Soltigua's parabolic trough PTM 24.

Soltigua's FTM Fresnel collector.

Parabolic or Fresnel?

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Two different linear concentrating technologies are offered to generate solar thermal energy for industrial process heat, solar cooling and polygeneration applications. But which is the best one? Based on the experience of Soltigua, the Italian provider of both award winning parabolic troughs and Fresnel collectors, this article provides a structured comparison of the two technologies across the different aspects of solar applications up to 250°C.

Technology presentation

Created by Sicilian inventor Archimedes of Siracusa in 200 BC, the parabolic trough technology uses the geometric principle for which the reflection of a stream of parallel rays is concentrated in the focus of a parabola. By means of tracking the sun, parabolic troughs obtain the effect of ensuring that the solar direct radiation hits the parabolic mirrors as a stream of parallel rays, which are then reflected in the geometric focus where the receiver tube is placed.

The actual efficiency of a parabolic trough depends on its optical and thermal efficiency.

The optical efficiency is the efficiency without any thermal loss, i.e. the theoretical efficiency of the trough which heats a fluid at a temperature almost identical to the ambient temperature. The optical efficiency is

influenced by several factors, such as:

- Geometrical accuracy.
- Reflectivity of the mirrors.
- Transparency of the glass case of the receiver tube.
- Absorbivity of the receiver tube.

The thermal efficiency measures the thermal losses due to the temperature difference between the heated fluid and the ambient. These thermal losses may be due to irradiation and to convectivity and they are influenced by:

- the area of the emitting surfaces.
- the emissivity of the receiver tube.
- the insulating properties of the fluid between the receiver tube and its glass case.

The concentrating factor of a parabolic collector is defined as the ratio between the areas of its collecting and its emitting surfaces. A higher concentration factor contributes towards a higher thermal efficiency.

First explored by Italian researcher Giovanni Francia in the 1970s, the Fresnel collector technology develops the parabolic trough concept by substituting the parabola with many different smaller reflecting surfaces, located in a lane below the fixed receiver tube. They rotate each around its own axis and are called primary mirrors.

Since the receiver is fixed and the mirrors rotate, their relative positions change during the day and some light aberration appears, so that not all sunrays can be focused in a single focal point.

For this reason, Fresnel collectors need to use a secondary mirror, to reflect back into the receiver tube those sunrays (in average about 50%) which have not hit the tube after the reflection of the primary mirrors. The use of the secondary mirror reduces the optical efficiency of the Fresnel collector, because of the reflectivity of the secondary mirror.

Fresnel receiver tube is normally placed further away from the mirrors than in a parabolic collector, so the primary mirrors are just slightly bent, almost flat, permitting easier manufacturability.

Technology comparison

While comparing the two technologies, several aspects need to be taken into account.

An adequate analysis needs to consider the properties of each technology at the level of the collector, of the solar field, of its integration with an industrial process and – last but not least – of the cost-benefit tradeoffs.

Collector properties

While presenting the two technologies, we have already highlighted that the parabolic trough has a higher optical efficiency due to the effect of the double reflection for Fresnel.

Also, since the focus of the parabola is closer than the receiver tube of Fresnel, the trough has lower optical end losses[1].

On the other side, it is easier to reach a higher concentrating factor for the Fresnel collector, since it needs just elevating the receiver tube higher than the plane of the mirrors, without implying any large structure to be rotated and kept precisely together.

In order to visualize the effects described above, Figure 3 plots the efficiency curves of PTM and FTM. Both curves have been going through extensive field testing and validation[2].

Beside efficiency, structural properties of collectors are important. In particular, weight distribution and wind resistance must be taken into account while considering rooftop applications.

Based on Soltigua's experience, the weight of Fresnel can be easily distributed across a larger number of supports and linked to an existing underneath support structure.

Wind resistance is also higher for Fresnel, because – due to the smaller size of its mirrors – it does not risk the "sail effect" that can affect a trough. The smaller mirrors reduce the strain not only on the collector, but also on its supporting structure.

The structural properties of Fresnel make it easier to install it on rooftops.

TABLE 1		PTM	FTM
Reference conditions		Toutlet = 180°C Tinlet = 165°C DNI = 900 W/sqm Tambient = 30°C	
Efficiency		60%	52%
Specific output	**(W/sqmsolar)**	540	468
Real Ground cover ratio*		0.42	0.55
Specific output per ground	**(W/sqmground)**	227	257
Solar field surface	**(sqm)**	1'850	2'150
Required ground surface	**(sqm)**	4'400	3'900

*= takes into account also the space occupied by the supporting structures, the space required around the collectors for maintenance tasks.

Solar field properties

One important feature of solar concentrating technologies is their capability to make a satisfying use of the space available for the solar field.

This requires both a good ground coverage in general terms and also the capability of mapping the available space for a specific installation.

When locating a solar field, parabolic troughs require to leave a certain empty space between one collector and the next one in order to avoid mutual shading when the position of the sun is inclined by a certain angle. In order to address this issue, one practical approach is to leave an empty space large from one to one and a half times the trough's aperture. For installations closer to the Equator, where the latitude angle decreases, smaller distances can be considered.

In Fresnel, the high distance of the receiver tube combined with its fixed position relative to the mirror plane permits to reduce the gap between adjacent rows, which are normally mirrors within the same collector. It is therefore possible to install Fresnel collectors one beside the other, with almost no interruption but the required space for maintenance.

The table 1 shows the ground coverage calculation for a solar field in South of Europe, for a nominal capacity of 1 MWth in reference conditions

For each specific installation, the ground coverage considerations above need to be completed by taking into account the actual shape of the surface available for the solar field.

In particular, Fresnel collectors are optimized when they can be installed in long rows of several collectors, in order to reach adequate lengths to minimize their end losses. In the case of Soltigua's FTM, which has been optimized for rooftop installations, the minimum required length is around 27 mt. The PTM collector has a minimum required length of about 20 mt.

As a rule of thumb, where space availability is an issue, Fresnel can make better use of long, narrow spaces. The trough is better suited for places with no space constraints, i.e. on grounds in open environments.

As far as installation and operations are concerned, no significant difference has emerged between the two technologies in Soltigua's experience. In particular, mirror cleaning is easy and straightforward in both technologies.

Integration with industrial systems

As anticipated in the introduction, this article focuses on comparing the Fresnel and parabolic technologies in industrial systems. Table 2 provides an overview of the applications which can be addressed by the two technologies. In these applications different heat transfer fluids can be used, such as steam, thermal oil, pressurized water.

The solar field circuit and the industrial process circuit can be linked through a heat exchanger or directly integrated. In the second case, the link is simpler but the two circuits must use the same fluid and, if the industrial circuit uses steam, the solar field

1 Assuming same length of collectors
2 The process has been completed for PTM and is being completed for FTM

Industry	Process	Temperature (°C)
Food and beverages	cleaning pasteurisation sterilisation drying cooking	80-150 80-110 130-150 130-240 80-100
Plastic	extrusion and drying	150-180
Chemical	heat treatments boiling distillation drying	150-180 95-110 110-300 150-180
Paper	bleaching and drying	130-180
Textile	washing heat treatment bleaching dyeing	80-100 80-130 60-100 100-160
Industrial cleaning	steam washing	150

TABLE 2. Examples of possible industrial applications for solar process heat.

TABLE 3	Parabolic trough	Linear Fresnel
Integration		Can be integrated easier into industrial processes with Direct Steam Generation
Installation	Can be installed in spaces with very limited maximum length (20 metres)	Easier installation on roofs because of more distributed weight and less wind load transmitted to foundations It requires less ground per peak thermal output installed
Performance	Higher optical efficiency Reaches higher annual yields per unit of mirror	
Cost	No clear winner	

must do Direct Steam Generation (DSG). This may have practical challenges in Europe where the risk of freezing during winter and spring nights must be taken into consideration when designing a solar system that must work in open environments.

DSG is a new concept for industrial applications up to 250°C. In doing DSG, Fresnel has the advantage of the fixed receiver which can generally bear higher pressures than the one of parabolic troughs because of the lack of movable joints. At a research level, DSG has also been done with parabolic troughs.

As of today, it is not clear yet by when the advantages of the circuit simplification will be supported by a full blown test of DSG at these temperatures.

Cost/performance tradeoffs

The comparison developed so far has shown that there is no clear set of advantages in favour of one of the two technologies.

Within our experience, cost considerations further reinforce the point, because the cost of the two technologies is quite similar.

According to some analysts, Fresnel costs are expected to decrease sharply because of the apparently greater simplicity of the specific components. We think this may happen, but it is definitely too soon to make a final judgment on that.

Our experience shows that the cost/benefit tradeoffs are highly dependent on the features of a specific installation and we believe it will continue to be so in the future.

Conclusion

Table 3 summarises the result of the comparison presented in this article.

In general terms, we may say that Fresnel technology has more potential for rooftop applications, while parabolic troughs can have a higher potential when mounted on ground.

This cannot be taken as a general rule. The only golden rule of solar systems for industry is that there is no golden rule to be followed, because the relative weight of the different requirements and constraints can vary greatly from case to case. This is why Soltigua performs an adequate analysis of each specific case before giving clients a final suggestion on which of the two technologies should be preferred.

For this reason we think that the answer to the question: "Parabolic or Fresnel ?"is and will continue to be: "Parabolic and Fresnel!".