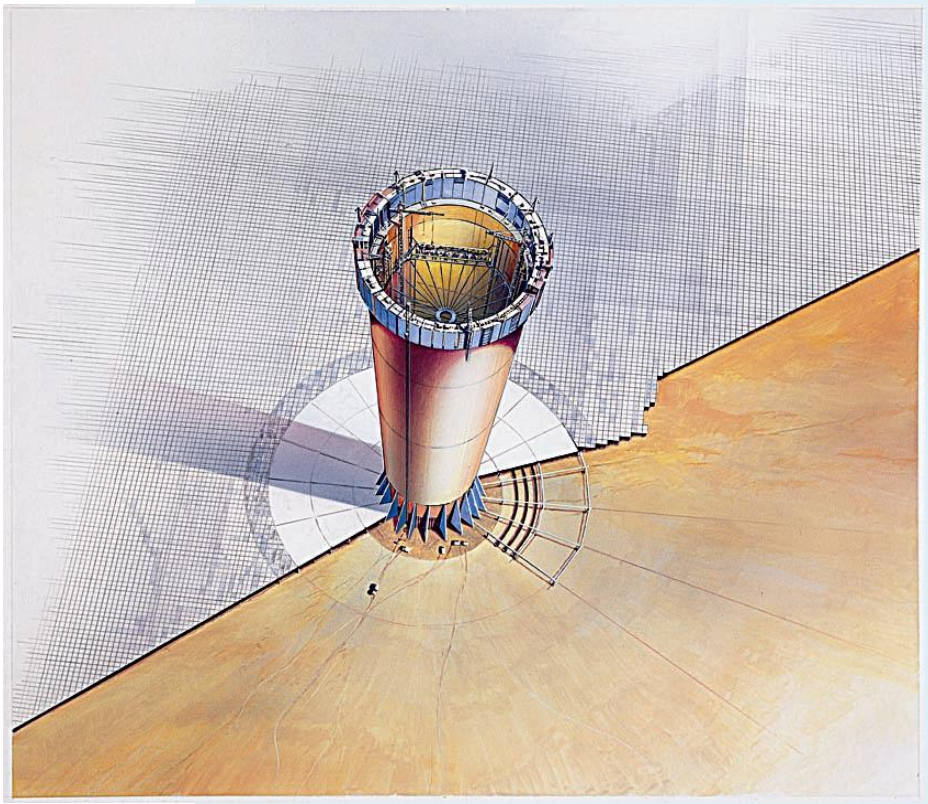
Solar Millennium


# Solar Thermal Power Plants



**408. Heraeus-Seminar „Energy Supply and Climate Change“**

*Dr. Henner Gladen, Lars Schnatbaum-Laumann, May 2008*

# Content

- Portrait of the Solar Millennium AG
- Potential of solar energy
- Parabolic-trough power plants
- Firm capacity and power generation on demand
- Solar chimney power plants
- Market development
- Import of solar power from north africa
- Cost of concentrating solar power – an example

# Portrait of the Solar Millennium AG

- Founded: 1998
- Headquarter: Erlangen, Germany
- Offices: Erlangen, Köln, Essen, Madrid (Spa.), Almeria (Spa.), Aldeire (Spa.), Berkeley (USA) …
- Sector: Renewable energies (large scale solar power plants, 50-250MW)
- Number of employees:

  Approx. 120 equivalent full-time
- Board members:

  Christian Beltle (Chairman)

  Dr. Henner Gladen

  Thomas Mayer
- Supervisory board:

  Helmut Pflaumer (Chairman)

  Hannes Kuhn

  Prof. Dr. Michael Fischer

# Business Model

## Solar Millennium AG

| Project-development | Project-financing | Technology | Power Plant Construction | Power Plant Investment |
|---|---|---|---|---|
| Site selection and qualification<br>Permission process<br>Real estate procurement | Financing of power plant projects<br>Sales of power plant investments | Technology provider throughout the planning and construction phases of solar power plants | Construction of solar thermal power plants | Minority holdings in power plant companies |

# Specialist for Solar Thermal Power Plants

## We're developing the future!

Solar Millennium AG

... is a successful pioneer thanks to the early entry into the market (1998)

... developed the first parabolic trough power plants in Europe

... is a technological leader in parabolic trough power plants

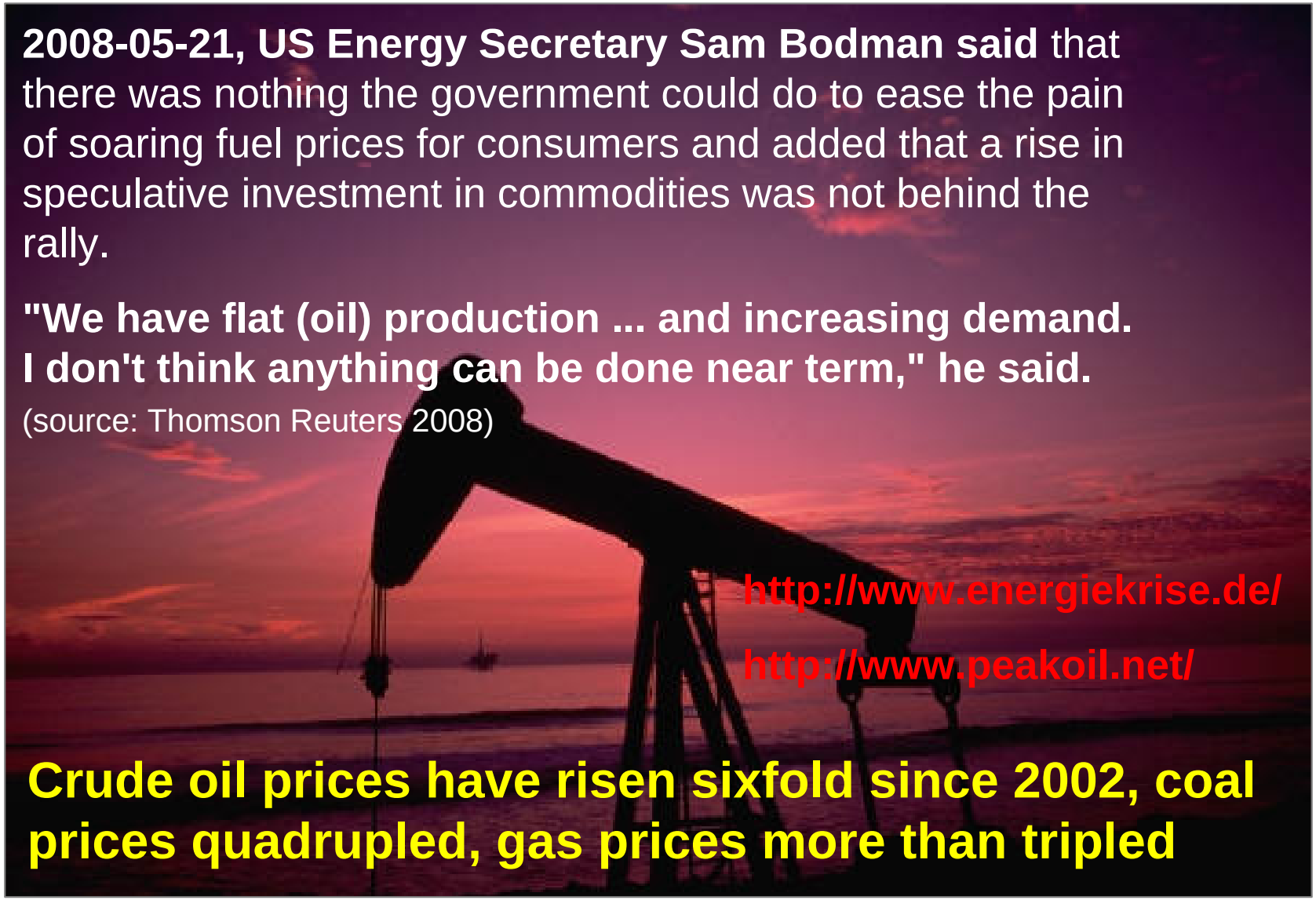
… enabled the first project-specific financing of solar-thermal power plants

… has strong growth due to flexible cooperation in the corresponding business sectors

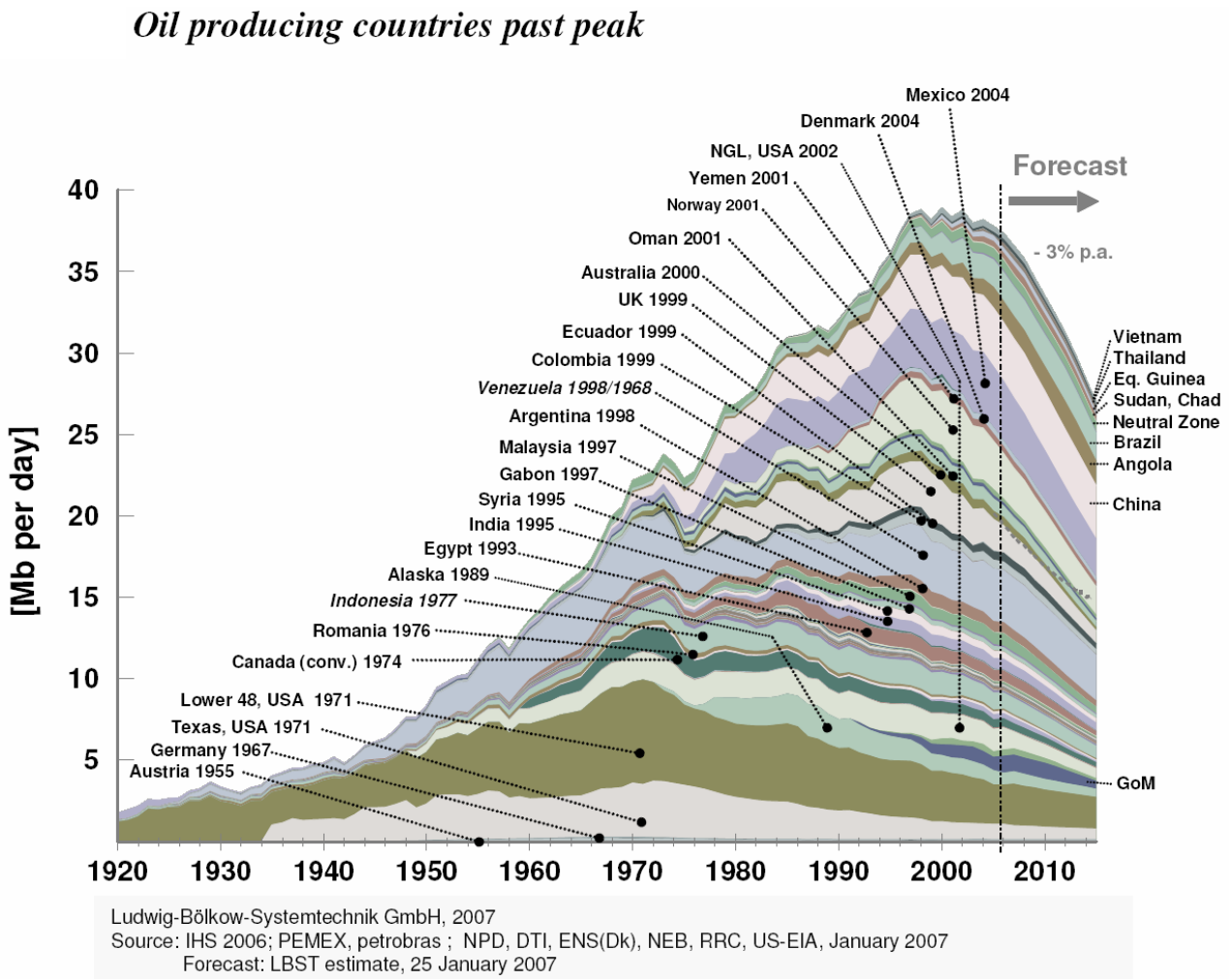
… is supplying the technology for Egypt's first parabolic trough solar field

… is developing a multitude of new projects worldwide

# Fossil fuel based economy comes to its limits as environmental damages increase and prices are out of control



# Most oil producing countries outside OPEC are past peak production




U. S. oil magnate T. Boone Pickens, who chairs the hedge fund BP Capital Management, projected that light crude will reach US$150 a barrel this year as demand outstrips supply.

(source: www.financialpost.com, 2008-05-21)

**More information @ http://www.energywatchgroup.org**

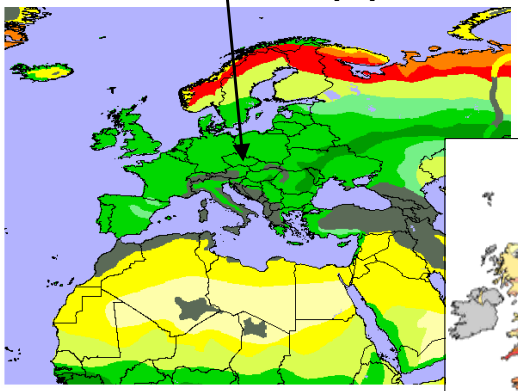
# Solar Energy is inexhaustible . . .

The yearly irradiation on earth amounts to 1.080.000.000 terawatthours – 60,000-times the global power demand.

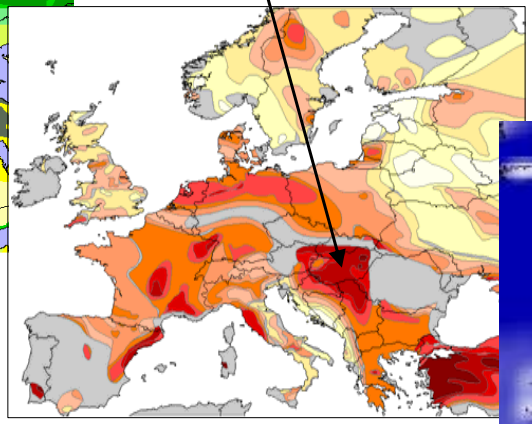
# … yields the highest energy density of renewables …

Biomass (1)

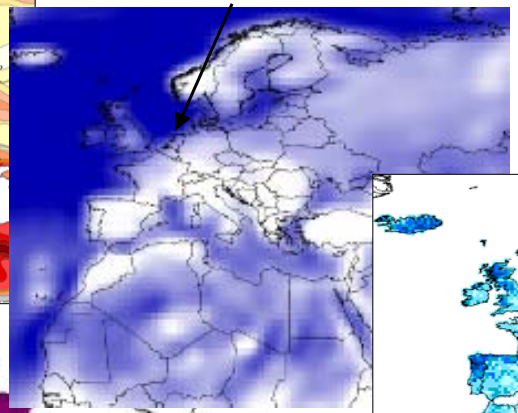
in brackets: (typical yield in $GWh_{el}/km^2/y$)



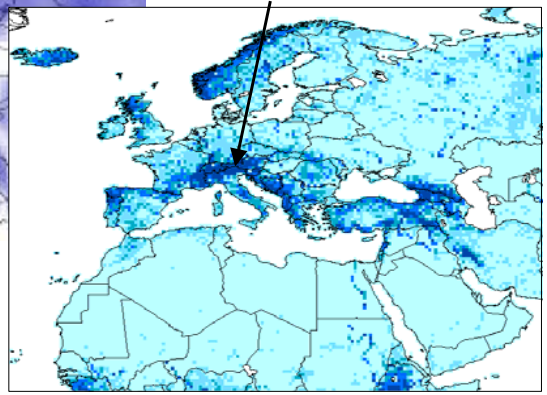
Geothermal (1)

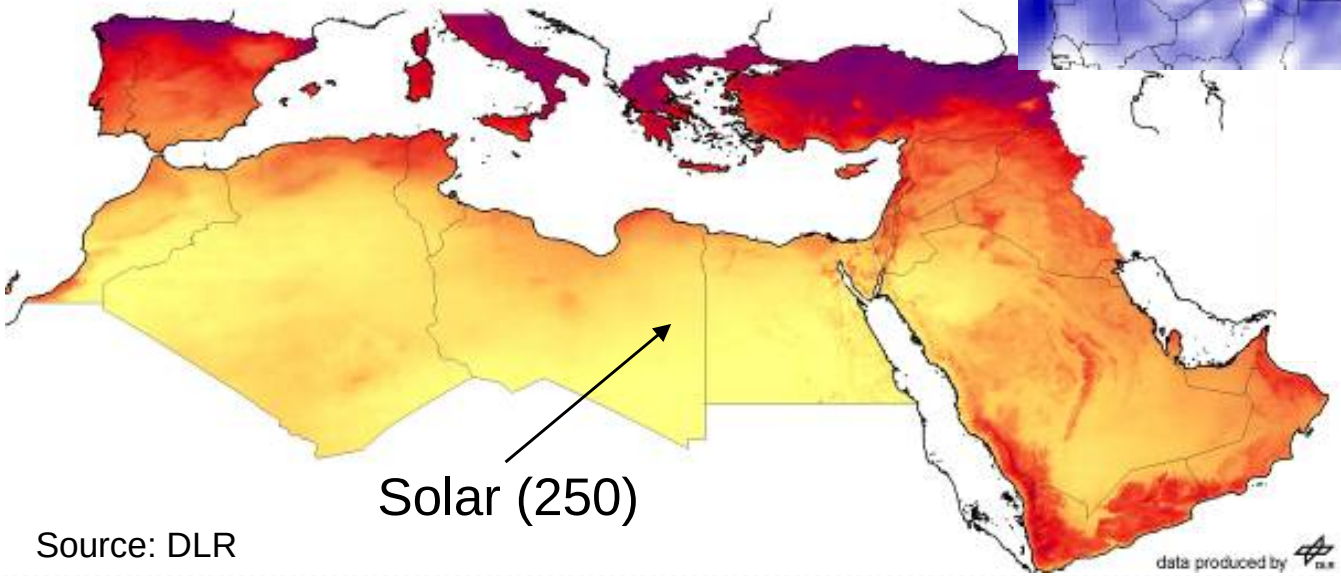


Wind (30)



Hydro (30)



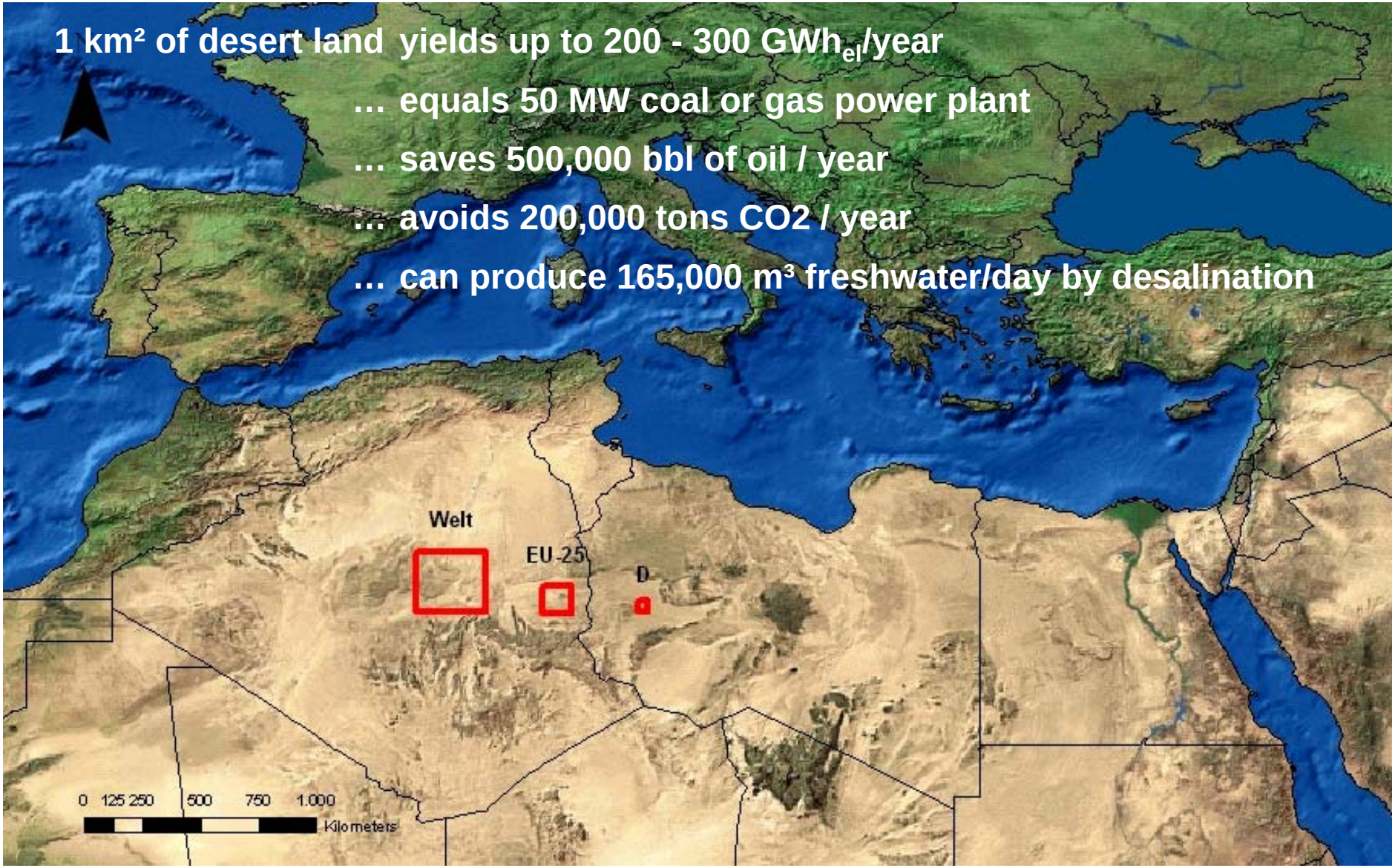



Solar (250)

Source: DLR

Every 10 km² in MENA yield 15 million barrels of fuel oil per year in form of solar energy

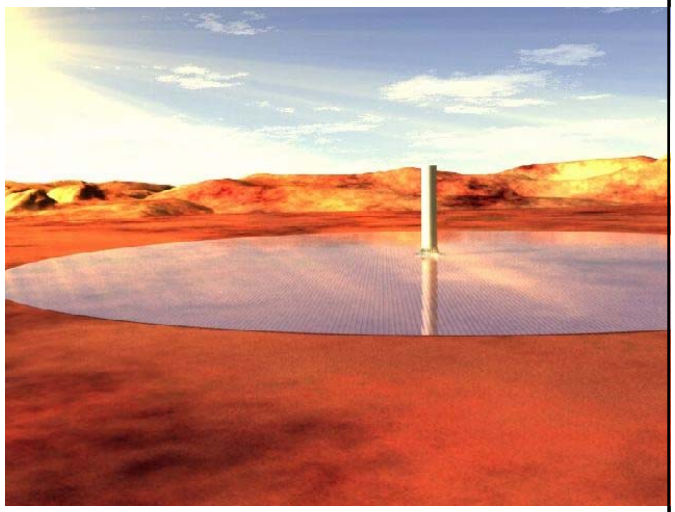
# … potential sites are abundant



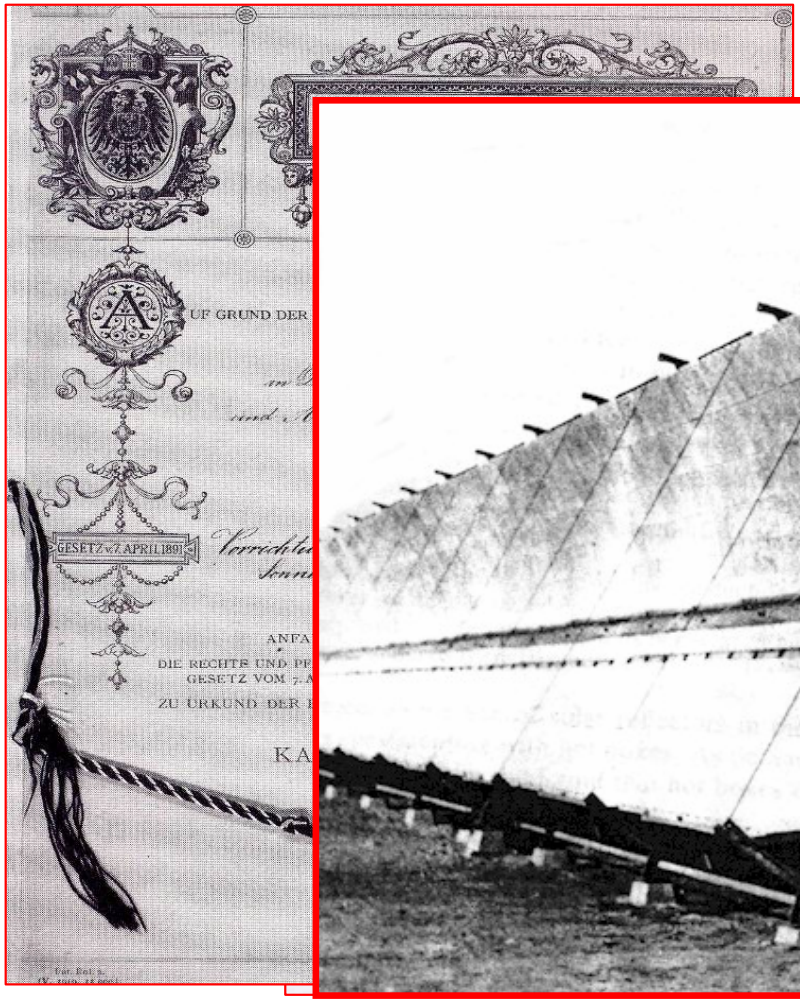

Source: DLR

# Solar Thermal Power Plants …

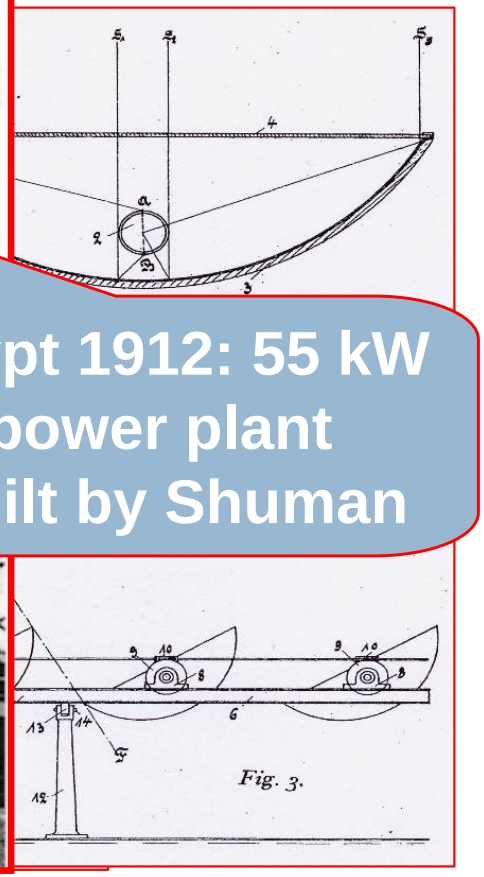
- utilize simple physical principles
- convert solar irradiation into heat and generate power with a conventional water/steam cycle
- allow large scale, climate friendly power generation: Power plants with 50 to 250 MW
- are located in the „sunbelt of the earth“
- is a collective term for different technologies; Solar Millennium AG focuses on parabolic trough power plants and solar chimney power plants



# History of the parabolic-trough power plants






**Egypt 1912: 55 kW power plant built by Shuman**

# California in the 1980's

**High oil prices triggered a boom for renewable energies.**

**Solar thermal power plants provide firm capacity during times of peak demand**

## Construction of SEGS* I - IX

- **9 power plants with 354 MWe**
- **1.2 Bill. US$ investment**
- **13 TWh power generation**
- **Revenues to date: 2.3 Bill. US$**

* SEGS = Solar Electricity Generation System

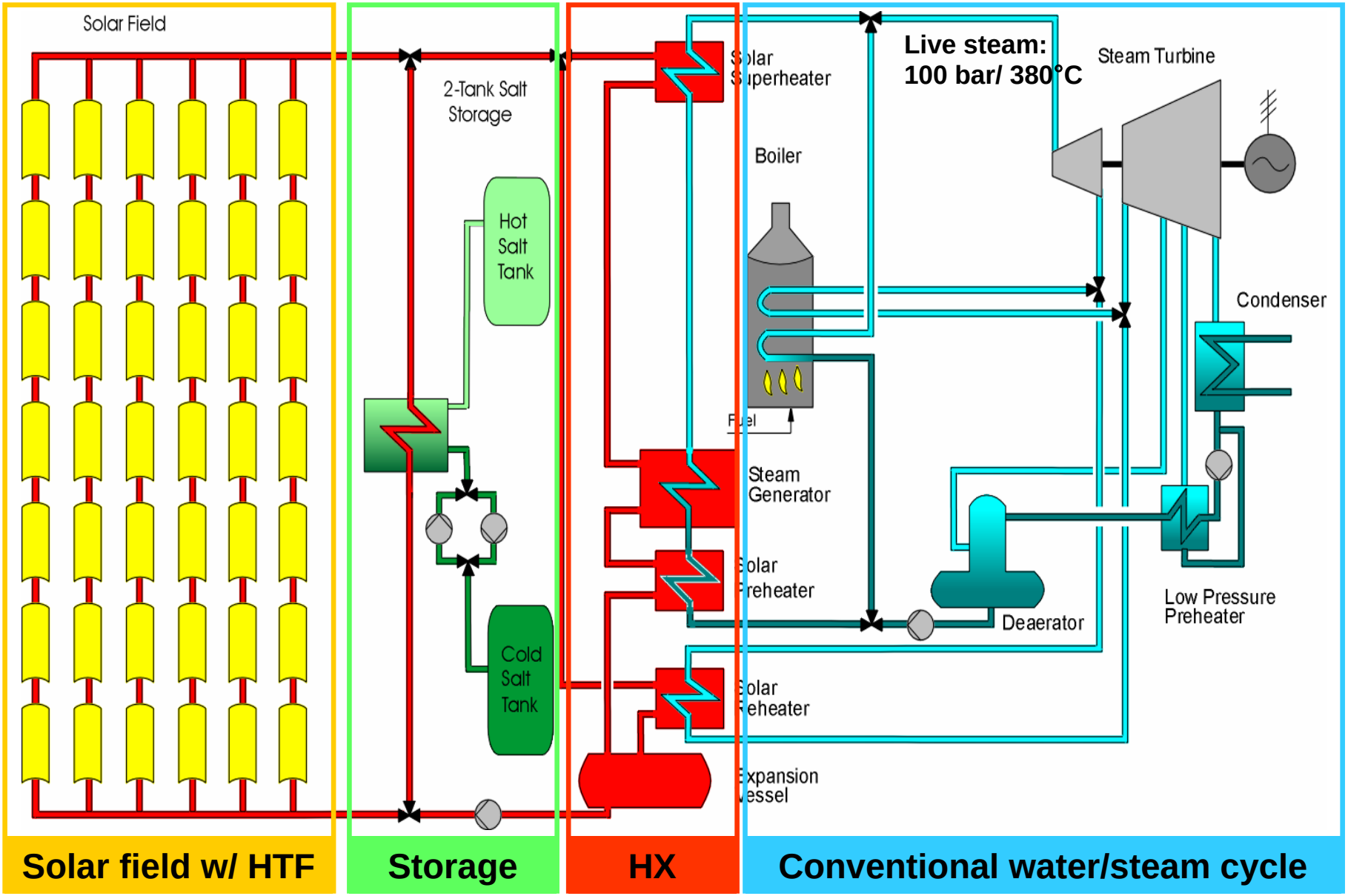
# Parabolic-trough power plants are a mature technology

- Solar irradiation is concentrated 70-80 times on a receiver tube, which is situated in the focal line of a parabolic-trough mirror; the heat is picked up by a thermo oil, flowing inside the tubes, and transferred to a conventional water/steam cycle with a steam turbine and generator set.

- Operation is possible in solar-only or hybrid mode (w/ natural gas co-firing)

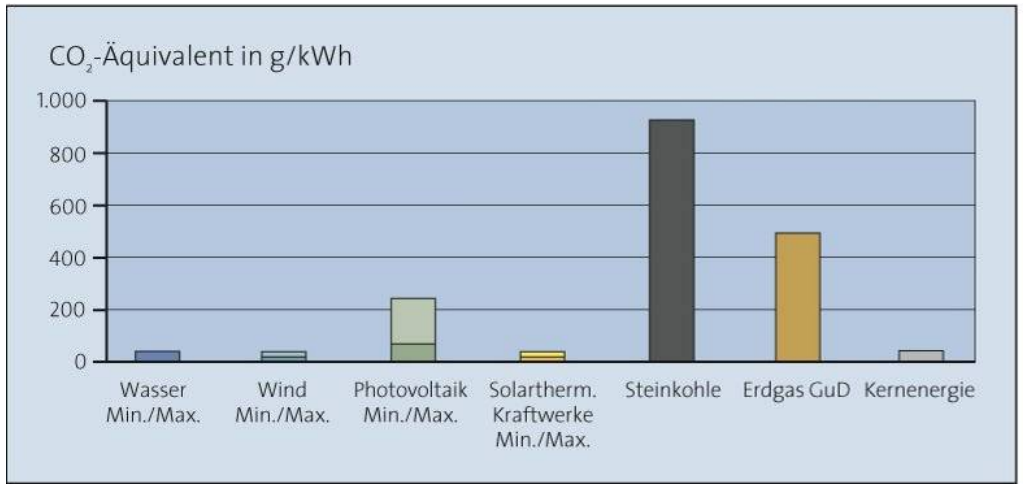
- Power generation is possible on demand; thermal storage and natural gas co-firing allow power generation independent from actual solar irradiation

# Process diagram of a parabolic-trough power plant with molten salt storage and natural gas co-firing



# Low $CO_2$-emissions and short energy payback periods

## Greenhouse gas emissions (BMU 2002)




## Energy Payback Period

- → Solartherm. power plants: app. 5 month
- → Windmills: 4 - 7 month
- → PV in middle europe: 2 - 5 years

Uranium, natural gas, coal, oil: never

**$CO_2$-Reduction of an Andasol-type power plant compared to a modern hard coal power plant: 149.000 $t_{CO2}$/y**

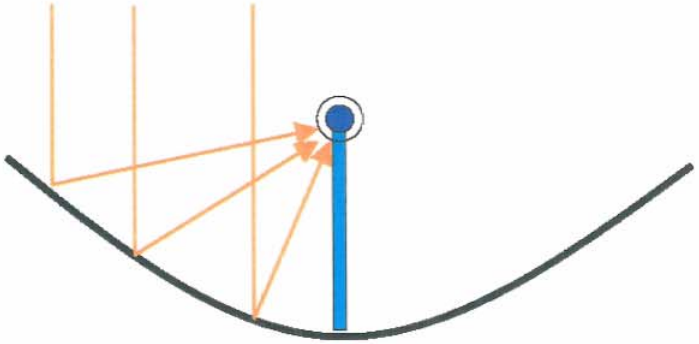
# New developments – improved receivers by Schott Solar

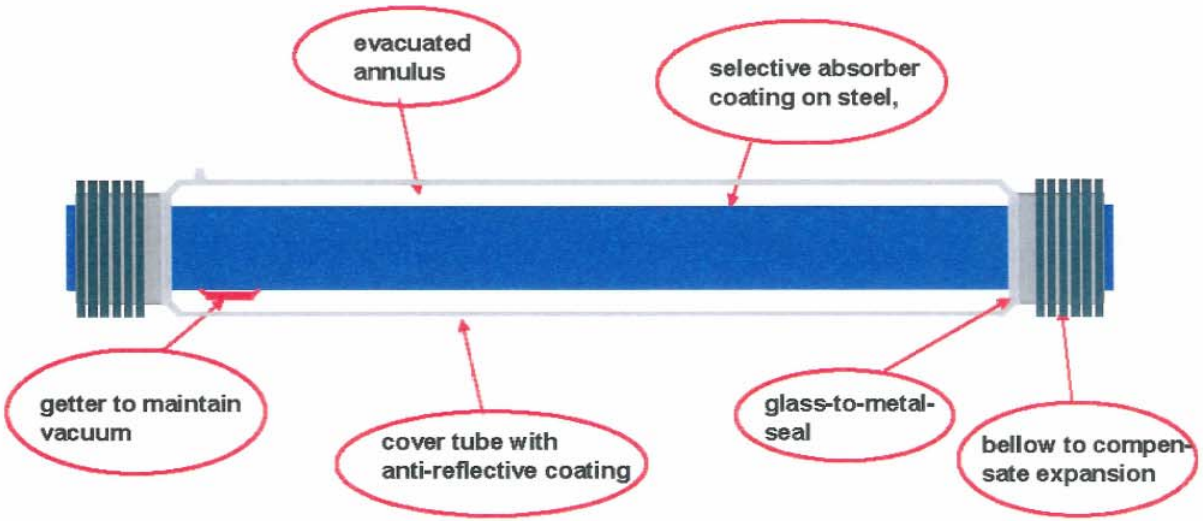
SCHOTT | Business Unit Solar Thermal

## Receiver is the Key Component in Parabolic Trough Collectors

The receiver achieves high efficiency with

- low thermal losses
  (→ vacuum, absorber with low thermal emittance)
- high solar absorptance
  (→ efficient absorber, highly transmittent cover )
- minimum of shading
  (→ short bellows)

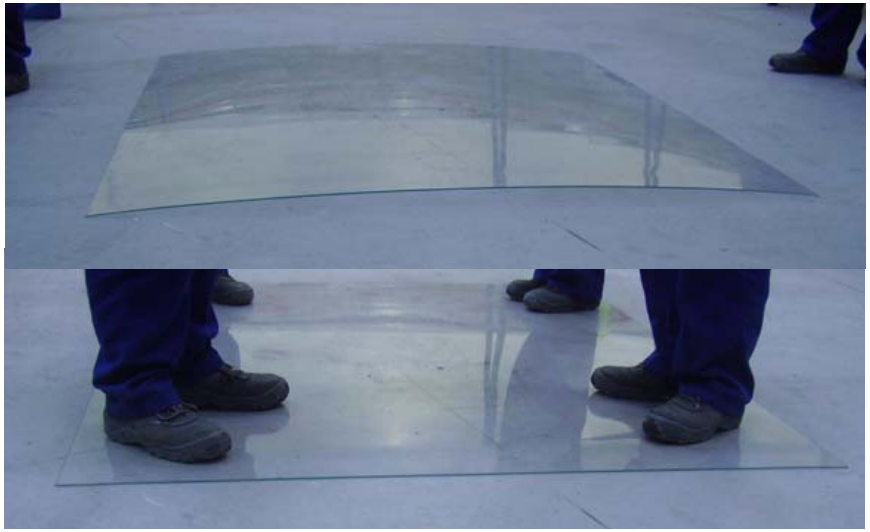




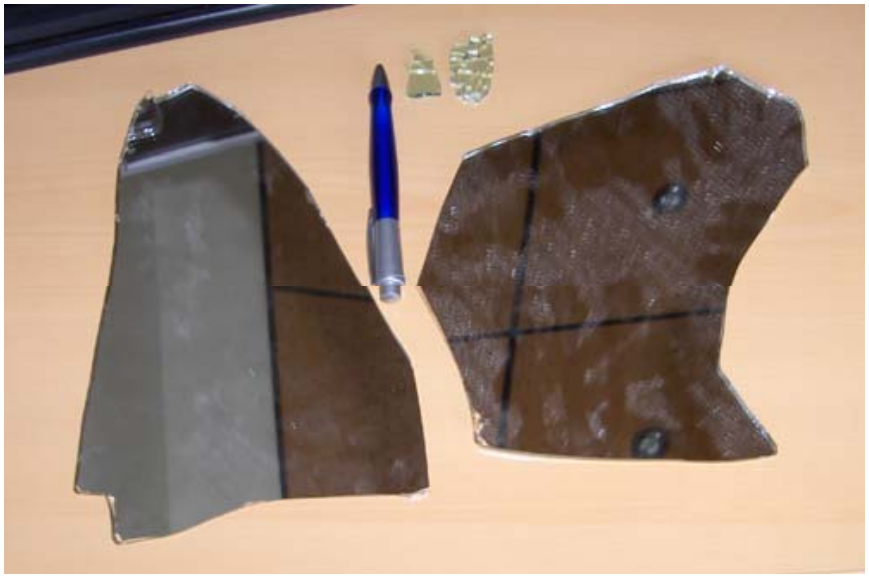

Jan 10, 2007
SHE/Bz

SCHOTT
glass made of ideas

# Enhanced mirrors by Rioglass Solar



**Advantages of tempered glass:**
**Higher strength and smaller splitters**



## Development targets for mirrors

- → Improve back side reflectivity, reduce front side reflectivity
- → Reduce absorption
- → Decrease energy consumption and cost of bending process
- → Increase mechanical strength
- → Implement cost effective mass production

# Current and advanced thermal storage technologies

## Andasol 1-3, molten salt storage

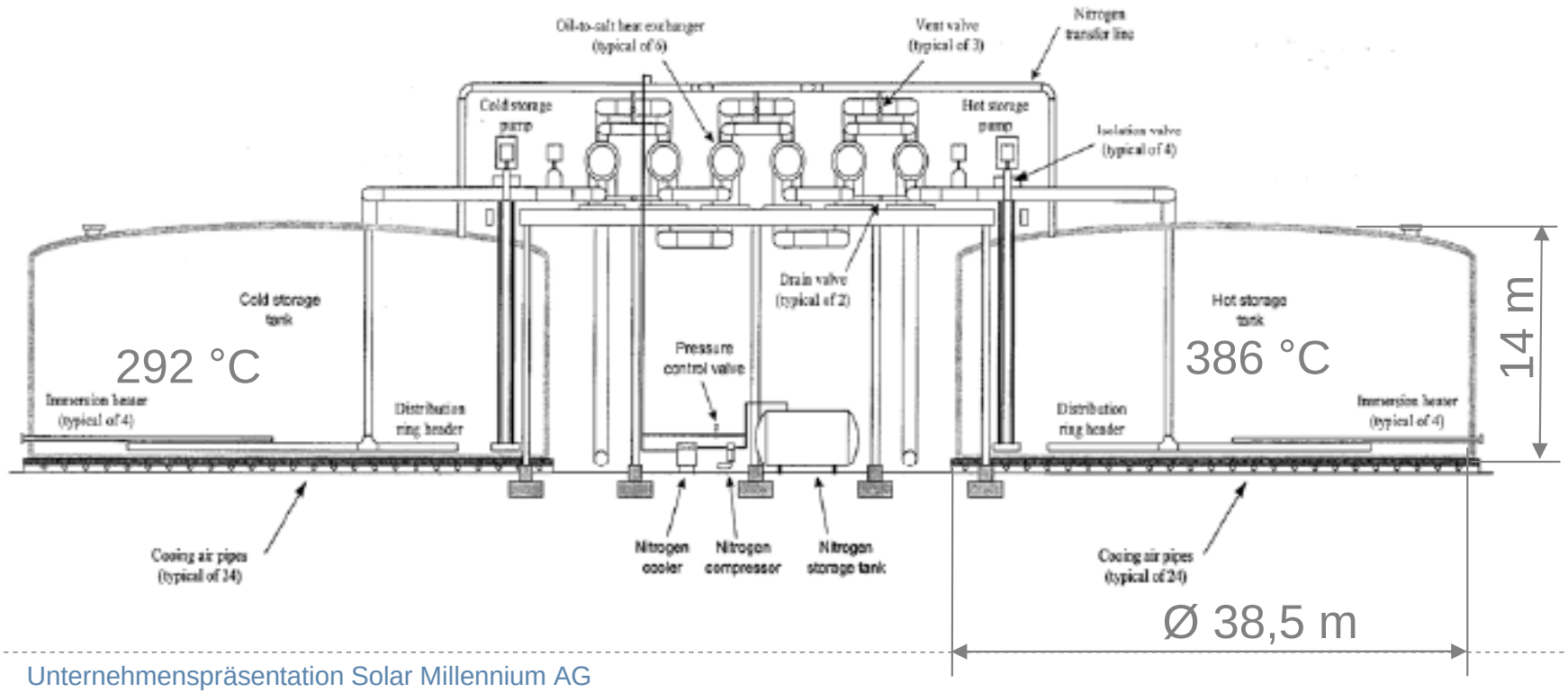
- Storage capacity 1010 MWh (7.7h)
- Nitrate salts (60% NaNO3 + 40% KNO3)
- Salt inventory 28.500 t
- Tank volume 14.000 m³
- 6 HTF/salt heat exchangers

## Selection of R&D projects (DLR)

→ Demonstrate pilot scale concrete storage

→ Further development of phase change material storage

→ Solid media storage for Solar Tower with Air Receiver



# Plant concepts currently in development

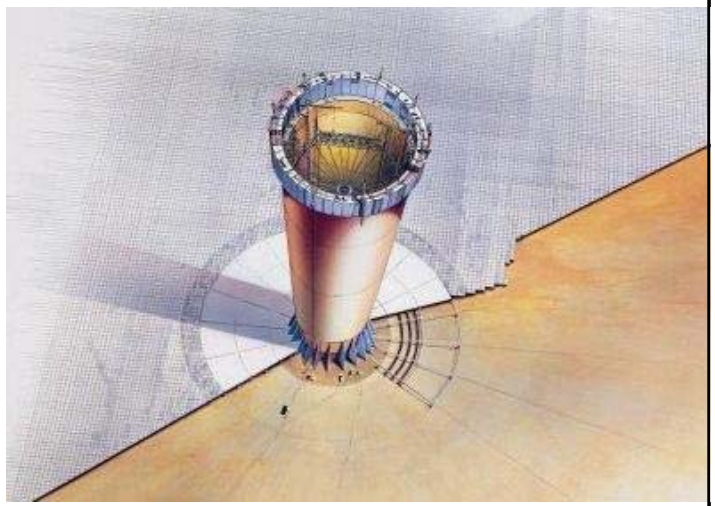
- Solar tower with direct steam generation (PS10/20, DPT550)
- Solar tower with molten salt (Solar tres)
- Solar tower with hot air and conventional boiler (STJ)
- Solar tower with gas turbine
- Parabolic trough with direct steam generation
- Parabolic trough with molten salt
- Parabolic trough with air
- Direct steam generation with Fresnel concentrator

# Research and Development

- **Parabolic Trough Power Plant**
  - Higher efficiency (e.g. direct steam generation)
  - More potential sites (e.g. dry cooling)
  - Expansion of the field of applications (e.g. desalination)

- **Biogas**

  e.g. as a technology for hybrid power plants in combination with parabolic trough plants



- **Solar Chimney Power Plant**

  as an alternative solar thermal power plant technology

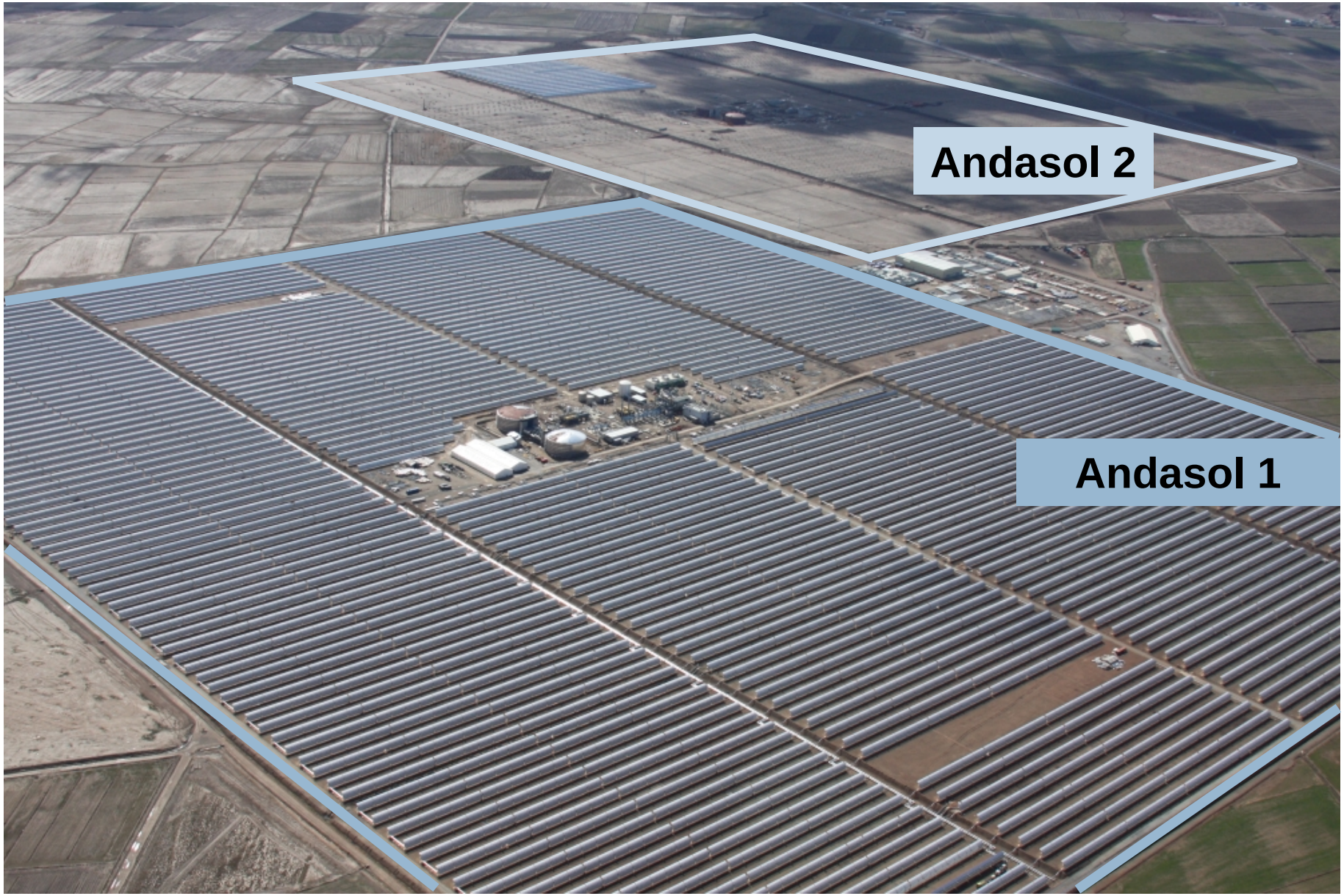
# Andasol 1-3: Largest site for solar power generation in the world


**Owing to the Andasol projects, Solar Millennium AG won the Energy Globe World Award 2008 in the category „fire“.**


- 3x 50 MW
- app. 471.000 MWh/y
- app. 447.000 t/a $CO_2$-Reduction
- 7.5 h thermal storage

# Parabolic-trough solar power plant Andasol 1

# Andasol movie



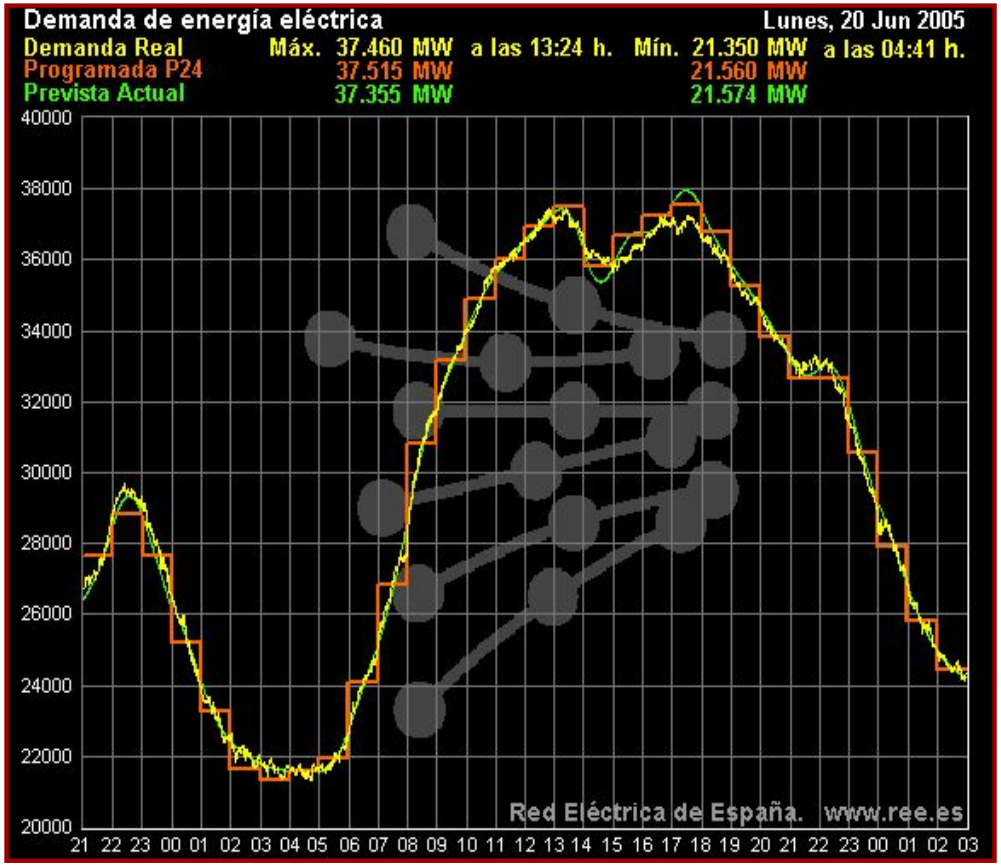
# Characteristic data of Andasol 1-3

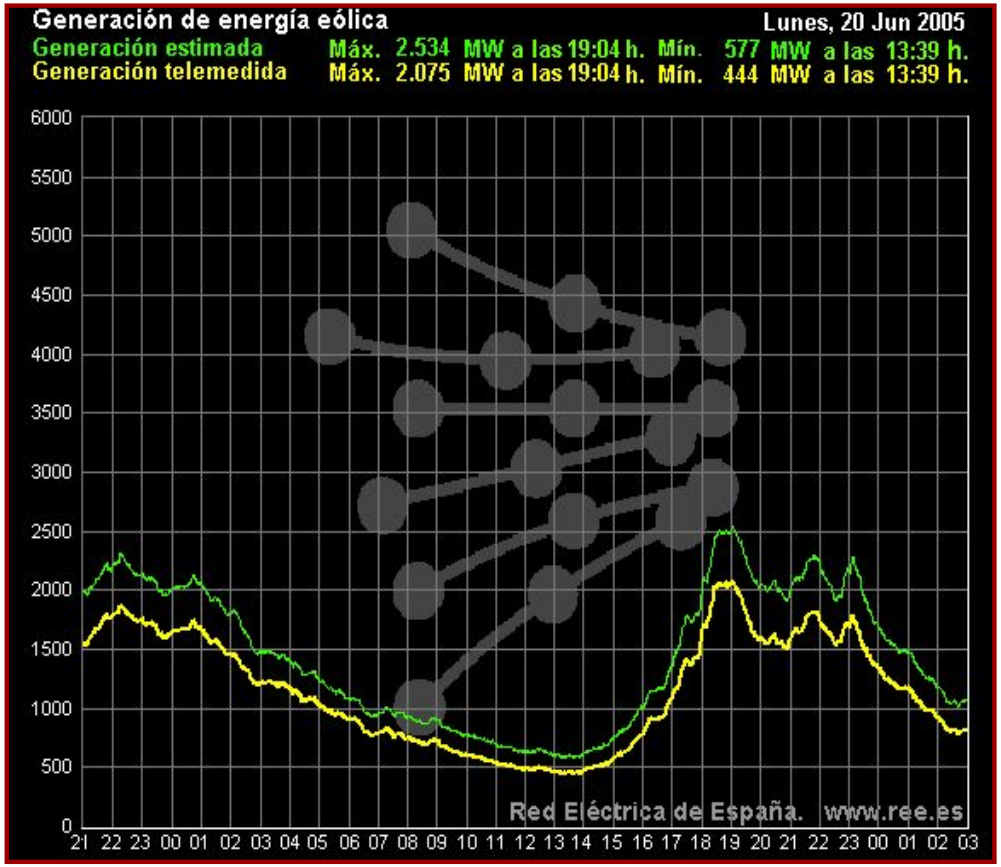
per power plant:

- 512.000 $m^2$ collector area (= 70 soccer fields)
- Thermal storage for 7.5 baseload hours almost doubles power generation of each plant – about 180 GWh (gross) per year
- Water/steam cycle with 50 MW steam turbine and wet cooling towers
- 149.000 to/y $CO_2$-reduction compared to a modern hard coal power plant
- about 300 Mio. Euro investment

# W/o large storage facilities for electricity, power generation needs to match power demand

## Spain: Demand and power generation by windmills on a summer day

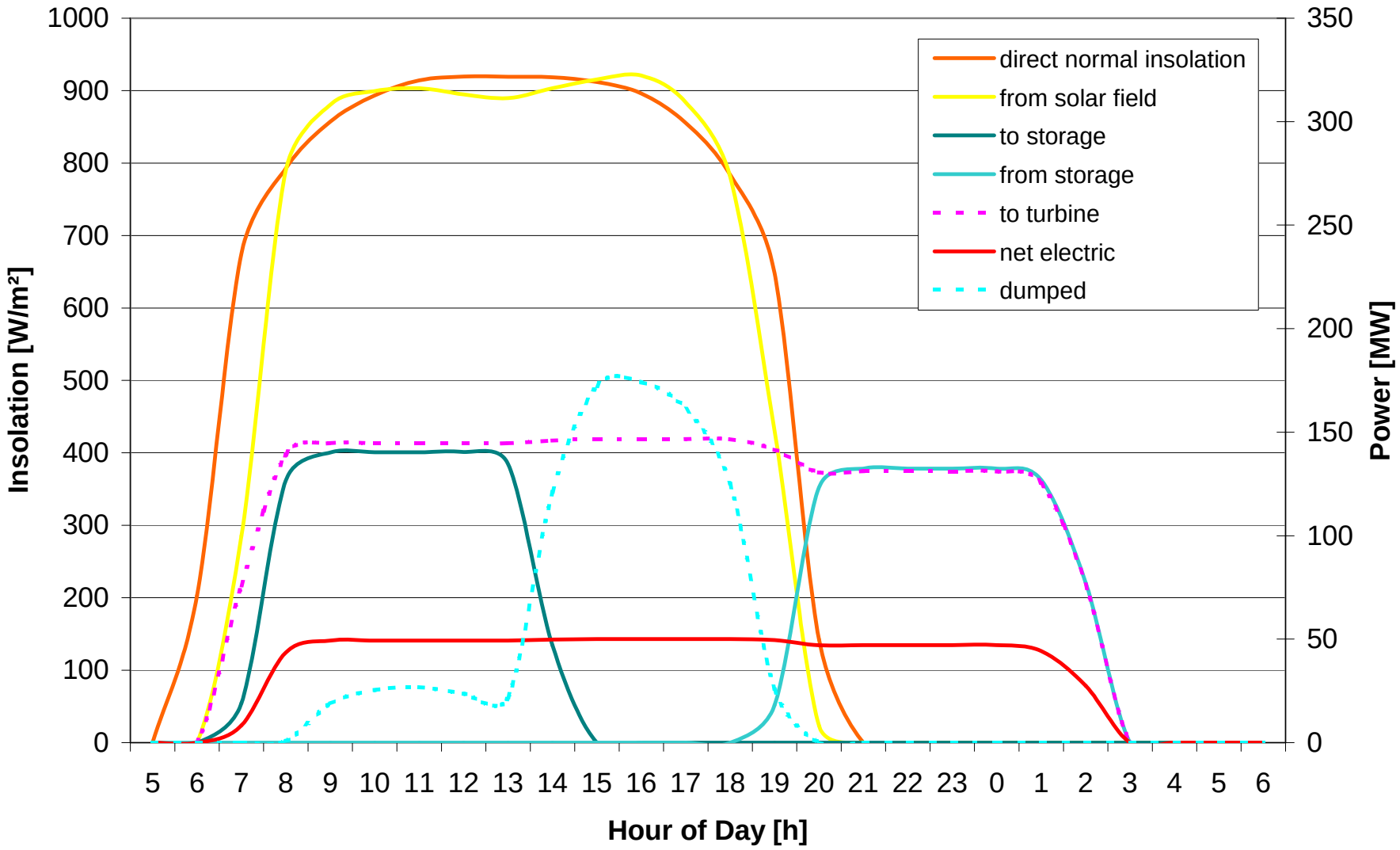


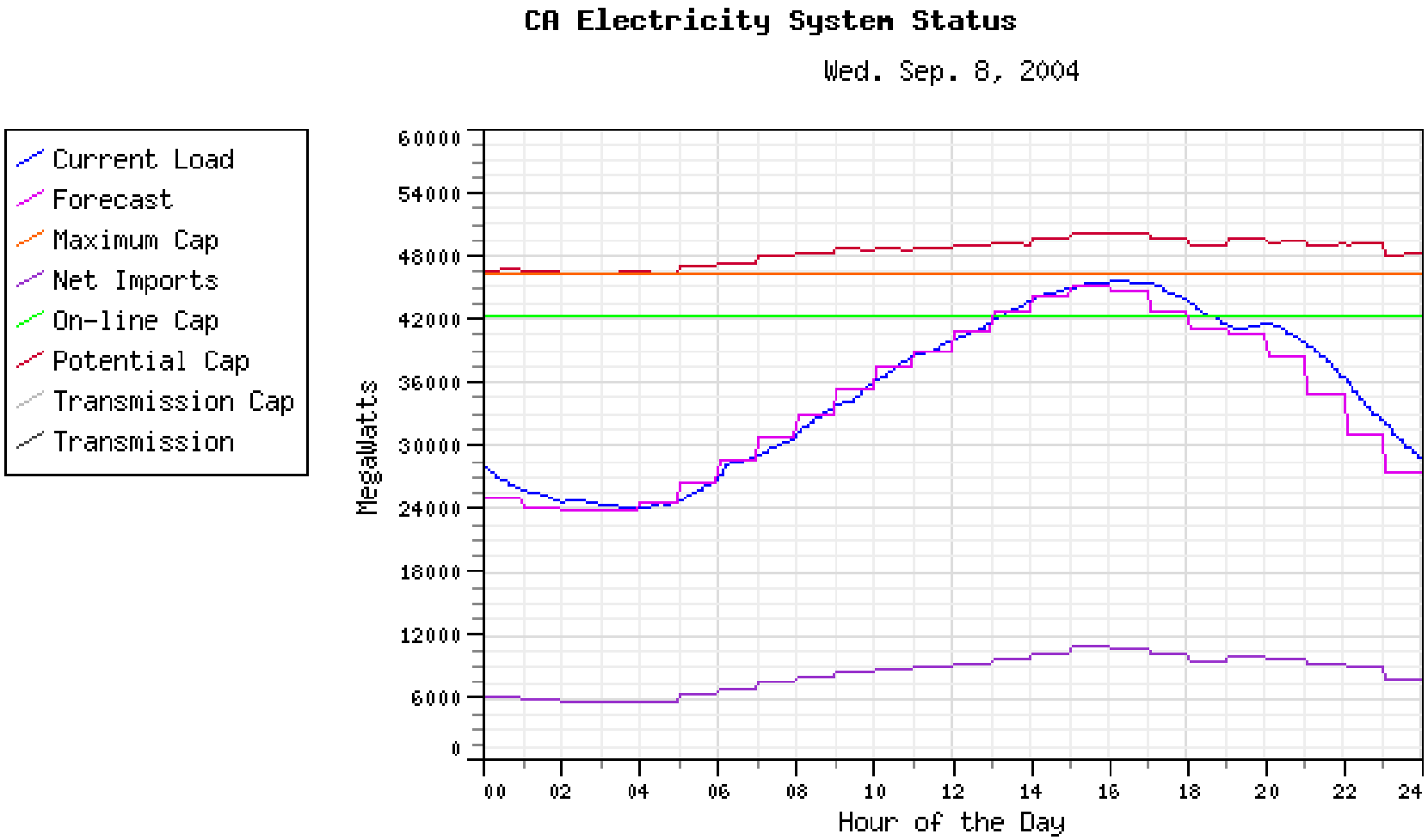

High peak load during daytime (Δ ~ 16.000 MW)

Feed-in by windmills mainly during night times

# Andasol, operation w/ 7.5h thermal storage

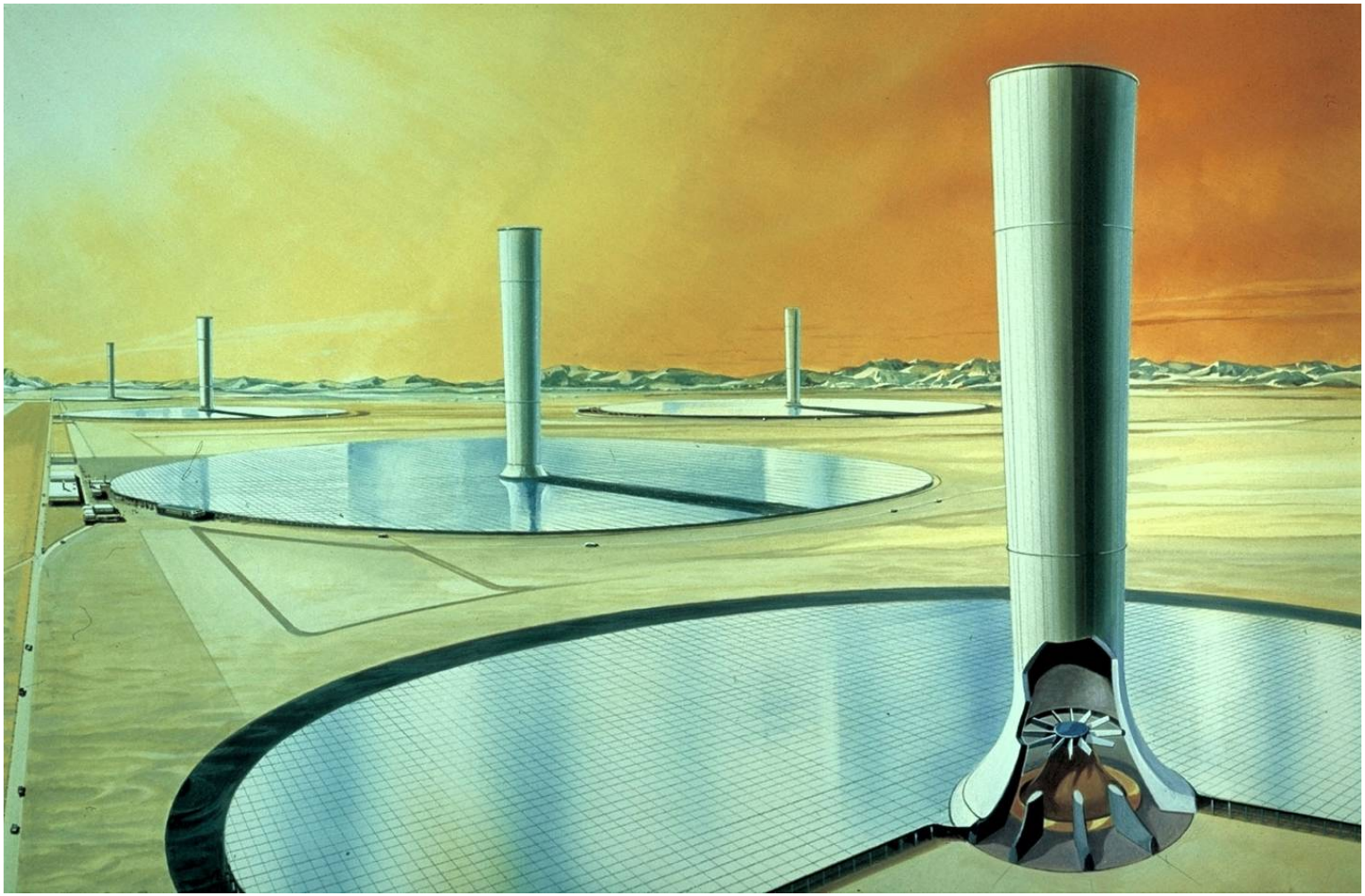


# Windpower is a fuel-safer but not firmly available during times of system peak

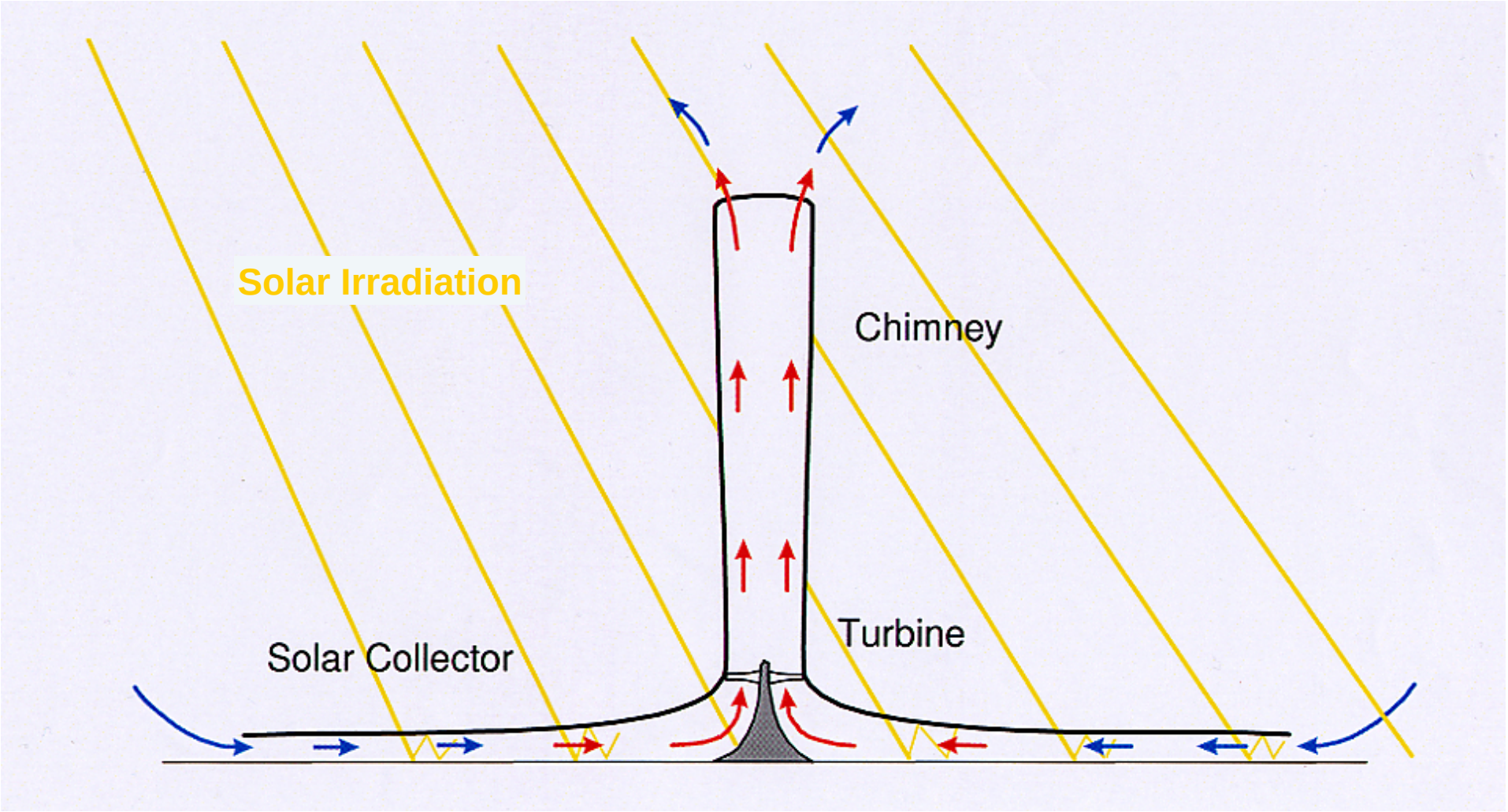



**NREL: Wind output on 9/8/04 at the time of the system peak was 60 MW out of 2100 MW of installed capacity (<3%).**

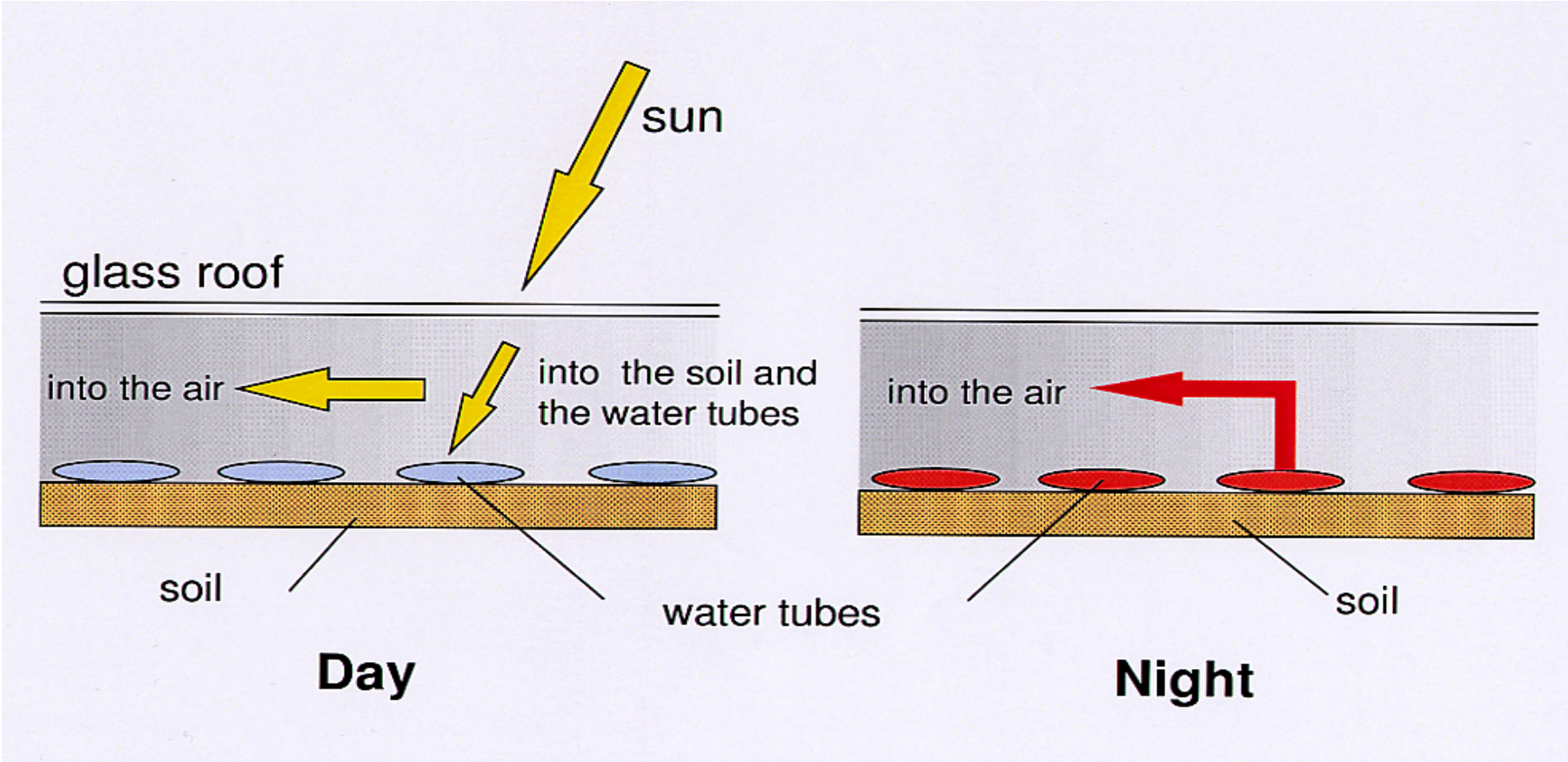
# Solar Chimey Power Plant



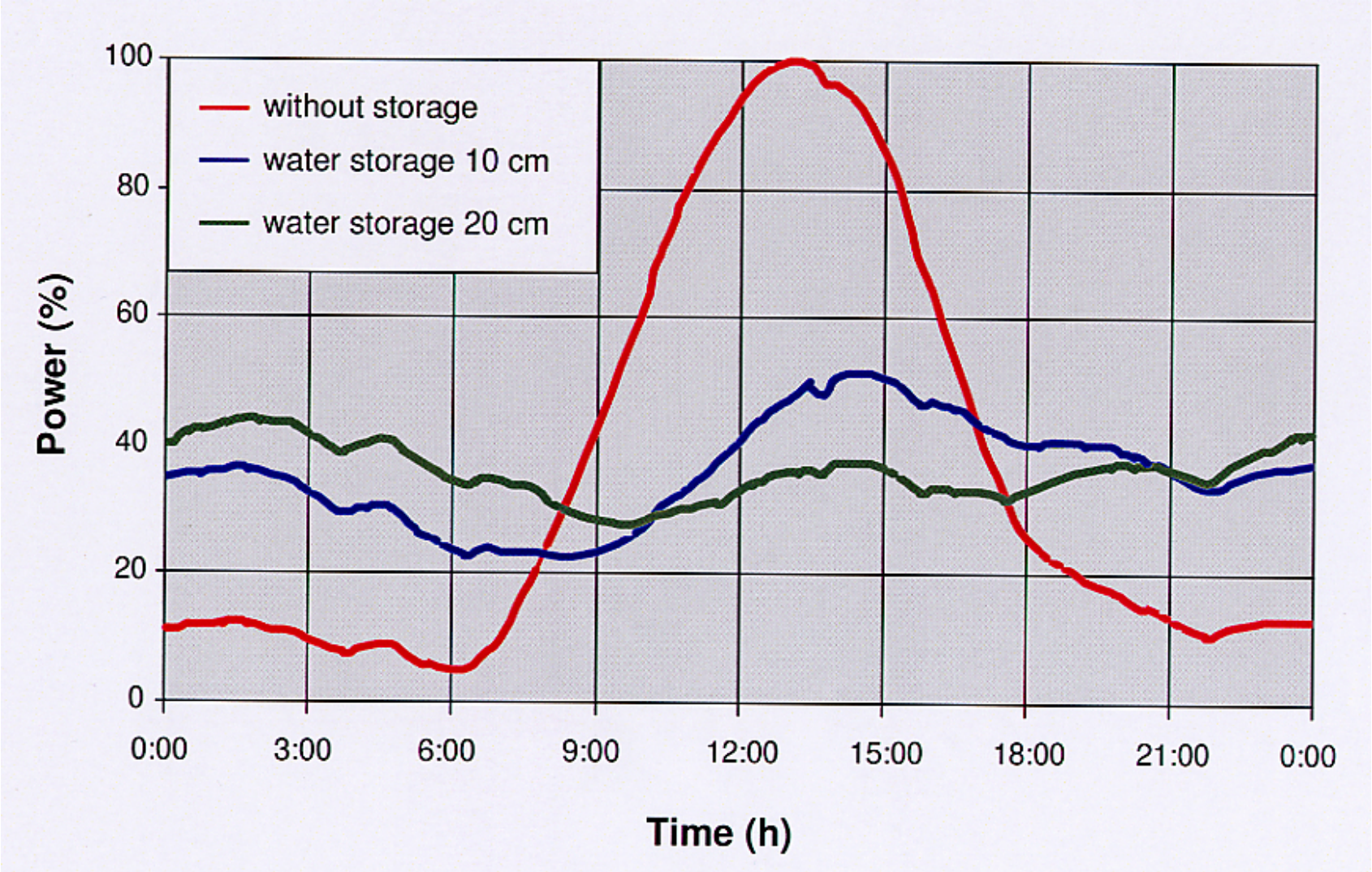
# Principle function of a Solar Chimney Power Plant



# Principle of energy storage



# The capacity of the thermal storage is adapted to the load profile of the grid



# Typical dimensions of a 100MW Solar Chimney Power Plant

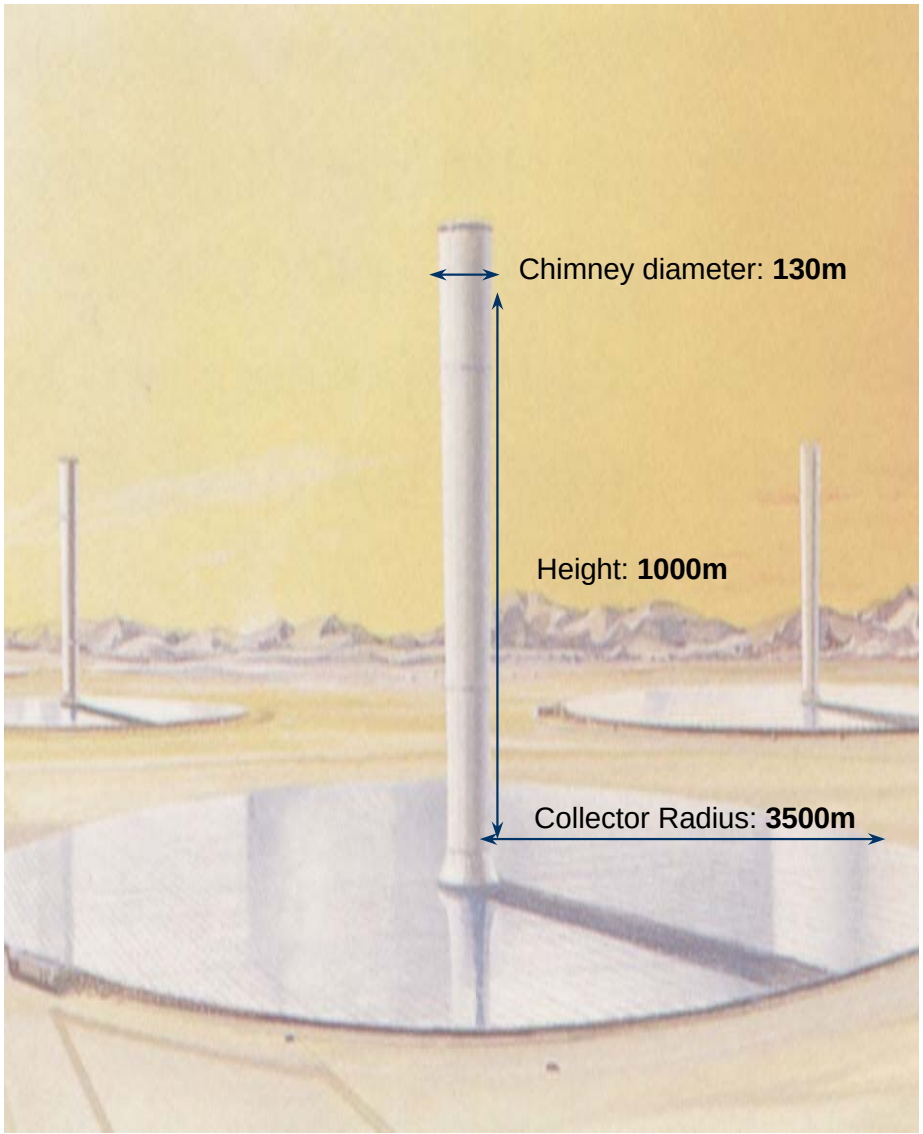
## Chimney

- Height: 1000m
- Diameter: 130m
- Wall thickn. bottom: 1m
- Wall thickness top: 0,25m

## Collector

- Radius: 3500m
- Height outer radius: 3,5m
- Height inner radius: 35m

**Yearly power generation: app. 700 $GWh_{el}/y$**

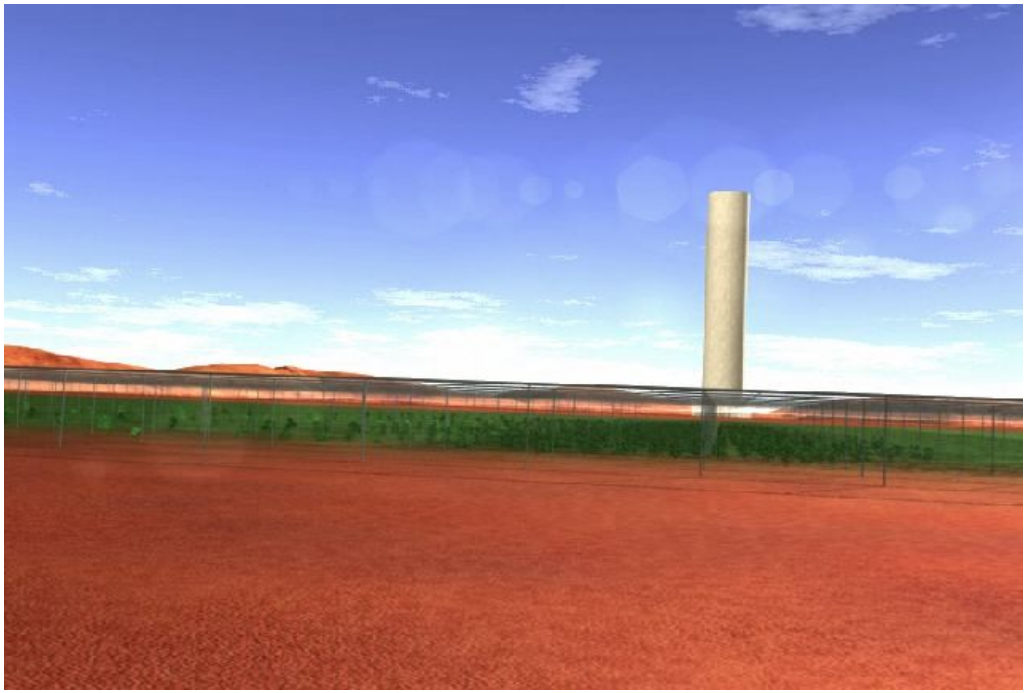


# The Highest Buildings in the World

# Prototype plant at Manzanares, Spain

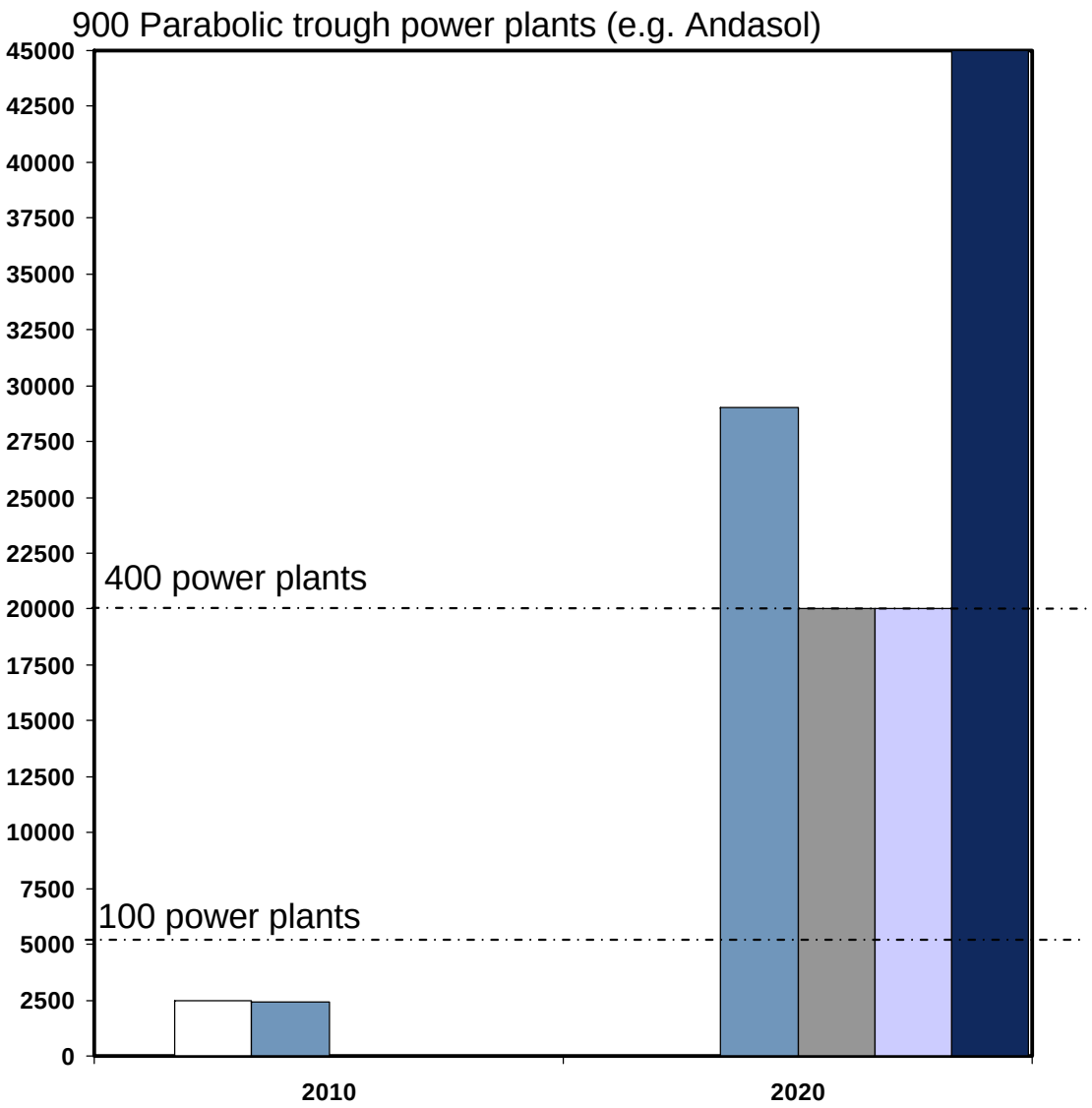
# Advantages of Solar Chimney Power Plants

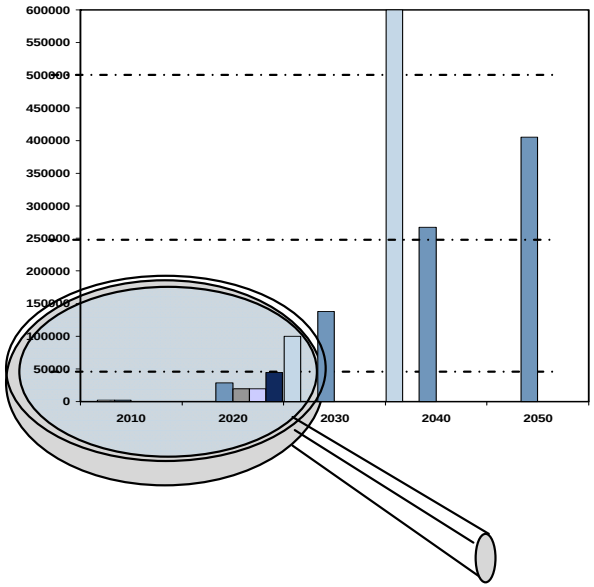
- No cooling water needed
- Base load plant
- Low generation costs for clean power
- Reduction of CO2 and other emissions
- Creation of many local jobs



# Large Potential for Market Growth

**MW solar-thermal power plants**

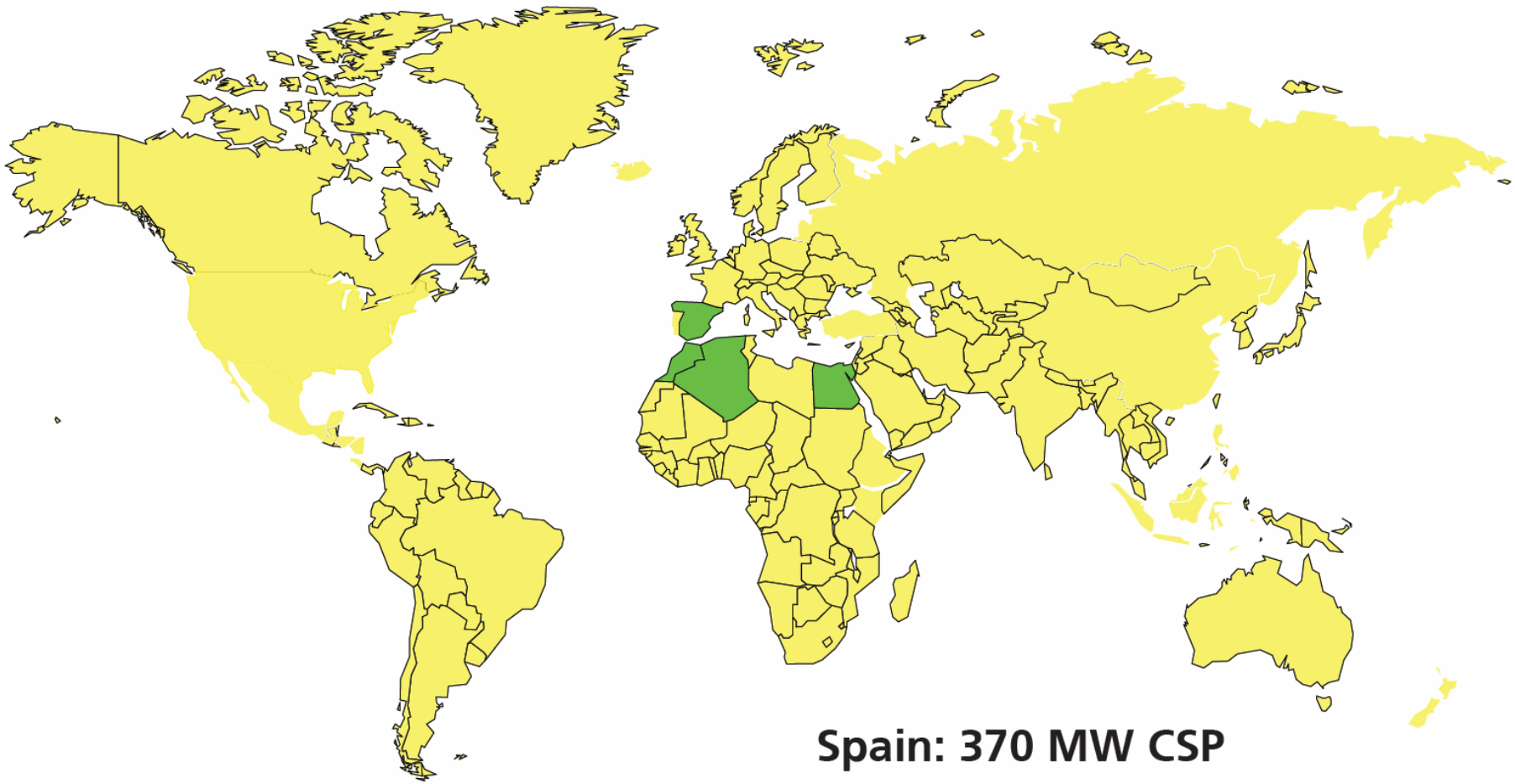



Studies

- Greenpeace/ESTIA 2005
- Sarasin 2007
- Greenpeace/EREC 2007
- DoE
- IEA min.
- IEA max.

# Today 450 MW of CSP power plants are under construction



**Spain: 370 MW CSP**

**Algeria: 135MW ISCCS with 30MW CSP**

**Morocco: 450 MW ISCCS with 30MW CSP**

**Egypt: 135 MW ISCCS with 20MW CSP**

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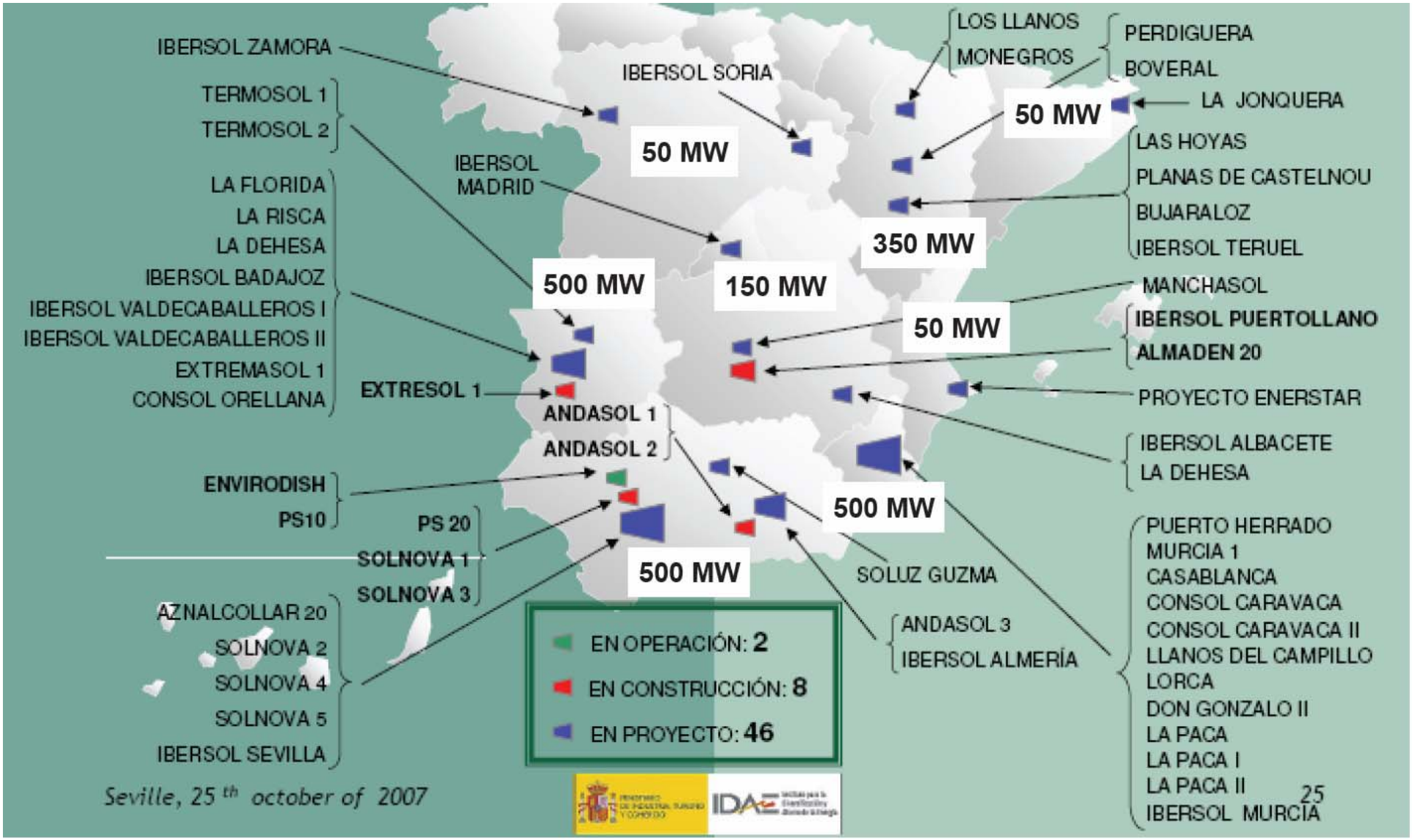
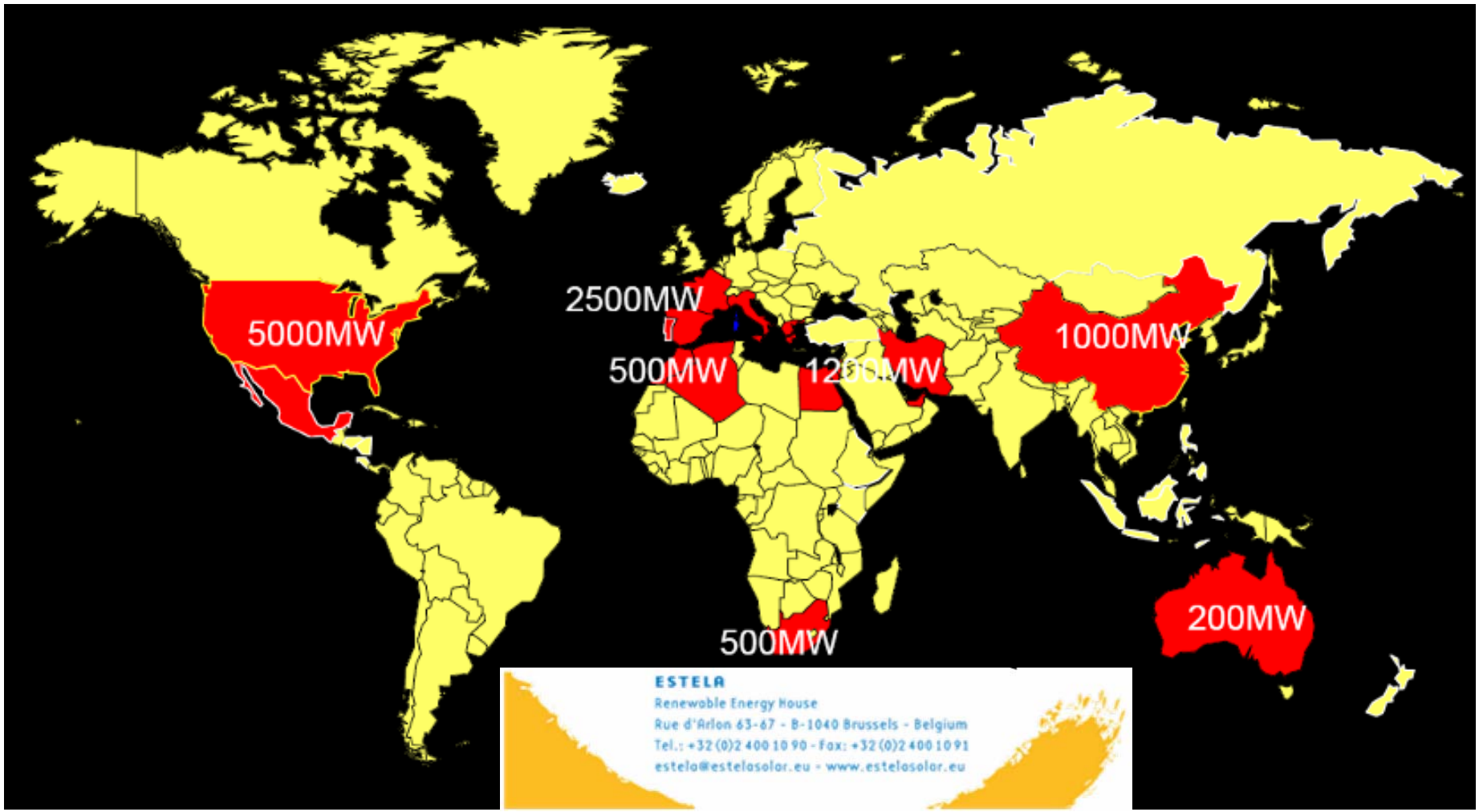
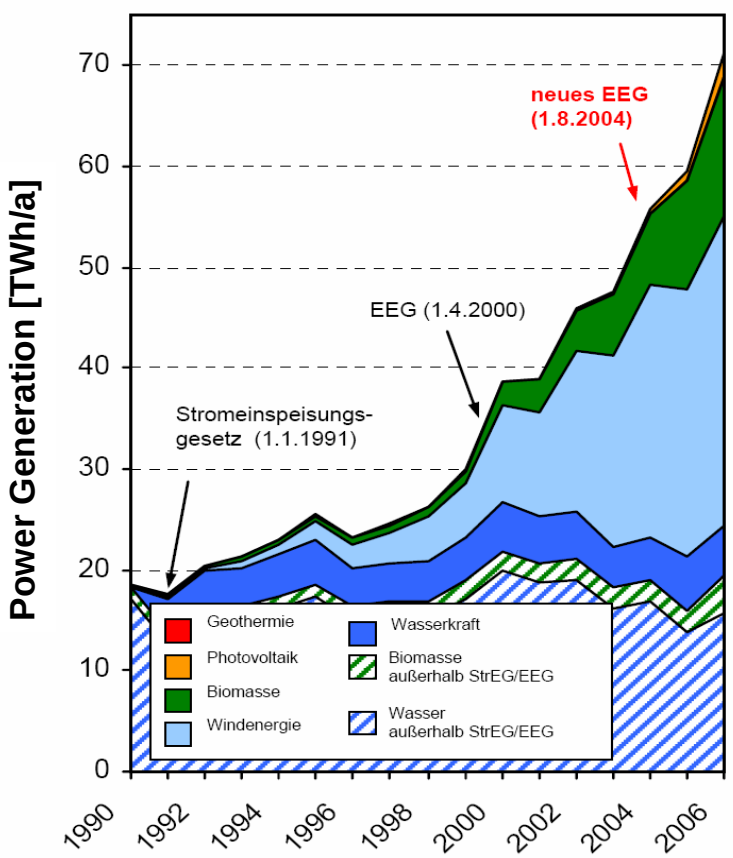
# In Spain, the feed-in tariffs initiated planning and construction of more than 2150 MW of new CSP power

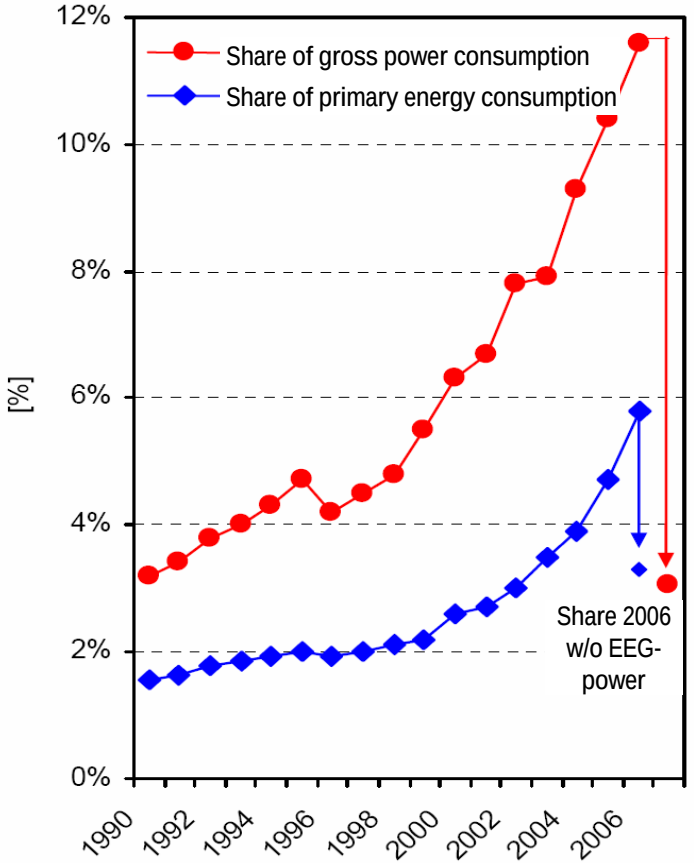


# Today, about 11GW of new CSP plants are planned worldwide, most of them waiting for political support



# How to implement renewable power generation?

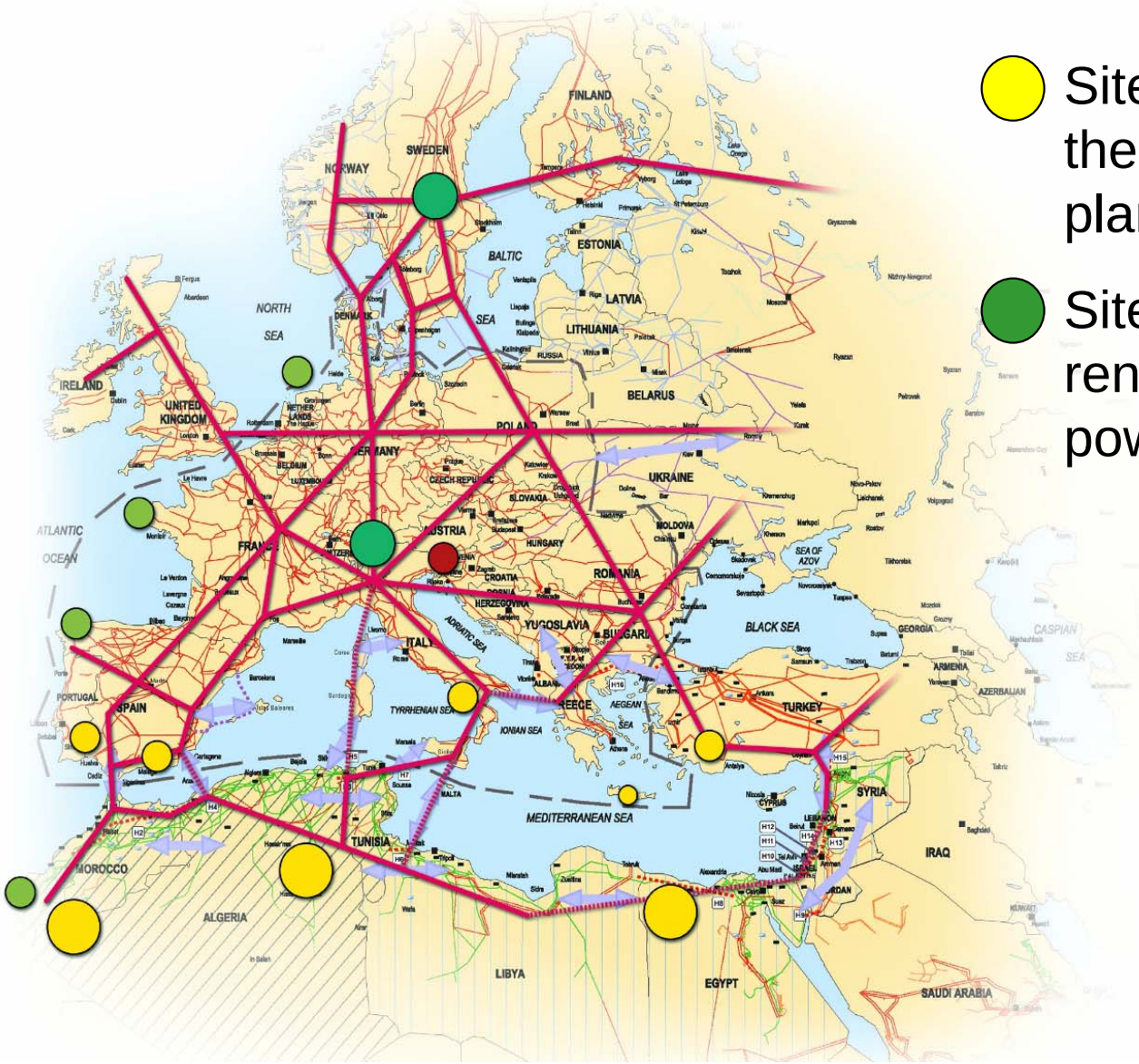



Source: BMU; EEG-Erfahrungsbericht 2007

**The most effective and efficient means to enhance the utilization of renewable energies are feed-in tariffs, e.g. like in Germany, Denmark or Spain. In contradiction, quota and trade systems in other countries showed little or no benefit.**

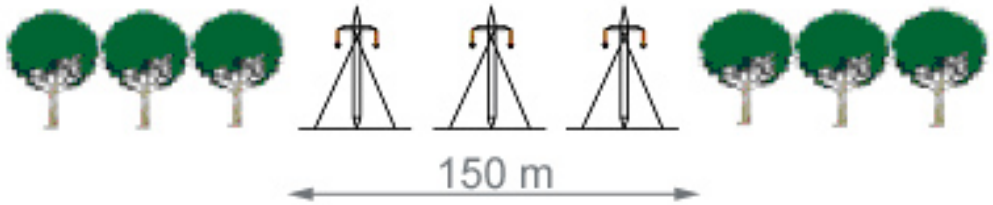
# High-voltage-direct-currency (HVDC) transmission lines are necessary for the secure energy supply of Europe



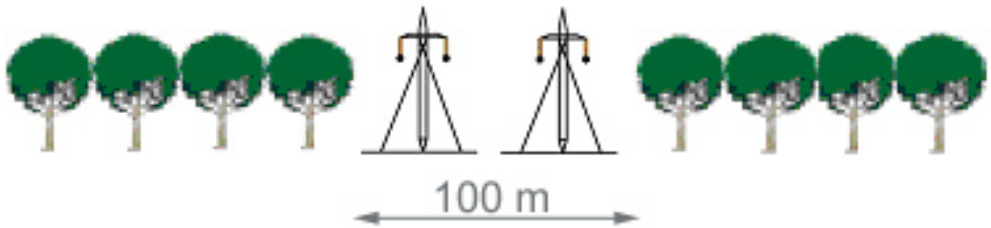

- Sites of solar thermal power plants
- Sites of other renewable energy power plants

# Space required for 10 GW power transmission


800 kV AC




600 kV HVDC

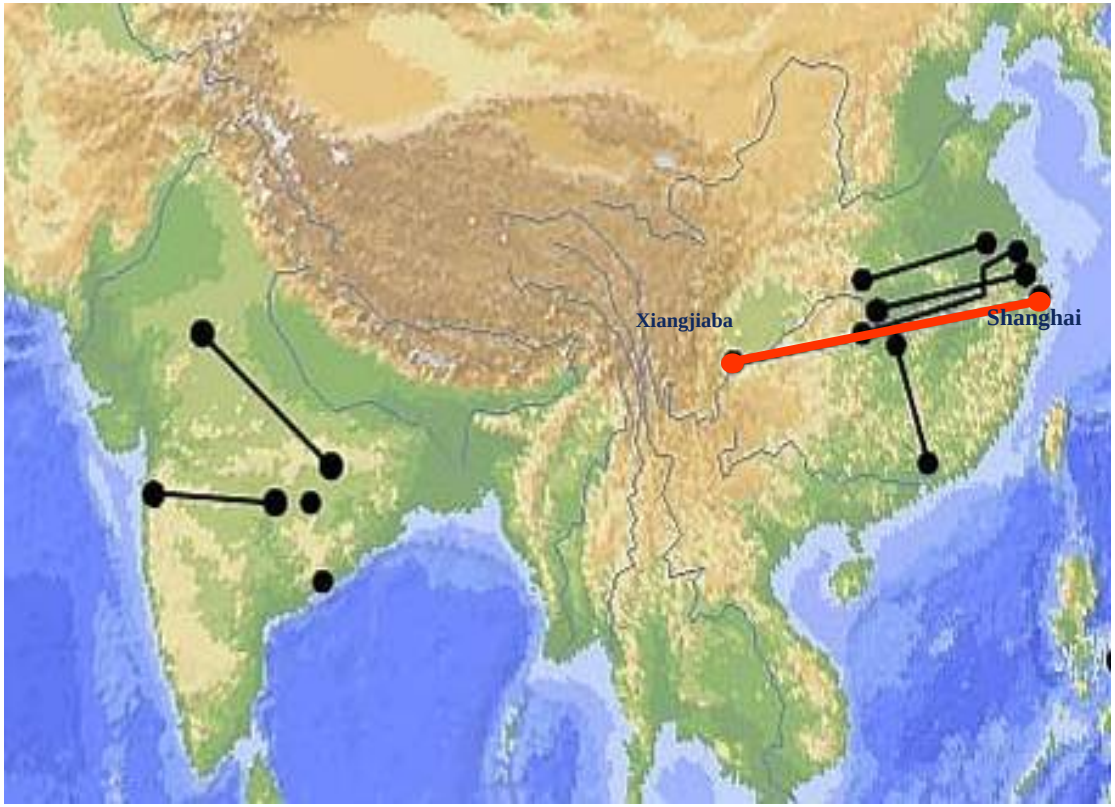



800 kV UHVDC

| | |
|---|---|
| AC | Alternate Current |
| HVDC | High Voltage Direct Current |
| UHVDC | Ultra High Voltage Direct Current |

Source: DLR; trans-csp; June 2006

# World largest HVDC line under construction in China: Remote hydropower Xiangjiaba - Shanghai




**Main data**

| | |
|---|---|
| Commissioning year: | |
| Pole 1: | 2010 |
| Bipole: | 2011 |
| Power rating: | 6 400 MW |
| No. of poles: | 2 |
| DC voltage: | ±800 kV |
| Length of over-head DC line: | 2 071 km |
| Losses: | < 7% |
| Main reason for choosing HVDC: | Long distance |

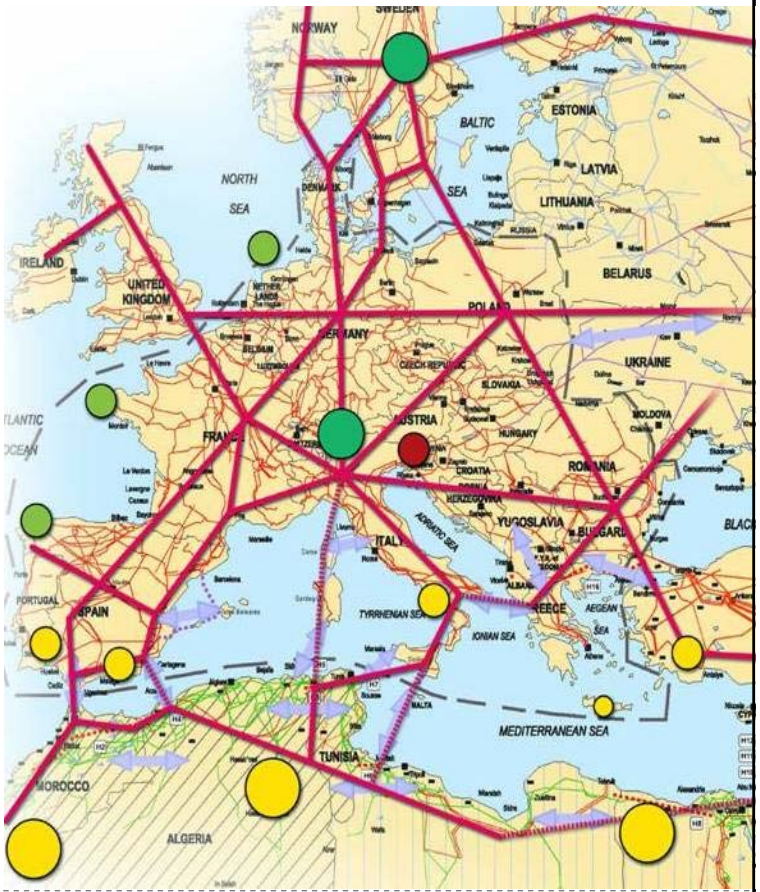
**Source:** ABB

# Import of solar electricity is worthwhile & possible

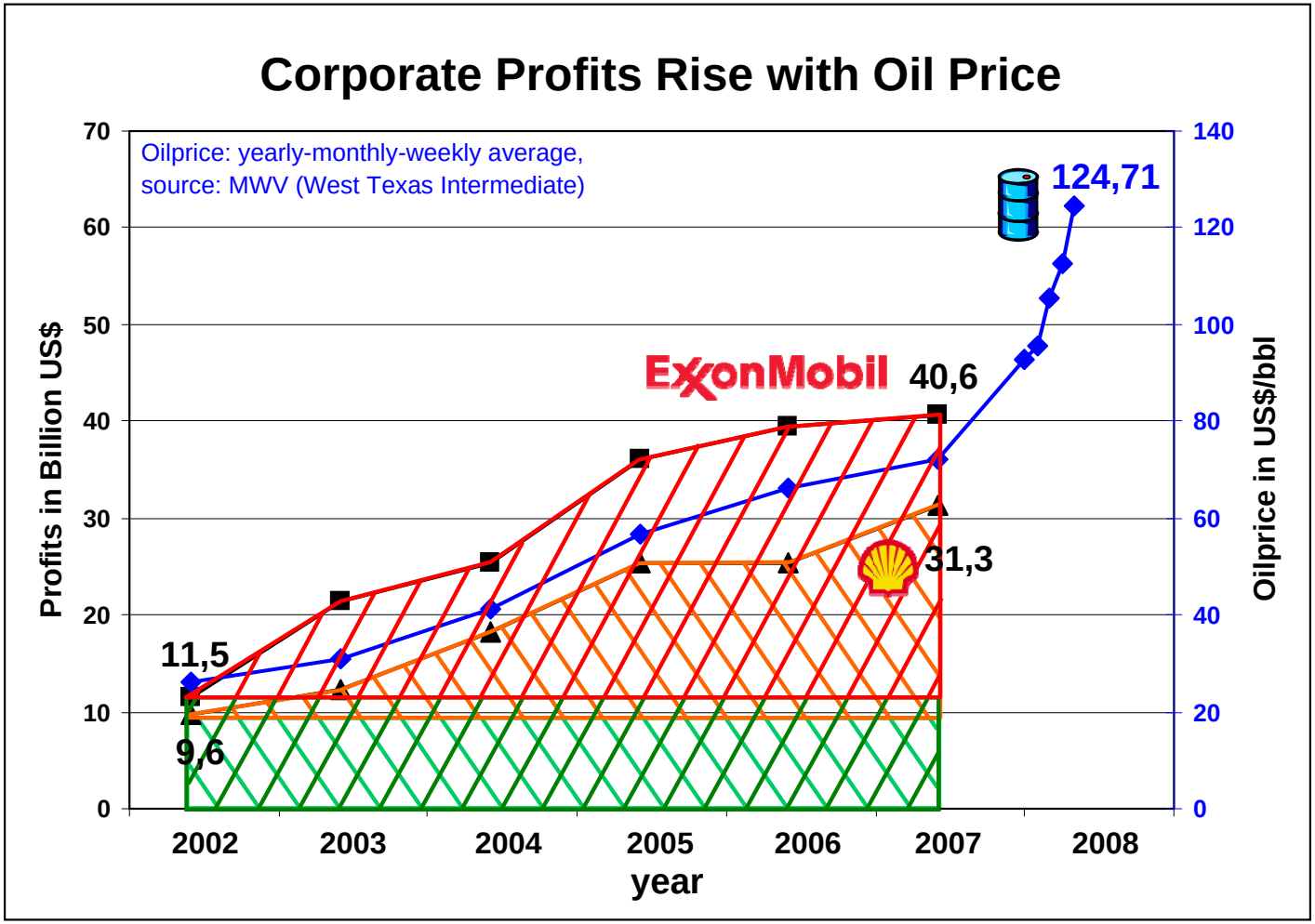
In 2050 Concentrating Solar Power Plants in the Mediterranean Region will deliver twice as much electricity per year as wind, PV, biomass and geothermal plants together. (Med-CSP-Study by German Aerospace Center, DLR)

In 2050, about 15 % of the European electricity demand can be met by solar imports from the Middle East and North Africa.
(Trans-CSP-Study by German Aerospace Center, DLR)

“We must use the chances provided by intelligent solar-politics across the globe, in order to promote economic development in a sustainable manner. This also prevents conflicts over raw materials or water getting out of control in the medium term...”
(German Federal Foreign Minister Steinmeier)



# Cost of CSP compared to our economic capacity … an example




**In 2002 ExxonMobil and Shell were on rank 4 and 5 of the 10 most profitable companies in the world and accounted for 6.5% of world oil production.**

**What would have happened, if their additional profit since 2002 would have been spent into renewable energy, e.g. CSP plants?**

**Between 2002 and 2007, additional profit due to rising oil prices accumulated to 170 Billion US$ for both companies**

# For 170 Billion US$ we can …

- **Install 56,7 GW of parabolic trough plants …**

  **= 42,9 % of installed power plant capacity in Germany**

- **Generate 141,7 TWh/y renewable power (RE)**

  **= 164% of actually generated RE in Germany**

- **Reduce $CO_2$ emission by 131 Million to/y**

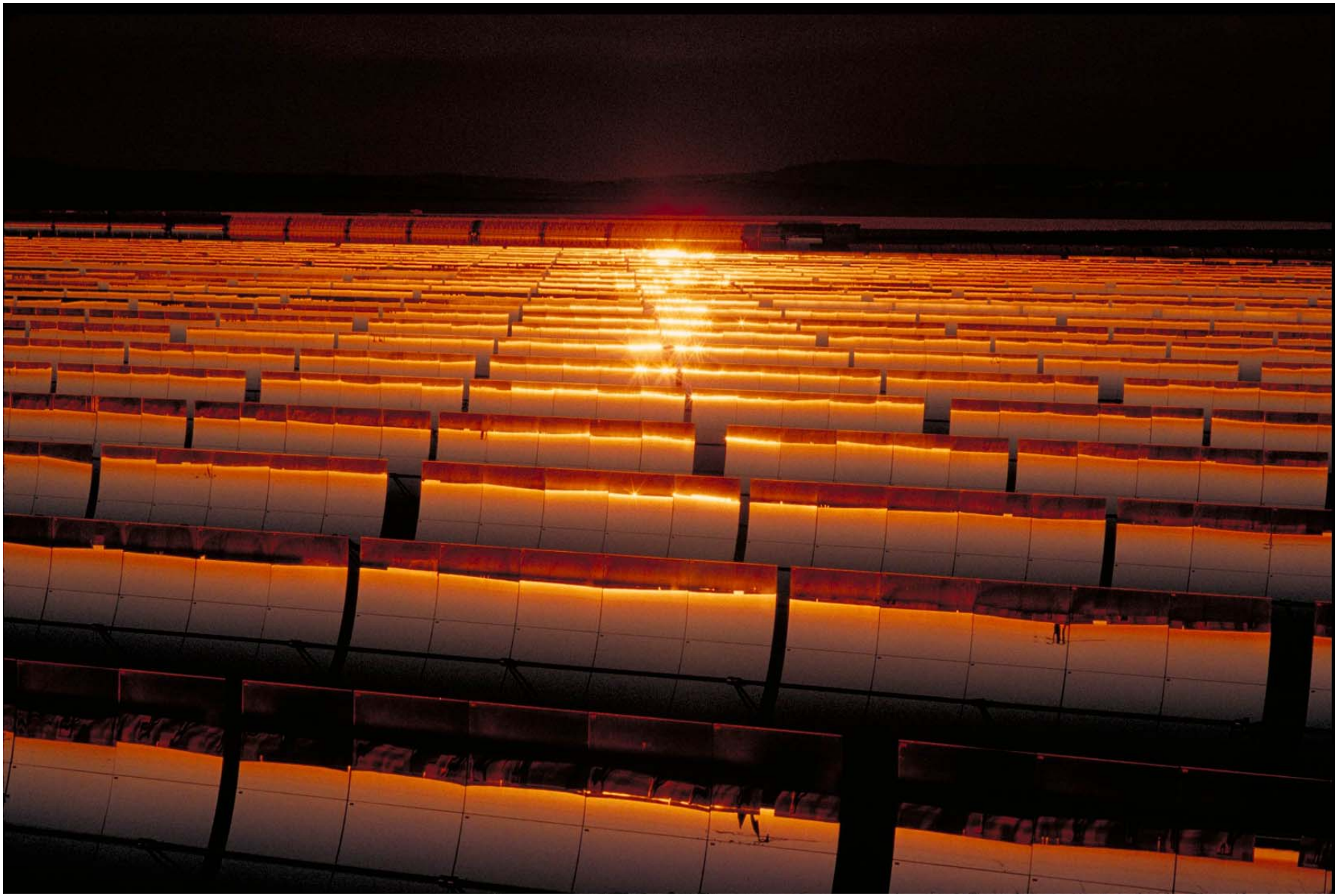
  **= 15.3% of $CO_2$ emissions in Germany**

*With a GDP of 3,322 Billion US$ in 2007, Germany is the third largest economy in the world. All comparison data for Germany from 2007.*

# We don‘t need rocket-science with the promise of a bright but distant future

- **Right now, we need the large scale deployment of available technology to bring down production cost**
- **We need increased R&D efforts to further enhance efficiency of solar energy conversion and decrease installation cost**
- **We have to start planning high capacity trans-mission lines to allow for on-demand production and distribution of renewable power.**

# Welcome to the Solar Millennium!



# Any questions ?

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