Joint Saudi Arabian - German CSP Research Workshop

19th of November 2013

Riyadh, Kingdom of Saudi-Arabia

- **System Analysis and Technology Assessment**
- **System and Market Integration of Renewable Energies and esp. Concentrating Solar Power**

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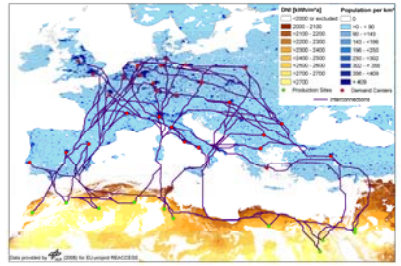
German Aerospace Center
Deutsches Zentrum für Luft und Raumfahrt e.V. (DLR)

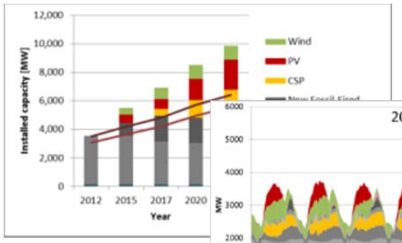
DLR - Who we are

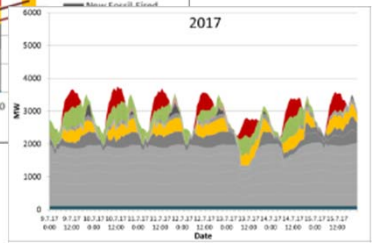
Research Areas

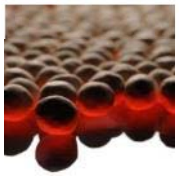
- Aeronautics
- Space Research and Technology
- Transport
- Energy
- Space Administration
- Project Management Agency

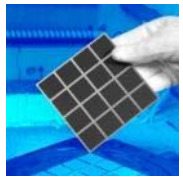
- Solar Research
- Wind Energy Research
- Systems Analysis
- Thermal & Chemical Storage
- High & low Temp. Fuel Cells
- Combustion & Gas Turbine Technologies











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Projects and Milesstone

- MED-CSP www.dlr.de/tt/med-csp 2005
- TRANS-CSP > DESERTEC www.dlr.de/tt/trans-csp 2006
- AQUA-CSP www.dlr.de/tt/aqua-csp 2007
- MED-CSD 2008-2010
- EU GCC Clean Energy Network 2010-
- CSP Finance 2011
- World Bank MENA Water Outlook 2011
- IRENA Solar Atlas 2010-2013
- BETTER 2012-
  - **B**ringing **E**urope and **T**hird countries closer **T**ogether trough **R**enewable **E**nergies
- QatDLR 2012-
- **DLR-KA.CARE Cooperation on CSP Research 2013-**
  - Joint Saudi Arabian - German CSP Research Workshop **today**

Systems Analysis and Technology Assessment

- Transformation of the Energy System towards Sustainability
- Seawater Desalination with Concentrating Solar Power
- Renewable Energy Resource and Site Assessment
- Renewable Energy Expansion and Unit Commitment Model REMix-CEM
- Flexible, High Value Solar Power Exports

Transformation of the Energy System towards Sustainability

Portfolio of Energy Sources for Electricity

- **Coal, Lignite**
- **Oil, Gas**
- **Nuclear Fission, Fusion**
- **Concentrating Solar Power (CSP)**
- **Geothermal Power (Hot Dry Rock)**
- **Biomass**
- **Hydropower**
- **Wind Power**
- **Photovoltaic**
- **Wave / Tidal**

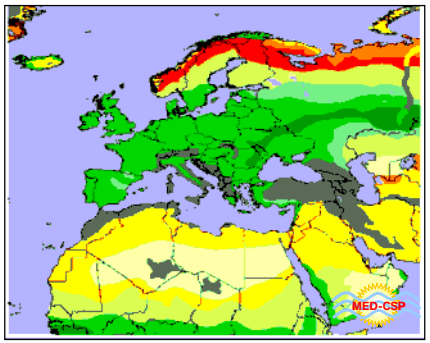
ideally stored primary energy

storable primary energy

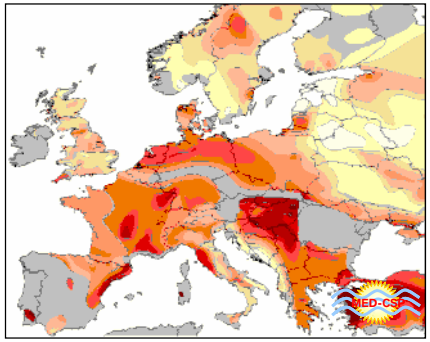
fluctuating primary energy

Renewable Electricity Potentials in EUMENA

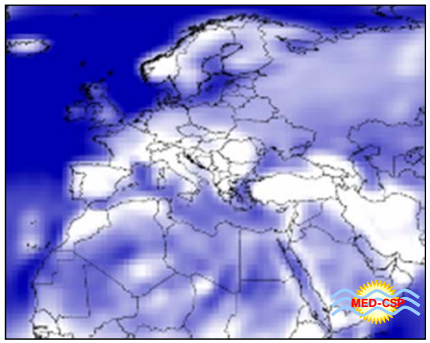
Biomass (0-1)



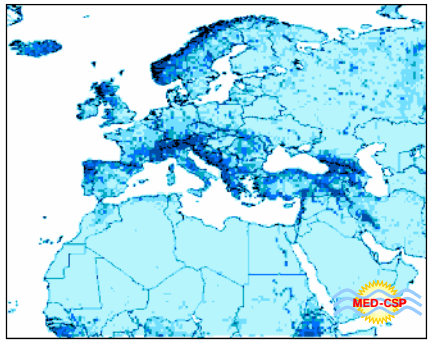
Geothermal (0-1)



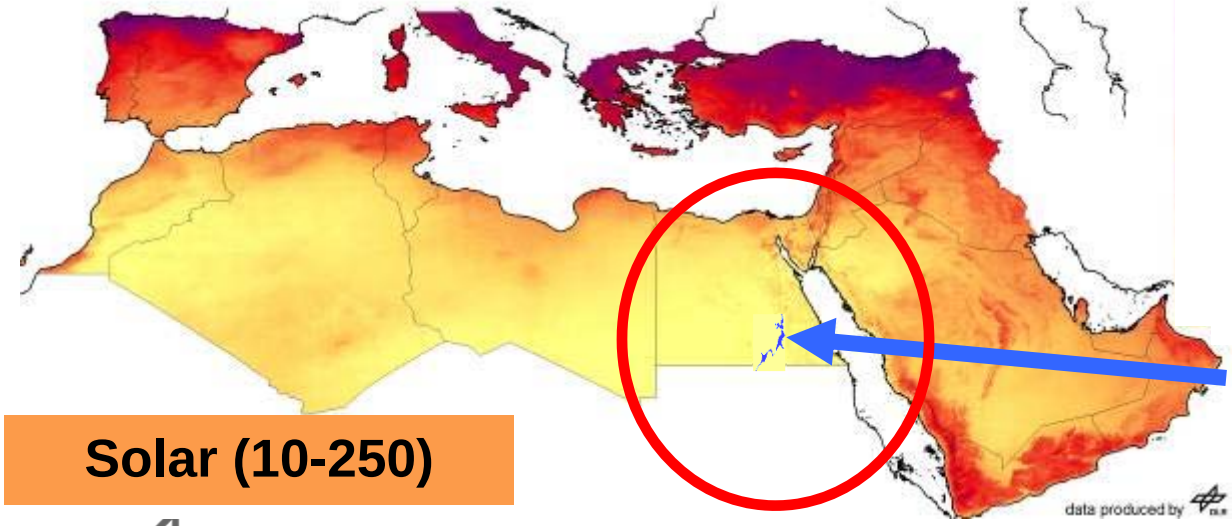
Wind (0-50)



Hydro (0-50)



Solar (10-250)



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

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Criteria for Sustainable Electricity Supply

1. Affordability
- Low cost
- Low subsidies
- Low structural effort

2. Security
- Diversification of supply
- Power on demand and redundancy
- Sustainable energy resources
- Available technology

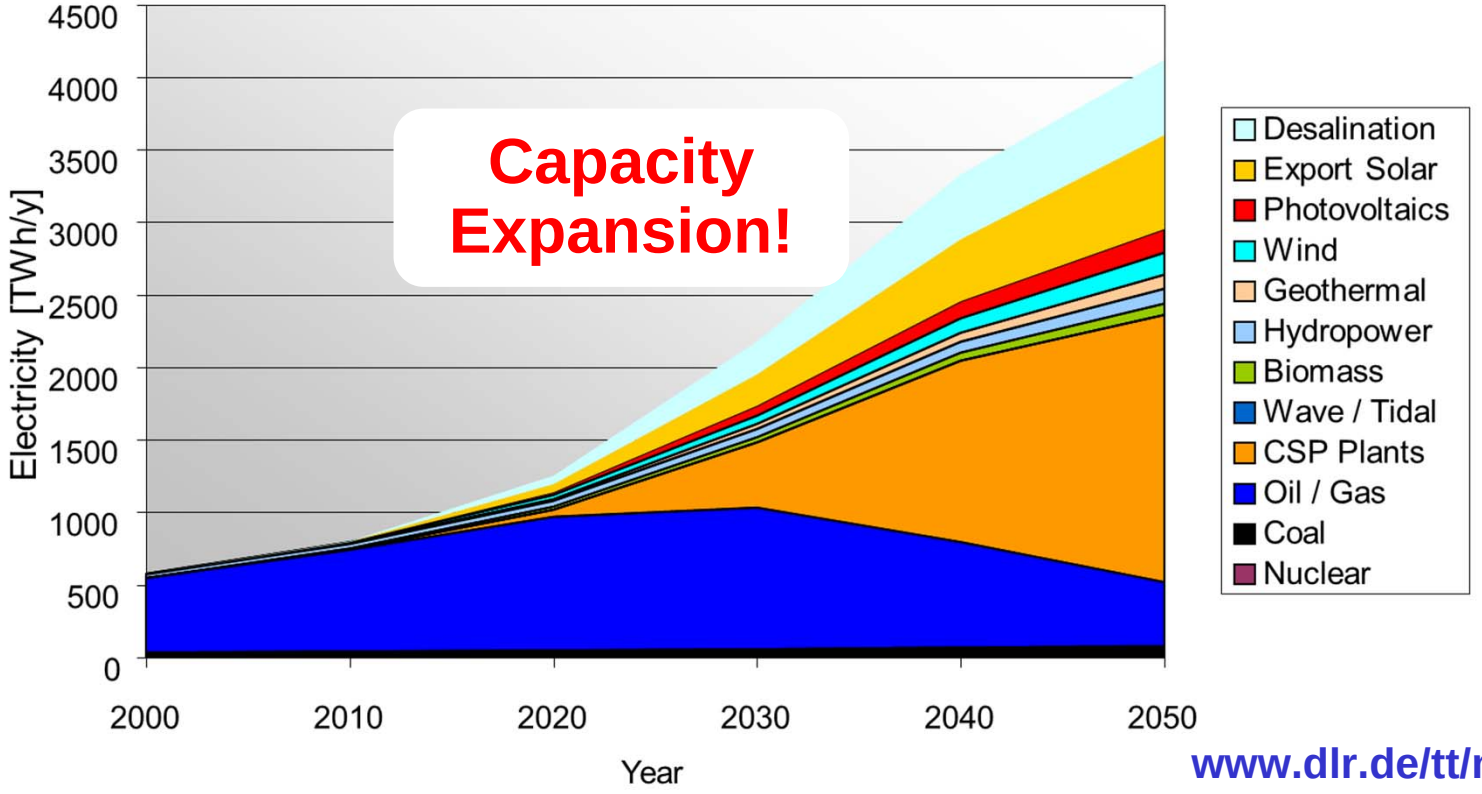
3. Environmental compatibility
- Low pollution, climate protection
- Low risks for health and nature
- Low land use and structural impacts

4. Social compatibility
- Fair access to energy
- Balance of dependencies and interdependencies
- Strategic flexibility during transition

➔ One consistent pathway towards sustainable supply under specific limitations

Prospects for RES-E expansion in MENA

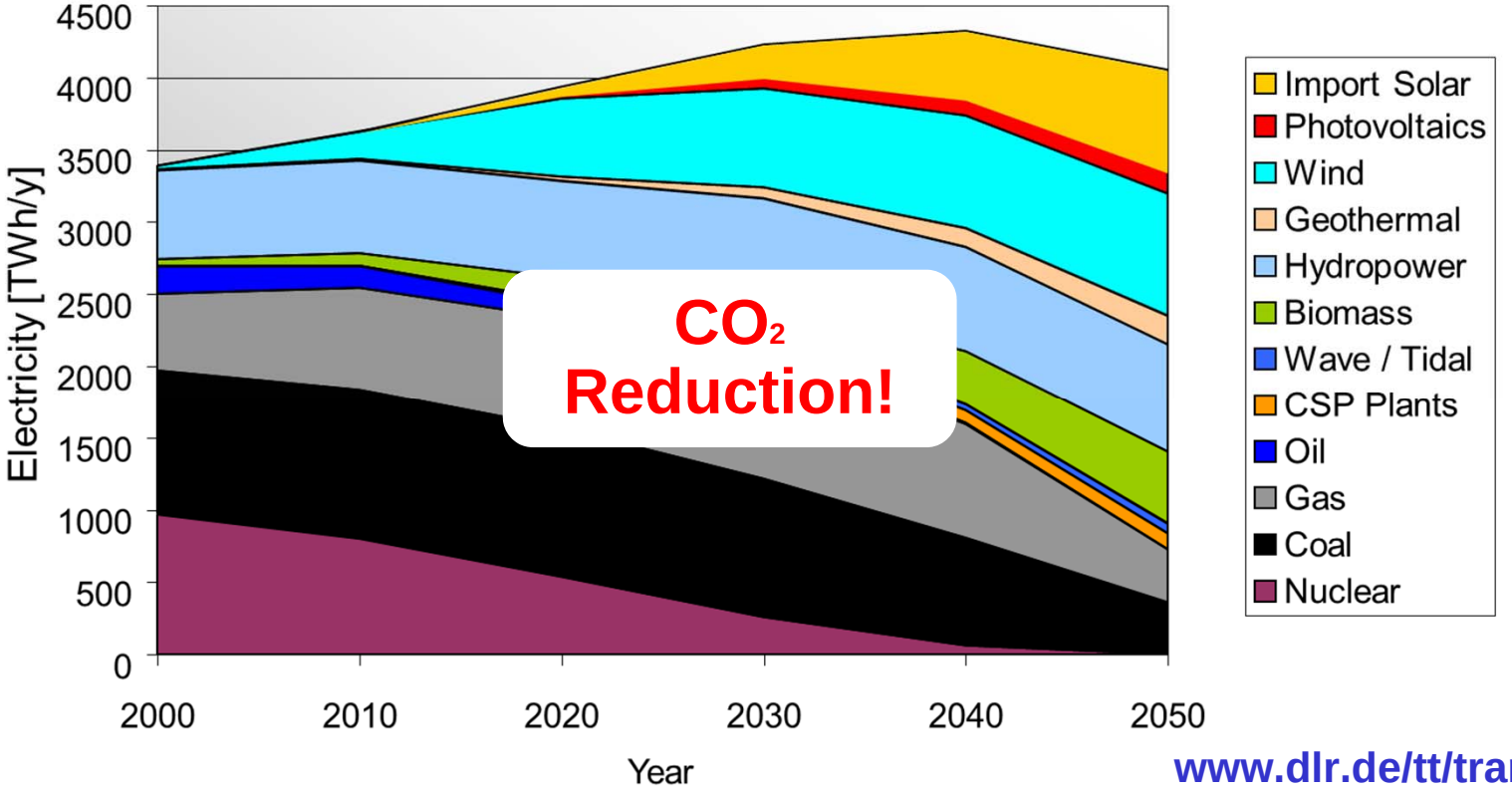
MED-CSP Study 2005:
Electricity supply in the Middle East & North Africa



www.dlr.de/tt/med-csp

Prospects for RES-E exports from MENA to Europe

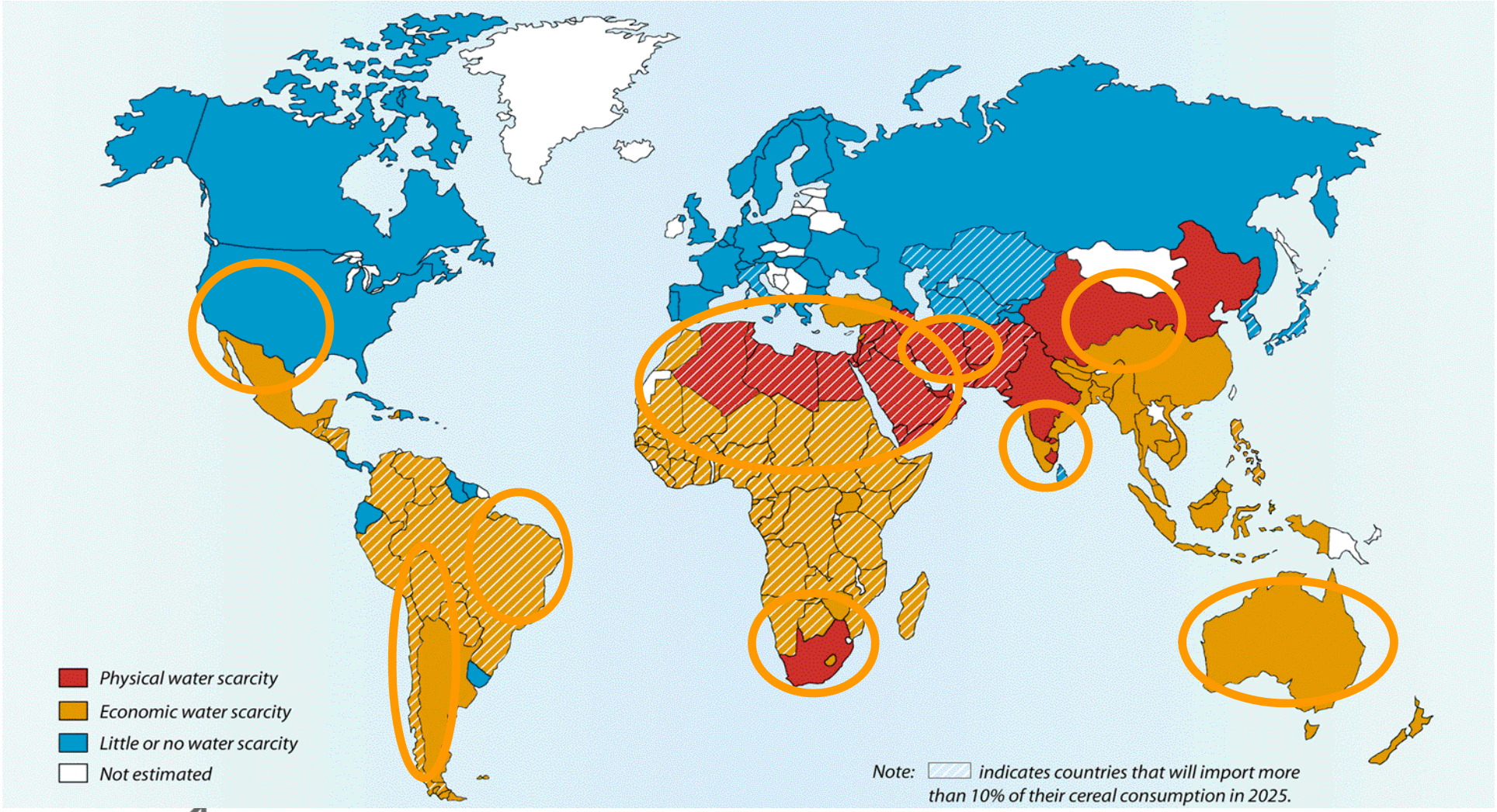
TRANS-CSP Study 2006: Electricity Supply in Europe



www.dlr.de/tt/trans-csp

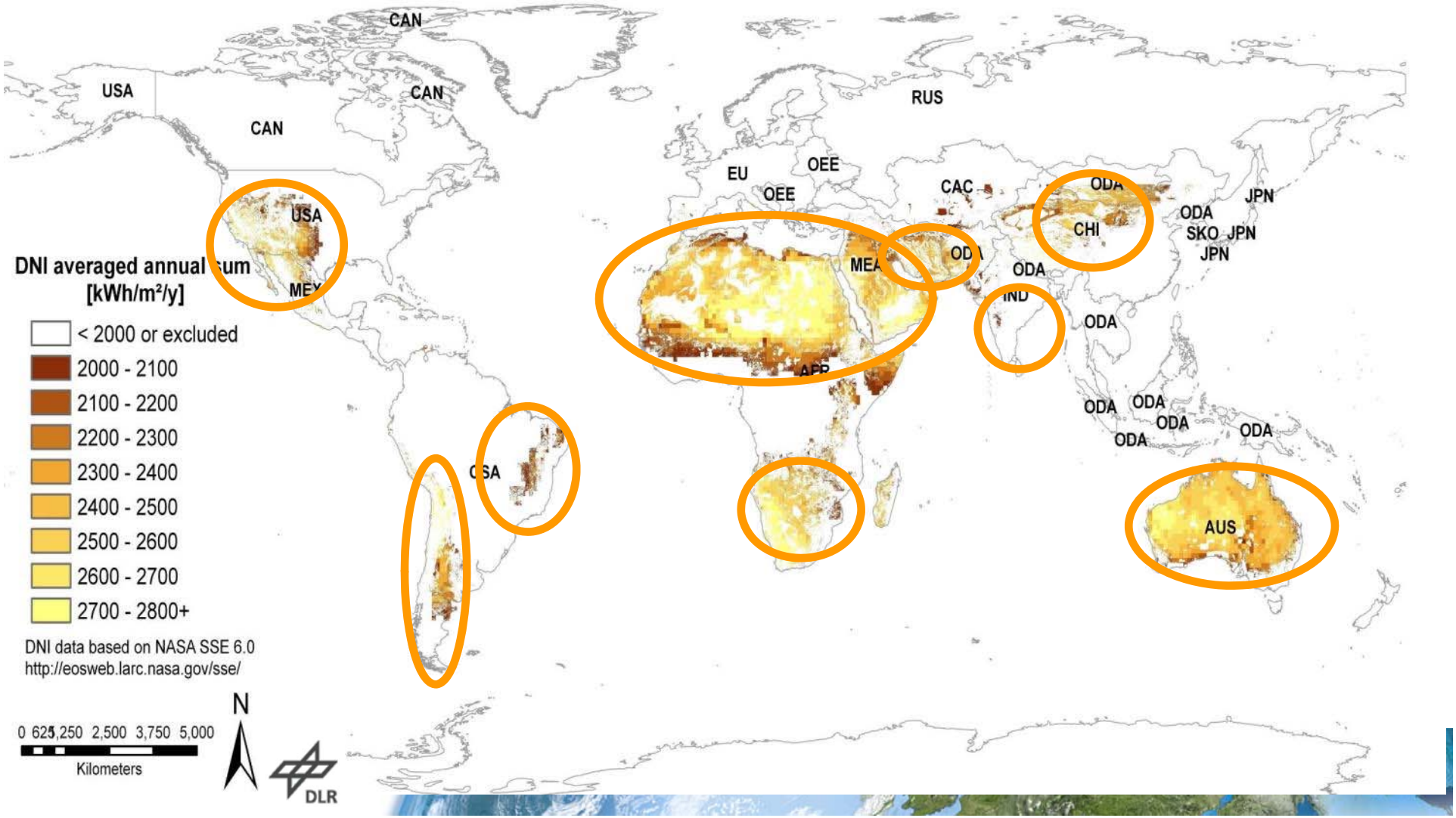
Seawater Desalination with Concentrating Solar Power

Global Water Scarcity

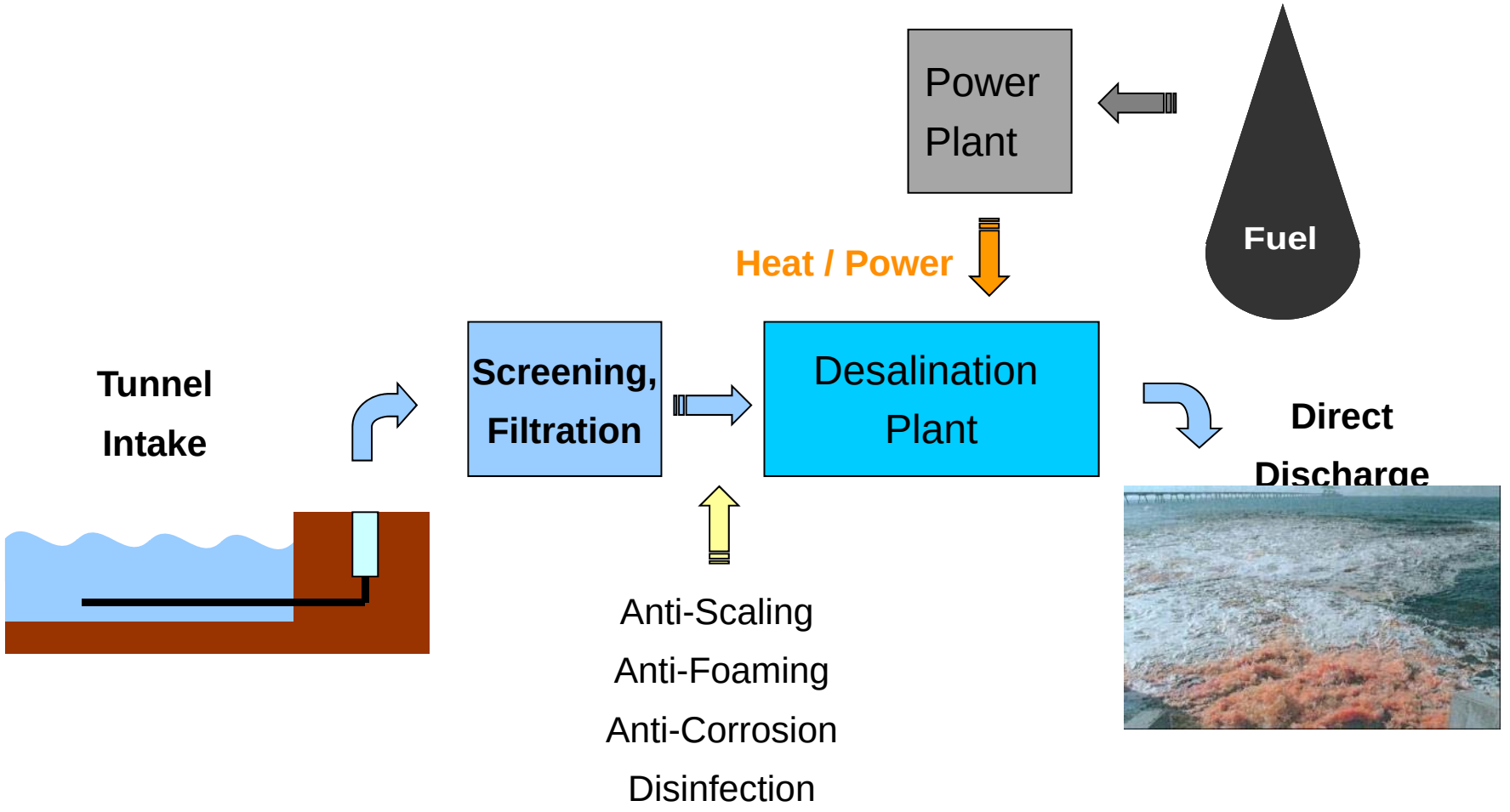


Global Potential for CSP Solar Power

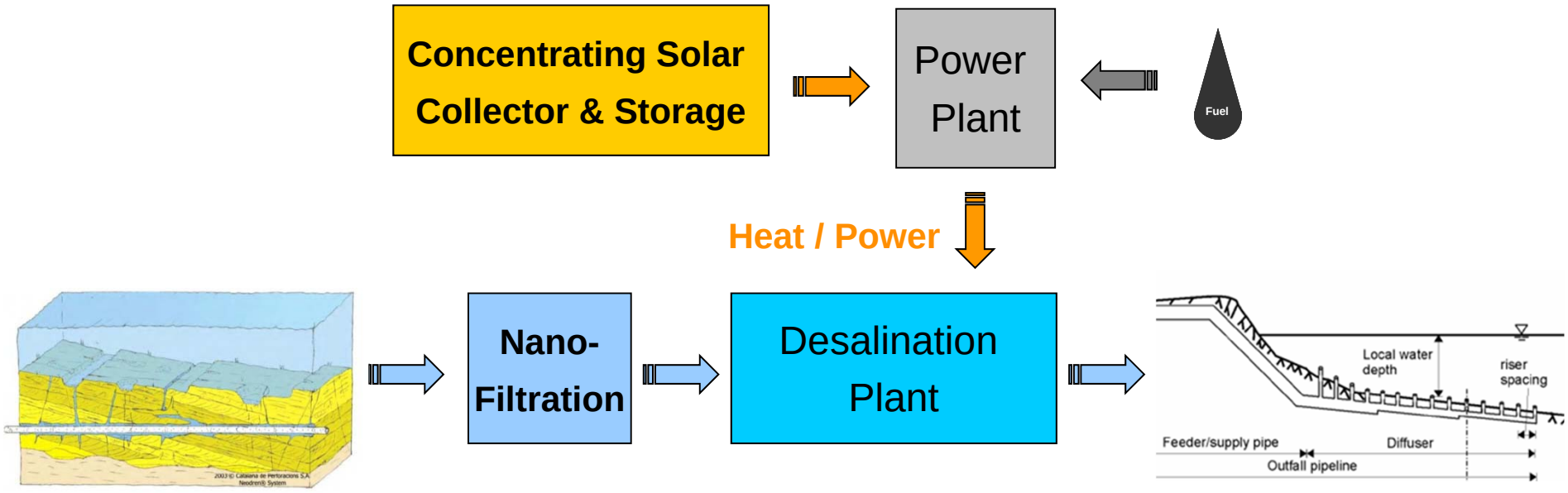
Global Potential 3,000,000 TWh/y – Global Demand 18,000 TWh/y



Conventional Desalination Plant



Advanced Renewable Desalination

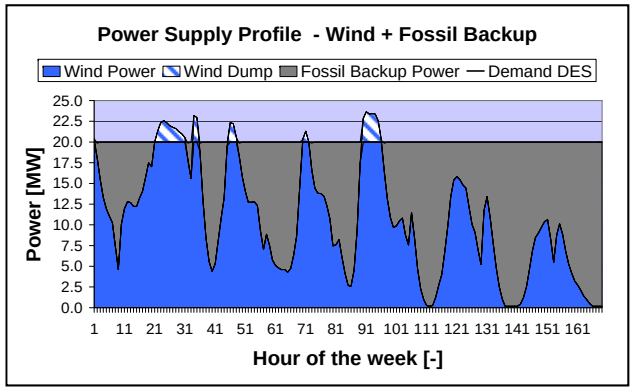


Horizontal Drain Intake or Micro- & Ultrafiltration

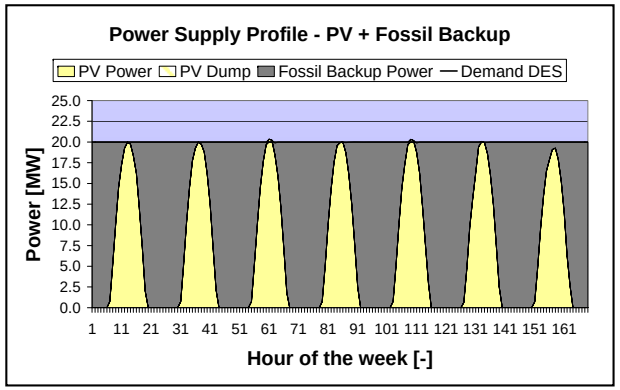
Multiport Diffuser Discharge

catalanadeperforacions.com; cormix.info

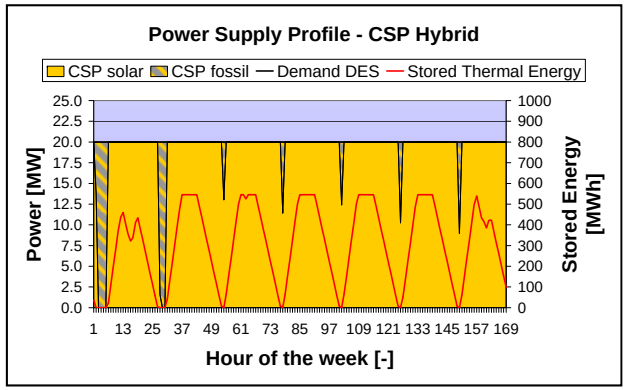
Renewable Energies for Desalination: Why CSP?



Wind



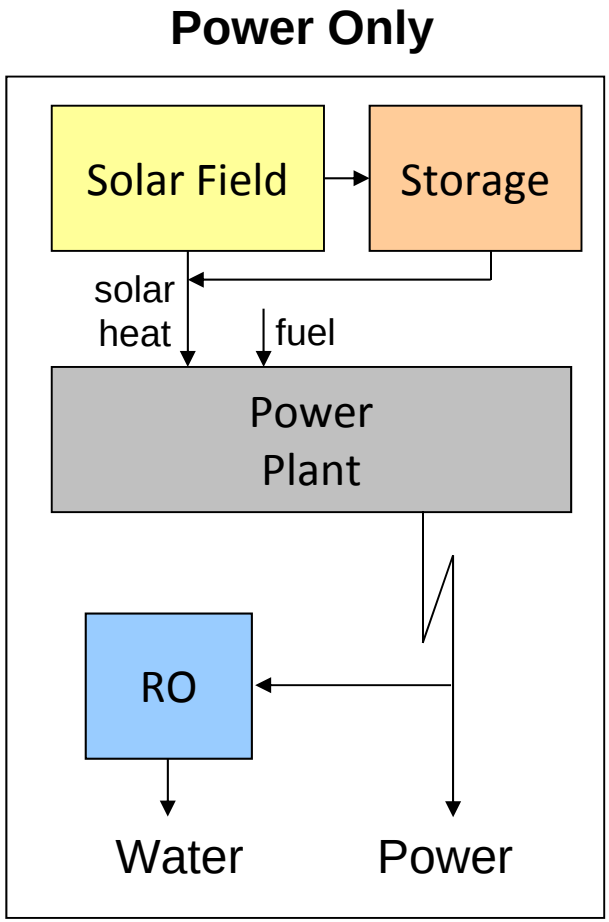
PV



CSP

- **Desalination plants require continuous operation**
  - Conflict with the intermittent nature of renewable energies
  - CSP offers the option of thermal energy storage (TES)
  - Hybrid operation is possible in the same power block (no “shadow power plant” required)
- **A fair technology comparison has to be carried out by definition of a load profile!**
  - To Wind and PV cost, storage (if available) and back-up cost have to be considered
  - Grid import is not for free

CSP-Desalination Plants: CSP-RO

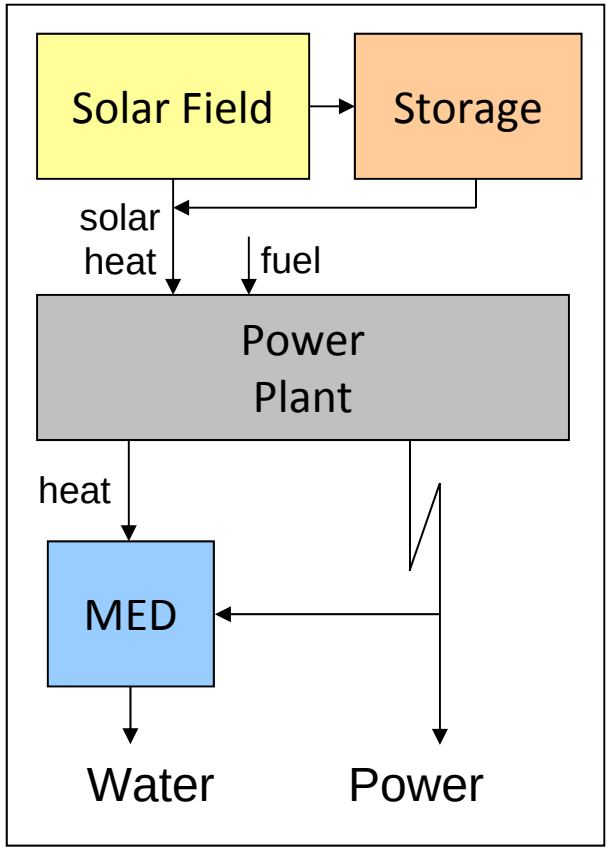


- Independent Operation
- Site flexibility :
  - Inland (high DNI, dry-cooling, electricity transmission, intake)
  - Coast (medium DNI, evap. Cooling, shared intake)

www.dlr.de/tt/aqua-csp

CSP-Desalination Plants: CSP-MED

Combined Heat & Power



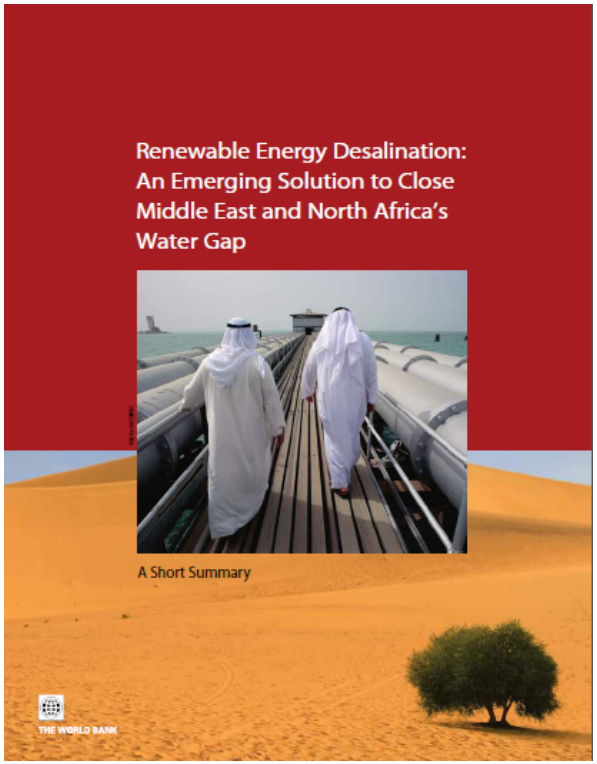
- Interdependent Operation
- Site constrains for the CSP plant :
  - Coast (medium DNI, cooling replaced by MED, shared intake)

Conclusions

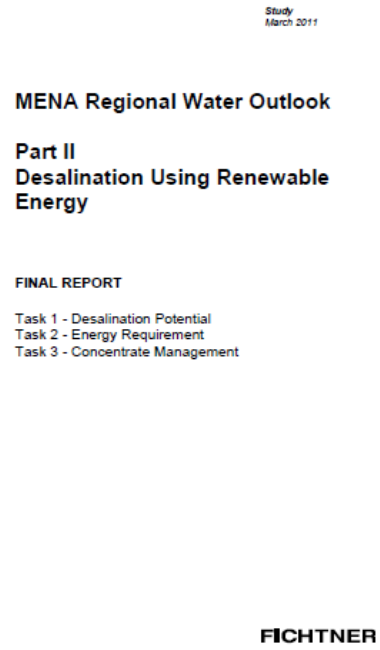
- Large scale conventional seawater desalination would create significant environmental impacts
- CSP+DES plants can reduce energy related emissions to few percent; Beach well or horizontal drain intake and nano-filtration can reduce additives; Horizontal drain discharge improves quick dilution of heat and salt
- **Advanced CSP seawater desalination can be compatible with the environment !**
- Final decision about the best CSP+DES technologies can not be generalized → site specific issues and current market trends have to be taken into account!

Publications

The World Bank



www.dlr.de/tt/menawater



Renewable Energy Resource and Site Assessment

> Carsten Hoyer-Klick

Resources and Potentials

Motivation:

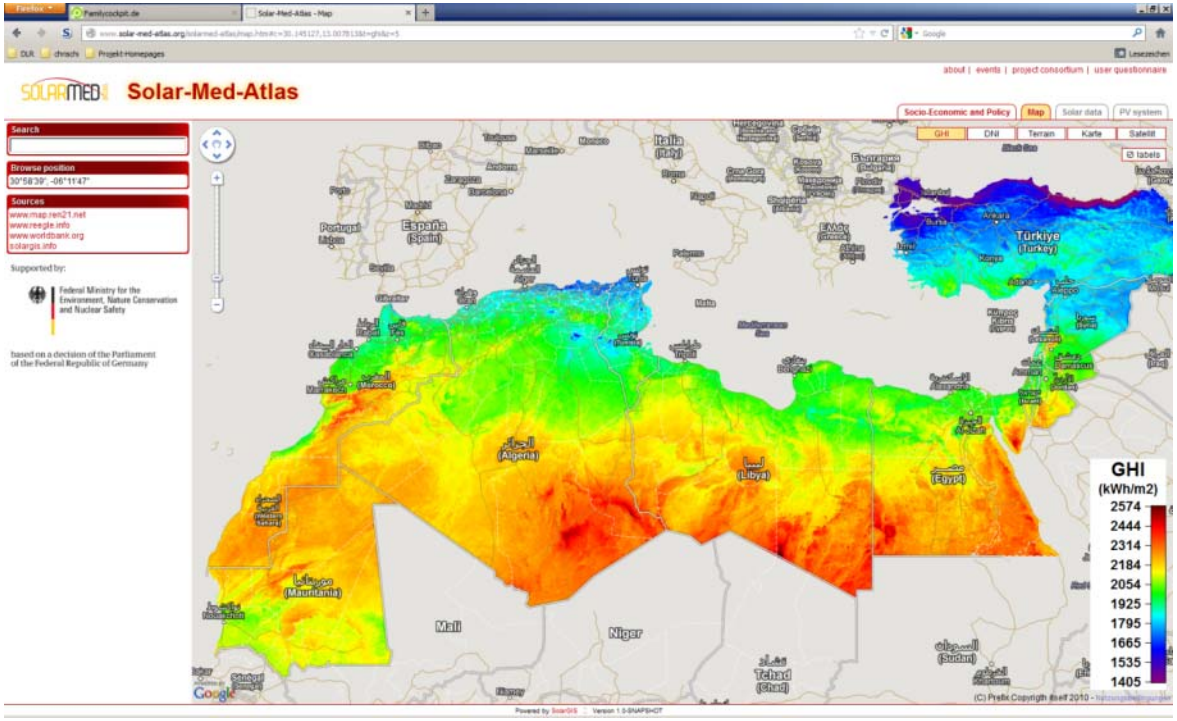
- Solar radiation, wind speed are the “fuel” of renewable energies
- This “fuel” is very variable in space and in time. It needs to be harvested where and when it is available.
- Knowledge about the spatial and temporal structures is esstials for the analysis with high shares of renewable energy

Main topics:

- Solar resource assessment (SOLEMI)
- Modeling of renewable energy systems in high spatial and temporal resolution (REMix)
- Analysis of spatial structures of resources and demand (GIS-Analysis)
- Web portals for decision support (Decision support)

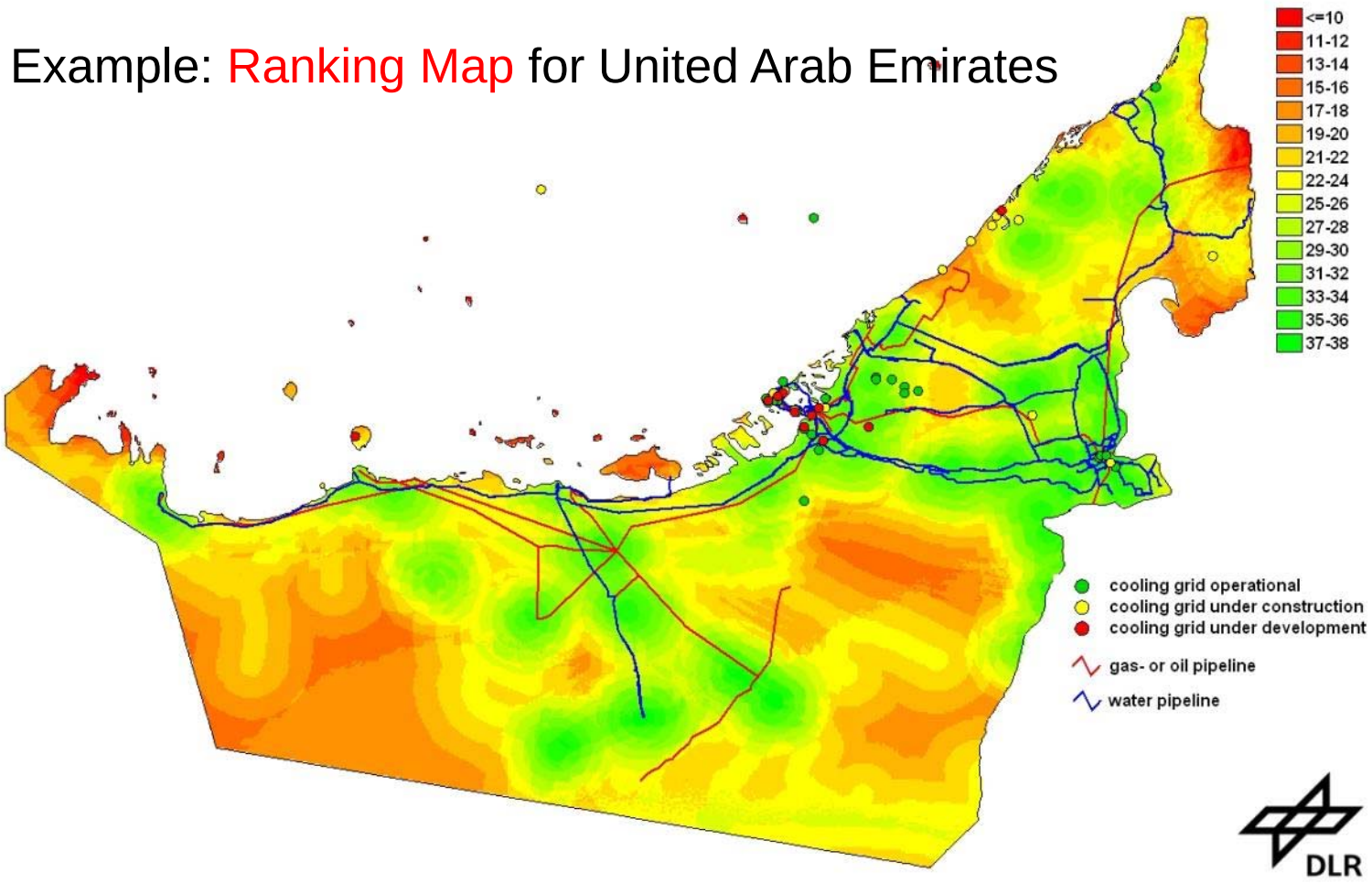
Solar Resource Assessment (SOLEMI – Solar Energy Mining) e.g.: Solar Atlas for the Mediterranean

- GHI and DNI
- 20 years of satellite-based data (1991-2010)
- Data access via web-portal
- Funded by German Ministry for Environment (BMU)
- European Consortium
- http://www.solar-med-atlas.org



Site Analysis for PV and CSP (WP 3)

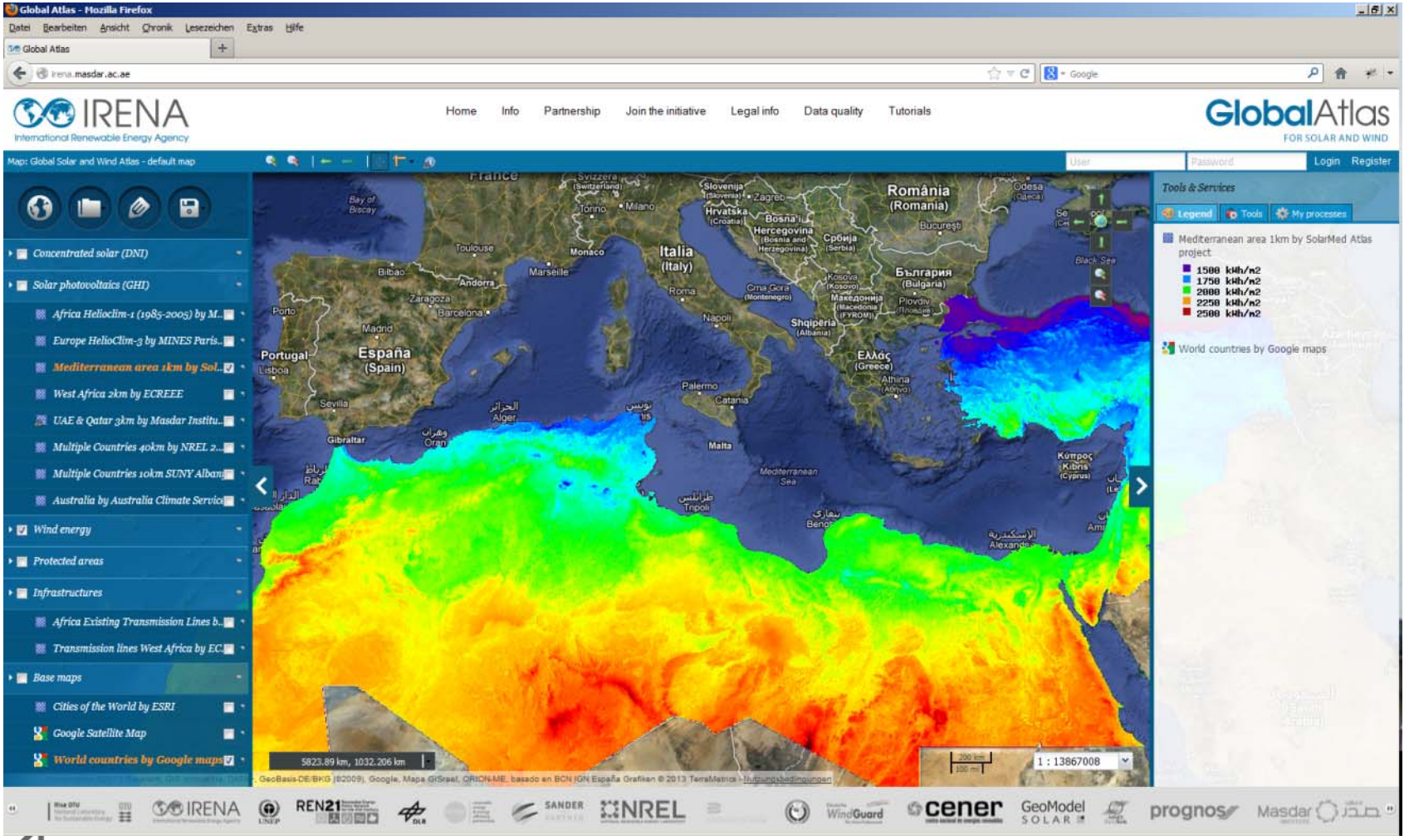
Example: Ranking Map for United Arab Emirates



Ranking map for potential CSP-sites. Data developed within SWERA-MASDAR-UNEP project.

IRENA Global Atlas for Solar & Wind Energy

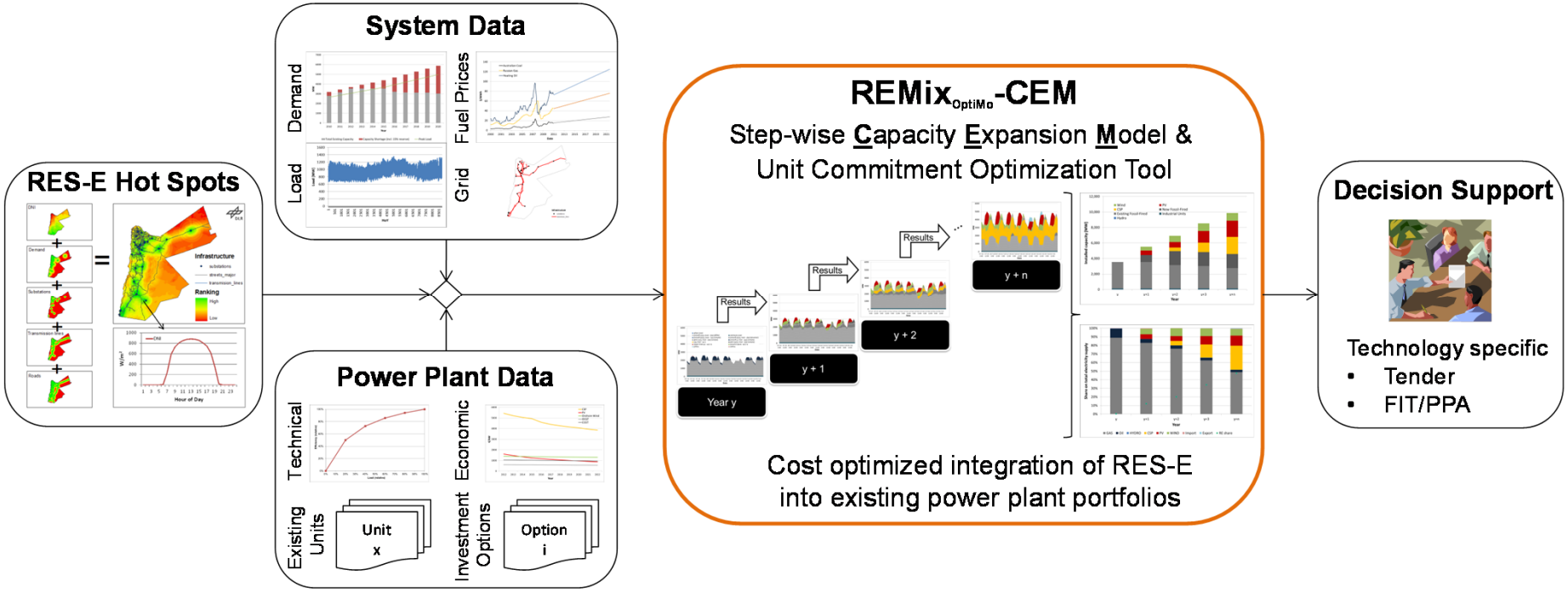
Map Interface



Renewable Energy Expansion and Unit Commitment Model REMix-CEM

Methodology for an optimized integration of RES-E technologies into existing power plant portfolios in MENA

- Emphasis on cost-optimized short-term integration of renewable energy systems for electricity generation (RES-E) and on security of supply
- Results for decision support for electricity authorities and power utilities in MENA



ReMix-CEM:

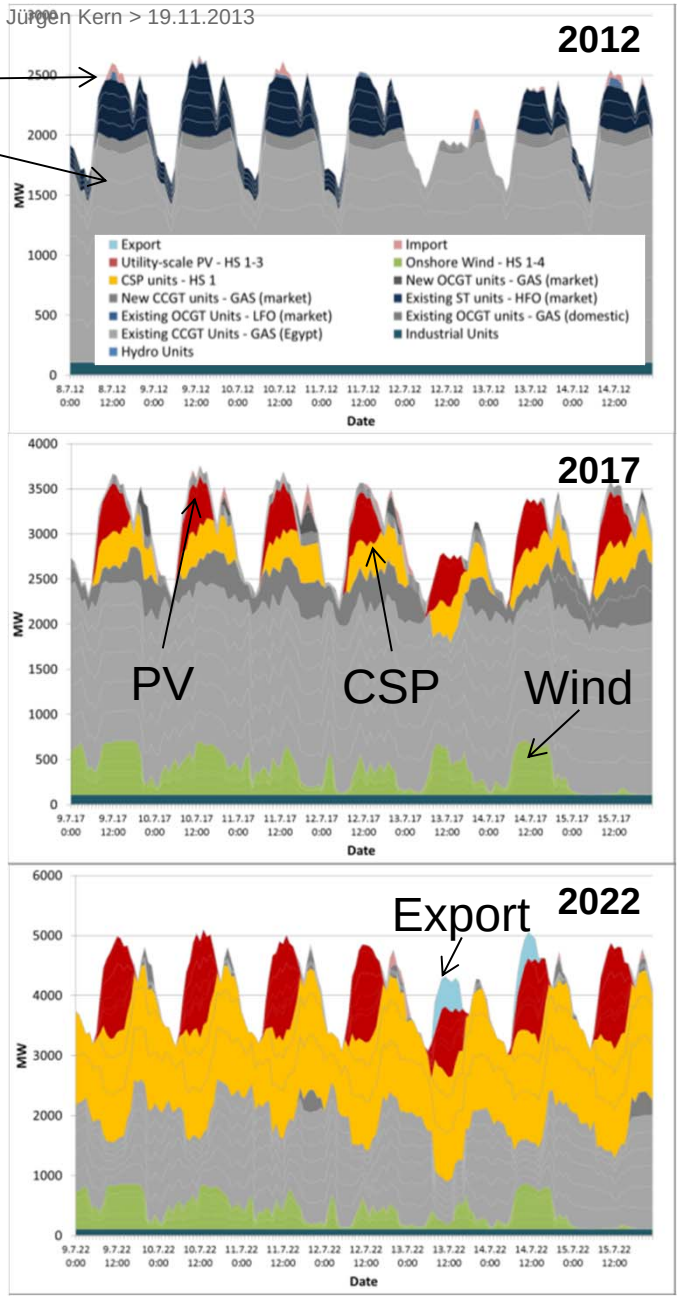
Optimization tool for cost efficient integration of renewable energy technologies in MENA countries

- Model for step-wise capacity expansion, replacement and unit commitment optimization (minimization of total system costs)
- Algorithm ensures that RE technologies are only integrated when their utilization contributes to lower total power generation costs
- Starting from present power plant portfolio of the investigated country
- Detailed hourly modeling of technical and economical restrictions and dynamics of each single conventional and RE power generation unit
- Optimization of CSP configuration (solar field and storage size)
- Taking into account all necessary system restrictions (firm capacity requirements, spinning reserve, tertiary reserve, etc.)

Business case MENA: Jordan

Strongly required firm and flexible renewable power capacity

- CSP competitive in the peak and upper-mid merit segment in the short-term.
- CSP providing strongly required **firm and flexible** power capacity.
- Very limited availability of electricity storage and of other flexible and firm RES-E.
- PV and Wind power as cheap "**fuel saver**"
- In the medium-term CSP competitive in mid-merit and base load segment.
- CSP in long-term as back-bone of electricity supply.

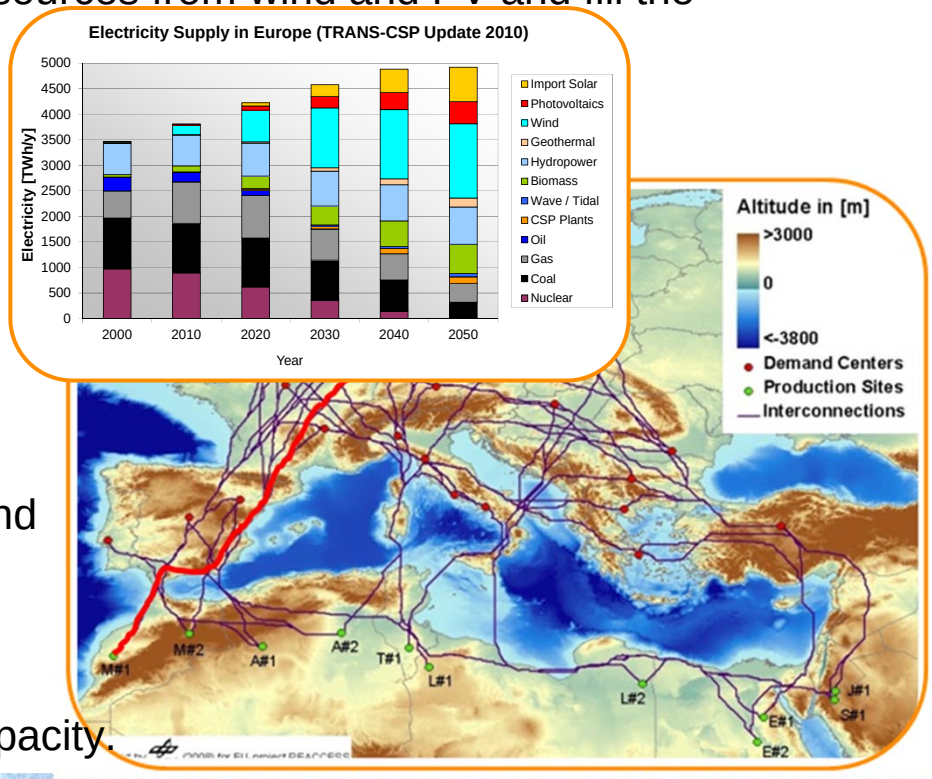


Source: Fichter (DLR) 2012, ReMix-MENA optimization tool

Flexible, High Value Solar Power for Export

Solar Electricity Imports from MENA to EU (DLR Concept)

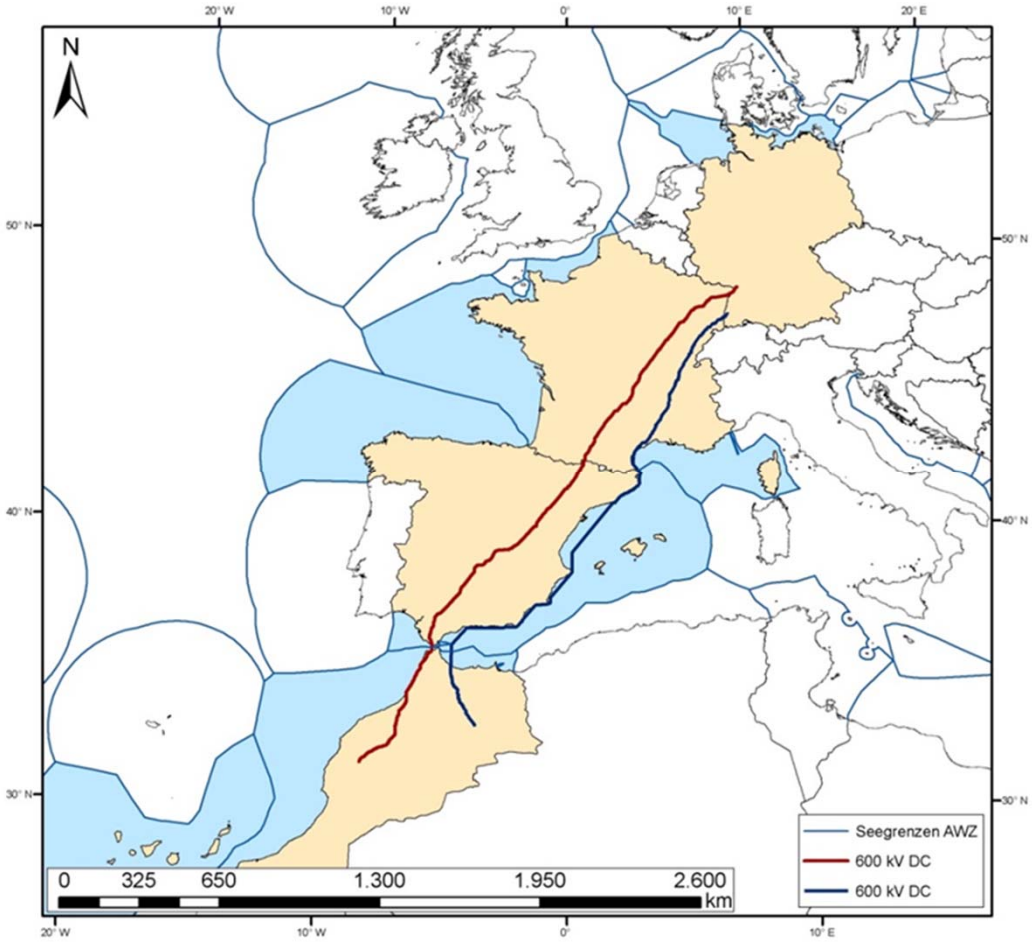
- Flexible solar power with firm capacity from CSP plants is transfered directly via point-to-point HVDC links from production sites in NA to European demand centers.
- CSP imports complement European sources from wind and PV and fill the remaining gaps.
- Export is not linked to or required for domestic demand in NA.
- Import capacity will always be lower than reserve capacity.
- About 40 HVDC links will provide 700 TWh/a (15% of demand) with 100 GW (7% of total) capacity.
- Point-to-point-links can be bundled and eventually interconnected to form a HVDC grid in the long term.
- CSP-HVDC links will reduce need for grid, storage and backup capacity.



Trieb et al., Energy Policy 42 (2012), 341–353.
doi:10.1016/j.enpol.2011.11.091

First model of CSP-HVDC link for Morocco and Germany

Length:	2300-2600 km
Capacity:	1500 MW_{net}
Transfer:	9.3 TWh/yr
Investment:	14-16 bn €
Cost:	12 €cent/kWh
Voltage:	±600 kV
Technology:	Trough/VSC
Land use CSP:	150 km²
Land use HVDC:	150 km²
Commissioning:	> 2025
Cooling:	dry
Water supply:	desalination
Project structure:	cooperative
Finance:	IIPPA
Economic Life:	40 yr



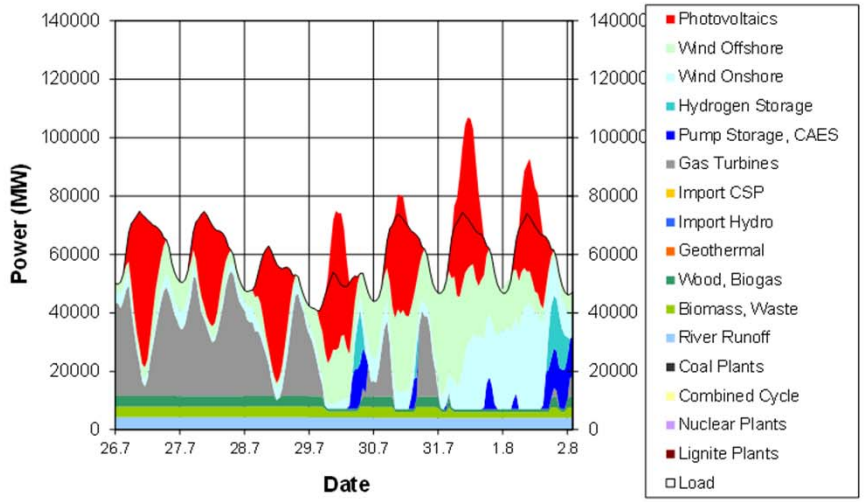
Role of CSP imports in Europe (without CSP imports)

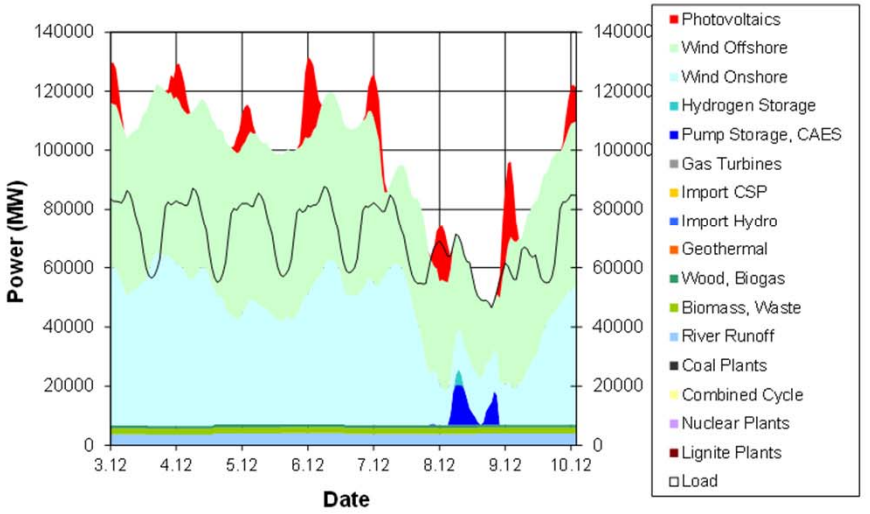
A 90% RES-E scenario for Germany without CSP imports:

375 GW + 40 GW NTC

+ 40 GW Storage

Energy source	Installed Capacity	Annual electricity yield	average utilization
	MW	TWh/a	h/a
Variable / renewable	235500	551.3	
Photovoltaics	100000	98.9	989
Wind Onshore	70000	156.4	2235
Wind Offshore	60000	257.7	4295
River Runoff	5500	38.2	6951
Flexible / renewable	8000	37.9	
Biomass, Waste	4000	22.1	5515
Wood, Biogas	4000	15.9	3964
Geothermal		0.0	0
Import Hydro		0.0	0
Import CSP		0.0	0
Fossile / Nuclear	90000	56.4	
Gas Turbines	90000	56.4	627
Coal Plants	0	0.0	0
Combined Cycle	0	0.0	0
Nuclear Plants	0	0.0	0
Lignite Plants	0	0.0	0
Storage and net transfer	80000	48.7	
Pump Storage, CAES	20000	15.7	785
Hydrogen Storage	20000	13.8	688
H2-Storage Capacity (days)	1		
Net Transfer Capacity (NTC)	40000	19.3	482
Total power park	**373500**	**579**	**1551**



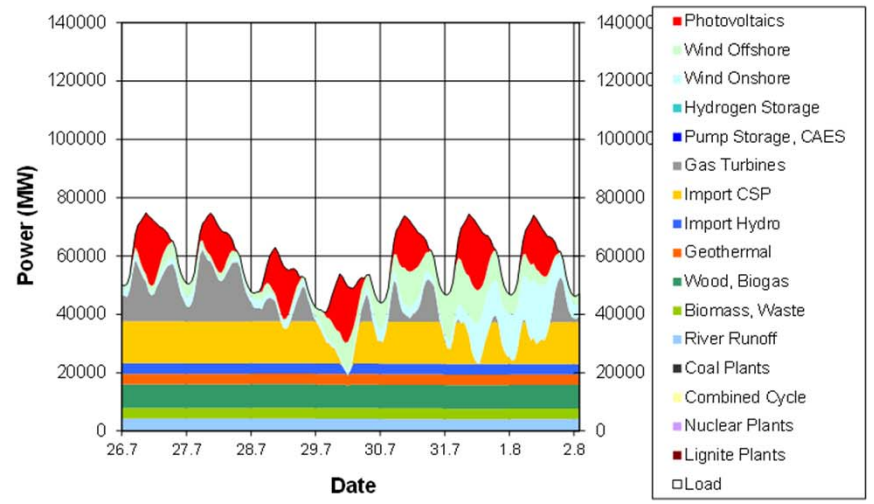


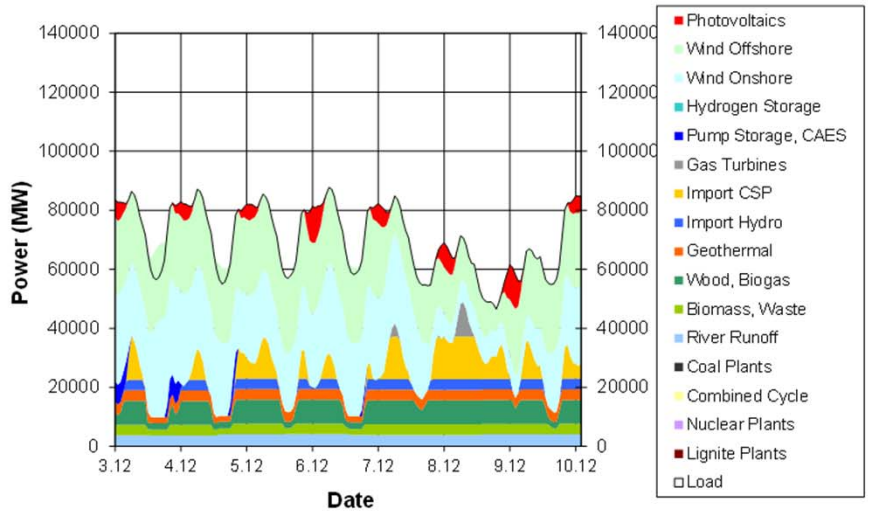
Role of CSP imports in Europe (with CSP import)

A 90% RES-E scenario for Germany with CSP imports:

225 GW + 8 GW NTC + 20 GW HVDC + 8 GW Storage

Energy source	Installed Capacity	Annual electricity yield	average utilization
	MW	TWh/a	h/a
Variable / renewable	117500	288.1	
Photovoltaics	45000	44.5	989
Wind Onshore	40000	89.4	2235
Wind Offshore	27000	116.0	4295
River Runoff	5500	38.2	6951
Flexible / renewable	35000	220.2	
Biomass, Waste	4000	30.0	7502
Wood, Biogas	7000	49.8	7112
Geothermal	4000	30.2	7547
Import Hydro	4000	25.8	6462
Import CSP	16000	84.3	5271
Fossile / Nuclear	65000	54.4	
Gas Turbines	65000	54.4	837
Coal Plants	0	0.0	0
Combined Cycle	0	0.0	0
Nuclear Plants	0	0.0	0
Lignite Plants	0	0.0	0
Storage and net transfer	16000	3.1	
Pump Storage, CAES	7500	1.9	255
Hydrogen Storage	0	0.0	0
H2-Storage Capacity (days)	0		
Net Transfer Capacity (NTC)	8500	1.1	135
Total power park	**225000**	**561**	**2494**





ready in 2020

takes 5 years in China

Role of RES-E imports in Europe

CSP imports from NA to Germany via HVDC links will lead to:

- 150 GW less power plants for the German “Energiewende”
- 5 times less grid capacity (no significant expansion)
- 5 times less power storage (no significant expansion)
- 90% RES-E can be achieved much faster and with much less effort
- Allows every European country to follow a similar strategy without creating external costs by RES-E surplus and gaps to be balanced by neighbors

Alternative:

Surplus (??) from Moroccan wind power and PV (??) exported to Europe through the AC grid of Andalucia (??)

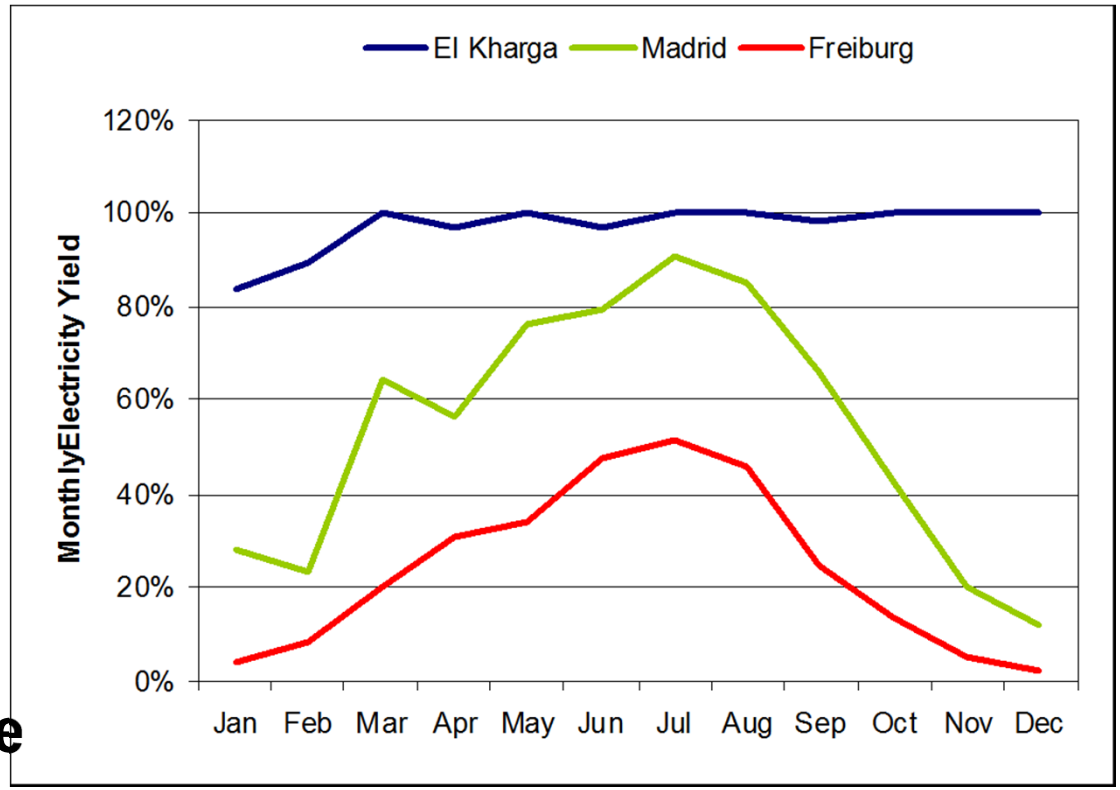
Why CSP imports from North Africa and Middle East?

- more sunny days
- better incidence angle

➔

- lower seasonal variation of electricity yield

➢ **better availability of firm and flexible power**



Relative monthly electricity yield of a CSP plant with large solar field and storage (SM 4)

Solar Power & Desalination Plants

- Energy,
- Water,
- Food,
- Labor and Income

for further 300 Million people in MENA

(artist view created with Google Earth)

Former projects related to the topics

- **MENA Regional Water Outlook** – CSP for Seawater Desalination in the Middle East and North Africa, World Bank (2012), www.dlr.de/tt/menawater
- **REACCESS** - Risk of Energy Availability: Common Corridors for European Supply Security, European Commission (2011), http://reaccess.epu.ntua.gr/
- **AQUA-CSP** - Concentrating Solar Power for Seawater Desalination, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2007), www.dlr.de/tt/aqua-csp
- **TRANS-CSP** - Trans-Mediterranean Interconnection for Concentrating Solar Power, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2006), www.dlr.de/tt/trans-csp
- **MED-CSP** - Concentrating Solar Power for the Mediterranean Region, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2005), www.dlr.de/tt/med-csp

Ongoing projects related to the topics

- **BETTER** - Bringing Europe and Third Countries closer together through renewable energies, Intelligent Energy Europe. Develop concrete action recommendations for projects within the 4th cooperation mechanism related to Art.9, EU RES Directive 2009. Case studies for Balkan, Turkey and North Africa for regional RES-E deployment and solar electricity exports to Europe. First draft of HVDC link between Morocco and Baden-Württemberg. Moroccan stakeholders named above are contacted for input data and peer review of results. North Africa case study lead by DLR (2012-2015).
- **SolarMedAtlas -** Mediterranean Solar Energy Atlas provided by the International Climate Initiative (IKI) project lead by DLR. Development of an internet based interactive service for solar energy resource information for Mediterranean countries from Morocco to Turkey (2010-2012).
- **REMix-CEM** - Renewable Energy Mix Capacity Expansion Model, mixed integer linear optimization model taking into account technical (start-up losses, transients, efficiency in part-load, etc.) and economic (merit order, marginal cost, fuel cost, investment, etc.) characteristics of every single power plant of a national power supply system to identify market niches for RES-E introduction that do not require subsidy and reduce the average electricity cost. First time applied to Jordan. DLR internal project (2011-2013).
- **SynKWS** - Synthetic Liquid Hydrocarbons for the storage and transport of renewable energy. Project of the Helmholtz Society (2012-2015).
- **QatDLR** – Innovative energy supply for the Arabian Peninsula. Project sponsored by the German Federal Ministry for Economy and Technology (2012-2014).

Selected publications

- MED-CSP www.dlr.de/tt/med-csp
- TRANS-CSP www.dlr.de/tt/trans-csp
- AQUA-CSP www.dlr.de/tt/aqua-csp
- MED-CSD www.med-csd-ec.eu/eng/
- MENA Regional Water Outlook www.dlr.de/tt/menawater
- Financing concentrating solar power in the Middle East and North Africa – Subsidy or investments? Energy Policy 39 (2011) 307-317 http://dx.doi.org/10.1016/j.enpol.2010.09.045
- Solar electricity imports from Middle East and North Africa to Europe Energy Policy 42 (2012) 341-353 http://dx.doi.org/10.1016/j.enpol.2011.11.091

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