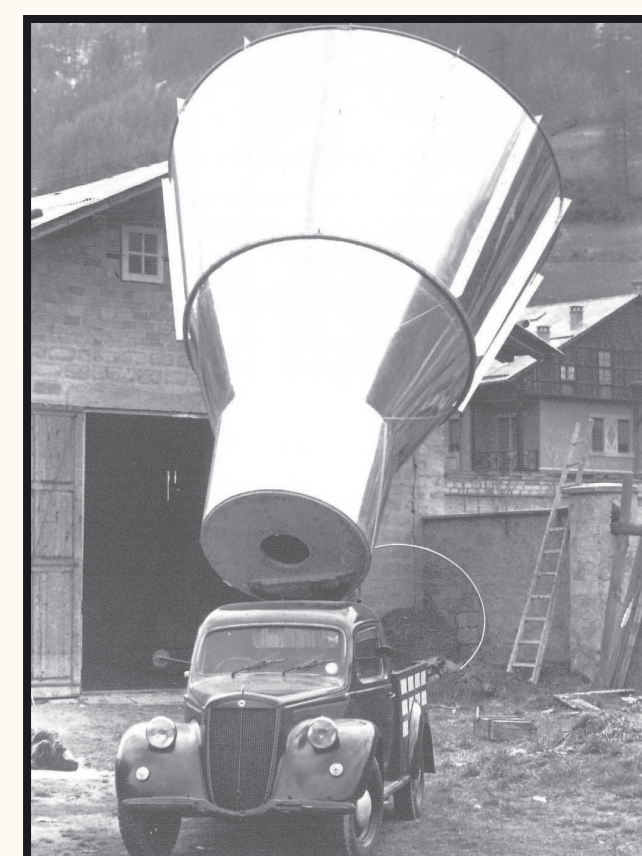
GIOVANNI FRANCIA (1911 – 1980)



Giovanni Francia at S. Ilario solar station in late 1970s, photo courtesy Francia's heirs.

Honeycomb structure and Francia's first solar boiler

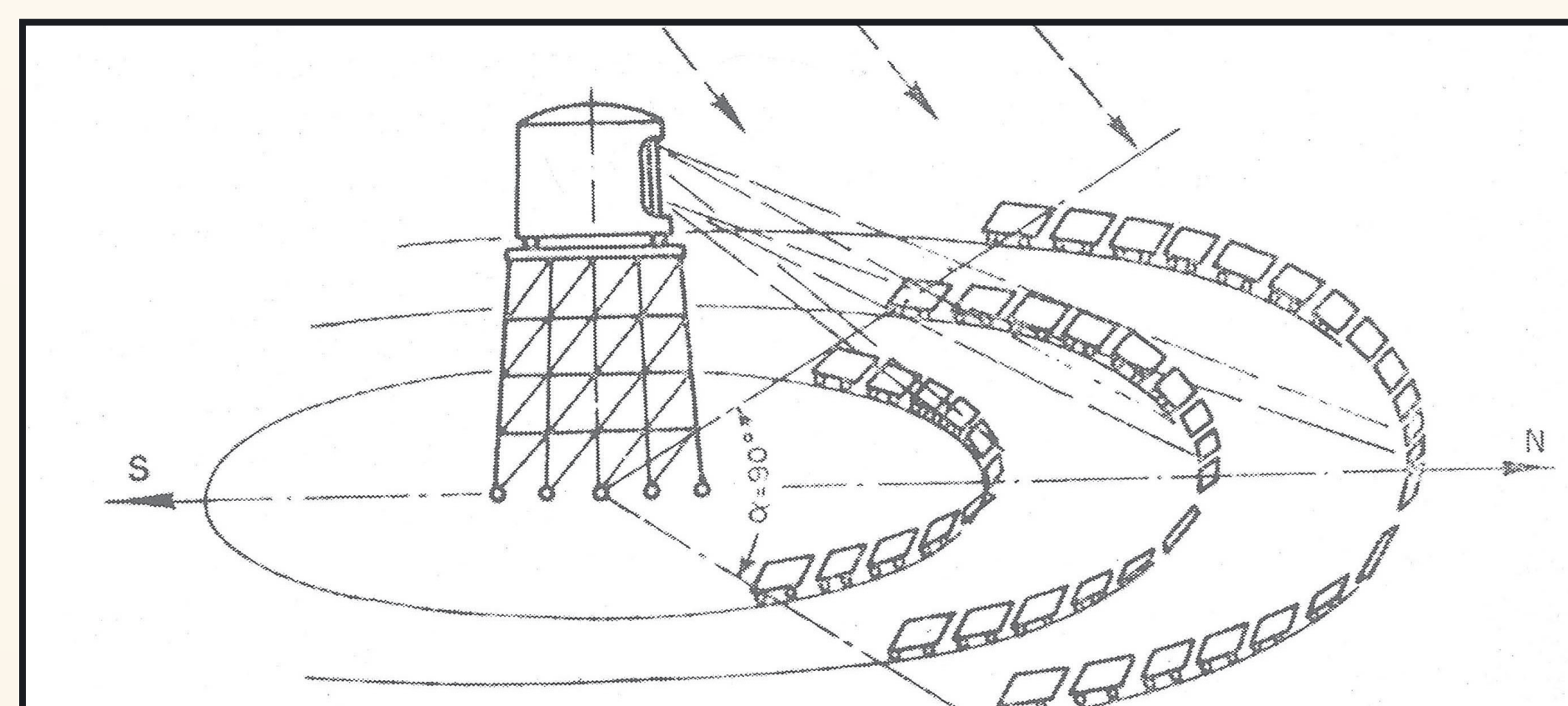
In 1960 Francia invented the honeycomb structure, an array consisting of a large number of long, thin, parallel tubes made of glass, quartz or plastic. Being transparent to solar radiation but opaque to the heat rays emitted by the hot surface, the array served to reduce the collector's losses from re-irradiation and convection.



First concentrator coupled with a boiler protected by a honeycomb structure tested in Cesana Torinese in 1960/1961, which reached the temperature of 600°C*. To track the sun the boiler was moved by a small truck.

Concentration of Sunlight with flat or almost flat reflectors

Before Francia came on the stage, the Fresnel reflector concept was explored in Italy, as shown above, by Alessandro Battaglia. Abroad the most significant work was done in the Soviet Union by Valentin A. Baum in the 1950s.

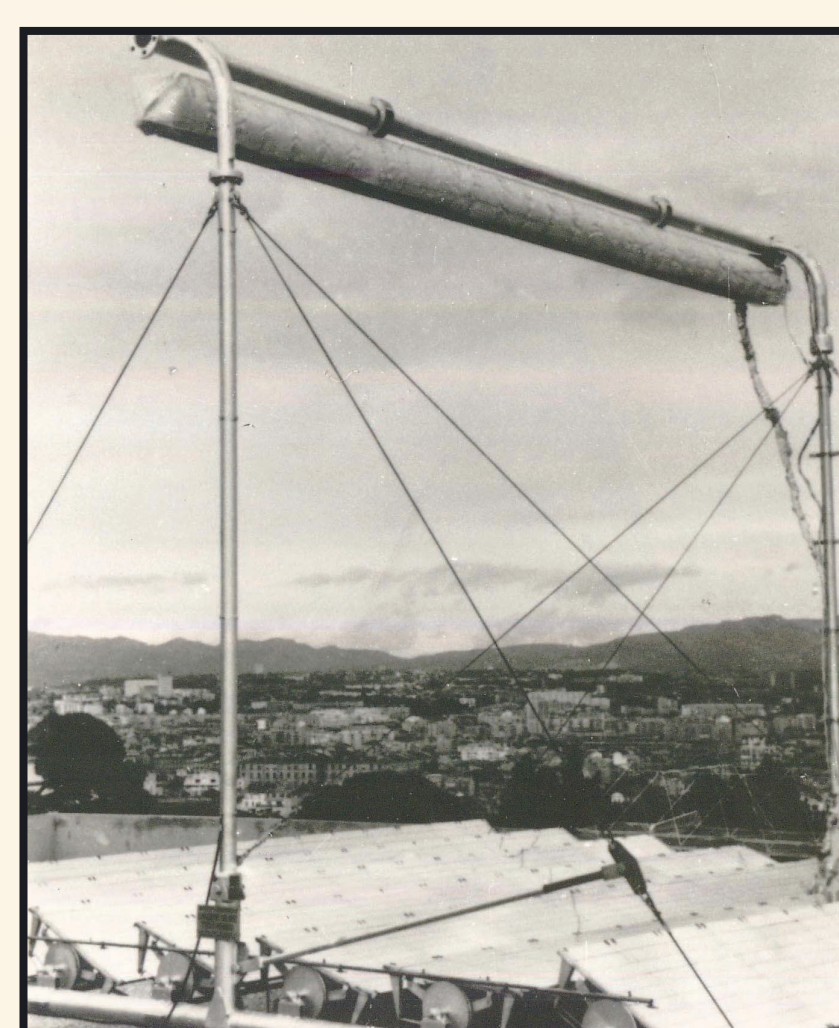


Solar Tower designed by V.A. Baum. Reflectors track the sun by moving on concentric rails around the tower where the boiler is mounted

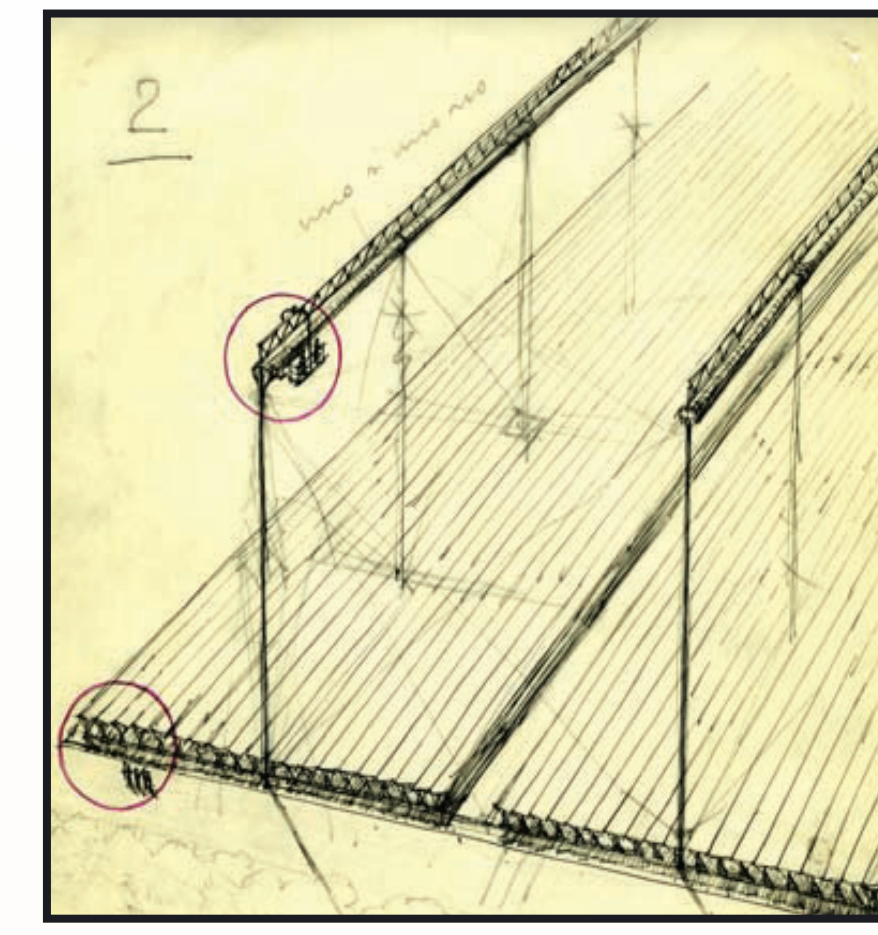
Francia, who was apparently unaware of Alessandro Battaglia's work, followed nonetheless the same conceptual path: separating the reflector from the boiler. Between 1962 and 1965, at world level, he designed, built, and tested the first real linear and point focus Fresnel reflector concentrators, LFCs and PFCs, demonstrating that it is possible to produce steam at high pressures and temperatures with solar heat and suggesting that "large solar plants can only be built with flat reflectors" (Letter by Francia to Touchais, Jan.1962).

Linear Fresnel Reflector Concentrator

Francia filed his first LFC patent in 1962 and built the first prototype, in Genoa, and in 1964 he reassembled and tested it at the Lacédémone-Marseilles solar station. The plant generated 38 kg/h of steam at 100 atm and 450°C.



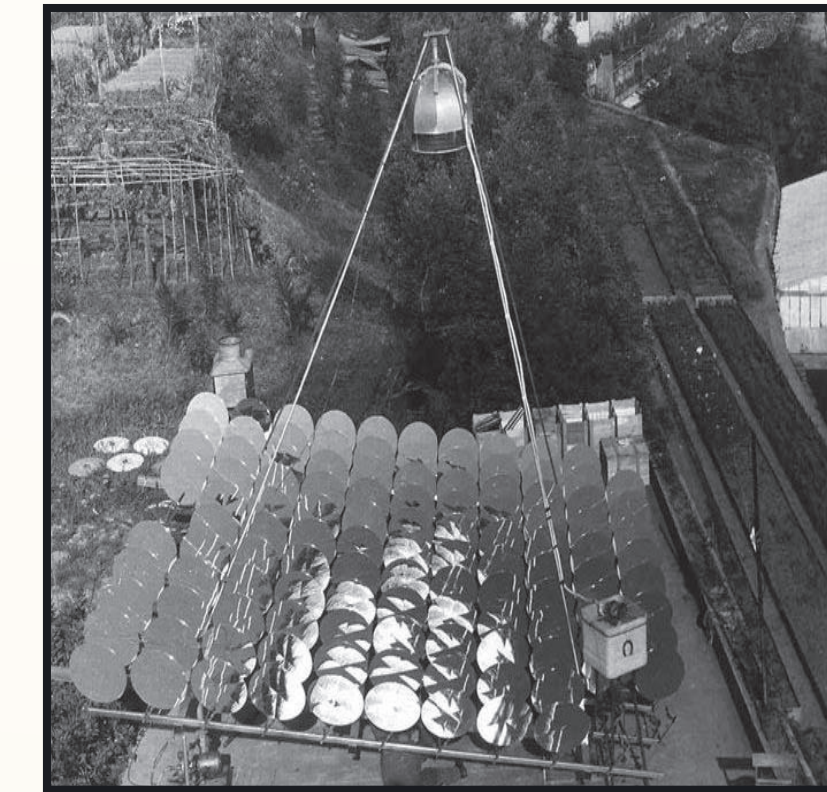
World's first linear Fresnel concentration-type solar plant, built and tested at Marseilles (France) in 1963/1964.*



Francia's drawing of the envisioned large solar LFC power plant circa 1965*.

Point focus Fresnel Reflector Concentrator or solar tower

In 1965 Francia built the first tower prototype at the Sant'Ilario solar station near Genova, which supplied 21 kg/h of steam at 150 atm and 500°C.



World's first point focus solar tower prototype, built and tested at Sant'Ilario (Nervi, Genoa, Italy), in 1965*. (*Images and photos from Francia Archive, Museum of Industry and Work, MUSIL, Brescia, Italy).

In the following years, 1967, 1972, and 1978, he built and perfected three additional tower prototypes.

He was involved in the 1 MWe Eurelios power plant at Adrano, Sicily, in Italy, the world's first large-scale demonstration power tower to be connected to a national power grid, which became operational in April 1981. Below a view of the heliostat field and the boiler tower of Eurelios in 1982 (Photo Parodi archive).



The Eurelios tests were completed in 1985, and ENEL published the results in 1991.

The authors of the report concluded that the per-kWh cost of electricity generated by Eurelios would be far from acceptable even if the up-front costs of the plant were reduced.

Developments of CSP today: curved or flat reflectors?

In theory, Linear Fresnel and Tower with flat reflector technology, adopted in large plants, promise to produce electricity at higher efficiencies than other CSP plants. The true test will come only when plants, currently under construction by companies such as Areva Solar and BrightSource Energy are operational. However, the principal competition is not among CSP technologies but that created by improvements in efficiencies and reduced costs of photovoltaic technology (PV), which for some experts might even bring about the end of CSP, a topic that is not in the scope of this poster presentation



Left: Compact Linear Fresnel Reflector (CLFR) developed by Ausra now Areva Solar, photo 2009, courtesy of Ausra. Right: An aerial view of the first unit (120 MW) out of three (392 MW), of the BrightSource Energy Solar Electric Generating System, under construction at Ivanpah California, photo 2011, courtesy of BrightSource Energy.

CONCLUSIONS

At present, the most established type of CSP plants in operation, under construction, and planned, is trough. Since early 2000, startup and corporation have been intensifying investments on Linear Fresnel and Towers. This is another reason to recall once again the Italian history on CSP with flat or almost flat reflectors.