DESERTEC: Solar Power from the Desert

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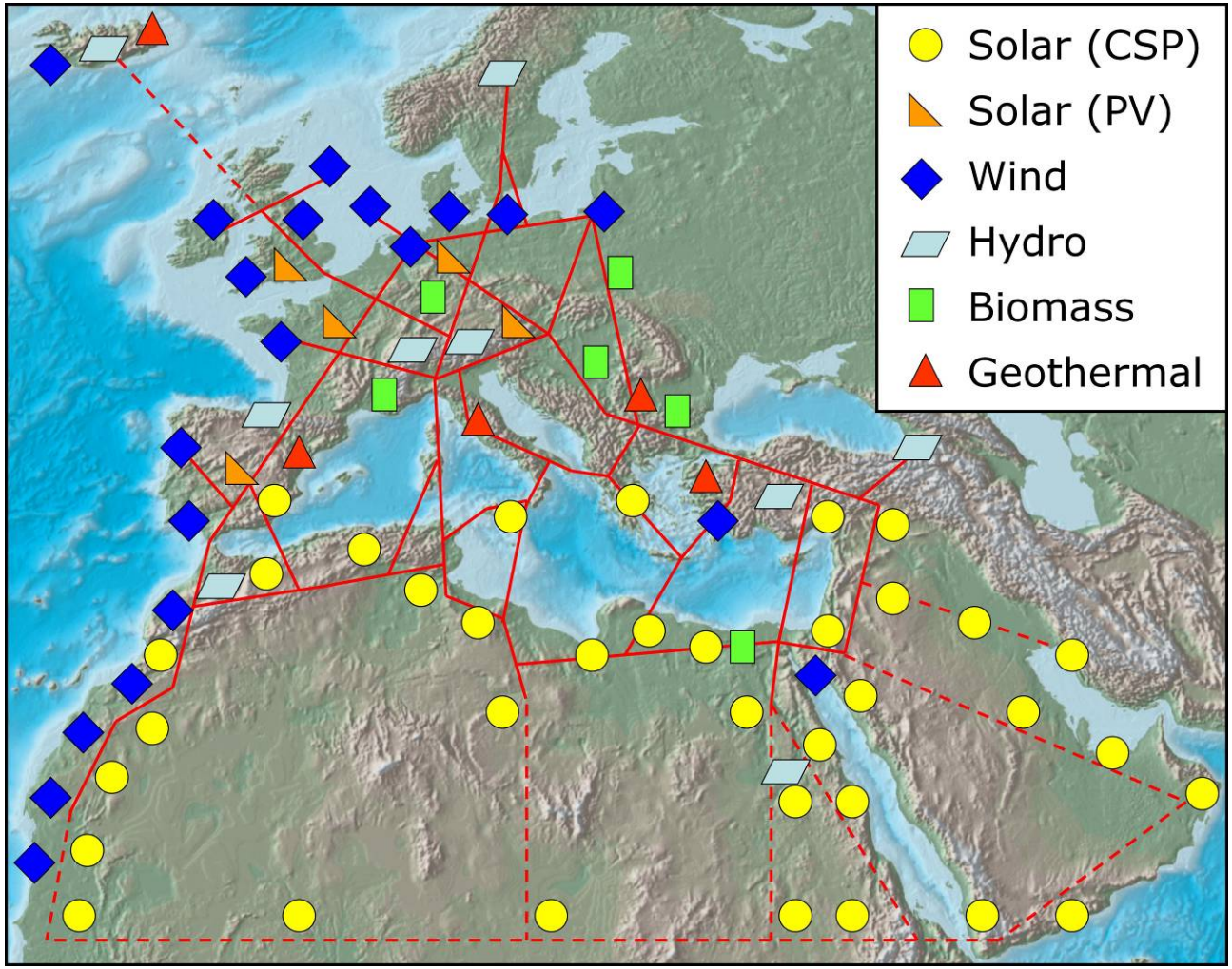
Trans-Mediterranean High Voltage Direct Current Electricity Grid: Interstate Highways for Renewable Electricity in EUMENA

TREC
Clean Power from the Deserts
Trans-Mediterranean
Renewable Energy Cooperation
In conjunction with The Club of Rome

THE CLUB OF ROME



EUMENA:
Europe
Middle East
North Africa

Studies:

MED-CSP

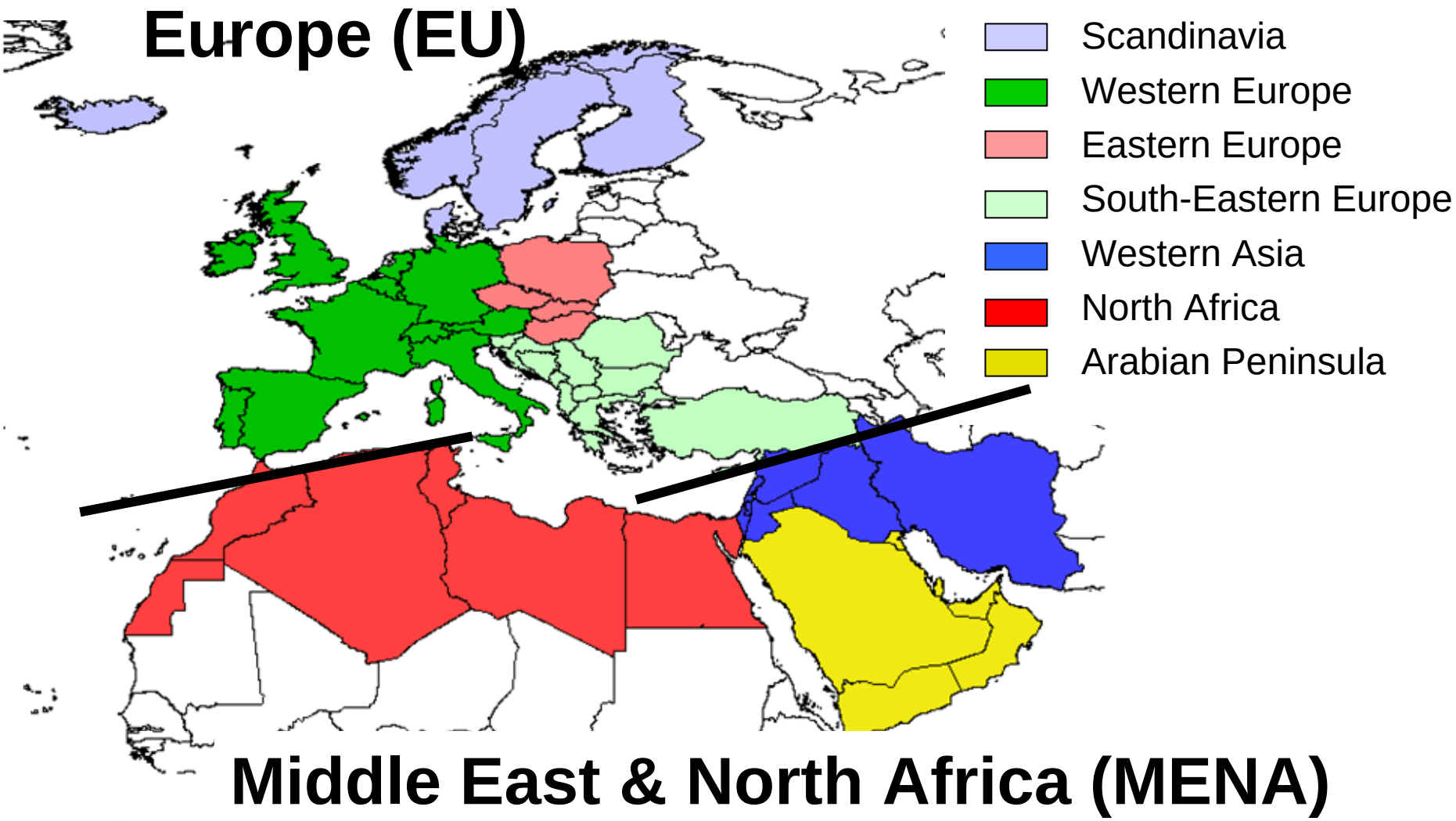
TRANS-CSP

AQUA-CSP

Assessment of the renewable energy potential for the sustainable supply of electricity and water in 50 countries of Europe, the Middle East and North Africa taking into consideration the option of Concentrating Solar Power (CSP).

Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit

50 Countries in EUMENA analysed



Criteria for Sustainable Electricity Supply:

✓ **Inexpensive**

low electricity cost
no long term subsidies

✓ **Secure**

diversified and redundant supply
power on demand
based on inexhaustible resources
available or at least visible technology
capacities expandable in time

✓ **Compatible**

low pollution
climate protection
low risks for health and environment
fair access

Portfolio of Energy Sources for Electricity:

- ✓ Coal, Lignite
- ✓ Oil, Gas
- ✓ Nuclear Fission, Fusion

} ideally stored primary energy

- ✓ Concentrating Solar Power (CSP)
- ✓ Geothermal Power (Hot Dry Rock)
- ✓ Biomass
- ✓ Hydropower

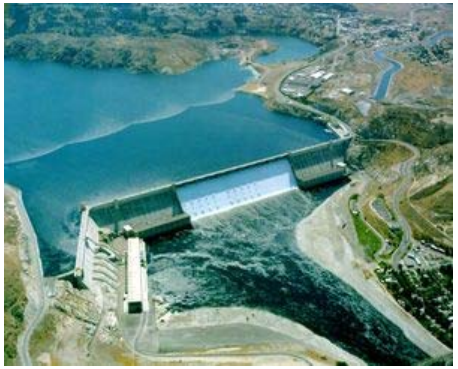
} storable primary energy

- ✓ Wind Power
- ✓ Photovoltaic
- ✓ Wave / Tidal

} fluctuating primary energy

Renewable Energy Technologies

Geothermal



Hydropower

Concentrating Solar Power

Biomass

Tides

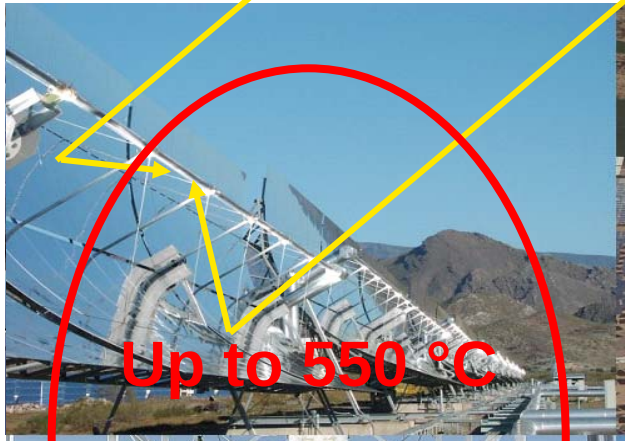
Photovoltaic

Wind Power

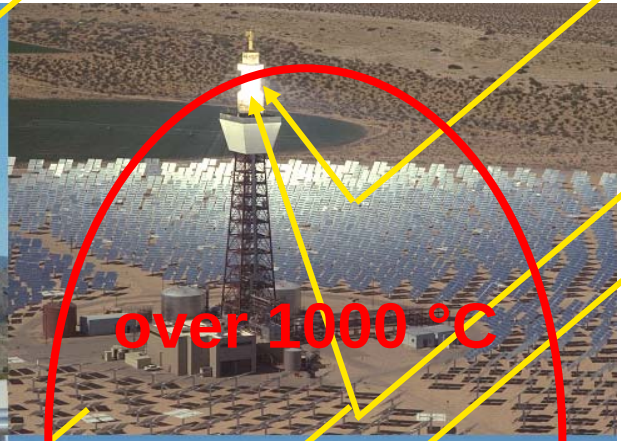
Waves

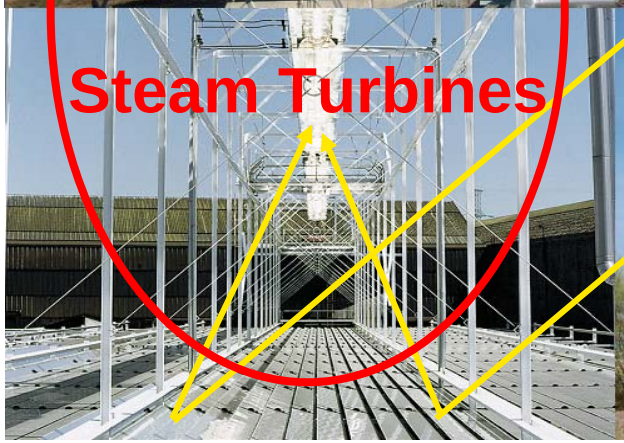
Concentrating Solar Power

Parabolic Trough (PSA)



Solar Tower (SNL)

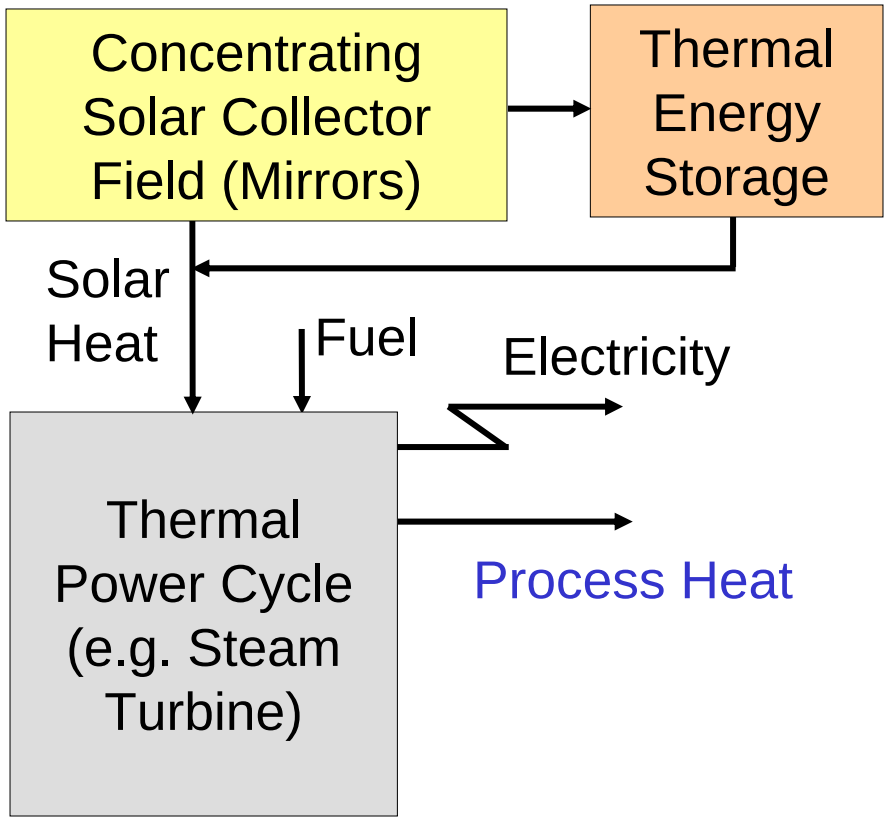




Linear Fresnel (MAN/SPG)

Dish-Stirling (SBP)

Principle of a Concentrating Solar Thermal Power Plant



- concentrated, easily storable solar thermal energy as fuel saver
- spinning reserve
- firm capacity, power on demand
- combined generation of process heat for cooling, industry, desalination, etc.

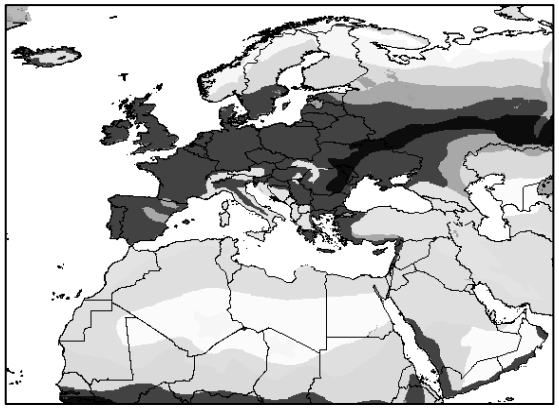
ANDASOL 1, Guadix, Spain (50 MW, 7 h Storage, 2009)

High Voltage Direct Current Transmission

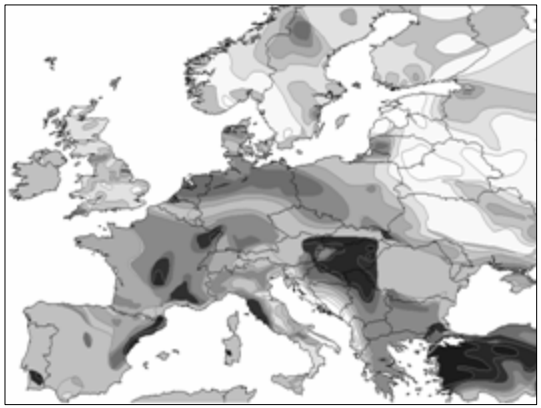
Voltage:	± 800.000 Volt
Power:	6400 Megawatt
Length:	2070 km
Source:	Hydropower

Renewable Electricity Potential in Europe, Middle East & North Africa

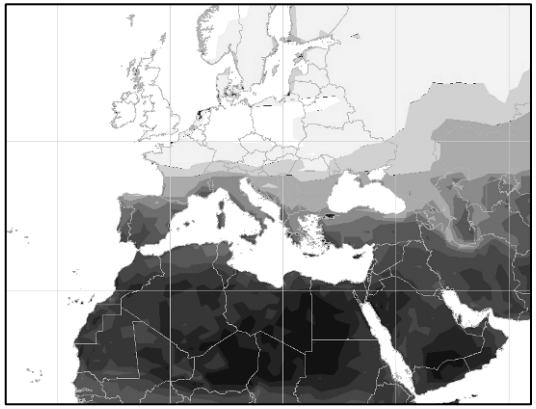
Biomass (0-1)

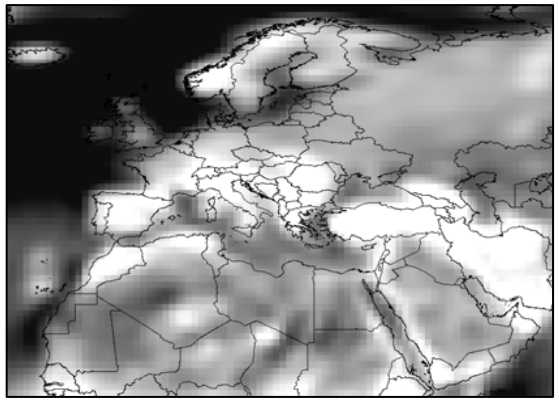


Geothermal (0-1)

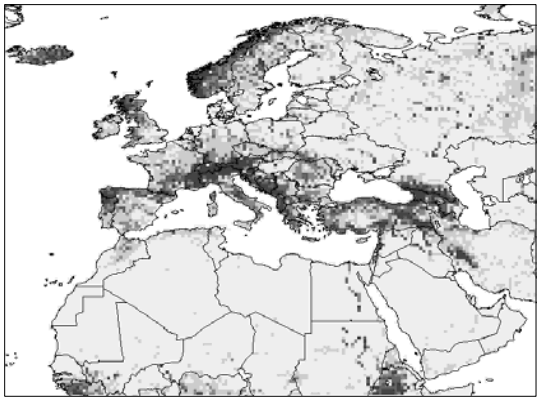


Solar (10-250)





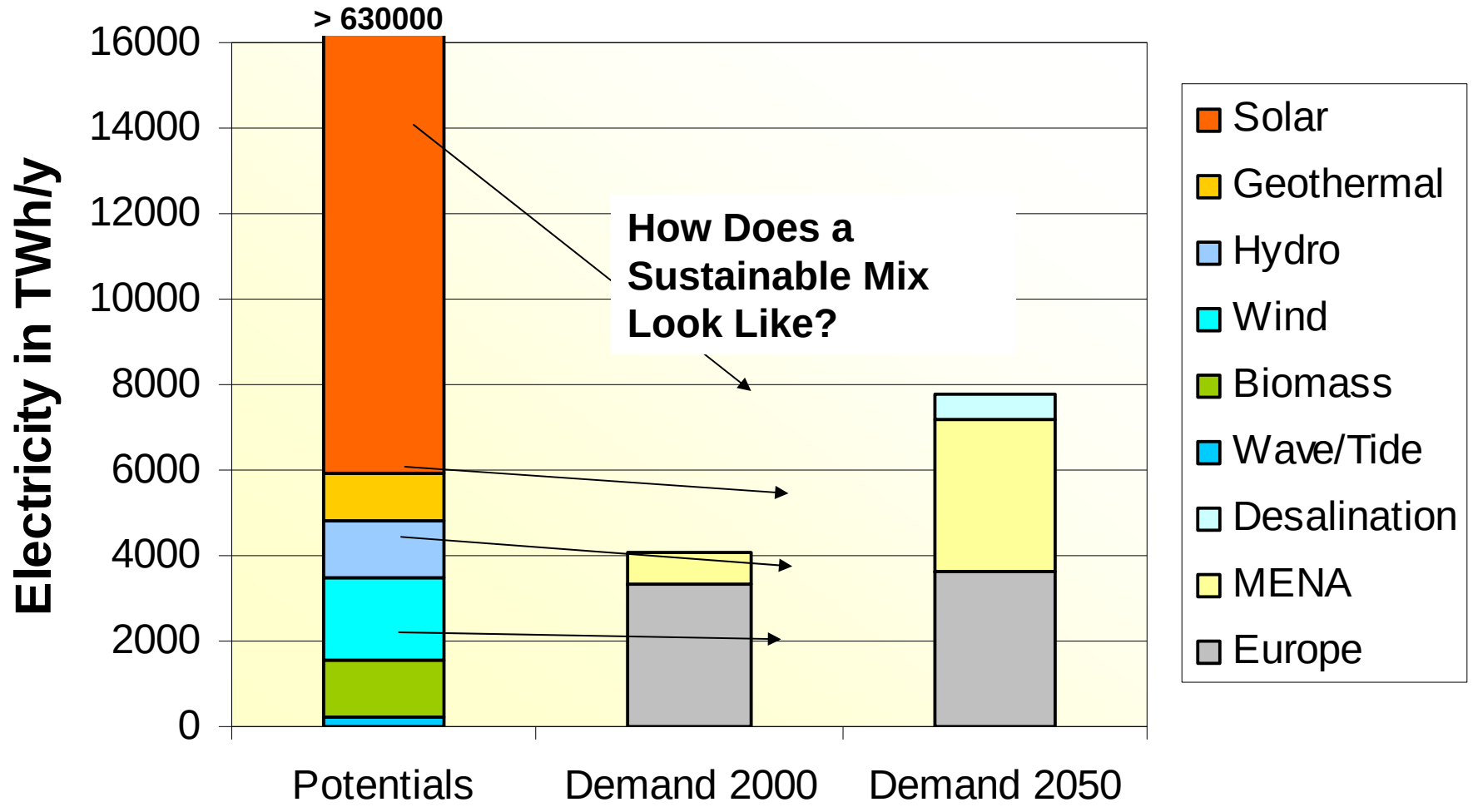
Wind Energy (5-50)



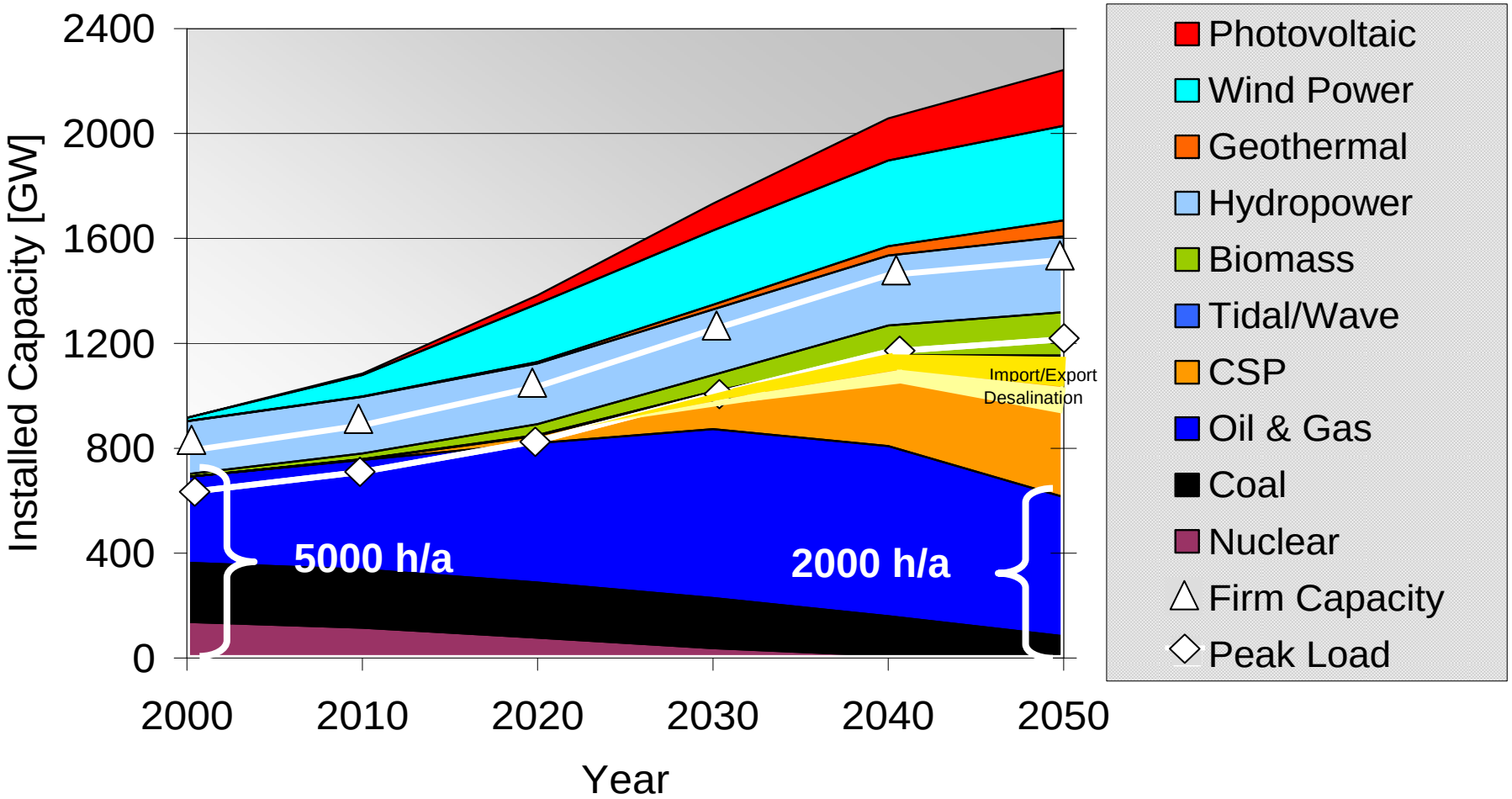
Hydropower (0-50)

Electricity Yield
in GWh/km²/y

Economic Renewable Electricity Potentials vs. Demand in EUMENA

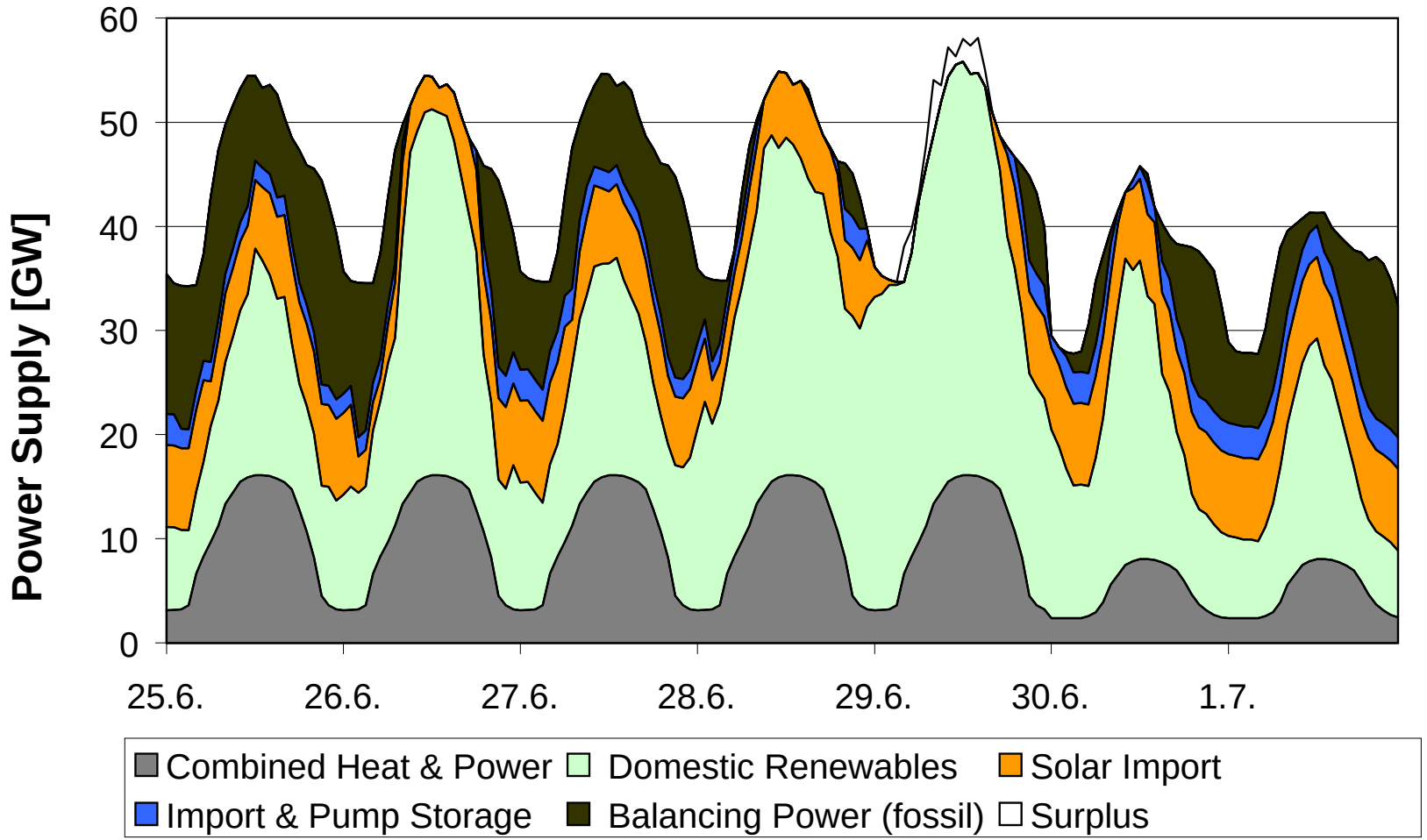


Installed Capacity vs. Peak Load in EUMENA



➔ 100 % availability plus 25 % reserve capacity

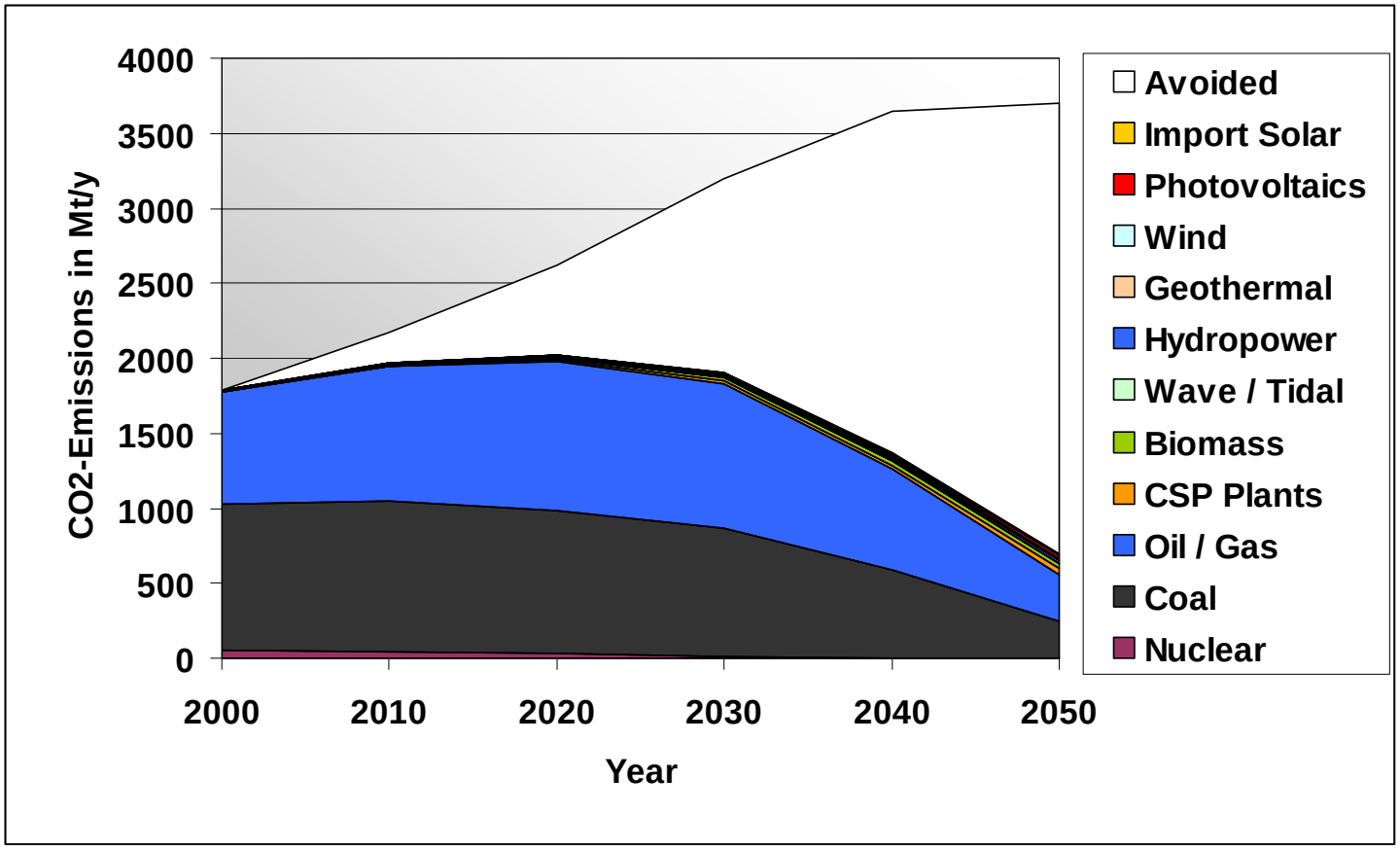
Firm Power Capacity based on Renewables and Fuel (no fossil or nuclear base load supply)



Availability and Redundancy

- Power on Demand by a Mix of Fluctuating and Balancing Sources
- Increased Number of Non-Correlated Energy Sources
- Increased Number and Reduced Average Size of Power Plants
- Increased Number of Supply Regions
- Additional HVDC Grid Infrastructure for Long-Distance Transfer
- Domestic Sources Dominate the Electricity Mix
- Non-depletable Sources Dominate the Electricity Mix
- Strategy is Based on Proven Technologies

Carbon emissions of EUMENA power sector are reduced to 38 % until 2050 in spite of a quickly growing demand

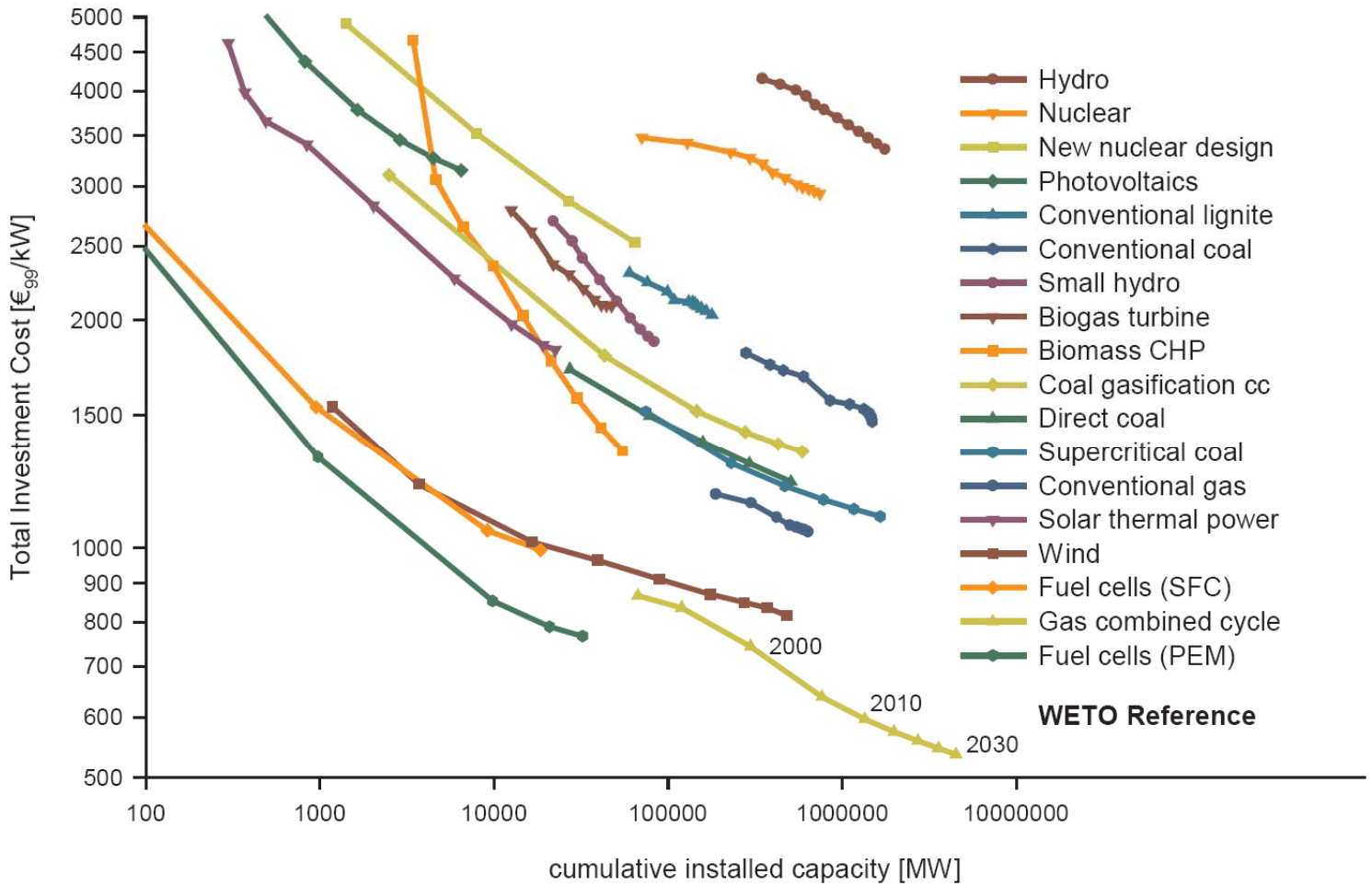


1% of Land Area Required

Environmental Security

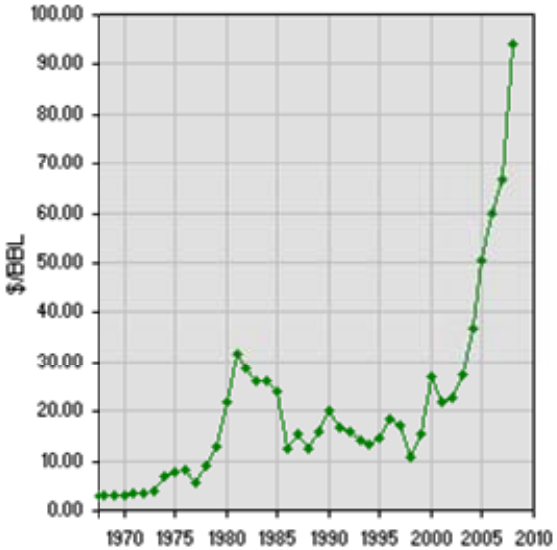
- Reduced Life Cycle Greenhouse Gas Emissions of Power Generation
- Reduced Risks of Nuclear Radiation and Proliferation
- Reduced Local Pollution by Combustion Products
- Optimal Land Use (1%) through Diversified Mix
- Technology based on Recyclable Materials

Equipment Cost Learning Curves

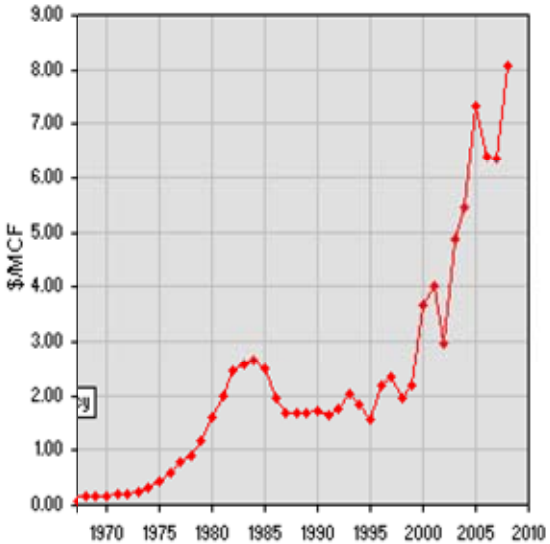


http://ec.europa.eu/research/energy/pdf/weto_final_report.pdf

Crude Oil Price

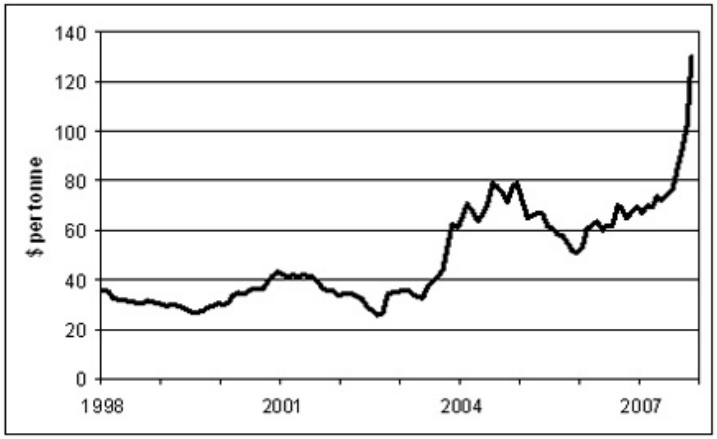


Natural Gas Price



www.oilnergy.com

Coal Price



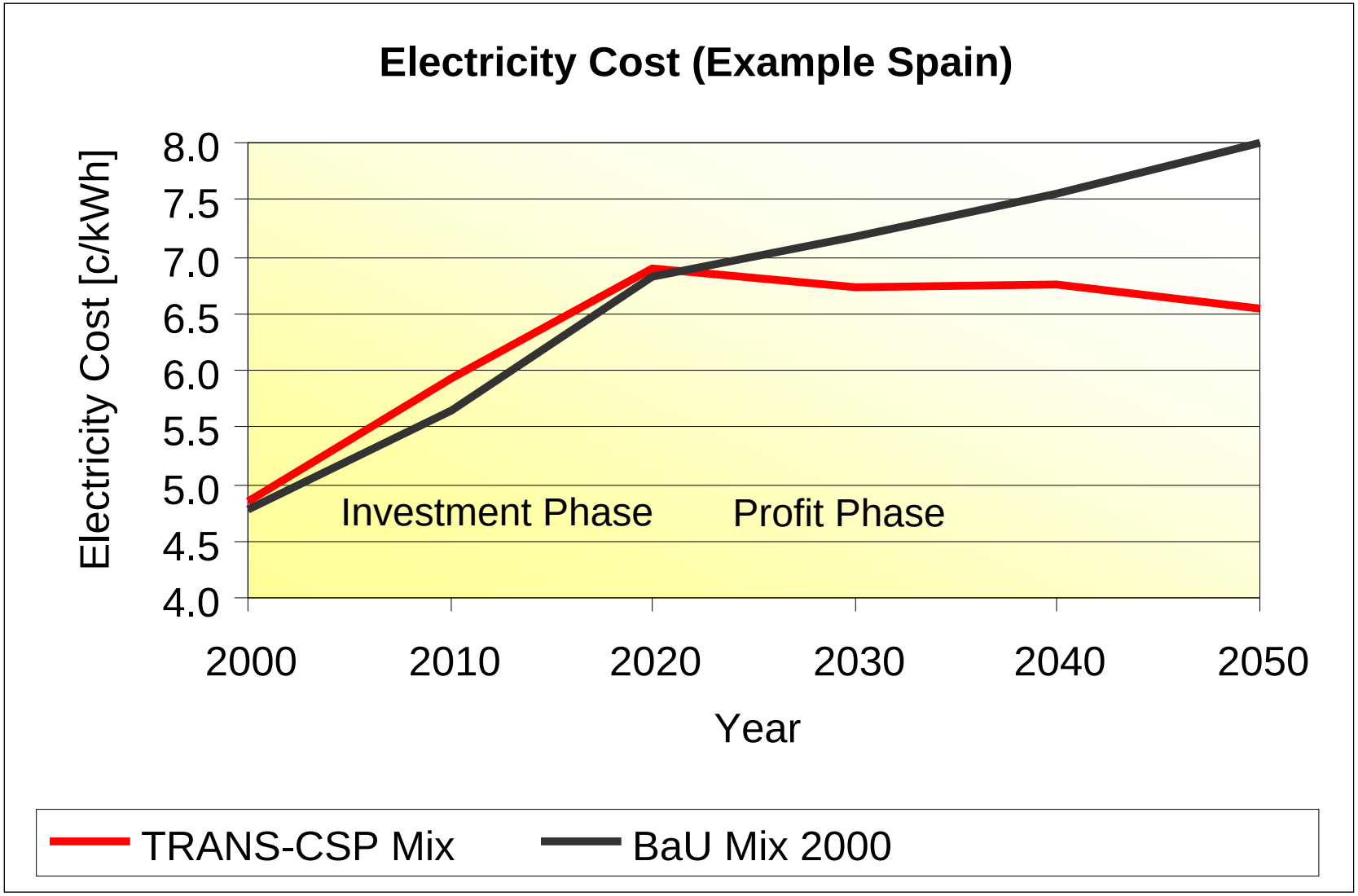
Nuclear Decommissioning Cost

National Audit Office UK
Nuclear Decommissioning Authority UK

11 GW Capacity
61 £ Billion of 2007

= 6000 €/kW

http://www.nao.org.uk/publications/0708/the_nuclear_decommissioning_au.aspx

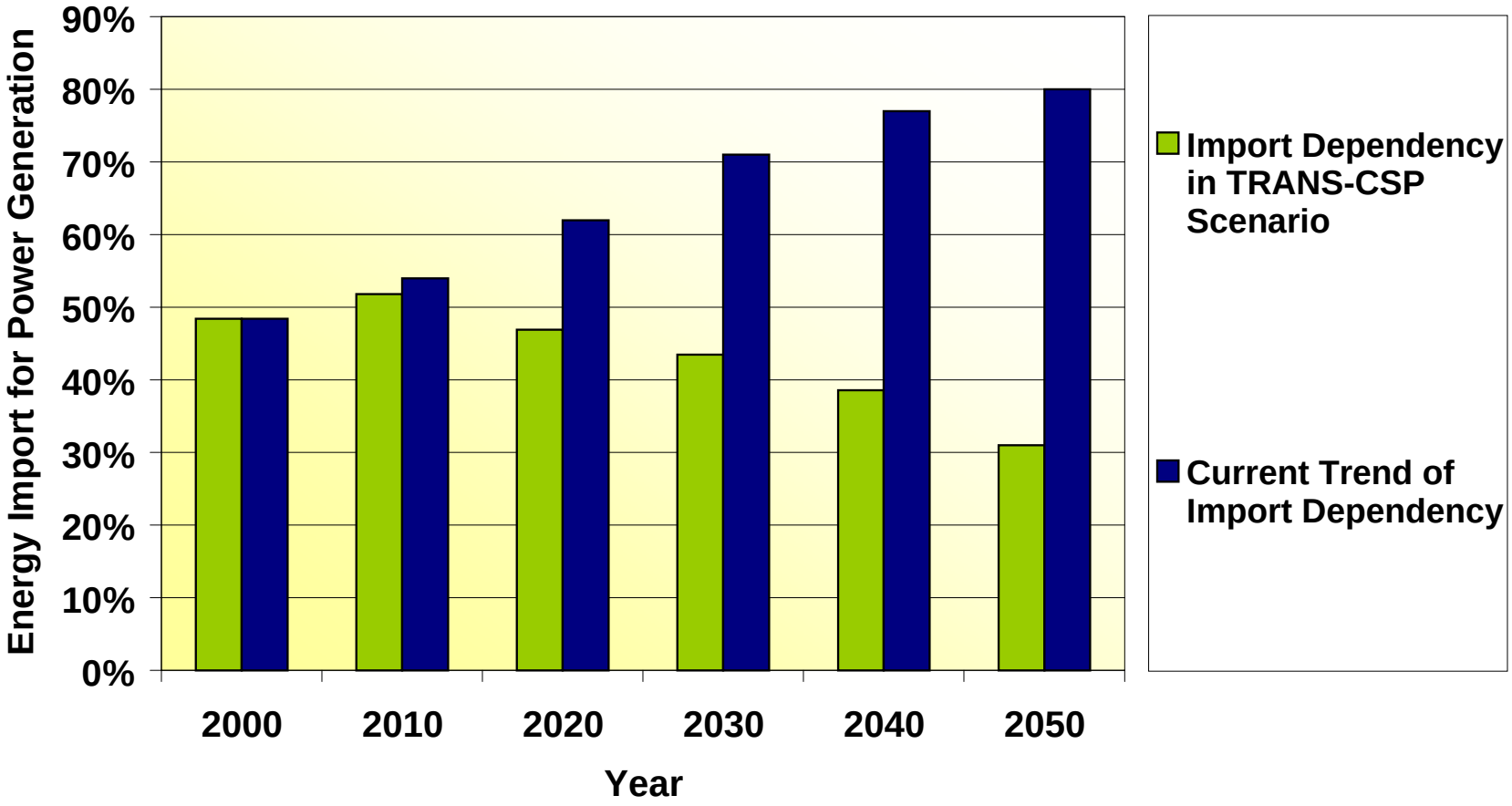


$€_{2000}$, Fuel Cost: IEA / WEO 2005, after 2020 CCS

Economic Security

- Economic Risk Hedged by Increased Portfolio
- Intrinsic Trend to Lower Cost and Lower Price Volatility
- Energy Cost Stabilization through Investment in New Sources
- Prevention of Cost Escalation due to Environmental Constraints
- Prevention of Cost Escalation due to Scarcity
- Reduction of Energy Subsidies in Europe and MENA

Import Dependency of European Power Generation



Solar Power & Desalination Plants

Energy,
Water,
Food,
Labor and
Income

for further
300 Million
People
in MENA ?

(artist view created with
Google Earth)

Political Security

- Conflict Prevention between EU and MENA Reducing Pressure on Fuels
- Conflict Prevention in MENA Solving Energy and Water Scarcity
- Conflict Prevention in Europe Increasing Energy Diversity
- Reduction of European Energy Import Dependency
- Addition of Energy Corridors for European Supply
- Initiating EU-MENA (Energy) Partnership

Challenges

- Requires New Structures and New Thinking (Change of Paradigm)
- Requires Long-Term Financing Schemes due to Long-Term Investments
- Based on International Cooperation and Interdependencies
- Higher Complexity than Using Ideally Stored Fossil Energy Sources
- More Stakeholders Involved due to Decentralized Generation
- Cultural and Political Differences in EUMENA
- Lobby Groups Acting Against Each Other
- Speed of Environmental Change and Conflict Potentials

Thank You!

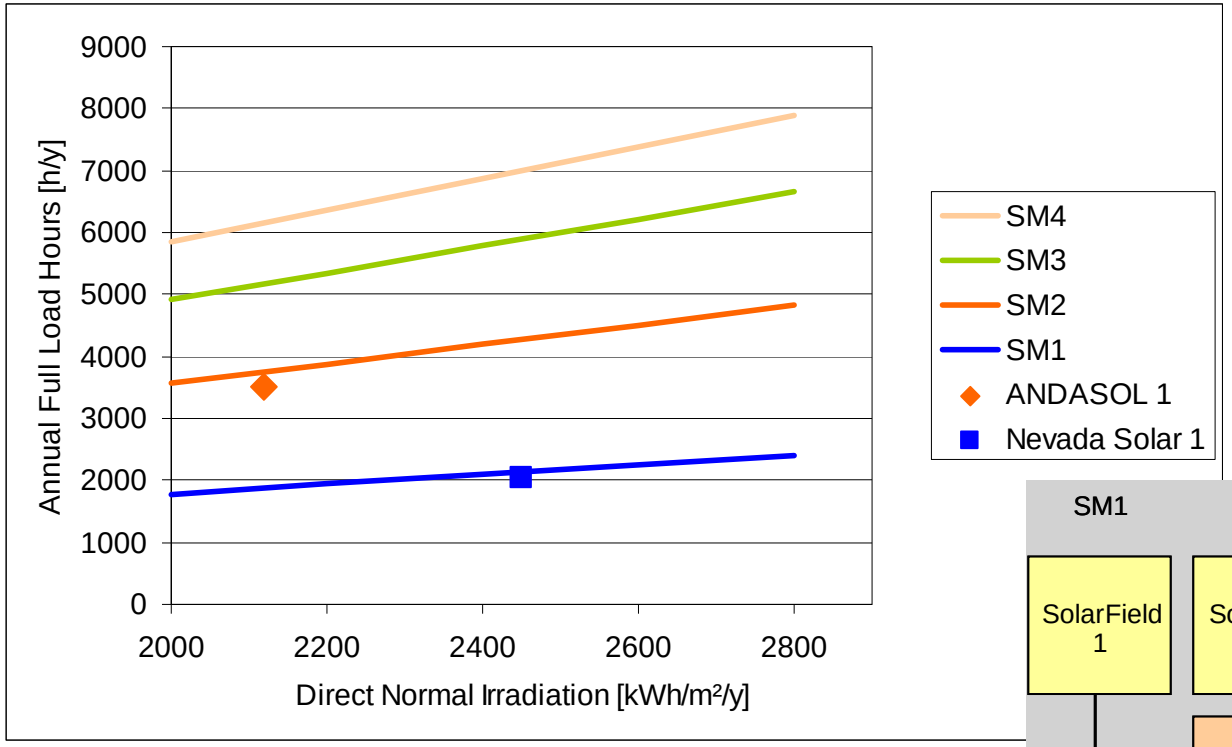
Some Background Information

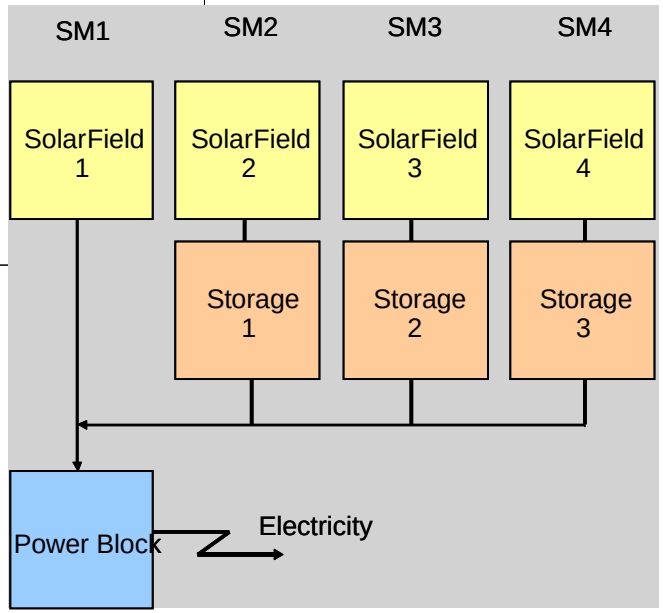
Total EU-MENA HVDC Interconnection 2020 – 2050 *

Year		2020	2030	2040	2050
Lines x Capacity GW		4 x 2.5	16 x 2.5	28 x 2.5	40 x 2.5
Transfer TWh/y		60	230	470	700
Capacity Factor		0.60	0.67	0.75	0.80
Turnover Billion €/y		3.8	12.5	24	35
Land Area	CSP	15 x 15	30 x 30	40 x 40	50 x 50
km x km	HVDC	3100 x 0.1	3600 x 0.4	3600 x 0.7	3600 x 1.0
Cum. Investment	CSP	42	134	245	350
Billion €	HVDC	5	16	31	45
Elec. Cost	CSP	0.050	0.045	0.040	0.040
€/kWh	HVDC	0.014	0.010	0.010	0.010

* All countries analysed in TRANS-CSP

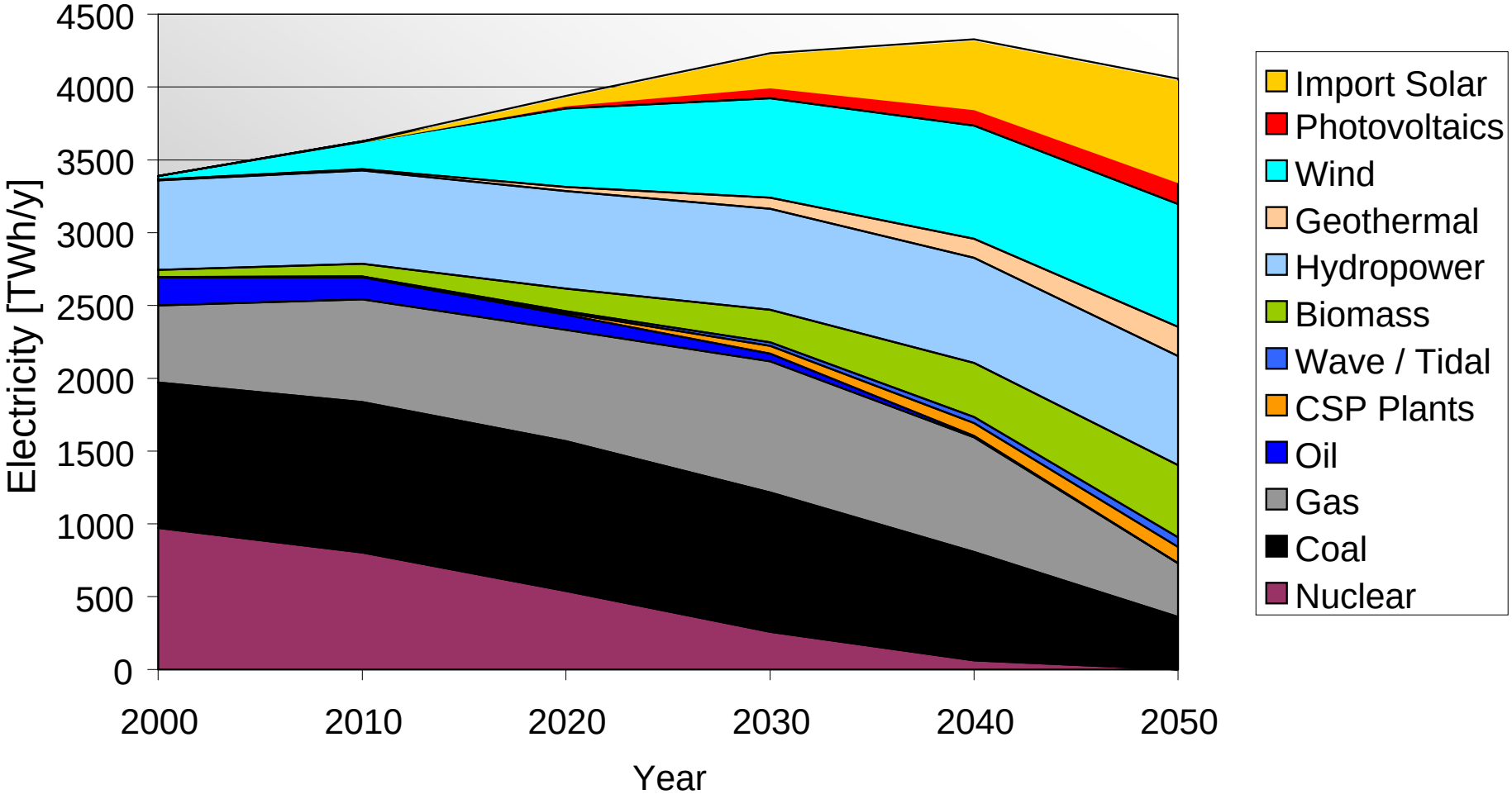
Effect of Thermal Energy Storage on the Availability of CSP



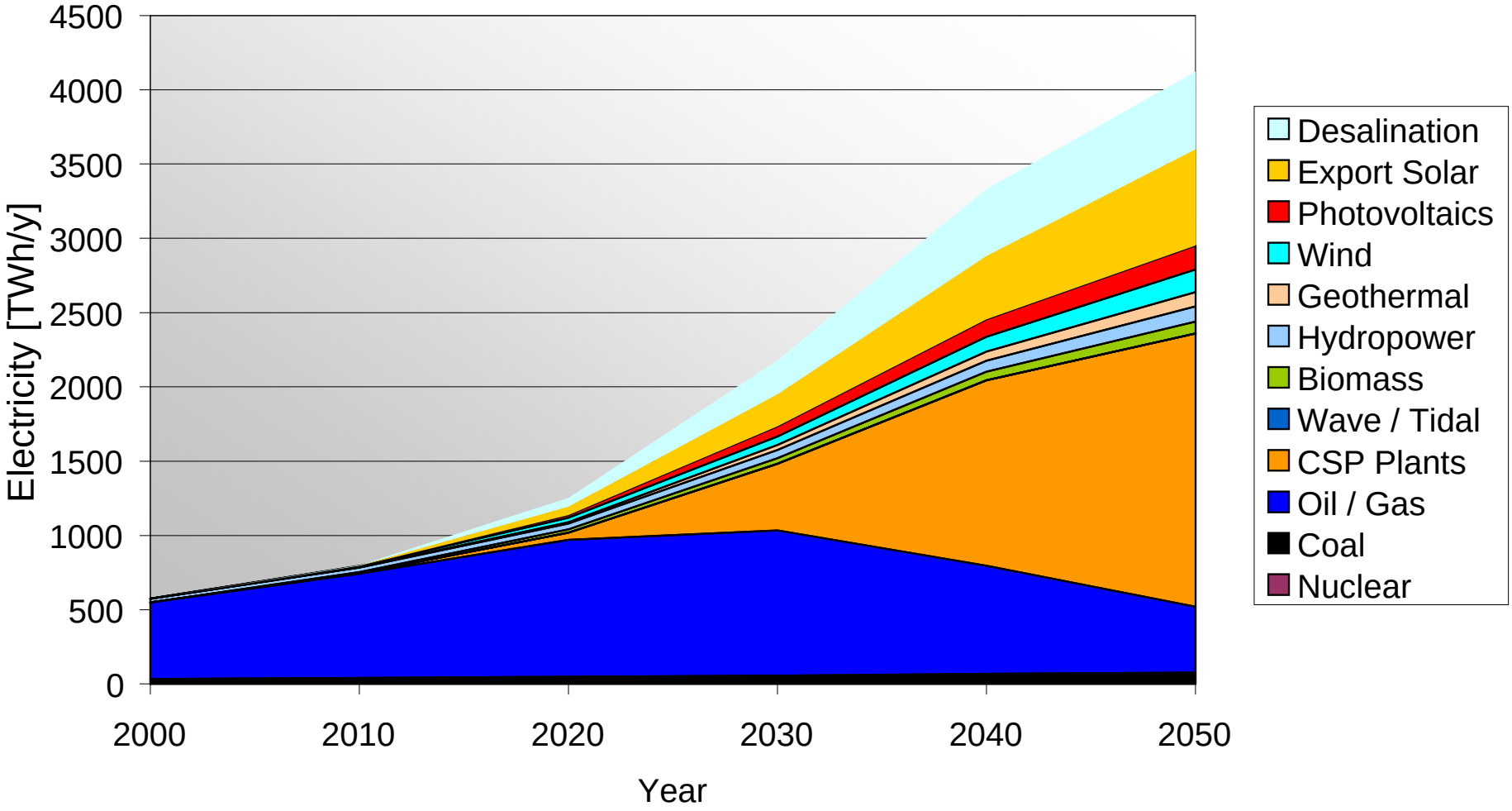


SM = Solar Multiple
1 Solar Field = 6000 m²/MW
1 Storage = 6 hours (full load)

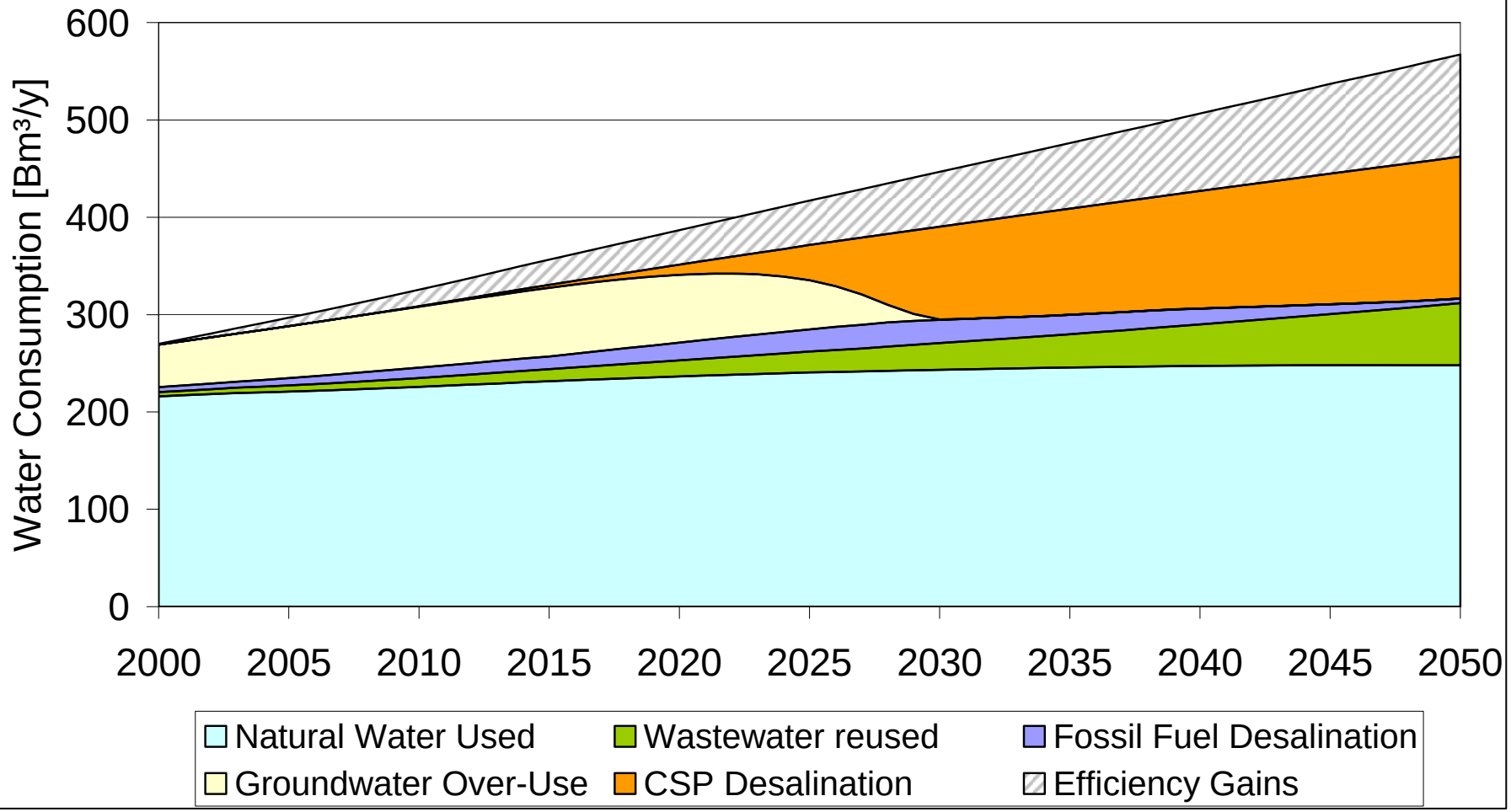
Electricity Supply in Europe (TRANS-CSP Scenario)



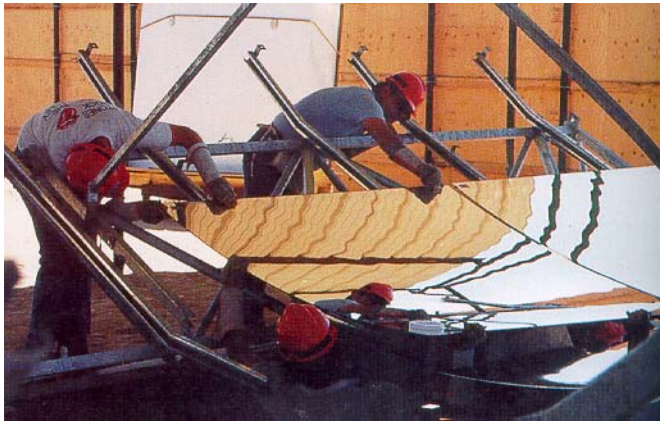
Electricity Supply in the Middle East & North Africa



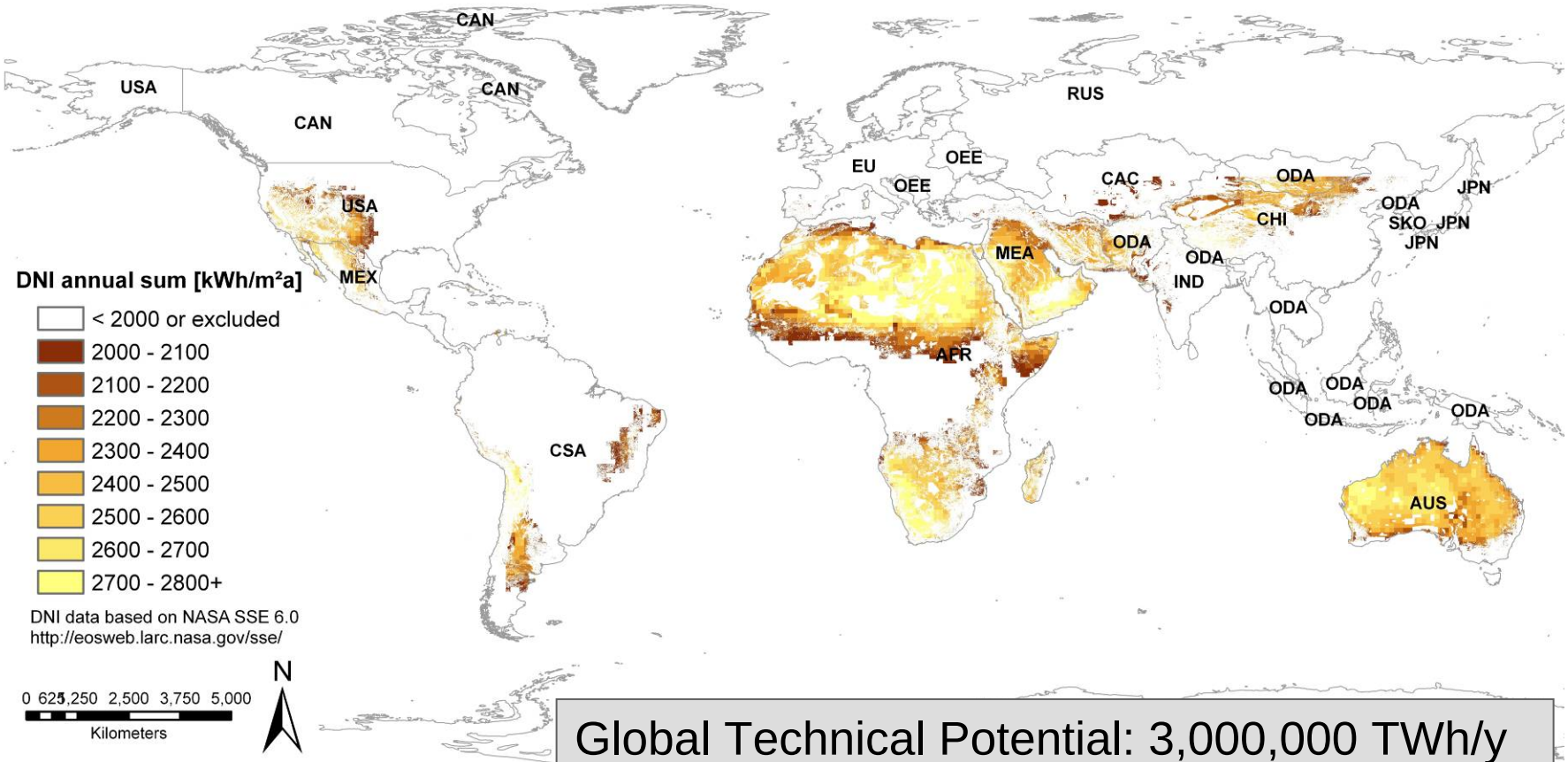
AQUA-CSP Scenario for Middle East & North Africa



Solar Electricity Generating System - SEGS, California, USA (354 MW, online since 1985)



Global Potential for Concentrating Solar Power



Global Technical Potential: 3,000,000 TWh/y
Global Electricity Consumption: 18,000 TWh/y

Data provided by DLR (2008) for EU-project REACCESS

DNI Class	Africa	Australia	Central Asia, Caucase	Canada	China	Central South America	India	Japan
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	**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
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	**290,639**	**40,675**	**75,561**	**21**	**0**	**0**	**2,409**	**103,704**

CSP potentials in TWh/y available in the REACCESS world regions for different DNI Classes