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The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Concentrating Solar Power for the Mediterranean Region (MED-CSP)

Trans-Mediterranean Interconnection for CSP (TRANS-CSP)

Results of the Study Projects for the Research & Development Programme of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

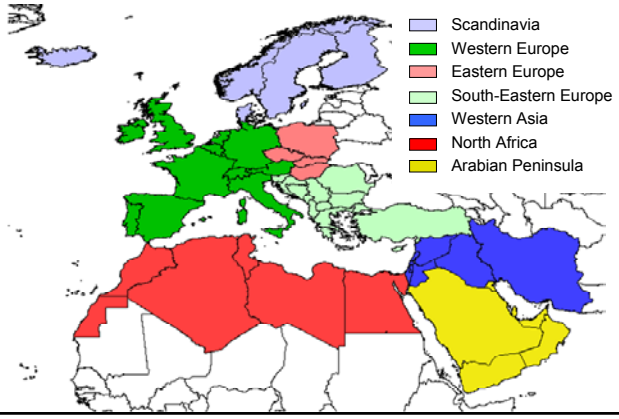
Scope

What are the renewable electricity potentials in EUMENA* and how could they be linked to provide sustainable power on demand?

- Assess Renewable Energy Resources
- Estimate Power Demand
- Develop National Electricity Scenarios
- Evaluate Socio-Economic and Environmental Impacts

* Europe, Middle East, North Africa

50 Countries in EUMENA analysed within the MED-CSP and TRANS-CSP Studies



Technology Portfolio:

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

→ ***ideally stored energy***

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

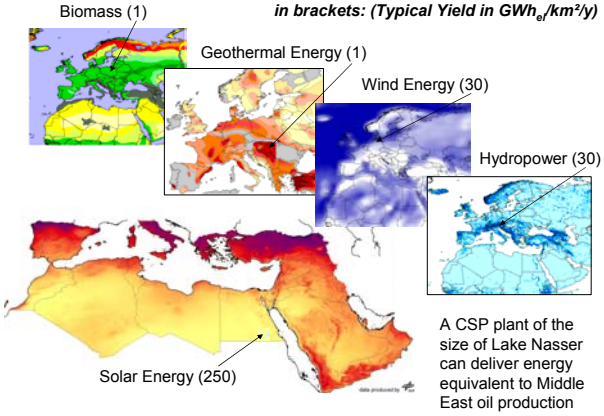
→ ***storable energy***

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

→ ***fluctuating energy***

Renewable Energy Resources in EUMENA

in brackets: (Typical Yield in $GWh_e/km^2/y$)



A CSP plant of the size of Lake Nasser can deliver energy equivalent to Middle East oil production

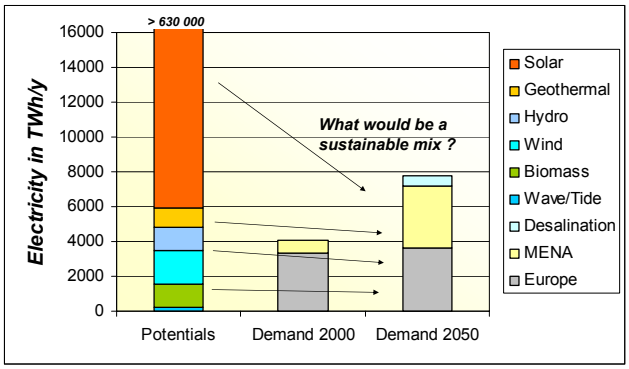
Rigorous Criteria for Sustainability:

✓ ***Inexpensive***
- low electricity cost
- no long term subsidies

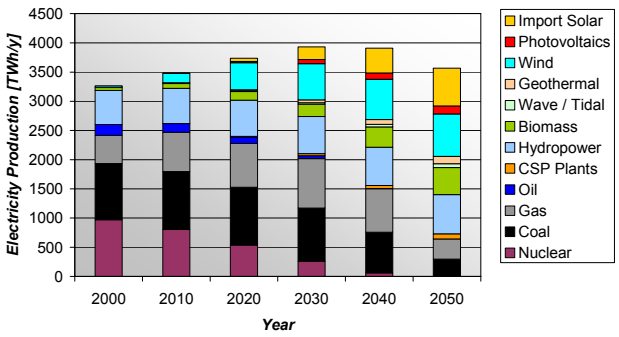
✓ ***Secure***
- diversified and redundant supply
- power on demand
- undepletable resources
- available or visible technology

✓ ***Compatible***
- low pollution
- climate protection
- low risks
- fair access

Economic Renewable Electricity Potentials vs. Demand in EUMENA

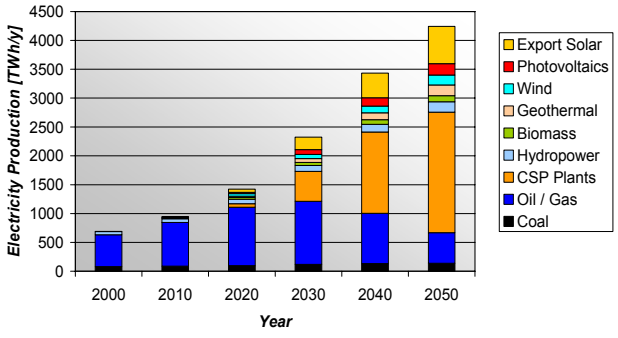


Electricity Production in Europe (TRANS-CSP Scenario)



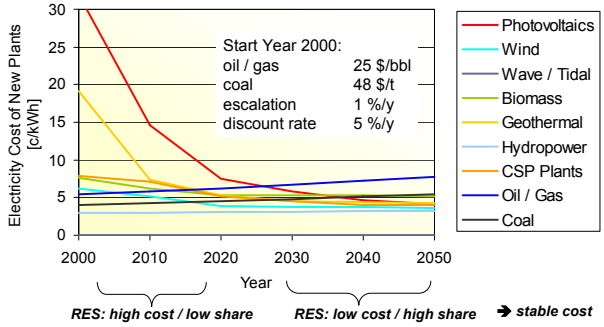
Iceland, Norway, Sweden, Finland, Denmark, Ireland, United Kingdom, Portugal, Spain, France, Belgium, Netherlands, Luxembourg, Germany, Austria, Switzerland, Italy, Poland, Czech Republic, Hungary, Slovakia, Slovenia, Croatia, Bosnia-Herzegovina, Serbia-Montenegro, Macedonia, Greece, Romania, Bulgaria, Cyprus, Malta

Electricity Production in MENA (MED-CSP Scenario)

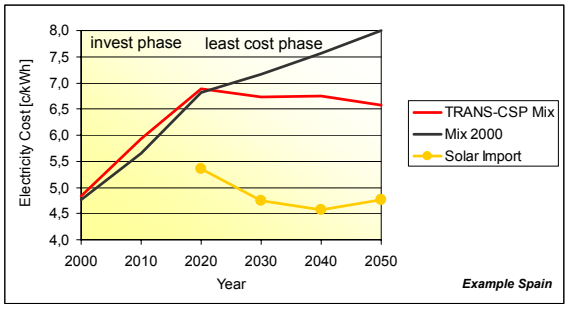


Morocco, Algeria, Tunisia, Libya, Egypt, Turkey, Iran, Iraq, Jordan, Israel, Lebanon, Syria, Saudi Arabia, Yemen, Oman, United Arab Emirates, Kuwait, Qatar, Bahrain

Electricity Cost of Power Technologies (Example Egypt)

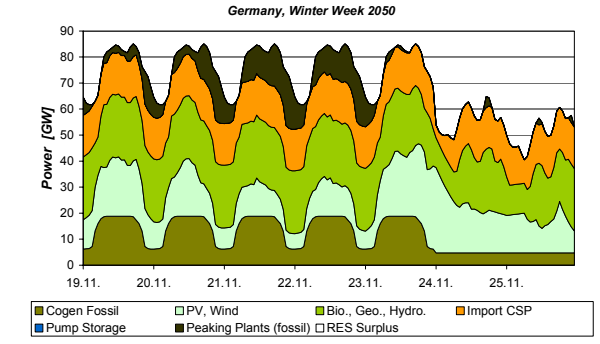


Inexpensive? Least Cost Electricity after Initial Investment



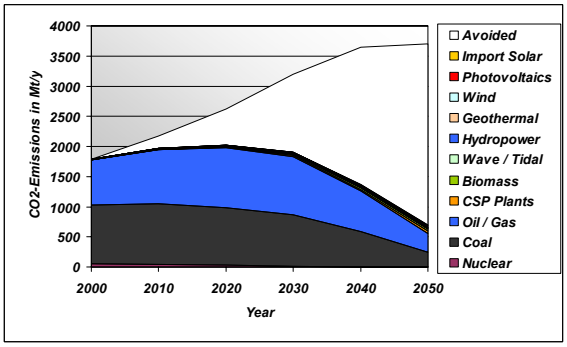
TRANS-CSP Mix : Energy Mix as described by TRANS-CSP
Mix 2000 : Maintaining the Energy Mix like in the Year 2000

Power On Demand ? Fossil Fuels supply Peaking Power

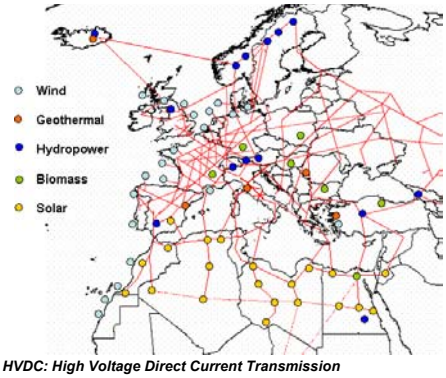


Based on hourly time series modelling of power supply in the TRANS-CSP scenario

Compatible? Carbon emissions reduced to 25 % in Europe and kept at low level in MENA in spite of growing demand



Redundant? HVDC Interstate Highways for Electricity interconnecting EUMENA



HVDC: High Voltage Direct Current Transmission

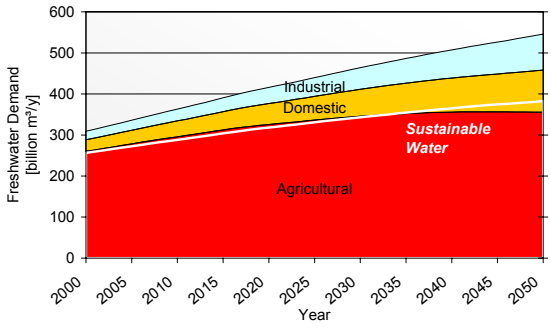
Study Report and Individual Country Scenarios at:

http://www.dlr.de/tt/med-csp

http://www.dlr.de/tt/trans-csp

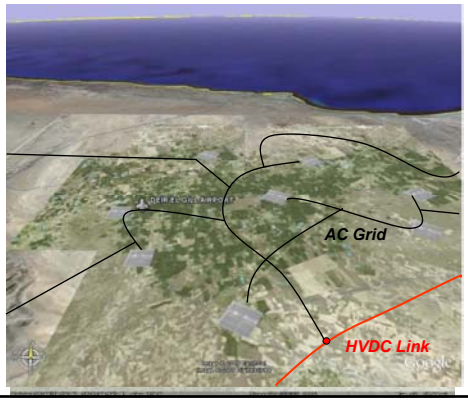
Thank You for Your Attention !

Water Demand in MENA



Sustainable Water Deficit: today: 60 billion m³/y; 2050: 160 billion m³/y

Positive Impacts in MENA: Concentrating Solar Thermal Power Plants combined with Sea Water Desalination in Coastal Desert Areas



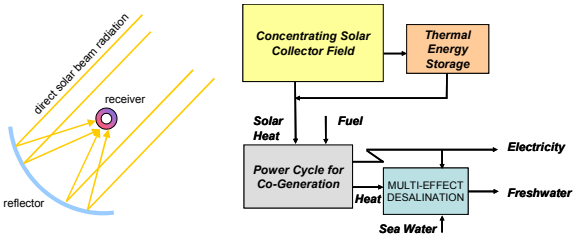
Energy
+
Water
+
Income

=

Sustainable economic development in arid regions

(artist view created with Google Earth)

Concentrating Solar Thermal Power: A Technology for Sustainable Energy and Water



Principle of a concentrating solar collector (left) and a solar power station with combined thermal sea water desalination (right). The generated electricity can be used for domestic power, for export and for further desalination via reverse osmosis. At present, a project of this type is developed in Jordan. The AQUA-CSP study starting in July 2006 will assess its potentials in MENA.

Adequate Political and Legal Framework Required

- ✓ Diversification of the energy portfolio is a key to energy security.
- ✓ The cost-stabilising effect of renewables must be valued adequately.
- ✓ RD&D for the cost reduction of renewables must be extended.
- ✓ Feed in tariffs are very effective instruments for market introduction.
- ✓ A EUMENA free trade zone for renewables should be established.
- ✓ Evaluation and negotiation of HVDC interconnections must start soon.
- ✓ Subsidisation of all energy technologies should be limited to a reasonable time span and subsequently reduced to zero.
- ✓ European support for MENA for the market introduction of renewables can attenuate the growing pressure on fossil fuel resources that would otherwise origin from the economic growth of this region, thus helping indirectly to secure fossil fuel supply in Europe.
- ✓ As a long term perspective, EUMENA could become a Community for Energy, Water and Climate Security.

Public and Private Investment by Renewable Electricity Feed-In Laws

- ✓ Low private investment risk through long term power purchase agreement granted by law
- ✓ Low equity interest rates required by private investors due to low investment risk
- ✓ Least cost market introduction of renewables through low equity interest rates of private investors
- ✓ Diversity of supply through individually adapted feed-in tariffs for each technology
- ✓ Stimulation of private investment and R&D for cost reduction through retrogressive feed-in tariffs
- ✓ Feed-in laws provide public investment over limited time span to stimulate private investment for the market introduction of renewables
- ✓ The initial tariff addition is covered by the consumers who benefit from future cost stability. Due to initially low renewable shares, the effect on consumer prices is very low.

Conclusions

➢ Renewable energy sources backed by fossil fuels can provide sustainable, secure and least cost electricity for Europe, with a share of 80 % in 2050.

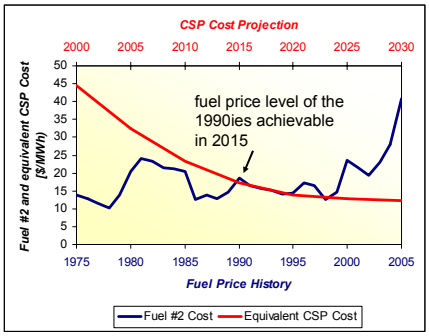
➢ Within 15 years, a well balanced power mix leads to less expensive electricity than business as usual. Domestic sources will reduce the import of fuels.

➢ Solar electricity from concentrating solar power stations in MENA transferred to Europe via high voltage direct current transmission can provide firm capacity for base- , intermediate- and peaking power, and supply up to 15 % of the European demand at a cost of 5 cent/kWh.

➢ Carbon emissions can be reduced to 25 % compared to the year 2000. 1 % of the European land will be required for the power mix, equivalent to the land presently used for transport and mobility.

➢ European support for MENA for the market introduction of renewables can attenuate the growing pressure on fossil fuel resources that would otherwise result from the economic growth of this region, thus helping to secure fossil fuel supply also in Europe. The necessary political process should be initiated by a renewable energy partnership and a common free trade area for renewable energies in EUMENA and culminate in a Community for Energy, Water and Climate Security. Long term power purchase agreements guaranteed by law (e.g. feed-in tariffs) can provide an adequate frame for industry and investors.

Instead of being escalating, volatile and hidden, renewable energy costs tend to decrease due to learning and economies of scale, as long as market introduction continues under a reliable legal policy framework



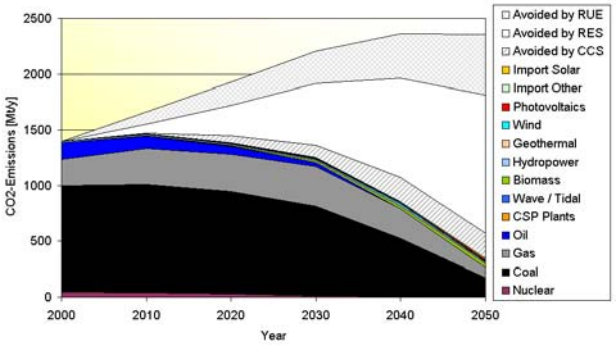
similar curves for all renewables

Comparing Strategies for Electricity in Europe

Electricity Mix dominated by Renewable Energy with Fossil Fuel Backup	*Electricity Mix dominated by Fossil Fuels and Nuclear Power*
Diversified supply and renewable resources	Supply based on few and limited resources
Domestic sources dominate the electricity mix	Energy imports dominate the electricity mix
Low vulnerability of power generation	High vulnerability of generation units
Low hazardous waste, recyclable materials	Unsolved disposal of nuclear waste and CO_2
Low risk of catastrophic accidents	Risks of catastrophic accidents
Requires public investment over limited time	Requires long-term continuous subsidisation
Low environmental impact	Climate change and pollution
Trend to lower cost and low price volatility	Trend to higher cost and high price volatility
Power on demand by a well balanced mix	Power on demand by ideally stored energy
Based on proven and demonstrated technologies	Still requires major technical breakthroughs: Safe fission and breeder technology. Commercial fusion reactor. Carbon capture and sequestration.

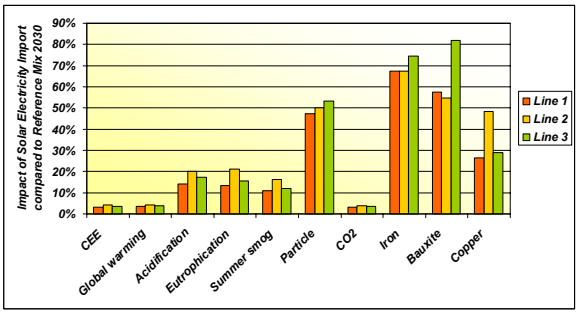
Low Risk
Low Cost
High Risk
High Cost

TRANS-CSP: CO_2 Emissions of All Countries



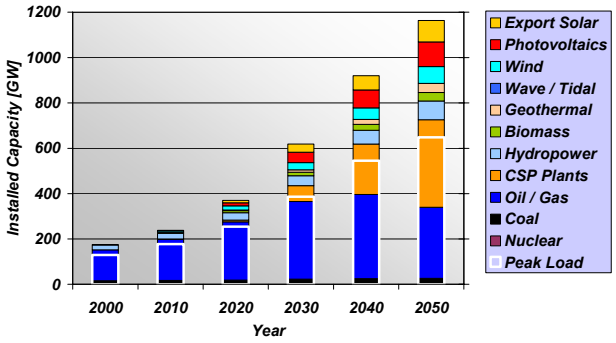
RUE Rational Use of Energy ***RES*** Renewable Energy Systems ***CCS*** Carbon Capture & Sequestration
Avoided CO_2 is calculated with respect to a mix as in the year 2000 including nuclear power

Life Cycle Assessment of Materials and Emissions of Solar Import Electricity



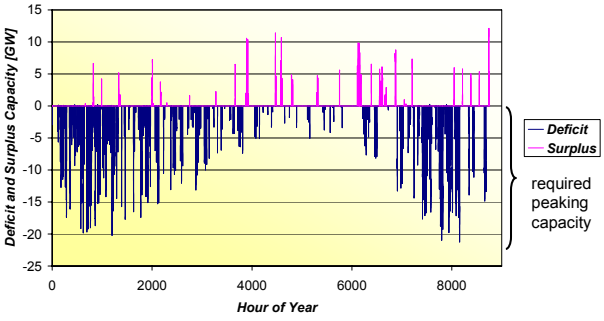
CEE Cumulated Energy Expenditure

Installed Capacity in MENA (MED-CSP Scenario)

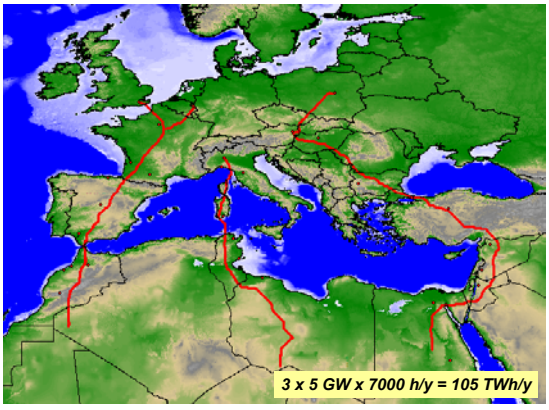


A Well Balanced Mix provides Firm Power on Demand

Capacity Balance Germany 2050



3 Analysed Samples for EU-MENA HVDC Interconnection

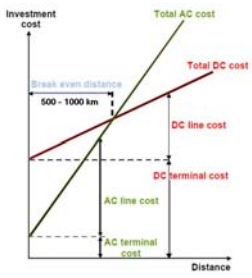


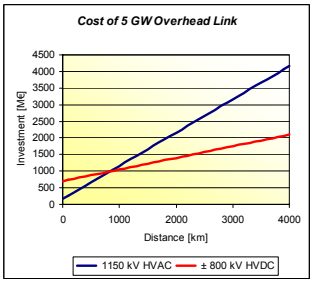
Total EU-MENA HVDC Interconnection 2020 – 2050 *

Year		2020	2030	2040	2050
Lines x Capacity GW		2 x 5	8 x 5	14 x 5	20 x 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 km x km	CSP	15 x 15	30 x 30	40 x 40	50 x 50
	HVDC	3100 x 0.1	3600 x 0.4	3600 x 0.7	3600 x 1.0
Investment Billion €	CSP	42	134	245	350
	HVDC	5	16	31	45
Elec. Cost €/kWh	CSP	0.050	0.045	0.040	0.040
	HVDC	0.014	0.010	0.010	0.010

* All countries analysed in TRANS-CSP

Comparison of AC and DC investment cost





Southern EU-MENA Renewable Electricity Potentials in TWh/year

	Hydro		Geo		Bio		CSP		Wind		PV		Wa/Ti	
	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.
Bahrain	0.0	n.a.	n.a.	n.a.	n.a.	0.2	36	33	n.a.	0.1	n.a.	0.3	n.a.	n.a.
Cyprus	24.0	1.0	n.a.	n.a.	n.a.	0.5	23	20	10.0	0.5	n.a.	0.2	n.a.	0.2
Iran	88.0	48.0	n.a.	11.3	n.a.	23.7	>	20000	n.a.	8.0	n.a.	16.0	n.a.	n.a.
Iraq	90.0	67.0	n.a.	n.a.	n.a.	8.6	30806	28647	300.0	10.0	n.a.	6.8	n.a.	n.a.
Israel	44.0	7.0	n.a.	n.a.	n.a.	2.2	318	318	22.0	0.5	n.a.	4.0	n.a.	n.a.
Jordan	n.a.	0.1	n.a.	n.a.	n.a.	1.6	6434	6429	109.0	2.0	n.a.	4.5	n.a.	n.a.
Kuwait	n.a.	n.a.	n.a.	n.a.	n.a.	0.8	1525	1525	n.a.	n.a.	n.a.	2.5	n.a.	n.a.
Lebanon	2.0	1.0	n.a.	n.a.	n.a.	0.8	19	14	9.0	0.2	n.a.	1.5	n.a.	n.a.
Oman	n.a.	n.a.	n.a.	n.a.	n.a.	1.1	20611	19404	44.0	8.0	n.a.	4.1	n.a.	n.a.
Qatar	n.a.	n.a.	n.a.	n.a.	n.a.	0.1	823	792	n.a.	n.a.	n.a.	1.0	n.a.	n.a.
Saudi Arabia	n.a.	n.a.	n.a.	70.9	n.a.	9.9	125260	124560	300.0	20.0	n.a.	13.9	n.a.	n.a.
Syria	7.0	4.0	n.a.	n.a.	n.a.	4.7	10777	10210	98.0	12.0	n.a.	8.5	n.a.	n.a.
UAE	n.a.	n.a.	n.a.	n.a.	n.a.	0.7	2078	1988	n.a.	n.a.	n.a.	3.0	n.a.	n.a.
Yemen	n.a.	n.a.	n.a.	107.0	n.a.	9.1	5143	5100	8.0	3.0	n.a.	25.8	n.a.	n.a.
Algeria	5.0	0.5	n.a.	4.7	n.a.	12.1	169440	168972	7278	35.0	n.a.	13.9	n.a.	n.a.
Egypt	80.0	50.0	n.a.	25.7	n.a.	15.3	73656	73656	7650	90.0	n.a.	36.0	n.a.	n.a.
Libya	n.a.	n.a.	n.a.	n.a.	n.a.	1.7	139600	139477	5363	15.0	n.a.	3.9	n.a.	n.a.
Morocco	5.0	4.0	n.a.	10.0	n.a.	14.3	20151	20146	1188	25.0	n.a.	17.0	n.a.	n.a.
Tunisia	1.0	0.5	n.a.	3.2	n.a.	3.2	9815	9244	50.0	8.0	n.a.	5.0	n.a.	n.a.
Greece	25.0	12.0	n.a.	4.7	n.a.	11.8	44	4	136.0	15.0	n.a.	4.0	n.a.	4.0
Italy	105.0	54.0	n.a.	9.8	n.a.	86.4	88	7	223.0	60.0	n.a.	10.0	n.a.	3.0
Malta	n.a.	n.a.	n.a.	n.a.	n.a.	0.2	2	2	n.a.	0.2	n.a.	0.1	n.a.	0.1
Portugal	33.0	20.0	n.a.	7.0	n.a.	26.6	436	142	63.0	20.0	n.a.	3.0	n.a.	7.0
Spain	70.0	41.0	n.a.	9.4	n.a.	111.1	1646	1278	226.0	60.0	n.a.	5.0	n.a.	13.0
Turkey	216.0	122.0	n.a.	150.0	n.a.	55.0	405	131	200.0	55.0	n.a.	28.6	n.a.	n.a.
Total	**432**		**414**		**402**		**632099**		**447**		**218**		**27**	

resource taken from literature

temperature map considering areas with T>180°C as economic

(bagasse) and municipal waste and renewable solid biomass potentials

CSP site mapping taking sites with DNI > 2000 kWh/m²y as economic

and site mapping taking sites with a yield > 14 GWh/y and from literature (EU)

except for EU. General PV growth rates used for calculation

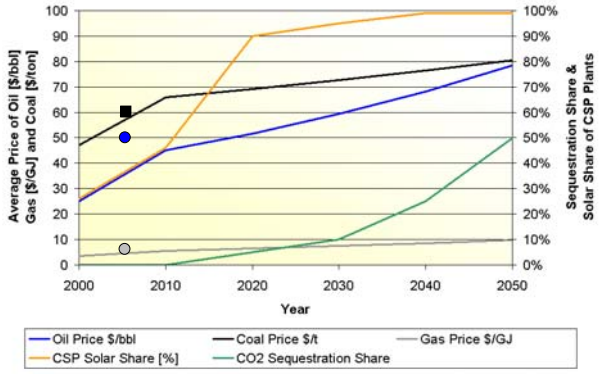
except for EU mid term economic potentials

for Iran, the CSP potentials are still rough estimates

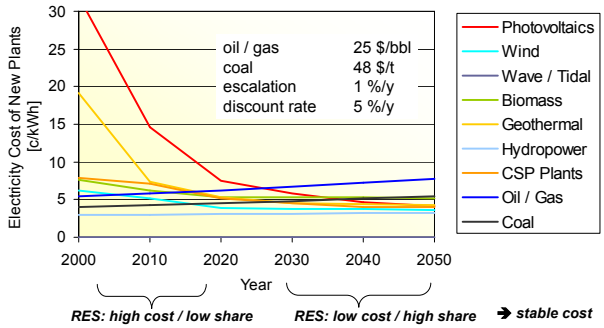
Northern EU-MENA Renewable Electricity Potentials in TWh/year

	Hydro		Geo		Bio		CSP		Wind		PV		Wa/Ti	
	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.	Tech.	Econ.
Austria	56,0	56,0	n.a.	4,1	n.a.	30,6	n.a.	n.a.	n.a.	3,0	n.a.	2,9	n.a.	n.a.
Cyprus	24,0	1,0	n.a.	n.a.	n.a.	0,6	23	20	n.a.	6,0	n.a.	0,1	n.a.	0,2
Denmark	0,0	0,0	n.a.	n.a.	n.a.	6,6	n.a.	n.a.	n.a.	55,0	n.a.	1,3	n.a.	2,2
Finland	20,0	20,0	n.a.	n.a.	n.a.	53,7	n.a.	n.a.	n.a.	27,0	n.a.	1,7	n.a.	2,6
France	72,0	72,0	n.a.	14,1	n.a.	79,1	n.a.	n.a.	n.a.	129,0	n.a.	23,4	n.a.	12,0
Czech Republic	4,0	3,0	n.a.	n.a.	n.a.	20,0	n.a.	n.a.	n.a.	5,8	n.a.	1,1	n.a.	n.a.
Belgium	0,3	0,5	n.a.	n.a.	n.a.	7,3	n.a.	n.a.	n.a.	13,0	n.a.	2,1	n.a.	0,2
Ireland	1,0	1,3	n.a.	n.a.	n.a.	6,2	n.a.	n.a.	n.a.	55,0	n.a.	1,1	n.a.	4,0
Luxembourg	n.a.	1,0	n.a.	n.a.	n.a.	0,4	n.a.	n.a.	n.a.	0,0	n.a.	0,8	n.a.	n.a.
Netherlands	0,1	0,1	n.a.	1,3	n.a.	9,6	n.a.	n.a.	n.a.	40,0	n.a.	4,3	n.a.	1,0
Sweden	130,0	90,0	n.a.	1,3	n.a.	80,4	n.a.	n.a.	n.a.	63,5	n.a.	3,7	n.a.	2,0
Switzerland	41,0	38,3	n.a.	n.a.	n.a.	8,0	n.a.	n.a.	n.a.	0,0	n.a.	3,7	n.a.	n.a.
United Kingdom	7,8	8,0	n.a.	0,3	n.a.	30,7	n.a.	n.a.	n.a.	344,0	n.a.	7,8	n.a.	60,0
Poland	14,0	7,0	n.a.	1,7	n.a.	52,1	n.a.	n.a.	n.a.	65,0	n.a.	3,1	n.a.	1,0
Bulgaria	15,0	12,0	n.a.	0,8	n.a.	7,7	n.a.	n.a.	n.a.	8,9	n.a.	2,0	n.a.	n.a.
Slowac Republic	7,0	6,0	n.a.	3,1	n.a.	10,7	n.a.	n.a.	n.a.	0,7	n.a.	2,0	n.a.	n.a.
Slowenia	9,0	8,0	n.a.	0,4	n.a.	6,3	n.a.	n.a.	n.a.	0,3	n.a.	1,0	n.a.	n.a.
Germany	26,0	26,0	120,0	28,2	n.a.	87,0	n.a.	n.a.	n.a.	262,0	n.a.	23,4	n.a.	7,0
Hungary	5,0	4,0	n.a.	51,9	n.a.	11,3	n.a.	n.a.	n.a.	1,3	n.a.	2,0	n.a.	n.a.
Greece	15,0	12,0	n.a.	9,4	n.a.	7,2	44	4	n.a.	49,0	n.a.	3,9	n.a.	4,0
Italy	105,0	65,0	n.a.	19,6	n.a.	46,1	88	7	n.a.	79,0	n.a.	17,6	n.a.	3,0
Malta	n.a.	n.a.	n.a.	n.a.	n.a.	0,1	2	2	n.a.	0,2	n.a.	0,1	n.a.	0,1
Portugal	33,0	20,0	n.a.	14,1	n.a.	15,2	436	142	n.a.	18,0	n.a.	3,9	n.a.	7,0
Spain	70,0	41,0	n.a.	28,2	n.a.	40,4	1646	1278	n.a.	93,0	n.a.	19,5	n.a.	13,0
Turkey	216,0	122,0	n.a.	300,1	n.a.	44,7	405	131	n.a.	110,0	n.a.	15,6	n.a.	n.a.
Macedonia	6,0	4,0	n.a.	n.a.	n.a.	2,6	n.a.	n.a.	n.a.	0,1	n.a.	0,6	n.a.	n.a.
Croatia	9,0	8,0	n.a.	1,1	n.a.	8,9	n.a.	n.a.	n.a.	2,6	n.a.	0,8	n.a.	3,0
Romania	36,0	18,0	n.a.	1,0	n.a.	40,9	n.a.	n.a.	n.a.	7,9	n.a.	2,0	n.a.	n.a.
Serbia & Montenegro	27,0	27,0	n.a.	4,1	n.a.	14,3	n.a.	n.a.	n.a.	0,3	n.a.	1,0	n.a.	2,0
Bosnia-Herzegowina	24,0	19,0	n.a.	n.a.	n.a.	9,5	n.a.	n.a.	n.a.	0,1	n.a.	0,6	n.a.	n.a.
Iceland	64,0	40,0	n.a.	182,4	n.a.	0,1	n.a.	n.a.	n.a.	1,0	n.a.	0,3	n.a.	10,0
Norway	200,0	178,0	n.a.	n.a.	n.a.	25,8	n.a.	n.a.	n.a.	76,0	n.a.	1,0	n.a.	10,0
Total														
Total	**908**		**667**		**764**		**1584**		**1517**		**154**		**144**	

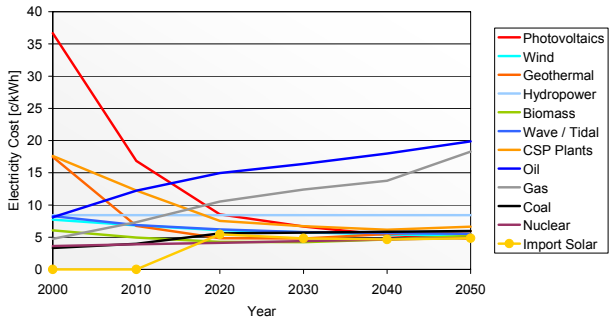
Parameters for Electricity Cost Calculation



Electricity Cost of Power Technologies (Example Egypt)

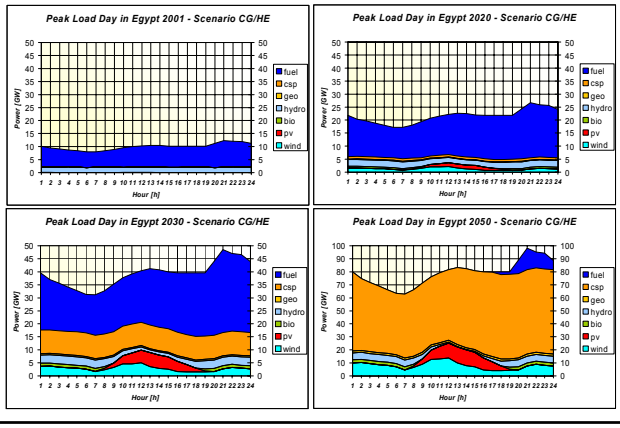


Electricity Cost of Power Technologies (Example Spain)

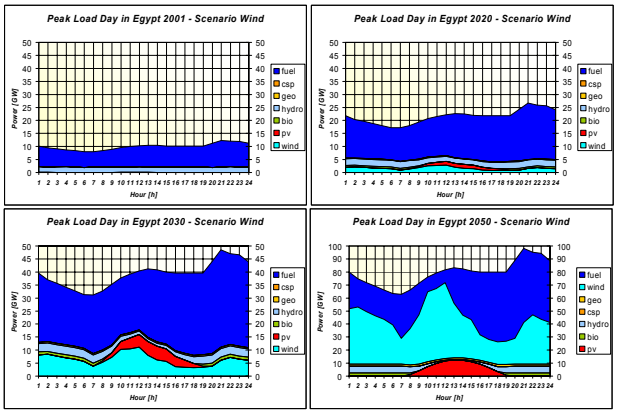


CO_2 Capture and Sequestration (CCS) included in fossil fueled generation costs after 2020
CSP in solar only operation. CSP import starts 2020.

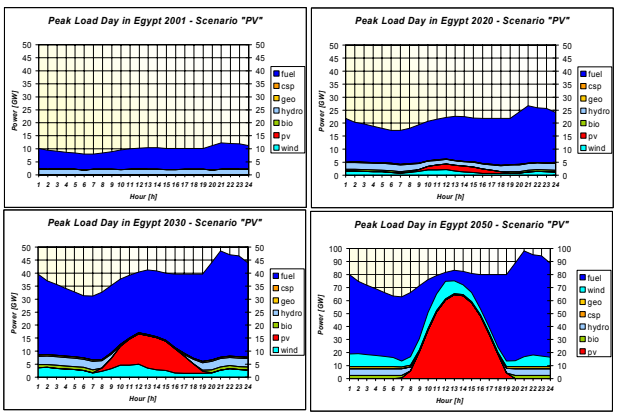
Scenario MED-CSP



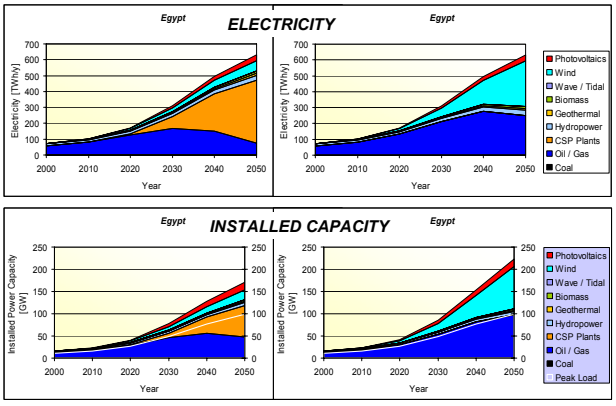
Scenario “Wind”



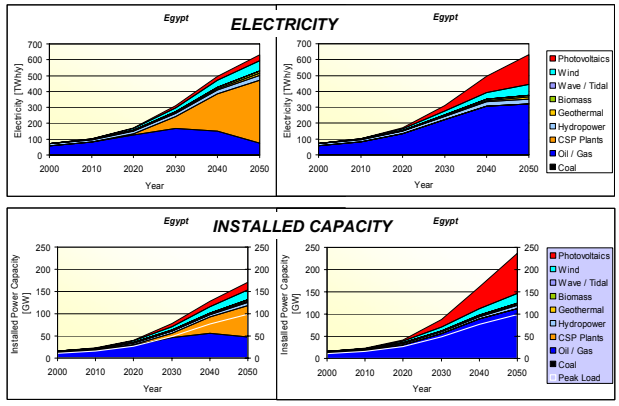
Scenario “PV”



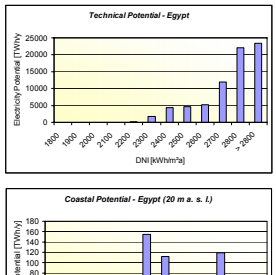
Scenario MED-CSP Scenario “Wind”

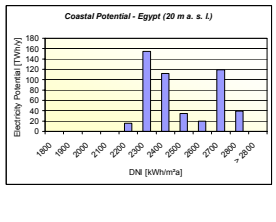


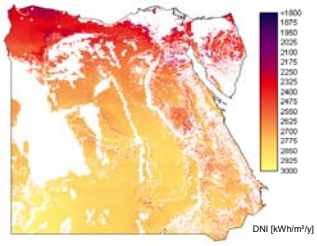
Scenario MED-CSP Scenario “PV”



Solar Thermal Electricity Generating Potentials in Egypt







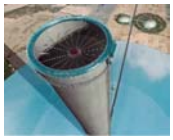
Technical Potential:	73656 TWh/y (DNI > 1800 kWh/m²/y)
Economic Potential:	73655 TWh/y (DNI > 2000 kWh/m²/y)
Power Demand 2000:	71 TWh/y
Power Demand 2050:	631 TWh/y (Scenario CG/HE)
Tentative CSP 2050:	395 TWh/y (Scenario CG/HE)
Coastal Potential:	496 TWh/y (< 20 m a. s. l.)
Water Demand 2050:	256 TWh/y (Power for Desalination)

Technology Portfolio: Renewable Energies

Wind Power (Enercon)

Hydropower (Tauernkraft)

Solar Chimney (SBP)

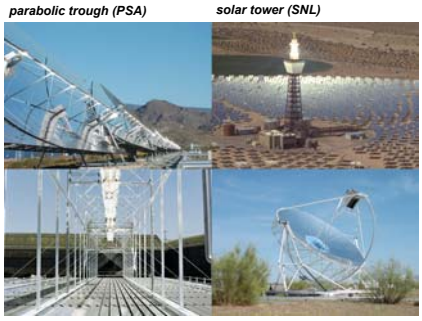


Photovoltaic (NREL)

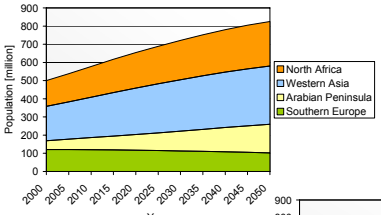
Hot Dry Rock (Stadtwerke Urach)

Biomass Power (NREL)

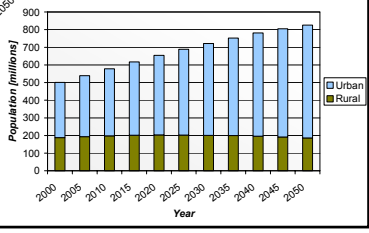
Technology Portfolio: Concentrating Solar Power (CSP)



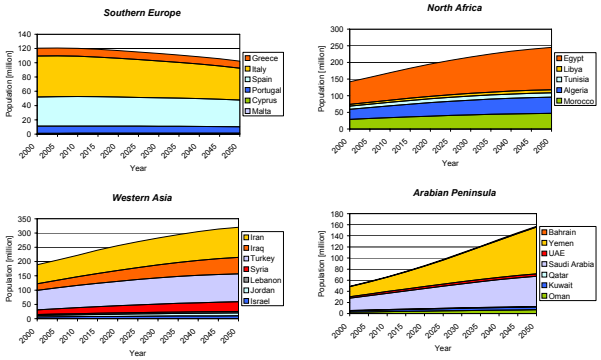
Driving Force: Growth of Population



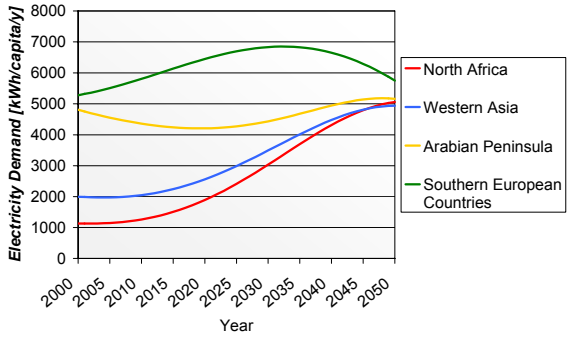
Source: United Nations Intermediate Growth Scenario /FAO 2004/



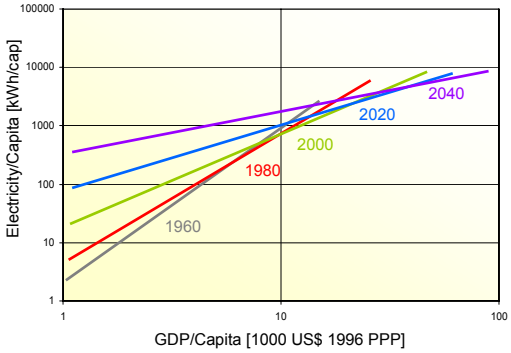
Development Trends of Population in the Regions analysed within MED-CSP



Per Capita Power Consumption in EU-MENA in the MED-CSP Scenario



Correlation and Extrapolation of Total Final Electricity Consumption per capita and GDP per capita for a Sample of 25 (150) Countries



Driving Force Growth of Economy: Per Capita GDP Growth Rates of the MED-CSP Scenario