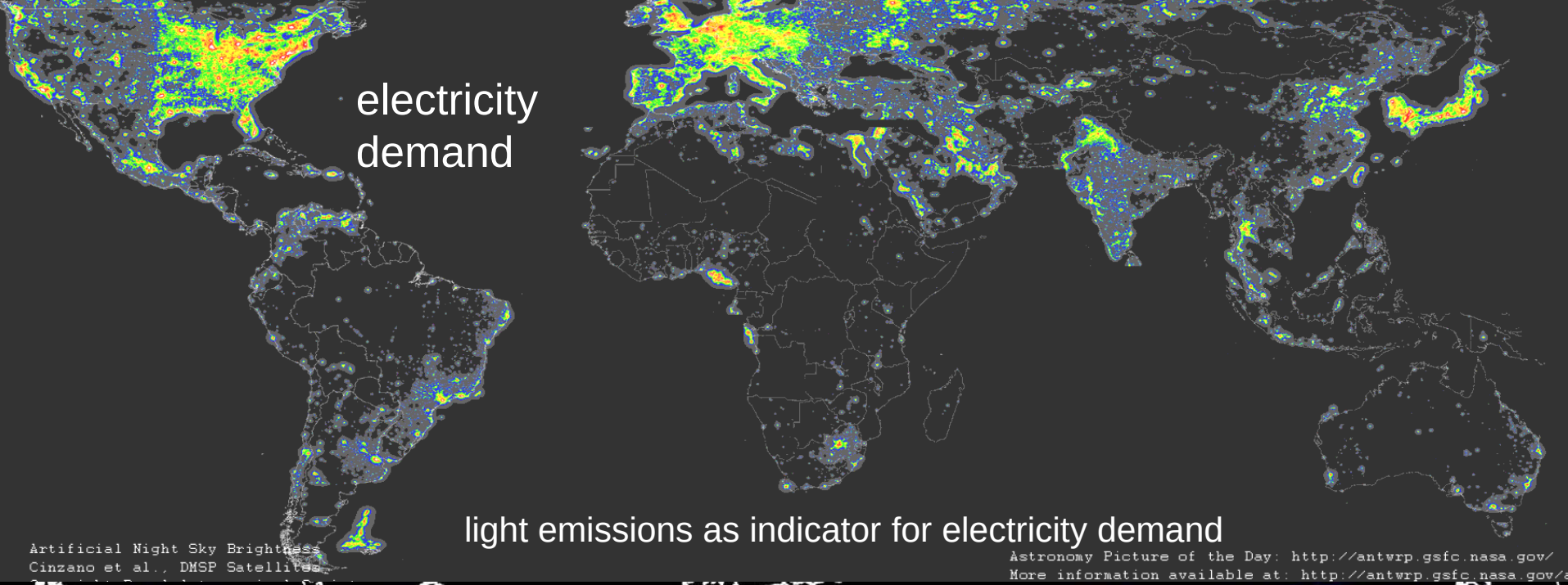
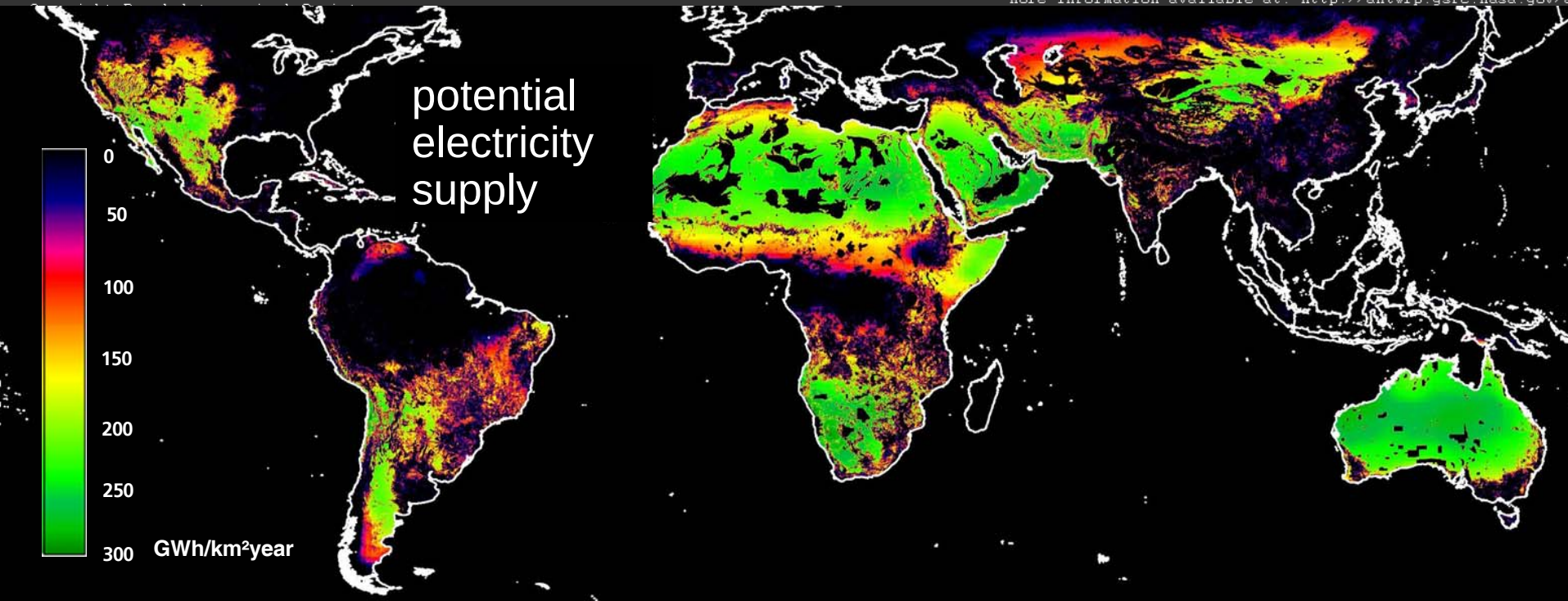


light emissions as indicator for electricity demand



"Linking the Deserts in North Africa with the Load Centers in Europe"

Results of a series of studies commissioned by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Hans Müller-Steinhagen and Franz Trieb
Institute of Technical Thermodynamics, German Aerospace Centre (DLR)

Project Partners

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

German Aerospace Center (Germany)
National Energy Research Center (Jordan)
University of Aden, (Yemen)
University of Sana'a, (Yemen)
University of Bahrain, (Bahrain)
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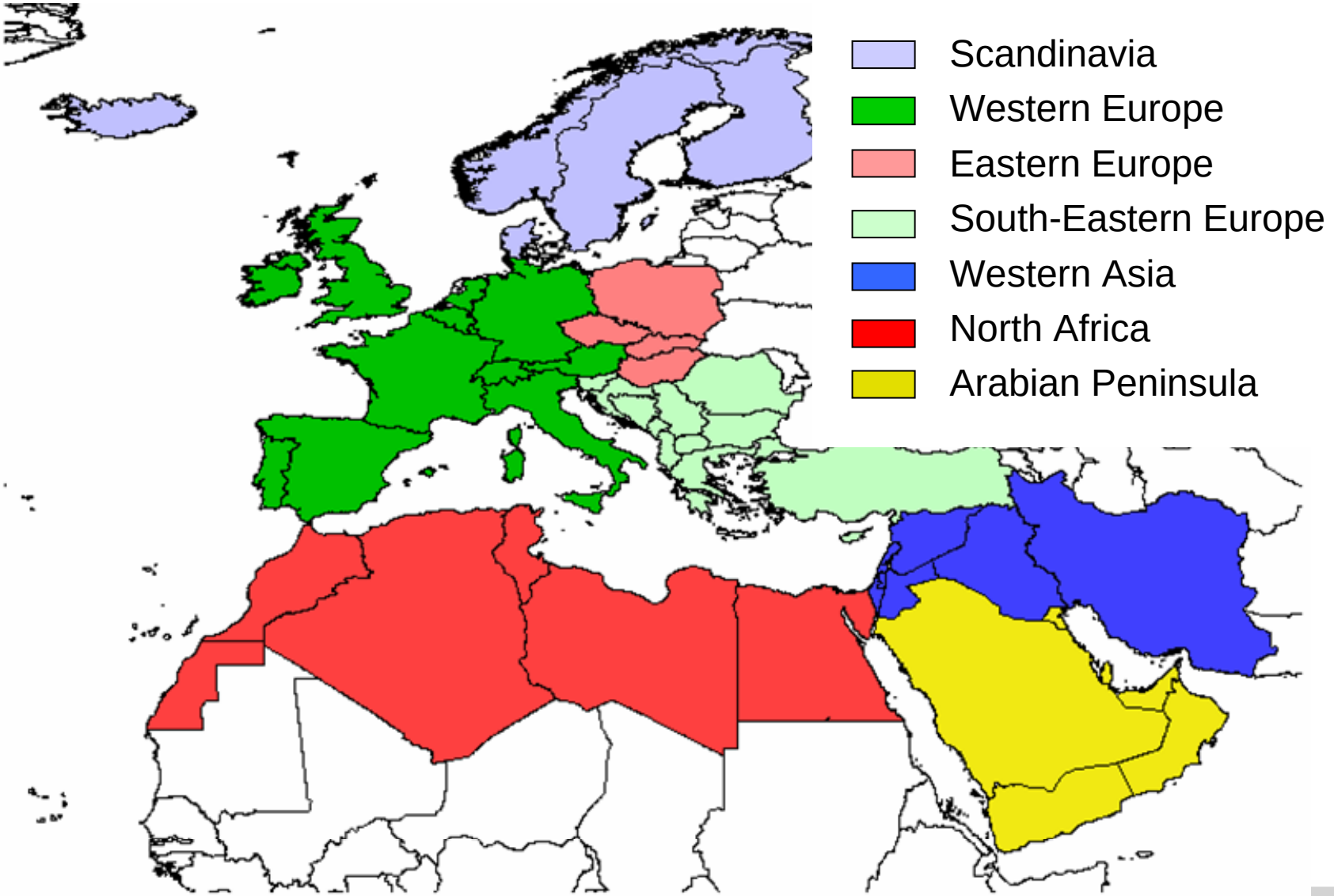
Intern. Forschungszentrum für Erneuerbare Energien e.V. (Germany)
Kernenergien – The Solar Power Company (Germany)
Nokraschy Engineering GmbH (Germany)
Deutsche Gesellschaft Club of Rome (Germany)
House of Water and Environment (Palestine)
Center for Solar Energy Studies (Libya)
Centre de Developpement des Energies Renouvelables (Morocco)
University of Bremen (Germany)
New Energy Algeria (Algeria)
New and Renewable Energy Authority (Egypt)
Hamburg Institute of International Economics (Germany)
Honorat Satoguina

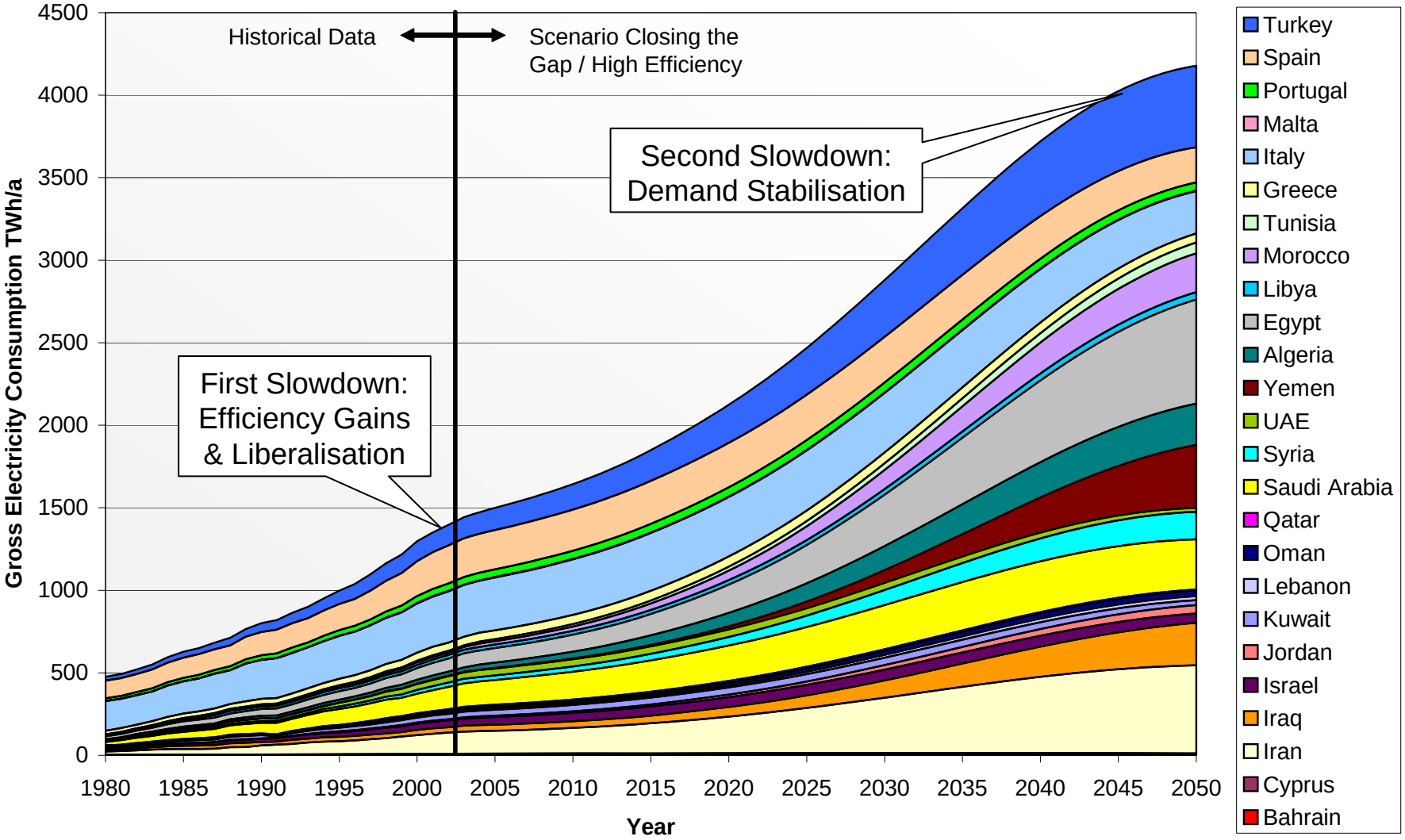
50 countries analysed within the MED-CSP and TRANS-CSP Studies



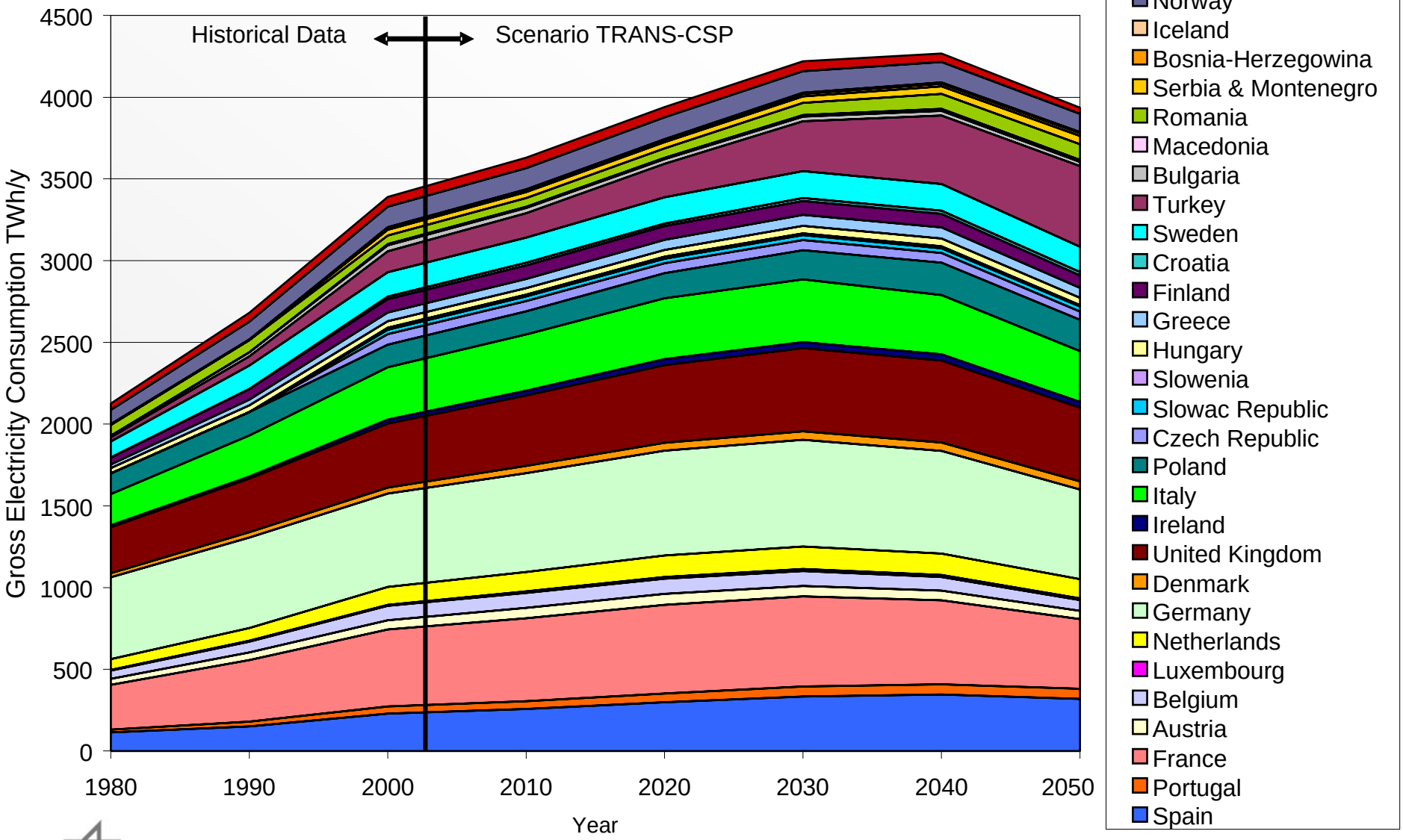
Parameters considered in the analyses

- Sustainability criteria
- Available resources
- Existing power plants in 2000 and their expected lifetime
- 100 % power availability
- Cost of fossil fuels (oriented at IEA Scenario)
- Existing grid Infrastructure
- Annual electricity demand
- Annual load curve
- Peaking power demand and 25 % reserve capacity
- Opportunities of finance
- Policies and energy economic frame conditions
- Maximum production growth rates of RE industry

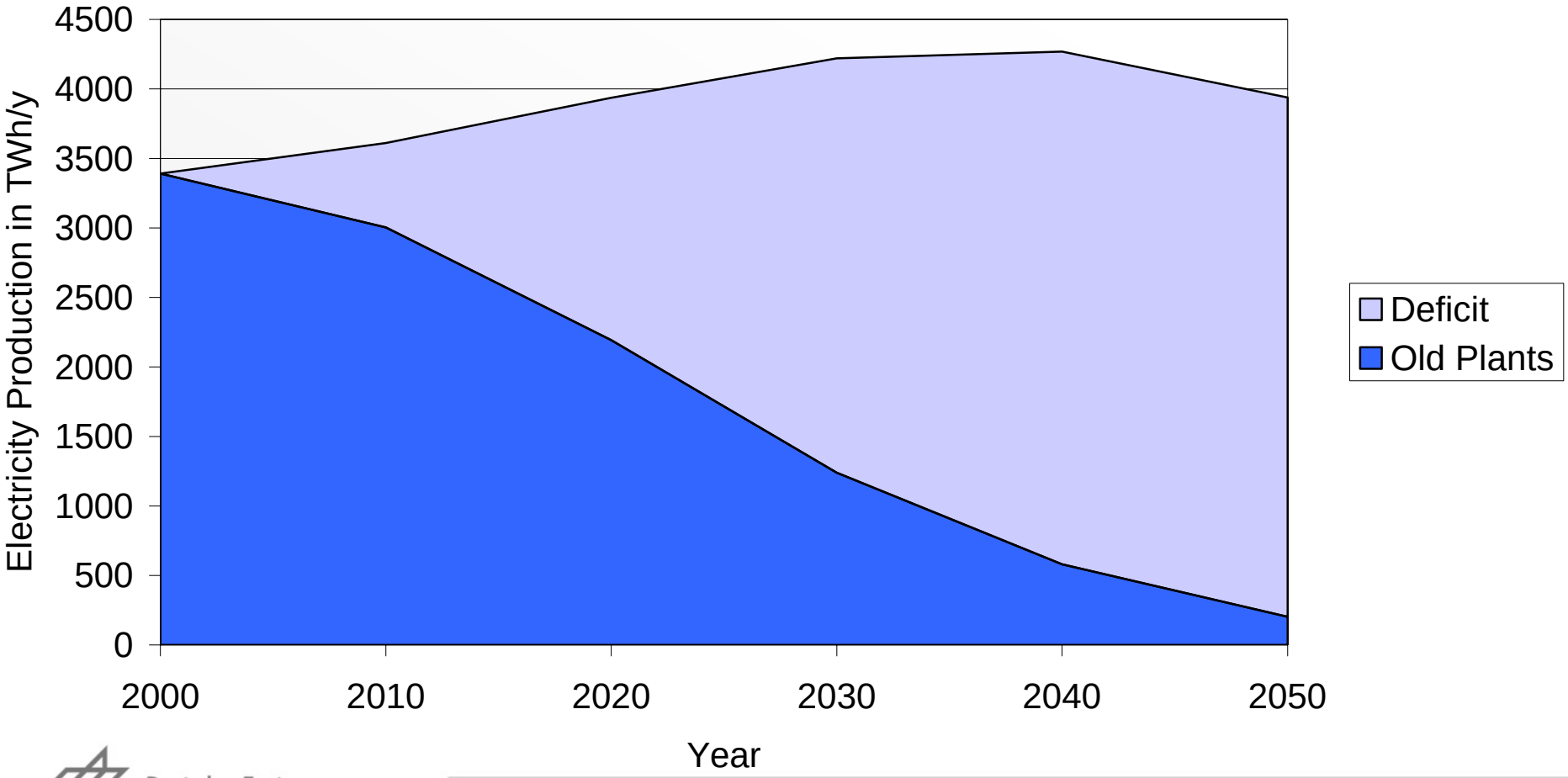
Gross electricity demand in the analysed MENA countries



Gross electricity demand in the analysed European countries

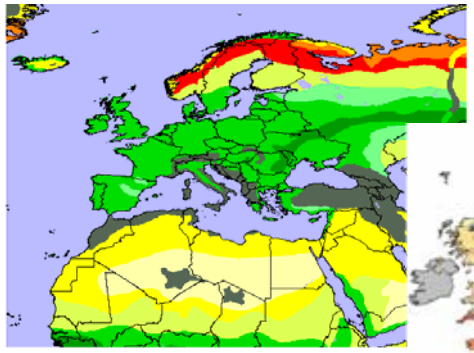


Electricity production of power plants already existing in 2000 and deficit to be covered by new plants until 2050, in the European countries analysed within TRANS-CSP

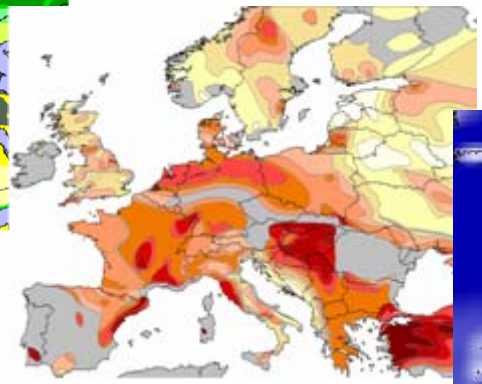


Renewable energy resources in Europe and MENA

Biomass (1)

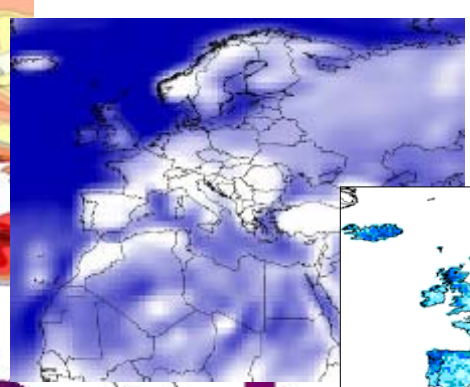


Geothermal (1)

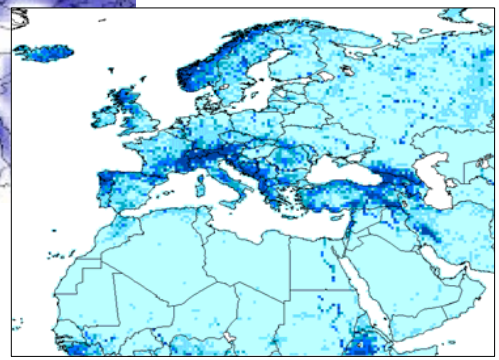


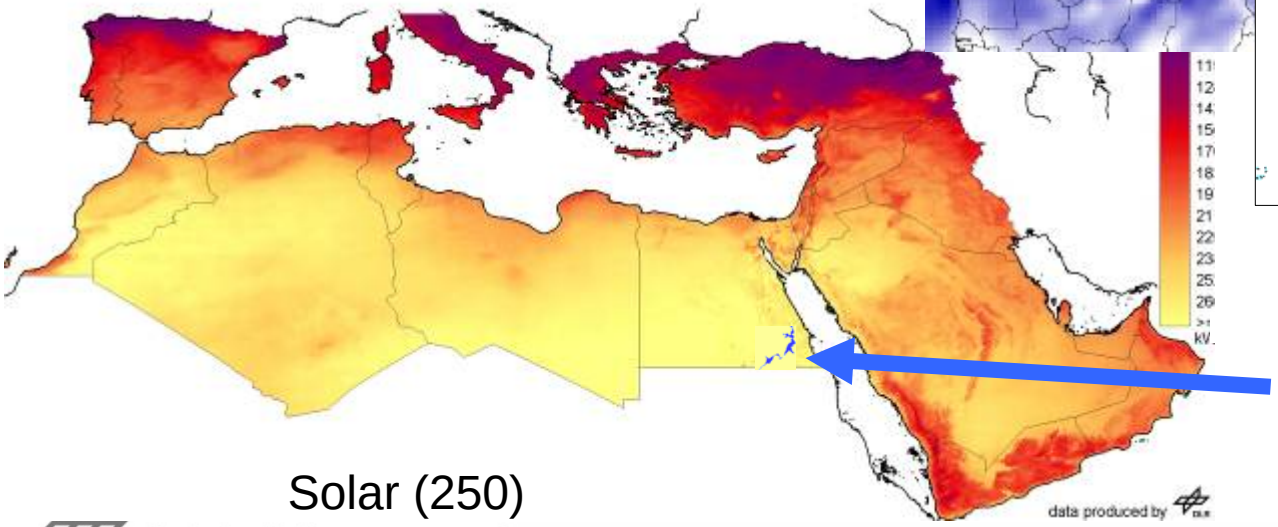
In brackets: (max. yield in GWh_{el} / km^2 /y)

Wind (50)



Hydropower (50)

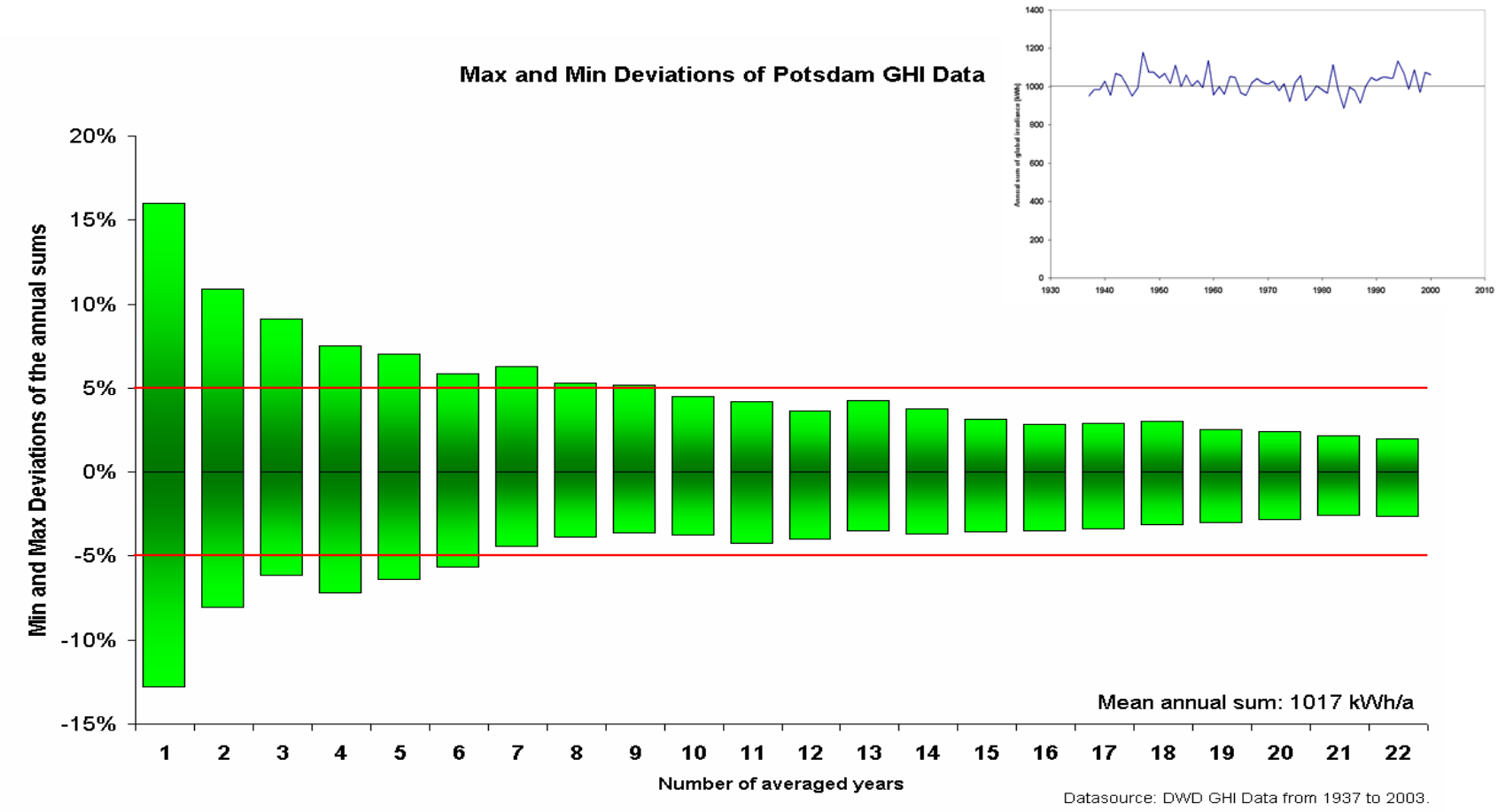




Solar (250)

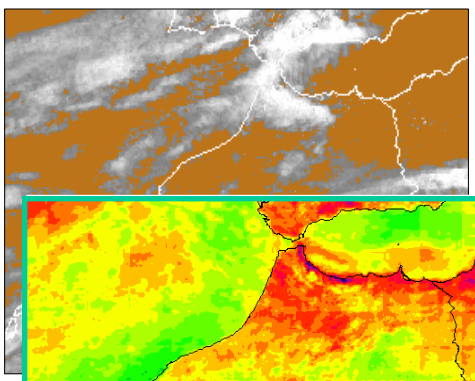
A CSP plant of the size of Lake Nasser equals the total Middle East oil production

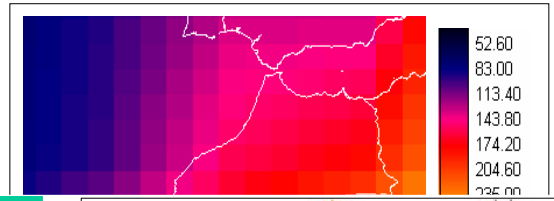
Long term variability of solar irradiance

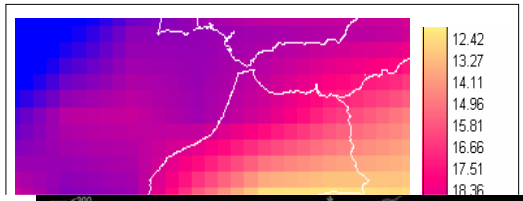


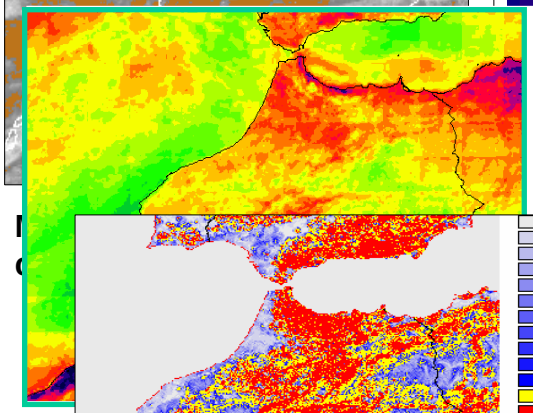
Datasource: DWD GHI Data from 1937 to 2003.

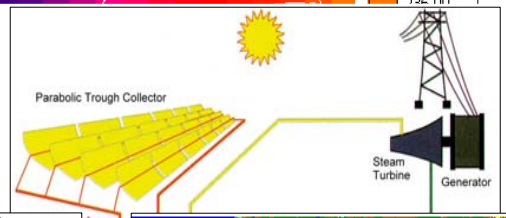
Identification of suitable sites using Meteosat data

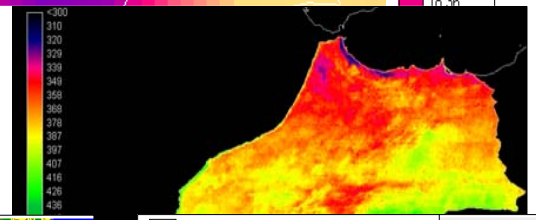


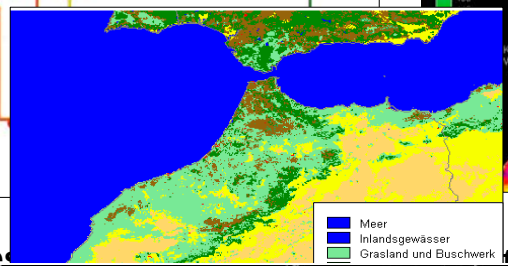


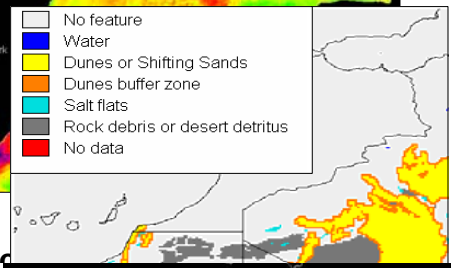


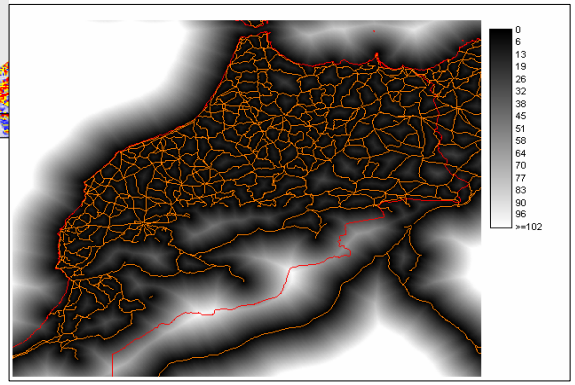


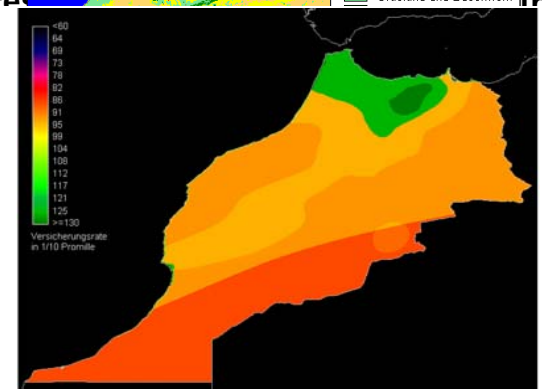


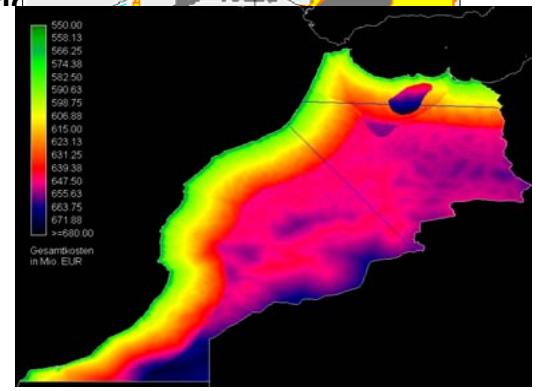












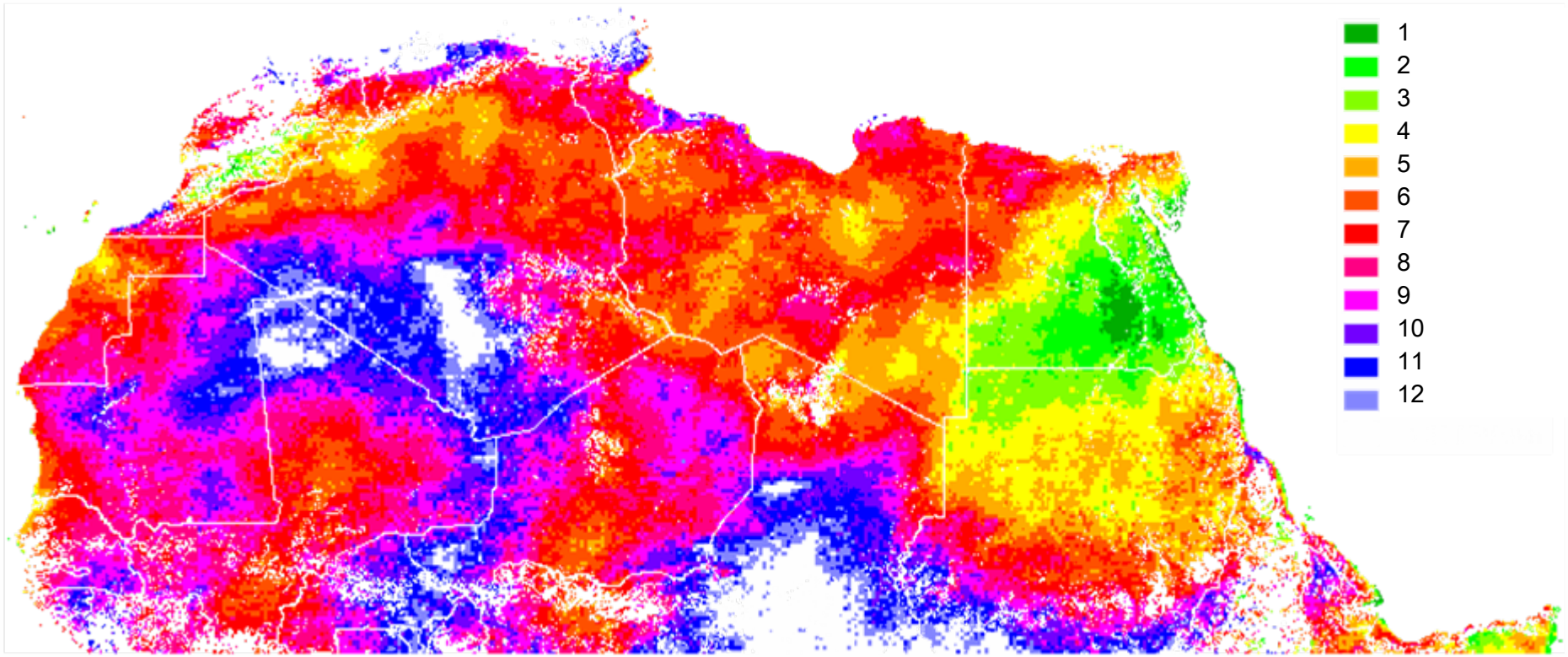
Infrastructure costs

Insurance costs

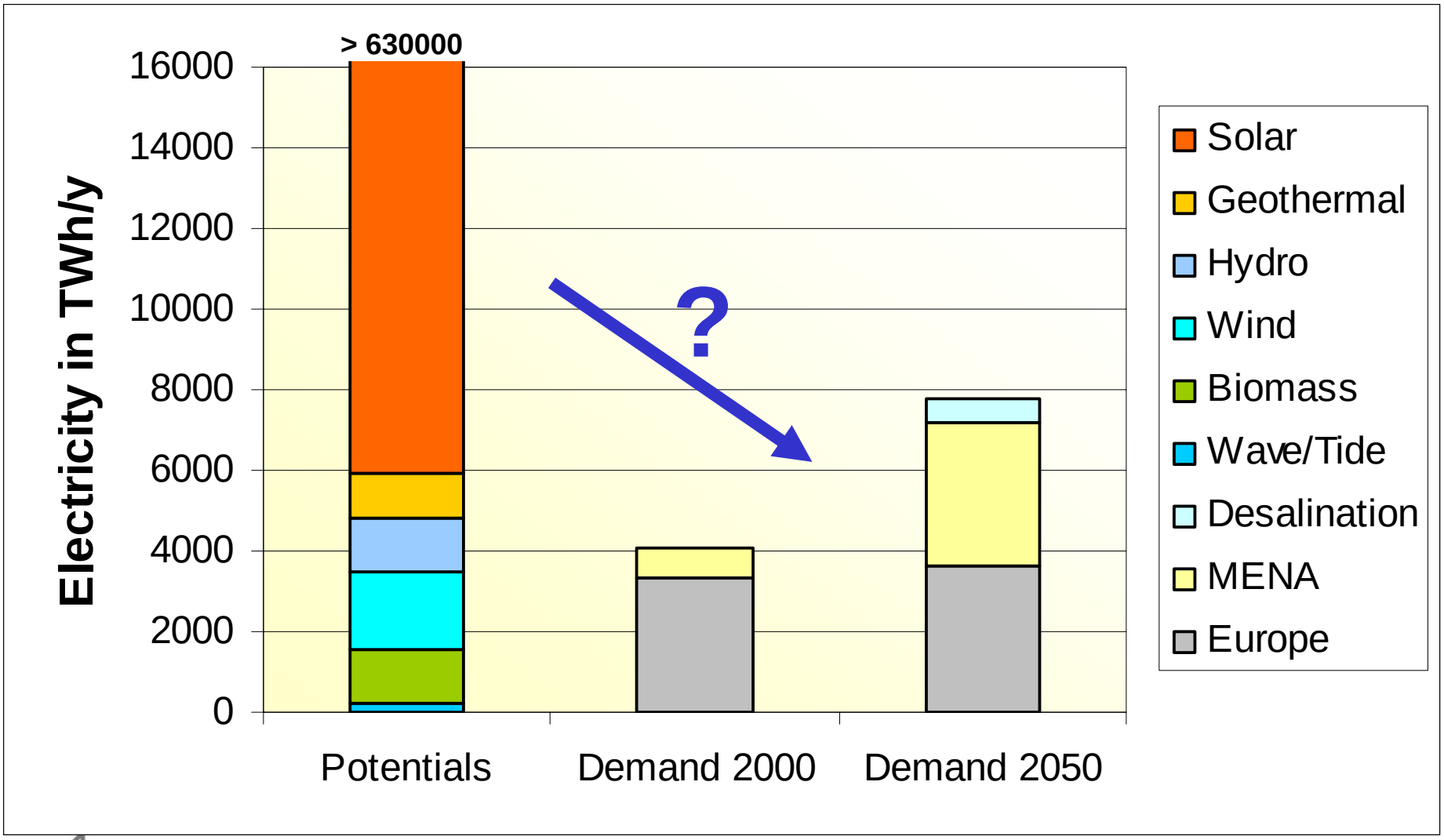
Total cost

Identification of suitable sites using Meteosat data

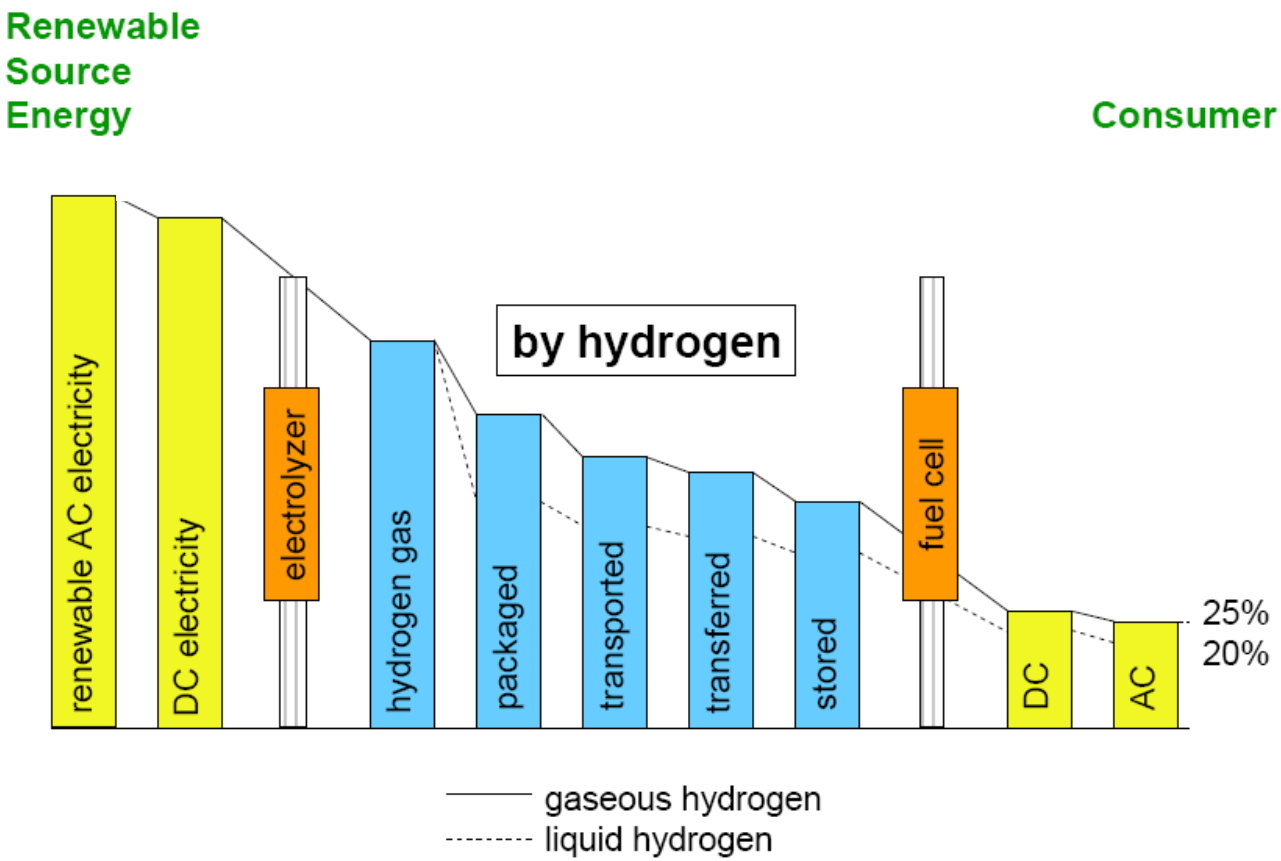
North Africa – solar thermal electricity generation costs



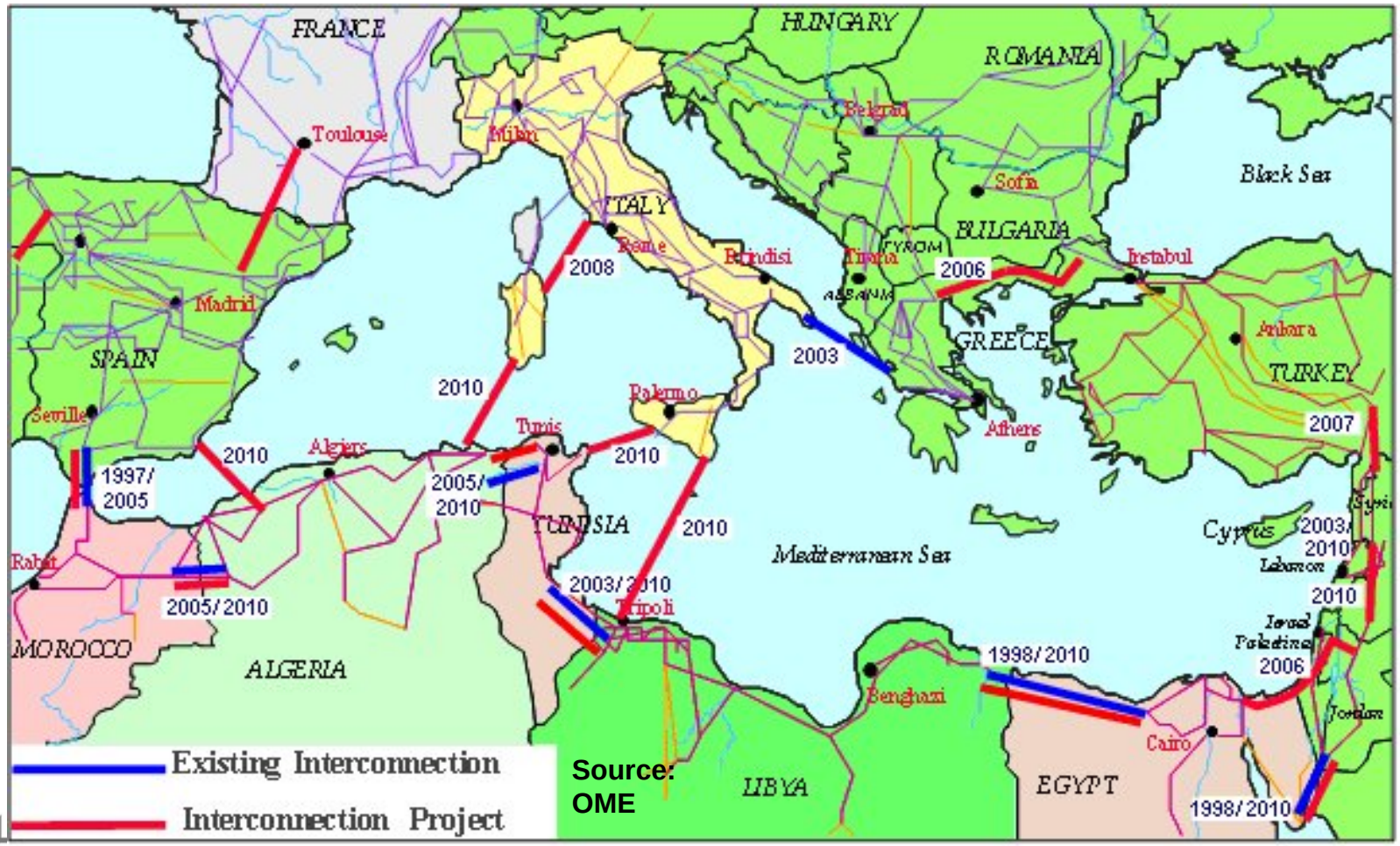
Economic renewable electricity potentials vs. demand in Europe and MENA



Power transmission via hydrogen is possible, but 75 % of the solar electricity would be lost.



After closing the Mediterranean Ring in 2010, about 0.5 % of European electricity demand could be imported through the conventional AC grid. If upgraded to European standards, 3 %. However, 45 % of the solar electricity would be lost over 3000 km.

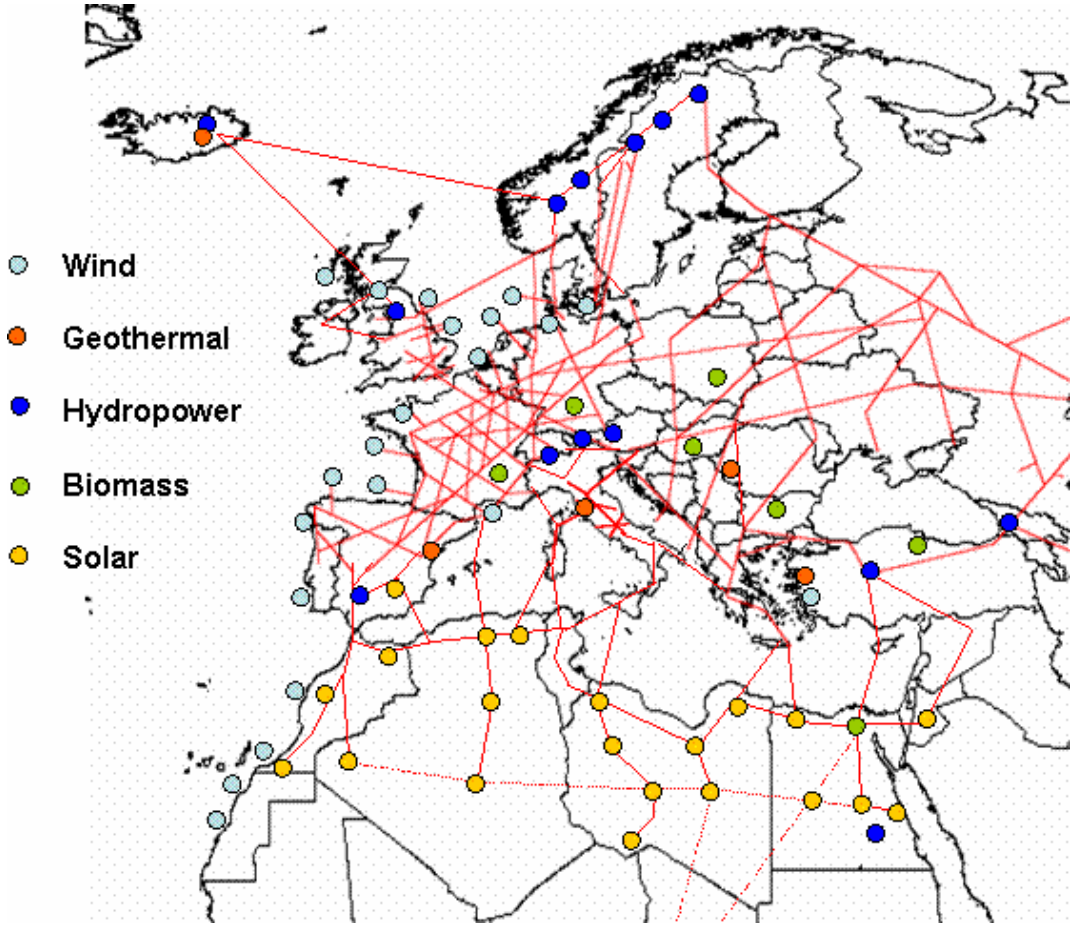


Source: OME

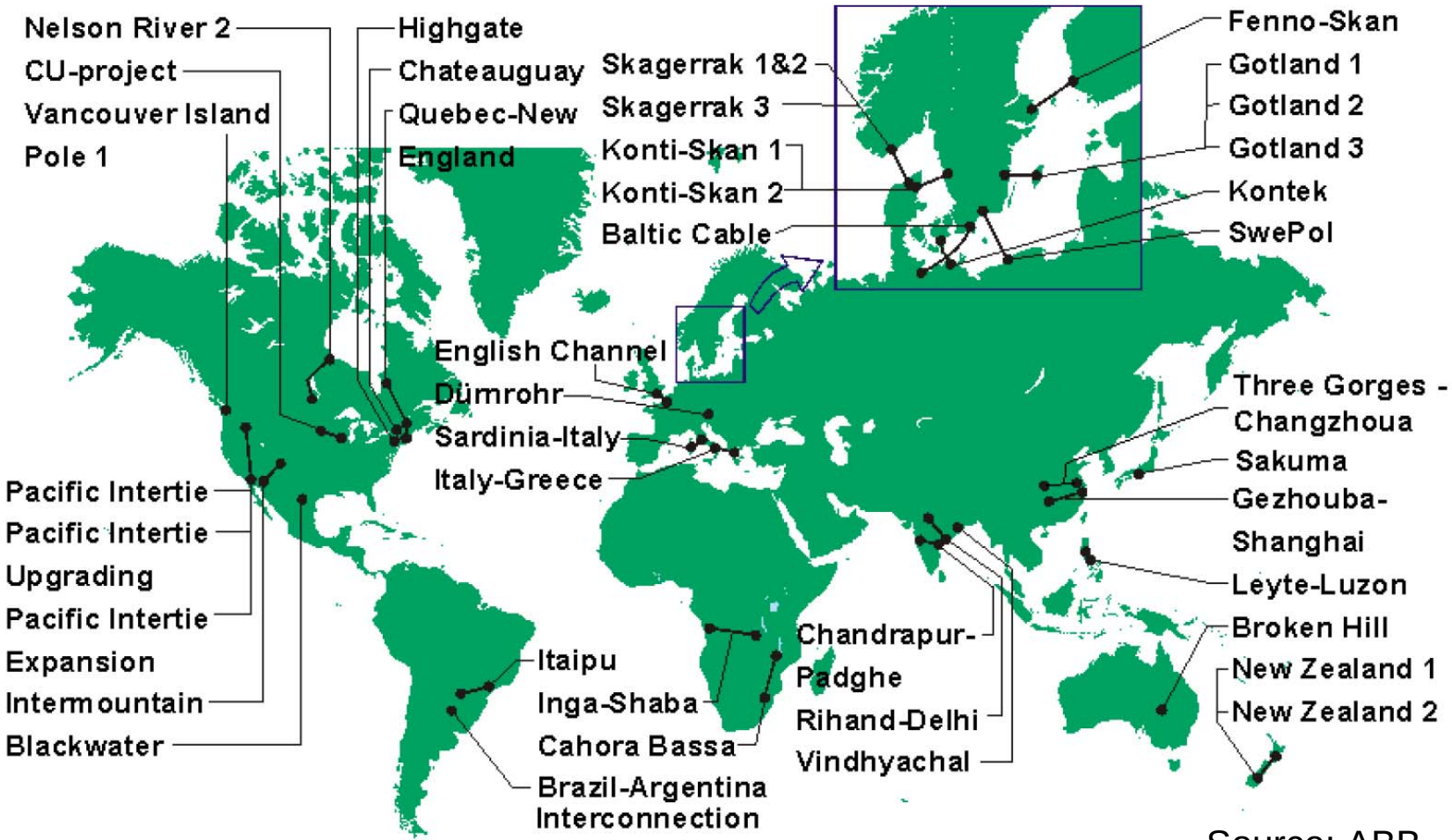
Security of power supply by a future trans-European HVDC grid

High Voltage Direct Current (HVDC) power transmission looses only 10% over 3000 km distance.

HVDC lines will serve long distance transfer, with few outlets to the conventional alternating current (AC) grid.

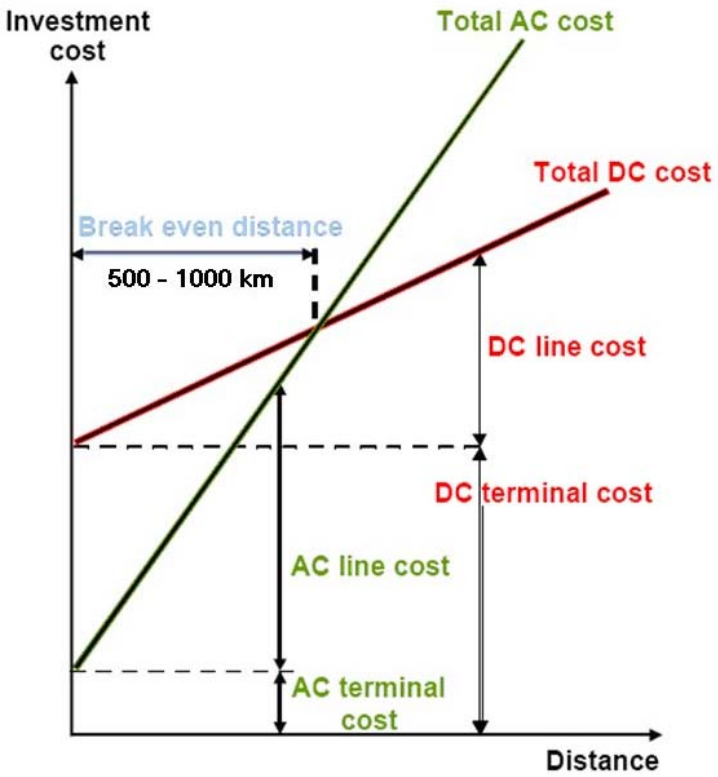


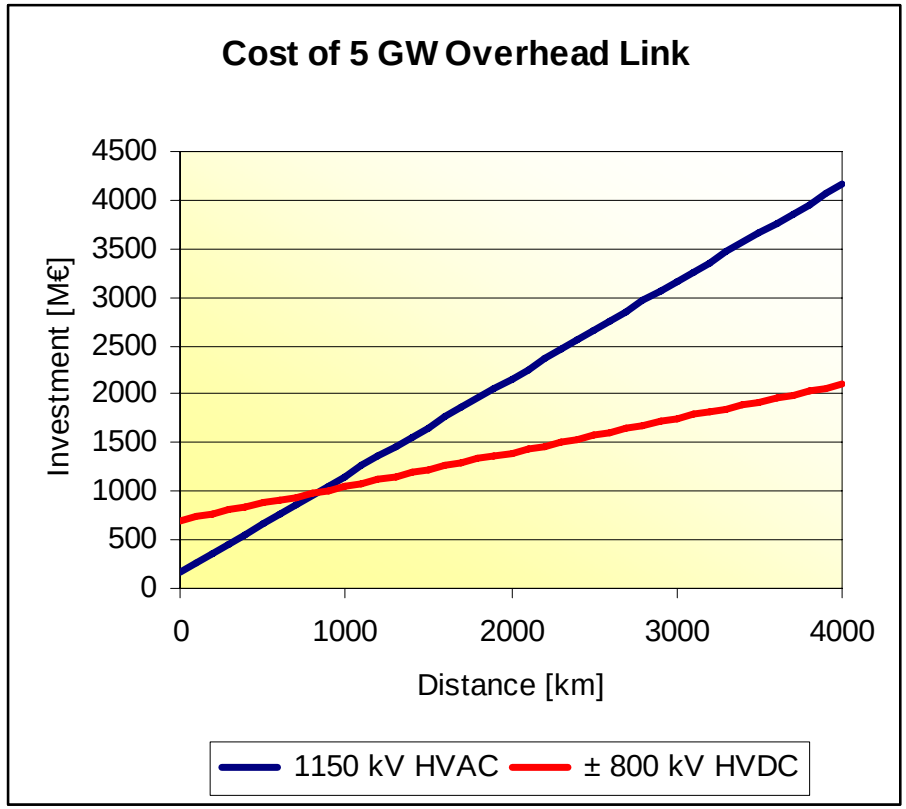
HVDC is a well-established technology, transmitting 75 GW world wide (mainly remote hydro- and geothermal power)



Source: ABB

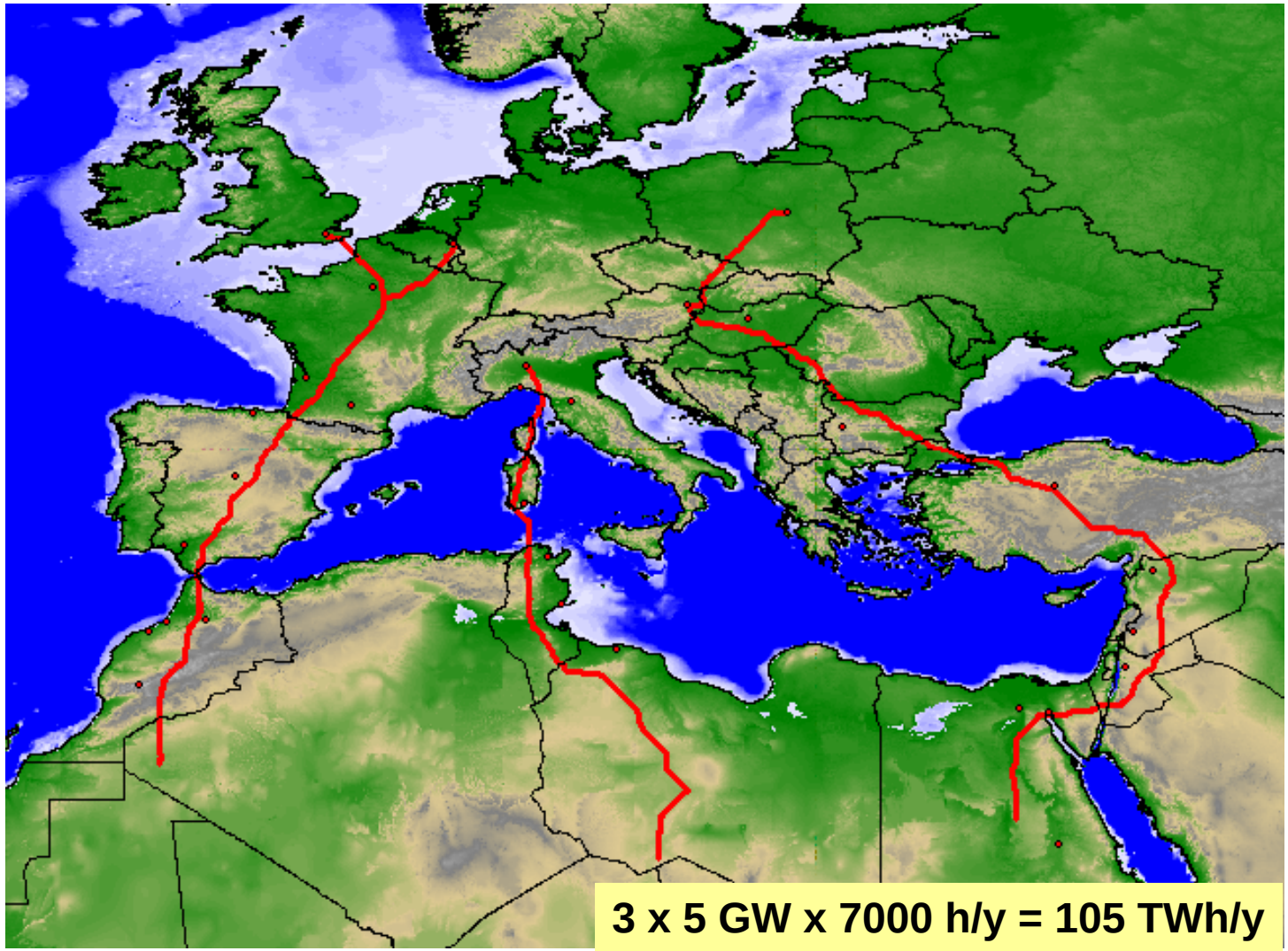
Cost of HVDC and HVAC links with 5 GW capacity



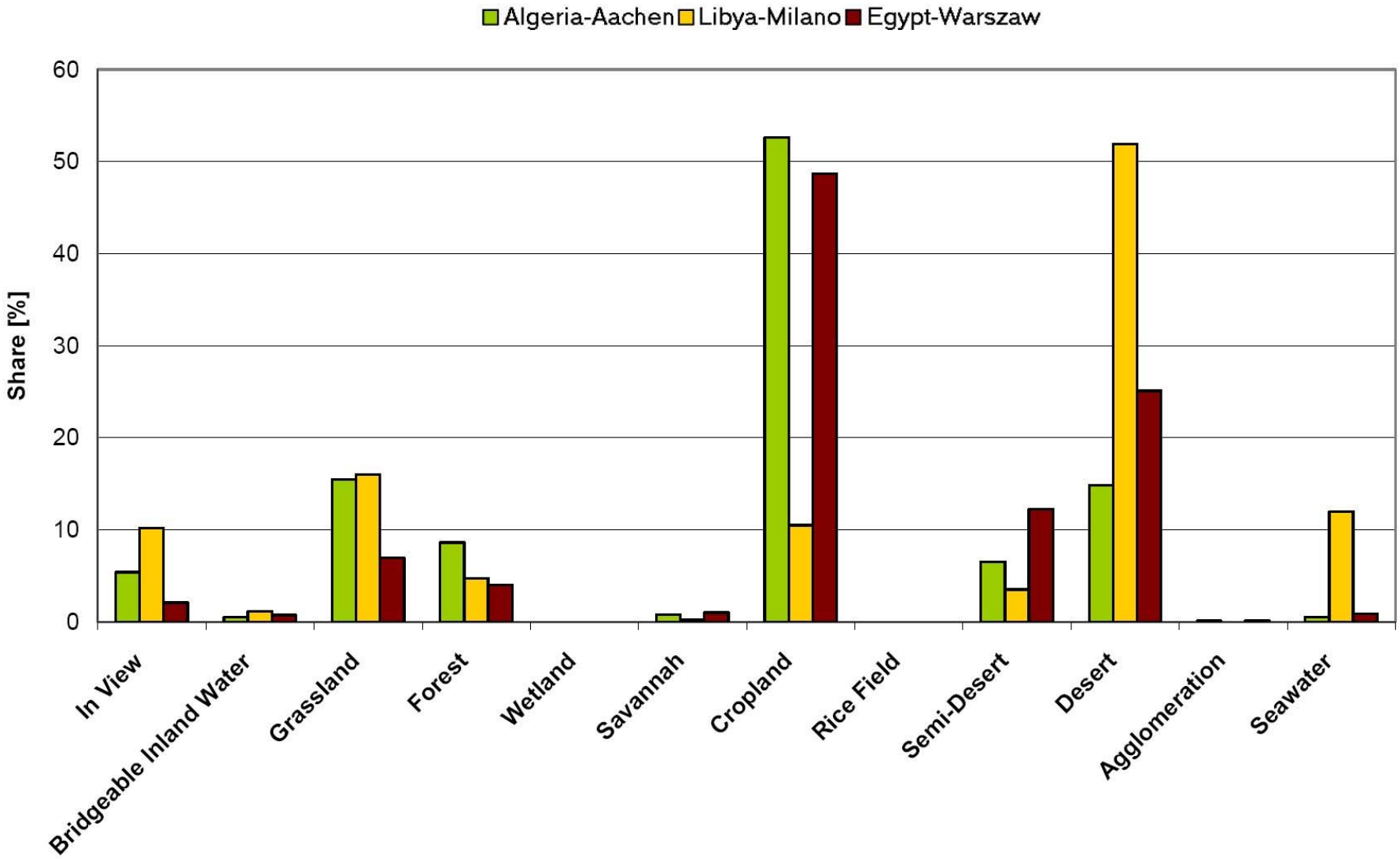


HVDC High Voltage Direct Current, HVAC High Voltage Alternating Current

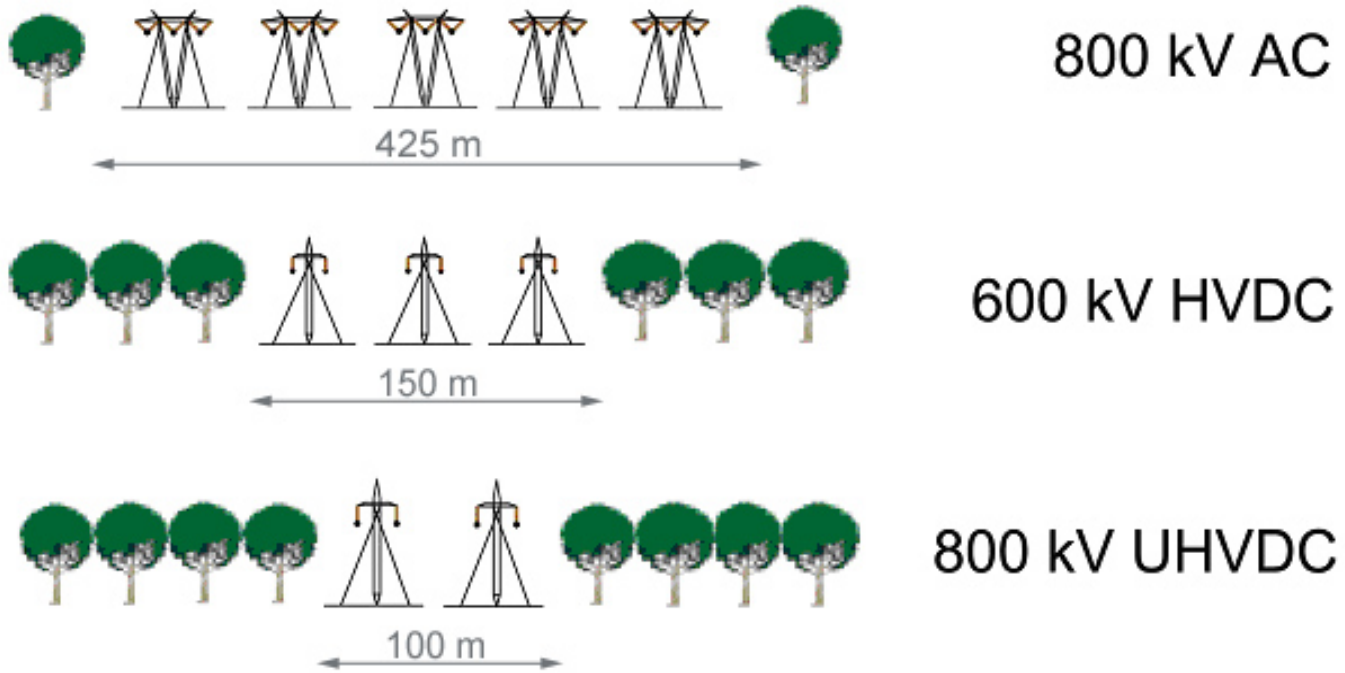
Analysed Examples for EU-MENA HVDC Interconnection



Impact of HVDC Lines on Landscape



Space required for 10 GW power transmission



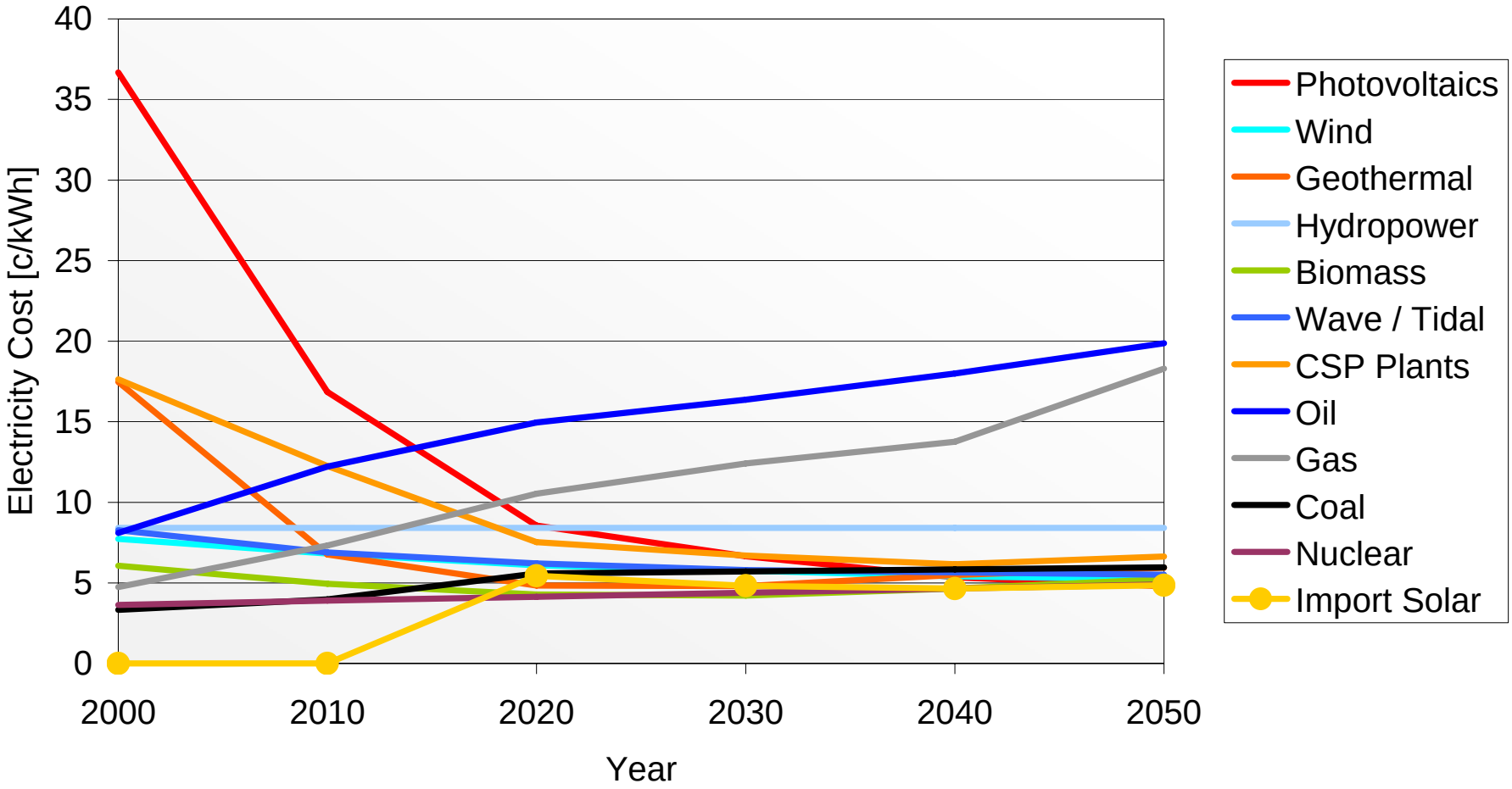
(Quelle: ABB, erweitert)

AC	Alternating Current
HVDC	High Voltage Direct Current
UHVDC	Ultra High Voltage Direct Current

Options for solar electricity transfer over 3000 km distance

Solar Power Transfer by:	Hydrogen	AC / HVAC	HVDC Line
Losses	75 %	45 % / 25 %	10 %
Cost	very high	high	low
Adaptation to Consumers (Transformer)	has to be transformed to AC first	directly transformable	has to be transformed to AC first
Over Sea Transport	by tankers or pipelines	not over 30 km	standard solution
Visibility Impact	very low	high	low
Materials and Emissions	moderate	moderate	low
Preferred Application	eventually fuel for transport	regional and local power	long distance power transfer

Electricity generation cost of various technologies



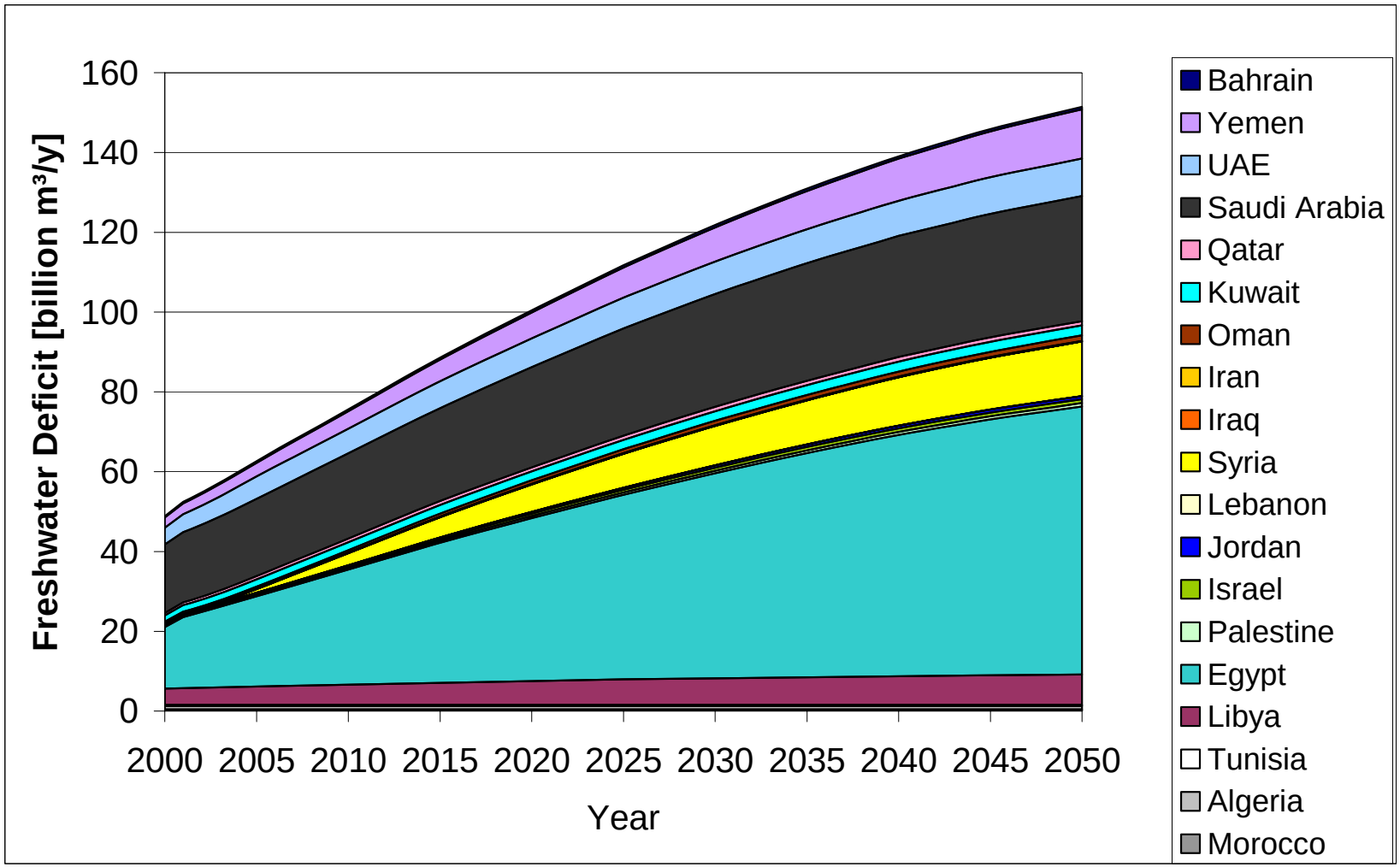
CO_2 Capture and Sequestration (CCS) included in fossil fueled generation costs after 2020
CSP in solar only operation

Scenario for total EU-MENA HVDC interconnection 2020 – 2050 *

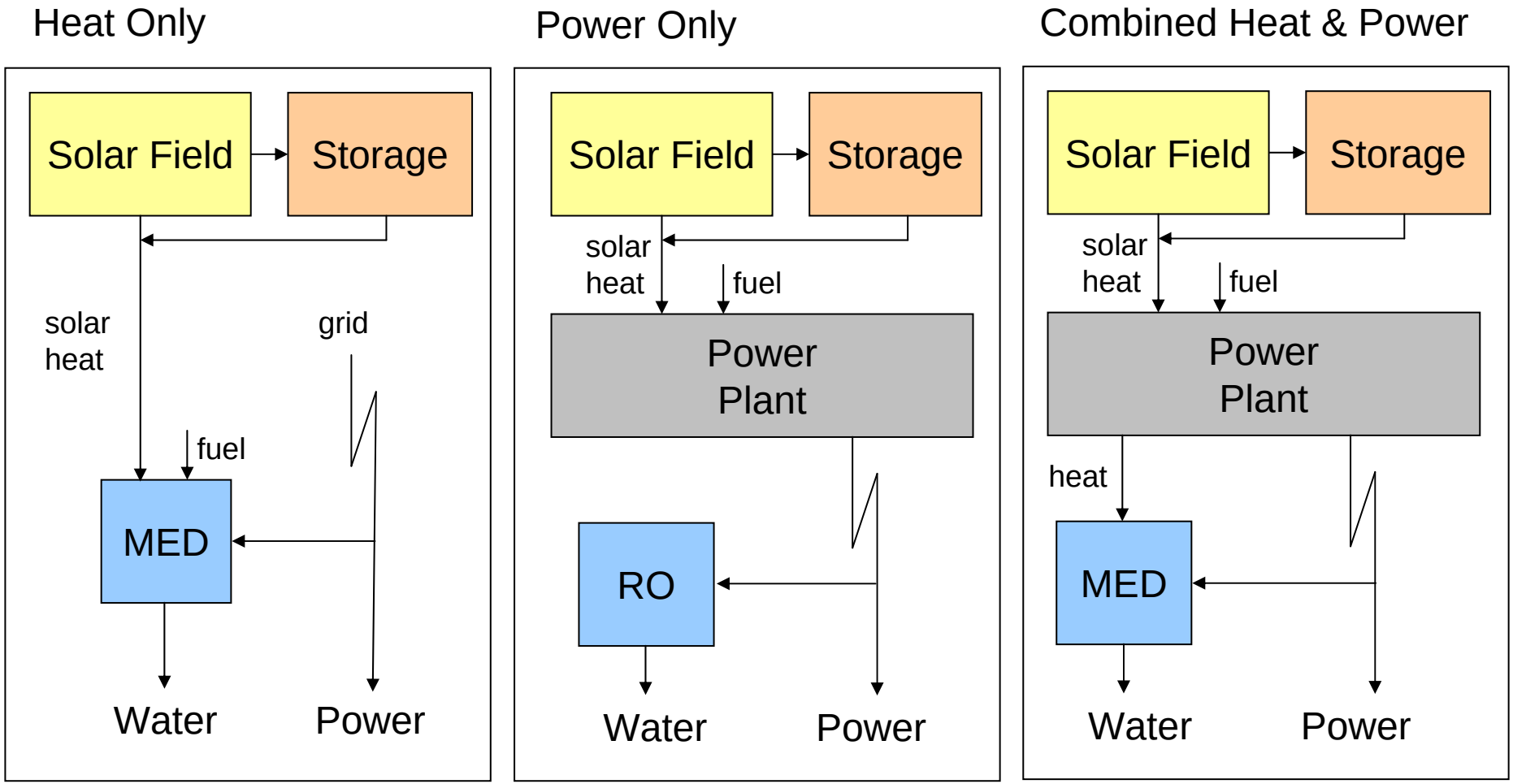
Year		2020	2030	2040	2050
Capacity GW		2 x 5	8 x 5	14 x 5	20 x 5
Transfer TWh/y		60	230	470	700
Capacity Factor		0.60	0.67	0.75	0.80
Land Area km x km	CSP HVDC	15 x 15 3100 x 0.1	30 x 30 3600 x 0.4	40 x 40 3600 x 0.7	50 x 50 3600 x 1.0
Investment Billion €	CSP HVDC	42 5	134 16	245 31	350 45

* All countries analysed in TRANS-CSP

Expected Water Deficits by Country

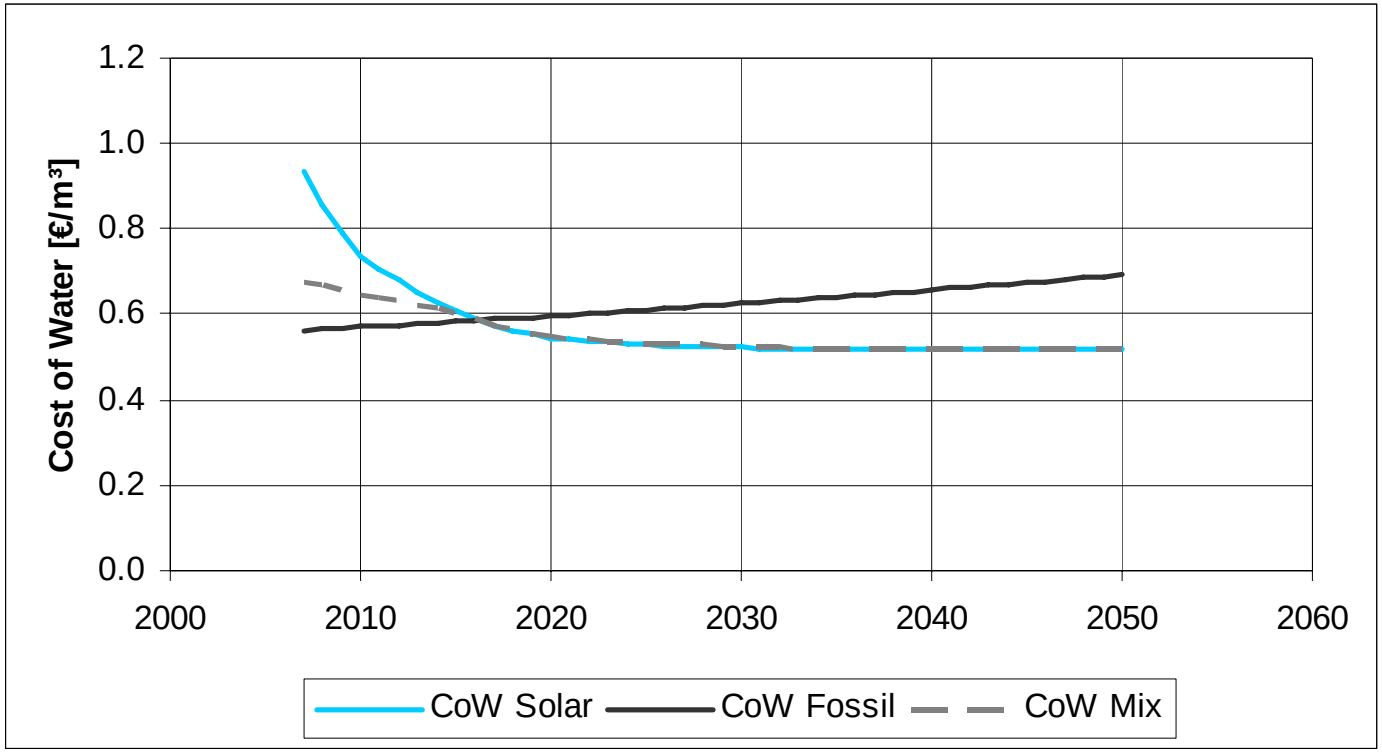


Concentrating Solar Thermal Power for Seawater Desalination (Options)

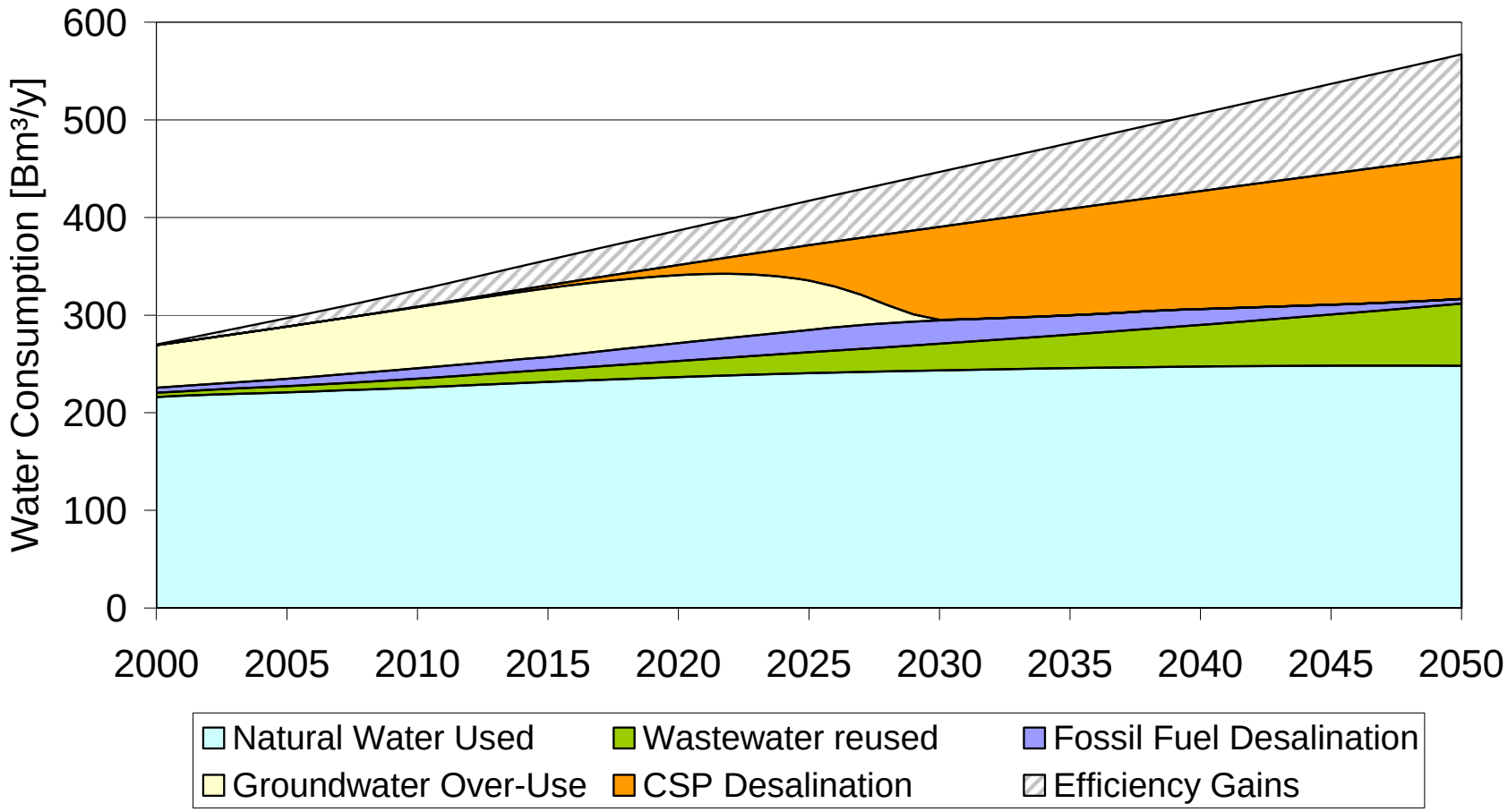


MED: Multi-Effect-Distillation; RO: Reverse Osmosis Membrane Desalination

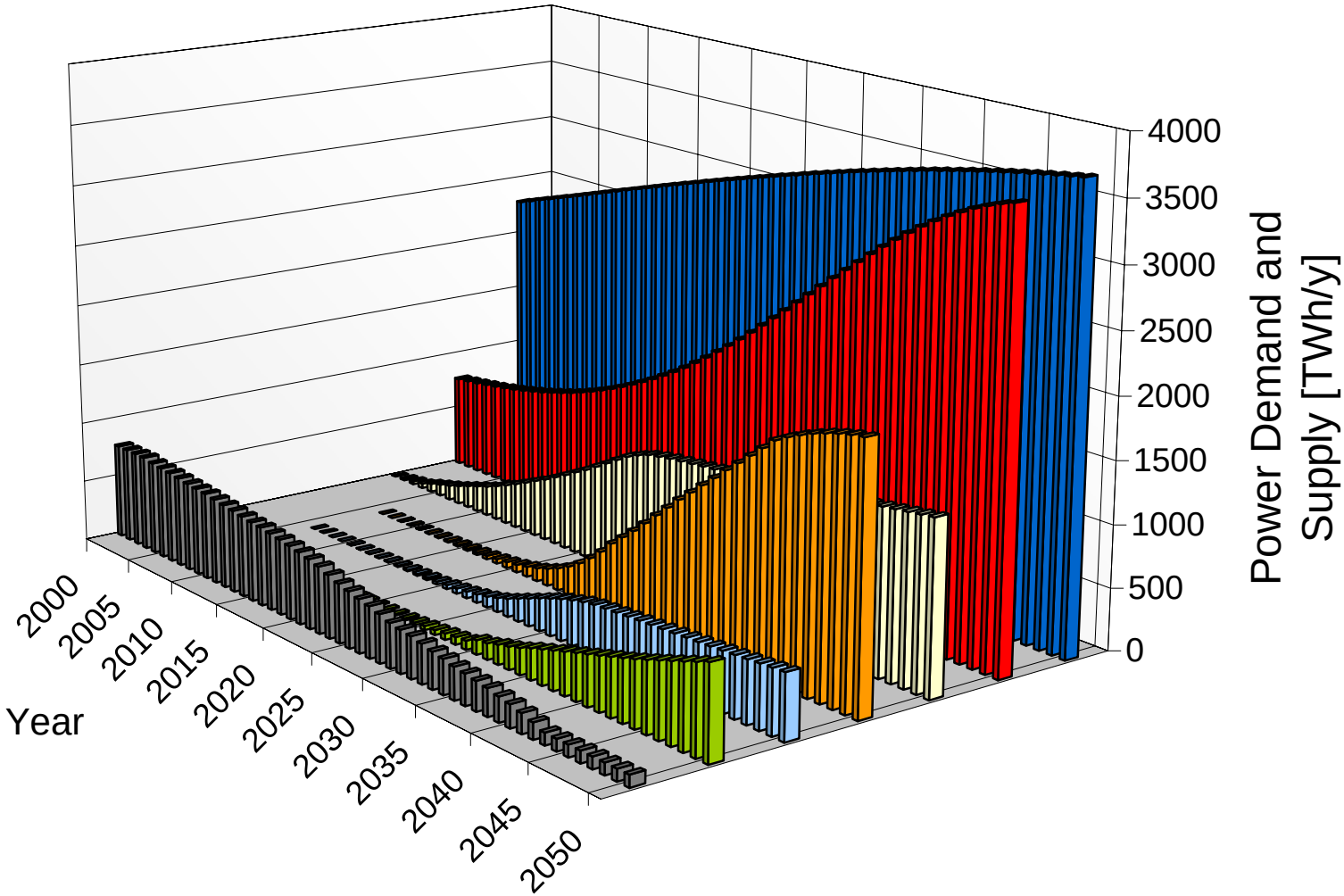
Projected cost of water (CoW) from RO using conventionally generated power or solar electricity



Middle East & North Africa



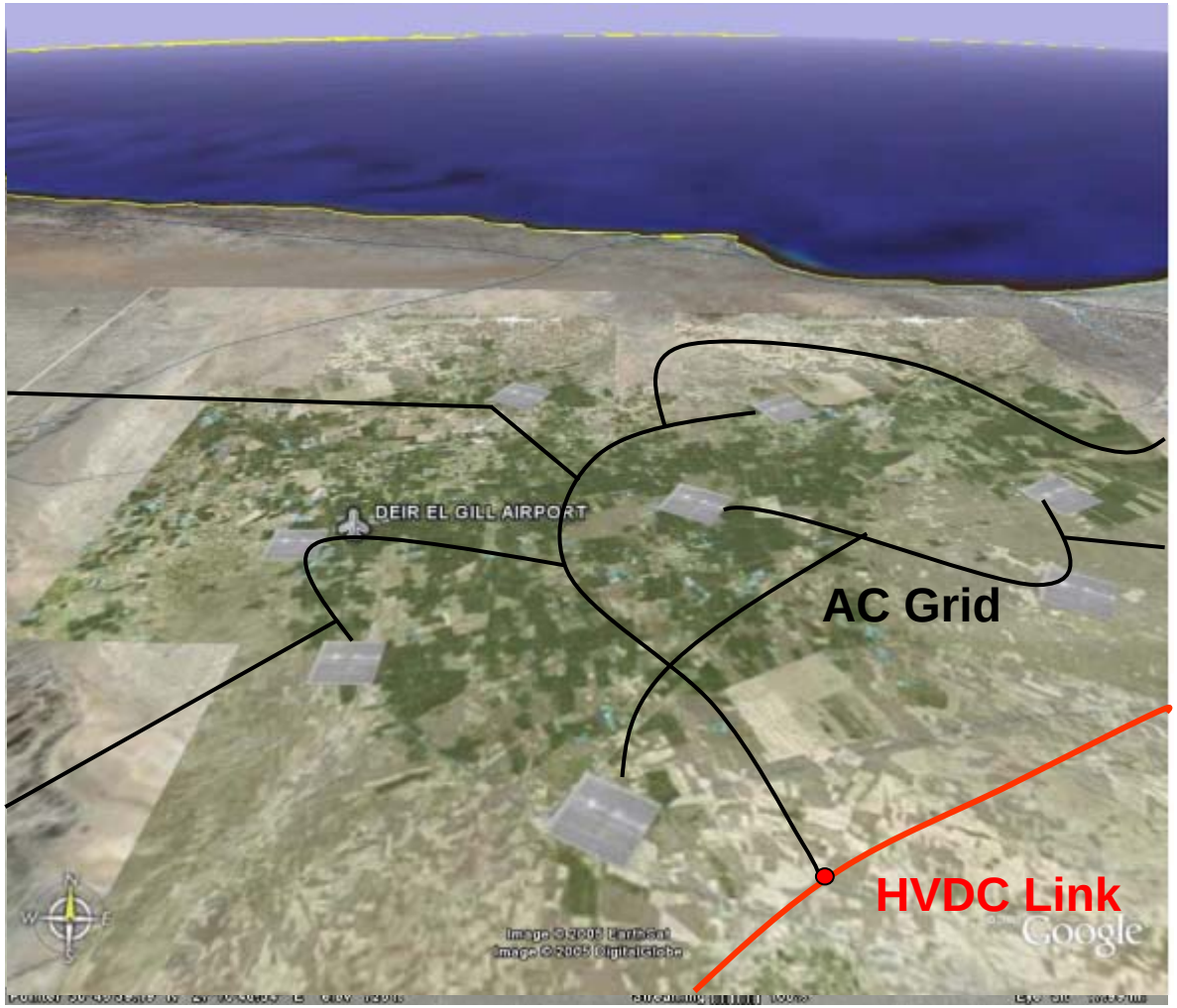
Electricity and fresh water provision in MENA



Conclusions

- Within 15 years, a well balanced power mix may lead to less expensive electricity than business as usual. Domestic sources reduce the import of fuels.
- Solar electricity from concentrating solar power stations in MENA can provide firm capacity for base load, intermediate and peaking power.
- The most efficient and economic way to transfer electricity from MENA to Europe is via high voltage direct current transmission lines, adding about 1.5-2 cents/kWh to the local generating cost.
- By 2050, 700 TWh/y solar electricity could be imported from 20 locations in MENA at a cost of 5 c/kWh, providing about 15 % of European electricity demand.
- MENA water deficits can only be alleviated by seawater desalination powered by CSP
- To establish and maintain such a trans-national HVDC electricity grid, strong political support will be required.

Deserts as Powerhouses and Waterworks



www.dlr.de/tt/med-csp

www.dlr.de/tt/trans-csp

www.dlr.de/tt/aqua-csp

(artist view created with Google Earth)