enerMENA Towards a Sustainable Implementation of Solar Thermal Power Plants Technology in the MENA

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The El-Borma ISCCS Case Study

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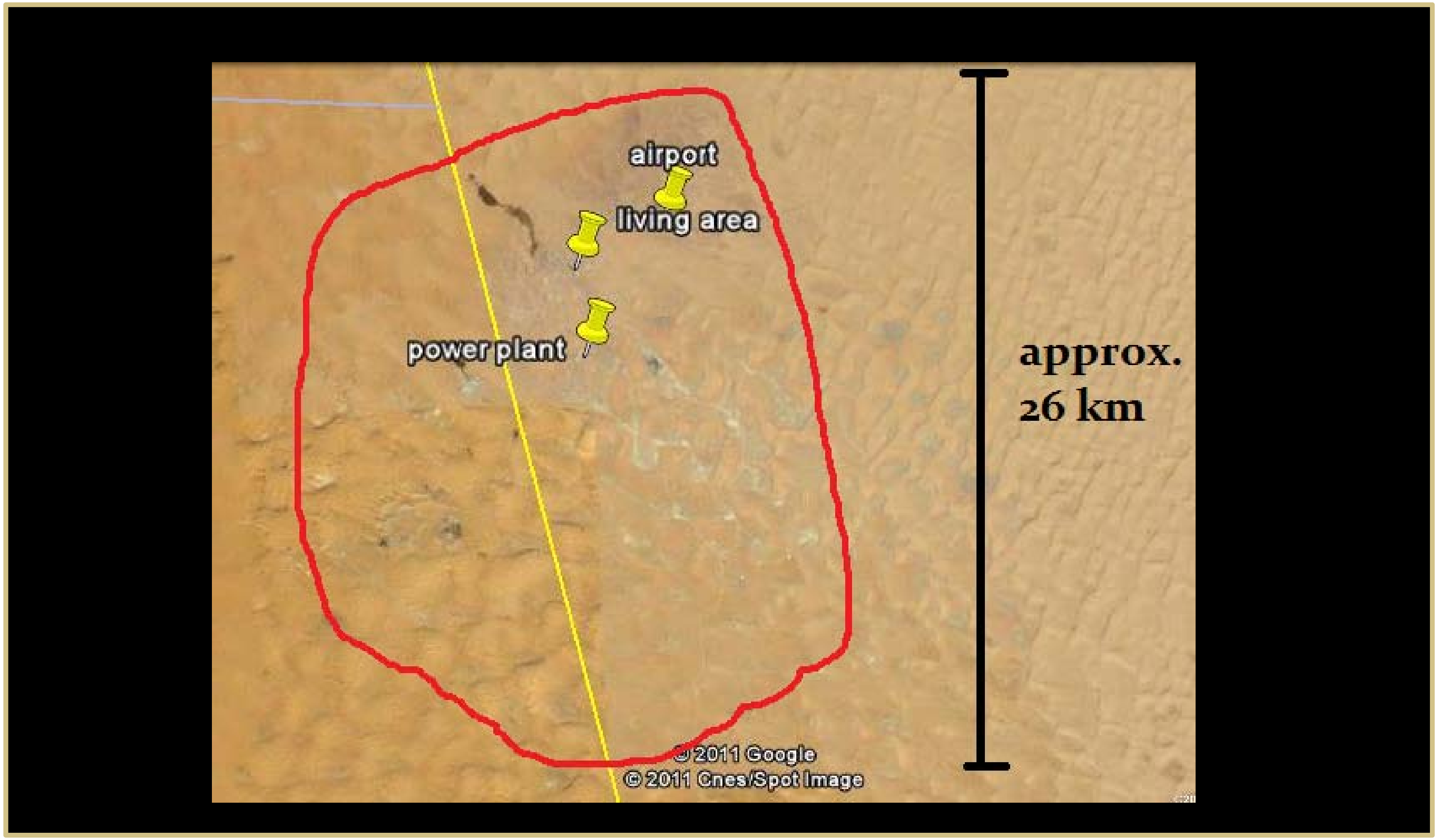
Outline

1. The El Borma Oil-Field and its Current Power Supply
2. The Future Concept
3. Methodology
4. Results
5. Conclusions

The El Borma Oilfield

- binational oilfield in Tunisia and Algeria
- biggest one in Tunisia
- utilization since 1966
  (peak extraction 1985: 70 Tb/d, today: 10 Tb/d)
- secondary extraction
- 2010 concession extended to 2043
- electricity supply with own power station

The El Borma Oilfield



Stakeholders

	SITEP (Société Italo-Tunisienne d'Exploitation Pétrolière) operating company, belongs to ENI and the state of Tunisia
	STEG (Société Tunisienne d'Electricité et du Gaz) national utility
	STEG ER (STEG Energies Renouvelables) Founded in May 2010, co-ordinates the Tunisian Solar Plan
	ENI Italian Oil and Gas enterprise

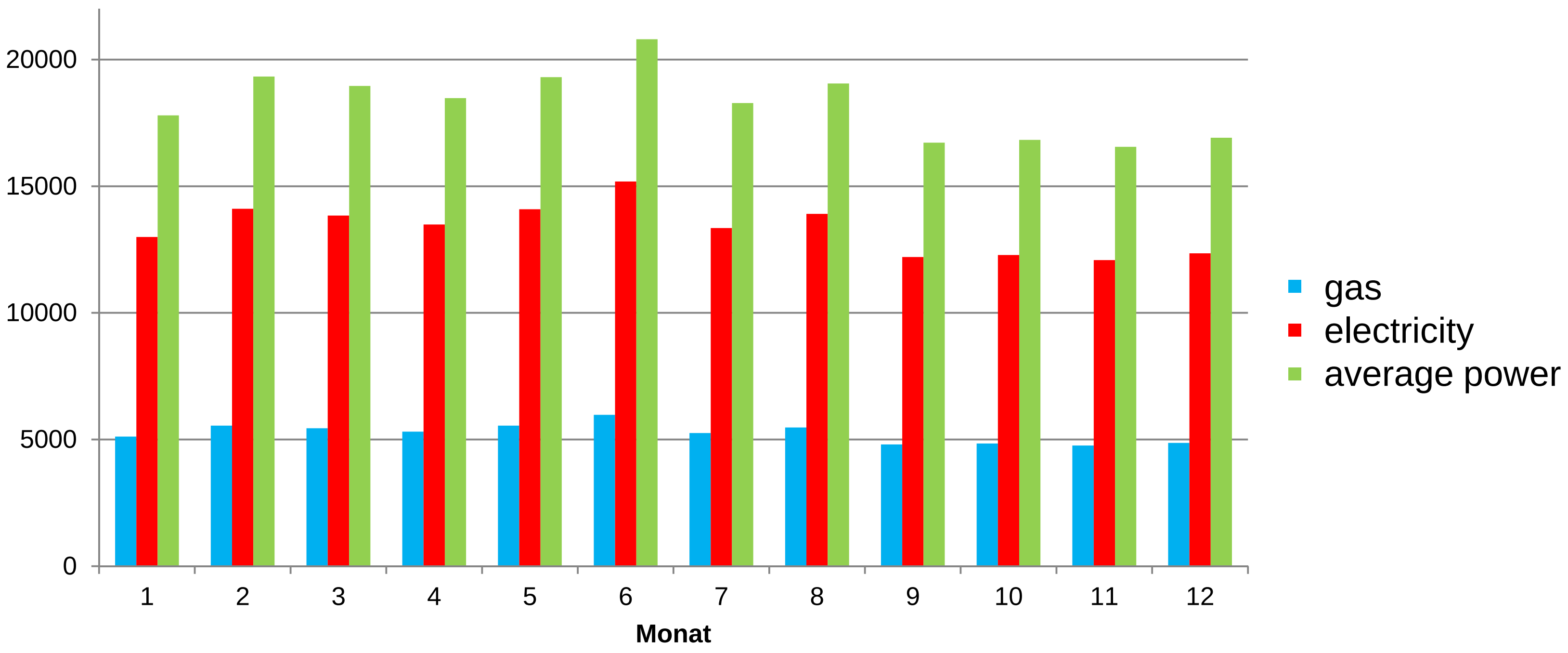
The Existing Power Supply

- commissioning: 1979/1980
  (Fiat)
- 3 gas turbines à 13,5 MW
  (2 in operation, 1 in stand-by)
- efficiency: 20-21%

11 kV-Grid with 114 km total length

Consumers (2009)

Load Distribution (2009)



- low seasonal differences

- low daily variation

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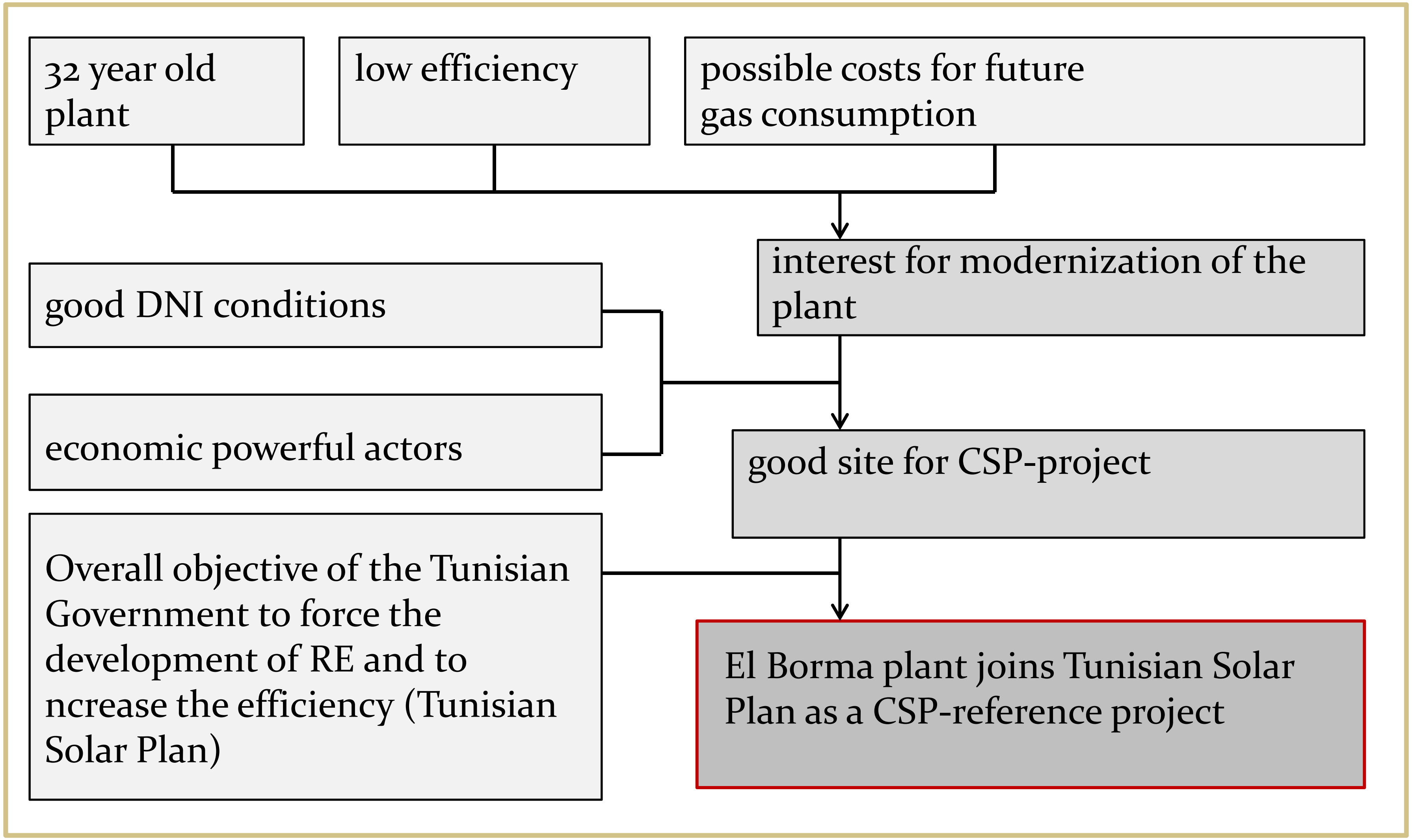
Future Plans for the El Borma Electricity Supply



The ISCCS El Borma as part of the Tunisian Solar Plan

TSP: 40 Projects in 5 groups:

1. Solar Energy (17)
2. Wind Energy (3)
3. Energy efficiency (7)
4. others (7)
5. Studies and realization of the TSP (6)

PROJECT SHEET N° 14

Construction of a 44 MW capacity solar-gas combine CSP plant

Subject

This project consists in the construction of a 44 MW capacity solar-gas combine CSP plant (39 MW gas and 5 MW solar) at the oil station of EL BORMA by the Tunisian-Italian Oil Company (SITEP).

Objectives & Outcomes

Use of solar energy for power production in the oil station of EL BORMA.

Project proponent

Tunisian-Italian Oil Company (SITEP).

Project cost

Estimated cost for the solar component: 87 MTND (japanese grant).

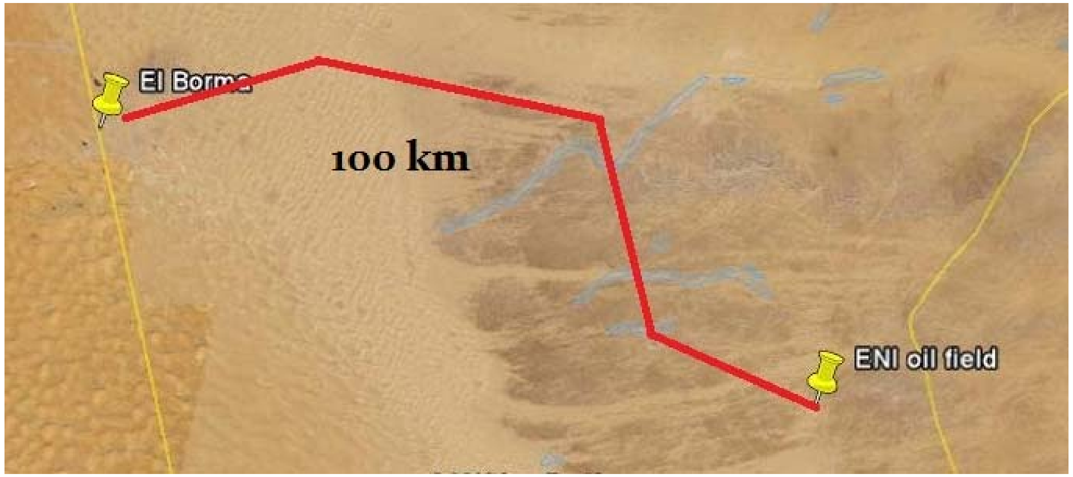
Expected energy saving

3,3 Ktoe / year.

CDM

CDM proceeds: 0,16 MTND / year, that is, 7750 t CO_2 avoided / year.

Future Power Requirements

22 MW	present maximum load of the El Borma Oil field
+ 8 MW	additional demand STEG (expansion of the gas-pipeline capacities)
+ 13 MW	ENI‘s additional demand for a second oil-field
43 MW	

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Parabolic Trough or Solar Tower?

Preconditions:

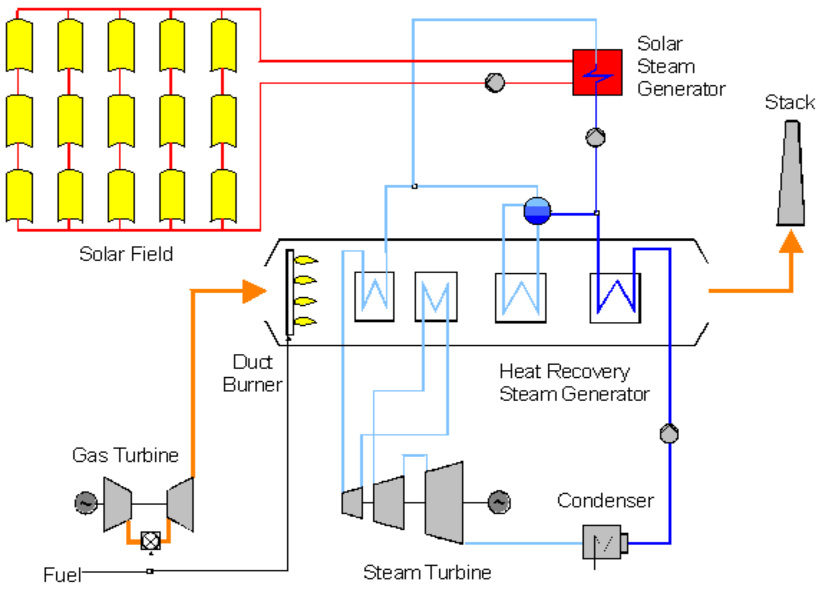
- ISCCS with solar input into steam cycle
- total power: 43 MW
- maximum solar contribution: 5 MW_{el}

Calculation of the fuel savings by the generation of solar heat and solar generated electricity

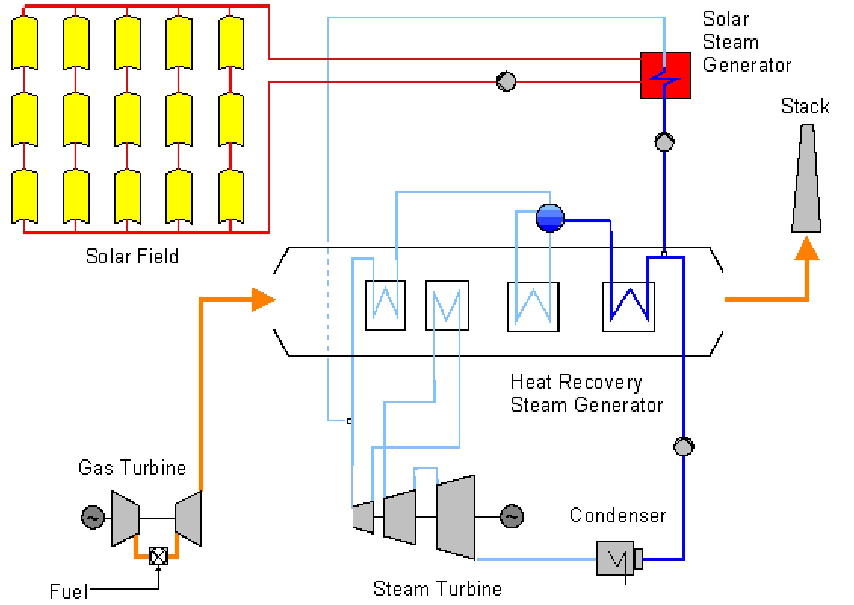
→ comparison of tower or trough solution

ISCCS-Configuration

solare backing of the evaporator



parallel solar generation of live steam



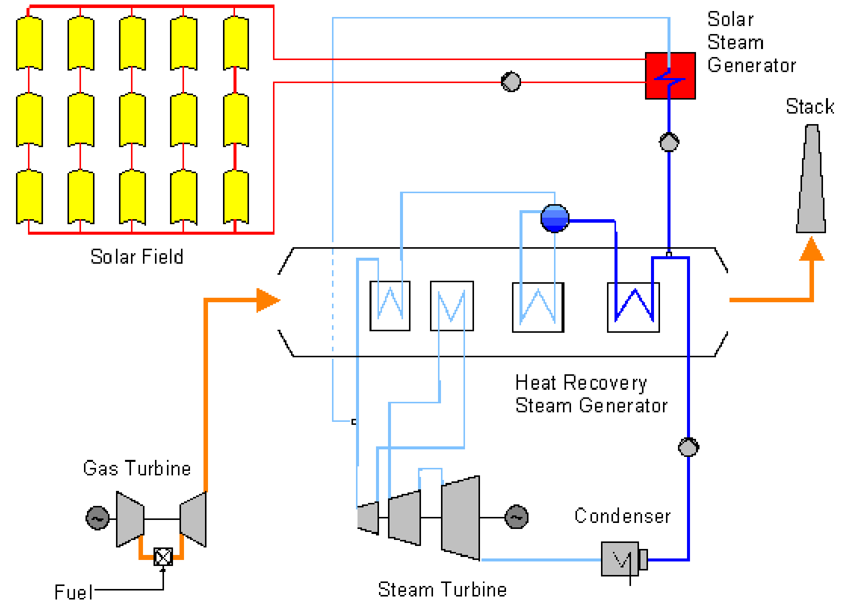
solar superheating needs high temperatures

→ point focussing systems, direct steam generating parabolic trough or trough with salt as a HTM

ISCCS-Configuration

El Borma: solar evaporation and superheating

parallel solar generation of live steam



solar superheating needs high temperatures

→ point focussing systems, direct steam generating parabolic trough or trough with salt as a HTM

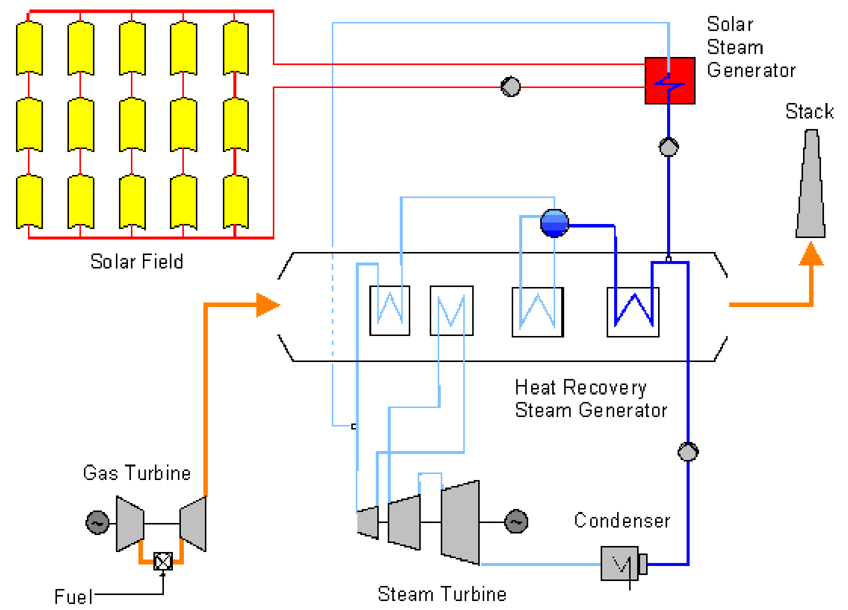
ISCCS-Configuration

El Borma: solar evaporation and superheating

- solar tower with open volumetric air receiver
- direct steam trough

steam parameter:
- 440°C
- 45 bar

parallel solar generation of live steam



solar superheating needs high temperatures

→ point focussing systems, direct steam generating parabolic trough or trough with salt as a HTM

Methodology

- comparison of the annual fuel consumptions
  43 kW ISCCS trough
  43 kW ISCCS tower
  43 kW CC conventional
- calculation of **Fuel Save** in the two ISCC
- solar electricty = output of reference CC with saved fuel
- time resolution: 1h

Methodology

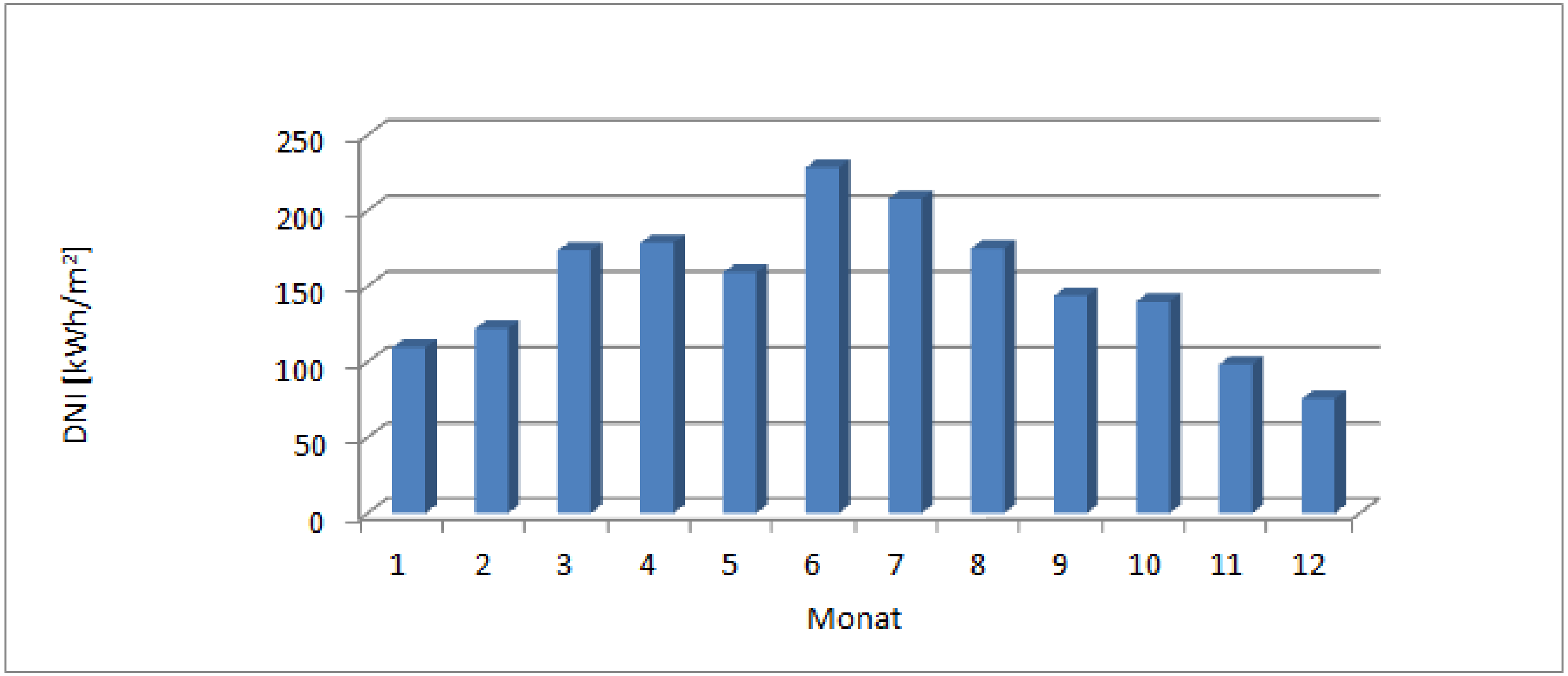
- annual calculation in **Greenius** (DLR)
  - lay-out of the solar fields + receivers
    - maximum solar thermal power: 20 MW_{th}
    - energ dumping ≈ 5% of solar thermal power)

- meteoroloical data by Meteonorm

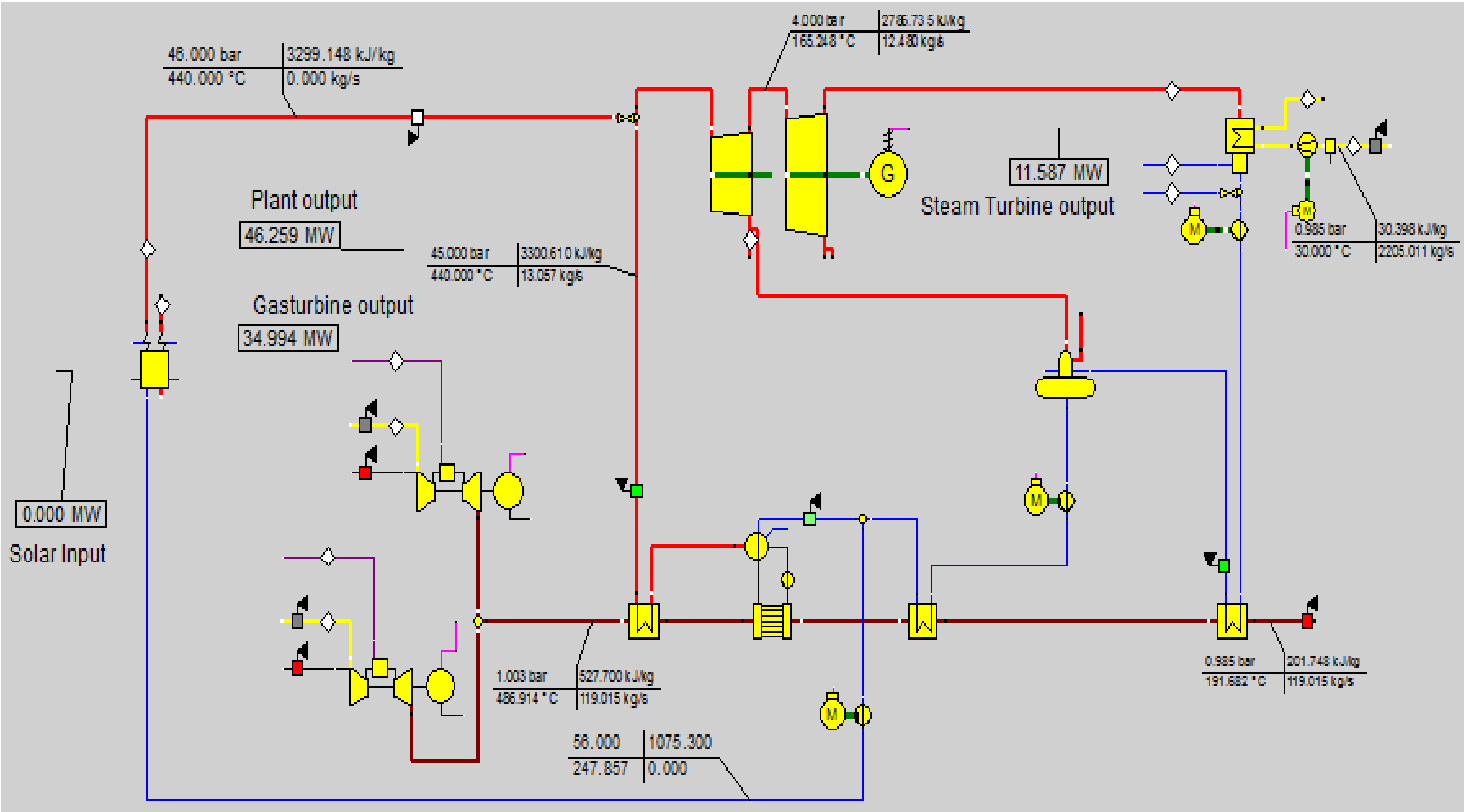
- modeling of the CC with **Ebsilon Professional**
- calculation of operating points
- interpolation for use in **Greenius**

Meteo data: DNI

DNI: 1814 kWh/m²/y



Power Plant Flow Chart (Ebsilon)



Calculation of the Operating Points (Ebsilon)

opertaing points defined by:

- ambient temperatur
- solar field thermal power
- plant power

paramters calculated:

- GT load
- solar electrical power
- auxiliaries
- fuel consumption
- feed water return temperatur (to solar field)

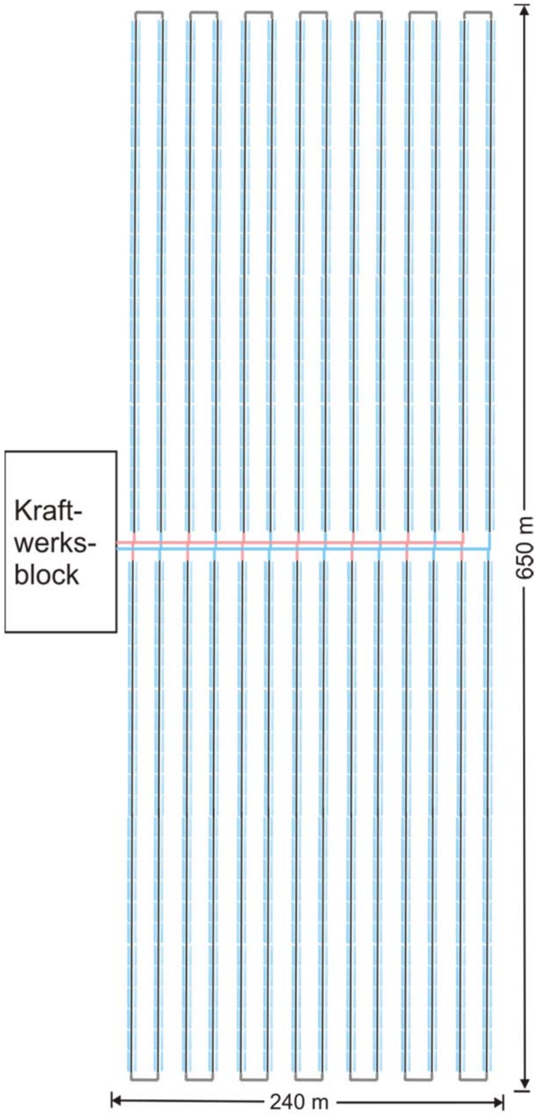
		Solarer Input									
		0 MW		5 MW		10 MW		15 MW		20 MW	
	P_gross_total	40.5 MW	46.5 MW	40.5 MW	46.5 MW	40.5 MW	46.5 MW	40.5 MW	46.5 MW	40.5 MW	46.5 MW
Umgebungstemperatur	0°C	0.654	0.792	0.604	0.742	0.553	0.689	0.505	0.641	0.464	0.601
		0	0	2.197	2.204	4.4	4.418	6.598	6.63	8.799	8.848
		495.1	495.7	507.3	507.9	522.2	523.4	539.8	541.4	566.2	569.4
		89914.8	98093.3	86798.2	95229.5	83589	92065.1	80501.2	89106.9	77819.8	86610.4
				236.9	238.5	237.6	239.6	237.5	239.8	237	239.6
	10°C	0.706	0.853	0.656	0.8037	0.604	0.7505	0.552	0.697	0.509	0.655
		0	0	2.194	2.204	4.394	4.411	6.59	6.619	8.789	8.835
		467.8	467.9	480.2	480	495	495.2	512.9	513.5	539.3	540.7
		88542.7	96519	85712.5	93834.2	82736.4	90988.3	79718.9	88032.8	77183.1	85656.3
				236.2	237.5	237.0	238.8	236.8	239	236.4	238.9
	20°C	0.784	0.919	0.733	0.879	0.679	0.834	0.624	0.784	0.5755	0.735
		0	0	2.19	2.2	4.387	4.405	6.581	6.609	8.777	8.821
		439.7	445.1	452.2	455.1	466.7	467.7	484.9	484.7	510.8	510.8
		87129.3	96469.5	84530.2	93279.4	81817.8	90060.4	79004.5	87129.2	76475.7	84630.1
				235.3	237.5	236.2	238.1	236.2	238.3	235.7	238.1
	30°C	0.868	1.0028	0.822	0.9605	0.773	0.918	0.716	0.873	0.66	0.83
		0	0	2.188	2.204	4.381	4.409	6.572	6.607	8.764	8.813
		415.1	423.6	426.1	433.7	438.8	447.4	457.1	461.9	482.7	486.1
		86720.9	96768.1	83841.4	93564.6	80959.4	90398.1	78399.3	87088.5	75833.9	84312.3
				235.0	238.5	235.5	238.6	235.6	238.1	235.0	237.6
	40°C	0.952	1.1	0.907	1.055	0.861	1.01	0.811	0.963	0.762	0.9245
		0	0	2.191	2.208	4.382	4.413	6.568	6.611	8.756	8.821
		400.7	408	411	421.3	423.7	435.7	439.5	450.6	462.4	478.6
		87168.1	96912.4	84176.1	94042.8	81124.9	91072.9	78261.7	87908.8	75563	85337.7
				235.7	239.3	235.7	239.1	235.2	238.4	234.6	237.8
	50°C	1.044	1.209	0.9965	1.1615	0.949	1.113	0.9	1.069	0.856	1.0265
		0	0	2.195	2.211	4.386	4.417	6.569	6.625	8.756	8.837
		386.4	395.5	397.1	409.4	411.5	424.2	426.7	447.3	451.8	472.5
		87679.4	96671.9	84820.2	94206	81953.7	91604.1	79044.5	89127.2	76453.5	86647.7
				236.5	240.0	236.1	239.5	235.3	238.8	234.5	238.0

Lay-Out of the Solar Field: Parabolic Trough

solar field maximum thermal power: 20 MW_{th}

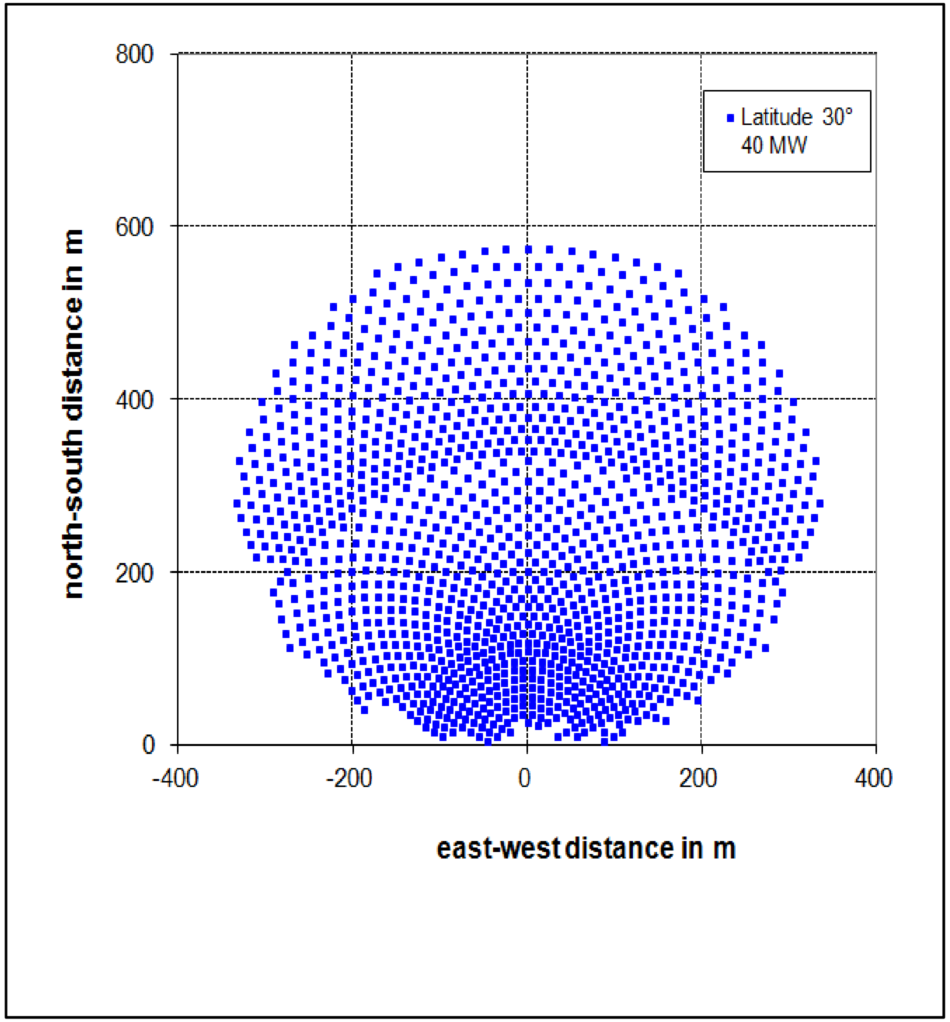
data of Eurotrough II collector used

→ 14 Loops



Lay-Out of the Solar Field: Heliostats

solar field maximum thermal power: 20 MW_{th}



interpolation within implemented field models (dependent on thermal power and geographical lattitude)

Lay-Out of the Solar Field: Heliostats

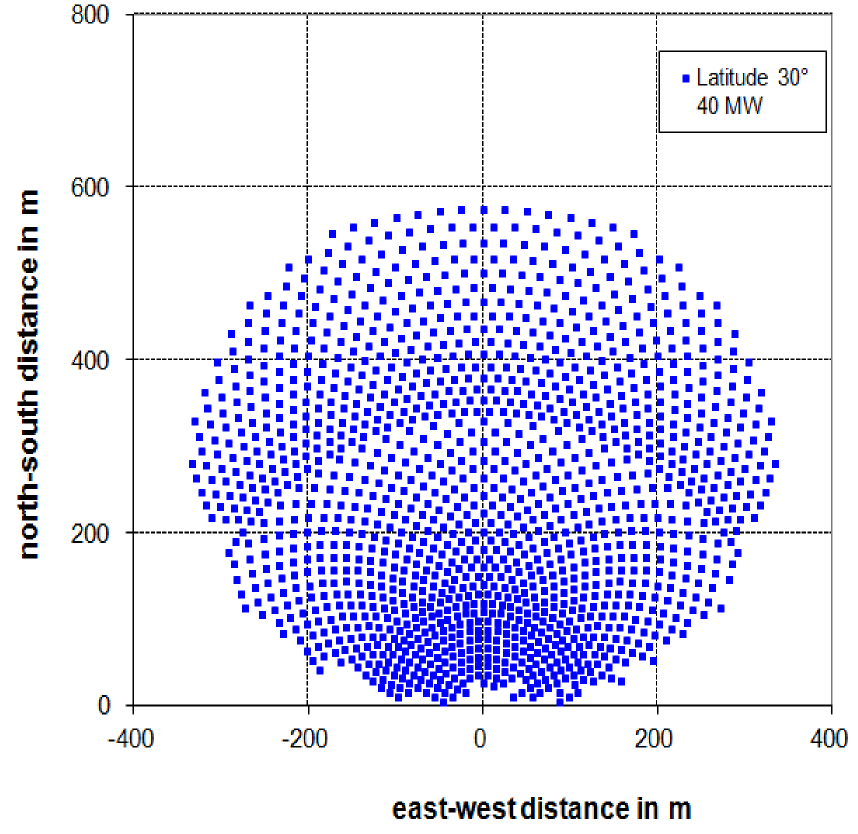
solar field maximum thermal power: 20 MW_{th}

↓

field-intercept 31,3 MW

Receiver-Intercept 26,6 MW

air outlet temperatur: 500°C



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Results I

		trough	tower
fuel save	MWh_{th}	21883	21935
	t	1575	1579
	%	2,72	2,72

		trough	tower
solar generated electricity	MWh_{el}	10250	10273
	%	2,72	2,73

Results II

		trough	tower	deviation trough vs. tower
aperture area	m^2	45780	46862	2,36%
mirror area	m^2	50458	46862	-7,13%
solar heat	MWh_{th}	39376	39036	-0,86%
fossil heat	MWh_{th}	783490	783439	-0,006%
dumping	MWh	2001	2047	2,30%
ground area solar field	ha	16	23	44%

Conclusions

- no significant differnces tower/trough (fuel save, solar generated electricity)

- significant difference: solar field size (not of major interest at this site)

- economic criteria, reliability and experience

  - economic comparison difficult (small, young and discontinous csp markets)

  - trough technology more mature but not with direct steam (one new commercial plant in Thailand + one test plant, Spain)