

Concentrated Solar Power

Cabal H. and Lechón Y. CIEMAT (Spain)

Biberacher M. RSA (Austria)



Gemasolar central tower plant

IRENA-ETSAP Joint Session

Paris, 17 June 2013



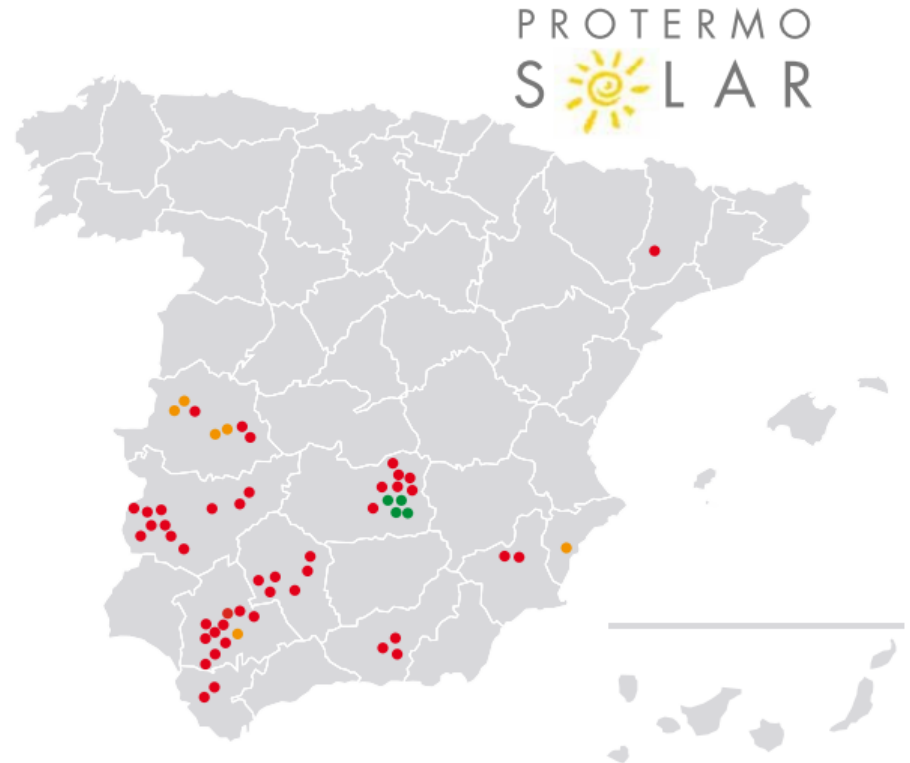
CSP plants operating in Spain in 2013

	Start		MW
1	2008	Andasol 1	50
2	2009	Andasol 2	50
3	2011	Andasol 3	50
4	2011	Arcosol	50
5	2012	Aste 1A	50
6	2012	Aste 1B	50
7	2012	Astexol II	50
8	2009	Extresol I	50
9	2010	Extresol II	50
10	2011	Gemasolar	17
11	2012	Extresol III	50
12	2012	Guzman	50
13	2012	Helios I	50
14	2012	Helios II	50
15	2011	Helioenergy I	50
16	2012	Helioenergy II	50
17	2009	Ibersol	50
18	2010	Majadas I	50
19	2012	La Africana	50
20	2011	La Dehesa	50
21	2010	La Florida	50
22	2009	La Risca/Alvarado I	50
23	2010	Lebrija I	50
24	2011	Manchasol I	50
25	2011	Manchasol II	50
26	2012	Olivenza	50
27	2012	Orellana	50
28	2012	Morón	50
29	2011	Palma del Rio I	50
30	2010	Palma del Rio II	50
31	2006	PS10	11
32	2009	PS20	20
33	2009	Puerto Errado I	1,4
34	2012	Puerto Errado II	30
35	2012	Solacor I	50
36	2012	Solacor I	50
37	2012	Solaben III	50
38	2013	Solaben II	50
39	2009	Solnova 1	50
40	2009	Solnova 3	50
41	2009	Solnova 4	50
42	2011	Termesol 50	50
43	2012	Termosolar Borges	22,5
44	2013	Termosol I	50
45	2013	Termosol II	50
	2013	total	2051,9

no storage, parabolic troughs
 low storage, power tower
 medium storage, parabolic troughs
 high storage, power tower

45 plants
2052 MW

3433 GWh in 2012
1.2% gross prod.
(1878 MW)

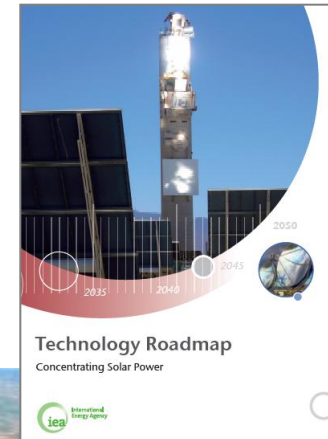


CSP technology **without** storage- **Parabolic troughs**

Data source: real plants constructed and operated in Spain and costs evolution projected by IEA

➤ ESOLTHC105: CON. SOL. CEN. Thermal

AF_2010	0.41 (WD), 0.49 (SD), 0.47 (ID)
LIFE	25 years
INV_COSTS_2010	4326 €2005/kW
INV_COSTS_2020	2812 €2005/kW
INV_COSTS_2050	2306 €2005/kW
FIXOM_2003	35.40 €2005/kW
FIXOM_2030	23.01 €2005/kW
FIXOM_2050	18.87 €2005/kW



Solnova 1,3 and 4 (Abengoa Solar)

http://www.abengoasolar.com/corp/web/es/nuestras_plantas/plantas_en_operacion/espana/Solnova_1_3_y_4_plantas_cilindroparabolicas_de_50_megavattios_cada_una

CSP technologies **with** storage- **Parabolic troughs** and **Power tower**

Three different technologies:

- ESOLTHC205: Power tower. Low storage (1h)
- ESOLTHC305: Parabolic troughs. Medium storage (7.5h)
- ESOLTHC405: Power tower. High storage (15h)

Data source:

Protermosolar, NREL (USA), Energías Renovables magazine (Jul-Aug, 2011), and costs evolution projected by IEA

2013 Update of CSP technologies **with** storage

	Power tower Low storage	Parabolic troughs Medium storage	Power tower High storage
AF SD	0,57	1	1
AF SN	0	0,10	0,77
AF ID	0,56	1	1
AF IN	0	0,10	0,72
AF WD	0,50	1	1
AF WN	0	0,08	0,67
INVCOST_2010 (€2005/kW)	3068	5581	12965
INVCOST_2020 (€2005/kW)	1841	3628	7779
INVCOST_2030 (€2005/kW)	1473	2975	6223
FIXOM (€2005/kW)	91	133	240
LIFE (y)	25	40	40
STORAGE (h)	1	7,5	15
START	2006	2008	2011



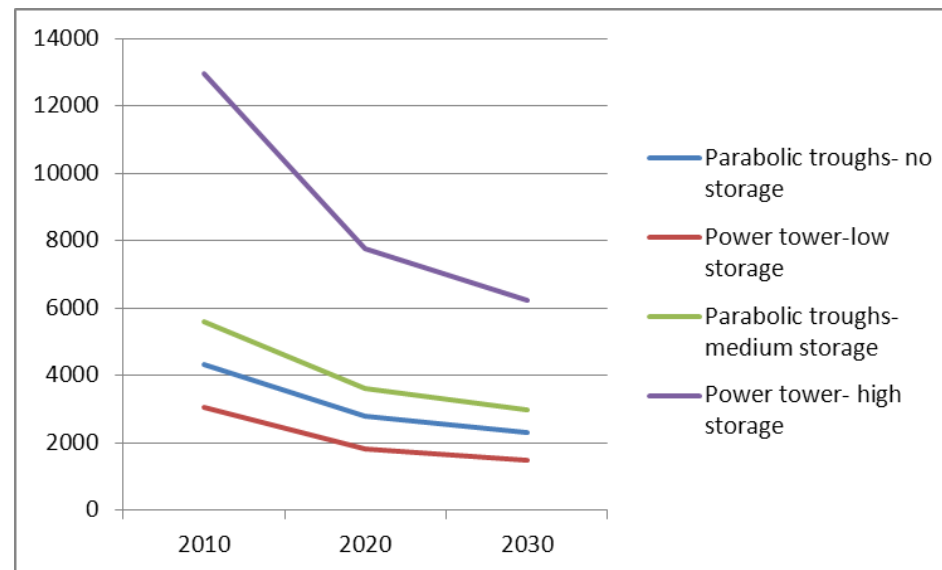
PS20. Power tower



Andasol 1 and 2. Parabolic troughs



Gemasolar plant. Power tower



(<http://www.torresolenergy.com/TORRESOL/gemasolar-plant/en>)



GOBIERNO DE ESPAÑA

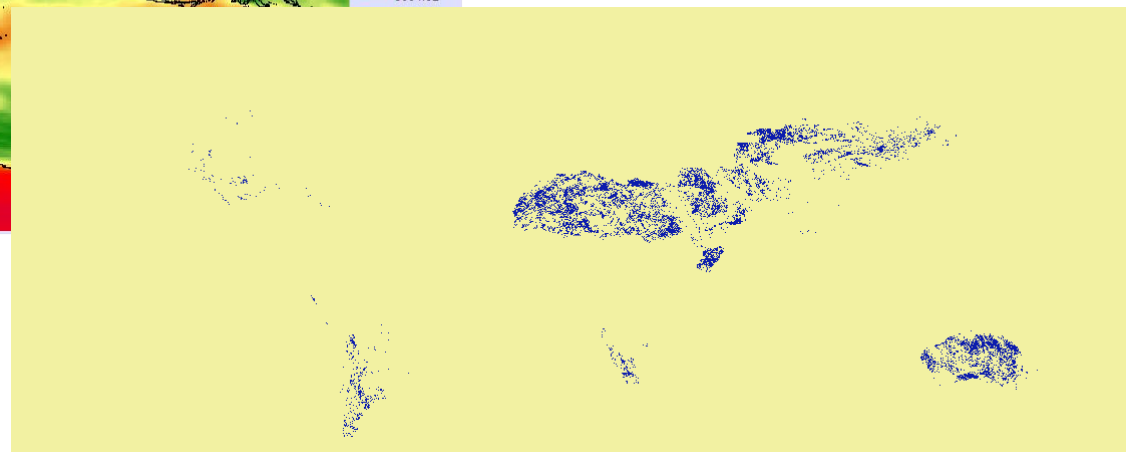
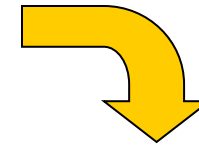
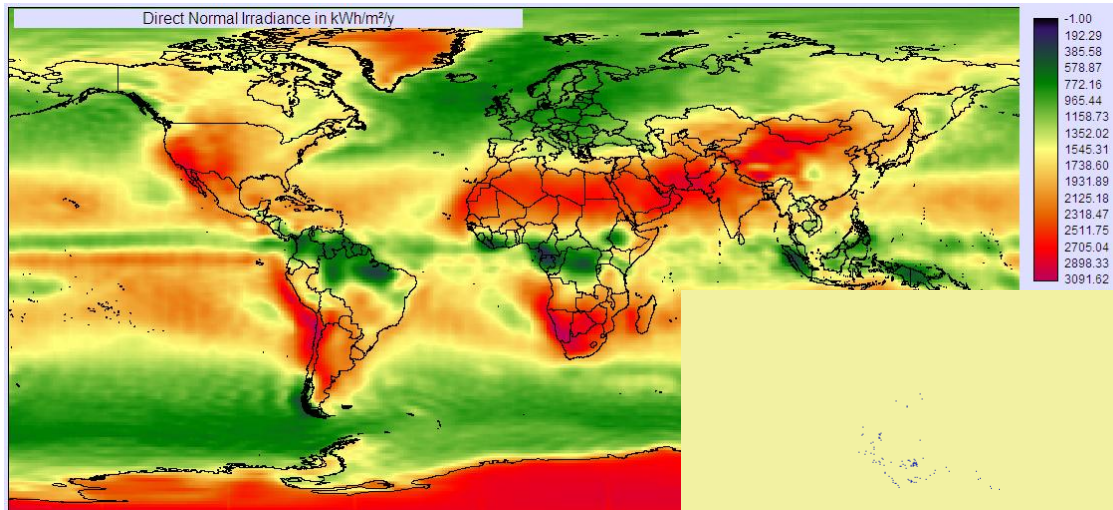
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD



Suitable areas and **maximum potentials** for CSP technologies

Concentrating solar power plants can not be built in all regions of the world. Only areas with direct normal irradiance above 1800 kWh/m² are suitable for the installation of these plants

Further to this limitation, other areas are excluded: protected areas and areas with slope higher than 2.1%. From the remaining areas, only areas classified as bare and sparsely vegetated areas (CORINE, GLC 2000) are considered to be suitable for the installation of this type of plants.



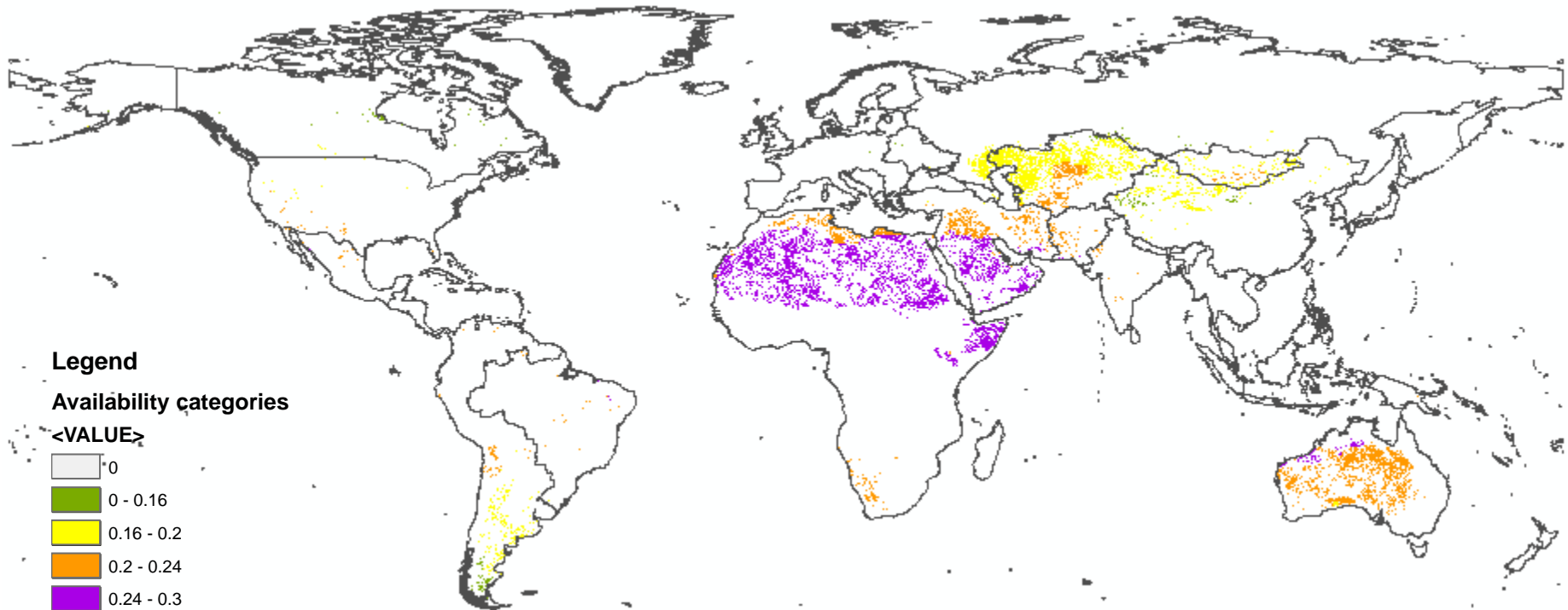
Suitable areas and **maximum potentials** for CSP technologies

	Max technical potential PJ/a	Suitable area in km ²
AFR	1757687	1295182
AUS	818702	530145
CAN	14224	15133
CHI	217054	147048
CSA	185403	149491
EEU	129	291
FSU	539181	534074
IND	8624	6225
JPN	83	84
MEA	569754	400666
MEX	16053	11442
ODA	142649	98530
SKO	2	2
USA	30037	21745
WEU	240	350

Regional **AF** for CSP technologies

Availability factors depend on the location of the CSP power plants but also on the season of the year

Seasonal availability factors have been calculated for the suitable areas in each region for CSP plants with no storage



From these AF and the storage capacity data, seasonal availability factors for the CSP plants with storage have been estimated

Regional **AF** for CSP technologies **without** storage

AF day	Intermediate	Summer	Winter	Annual
AFR	0.53	0.56	0.45	0.52
AUS	0.47	0.37	0.52	0.46
CAN	0.27	0.37	0.11	0.28
CHI	0.33	0.44	0.21	0.34
CSA	0.37	0.28	0.44	0.37
EEU	0.30	0.38	0.15	0.30
FSU	0.37	0.47	0.21	0.37
IND	0.47	0.46	0.44	0.46
JPN	0.37	0.40	0.26	0.35
MEA	0.50	0.57	0.39	0.49
MEX	0.49	0.50	0.37	0.46
ODA	0.42	0.47	0.30	0.41
SKO	0.38	0.40	0.31	0.37
USA	0.46	0.49	0.31	0.43
WEU	0.36	0.45	0.21	0.36
World average	0.47	0.49	0.41	0.46

Regional day/night AF for a CSP technology without storage

Regional AF for CSP technologies with storage

AF day	ESOLTHC205				ESOLTHC305				ESOLTHC405			
	Intermediate	Summer	Winter	Annual	Intermediate	Summer	Winter	Annual	Intermediate	Summer	Winter	Annual
AFR	0.62	0.63	0.54	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
AUS	0.55	0.46	0.60	0.54	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CAN	0.35	0.43	0.24	0.37	0.90	0.83	1.00	0.91	1.00	1.00	1.00	1.00
CHI	0.41	0.51	0.31	0.42	0.96	0.96	0.99	0.97	1.00	1.00	1.00	1.00
CSA	0.46	0.38	0.51	0.46	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00
EEU	0.39	0.44	0.26	0.38	0.93	0.86	1.00	0.92	1.00	1.00	1.00	1.00
FSU	0.45	0.53	0.32	0.45	1.00	0.97	1.00	0.99	1.00	1.00	1.00	1.00
IND	0.55	0.54	0.53	0.54	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
JPN	0.45	0.47	0.36	0.43	1.00	0.94	1.00	0.98	1.00	1.00	1.00	1.00
MEA	0.59	0.64	0.48	0.58	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEX	0.57	0.57	0.47	0.54	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ODA	0.50	0.54	0.41	0.49	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SKO	0.46	0.47	0.41	0.45	1.00	0.94	1.00	1.00	1.00	1.00	1.00	1.00
USA	0.54	0.57	0.41	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WEU	0.44	0.51	0.32	0.44	0.99	0.95	1.00	0.98	1.00	1.00	1.00	1.00

World average:	0.56	0.57	0.50	0.55	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00
----------------	------	------	------	------	------	------	------	------	------	------	------	------

AF night	Intermediate	Summer	Winter	Annual	Intermediate	Summer	Winter	Annual	Intermediate	Summer	Winter	Annual
AFR	-	-	-	-	0.16	0.16	0.11	0.14	0.78	0.84	0.69	0.77
AUS	-	-	-	-	0.09	0.05	0.11	0.08	0.72	0.62	0.81	0.71
CAN	-	-	-	-	-	-	0.04	-	0.52	0.62	0.50	0.53
CHI	-	-	-	-	-	-	-	-	0.58	0.72	0.51	0.59
CSA	-	-	-	-	-	0.01	-	-	0.62	0.56	0.71	0.62
EEU	-	-	-	-	-	-	0.02	-	0.55	0.63	0.50	0.55
FSU	-	-	-	-	-	-	0.02	-	0.62	0.78	0.52	0.62
IND	-	-	-	-	0.09	0.05	0.11	0.09	0.72	0.73	0.68	0.71
JPN	-	-	-	-	-	-	0.01	-	0.62	0.66	0.54	0.60
MEA	-	-	-	-	0.13	0.16	0.08	0.12	0.75	0.87	0.64	0.74
MEX	-	-	-	-	0.12	0.07	0.06	0.08	0.74	0.78	0.62	0.71
ODA	-	-	-	-	0.04	-	0.05	0.03	0.67	0.77	0.58	0.66
SKO	-	-	-	-	0.01	-	0.05	-	0.63	0.66	0.58	0.62
USA	-	-	-	-	0.08	0.04	0.04	0.05	0.71	0.79	0.58	0.68
WEU	-	-	-	-	-	-	0.01	-	0.61	0.74	0.52	0.61

World average:	-	-	-	-	0.10	0.10	0.08	0.09	0.72	0.77	0.67	0.71
----------------	---	---	---	---	------	------	------	------	------	------	------	------

Regional day/night AF for the CSP technology with storage

Thank you

- Wind
- Photovoltaics
- Geothermal
- Biomass
- CSP Plants
- Wave / Tidal
- Hydropower
- Oil / Gas
- Coal
- Nuclear

