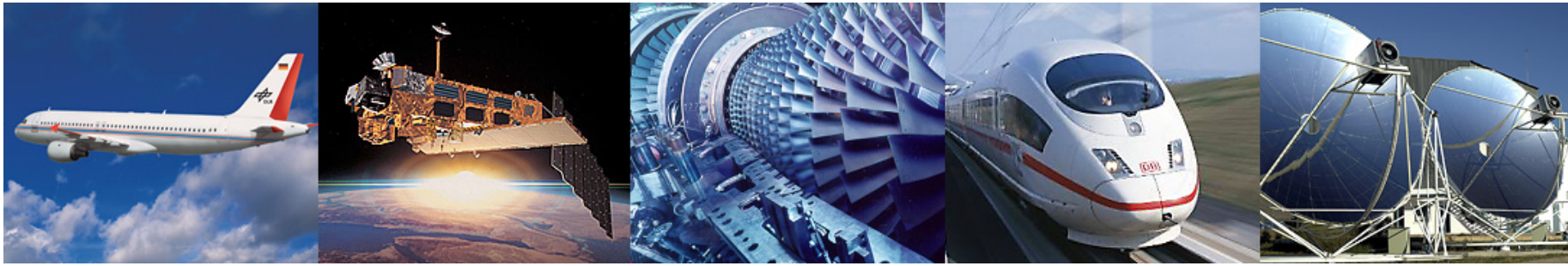
Concentrating Solar Thermal Technology and Solar Process Heat Projects: A focus on the MENA Region

German Aerospace Center (DLR)

Institute of Solar Research

Dirk Krüger

German Aerospace Center (DLR)



- Research Institution, Space Agency and Project Management Agency
- Research Areas:

  Aeronautics | Space Research and Technology | Transport | Energy | Defence and Security
- 8000 employees across 33 institutes and facilities at 16 sites in Germany
- 17 subsidiaries, co-operations and outposts in Germany, the Netherlands and Spain
- Offices in Brussels, Paris, Tokyo and Washington
- Total income 2015: €891 Mio. (about 9% for Energy Research)

Institute of Solar Research

150 people
4 sites

Institute of Solar Research

Directors

Prof. Dr. Robert Pitz-Paal/ Prof. Dr. Bernhard Hoffschmidt

Point-Focus Systems
Dr. Reiner Buck (34 P)

Line-Focus Systems
K. Hennecke (16 P)

Qualification
Dr. P. Heller (33 P)

Solar Chemical Engineering
Dr. C. Sattler (24 P)

Facilities and Solar Materials
Dr. K.-H. Funken (20 P)

DLR Solar Research Goals

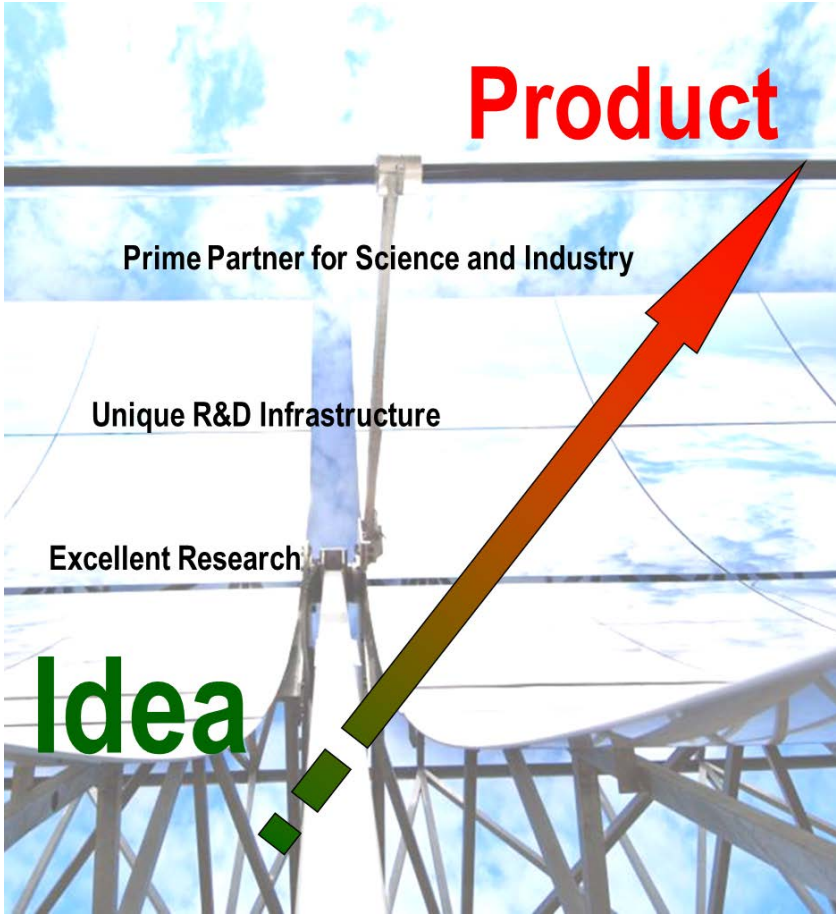
<u>Short Term:</u> Support deployment of mature technologies

- Technology transfer, Consulting, Studies
- Quality Assurance, Standardisation

<u>Medium Term:</u> Technology development for sustainable market penetration

- High Temperatures for high efficiency
  - New heat transfer media
  - High temperature receivers
- Improved operation for increased revenues
  - Include weather and market forecast
- Exploitation of new market segments
  - Process heat, water desalination…

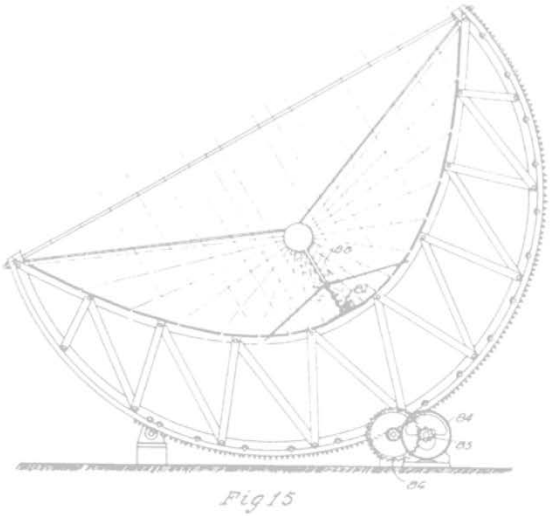
<u>Long Term:</u> Solar fuels for long term storage, transport and mobility

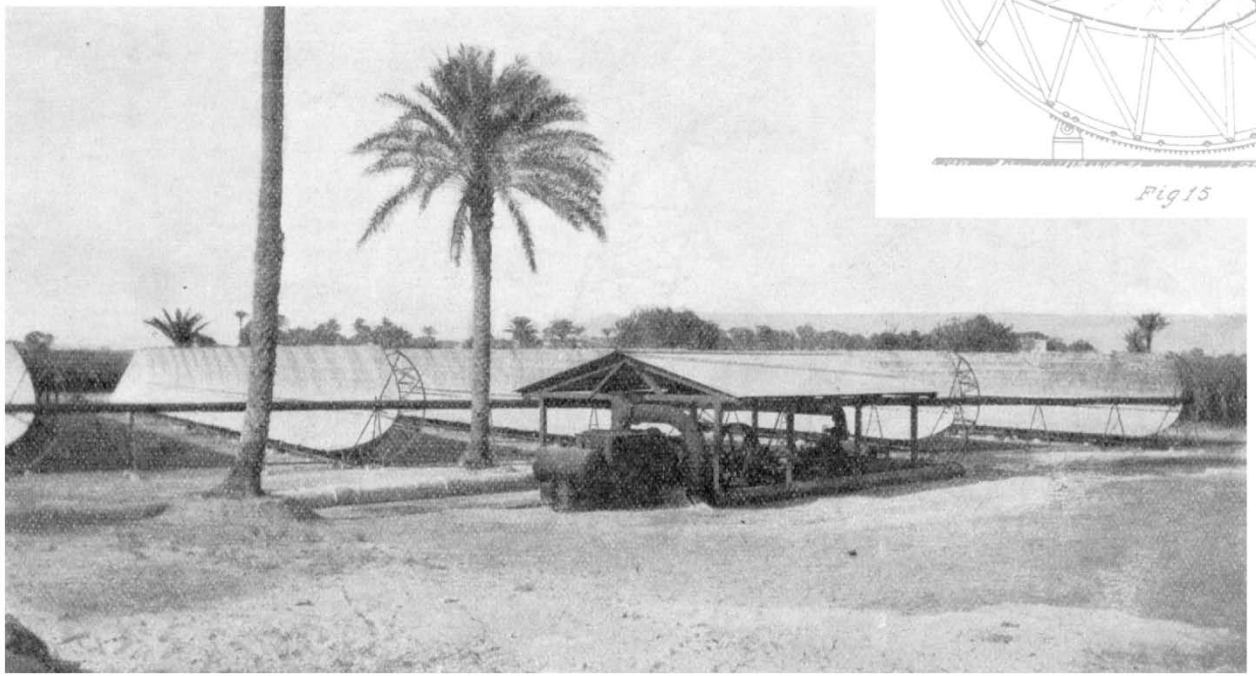


Introduction to CSP

first parabolic trough collectors:

- construction in 1912 in Egypt (Meadi)
- saturated steam at 1 bar
- steam motor connected to a water pump (380 l/s)

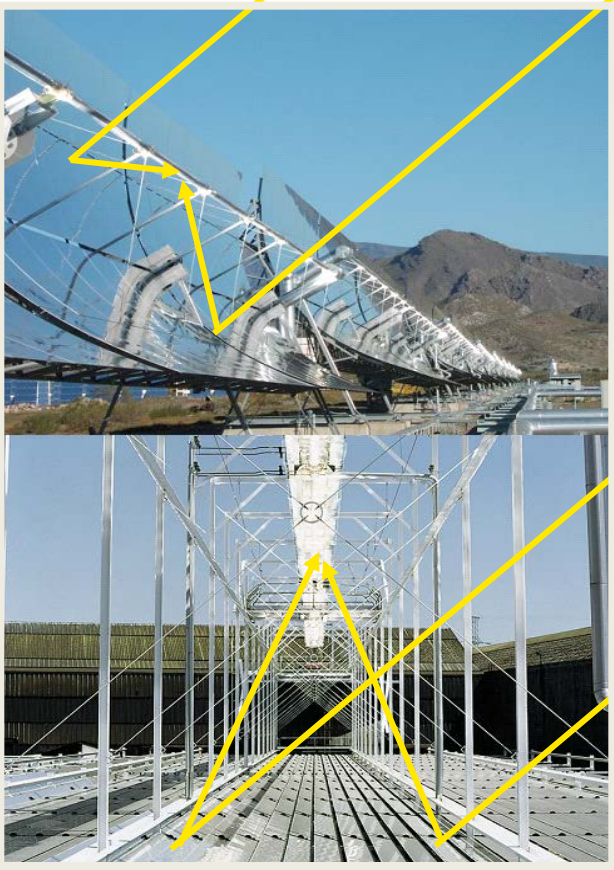




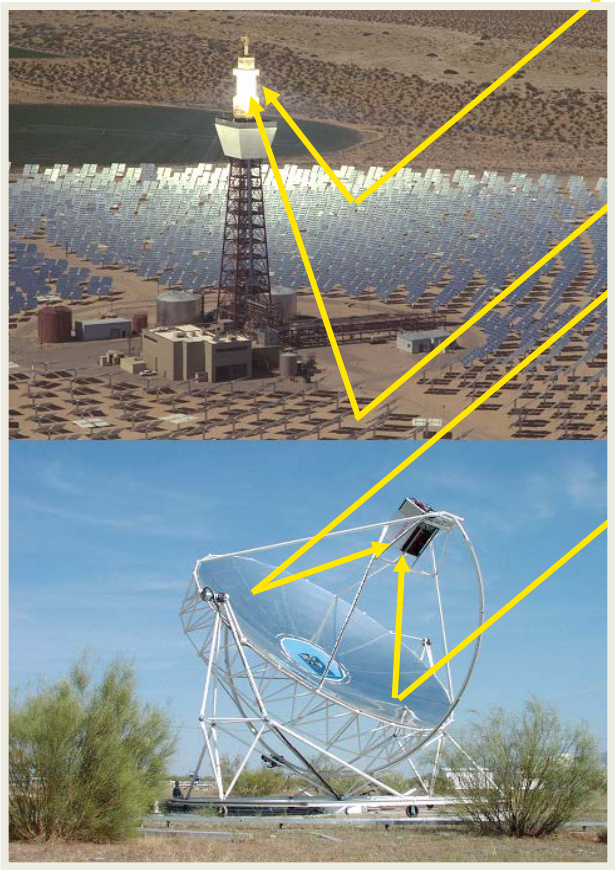
Introduction to CSP

How does it work?

Parabolic Trough (Foto DLR)



Solar Tower (Foto SNL)



Up to 550 °C Steam Turbines

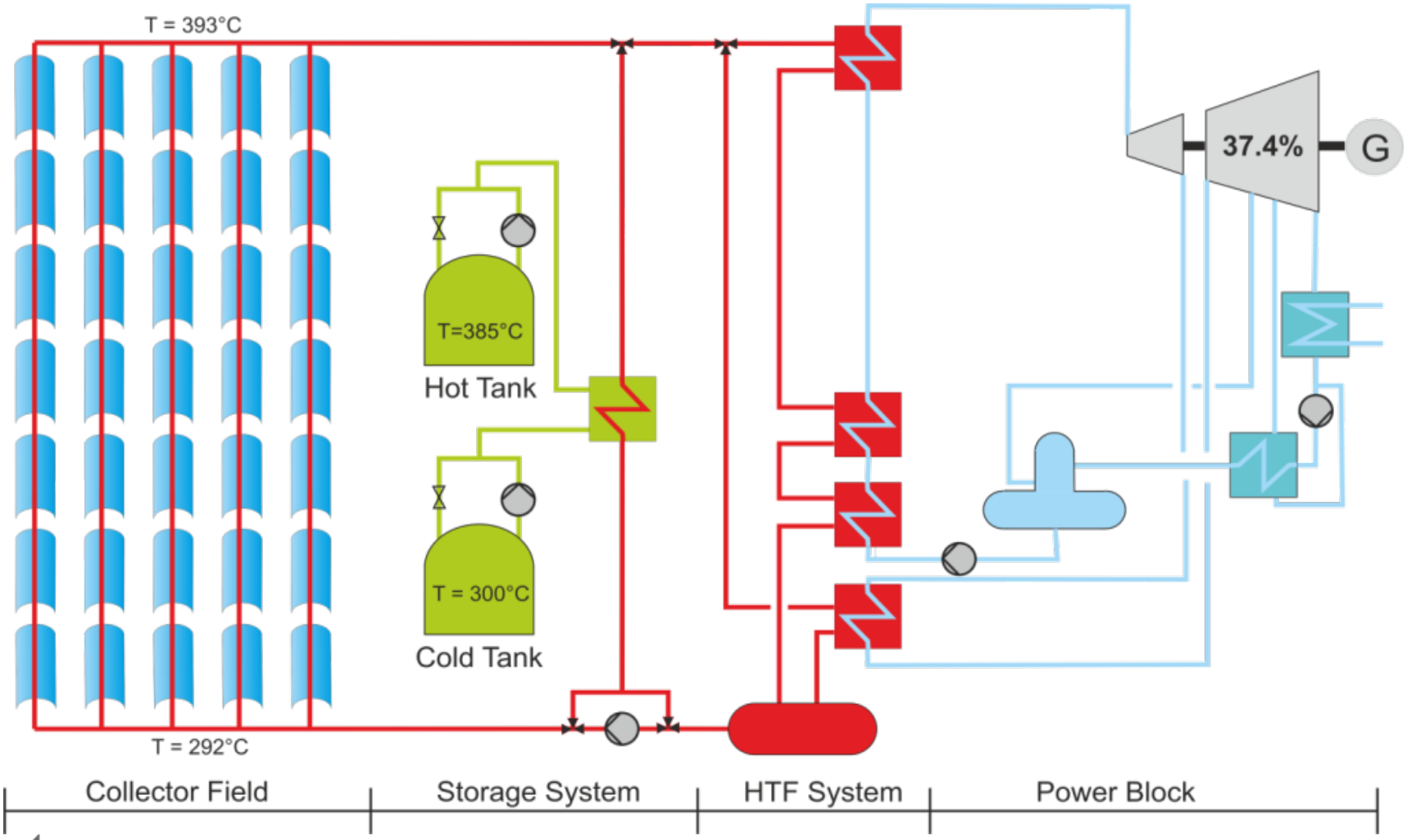
Up to 1000 °C Gas Turbines, Motors

Linear Fresnel (Foto MAN/SPG)

Dish-Stirling (Foto SBP)

Introduction to CSP plants

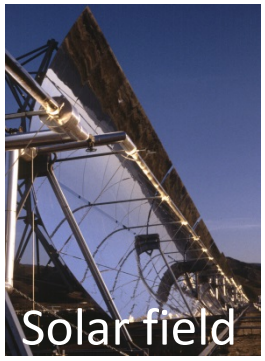
What distinguishes a CSP plant?



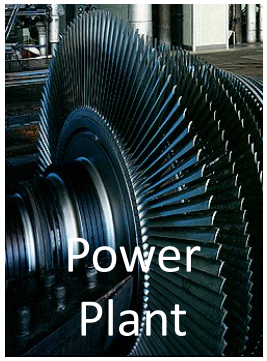
Introduction to CSP plants

What distinguishes a CSP plant?

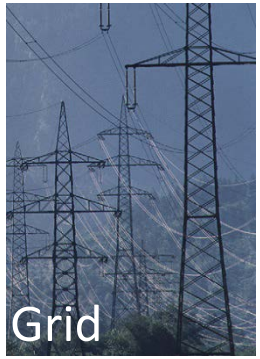
Solar-Irradiation



Heat



Electricity

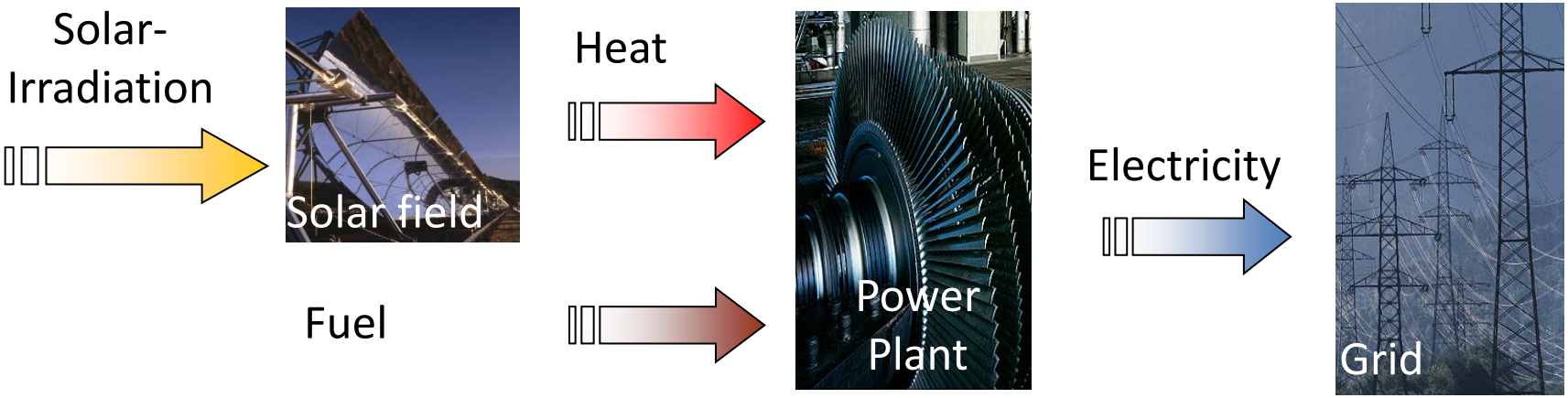


Pure solar electricity production

Additional generation capacity required in the grid

Introduction to CSP plants

What distinguishes a CSP plant?

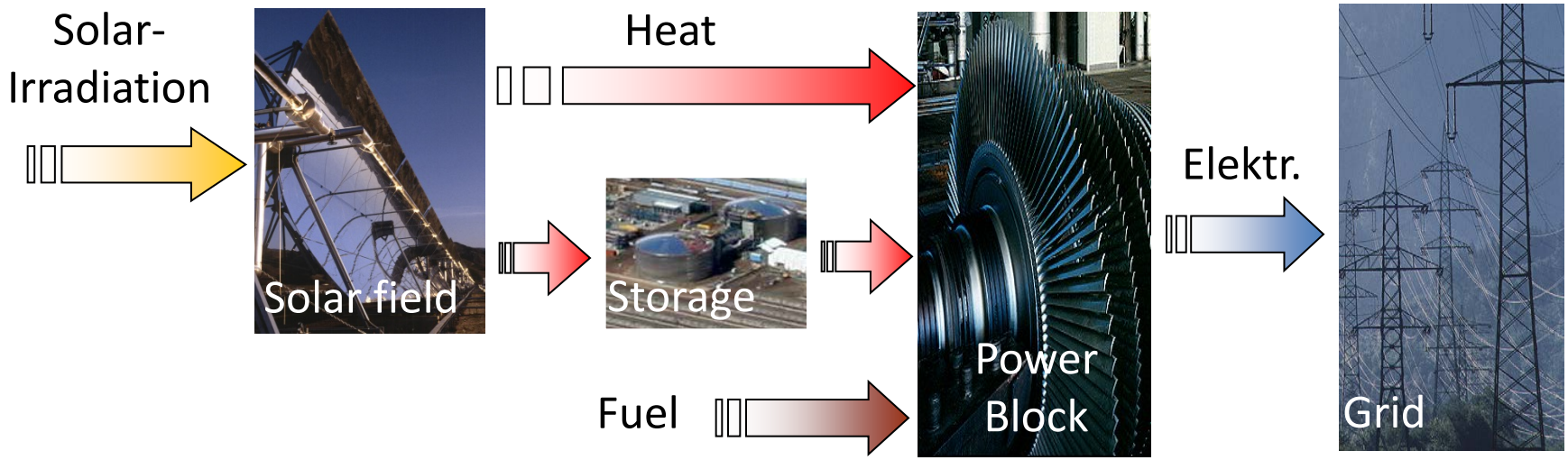


Solar electricity generation

Integrated back-up for power as required

Introduction to CSP plants

What distinguishes a CSP plant?

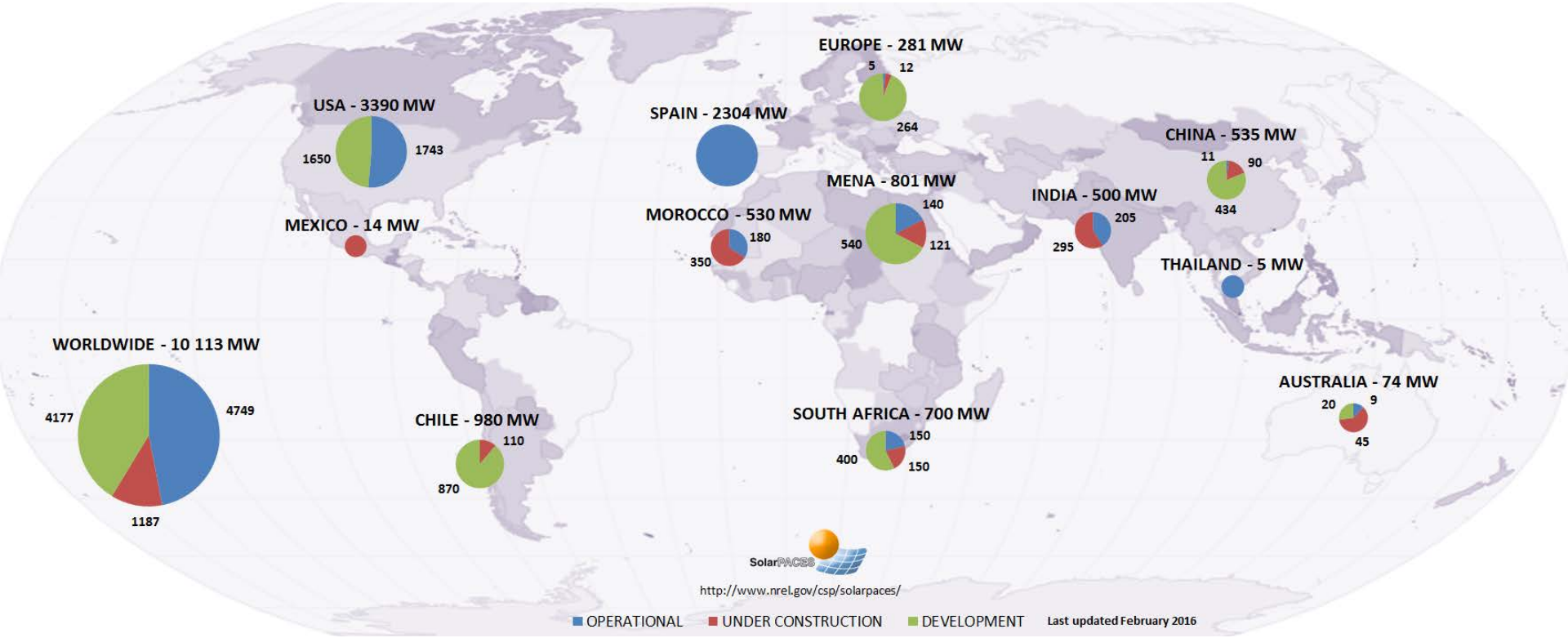


Solar electricity generation

Integrated back-up for power as required

Integrated storage capacity to increase solar share

CSP worldwide market

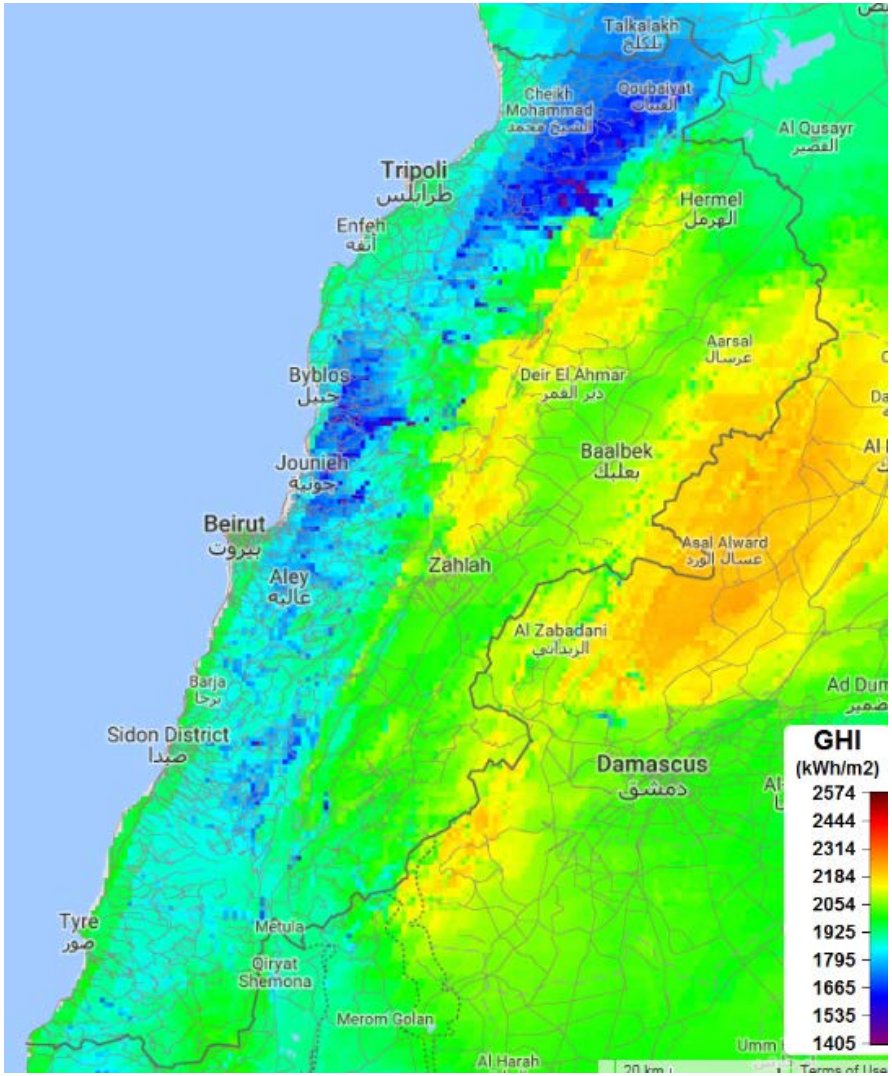


http://www.nrel.gov/csp/solarpaces/

Feb. 2016

Solar Radiation Profile of Lebanon

MeteoNorm data:
Annual DNI (Direct Normal Radiation)
in Beirut: 1864 kWh/m²
in Ksara: 2179 kWh/m²



Commercial Parabolic Trough TechnologyInstallation NOOR 1 Ouarzazate, Morocco

The Moroccan solar plan foresees 2000 Mwel of solar power.

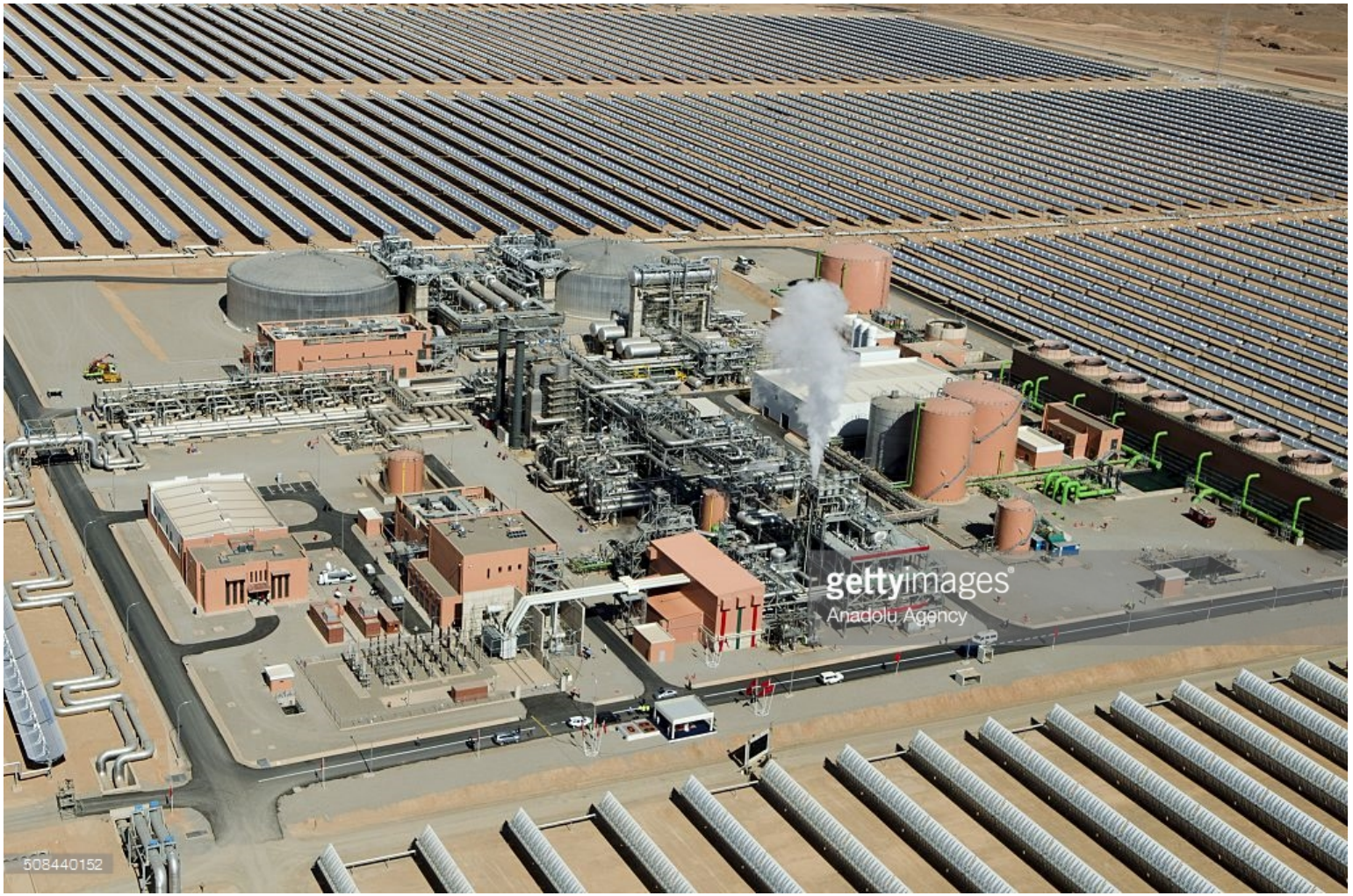
The first plant within this complex is the 160 MW Ouarzazate CSP Project with 3 hours of thermal energy storage to be developed on a Build, Own, Operate and Transfer (BOOT) basis.

Installation	Max. Power (MW)	Type	Start operation
1	160	Parabolic Trough Plant	February 2016
2	200	Parabolic Trough Plant	in construction
3	160	Solar Tower Plant	in construction
4	50	PV Plant	in planning

Abengoa

Commercial Parabolic Trough Technology
Noor 1 Plant, Morocco

Commercial Parabolic Trough Technology
First Noor Plant, Morocco



Commercial Parabolic Trough Technology
Solana, Arizona, USA

- Thermal Oil
- 280 MWe
- 6h storage (molten salt)

Abengoa

Commercial Tower Technology
Crescent Dunes / Tonopah, Nevada, USA

- Molten Salt
- 110 MWe
- 10 h Storage

Solar Reserve

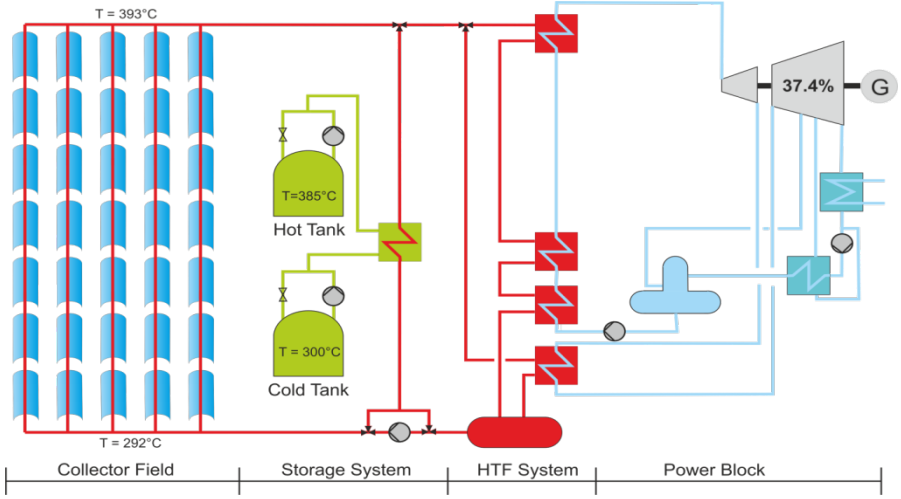
Commercial Parabolic Trough Technology
TSE-1, Kanchanaburi, Thailand

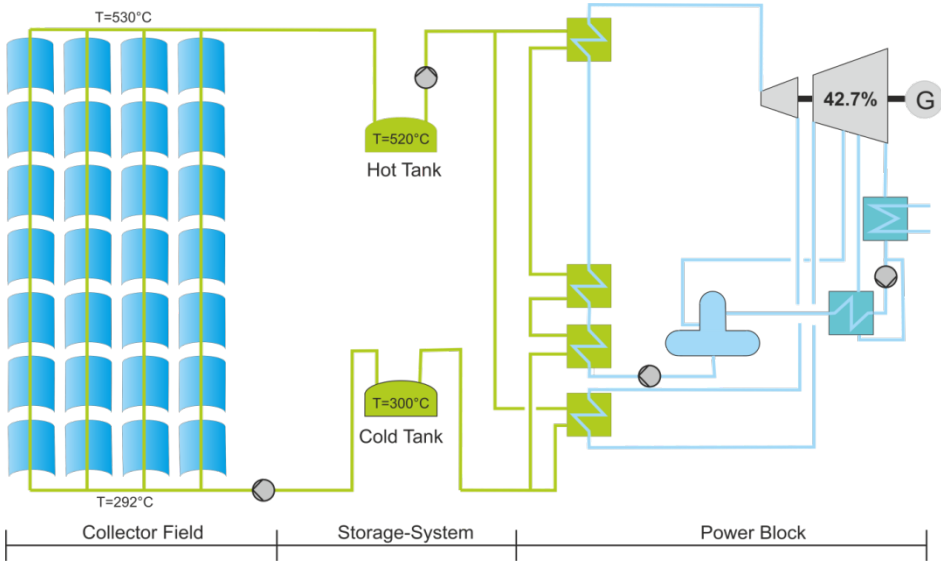
- Direct Steam Generation at 330°C and 30 bar
- 5 MW Electrical Power

Solarlite

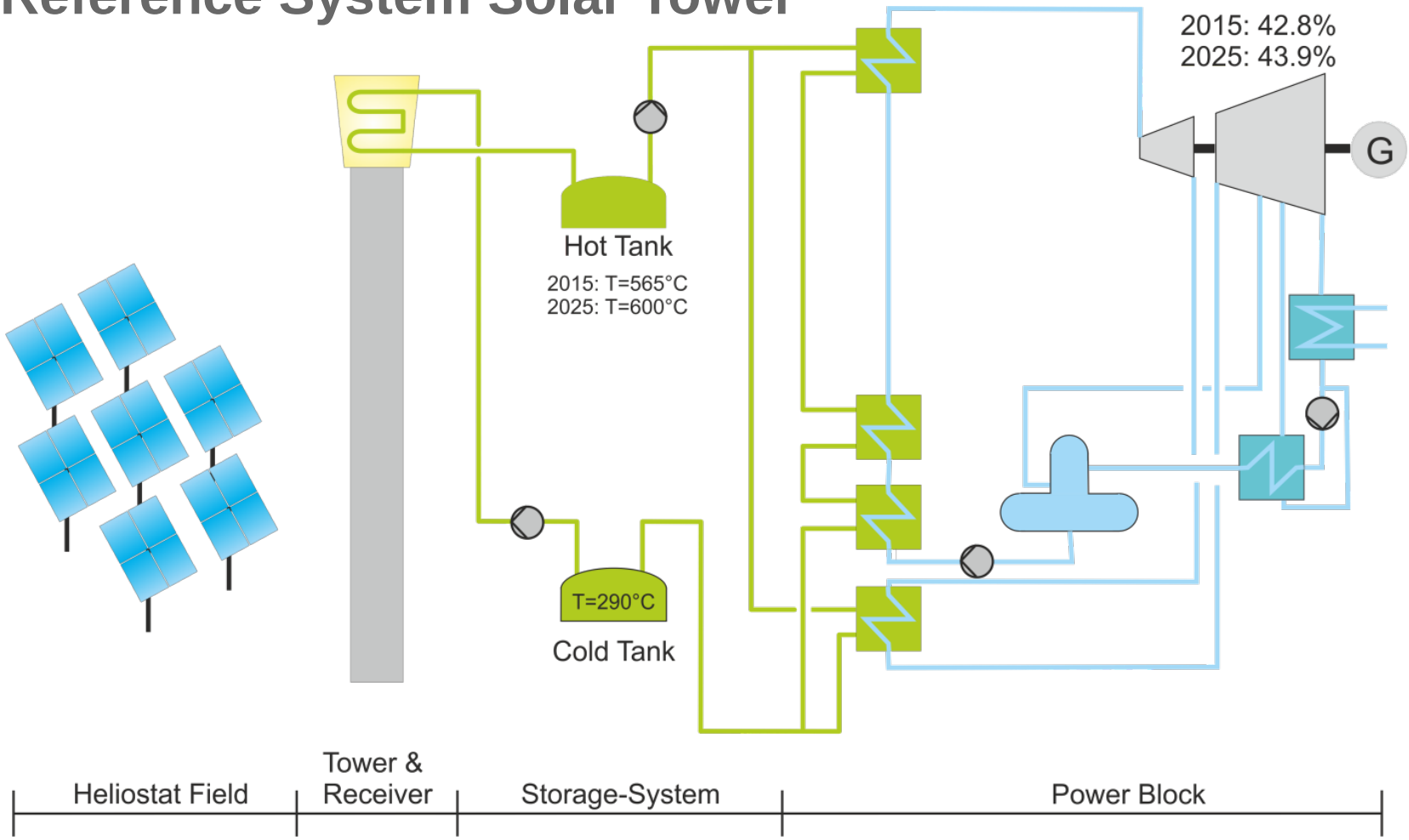
IRENA cost reduction study
Reference Systems Parabolic Trough

- 2015 Thermal Oil HTF & Molten Salt Storage
- 2025 Molten Salt HTF & Molten Salt Storage





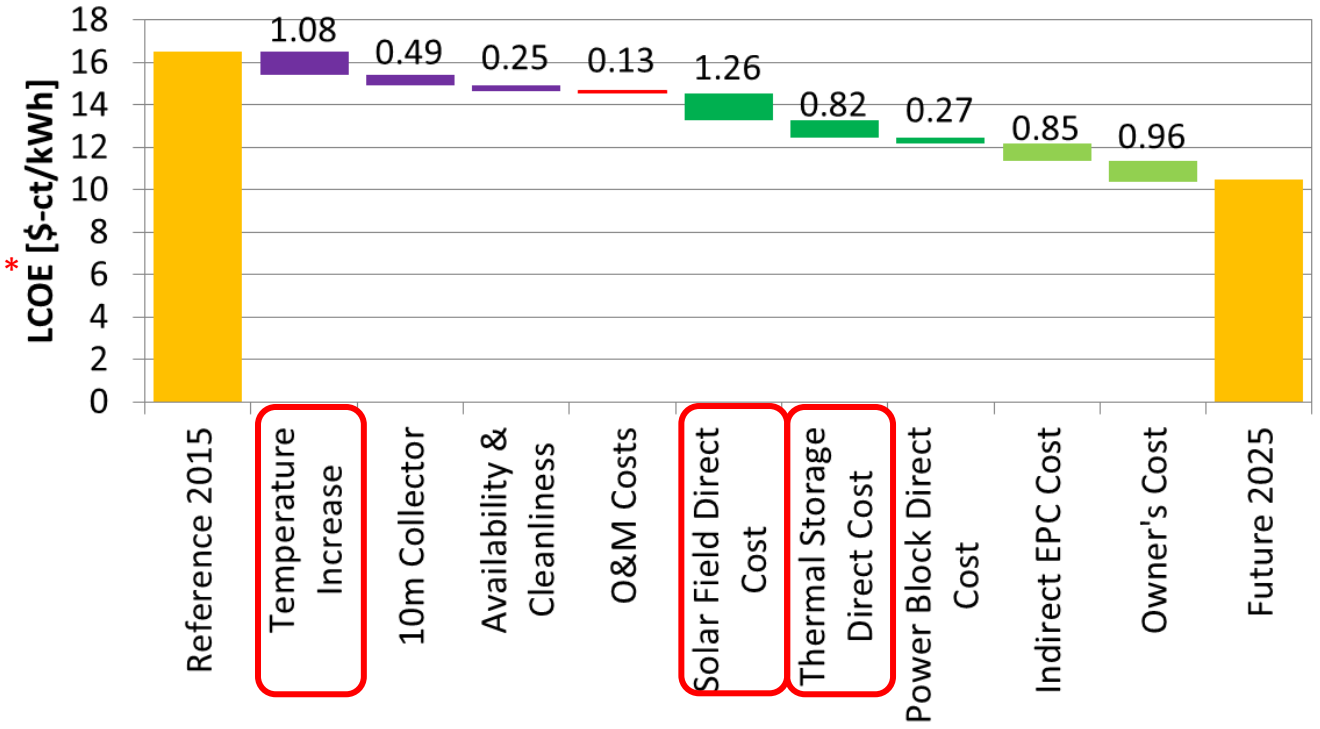
IRENA cost reduction study
Reference System Solar Tower



IRENA cost reduction study
Reference Plants Boundary Conditions

Design Parameters in Year 2015	Unit	Parabolic Trough	Solar Tower
Site		Ouarzazate, Morocco	
Direct normal irradiation (DNI)	[kWh / (m²·a)]	2017 / 2558 / 2935	
Solar collector / heliostat		Ultimate Trough®	Stellio®
Heat transfer fluid (HTF)		Thermal Oil	Molten Salt
Storage medium		Molten Salt	Molten Salt
Maximum HTF temperature	[°C]	393	565
Thermal energy storage capacity (full load hours)	[h]	7.5	9[1]
Gross electrical output	[MW]	160	150

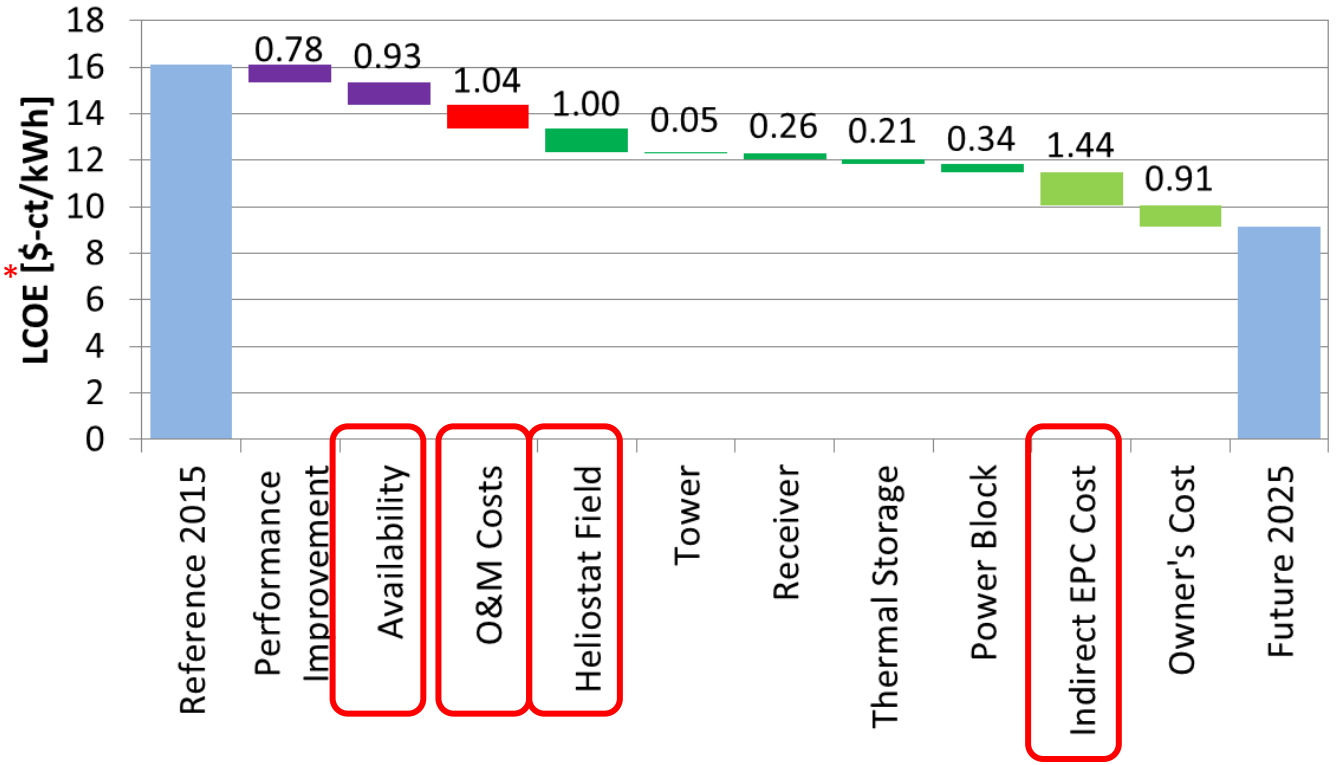
IRENA cost reduction study
Main Cost Drivers Parabolic Trough Technology



- Molten Salt as HTF ($T_{HTF,out}$ = 530°C → η_{Carnot} + storage CAPEX)
- Troughs with 10m aperture width → Solar field CAPEX

*Based on 7.5% WACC

IRENA cost reduction study
Main Cost Drivers Solar Tower Technology



- Aggressive learning rate (Availability, O&M costs, Indirect EPC Costs)
- Heliostat field CAPEX

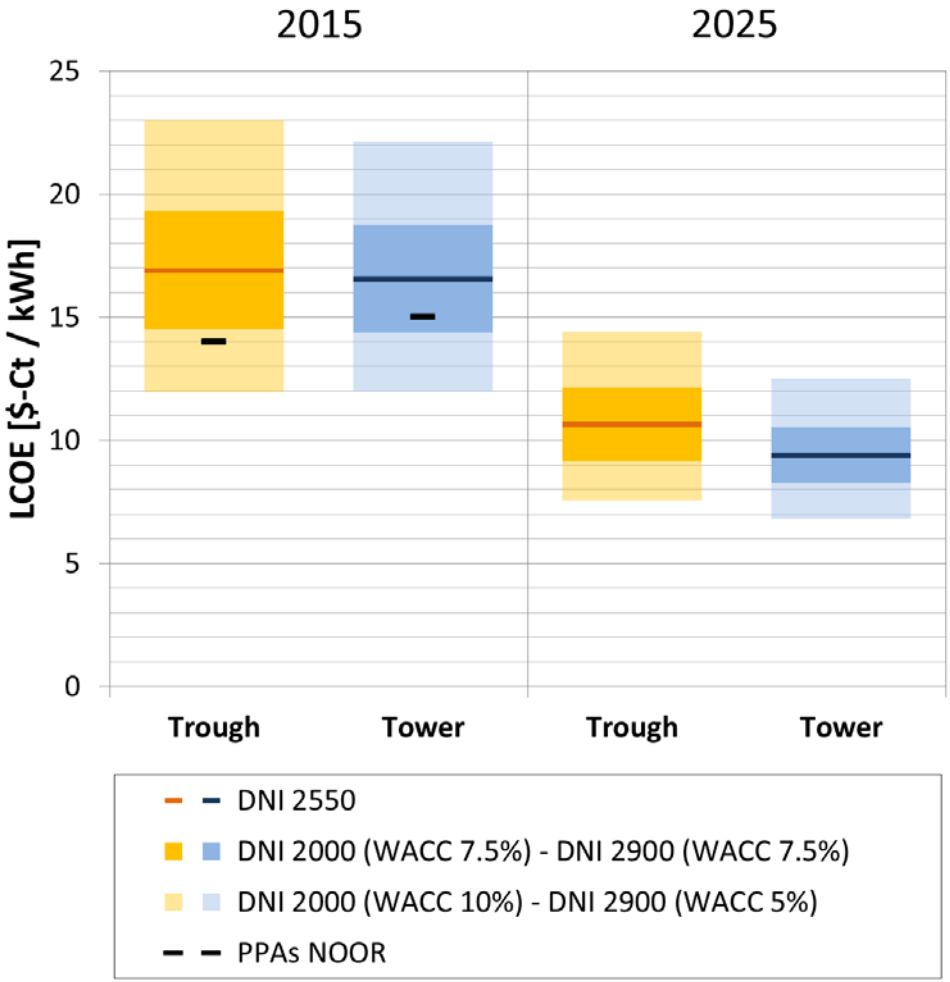
*Based on 7.5% WACC

IRENA cost reduction study
LCOE Comparison of Trough and Tower Technology

- Trough technology has strong ***technical cost reduction*** *potential* with molten salt as HTF

- Tower technology in 2015 includes massive ***risk and contingency surcharges***:
  - 93% availability (vs. 99%)
  - 39% indirect EPC/owner (vs. 29%)

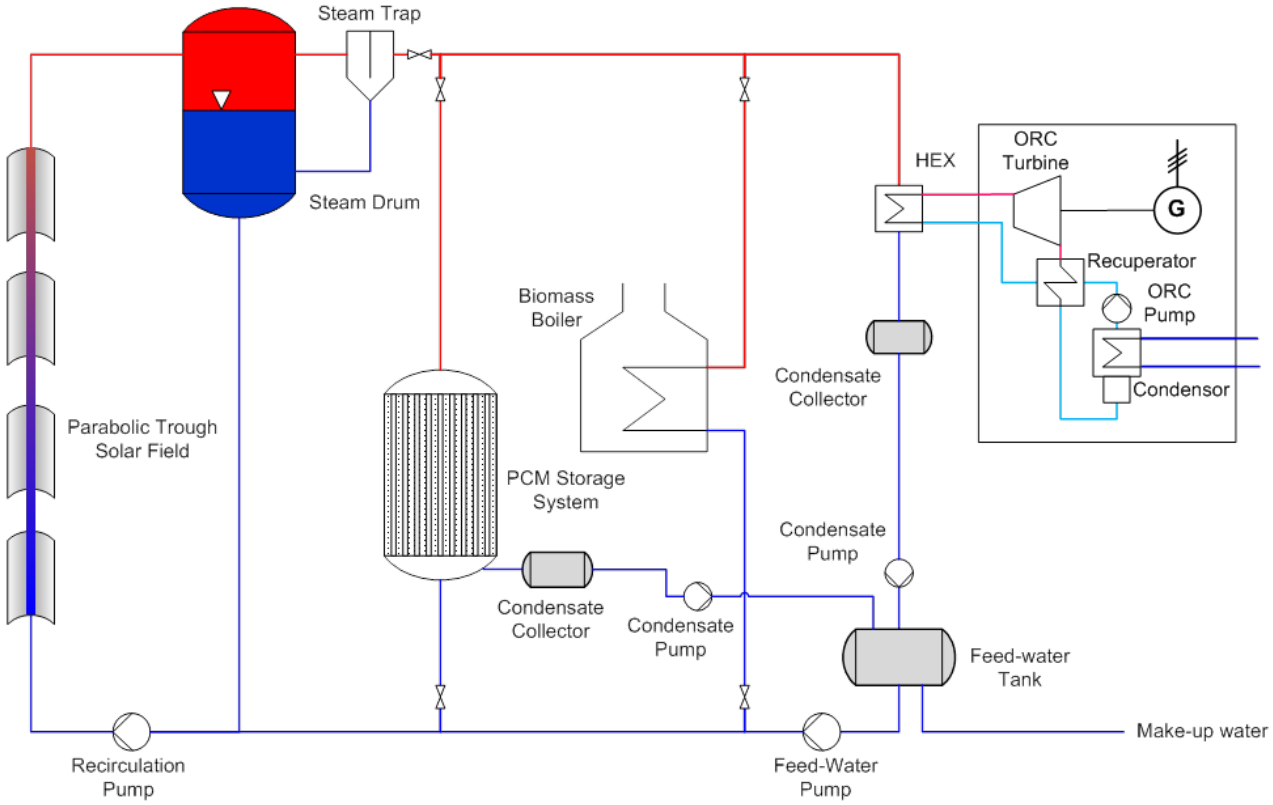
  → Maturing of tower technology releases strong cost reduction potential



Small scale solar power
EU-funded R&D project ReelCoop

Demo-plant at ENIT, Tunesia

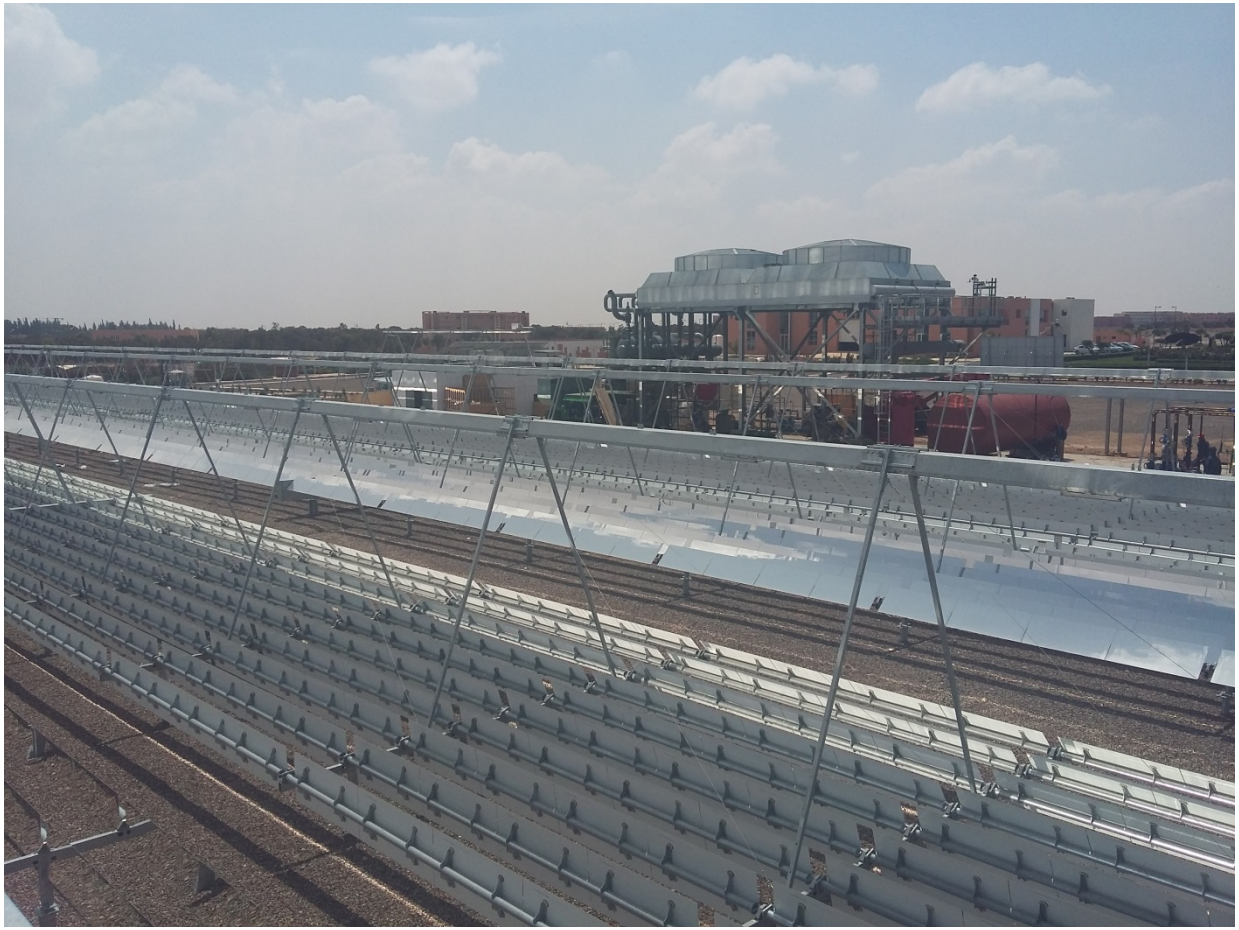
- Direct steam generation in parabolic trough (1000m²)
- Solar steam at 170°C
- Biomass boiler
- Electricity production with Organic Rankine Cycle (60 kWe)



Small scale solar power
ReelCoop / Site status May 2016

Small Scale Solar Power Project 1 Mwel, in Morroco

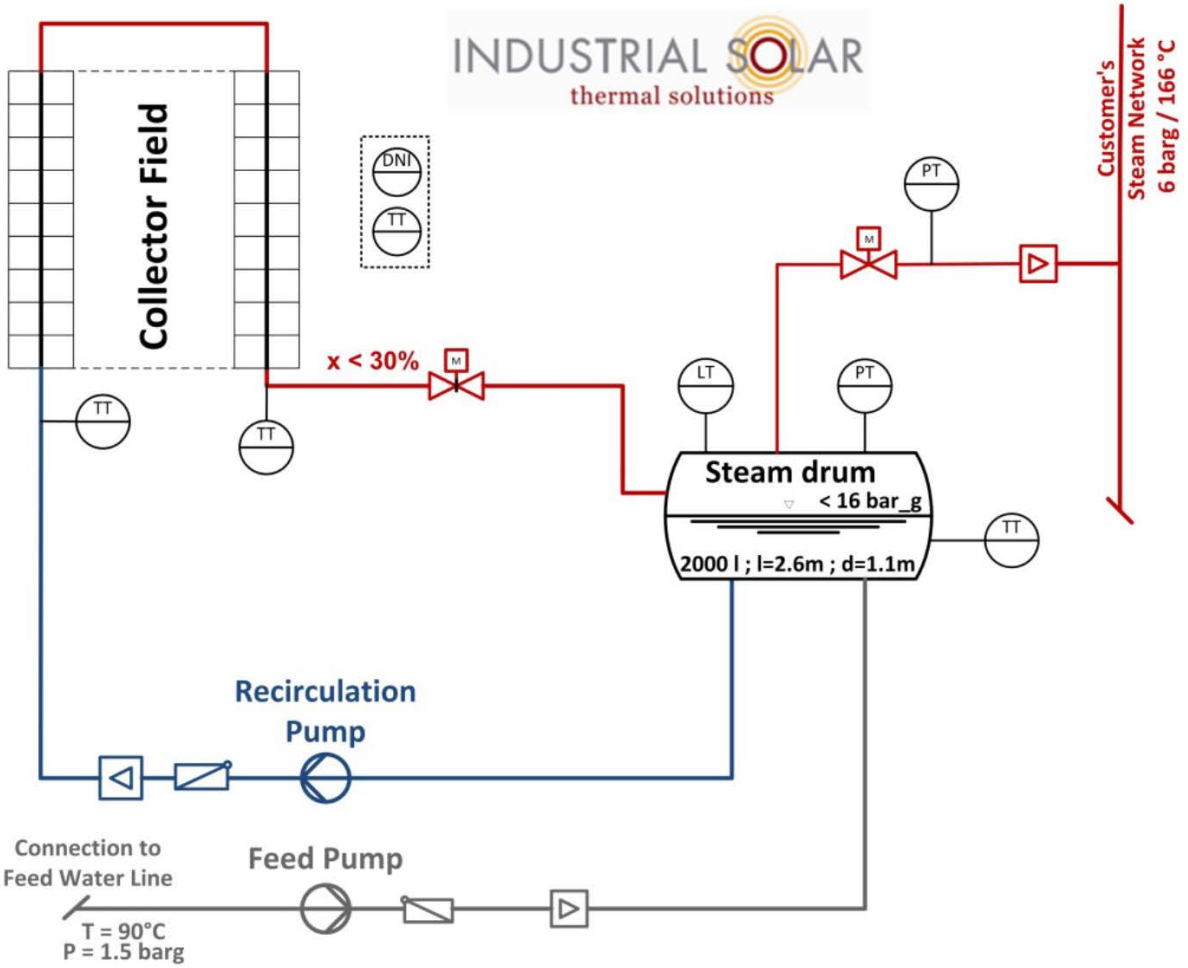
- Demonstration Plant
- Fresnel collector field (11600 m²)
- Plant construction in final phase



Solar Process Heat Project in Amman

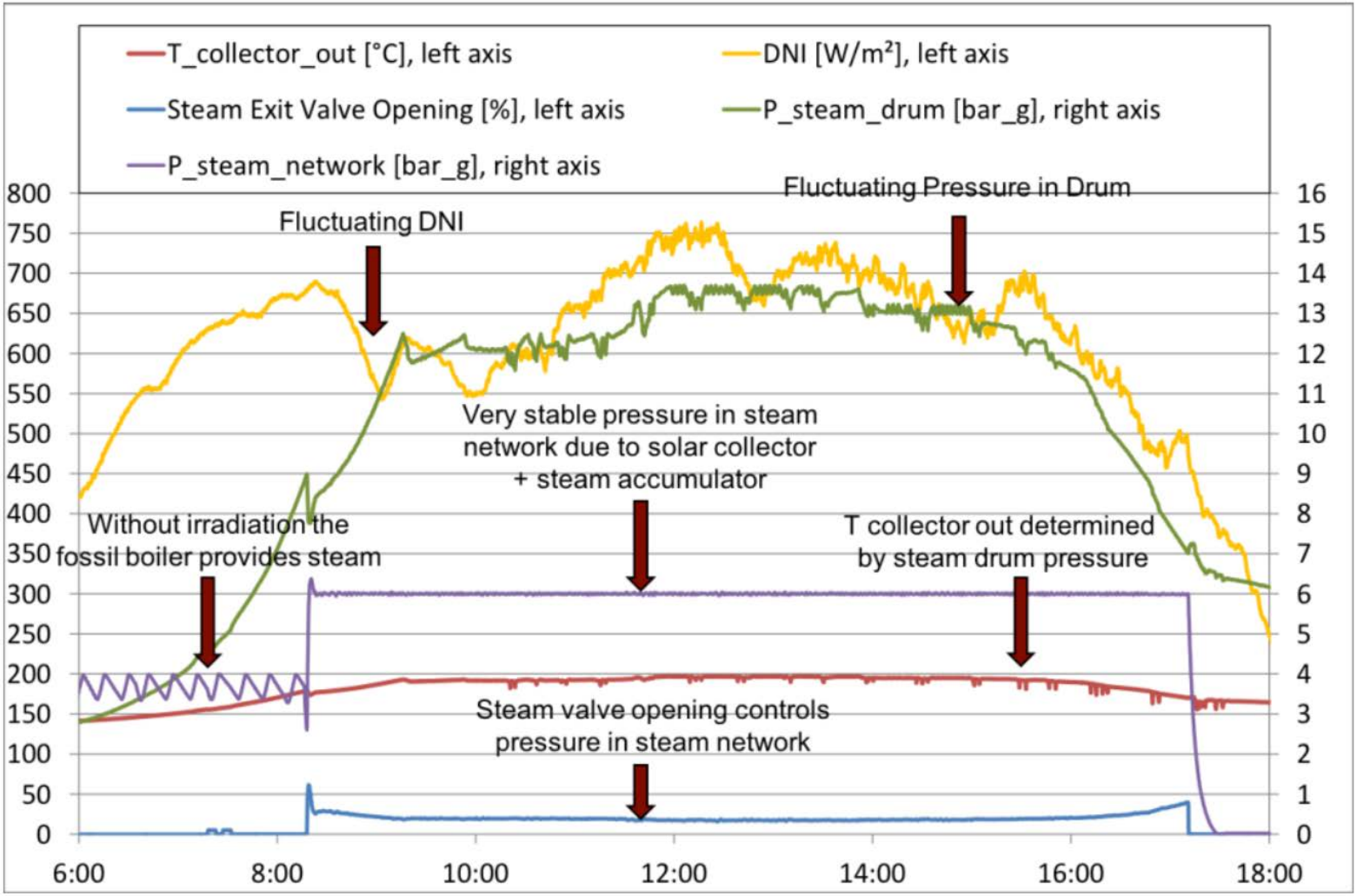
- Commercial plant at RAM-Pharma, Amman
- Direct steam generation in Fresnel collector field (394 m²)
- Roof top installation
- Steam at about 160°C to industrial steam network

Solar Process Heat Project in Amman



P&ID of RAM Pharma plant

Solar Process Heat Project in Amman



P&ID of RAM Pharma plant

Process Heat Projects
Sheffler Dishes

Facility in India for steam generation

Several hundred of Scheffler dishes for solar cooking or other purposes

Local production

Local share

Local products/work:

Piping and welding works

Foundations

Fencing (if necessary)

Local share roughly 20 to 30% in process heat when collectors are imported

Later possibly 40%

Higher with local solar collector production

Local share depends also on availability of products and specialised personnel

ENERMENA Project

Teaching material for concentrating solar thermal technbologies

See DLR Webpage for more information:

www.dlr.de/enermena

During the last years, the market for CSP technologies showed a rapid growth after several years of standstill. This growth is mainly driven by new solar power plants in markets like China, India, Southafrica and the countries of the MENA region.

The MENA region has a huge potential for the implementation of such technology due to its excellent solar resource conditions. The enerMENA project takes essential steps to prepare the ground towards a sustainable realization of CSP power plants in the MENA region.

Funded by the German Federal Foreign Office, the project was initiated and is run by the Institute of Solar Research at the German Aerospace Center (DLR), a pioneer in the field of CSP technology.

The aim of enerMENA is to provide knowledge and practical experience to CSP specialists and stakeholders in the MENA region. By this it contributes both to the optimization of the construction and the operation of solar thermal power plants.

It includes R&D activities to develop efficiency improvement measures and offers professional training courses for different target groups. With it's wide training program enerMENA adresses engineers and technicians working on site as well as researchers, University professors and students in the partner countries.

The German Aerospace Center (DLR) works jointly with over 45 partners from Egypt, Algeria, Morocco, Tunisia and Jordan to realize the objectives of the enerMENA project. Among partners are engineers, skilled workers, and decision makers at energy centers, national energy agencies, universities, engineering companies and related ministries.

A network of CSP professionals and specialists is being established and supported in the framework of the project to coordinate future activities.

The enerMENA course program adresses CSP specialists and stakeholders, professionals and students. Source: DLR

Reflectivity Measurement Training on Site. Source: DLR

Photogrammetry Training on Site. Source: DLR

The enerMENA project consists of three different modules:

- enerMENA Partners
- enerMENA Capacity Building Program
- enerMENA Meteo-Network
- CSP Technology Support for enerMENA Partner Countries

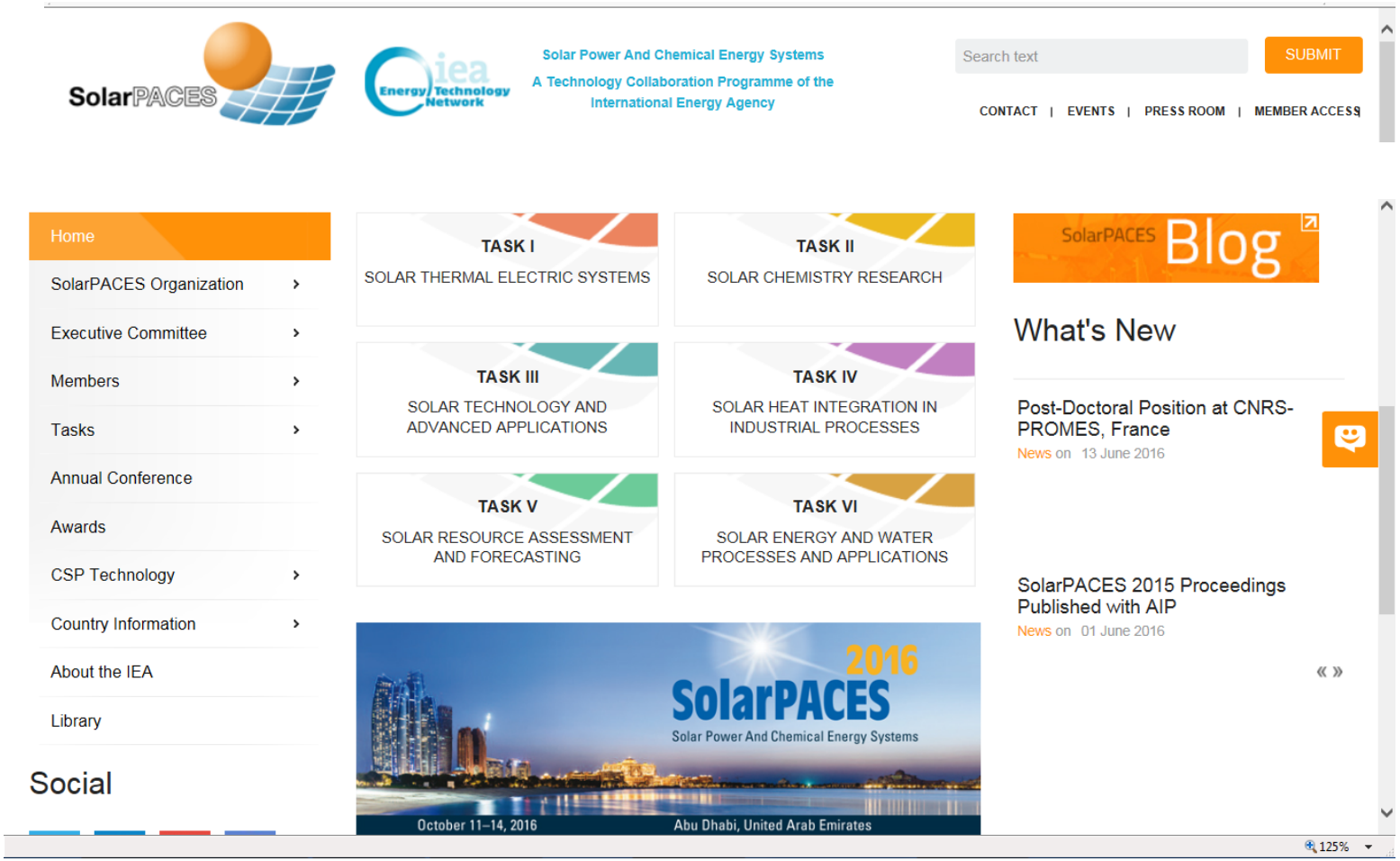
enerMENA News

- News
- News Archive

CSP Links

- Protermo Solar
- solarPACES
- DUN Desertec University Network

SolarPACES www.solarpaces.org



Conclusions

Summary

- CSP and solar process heat will play a significant role in the future energy market
  - Electrical and thermal power on demand due to storage and/or back-up boiler
- Present near term developments internationally aim at large scale central power stations (100 MW range)
  - Molten salt technology (tower and parabolic trough)
- Studies indicate potential markets for decentralized CSP with Biomass back-up
  - Technology/components are available
  - First demonstration in progress (R&D driven)

Joint effort by R&D, Industry and Finance is needed to pull it into the market!

Thank you for your attention!

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