MOSAIC
MODULAR HIGH CONCENTRATION

MOSAIC: CSP plant concept for the highest concentration ratios at the lowest cost

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MOTIVATION

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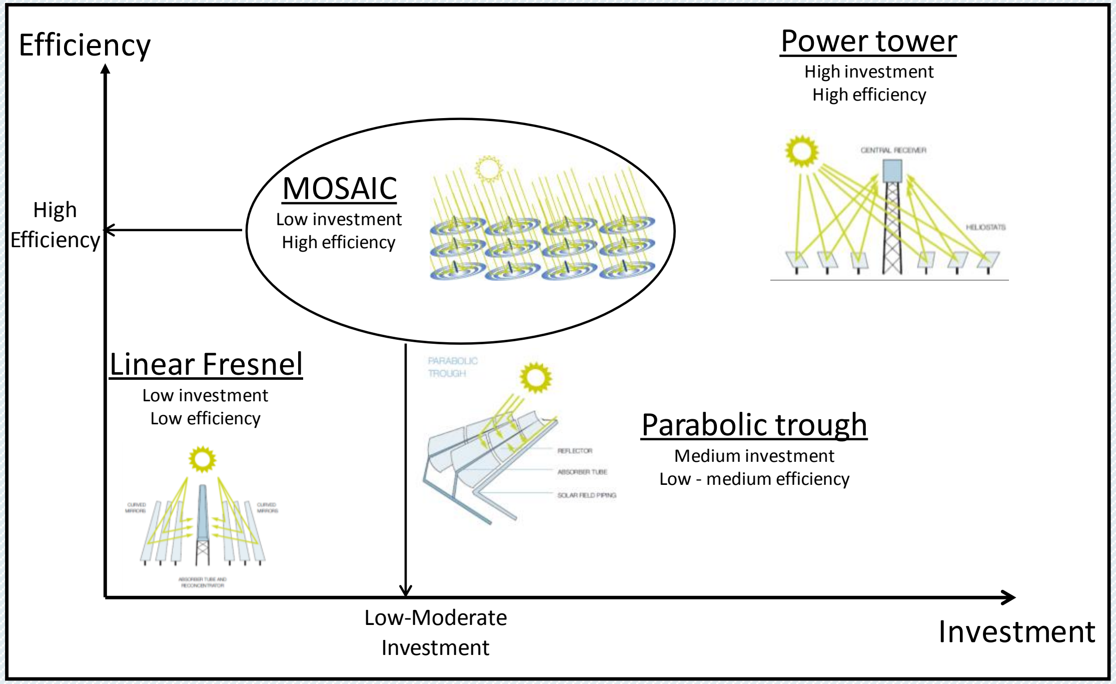
GOAL

Achieve high concentration ratios at lower cost to reduce LCOE

- **Main costs in CSP are due to the solar field** (mainly tracking)
- **3D concentration is required to achieve:**
  - High concentration ratios
  - High temperatures and efficiencies
- **Modular systems can achieve high efficiencies at lower cost**
- **Fixed solar fields have great potential for cost reduction**
  - Spherical concentrators have been seldom studied



Certain challenges need to be overcome but it is worth exploring new ways to implement the concept of spherical concentrators

APPROACH:
FIXED SOLAR FIELD WITH FRESNEL HEMISPHERICAL CONCENTRATION

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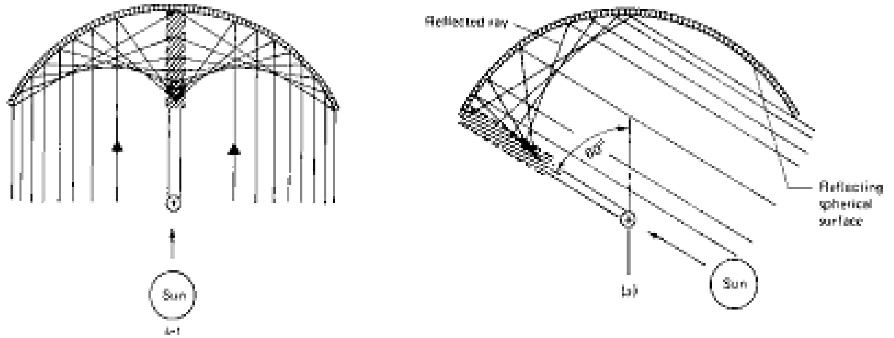
Characteristics of hemispherical concentrators:

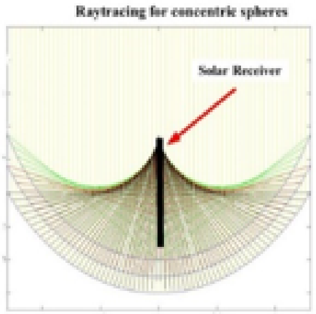
- Spherical reflector
- Fixed mirror concept
- Linear receiver
- 3D concentration.

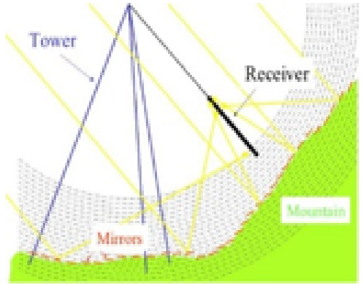
→ Single tracking system
But huge civil works

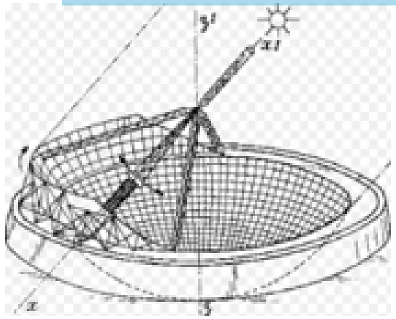
Fresnel approach can be applied:

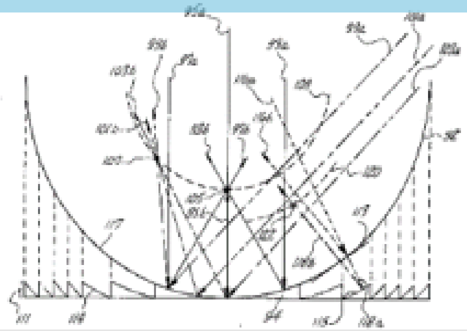
- A series of concentric spheres concentrates in a single line
- Easily adapted to any terrain shape

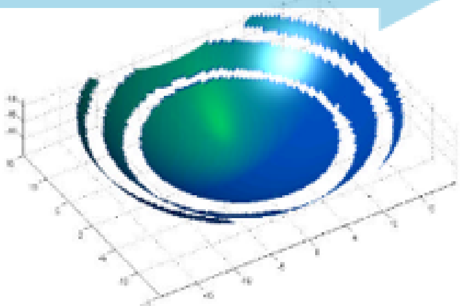


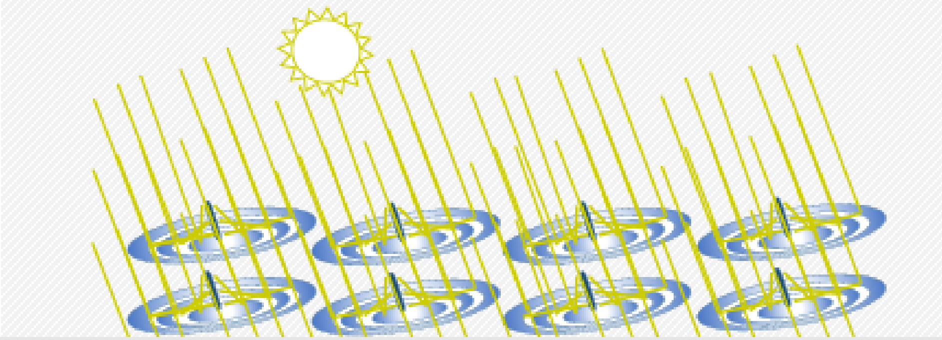












APPROACH: HEMISPHERICAL REFLECTOR PLANTS

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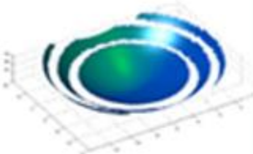
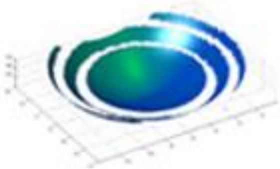
Previous experiences for the implementation of hemispherical concentrators

	Non-EU projects				EU Projects			
	Experience 1	Experience 2	Experience 3	Experience 4	Experience 5	Experience 6	Experience 7	Experience 8
Description	Hemispherical reflector plant	Hemispherical reflector plant	Hemispherical reflector plant	Hemispherical reflector plant	Hemispherical reflector plant	Hemispherical reflector power plant	Hemispherical Fresnel reflector	Semi-Fresnel fixed reflector
Photograph								
Date	1970's	1970's	1990's	2000's	1980's	Late 1990's	Early 2000's	2004
Validation site	Crosbyton, TX, USA	Haifa, Israel	Auroville, India	Armenia	Marseilles, France Recife, Brazil	Republic of Crete	UK	No experimental validation
Size	19.7m diameter	10m diameter	15m diameter	Data not available	10m diameter	30m diameter 110kWt / 35kWe	Proof of concept	Theoretical design
HTF temp	Steam at 538 ºC	Data not available	Steam	Air at 850ºC	Data not available	Air at 850ºC	-	-
Status	Decommissioned	Decommissioned	Still in operation	Not completed	Decommissioned	Decommissioned	-	Positive techno-economic analysis

APPROACH: RELEVANT REFERENCES

The most relevant references for the project

	Solar Projects			
	Experience 3	Experience 6	Experience 7	Experience 8
Description	Hemispherical reflector plant	Hemispherical reflector power plant	Hemispherical Fresnel reflector	Semi-Fresnel fixed reflector
Photograph				
Date	1990's	Late 1990's	Early 2000's	2004
Validation site	Auroville, India	Republic of Crete	UK	No experimental validation
Size	15m diameter	30m diameter 110kWt / 35kWe	Proof of concept	Theoretical design
HTF temp	Steam	Air at 850ºC	-	-
Status	Still in operation	Decommissioned	-	Positive techno-economic analysis

...

Other possible inspirations	
A	B
Hemispherical radio-telescope	Hemispherical radio-telescope
	
Arecibo, Puerto Rico	Guizhou, China
305m diameter (5 arcsec accuracy)	500m diameter
N/A	N/A
Working	Open

RELEVANT REFERENCES & SELECTED APPROACH

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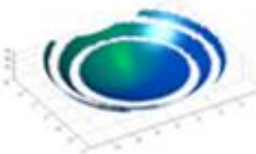
SELECTED APPROACH

Modular multi-bowl plant concept

Fixed hemispherical semi-Fresnel concentrators

Ad-hoc Tracking system

	Solar Projects				Other possible inspirations	
	Experience 3	Experience 6	Experience 7	Experience 8	A	B
Description	Hemispherical reflector plant	Hemispherical reflector power plant	Hemispherical Fresnel reflector	Semi-Fresnel fixed reflector	Hemispherical radio-telescope	Hemispherical radio-telescope
Photograph						
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Size	15m diameter	30m diameter 110kWt / 35kWe	Proof of concept	Theoretical design	305m diameter (5 arcsec accuracy)	500m diameter
HTF temp	Steam	Air at 850ºC	-	-	N/A	N/A
Status	Still in operation	Decommissioned	-	Positive techno-economic analysis	Working	Open

APPROACH
MOSAIC CONCEPT: INTENDED BENEFITS

Cost effective system:

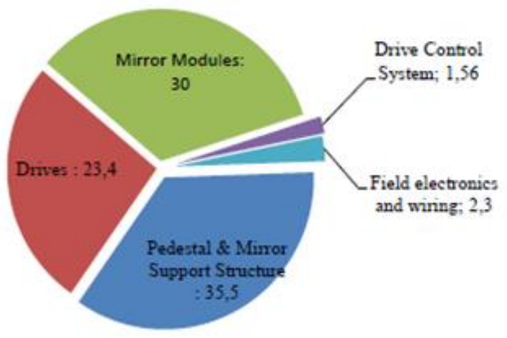
- Fixed mirror concentrators (unique vs hundreds of tracking systems)
- No need for wiring
- Cheaper and easier to install and repair structures/mirrors:
    - Fixed at ground level (low wind forces)

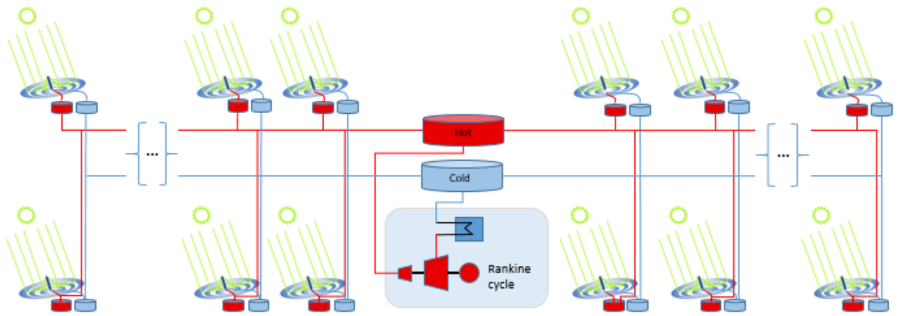
High and progressive flux :

- 3D concentration but a single linear focus → linear receivers
- Progressive concentration allows for optimum receiver design (minimum losses)
- High temperatures and efficiencies
- Lower costs for storage system

Modular approach:

- Affordable investment required to validate/optimize the concept
- Suitable for distributed applications as well as large plants
- Cost-effective power blocks





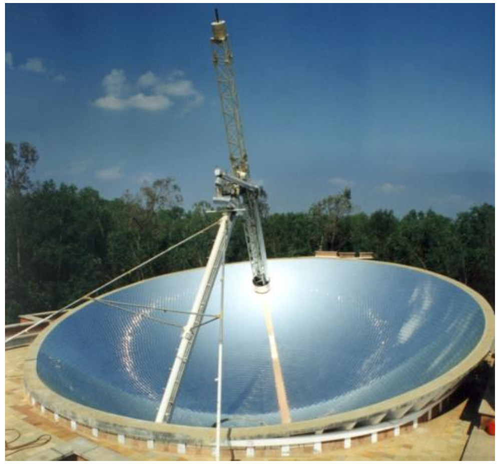
MOSAIC CONCEPT: KEY CHALLENGES

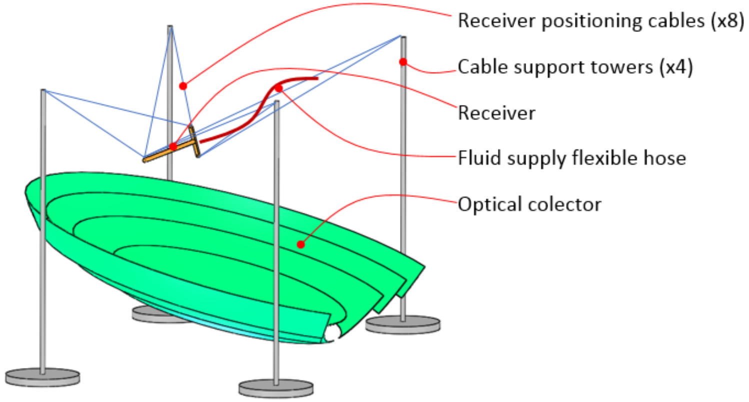
Tough flux conditions:

- High and very uneven fluxes
- Limited flux control

A single tracking system per module but much more complicated:

- Mobile receiver at high temperature and under high fluxes
- Long displacements
- Complex feeding and drainage





Development: TARGET LOCATIONS

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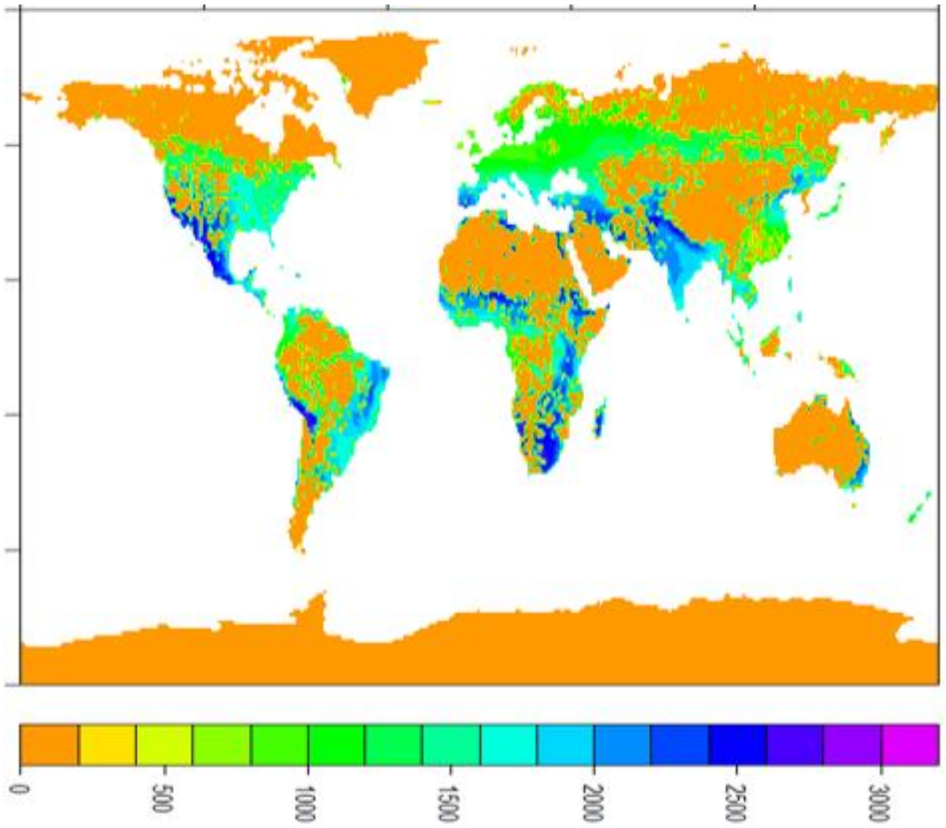
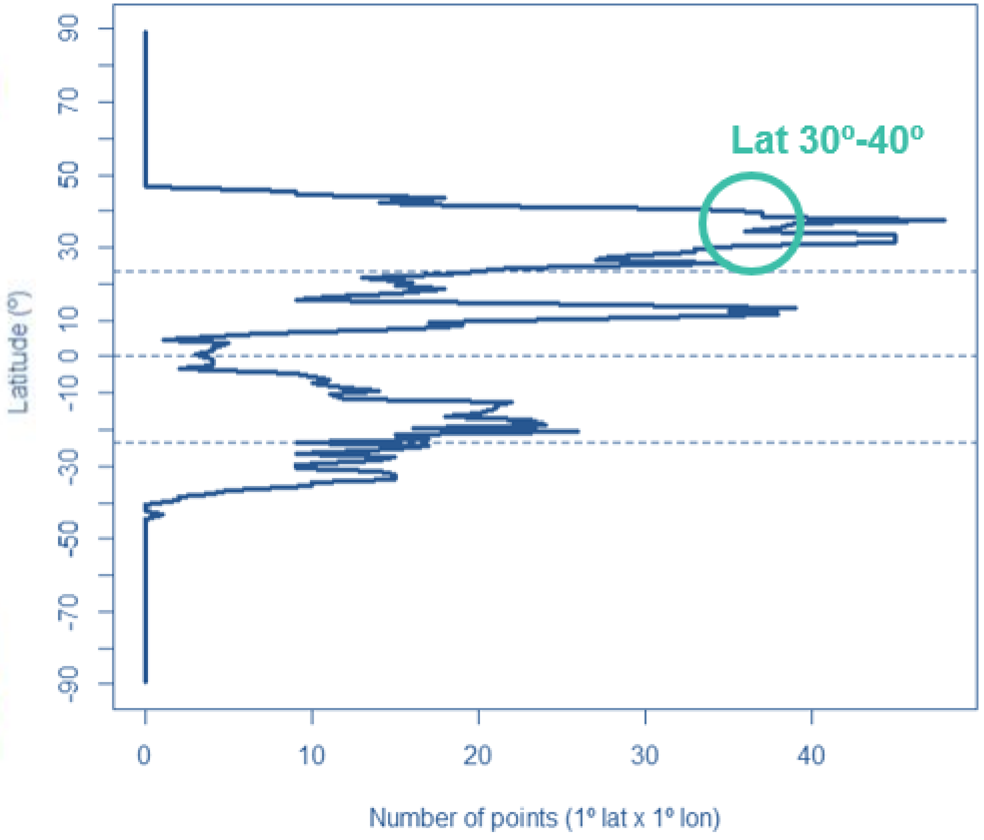
MOSAIC concept can and have to be adapted to location conditions (latitude, type of soil, etc.)
Most interesting locations have been identified

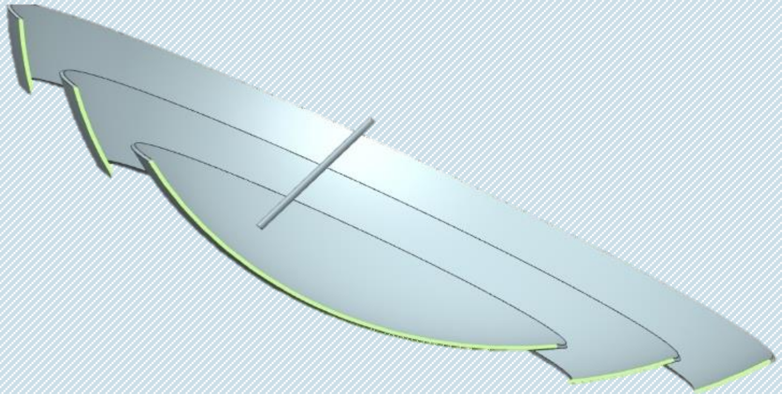
DNI (kWh/m^2 year) for populated areas

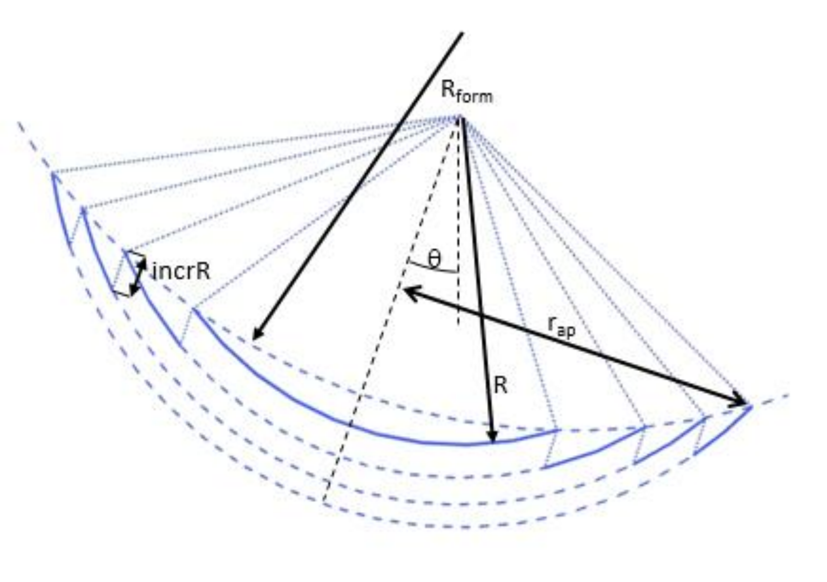




Populated areas with DNI above 2000 kWh/m^2·year

DEVELOPMENT: SEMI-FRESNEL CHARACTERISTICS and CONCENTRATOR GEOMETRY





Selected conditions:

- Latitude: 30.5° N
- DNI: 3348 kWh/m2 (Clear sky)

Optimization Variables:

- θ: Tilt angle
- r_{ap}: Aperture radius
- R: Form radius of the inner disk
- R_{form}: Global form radius
- incrR: Increment in radius

- Receiver length and radius
- Workspace (azimuth & elevation)
- …

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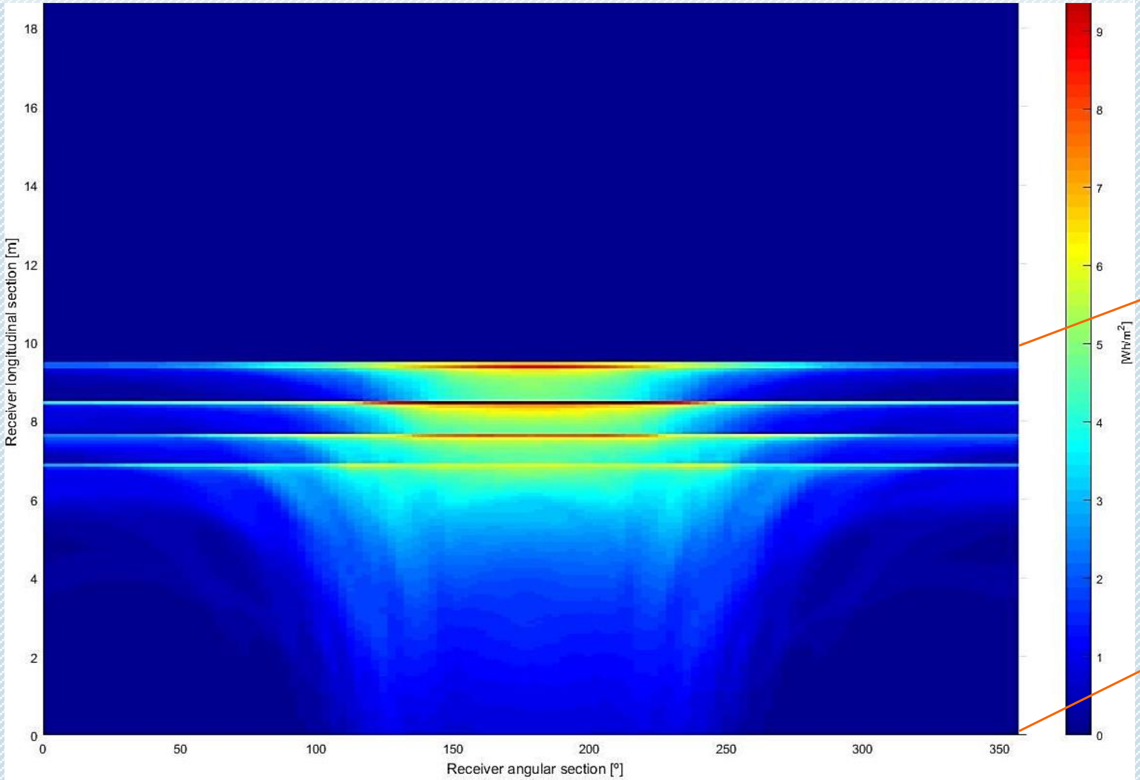
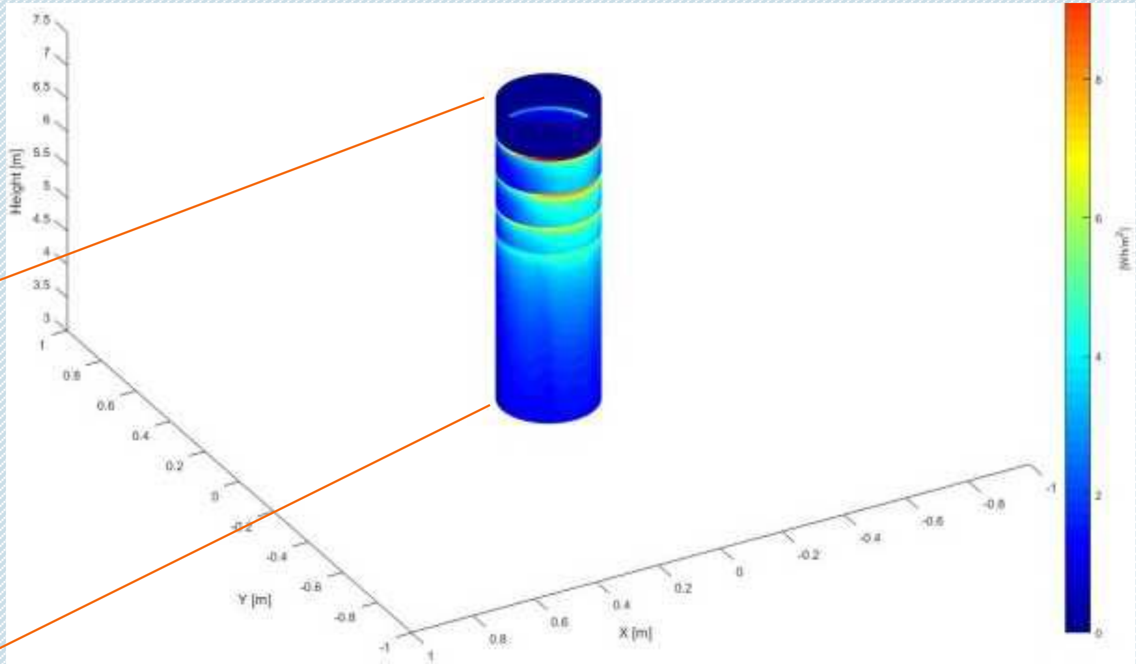
UNWRAPPED CYLINDER SURFACE

EXAMPLE

- R: 20m
- θ: 7.18°
- Receiver radius: 0.15m
- Central bowl + 3 rings





ACCUMULATED FLUX ALONG THE YEAR

DEVELOPMENT:
SEMIFRESNEL CHARACTERISTICS
RECEIVER LENGTH OPTIMIZATION

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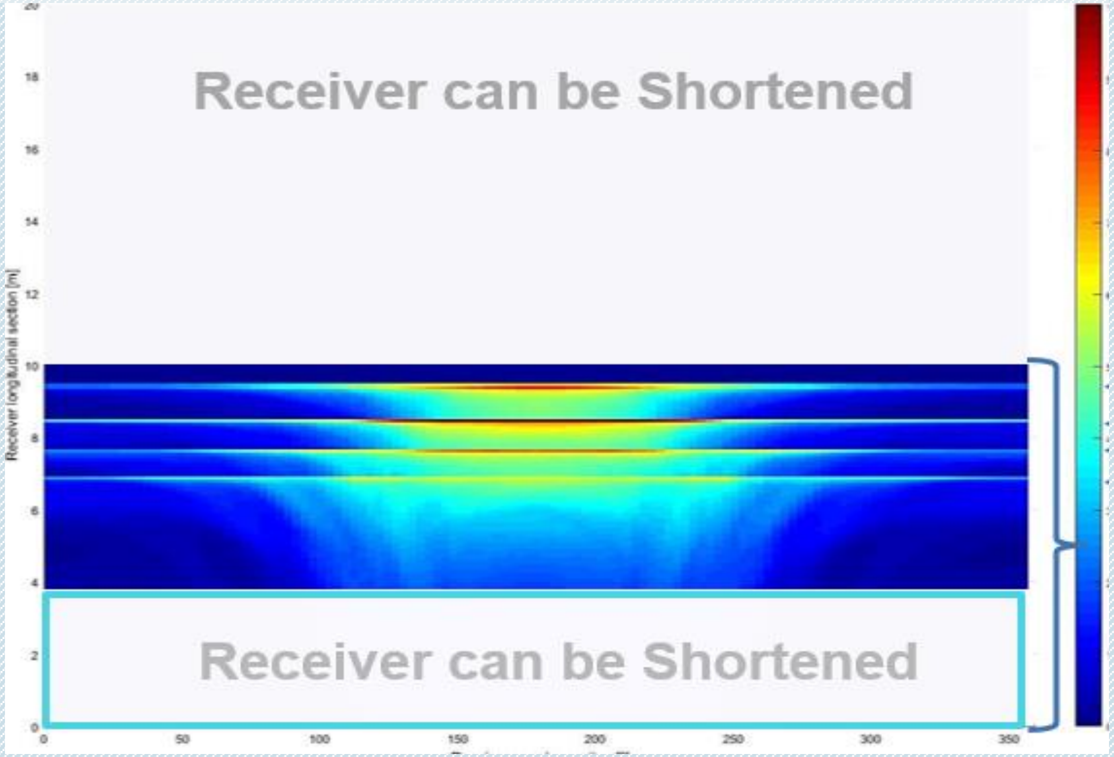
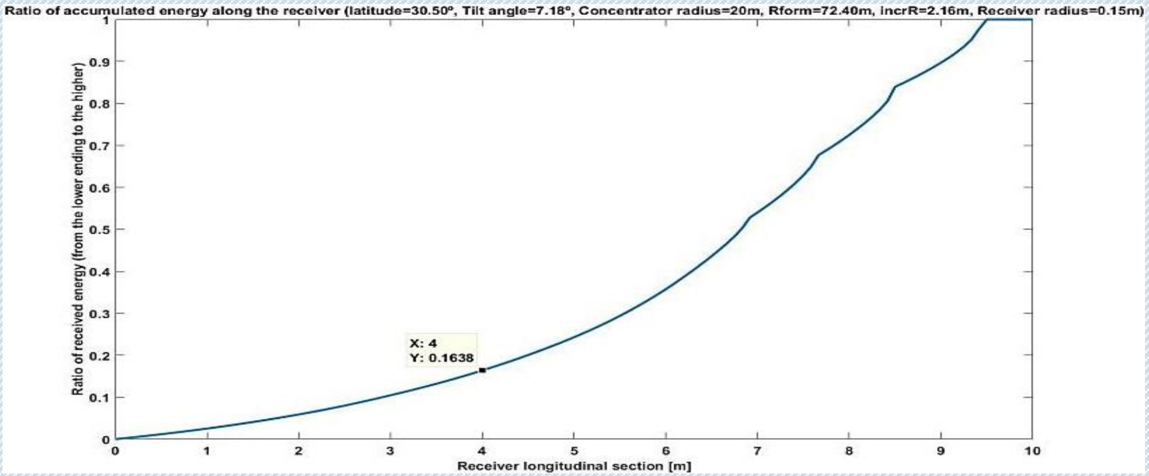
UNWRAPPED CYLINDER SURFACE



Main flux characteristics:

- Uneven flux
- Ring contributions
- Flux only from R/2 to mirrors
- Low flux on the lowest section



ACCUMULATED FLUX ALONG THE YEAR

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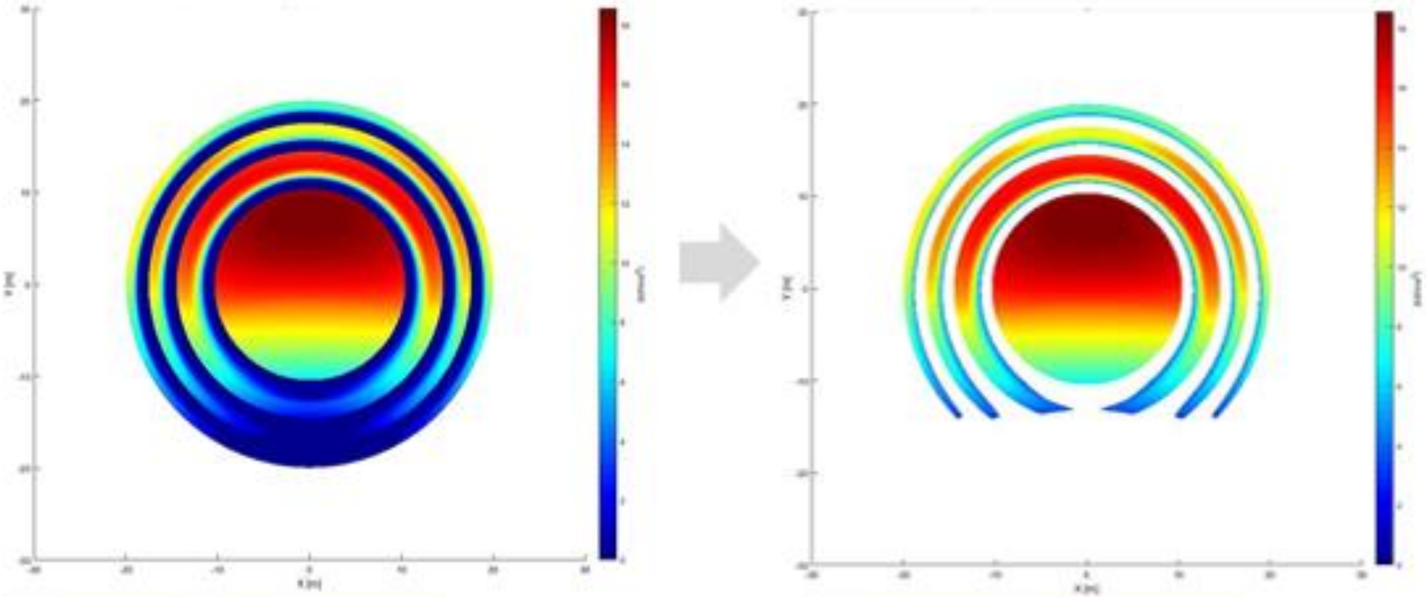
R= 20m   θ= 7.18°   rap= 20m   incrR= 2.16m

Flux contribution from each mirror (kWh/m²·year)



Energy: 1205 MWh
Mirror area: 1627 m²
Solar field cost: 240 k€

Energy: 1176 MWh
Mirror area: 1000 m²
Solar field cost: 148 k€

ENERGY
-3%

COST
-38%

COST PER kWh
-37%

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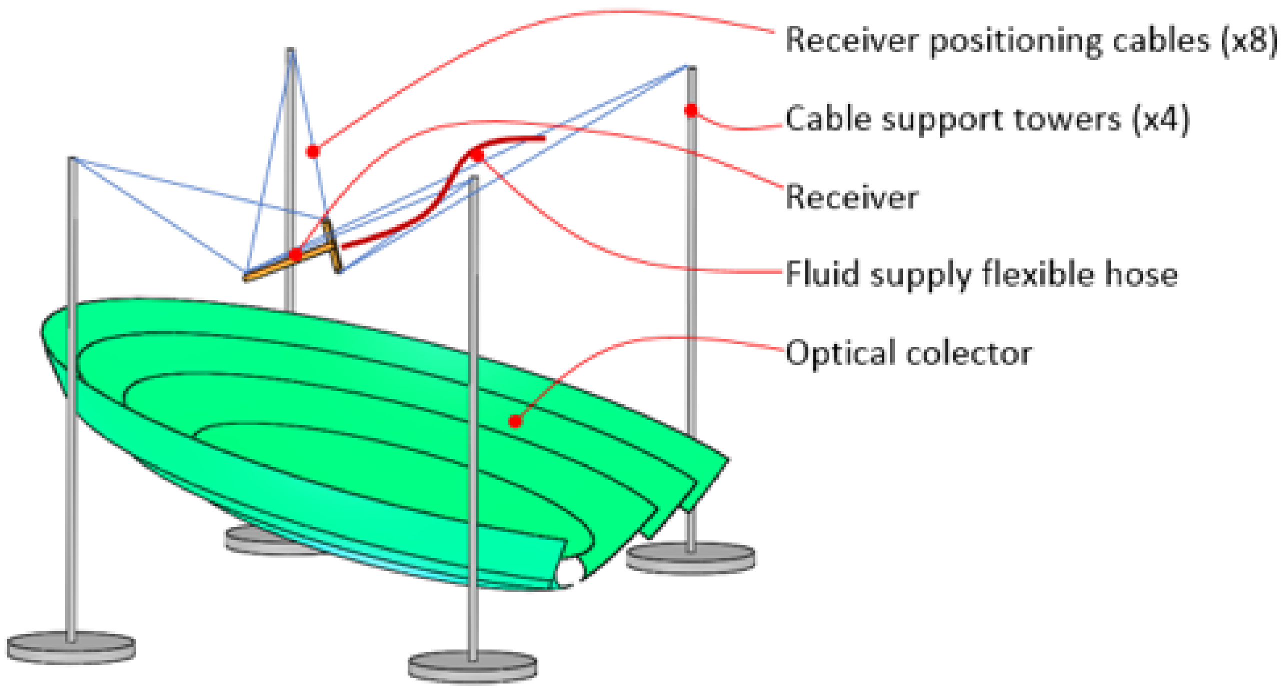
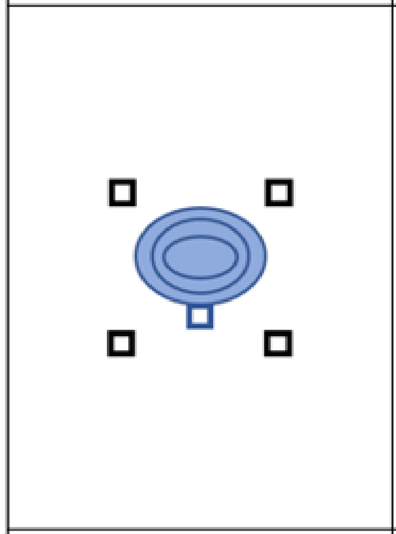
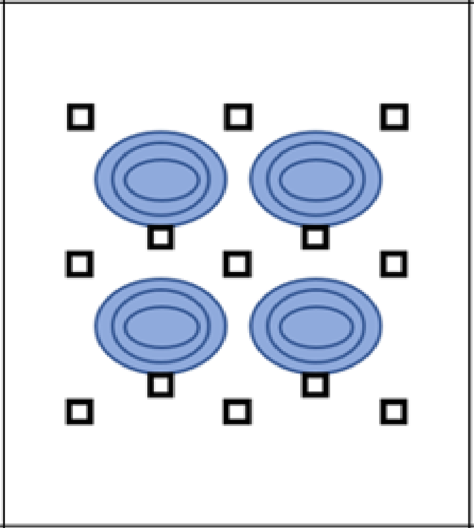
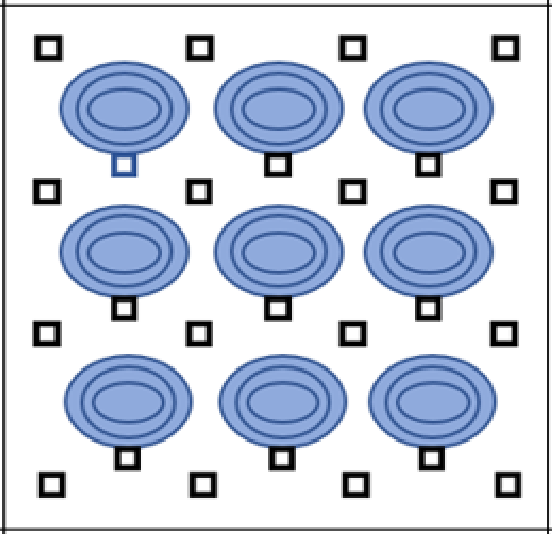
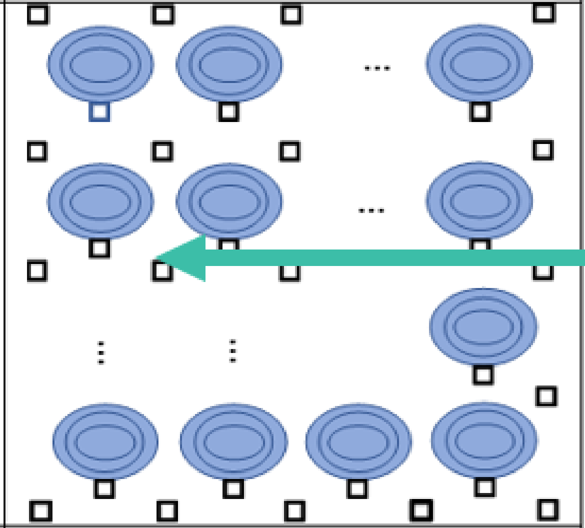
Classical tripod systems are costly when large displacements are required

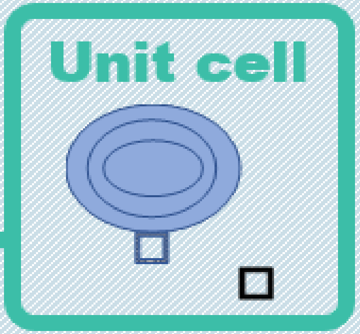
Parallel kinematics based on cables are proposed:

- Potential for cost reduction
- Large distances can be achieved
- Supporting structures can be shared



Development: How modules could share elements

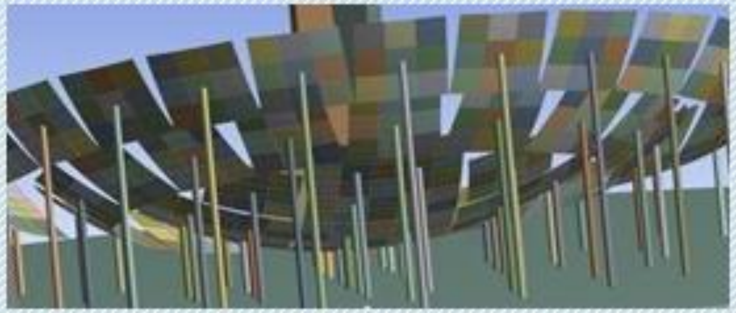
Plant view 1 module	Plant view 4 modules	Plant view 9 modules	Plant view N modules
			
5 towers: 4 pulling towers + 1 supporting tower	13 towers: 9 pulling towers + 4 supporting towers	25 towers: 16 pulling towers + 9 supporting towers	$N + (\sqrt{N}+1)^2$ towers: $(\sqrt{N}+1)^2$ pulling towers + N supporting towers



Development: Structure & 5th Tower

Modular approach for the solar field:

- Replicable structures for each ring (3x3 mirrors)
- Primary structure (columns and beams)
- Secondary structure (profiles)
- 3 pad mirrors



Additional structures:

- 4 towers to support pulling cable systems
- 18m. height tower to support thermal loop and hose
    - 1.80x1.80m. width
    - 4m. long cantilever arm
    - Skid for the HTF Loop on top

Development: Current state of development

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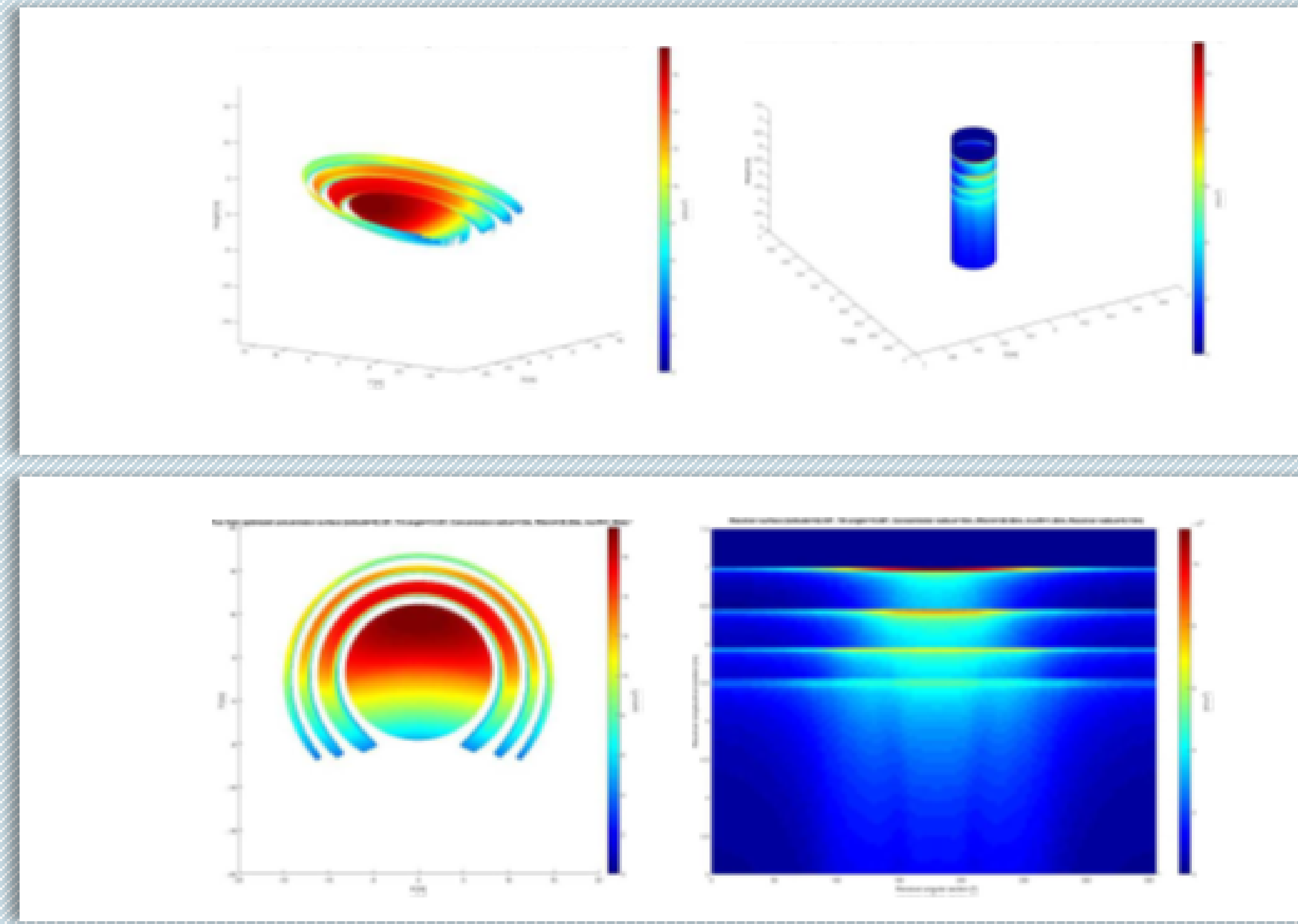
Global design has been finished:

- Solar field optimized
- Tracking system suitable for large displacements
- Optimized receiver design

Prototype under construction:

- Mirrors already under construction
- Purchase order for structures launched
- Receiver and thermal loop under construction
- On-site civil works will begin in August



EXPECTED BEHAVIOUR OF THE VALIDATION PROTOTYPE

Conclusions and next steps

A new concept of CSP with potential for cost reduction has been proposed

All required components have been designed:

- Solar field including tailored mirrors
- Cost effective tracking system
- Receiver and flexible hose

A prototype to validate the concept is under construction:

- On-site civil works will start in Aug. 2019
- Testing phase will start in Spring 2020
- Details will be shown in SOLARPACES 2019

The most promising cases for commercial applications (distributed and large plants) will be defined

Thank you

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