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A next-generation parabolic trough collector for low-cost, dispatchable, high-temperature solar thermal power

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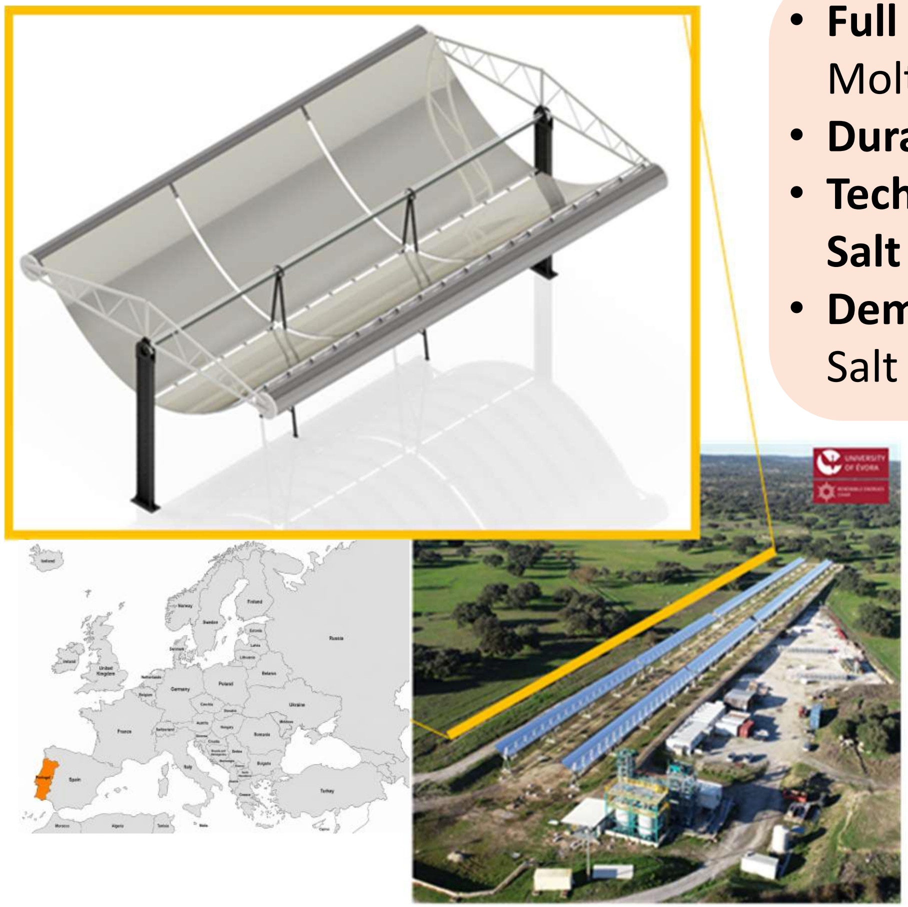
Project description

MSA-Trough collector



- **Full title**: Development of a parabolic Trough concentrator system for Molten Salt Application
- **Duration**: 01.10.2023 – 31.03.2027
- **Technological development:** scale-up from DLR national project **“Molten Salt Trough - Development of a Parabolic Trough Collector**” (Spain)
- **Demonstration:** a 350m-long prototype will be tested at the Évora Molten Salt Platform (Portugal)

MS-Trough collector

Technical challenges of state-of-the-art PTCs with molten salts

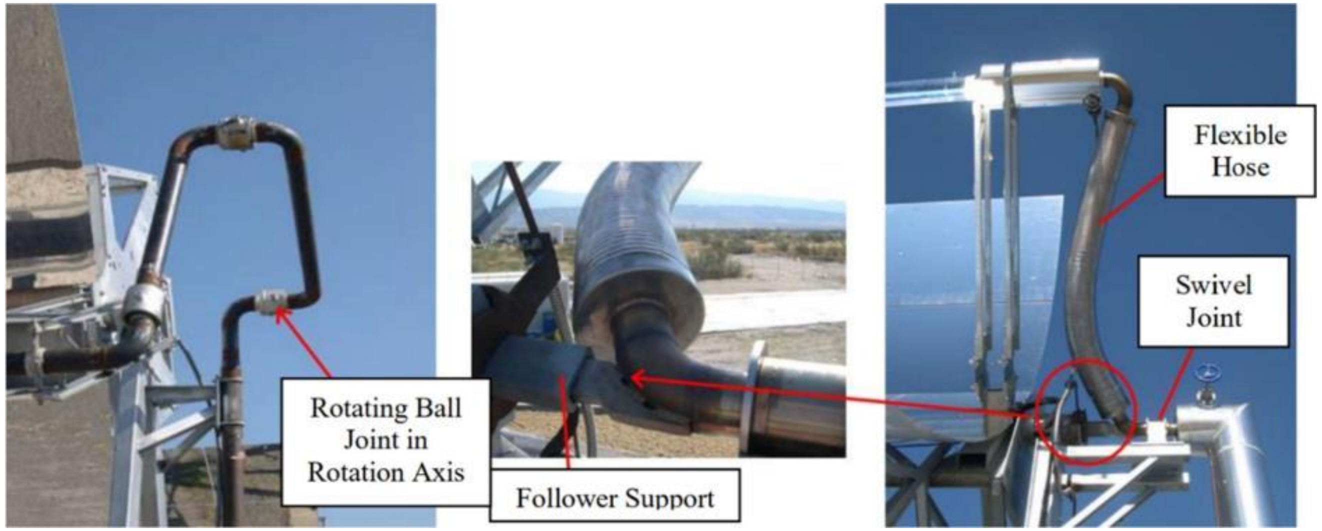
Parabolic troughs are the most established CSP technology, yet almost all commercial plants operate with thermal oil, which caps the achievable operating temperature

Molten salts allow operation at higher temperatures and facilitate thermal storage integration, but introduce significant design and operational constraints

1. Higher operating temperatures increase receiver thermal losses, progressively penalizing solar-field efficiency
2. Direct molten-salt use introduces operational constraints related to freeze protection, start-up, drainage and off-sun operation
3. Conventional collector layouts impose optical, structural and hydraulic constraints, increasing system complexity, material and cost

Motivation

Why moving receivers limit molten-salt PTCs



Moving receivers require moving fluid connections.

At molten-salt temperatures, moving connections require heat tracing and careful freeze protection, with direct implications for system reliability.

550 °C

operating level of advanced molten-salt PTC

1. **Rotating interfaces**
   Flexible hoses and swivel joints must survive thermal cycling.
2. **Fragmented piping**
   Inter-collector connections add pressure drop, losses and maintenance.
3. **Freezing risk**
   Night circulation or drainage and reliable start-up are unavoidable.

MSA-Trough concept

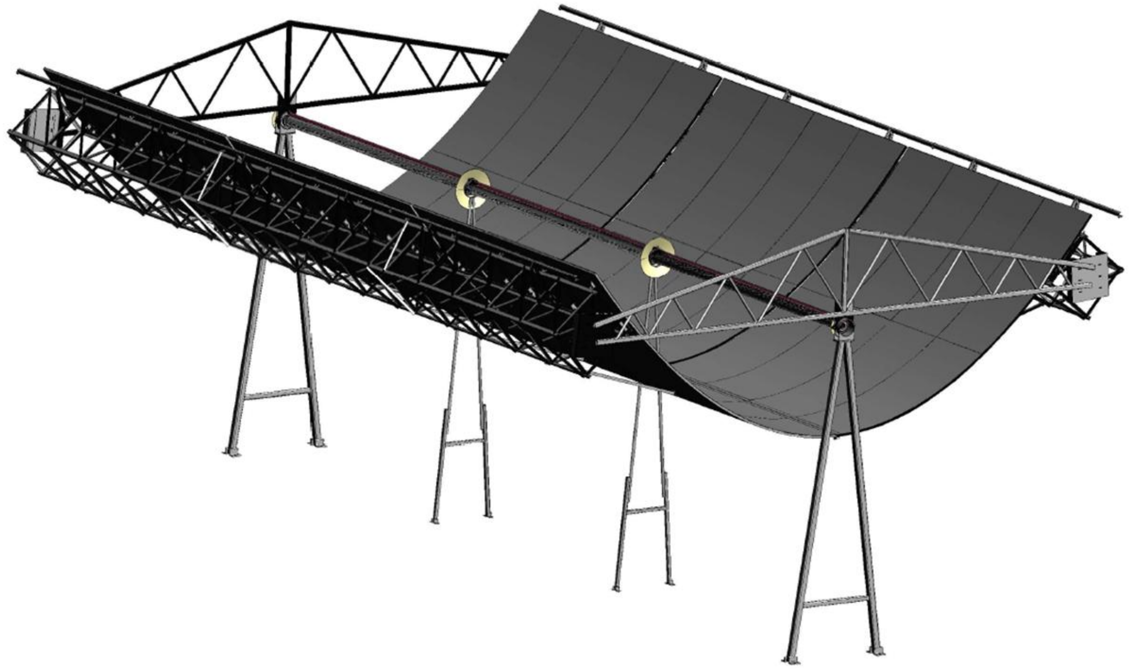
Mechanical decoupling of concentrator and absorber

1. **Stationary absorber tube**
   The mirror modules track the sun while the receiver remains fixed.

2. **Continuous receiver line**
   inter-collector piping and rotating joints are eliminated, simplifying the hydraulic layout.

3. **Fixed-focus, torque-frame architecture**
   with reduced structural mass and lighter pylons and foundations.

Direct molten-salt operation up to 555 °C



MSA-TROUGH PROTOTYPE

The same molten salt can be used as both HTF and thermal-storage medium

Sliding rails and cavity bearing heads

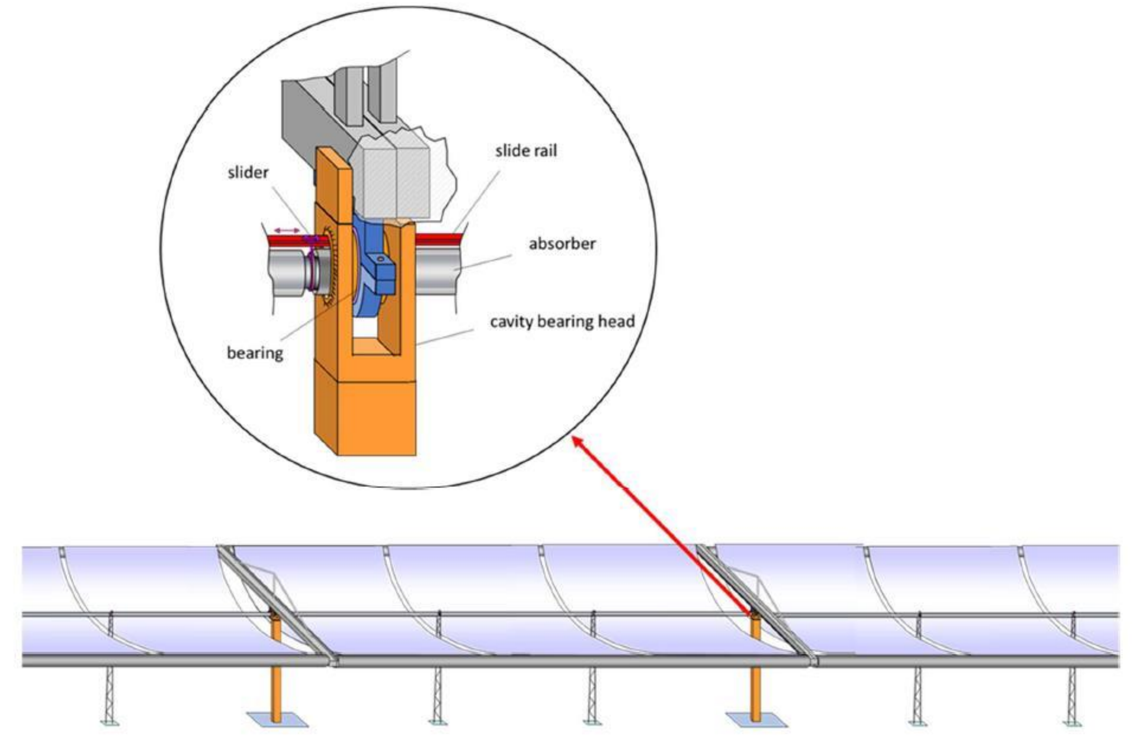
≈ 800 m

maximum continuous absorber line enabled by the decoupling

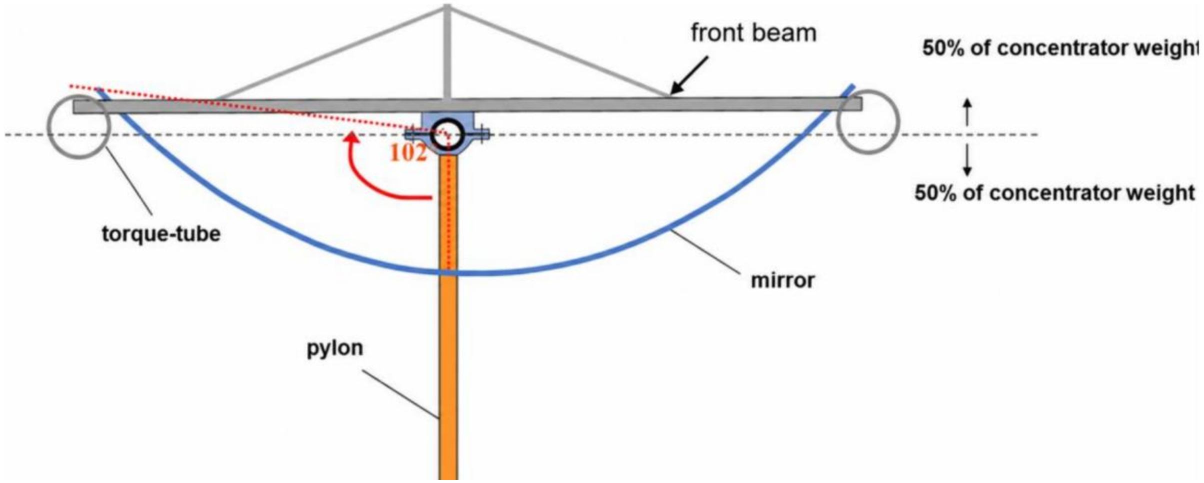
1. **Sliding rail**
   The absorber assembly moves axially on sliders through the bearing openings, taking up thermal expansion.

2. **Cavity bearing head**
   Bearing heads integrated into the pylons support the concentrator modules directly from the ground.

3. **No rotating joints**
   The receiver stays straight and stationary while the mirrors track, so ball joints and flexible hoses are no longer required.



Centre of gravity aligned with the rotation axis



Two lateral torsion tubes and two upper front beams counterbalance the weight of the mirror assembly

The concentrator centre of gravity is aligned with the rotation axis, which coincides with the absorber tube axis, minimising imbalance and permanent torsional deformation.

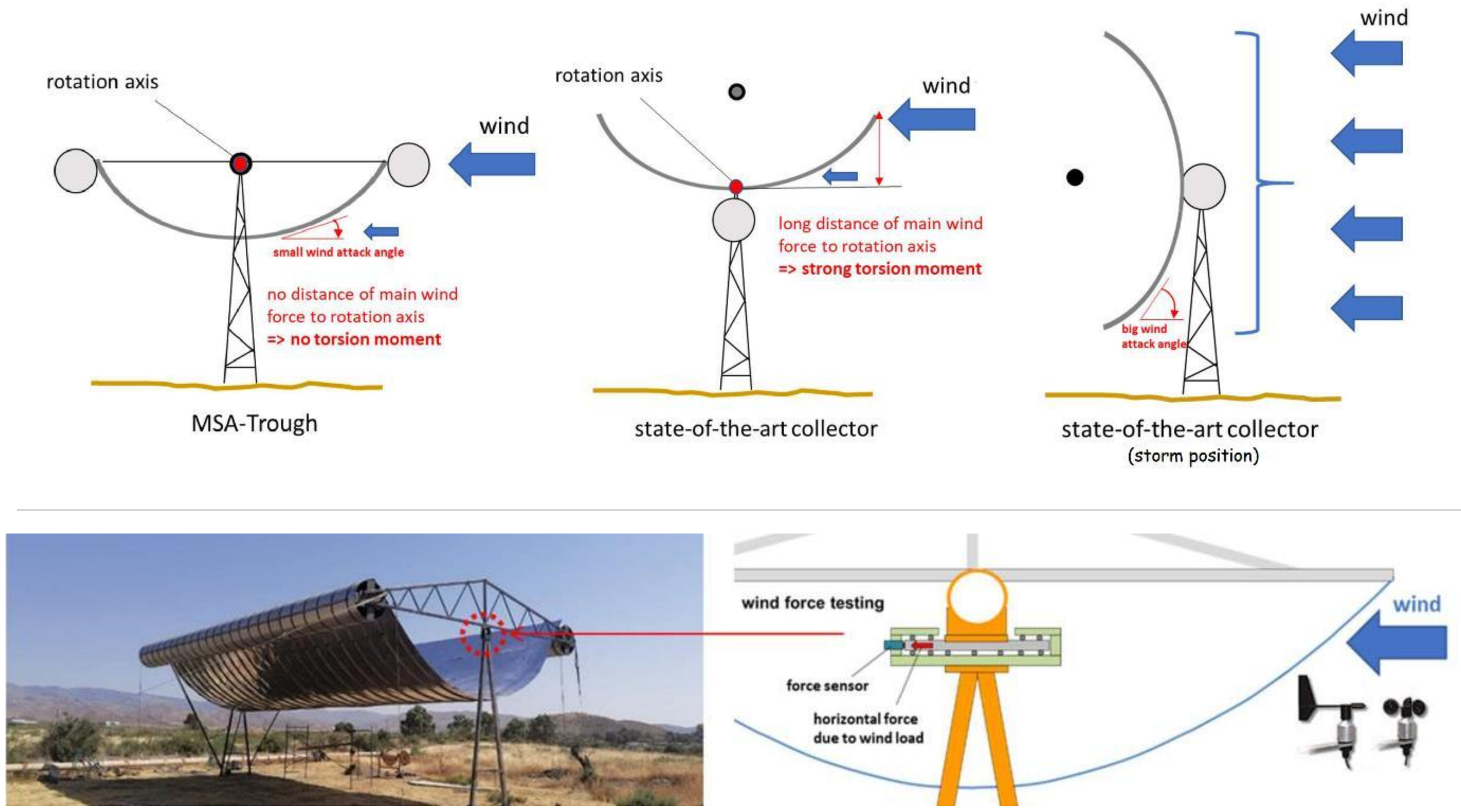
1.36 m

Mean focal length, against ≈1.71 m for representative state-of-the-art PTC

1. **Continuous torque tubes**
   Not interrupted at the pylons, so no local loss of torsional stiffness along the row.
2. **Self-supporting mirrors**
   Outer mirror edges are supported: no free ends, lower bending-induced optical error.
3. **Thinner spiral tubes**
   1 mm wall instead of ≈6 mm; ≈50% less torque-tube material, produced on site in ≈5 min per 12 m.

Collector design

Storm position and drilled foundations



1. **Enabled by the wind-load reduction**
   The lower wind load allows compact drilled elements instead of large concrete blocks.

2. **Fast installation**
   Boreholes are produced with mobile drilling equipment; the limited excavated soil is redistributed locally instead of being disposed of off site.

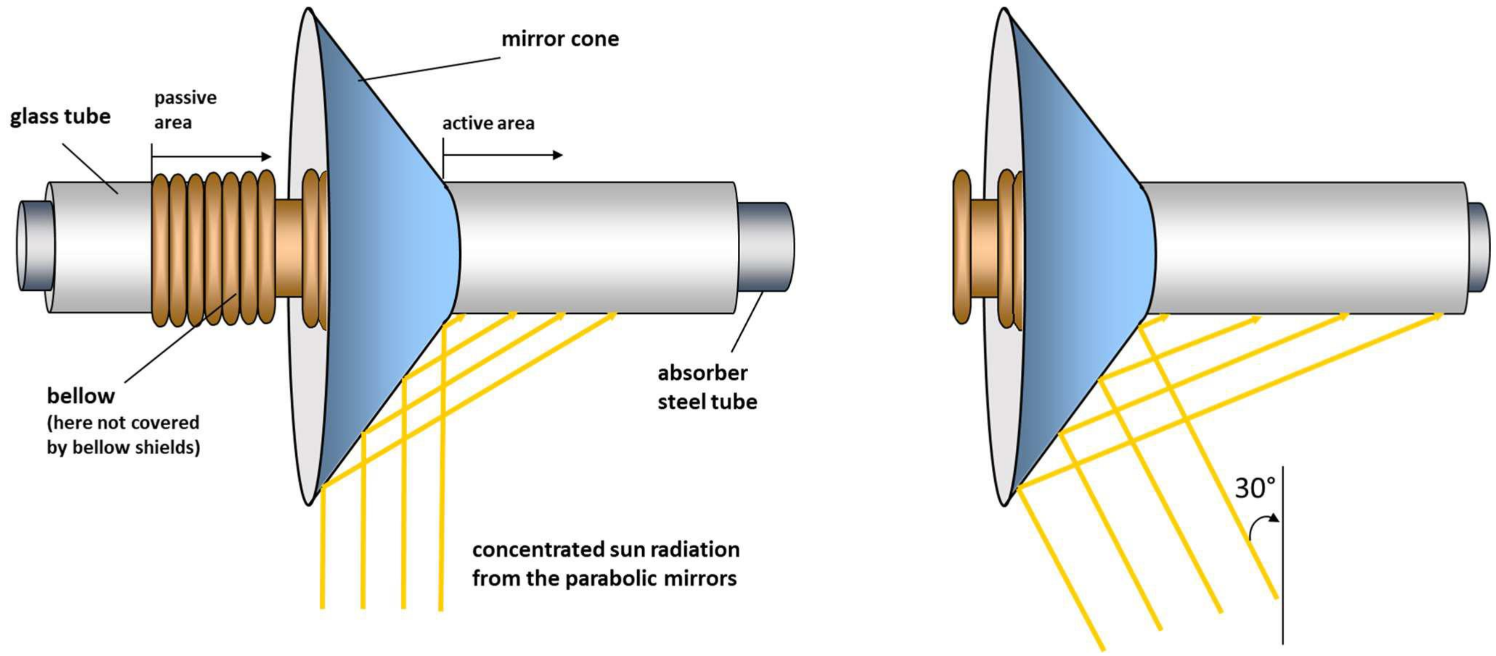
3. **End-of-life removal**
   Elements can be extracted vertically and sent to concrete recycling.

≈75 %
Lower overall wind load in the horizontal storm position

−40 % · −80 %
structural steel · foundation concrete

Collector design

Mirror cones reduce receiver-end optical losses



≈ 5%

of concentrated radiation intercepted by the bellow shields in a 4 m receiver

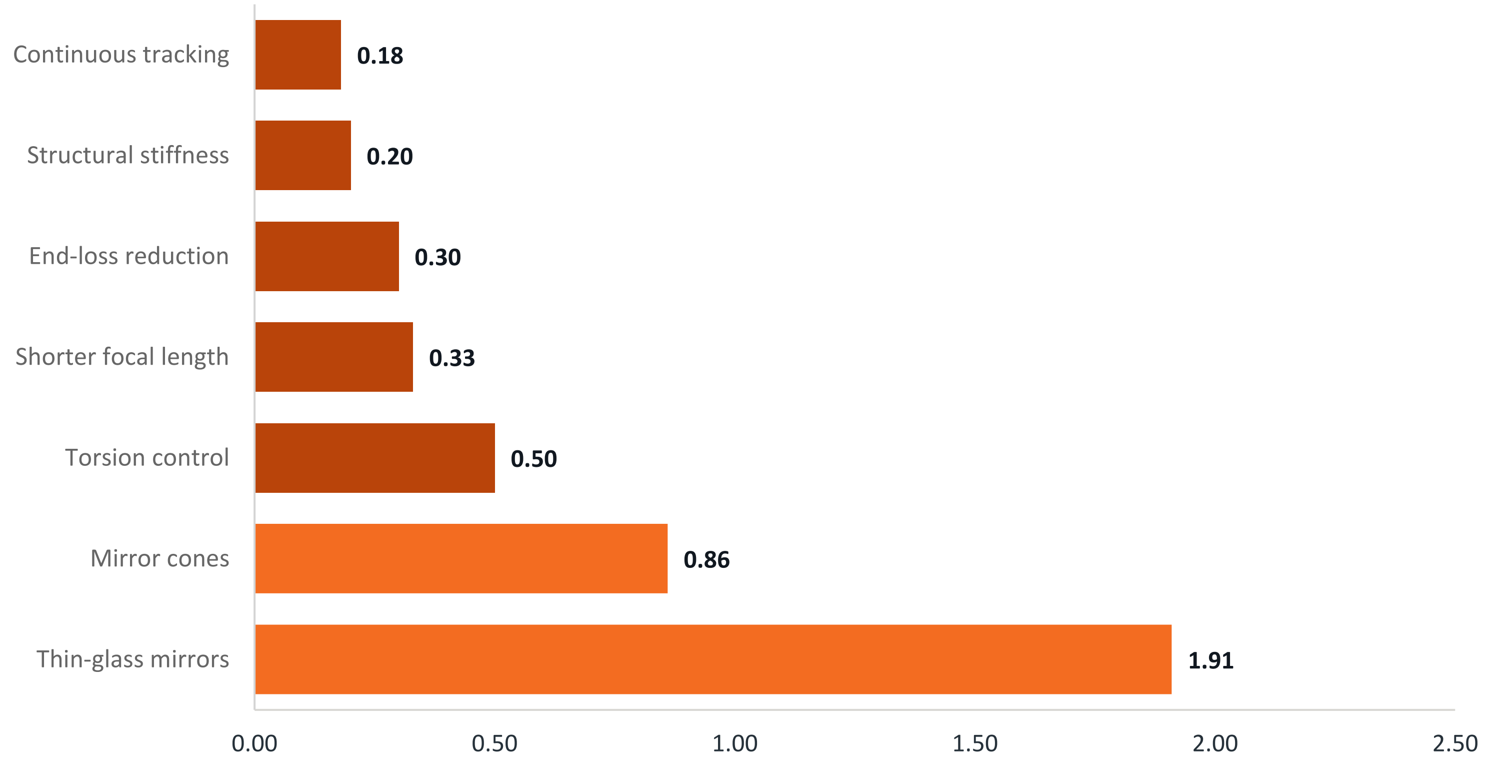
1. **Conical mirror reflectors**
   Mounted on the bellow regions, they redirect the concentrated radiation onto the active absorber surface.

2. **Effective up to 30°**
   The redirection works from normal incidence up to about 30° of incidence angle.

3. **Plane mirrors at the bearings**
   Where cones cannot fit, plane reflectors on the bearing housing recover part of the inclined radiation.

Collector design

Optical efficiency improvement



82%

Nominal optical efficiency for MSA-Trough

vs 78%

Advanced molten-salt baseline

+4.28 points estimated
+4.0 points adopted

Two night-operation strategies under assessment

REFERENCE MODEL

Overnight drainage

Pro

Removes freeze exposure from the receiver field

Cons

Requires repeatable drainage, solar preheat and refill

ALTERNATIVE

Insulating cover

ENEA — WP leader

Pro

Reduces heat loss during night-time circulation

Cons

Adds moving hardware

Method and main assumptions

01

Tool

Greenius

Hourly annual simulation of solar field, storage and power block.

02

Site

Guadix (Spain)

Measured DNI dataset, 2,111 kWh m^{-2} per year.

03

Financing

25 years

30% equity, 70% loan at 5.64% annual interest.

04

Power generation

100 MW_{el}

Heat generation

7.5 MW_{th}

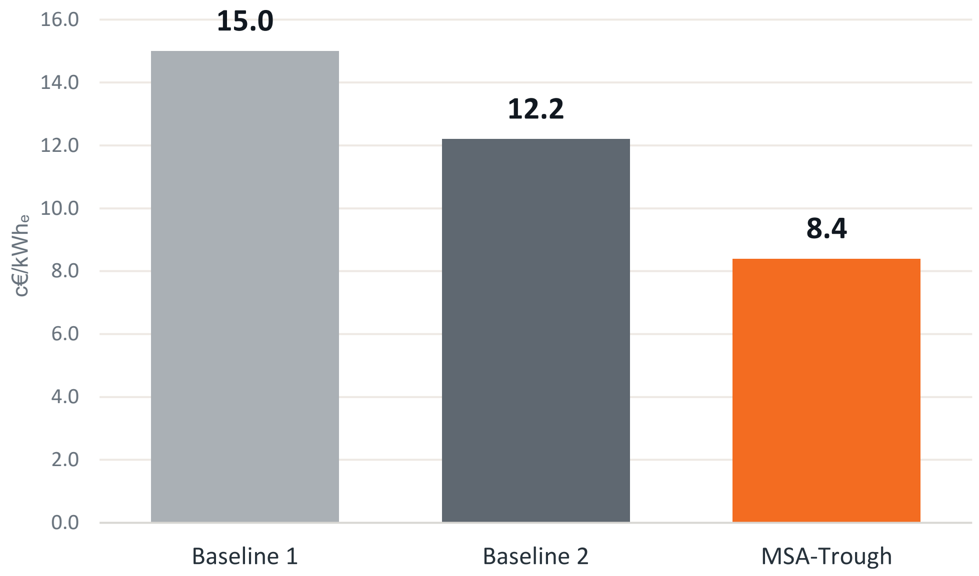
Comparison with state-of-the-art PTC plants

	BASELINE 1	BASELINE 2	PRESENT WORK
	EuroTrough	**HelioTrough**	**MSA-Trough**
HTF	**Therminol VP-1**	**Solar Salt**	**Solar Salt**
Max. HTF temperature	**393 °C**	**550 °C**	**555 °C**
Optical efficiency	**77%**	**78%**	**82%**
Thermal energy storage	**7 h**	**11 h**	**11 h**
PB efficiency	**39%**	**43%**	**43%**
Solar-field cost	**198 €/m²**	**205.92 €/m²**	**139.90 €/m²**

Results

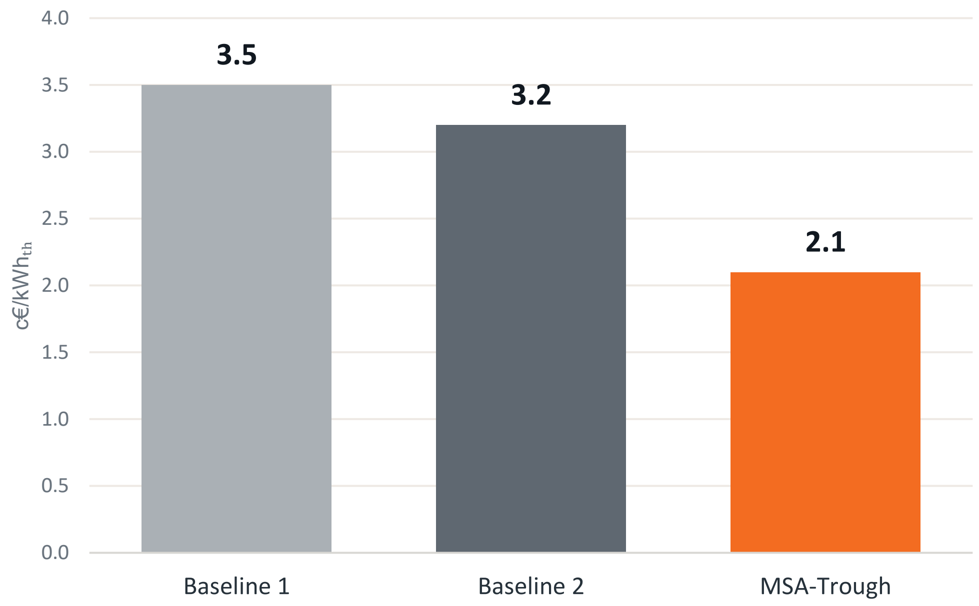
Electricity · LCOE

−31% vs Baseline 2



Process heat · LCOH

−34% vs Baseline 2



Conclusions and next steps

1. The stationary, continuous receiver makes direct molten-salt operation possible without rotating joints or inter-collector piping
2. The new collector design reduces foundation and structural steel requirements, as well wind loads, while improving optical performance and lowering solar-field cost
3. At commercial scale, the projections indicate an LCOE of 8.4 c€/kWh$_{el}$ and an LCOH of 2.1 c€/kWh$_{th}$, 31% and 34% lower than the advanced molten-salt baseline
4. The 350 m demonstrator in Évora will be used to validate the concept under real operating conditions

Thank you for your attention

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