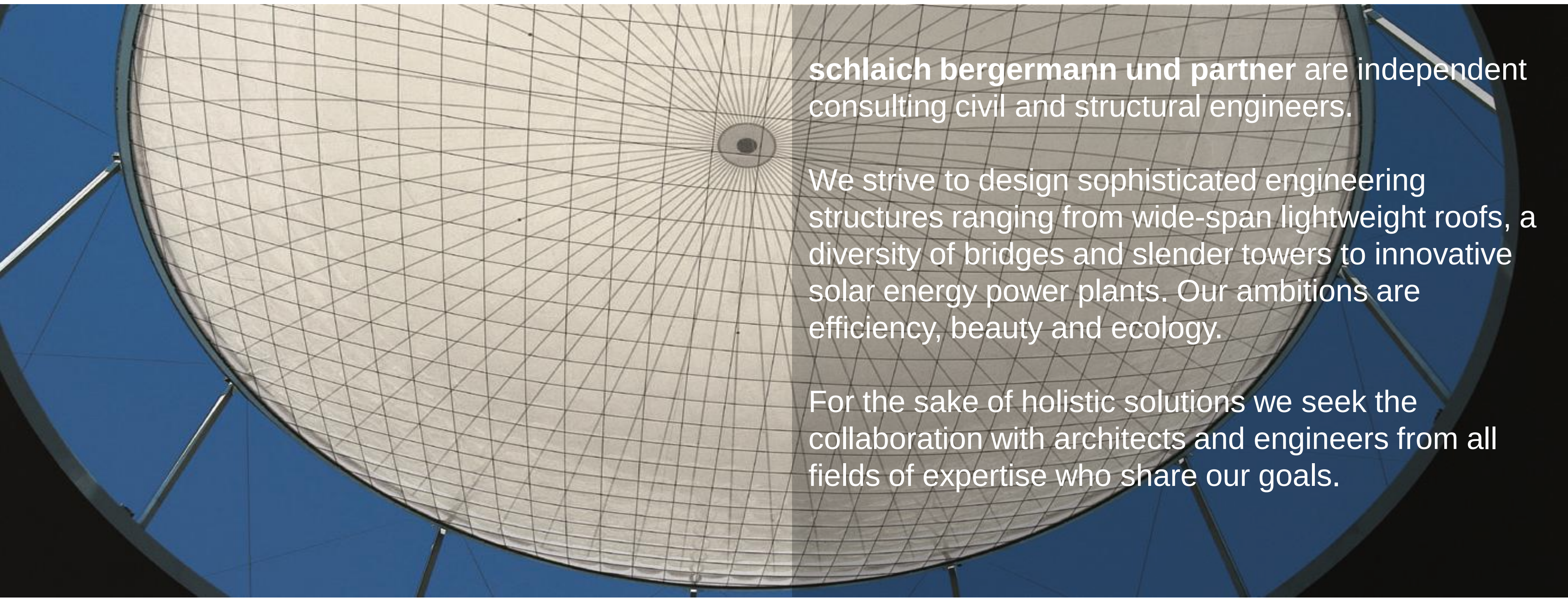
schlaich bergermann und partner

sbp sonne gmbh

From Moses Mabhida Stadium to Solar Power Generation in South Africa

Dipl. Ing. (FH) Markus Balz

Managing Director



schlaich bergermann und partner are independent consulting civil and structural engineers.

We strive to design sophisticated engineering structures ranging from wide-span lightweight roofs, a diversity of bridges and slender towers to innovative solar energy power plants. Our ambitions are efficiency, beauty and ecology.

For the sake of holistic solutions we seek the collaboration with architects and engineers from all fields of expertise who share our goals.

Nelson Mandela Bay Arena Port Elizabeth, South Africa

Soccer City Stadium Johannesburg, South Africa

Greenpoint Stadium Cape Town, South Africa

Moses Mabhida Stadium Durban, South Africa

(My) Conclusions of working in South Africa

- Wide experience in all building technologies
- Experienced contractors that know how to handle large projects (….and international sub contractors)
- Real team work between parties involved (client, architects, engineers, contractors)
- Make a plan (…but really not too early)
- Contractors listen to good advise
- Building risks involved are considered and accepted
- Fun!

Consulting Engineers for Renewable Energy

A growing team, **sbp sonne gmbh**, is working on making advantage of renewable energies.

The technologies within this field are the Dish-Stirling-applications for decentralised and small-scale power plants. Central receiver systems, Parabolic trough and the solar updraft tower technology is used in large scale application.

Our highly qualified, motivated and constantly growing team is willing to contribute in research and development of any kind of Technologies.

Consulting Engineers for Renewable Energy

Consultancy for client, owner and contractor

Feasibility studies

Efficiency calculation of power generation

Structural concept, calculation and optimization

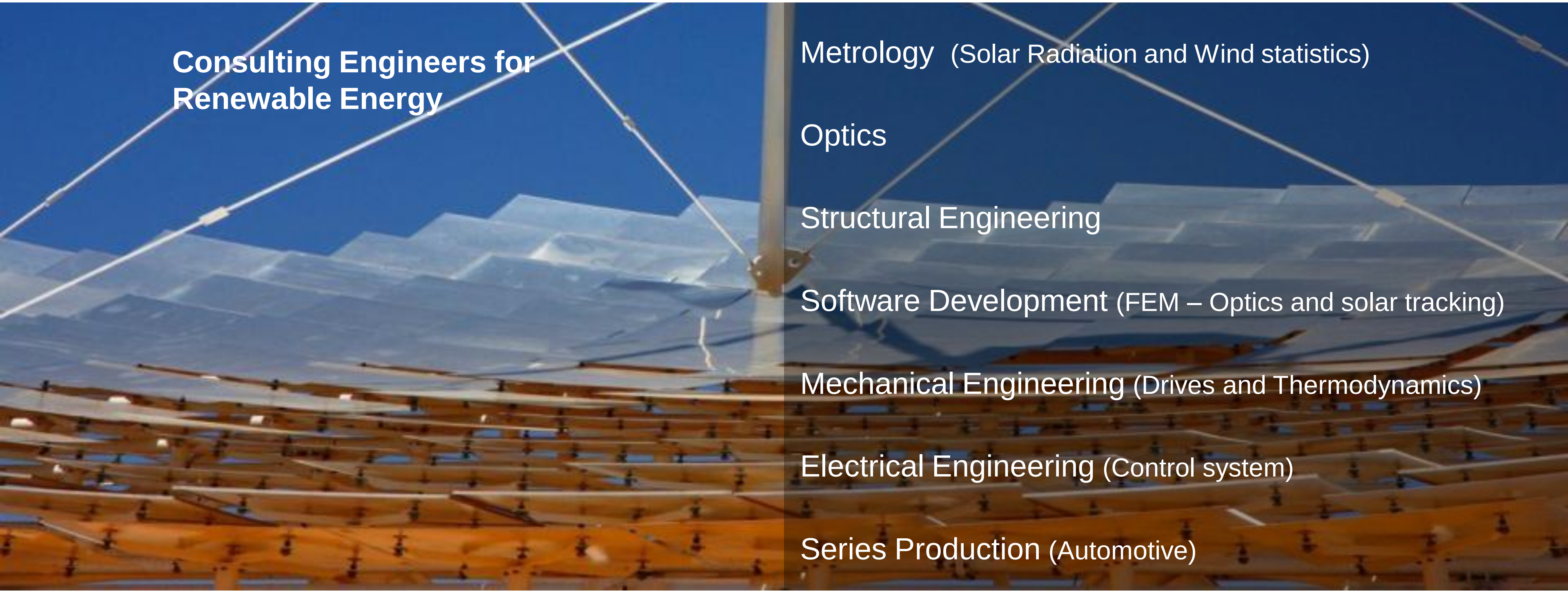
Optics evaluation and optimization

Concept and calculation of controls and drives

Planning of prototype and series production

Supervision and quality management

Our Scope of Work



Consulting Engineers for Renewable Energy

Metrology (Solar Radiation and Wind statistics)

Optics

Structural Engineering

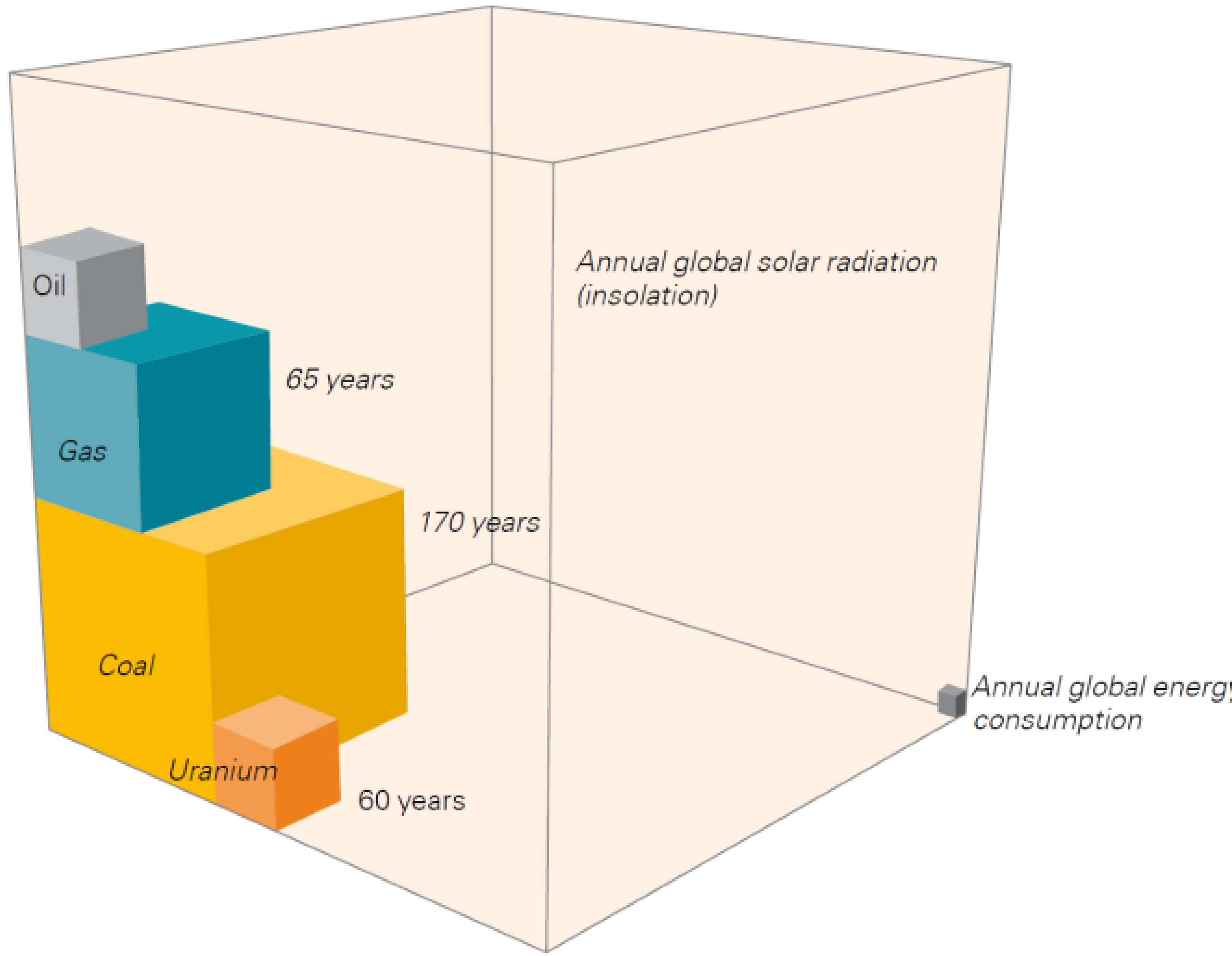
Software Development (FEM – Optics and solar tracking)

Mechanical Engineering (Drives and Thermodynamics)

Electrical Engineering (Control system)

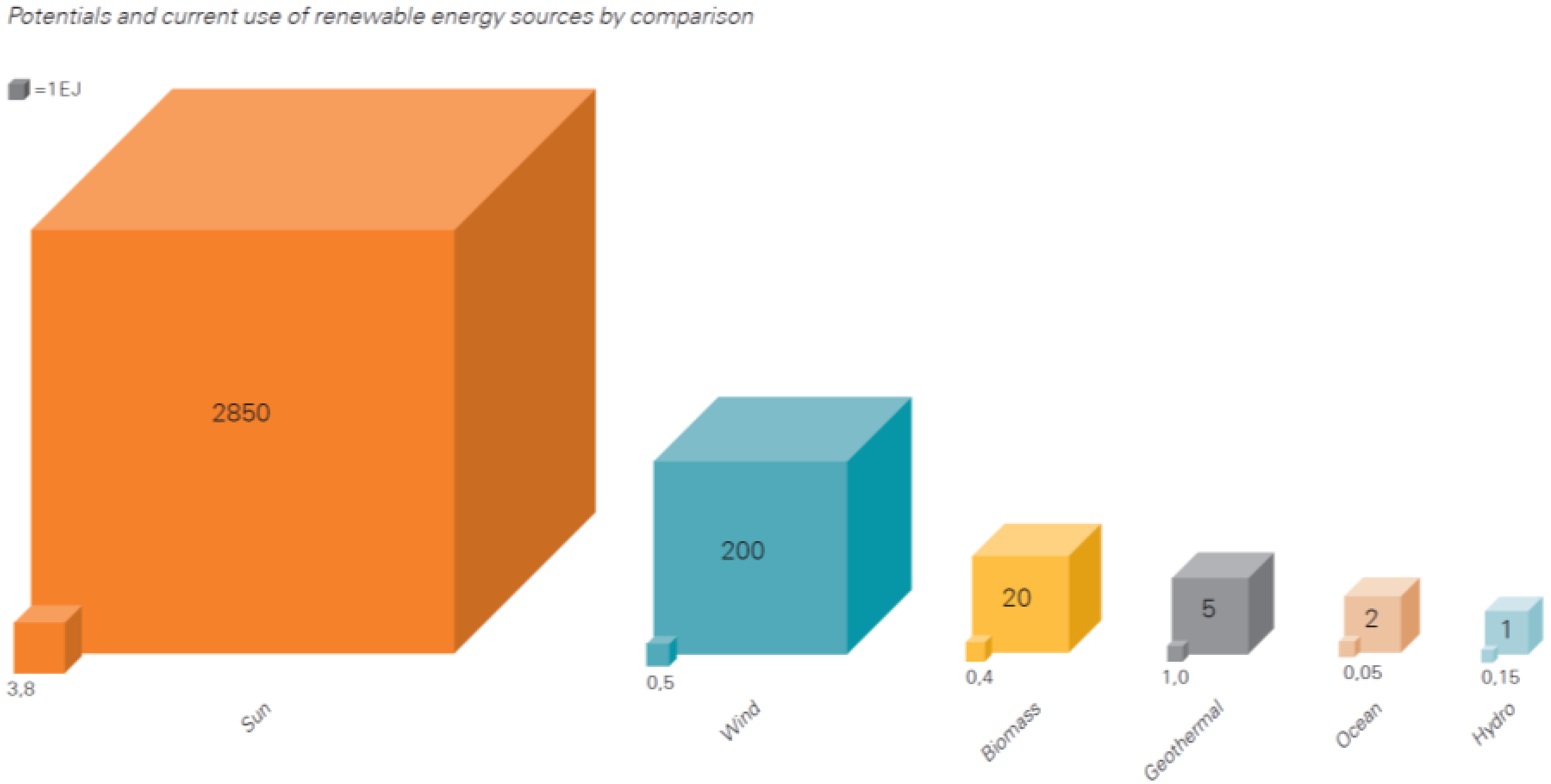
Series Production (Automotive)

Technical Expertise

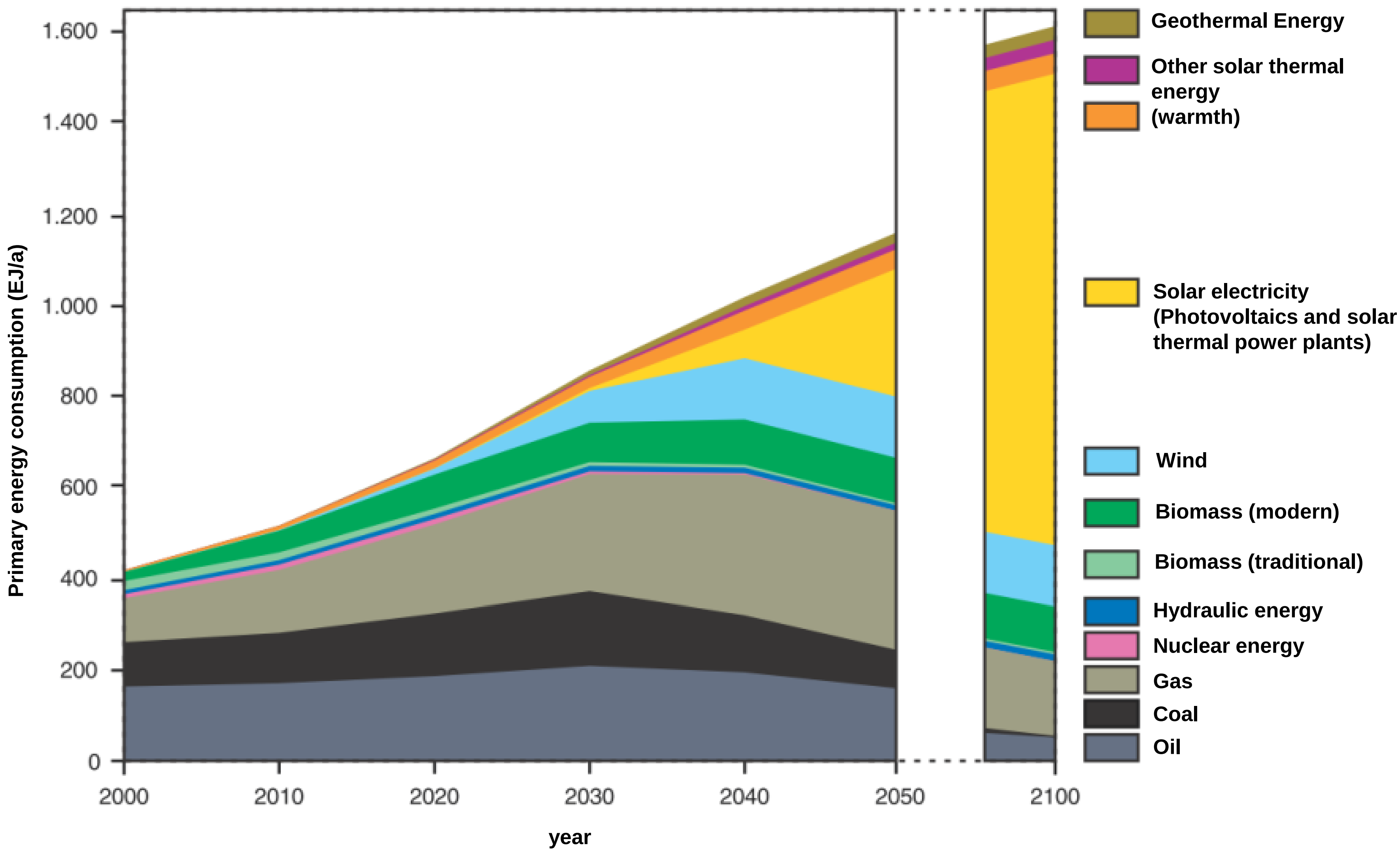


Global fossil fuel reserves

Global resource of conventional energies and yearly solar radiation



The global supply of natural/renewable resources and economical potential to exploit it with present technologies – primary energy



Source: Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen

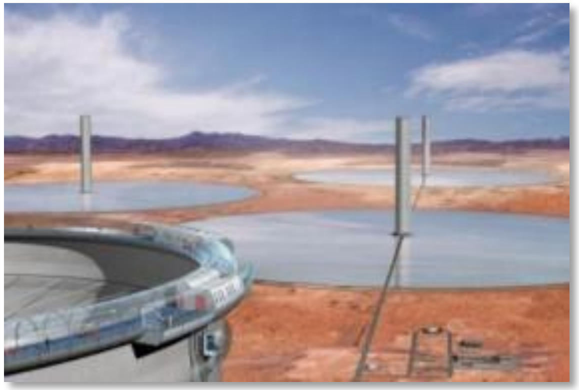
Global use of primary energy (EJ/a)











Current Solar Technologies – sorted by size





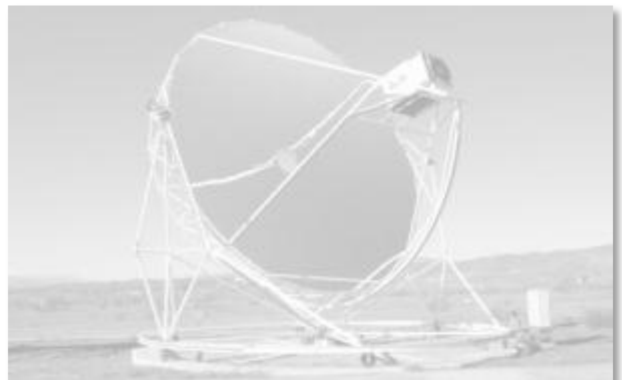




Current Solar Technologies – schlaich bergermann and partner



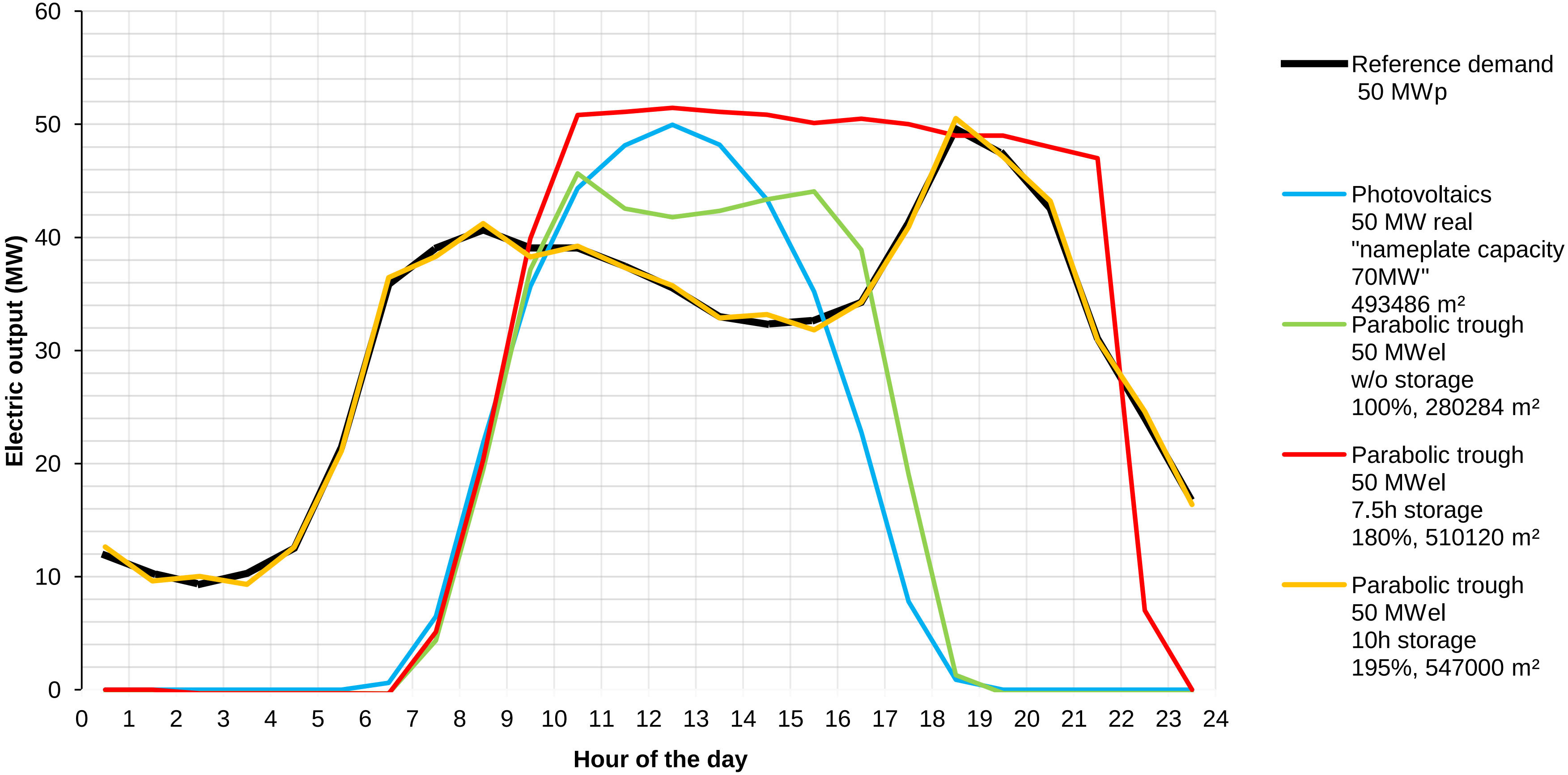




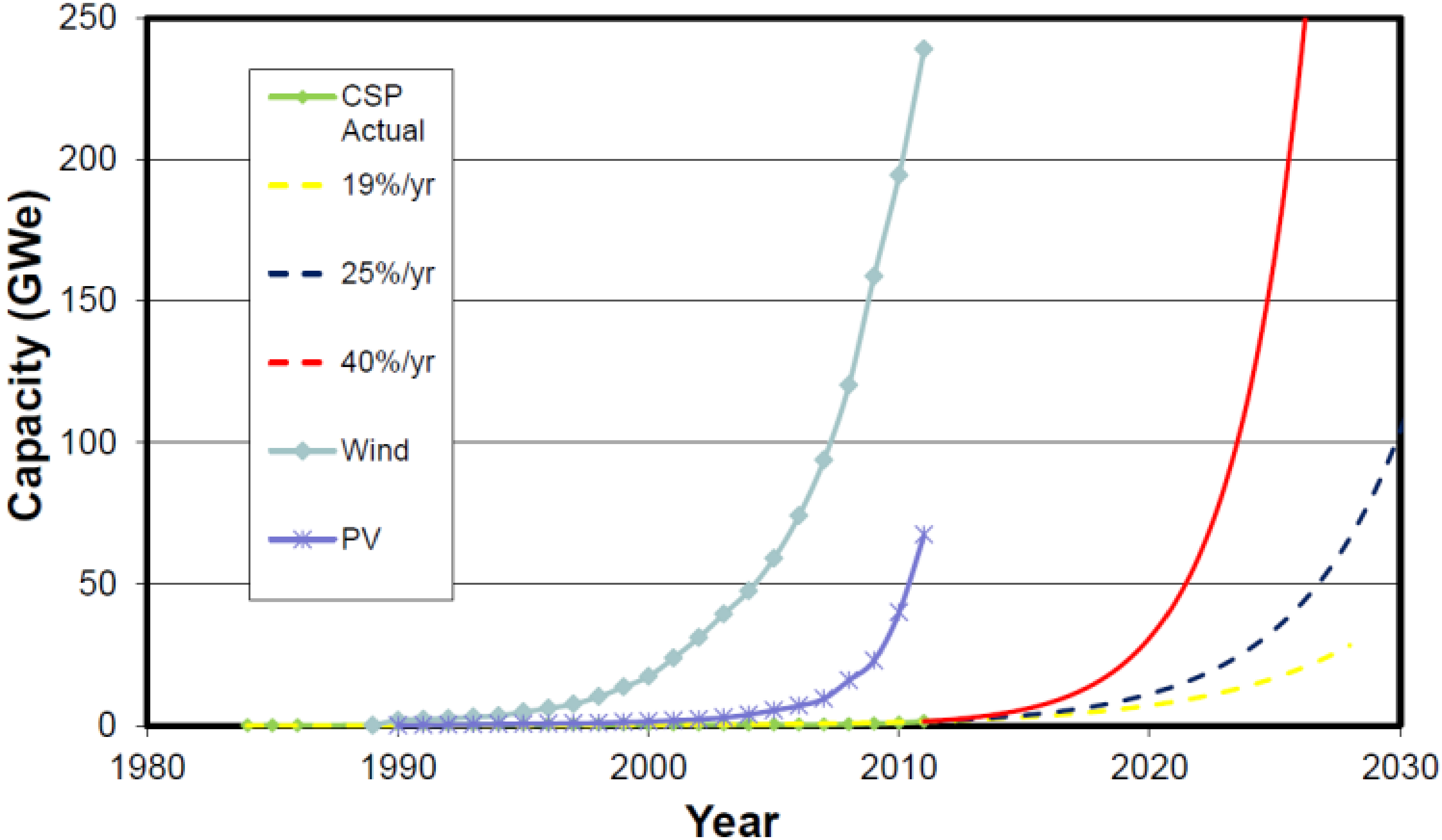


Current solar technologies – dispachtable (storable) solar energy generation

Illustration of area ratio (m²) between power output of PV and CSP (with and without storage)

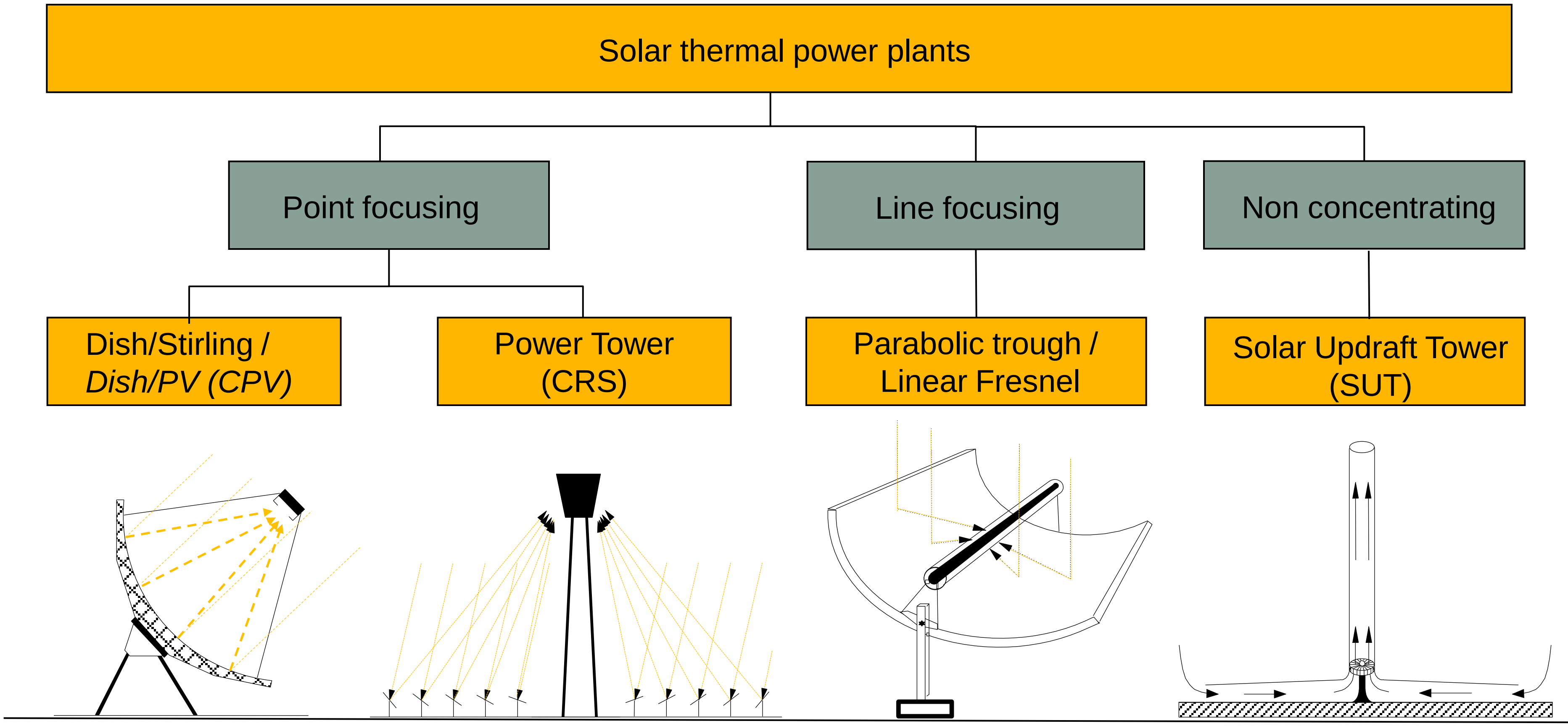


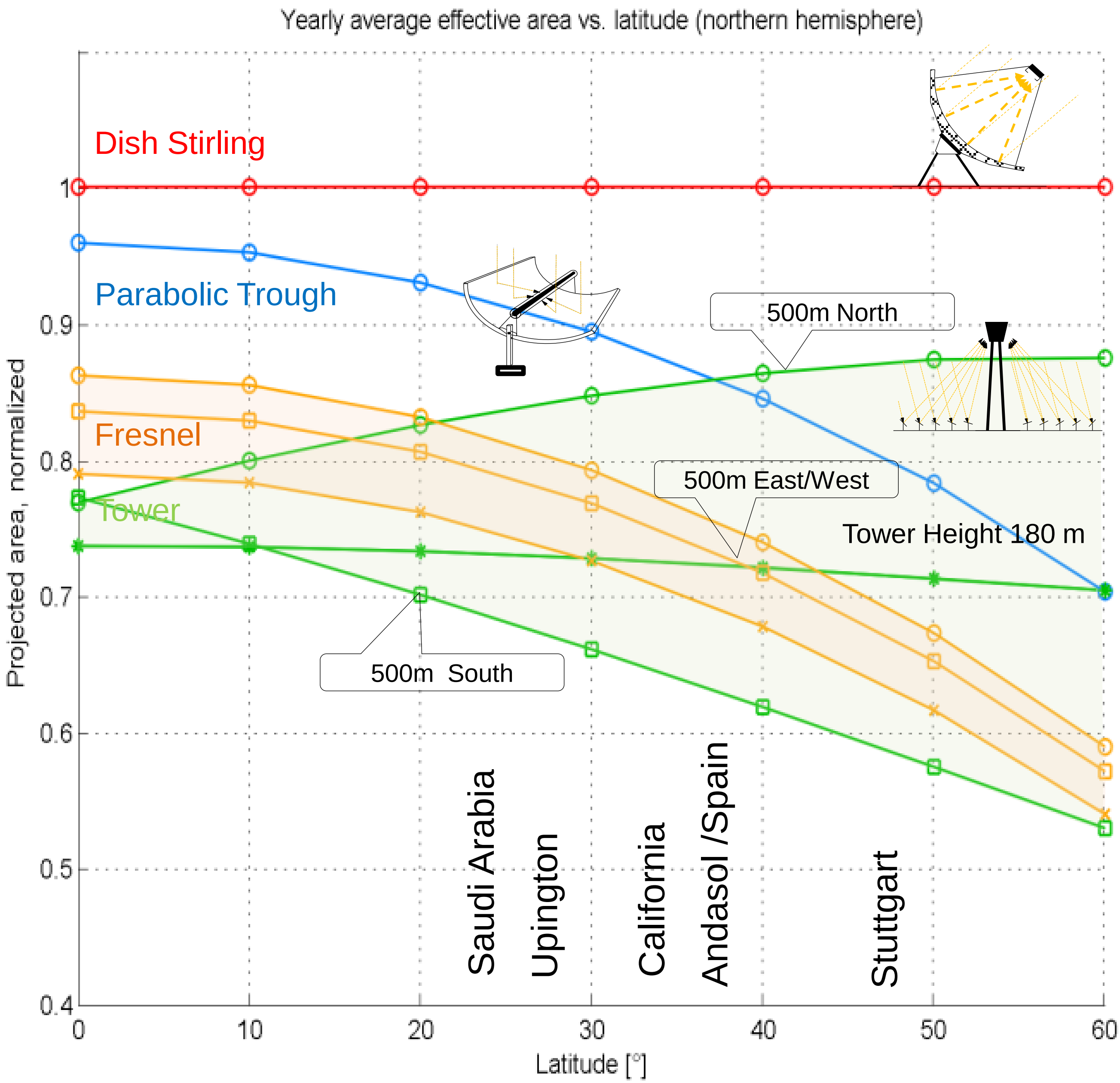
Solar plants electric output (yearly mean) vs electric demand of South Africa



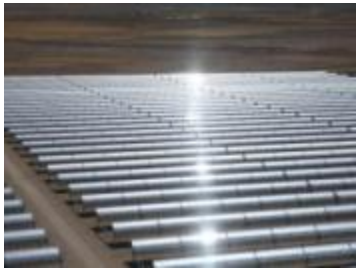
Capacity Trends of Renewable Energy Systems

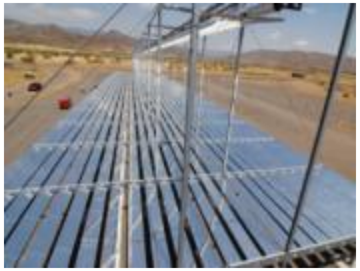
CSP Technology Choice


Solar thermal power plants
Point focusing
Line focusing
Non concentrating
Dish/Stirling /
Dish/PV (CPV)
Power Tower
(CRS)
Parabolic trough /
Linear Fresnel
Solar Updraft Tower
(SUT)



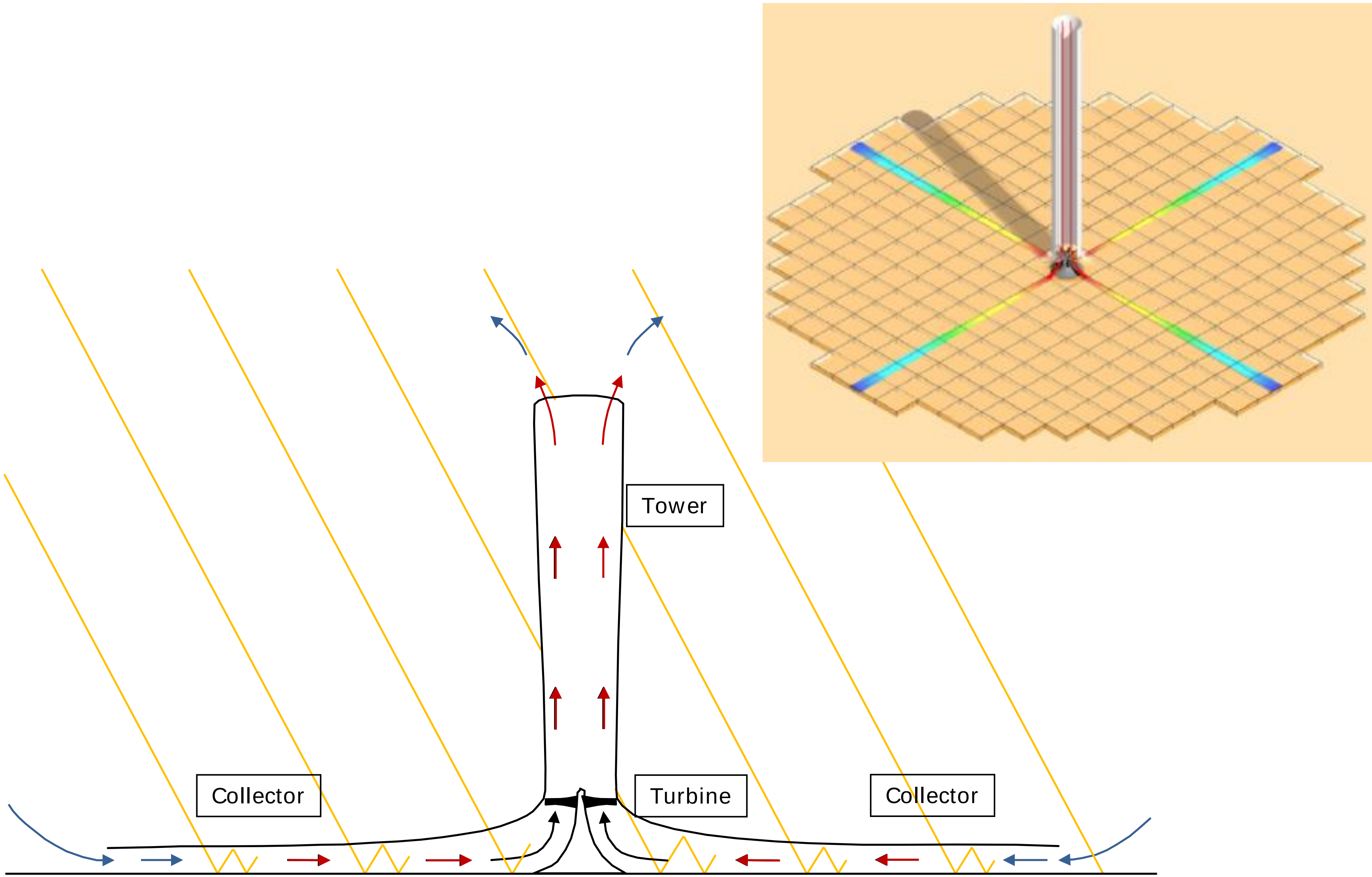
Yearly average effective area vs. latitude (northern hemisphere)
Dish Stirling
Parabolic Trough
Fresnel
Tower
500m North
500m East/West
500m South
Tower Height 180 m
Saudi Arabia
Upington
California
Andasol /Spain
Stuttgart
Projected area, normalized
Latitude [°]
0
10
20
30
40
50
60
0.4
0.5
0.6
0.7
0.8
0.9
1





Solar Updraft Tower

- Non concentrating



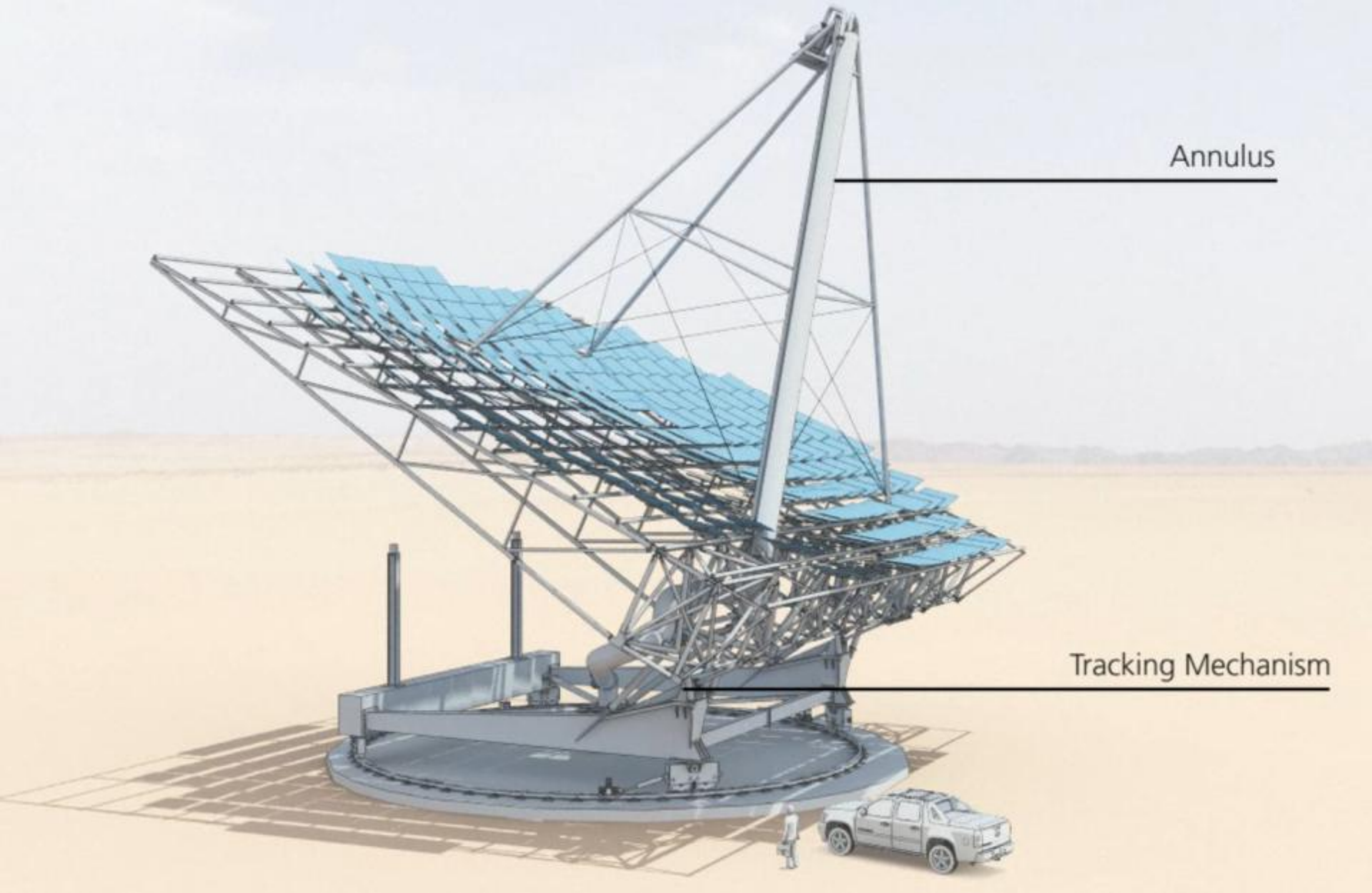
Solar Updraft Tower Principle

Prototype Manzanares, 1982, Castilla - La Mancha

Solar Updraft Tower (Conceptual Design)

Solar Updraft Tower Conceptual Design

Solar Thermal Boosting



HelioFocus solar concentrator – 500m² fresnel dish

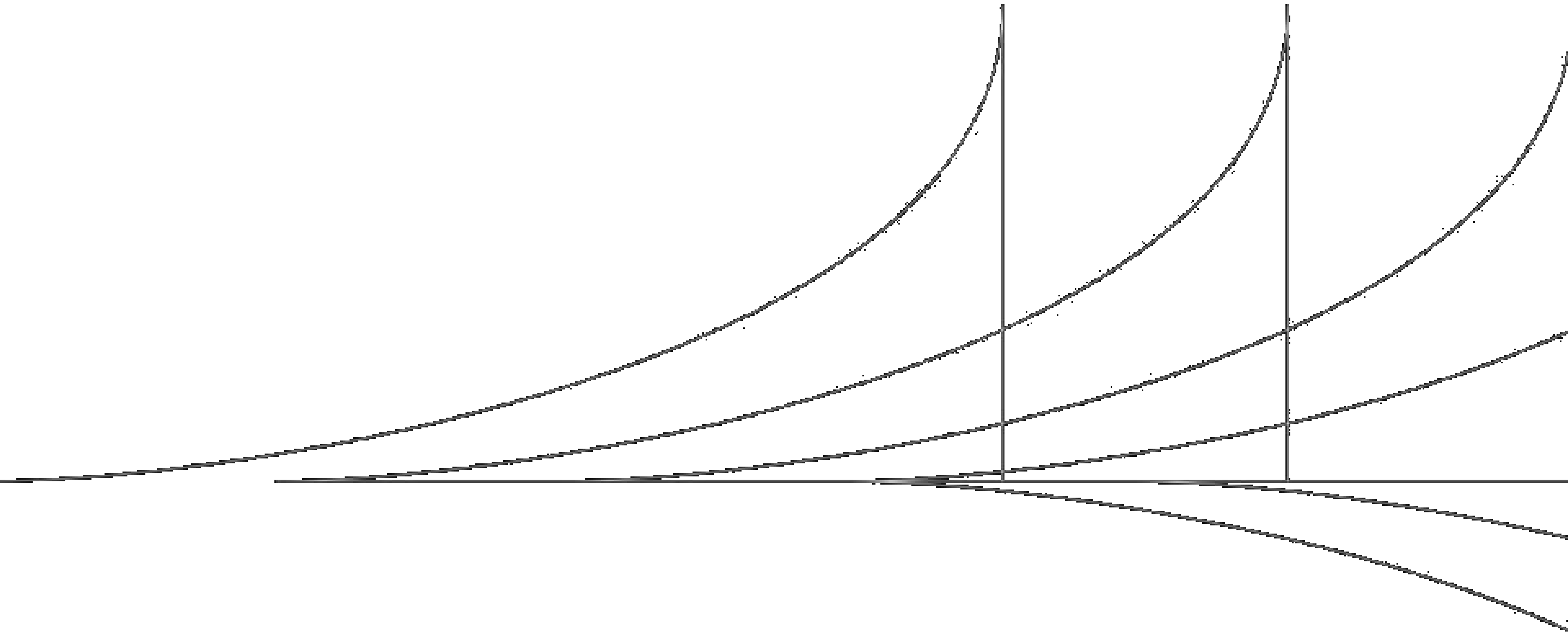
Prototype Dish HelioFocus, Israel

Prototype Dish HelioFocus, Israel

HelioFocus test site close to Wuhai/Huinong

29th October 2013 Inauguration of Heliofocus Test Site with 8 x 500 m² Dish units in China

Parabolic Trough Technology



EUROTROUGH

Technology Development

Start of development: 1998

1. Conceptual Design
2. Prototype:
   - PSA/Spain 1998
3. Test loop:
   - EuroTrough Loop KJC: Kramer Junction, USA: 2003

Commercial Application

Large Scale Power Projects

- 50 MW Andasol I, II, III: Aldeire Spain: 2008, 2009, 2012
- 50 MW Power Plant Moron, Spain: 2011
- 50 MW Power Plant Astexol, Badajoz, Spain: 2012
- 50 MW Power Plant Extremasol: Badajoz, Spain: 2012
- 125 MW Solar Combined Power Plant Kuraymat: Egypt, 2010
- 50 MW Solar Power Plant, Rajasthan, Godawari, India; 2013
- 25 MW Solar Power Plant, Gujarat, Cargo Ltd, India, 2013

Coming Projects in:
- **Algeria**
- **Iran**
- **India**
- **Morocco**
- **South Africa**

HELIOTROUGH

Technology Development

Start of development: 2005

1. Conceptual Design
2. Prototype:
   - Dortmund/Germany 2006
3. Test loop:
   - HelioTrough Loop KJC: Kramer Junction, USA: 2009

Commercial Application

Large Scale Power Projects

Designed for 4 x 250 MW Blythe, California: 2014

ULTIMATE TROUGH

Technology Development

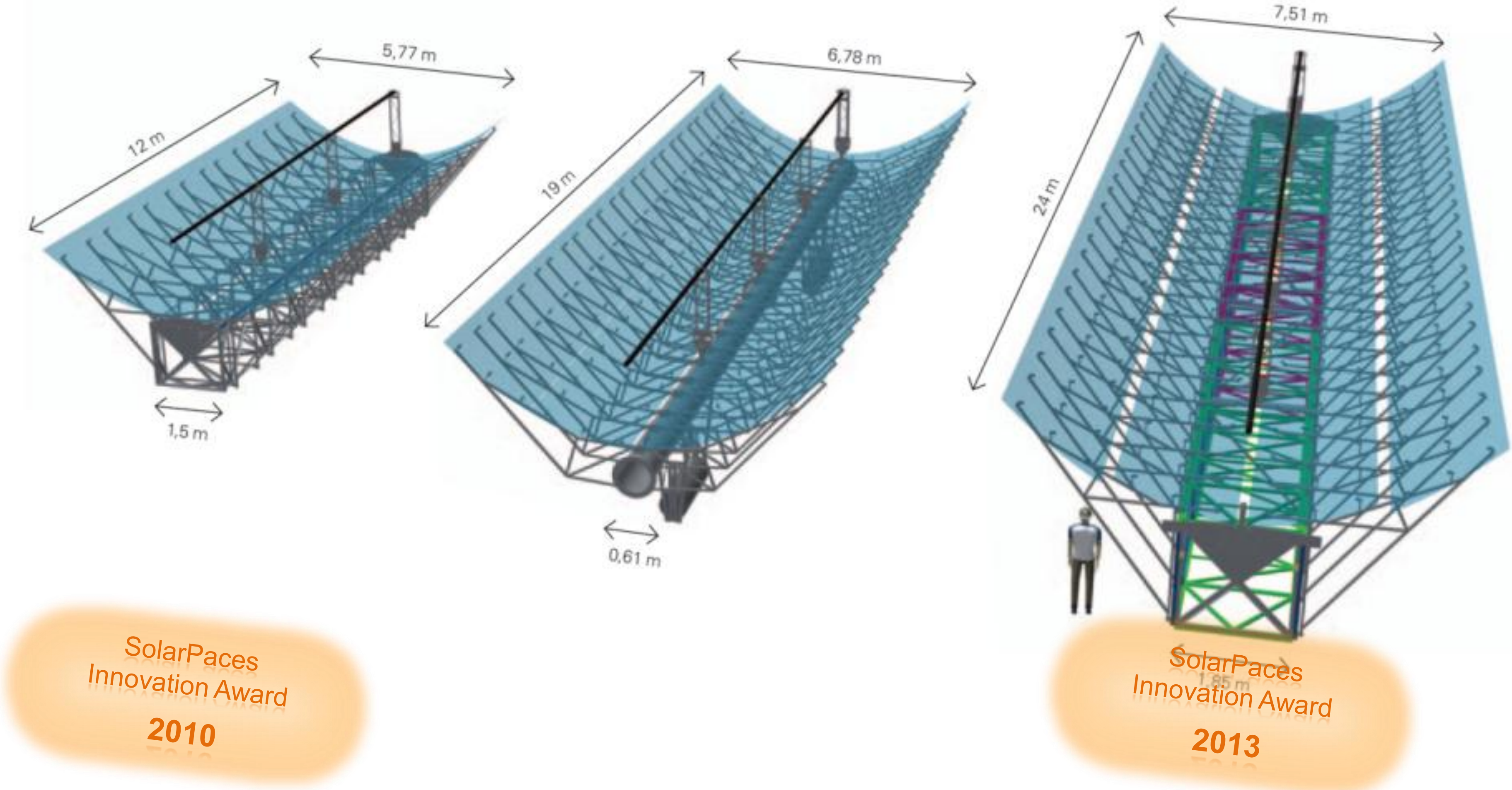
Current development: 2009

1. Conceptual Design
2. Prototype:
   - Cologne/Germany 2011
3. Test loop:
   - UT Collector Trough Loop: Harper Lake, USA: 2012

Commercial Application

Large Scale Power Projects

?



<u>EuroTrough Collector:</u>

- Standard technology
- Moderate complexity
- Good optical performance
- Higher demand of manpower

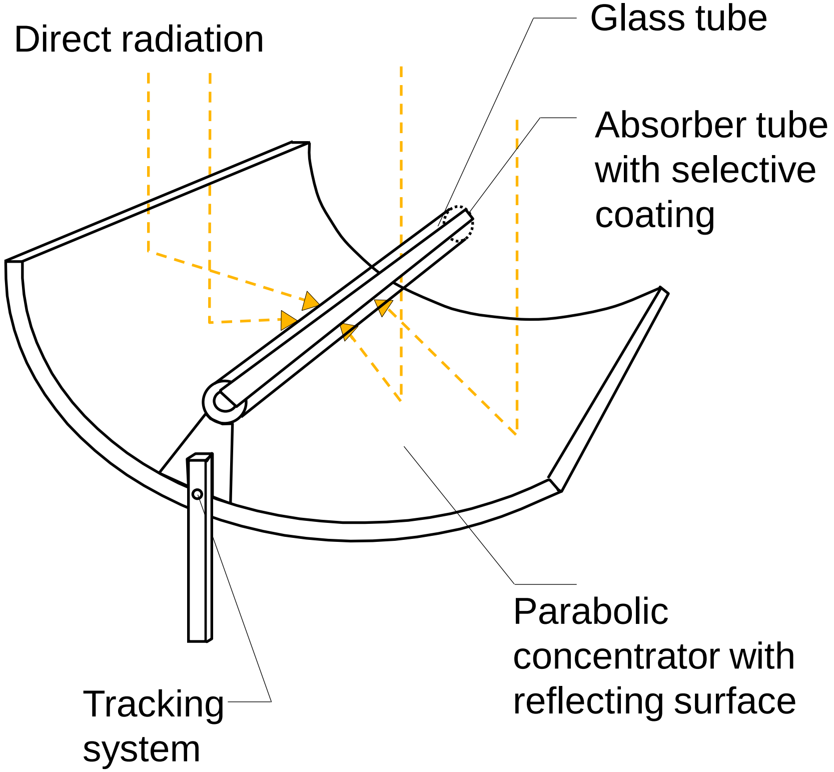
<u>HelioTrough Collector:</u>

- Reduction of numbers of elements
- Sophisticated complexity
- Currently highest optical performance
- Automized manufacturing processes

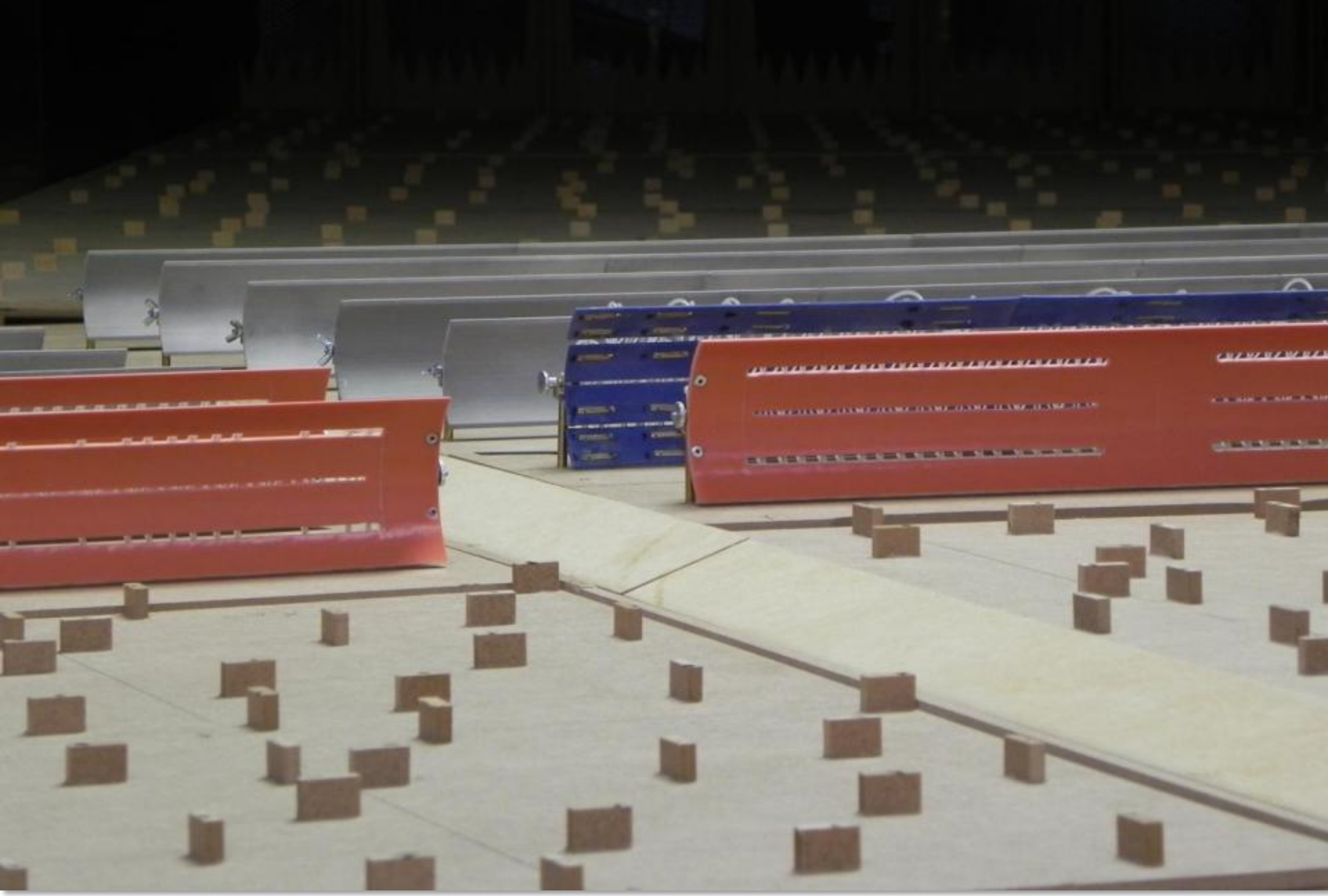
<u>UltimateTrough Collector:</u>

- Optimized manufacturing technology
- Sophisticated complexity
- Very high optical performance

Continuing Development – Size and optical quality does matter



Principle of a Solar Parabolic Trough Power Plant



Design development - wind tunnel testing

EuroTrough 2 Prototype, Plataforma Solar de Almeria/Spanien 2002

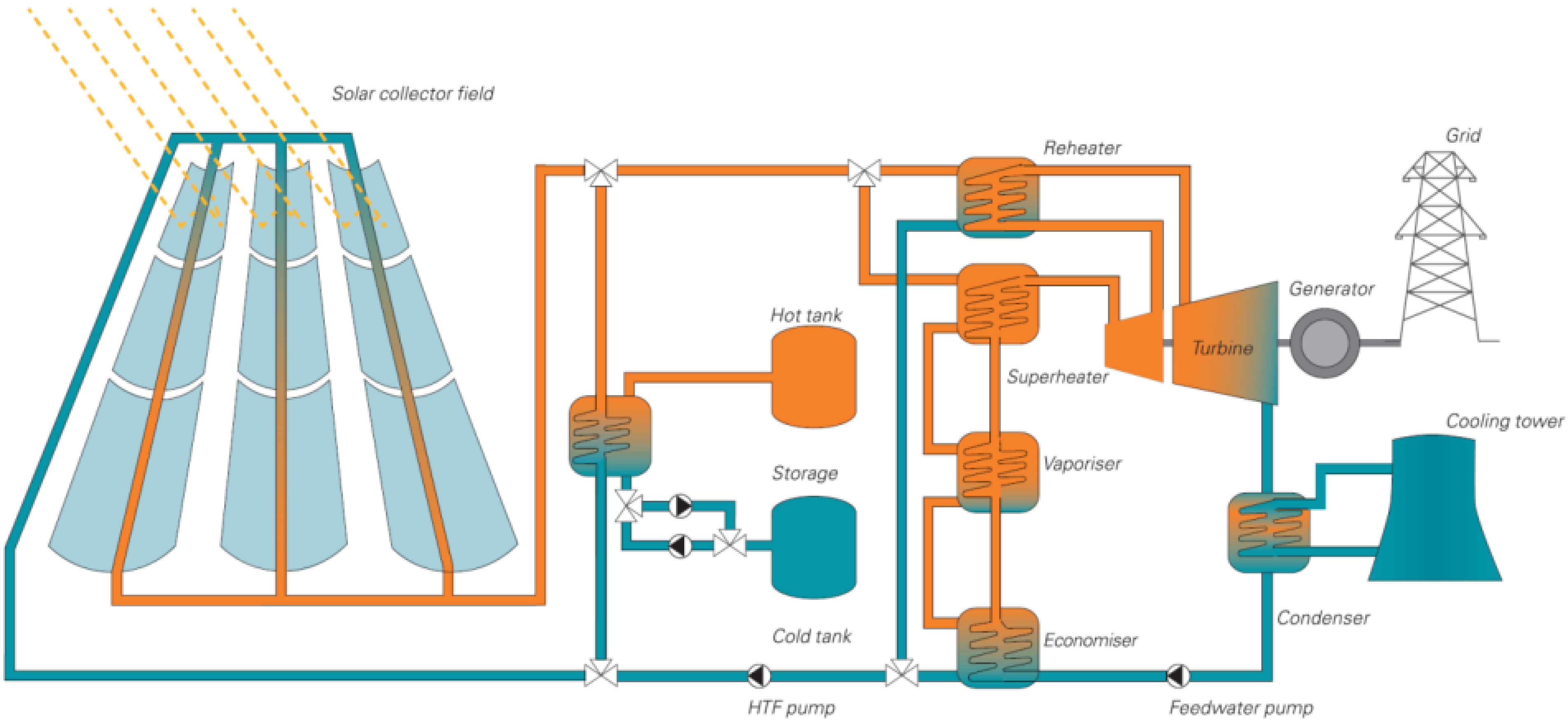
SKAL-ET loop integrated in the SEGS V plant in California

Andasol collector field, Spain

Commercial 50 MW Plants in Spain: Andasol 1, Andasol 2, Andasol 3 (under construction)

Andasol 1 power block

Andasol 1 molten salt heat storage



Parabolic trough power plant – thermal flow

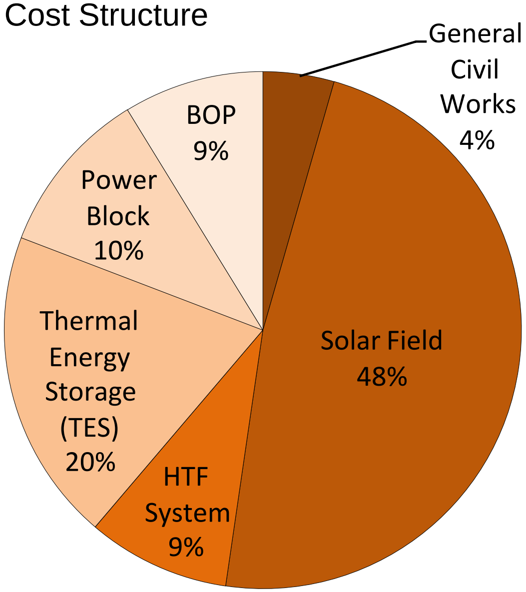
On-site collector assembly hall

Mirror assembly

Assembly on Site

Parabolic Trough Technology
Ongoing Development

Cost Structure



Procurement and erection cost breakup
(Estimated current cost ~220 M€ - European cost basis)

The Solar Field is the most important cost item of a Parabolic Trough Power Plant

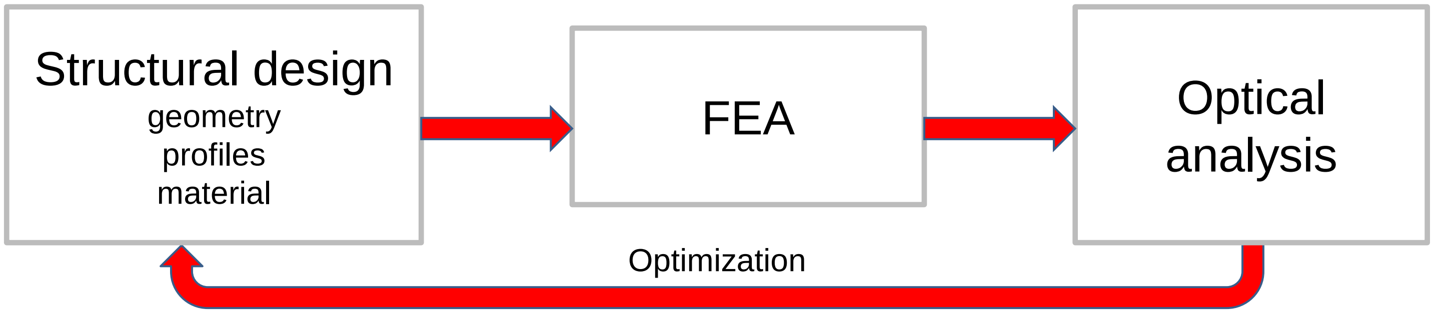
Cost efficient Solar Field has a significant impact on the economics of the project

Within the Solar Field, the collector structure and mirrors account for 60 % of the solar field costs

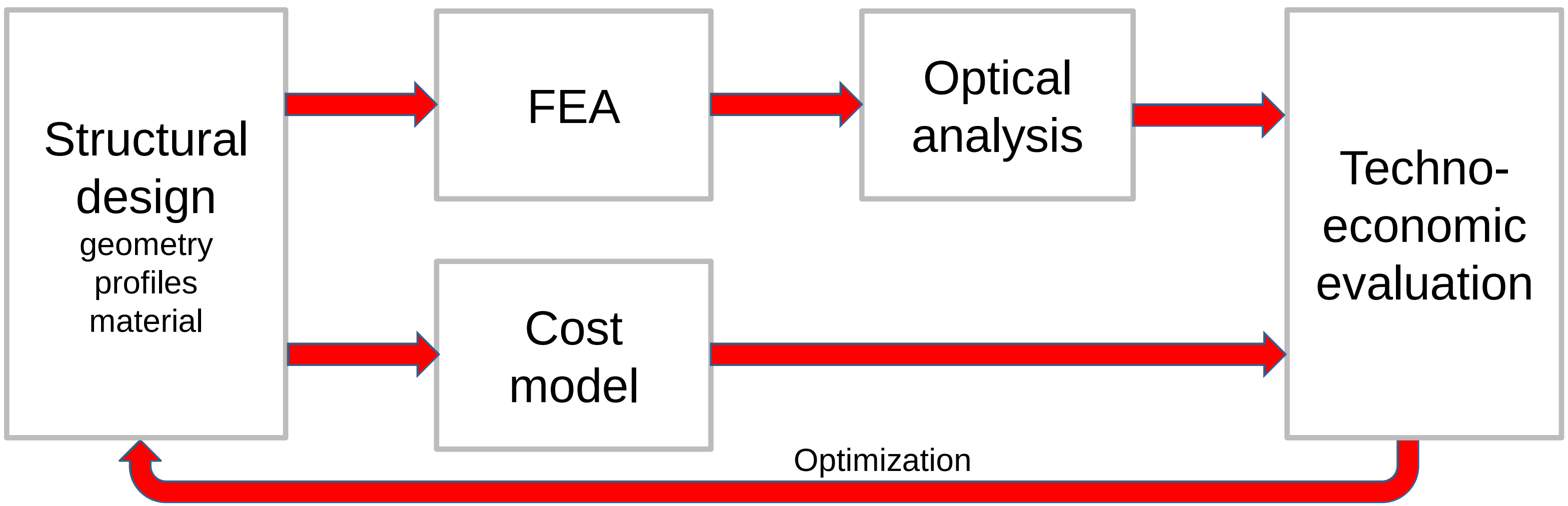
Significant savings can be realized with an economically optimized collector design

Cost efficient solutions for parabolic trough power plants:
An economically optimized collector design is a key to reduce CSP project costs

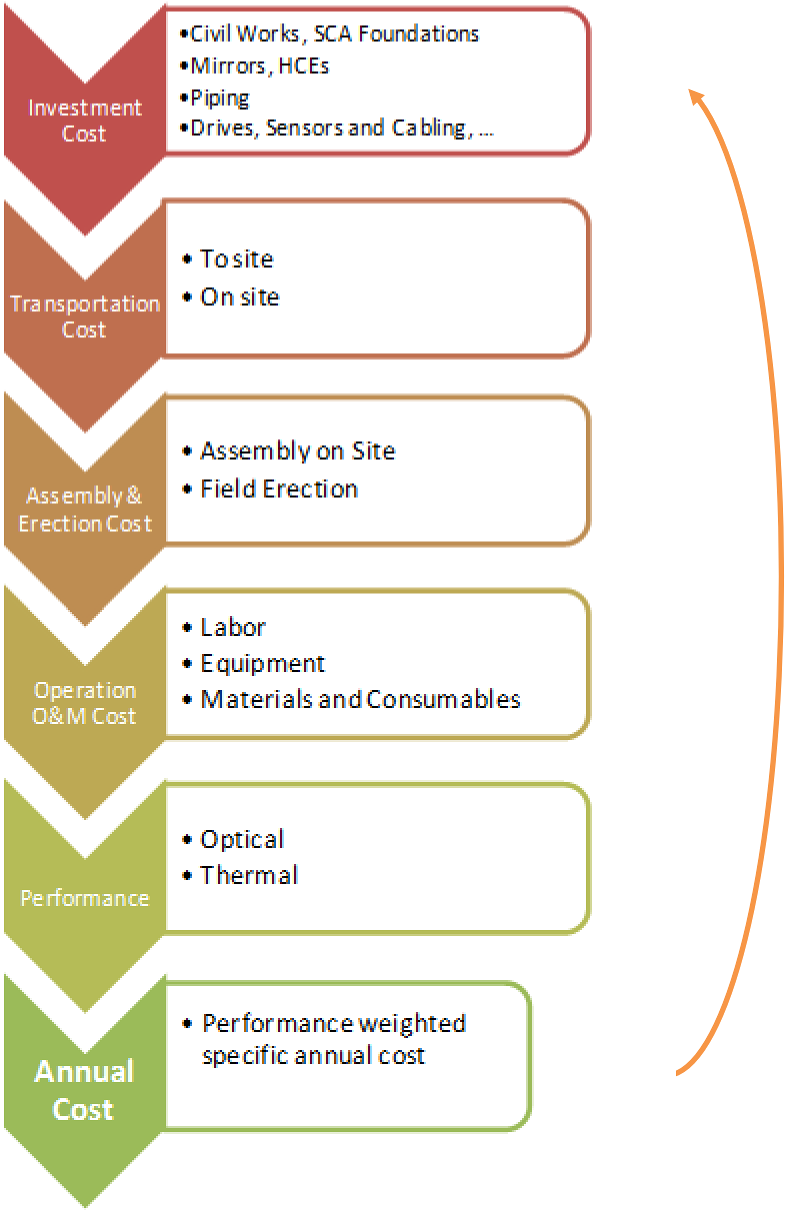
Technical optimization



Techno-economic optimization



Analysis of Ultimate Trough – Technology Identification of potential improvements



Expectations (development aims):

20 - 25 % reduction of solar field investment cost achieved by: less investment and erection costs for solar field

higher collector performance (higher optical efficiency, lower auxiliary consumption)

In total:

Levelized Cost of Electricity (LCoE) will decrease by ~12 % compared to today's parabolic trough technology.

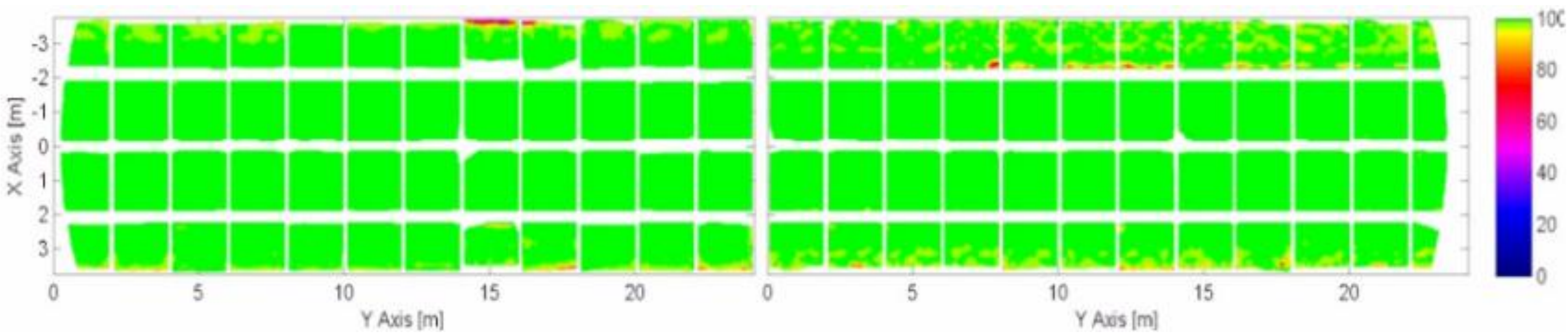
UT – Techno – economical design approach

Ultimate Trough Prototype April 2011 Köln

Design: Mirrors are attached stress free to the collector metal structure
Measurement and validation: Optical assessment by 3rd party

- Optical assessment with deflectometry & photogrammetry – dual measurement for result validation
- Intercept factor - sun rays hitting the receiver under consideration of the sun shape
  - = 99.2% @ 94 mm HCE (for oil as HTF)
  - = 97.5% @ 70 mm HCE (for salt as HTF)
- Average focal deviation of assembled collector, FDx < 8 mm - combined deviation caused by mirrors and steel structure

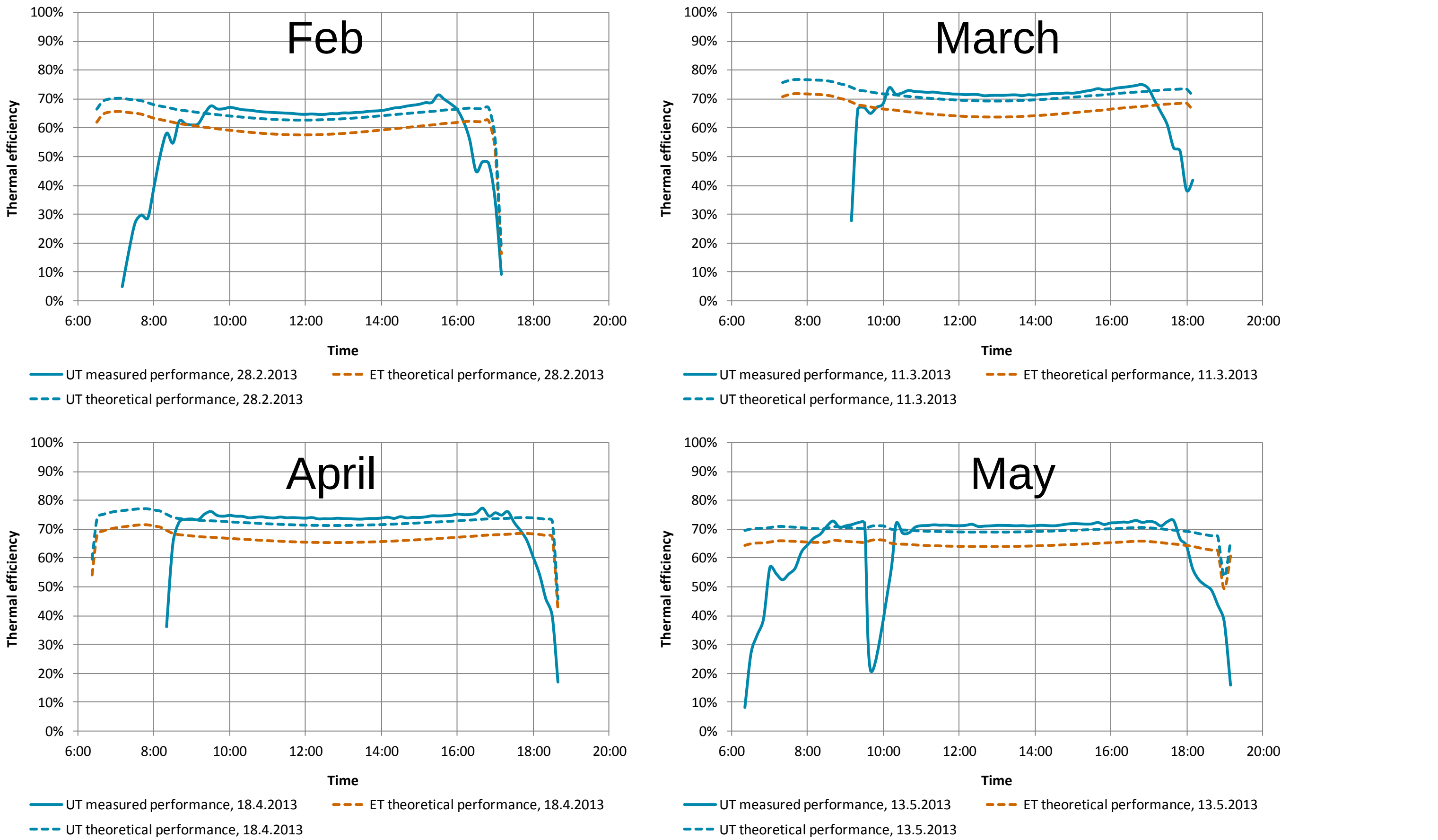
module	SDx [mrad]	FDx [mm]	IClaser [%]	ICsun [%]	ICdegsun [%]
1	1.7	7.9	100.0	99.2	99.1
	1.4	7.1	99.9	99.1	99.0
	1.5	7.5	100.0	99.2	99.0
2	1.7	7.7	100.0	99.2	99.1
	1.7	8.3	100.0	99.2	99.0
	1.7	8.1	100.0	99.2	99.1



Optical performance of UltimateTrough - Test Loop

Ultimate Trough Testloop - California

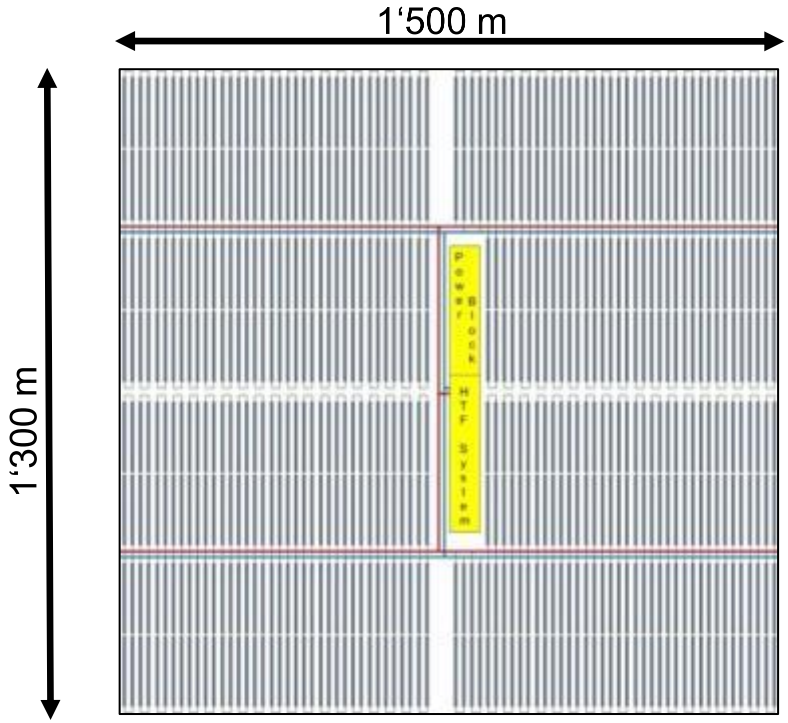
Ultimate Trough Test Loop - California



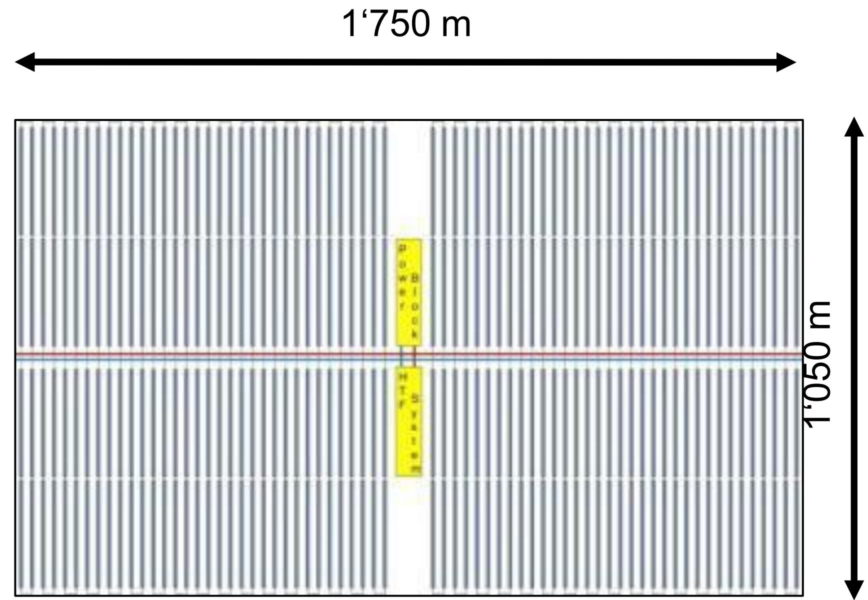
- One day per month evaluated and compared to model
- **The actual performance is consistently better than the expected performance.**
- There are still some uncertainties in the measurements which will be evaluated and corrected during the next weeks of operation.

Ultimate Trough – Test loop performance

Eurotrough, 510‘000 m²



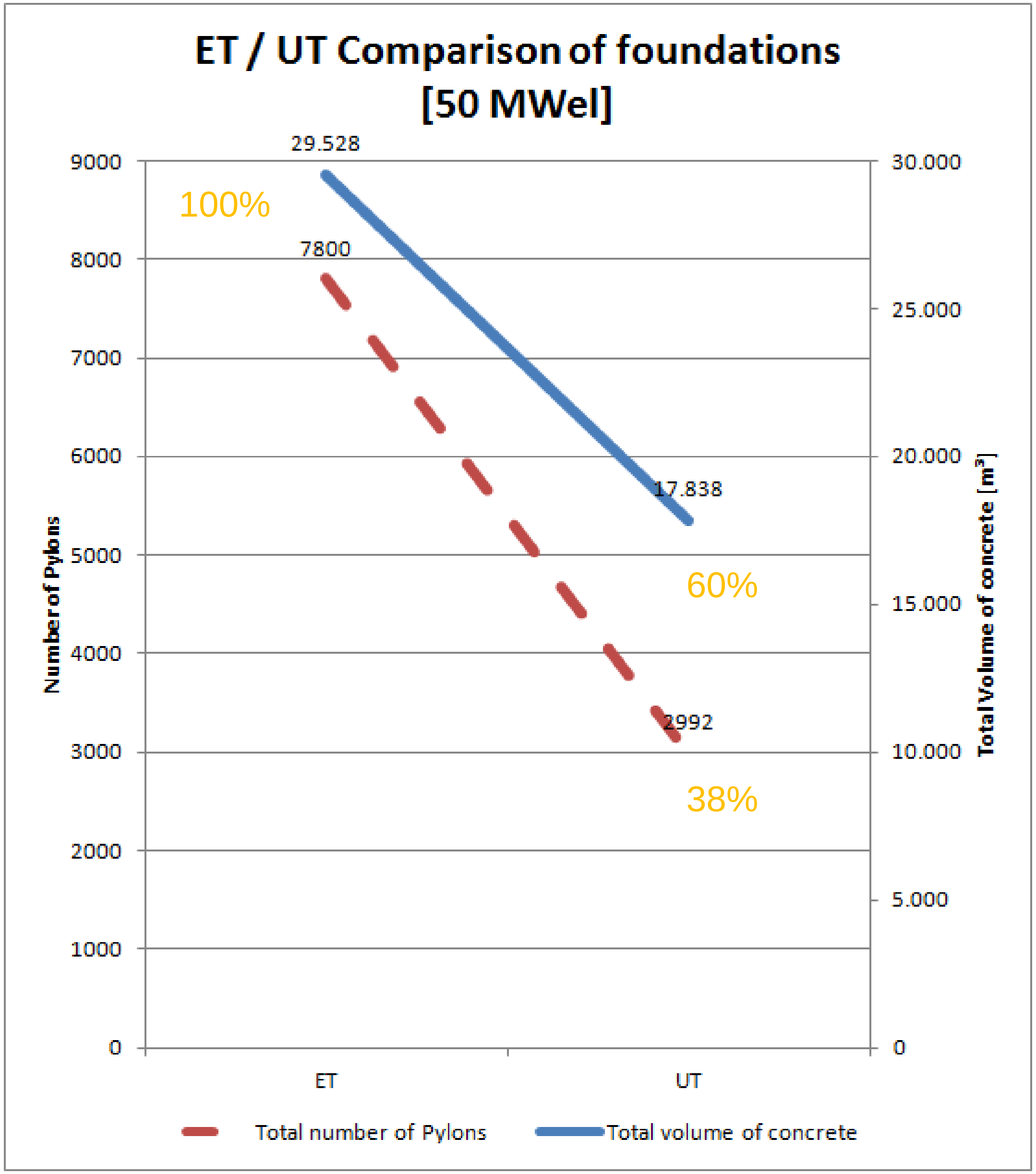
Ultimate Trough, 466‘000 m²

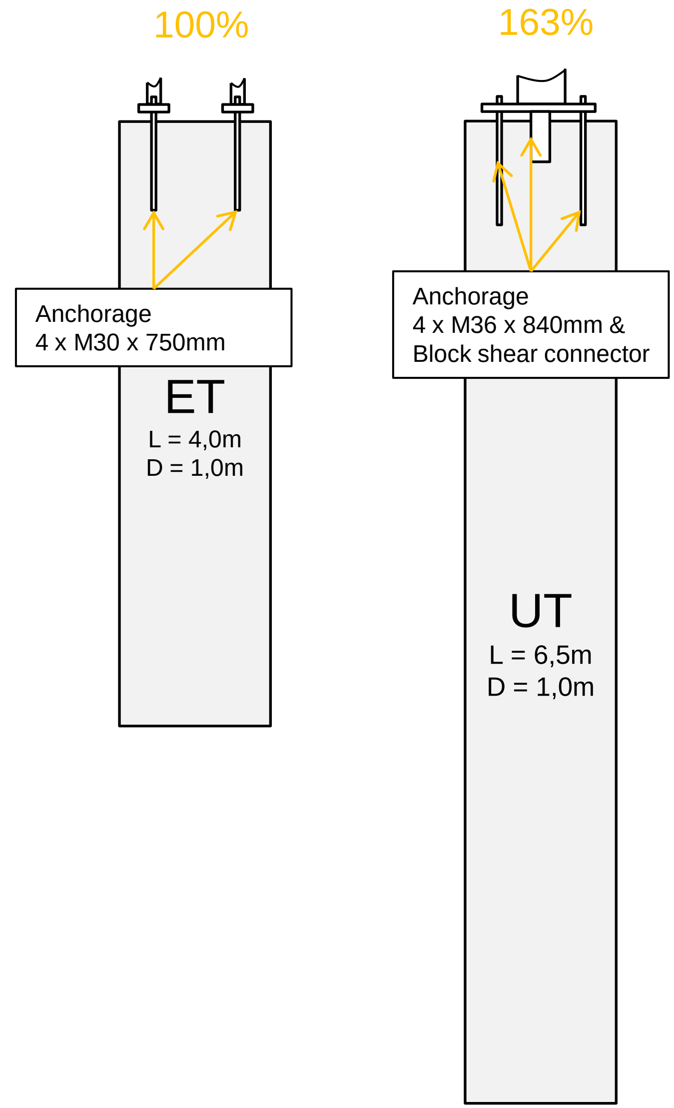


Header piping		ET	UT	Ratio
north-south	m	1'678	n/a	
east-west	m	6'840	3'757	55%
total	m	8'518	3'757	44%
HTF Volume	m³	1'813	1'353	75%

Significant cost reduction due to
- Less piping (material, installation, insulation)
- Less heat transfer fluid

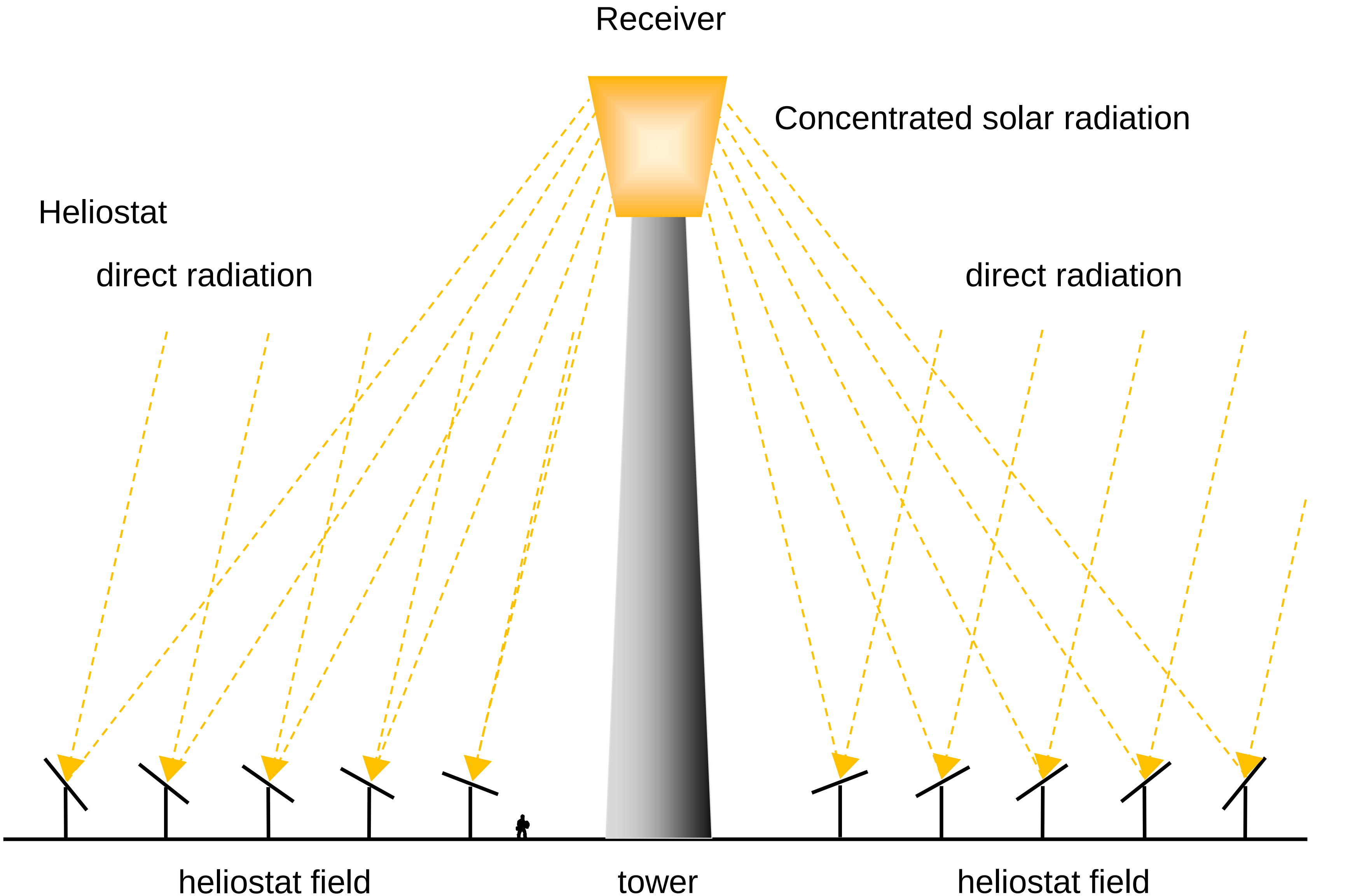
ET / UT – Solar field layout for a 50 MW plant with storage





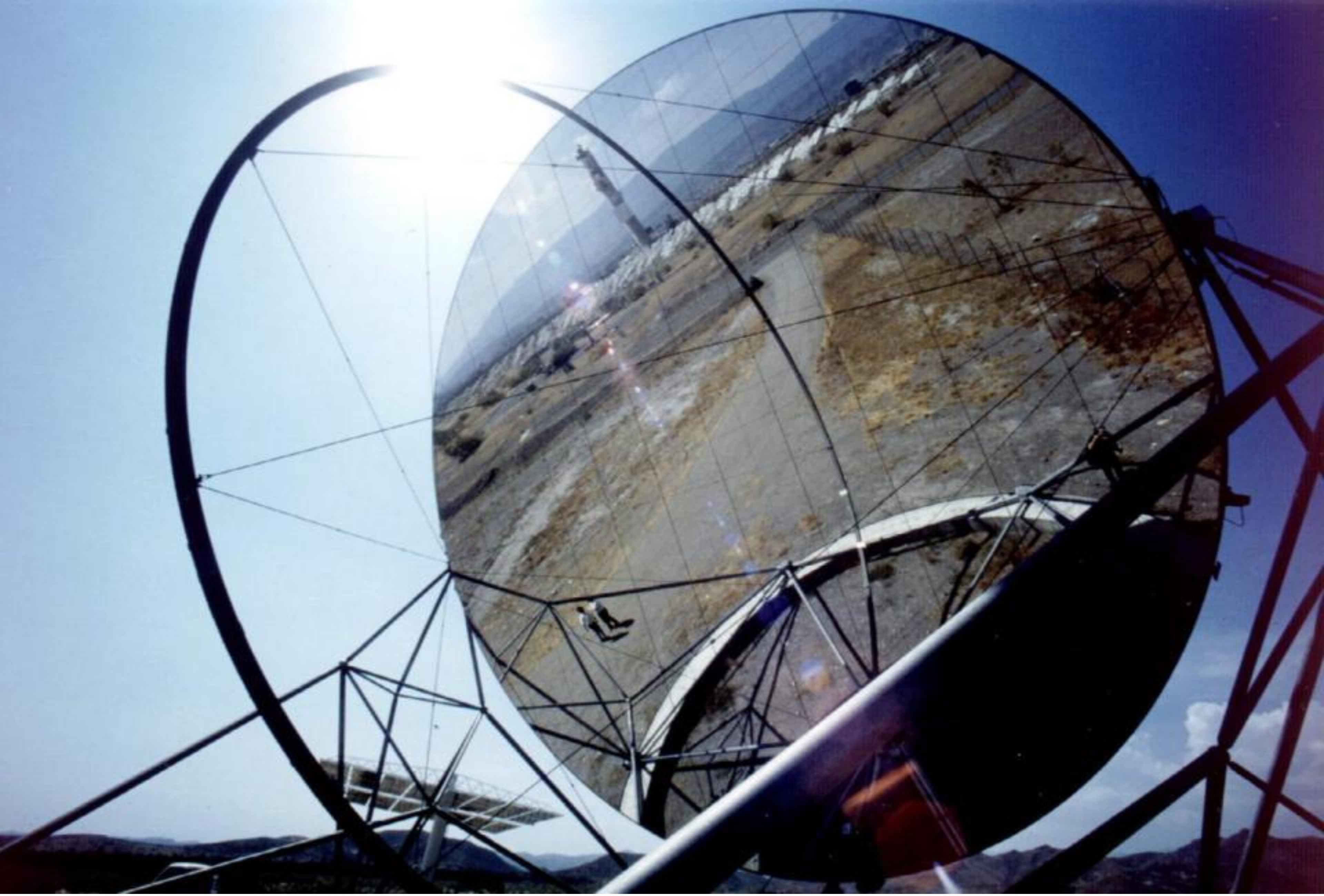
Comparison of foundations

Central Receiver Systems

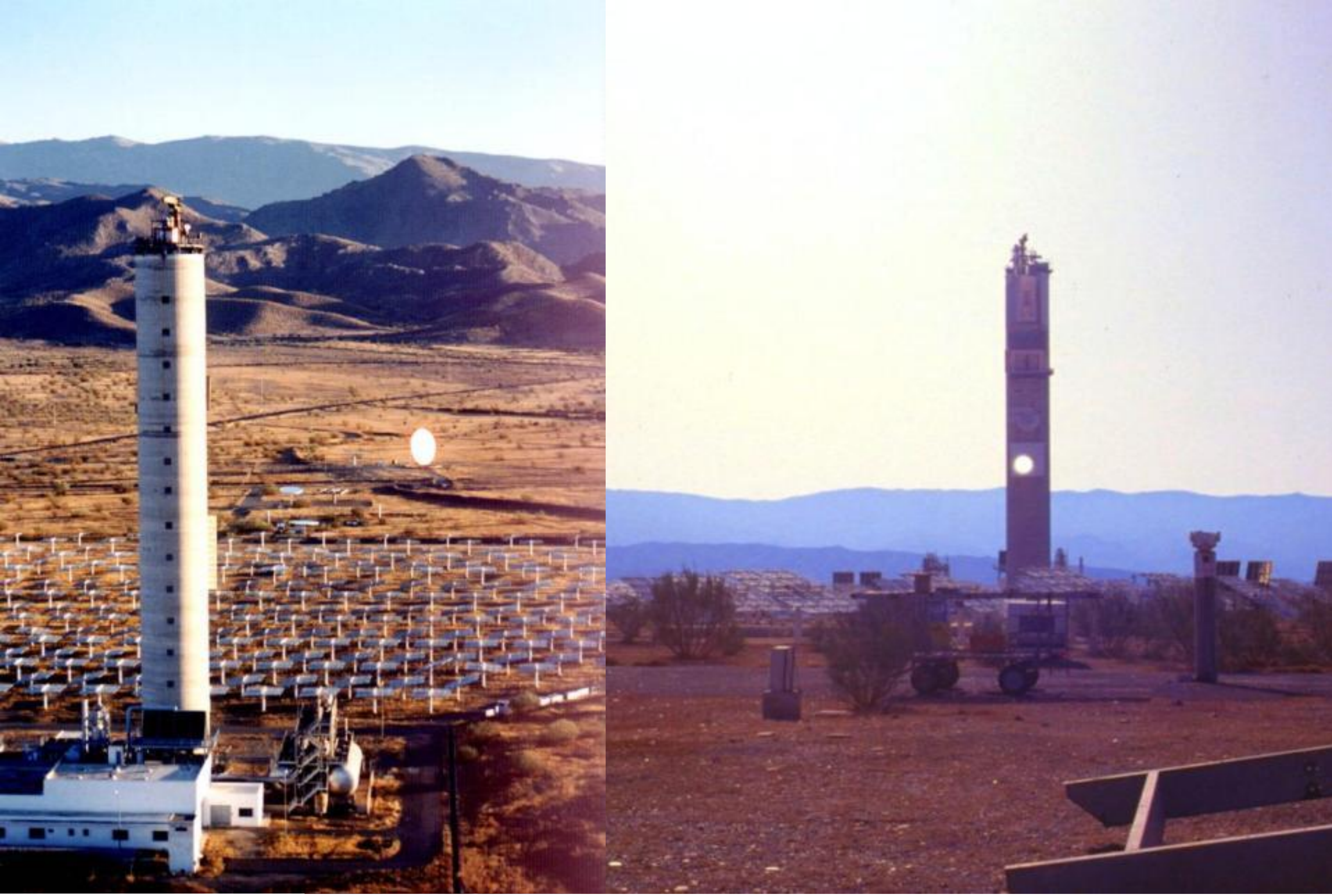

Receiver
Concentrated solar radiation
Heliostat
direct radiation
direct radiation
heliostat field
tower
heliostat field

GemaSolar by Torresol 19 MW (17h storage)

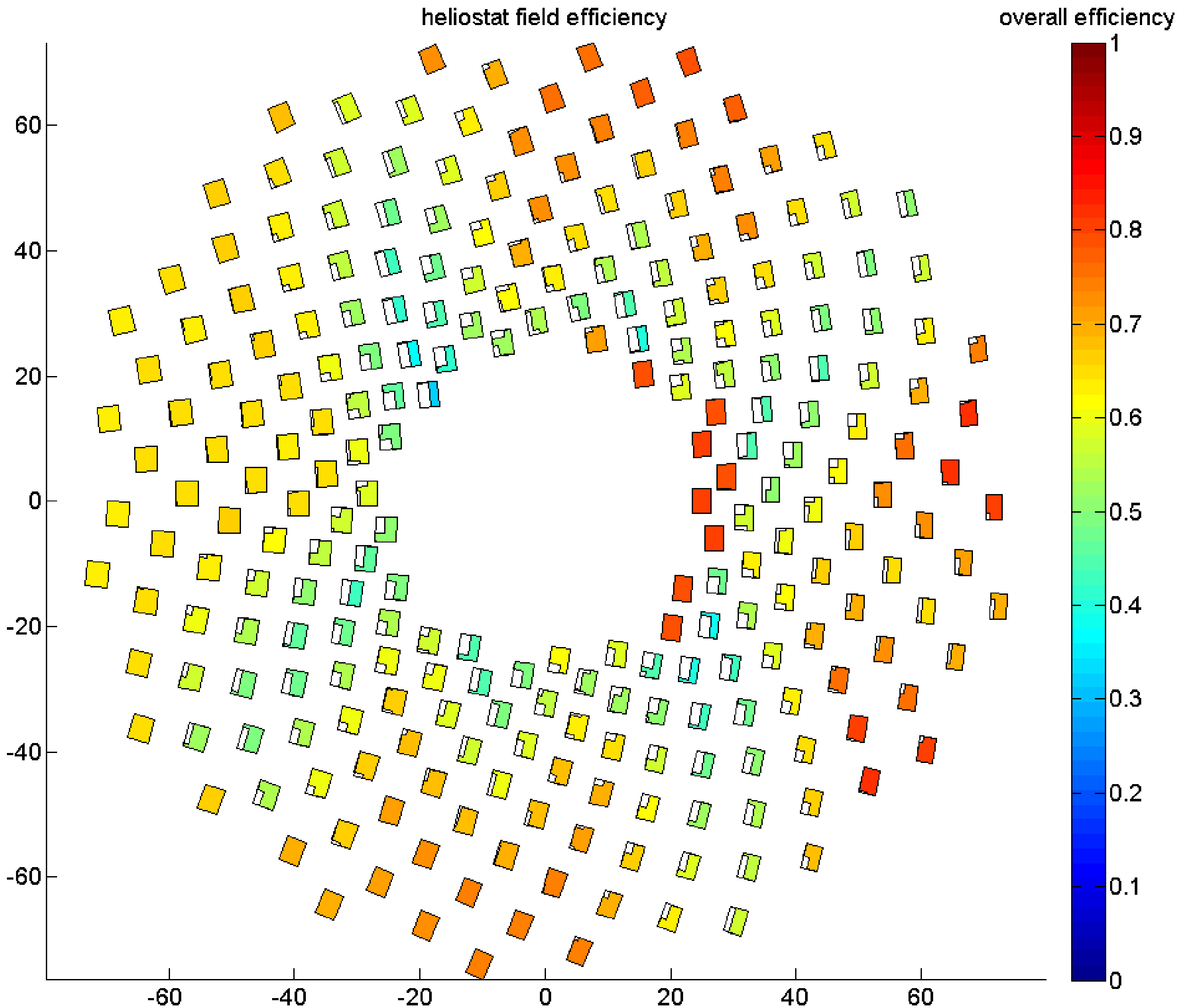
Conventional heliostat



SBP / Steinmüller 150 m² metal membrane heliostat – optical quality

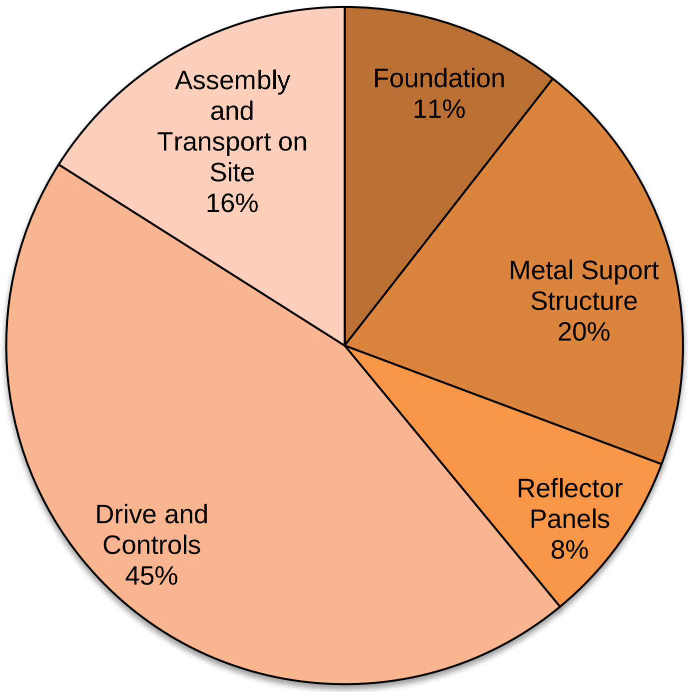


SBP 150 m² metall membrane heliostat – variable focal length

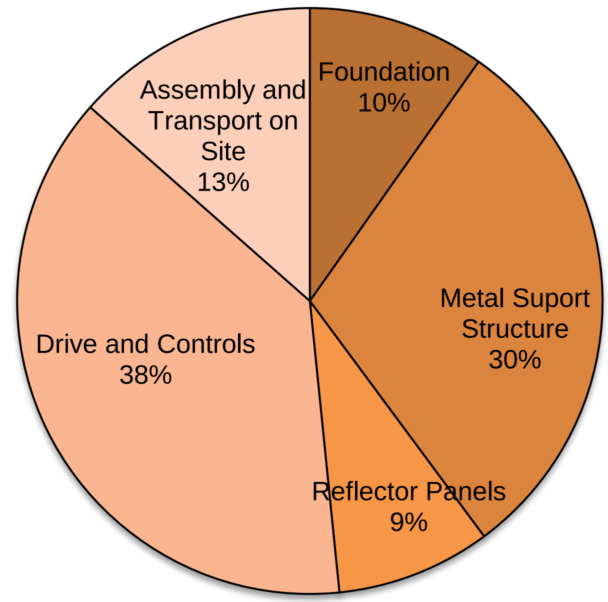


SBP Solar field efficiency – blocking and shading optimisation

Benchmark Heliostat



Current Heliostat Development (Status 6/2013)



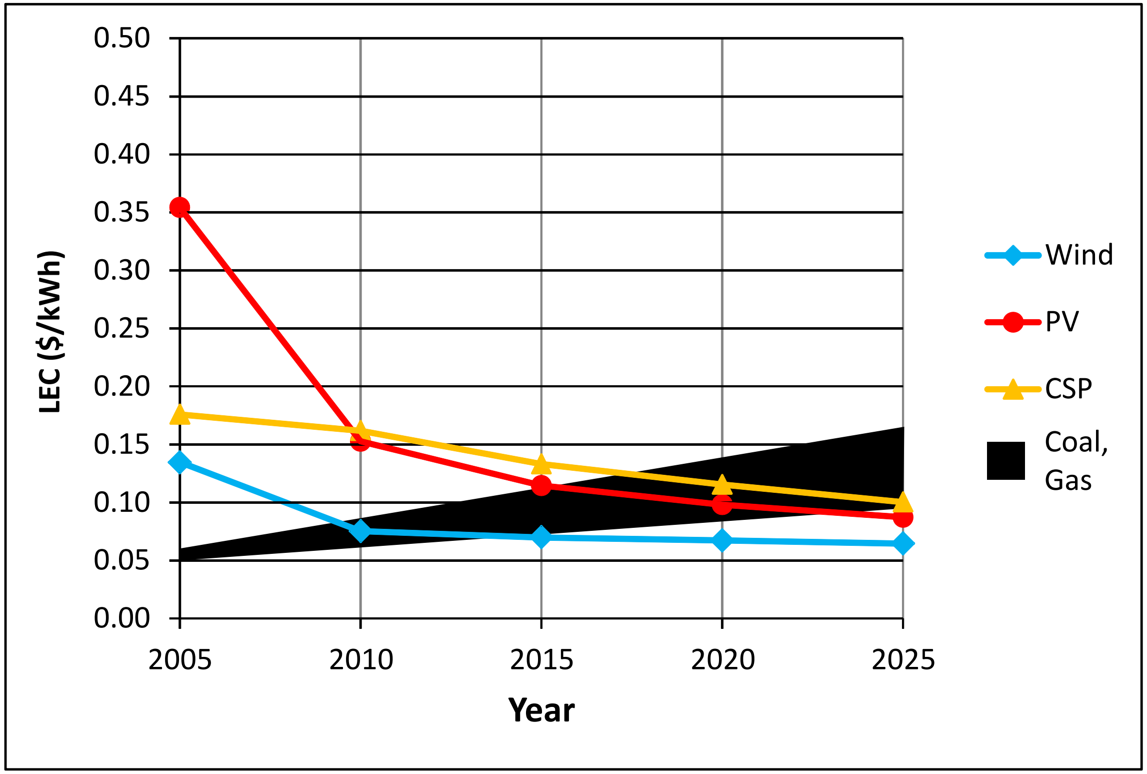
Benchmark Solarfield
60 MW_{el} 13h storage
~115 mio. MWh Thermal Power on Receiver annualy
Solarfield Cost = 164 Mio $
LCoE (project related) = 16,7 c$/kwh

Evolution Design
- higher optical efficiency
- reduction of drive costs
- new structural system

Solarfield Cost = 147 Mio $
LCoE (project related) = 14,4 c$/kwh
Cost reduction of solar field = 11%

Comparison of benchmark heliostat and current heliostat development

Technology trends



Installed capacity: 100 MW

Site: North Africa

Linear fuel cost escalation
as in 2000-2010, market prices

PV 2000 h/yr, 30 yr
Wind 2500 h/yr, 20 yr
no storage, no backup

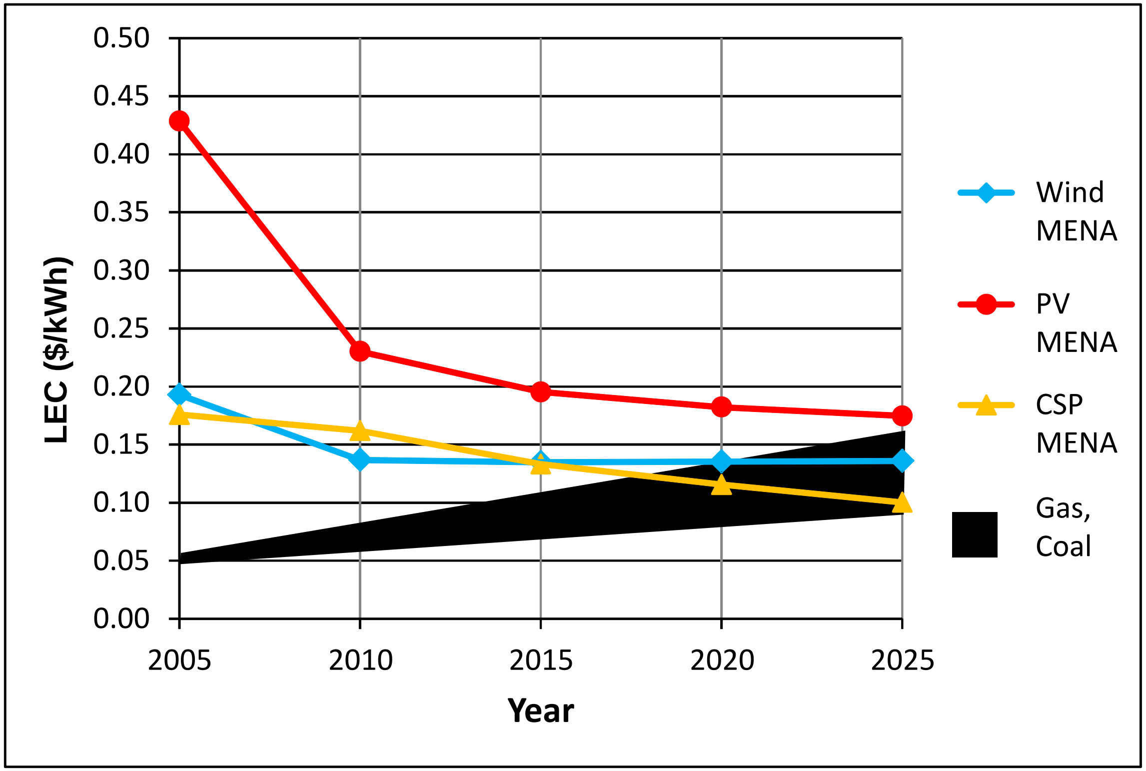
CSP 5500 h/yr, 40 yr
incl. thermal energy storage
and 10% hybrid operation with
natural gas

LEC = levelized electricity cost

Source: German Aerospace Center DLR, 2012

CSP, PV, Wind, Fuels: cost of generation in MENA

CSP, PV, Wind, Fuels: cost of flexible power in MENA



Load: 100 MW, 5500 h/y, 40 yr

Site: North Africa

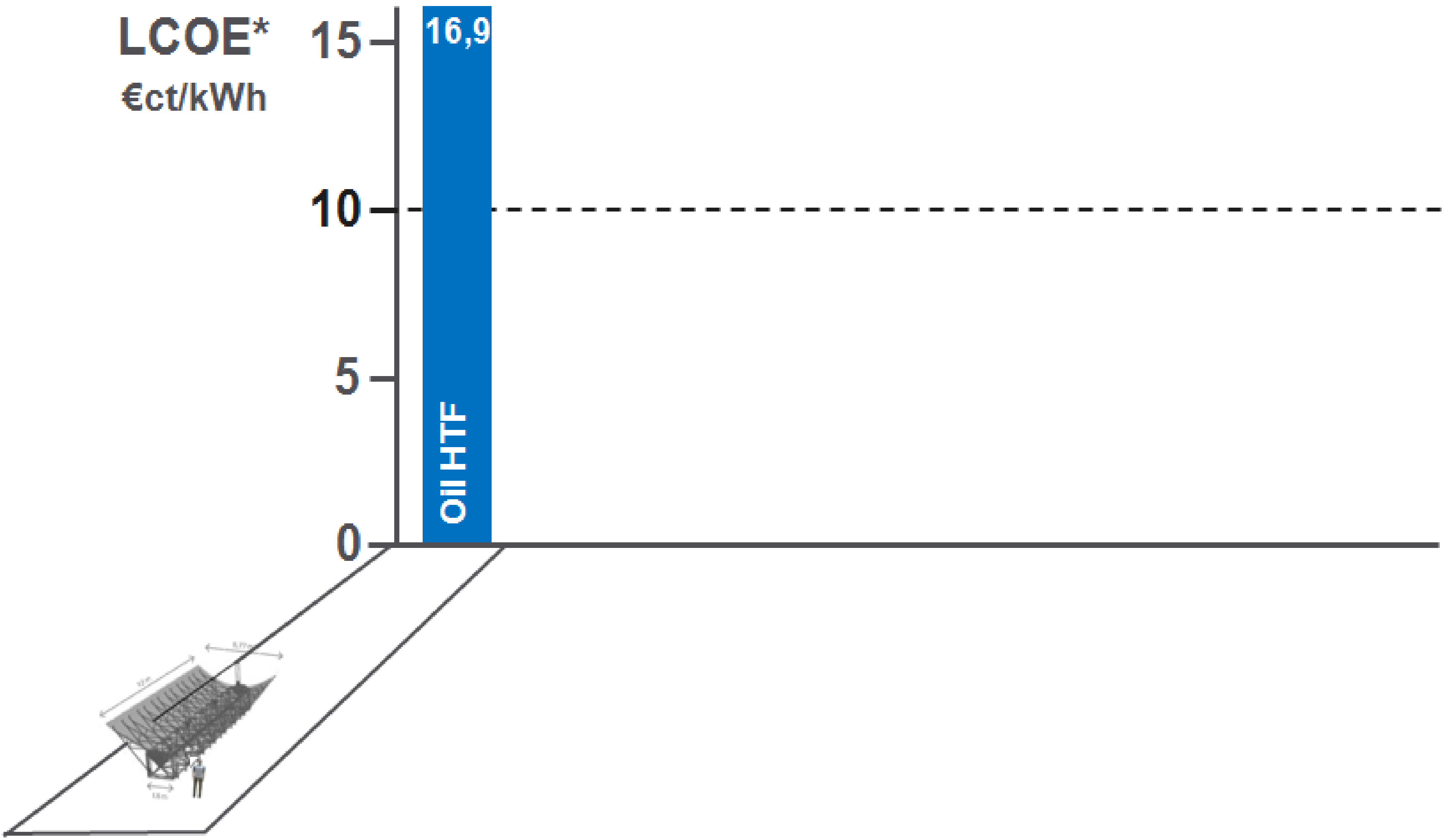
Linear fuel cost escalation as in 2000-2010, market prices

PV, Wind incl. pump storage; 10% backup by natural gas combined cycle

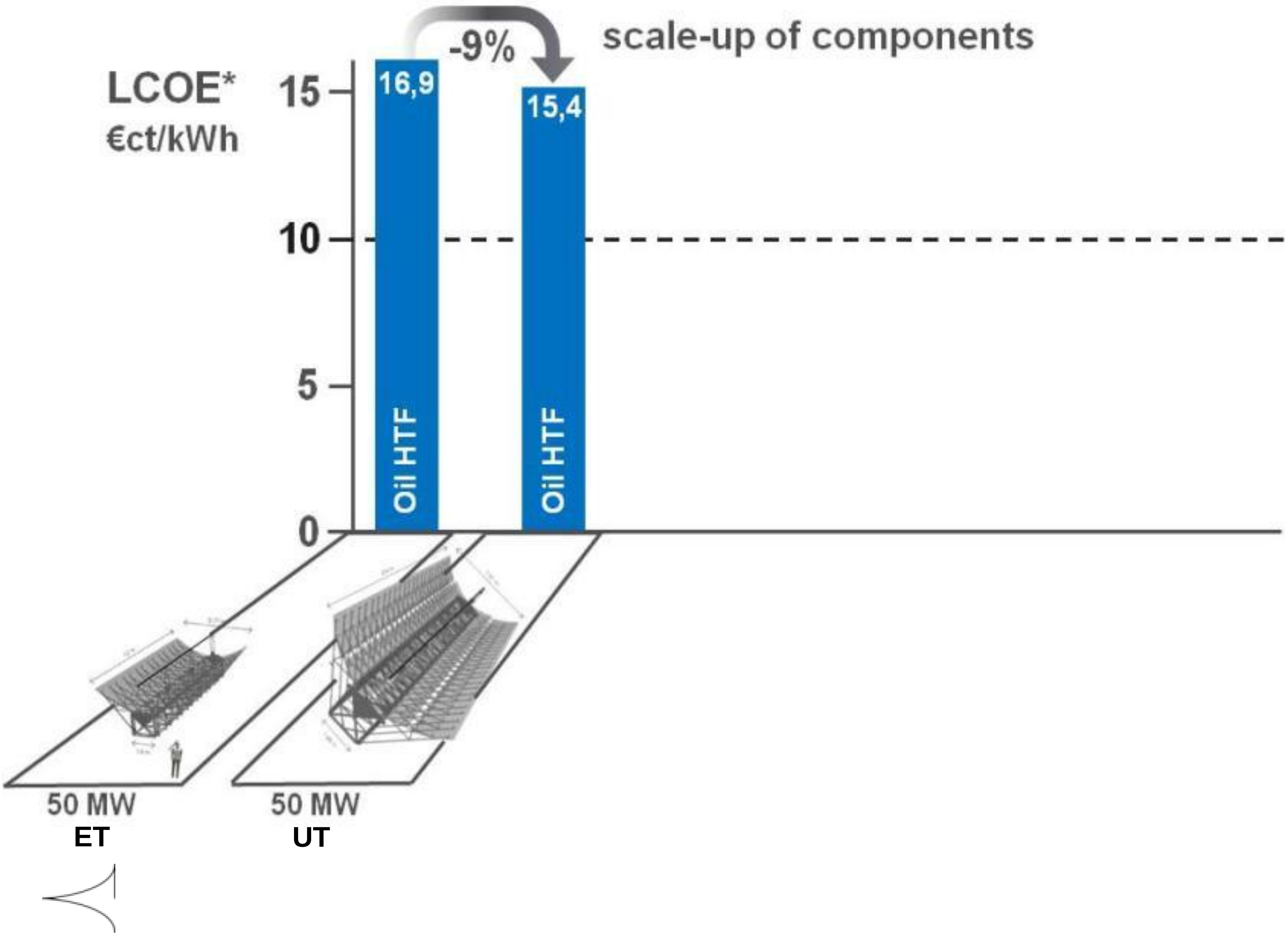
CSP incl. thermal energy storage and 10% hybrid operation with natural gas

LEC = levelized electricity cost

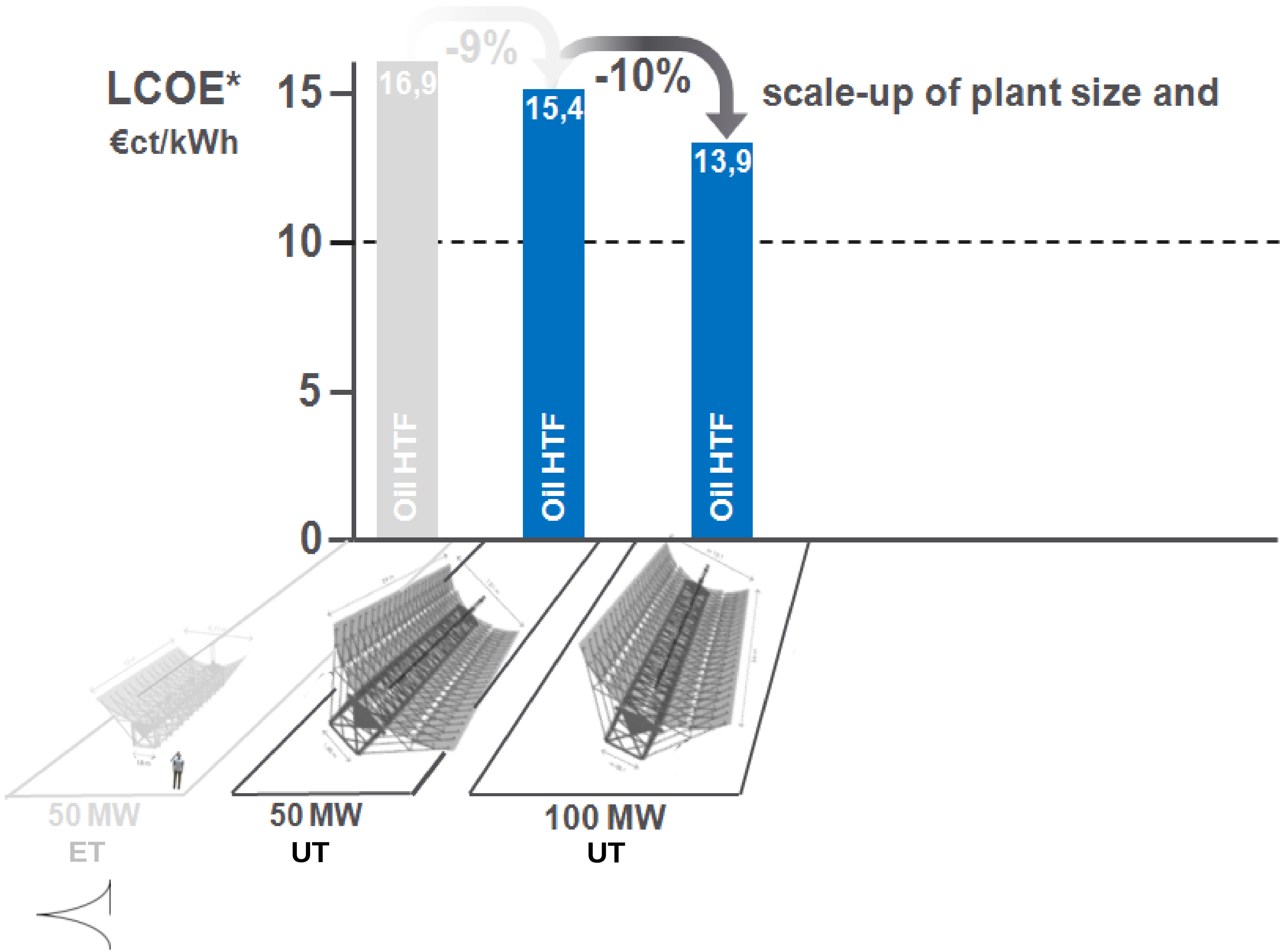
Source: German Aerospace Center DLR, 2012



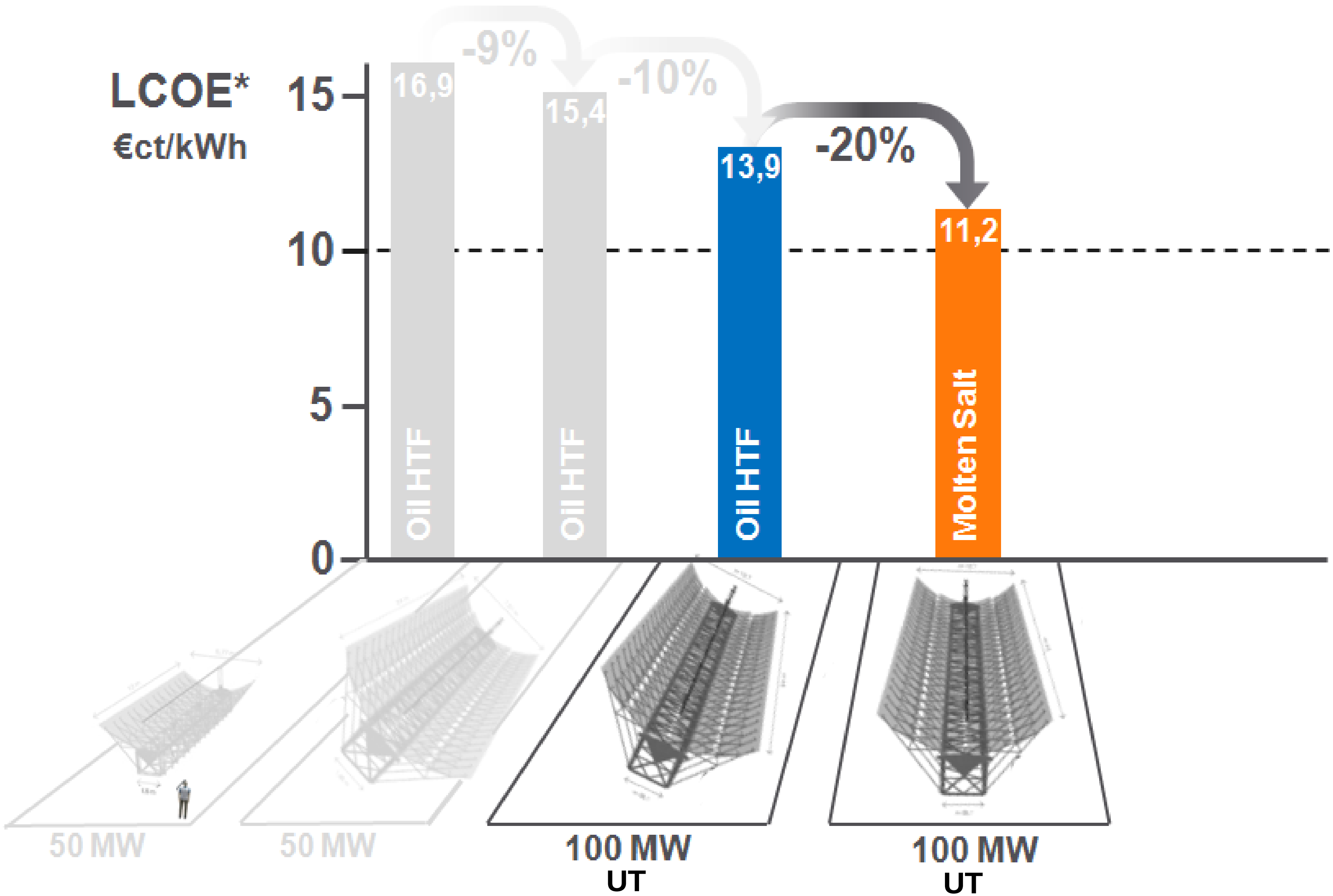
50 MW
ET



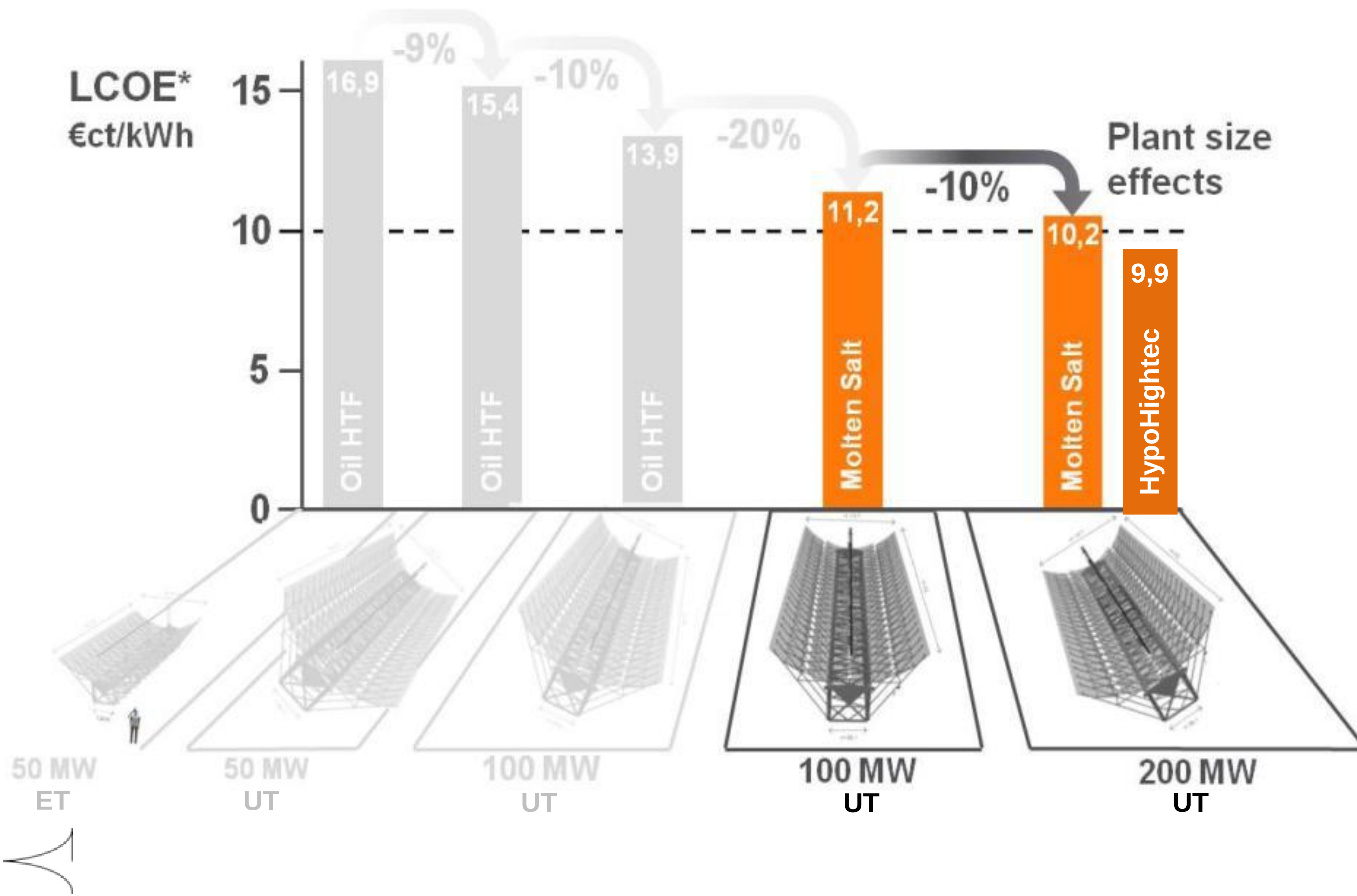
-9%
scale-up of components
LCOE*
€ct/kWh
15
10
5
0
16,9
15,4
Oil HTF
Oil HTF
50 MW
ET
50 MW
UT



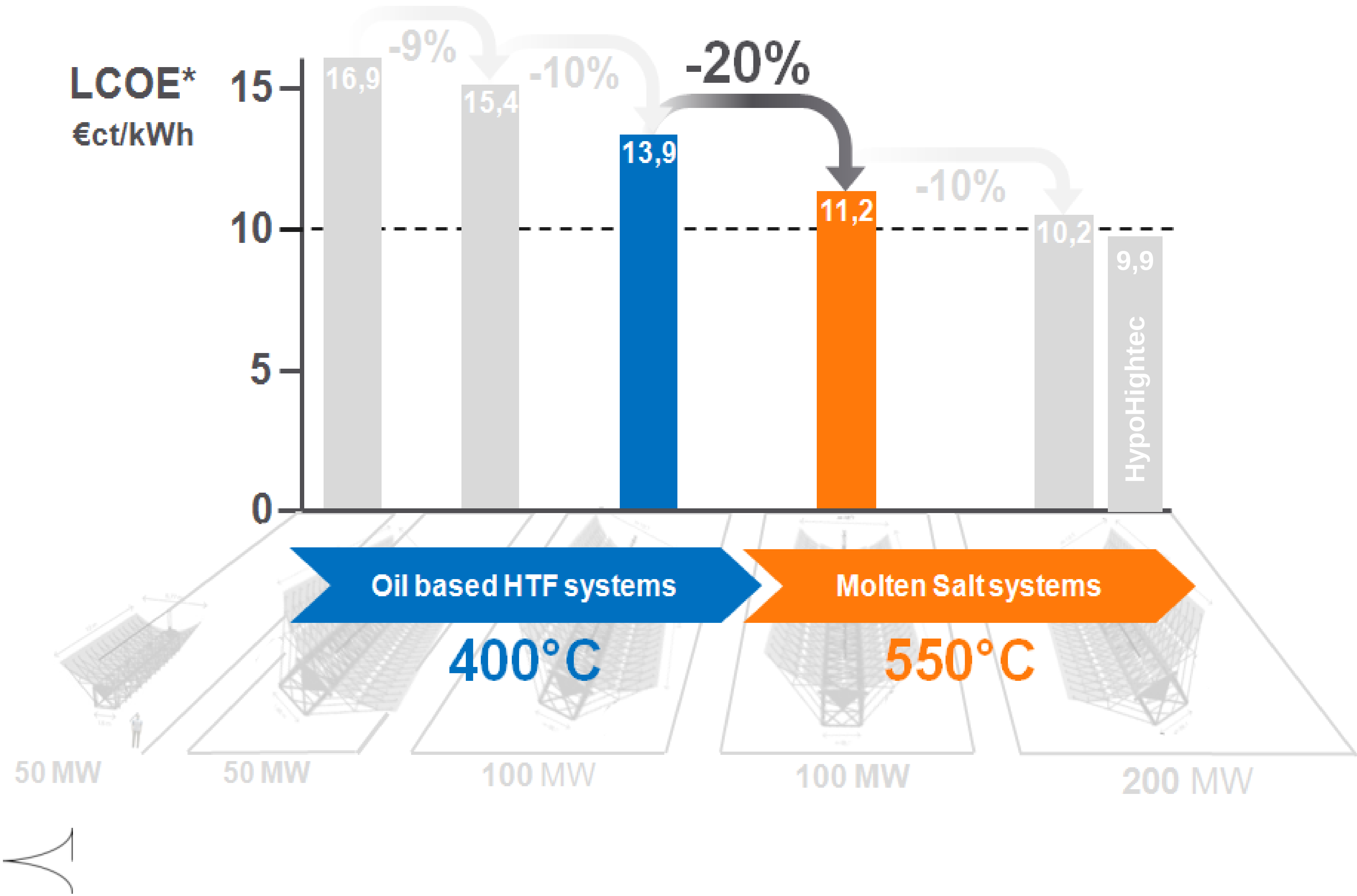
LCOE*
€ct/kWh
15
10
5
0
16,9
-9%
15,4
-10%
13,9
scale-up of plant size and
Oil HTF
Oil HTF
Oil HTF
50 MW
ET
50 MW
UT
100 MW
UT



LCOE*
€ct/kWh
15
10
5
0
16,9
-9%
15,4
-10%
13,9
-20%
11,2
Oil HTF
Oil HTF
Oil HTF
Molten Salt
50 MW
50 MW
100 MW
UT
100 MW
UT

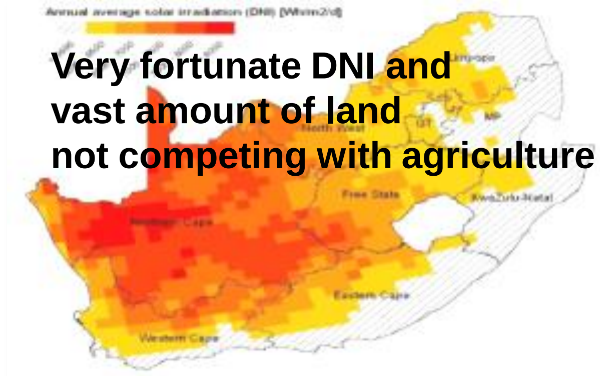


LCOE*
€ct/kWh
15
10
5
0
16,9
15,4
13,9
11,2
10,2
9,9
-9%
-10%
-20%
-10%
Plant size effects
Oil HTF
Oil HTF
Oil HTF
Molten Salt
Molten Salt
HypoHightec
50 MW
ET
50 MW
UT
100 MW
UT
100 MW
UT
200 MW
UT

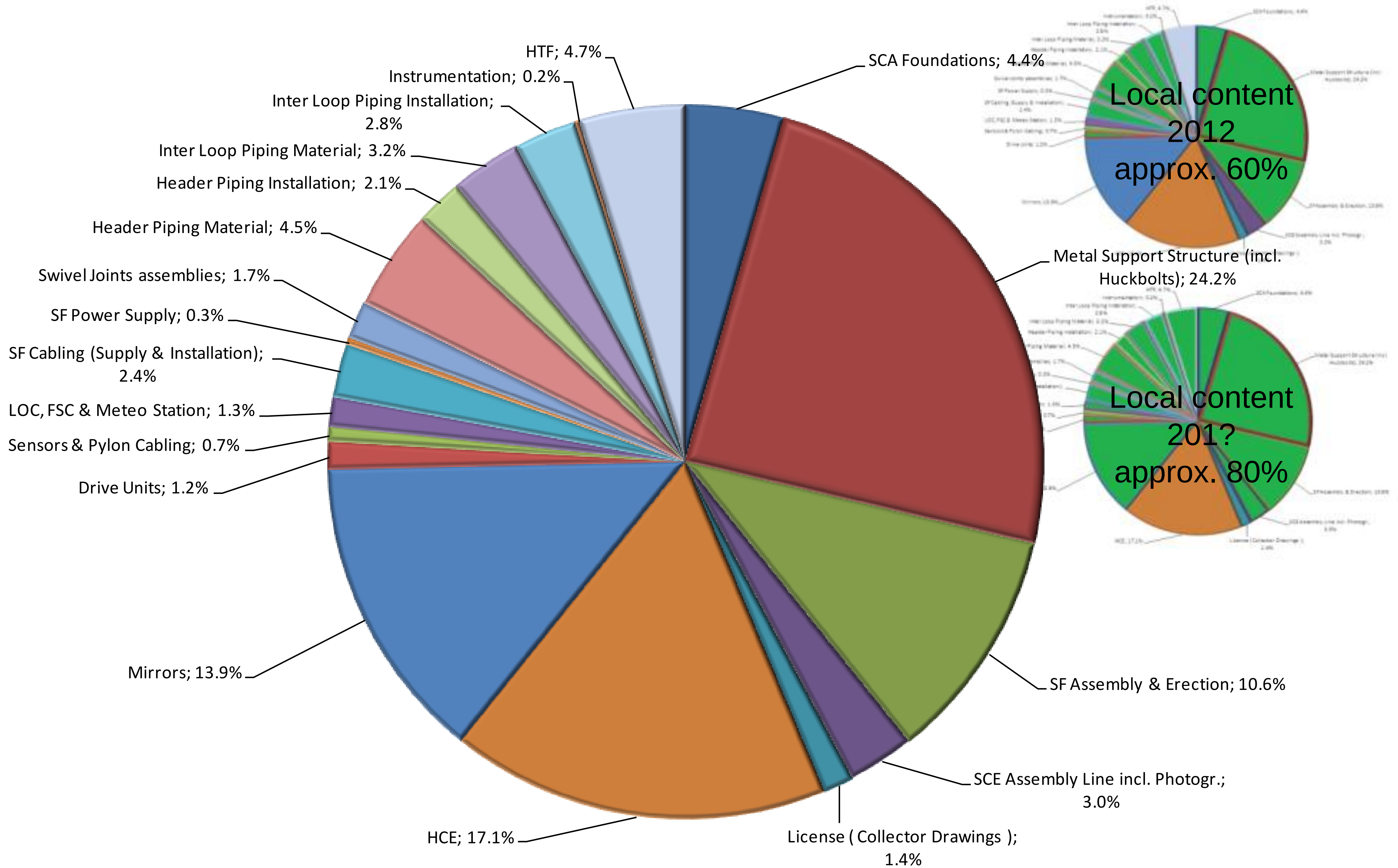


LCOE*
€ct/kWh
15
10
5
0
16,9
-9%
15,4
-10%
13,9
-20%
11,2
-10%
10,2
9,9
HypoHightec
Oil based HTF systems
400°C
Molten Salt systems
550°C
50 MW
50 MW
100 MW
100 MW
200 MW

CSP in South Africa



Significance to South Africa



Solar field costs – South African local content

Conclusions for South Africa

- CSP is the answer for many of SAs needs and requirements (Grid requirements, Flexibilty, local content , unemployment, solar resources etc.)
- SA has recognised the value of CSP (allocation 200MW/year and two tear feed in tariff), but it is very conservative facing technological/financial risks
- SA building contractors do not get in gear – why?
- SA has the manufacturing capabilities the technological institutions to support growth and significant development within this field

Thank you!

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