Global Potential of Concentrating Solar Power

Franz Trieb, Christoph Schillings, Marlene O'Sullivan, Thomas Pregger, Carsten Hoyer-Klick

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Electricity, fuels and clean water powered by the sun

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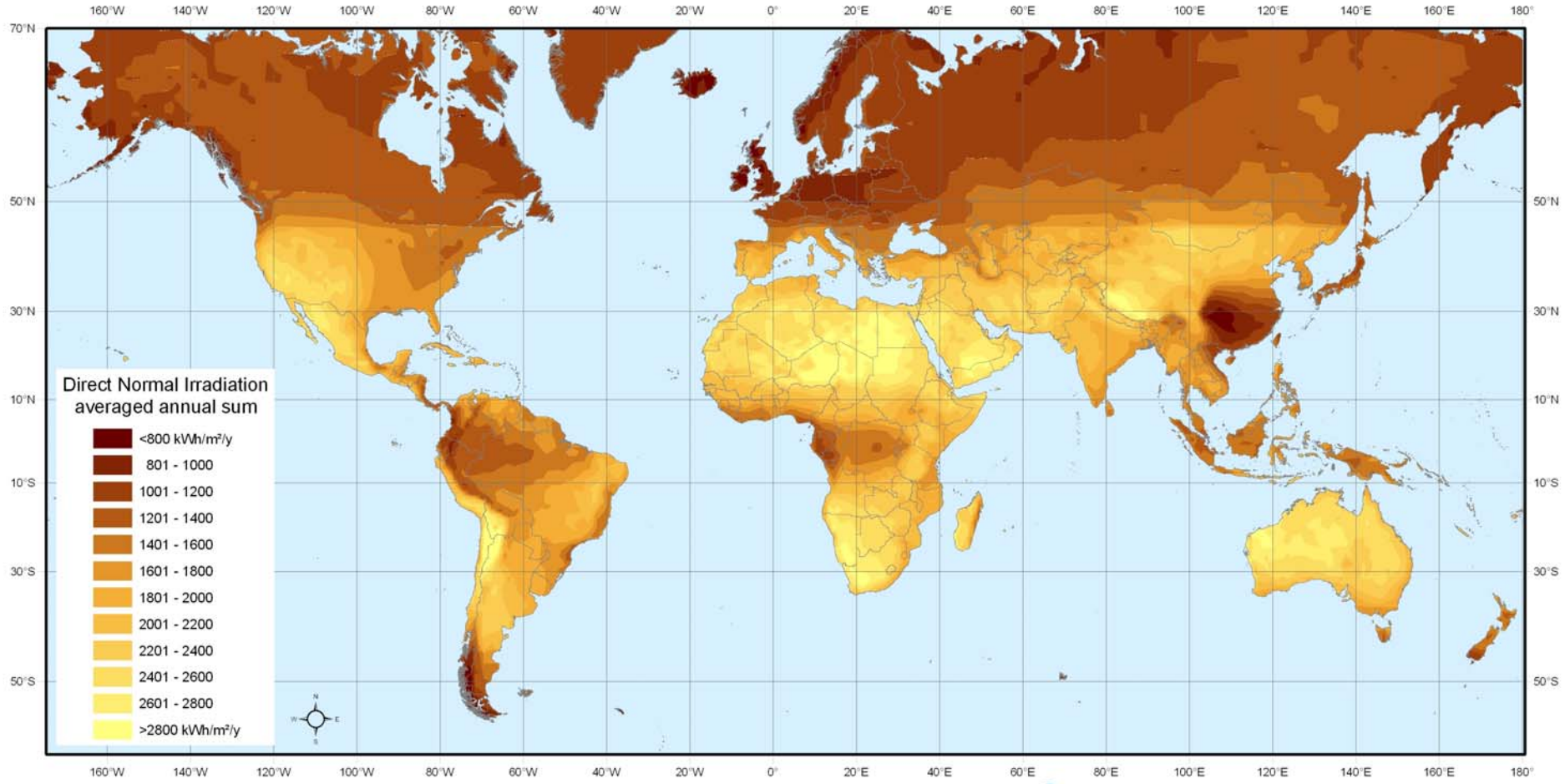
SolarPACES
Concentrating Solar Power and Chemical Energy Systems

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

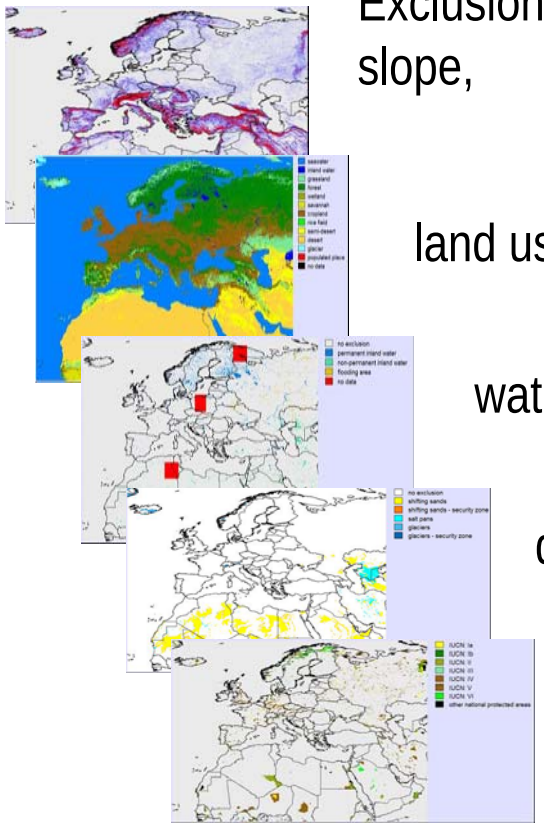
Solar Energy Resource Assessment



Data based on SSE 6.0 dataset for a 22-year period (July 1983 - June 2005)
(http://eosweb.larc.nasa.gov/sse/)

Map created and map layout by DLR 2008
(http://www.dlr.de)

Land Area Resource Assessment



Exclusion of:
slope,

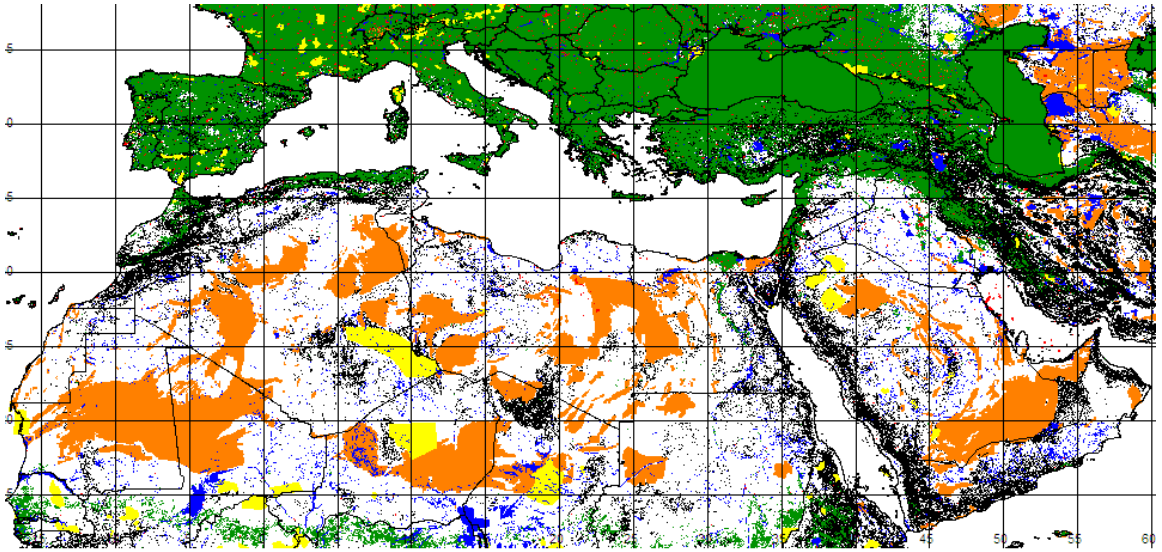
land use,

water,

dunes,

national parks,
infrastructure,

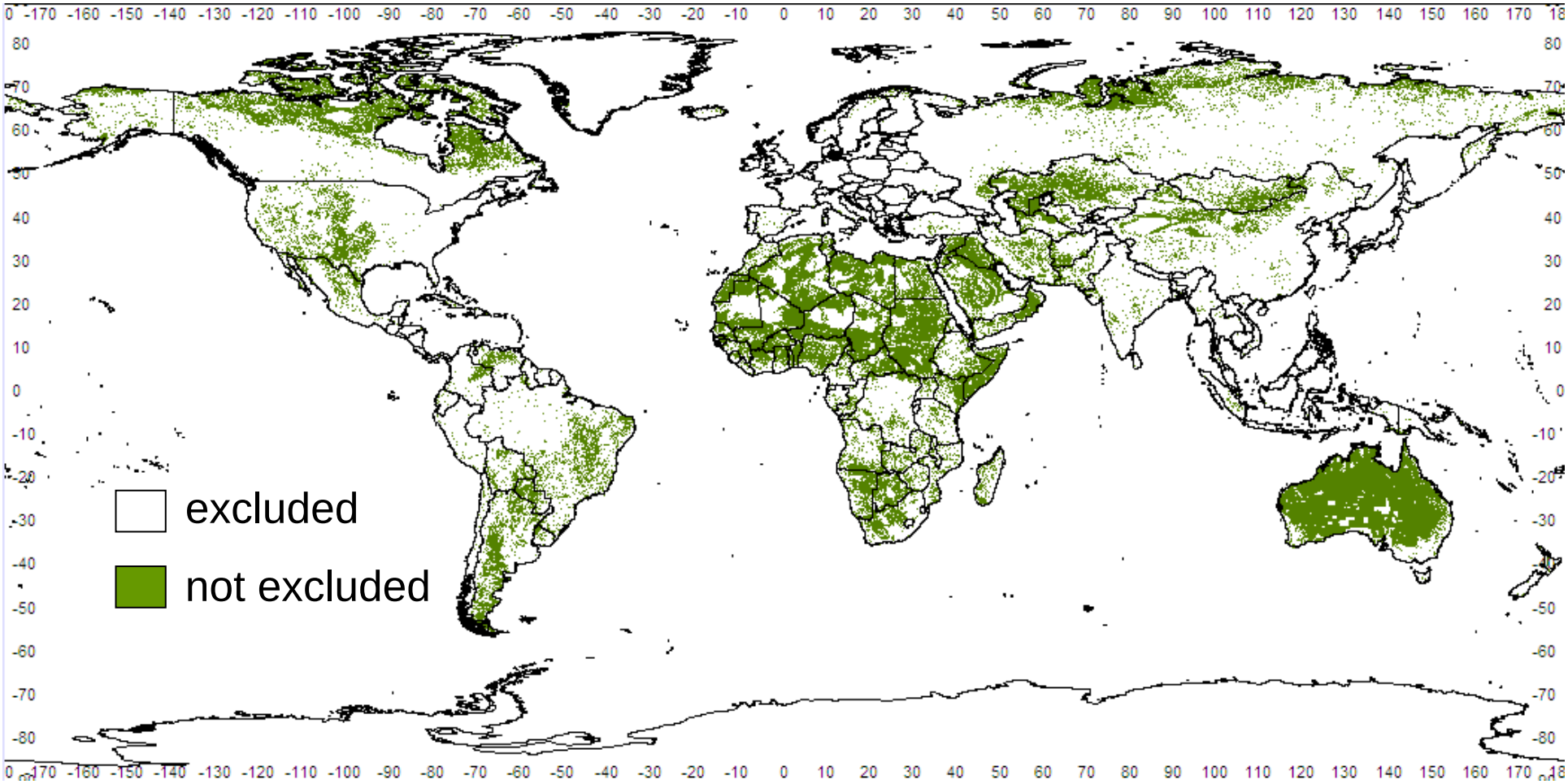
etc....



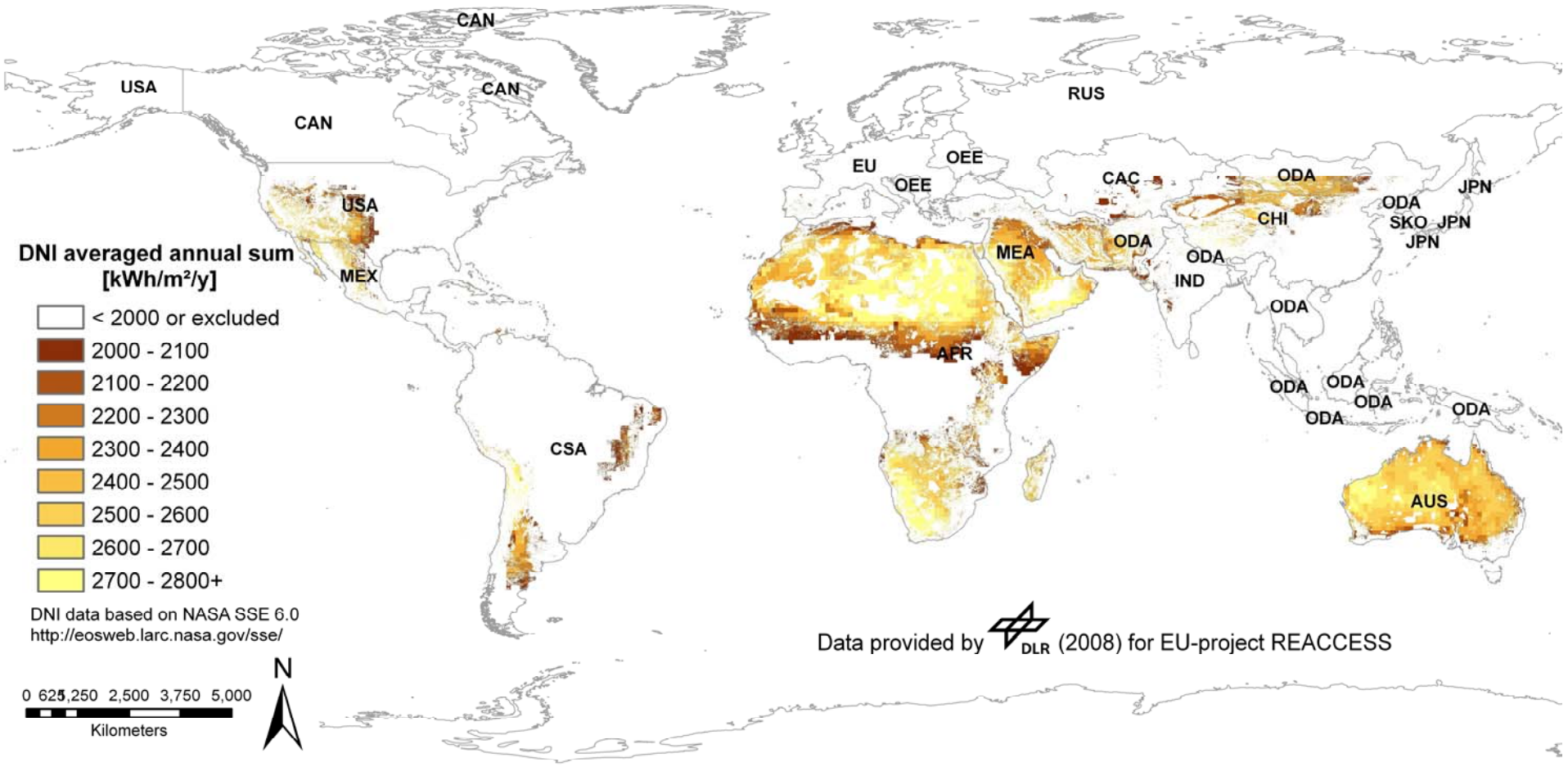
add all layers

- no exclusion
- urban or industrial
- hydrography
- protected area
- land cover
- geomorphology
- topography

Site Exclusion for Concentrating Solar Power Plants (Trough)



Global Annual DNI > 2000 kWh/m²/y after Site Exclusion



see slide 8 for abbreviations

CSP Performance Model

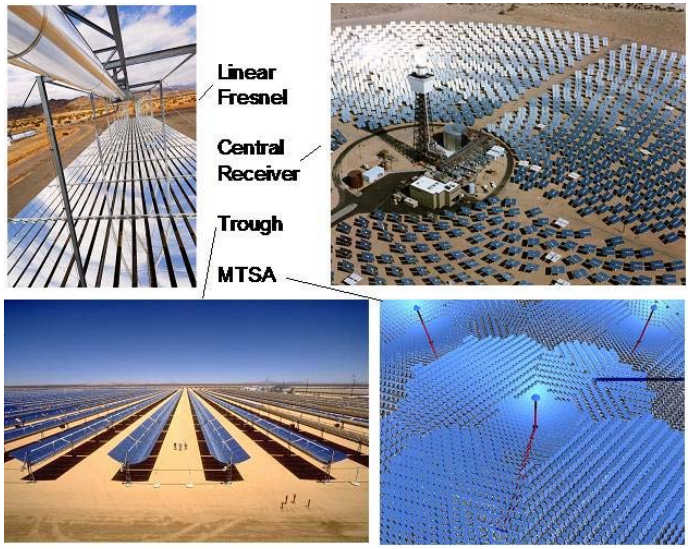
Average Land Use Efficiency (LUE)

= Solar-Electric-Efficiency (12%)

x Land Use Factor (37%)

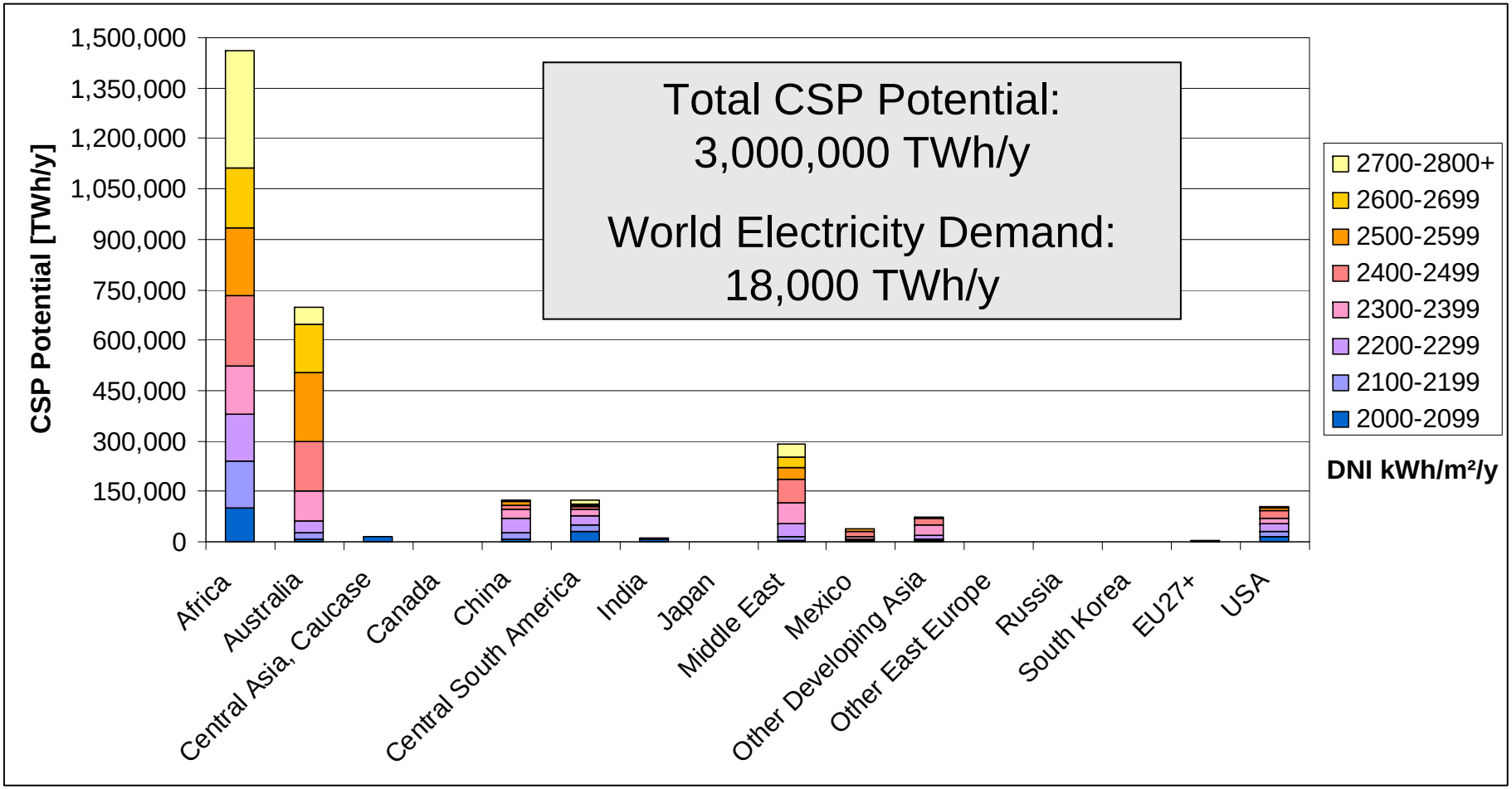
= 4.5% for parabolic trough steam cycle

with dry cooling tower



Collector & Power Cycle Technology	Solar-Electric Aperture Related Efficiency	Land Use Factor	Land Use Efficiency
Parabolic Trough Steam Cycle	11 - 16%	25 - 40%	3.5 - 5.6%
Central Receiver Steam Cycle	12 - 16%	20 – 25%	2.5 – 4.0%
Linear Fresnel Steam Cycle	8 - 12%	60 - 80%	4.8 - 9.6%
Central Receiver Combined Cycle*	20 - 25%	20 - 25%	4.0 – 6.3%
Multi-Tower Solar Array Steam or Combined Cycle*	15 - 25%	60 - 80%	9.0 – 20.0%

Global CSP Potentials by DNI Classes and Regions (4.5% LUE)

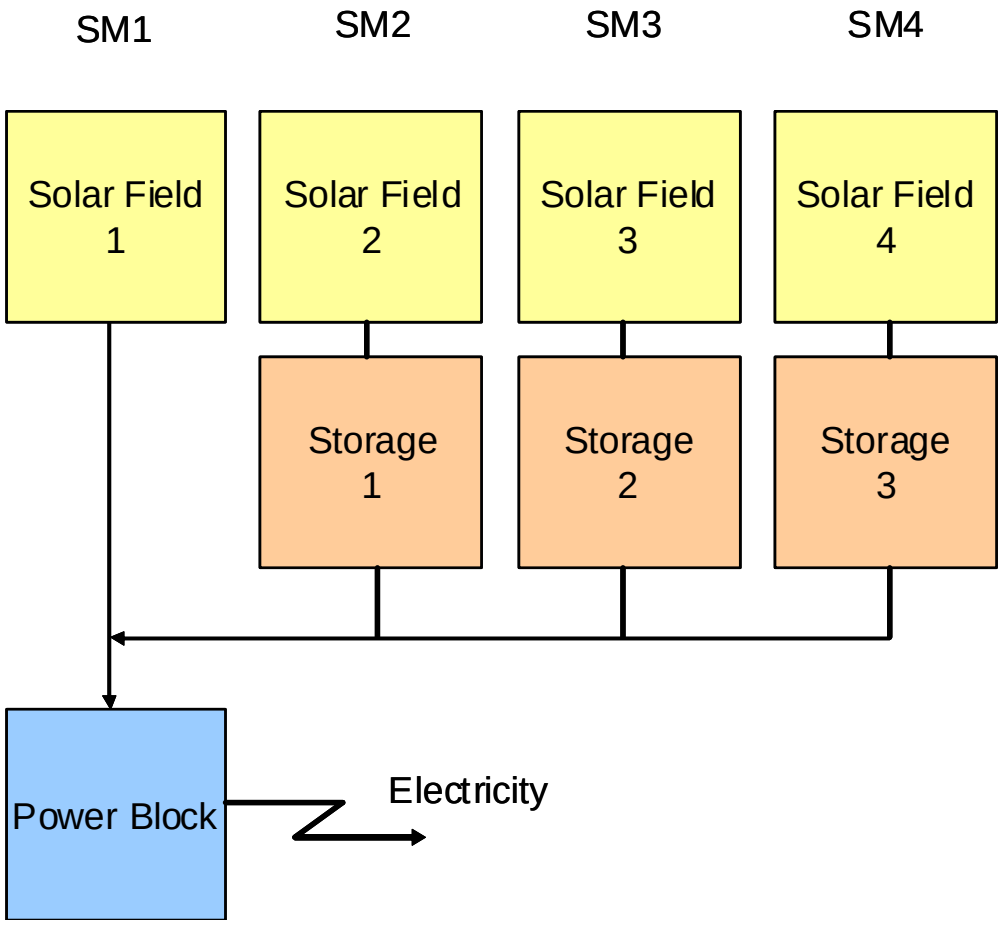


Global CSP Potentials by DNI Classes and Regions (4.5% LUE)

DNI Class	Africa	Australia	Central Asia, Caucase	Canada	China	Central South America	India	Japan
kWh/m²/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y
2000-2099	102,254	6,631	14,280	0	8,332	31,572	7,893	0
2100-2199	138,194	18,587	300	0	18,276	20,585	1,140	0
2200-2299	139,834	36,762	372	0	43,027	24,082	550	0
2300-2399	141,066	87,751	177	0	28,415	20,711	774	0
2400-2499	209,571	148,001	64	0	11,197	6,417	426	0
2500-2599	203,963	207,753	0	0	11,330	3,678	13	0
2600-2699	178,480	142,490	0	0	2,180	5,120	119	0
2700-2800+	346,009	49,625	0	0	3,079	11,827	15	0
Total [TWh/y]	**1,459,370**	**697,600**	**15,193**	**0**	**125,835**	**123,992**	**10,928**	**0**

DNI Class	Middle East	Mexico	Other Developing Asia	Other East Europe	Russia	South Korea	EU27+	USA
kWh/m²/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y	TWh/y
2000-2099	3,432	1,606	4,491	6	0	0	866	14,096
2100-2199	12,443	3,378	5,174	13	0	0	497	17,114
2200-2299	39,191	3,650	10,947	2	0	0	660	21,748
2300-2399	60,188	5,807	30,776	0	0	0	162	16,402
2400-2499	71,324	15,689	19,355	0	0	0	90	23,903
2500-2599	34,954	7,134	4,429	0	0	0	69	8,116
2600-2699	32,263	1,534	253	0	0	0	31	2,326
2700-2800+	36,843	1,878	136	0	0	0	34	0
Total [TWh/y]	**290,639**	**40,675**	**75,561**	**21**	**0**	**0**	**2,409**	**103,704**

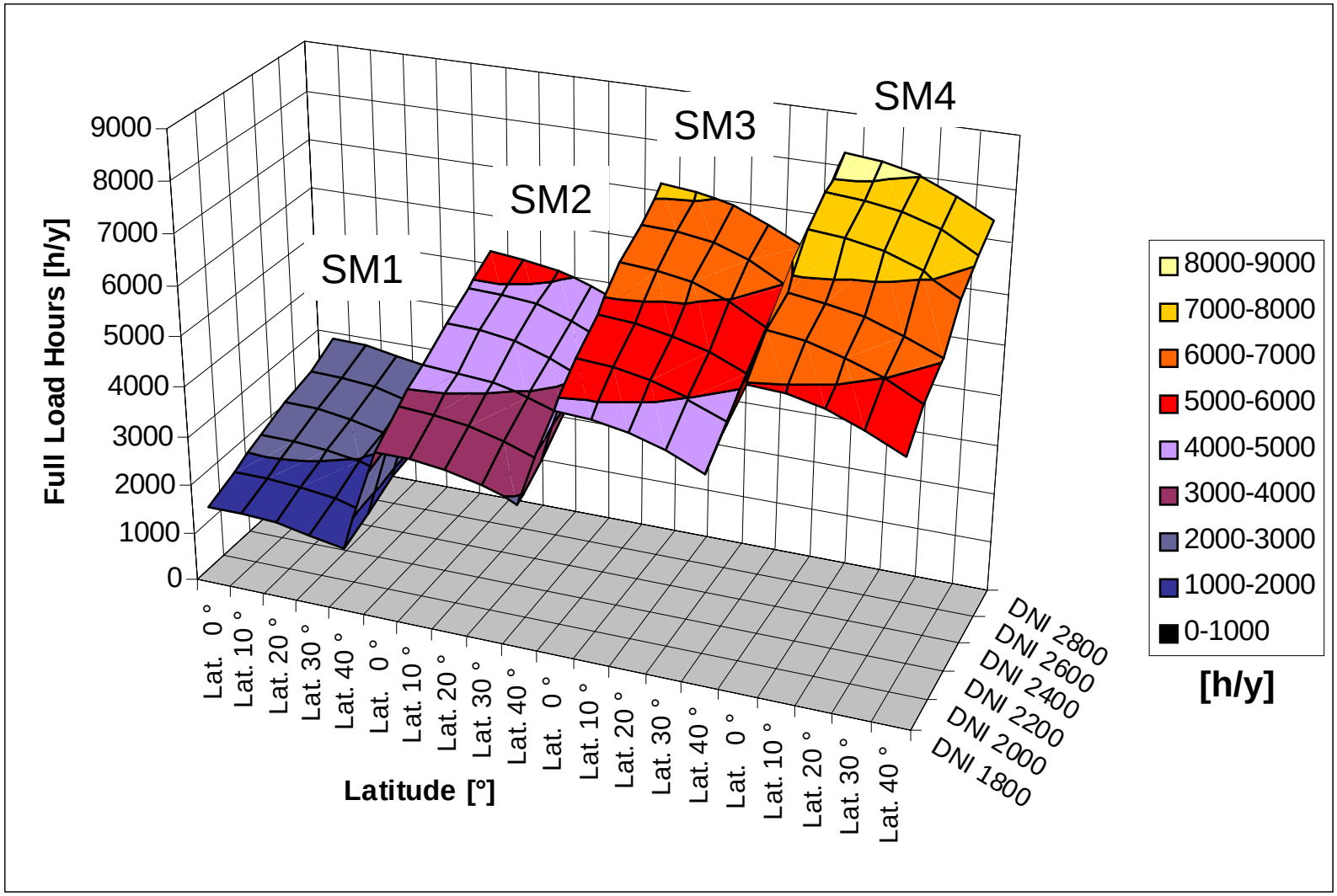
CSP Performance Model (Hourly Time Series)



Collector Unit: 6000 m²/MW

Storage Unit: 6 h

CSP Performance Model (Hourly Time Series)



Annual Full Load Hours (h/y) for different sites and DNI

SM1	DNI 1800	DNI 2000	DNI 2200	DNI 2400	DNI 2600	DNI 2800
Lat. 0 °	1613	1869	2128	2362	2594	2835
Lat. 10 °	1607	1859	2130	2344	2581	2808
Lat. 20 °	1559	1801	2082	2269	2502	2725
Lat. 30 °	1460	1689	1977	2128	2350	2580
Lat. 40 °	1310	1524	1815	1920	2127	2366

SM2	DNI 1800	DNI 2000	DNI 2200	DNI 2400	DNI 2600	DNI 2800
Lat. 0 °	3425	[illegible]	4221	4645	4931	528
Lat. 10 °	3401	[illegible]	4187	4612	4909	522
Lat. 20 °	3310	3719	4098	4495	4810	5096
Lat. 30 °	3147	3539	3943	4283	4605	4887
Lat. 40 °	2911	3285	3719	3984	4301	4604

Spain, SM2

Egypt, SM2

+ 1500

SM3	DNI 1800	DNI 2000	DNI 2200	DNI 2400	DNI 2600	DNI 2800
Lat. 0 °	4869	5414	5810	6405	6713	714
Lat. 10 °	4829	5358	5752	6365	6690	707
Lat. 20 °	4711	5223	5630	6229	6583	6929
Lat. 30 °	4499	4995	5434	5970	6352	6676
Lat. 40 °	4189	4674	5163	5601	5987	6322

Egypt, SM3

+ 3400

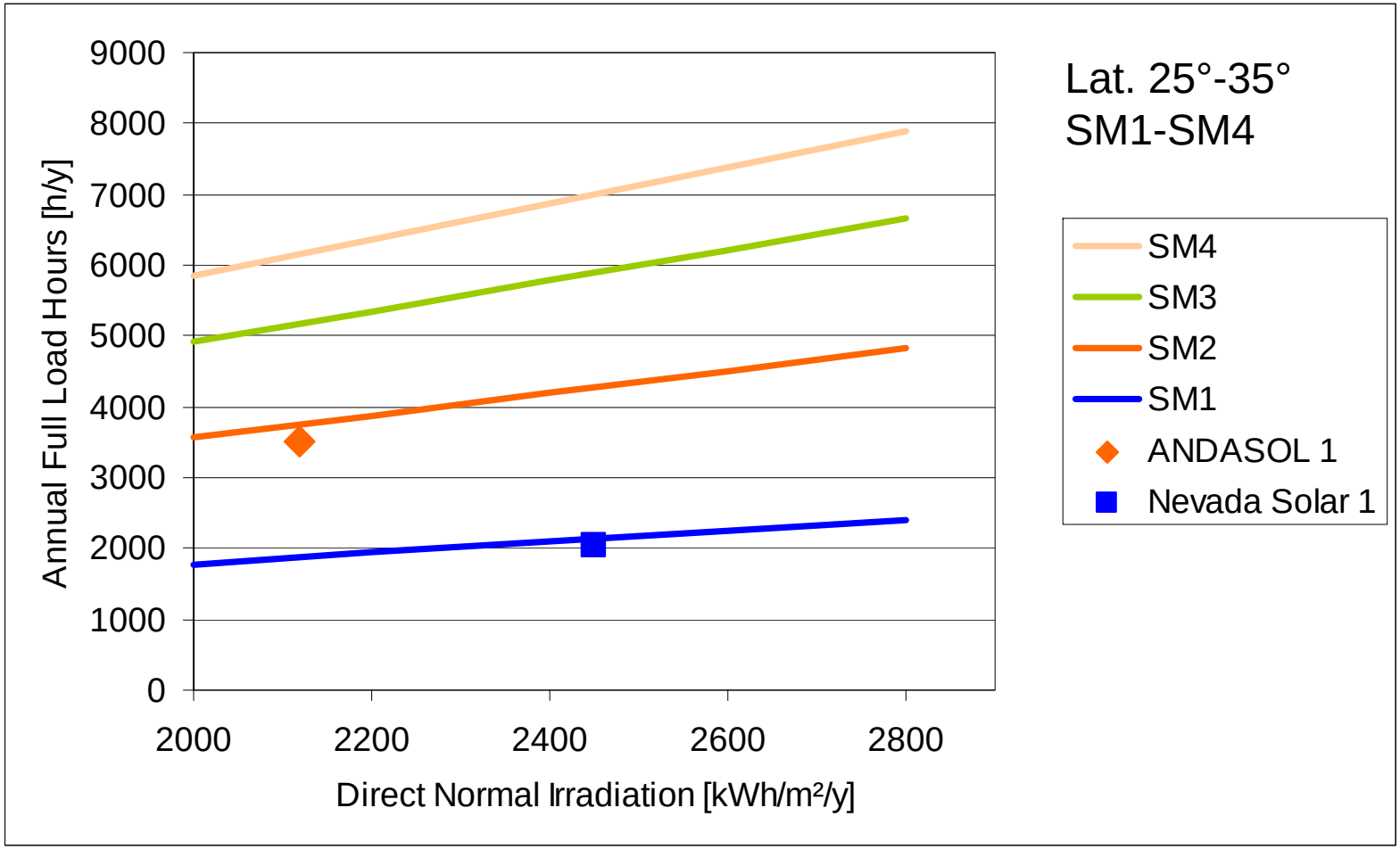
+ 1500

Spain, SM3

SM4	DNI 1800	DNI 2000	DNI 2200	DNI 2400	DNI 2600	DNI 2800
Lat. 0 °	5987	[illegible]	6796	7563	7859	8243
Lat. 10 °	5918	6430	6711	7514	7831	8160
Lat. 20 °	5761	6260	6563	7380	7724	8009
Lat. 30 °	5506	5999	6340	7110	7497	7738
Lat. 40 °	5155	5650	6045	6717	7115	7348

Simplified CSP Performance Model

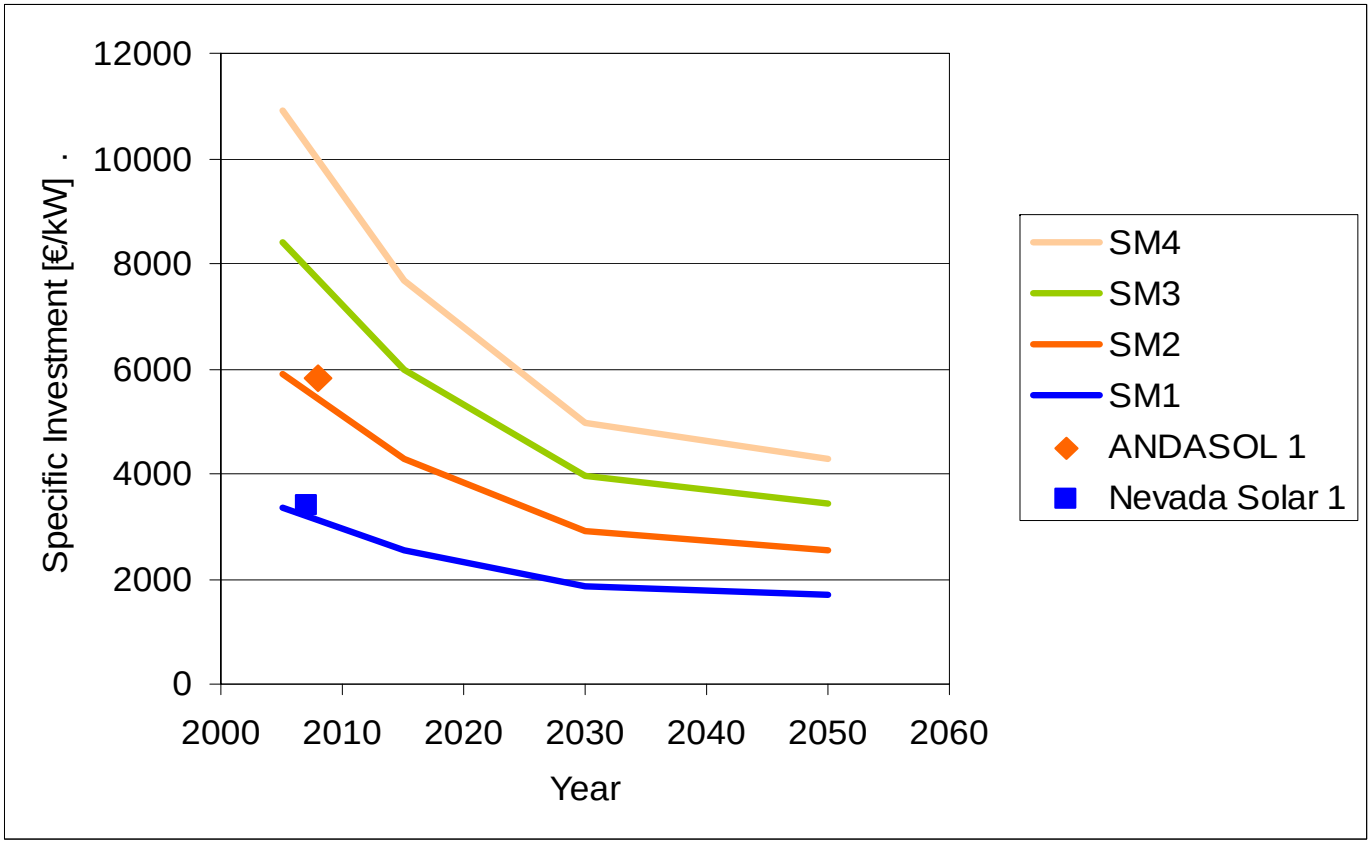
$$Flh = (2.5717 \cdot DNI + 694) \cdot (-0.0371 \cdot SM^2 + 0.4171 \cdot SM - 0.0744)$$



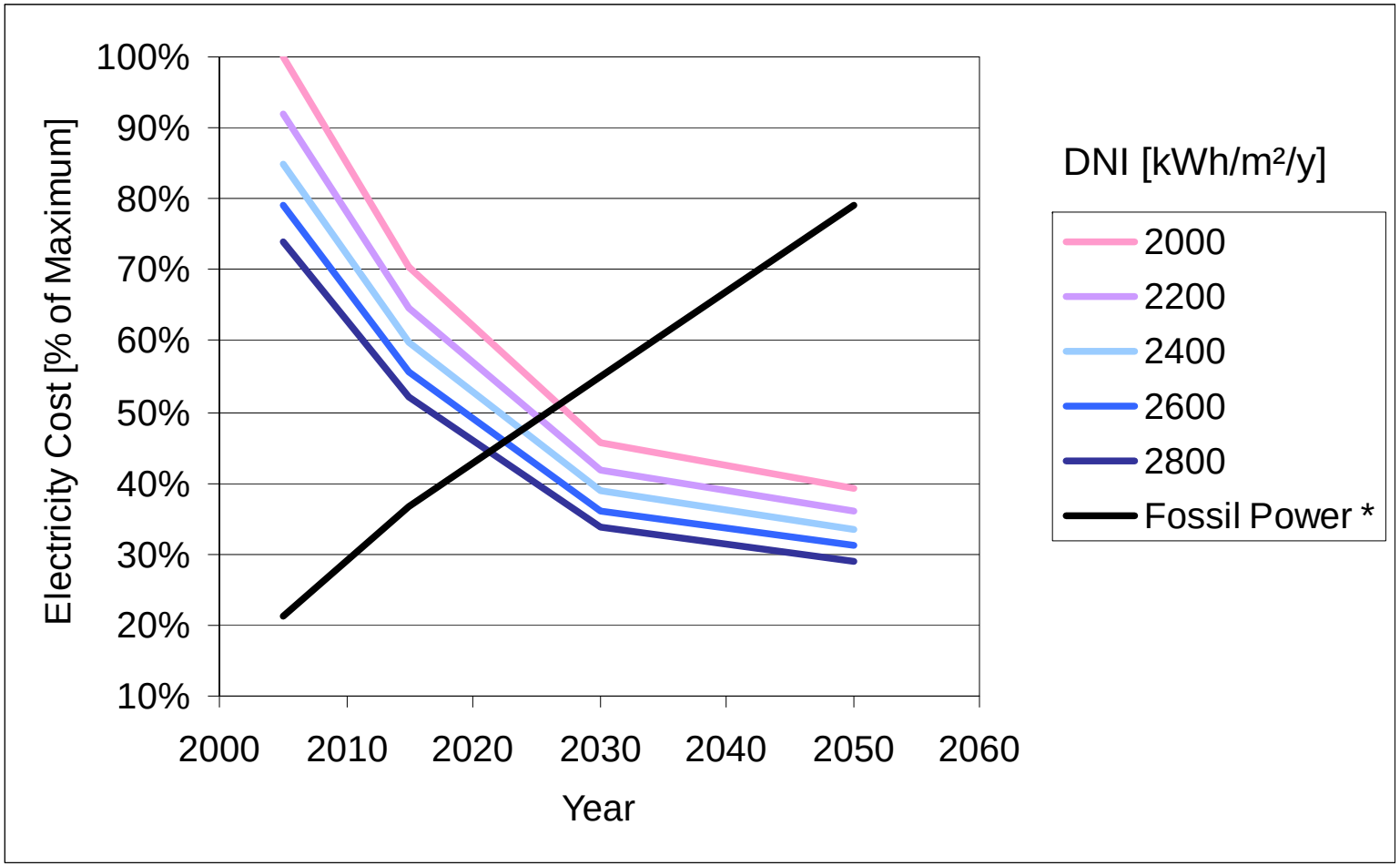
Simplified CSP Investment Cost Model

$$c_x = c_0 \cdot \left(\frac{P_x}{P_0} \right)^{\frac{\log PR}{\log 2}}$$

Year	*PR*	2005	2015	2030	2050	Unit
World CSP Capacity		354	5000	150000	500000	MW
Solar Field	90%	360	241	144	120	€/m²
Power Block	98%	1200	1111	1006	971	€/kW
Storage	92%	60	44	29	25	€/kWh



Simplified CSP Electricity Cost Model



SM4, real constant €$_{2005}$, discount rate 6%, life 25 years, fossil incl. CO_2 cost, O&M 2%/y, insurance 0.5%/y

Thank You!