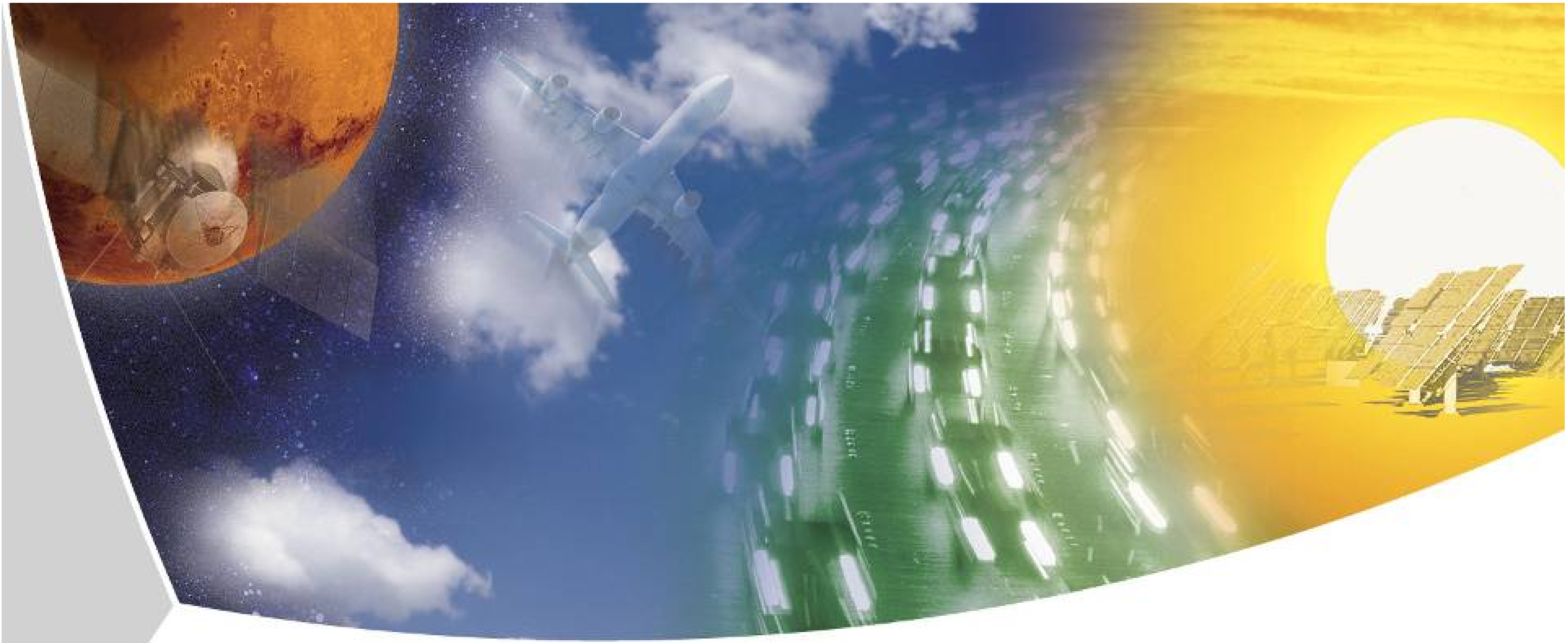

Water saving heat rejection for solar thermal power plants

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Overview

- Project goals
- Heat rejection technologies
- Simulation tool
- First results
- Outlook

Research Project „EFCOOL“

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

- Title: “Water efficient cooling of solar thermal power plants”
- Solar Paces Task III Activity „Efficient Cooling Strategies for Solar Thermal Power Plants“
- Motivation: Solar thermal power plants with Rankine cycles need heat rejection for condensation of the turbine exhaust steam in order to reach low exhaust pressures and to recycle the working fluid
- Typically ambient temperatures are high and water is rare at sites showing attractive annual DNI values

EFCOOL Tasks

- Investigation of different heat rejection technologies for STPP
- Developing of a simulation tool for annual calculations at different sites
- Identification of potential enhancements for existing cooling technologies
- Investigation of new operation strategies for STPP with respect to cooling (e.g. the usage of thermal storage to shift the cooling load to night hours)

Cooling technologies

- **Once through cooling**

  Most efficient and cheapest technolgy but rarely applicable for STPP

- **Wet cooling tower**

  Efficient at moderate investment costs but high water consumption

- **Indirect dry cooling (Heller System)**

  Less efficient and more expensive than wet cooling but almost no water consumption for cooling.

- **Air cooled condenser (ACC)**

  Less efficient and more expensive than wet cooling but almost no water consumption for cooling.

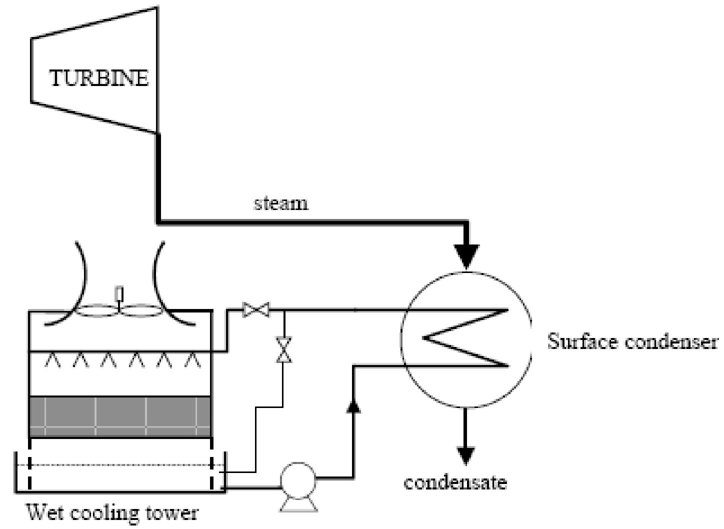
- **Hybrid cooling**

  Combination of wet and dry cooling technologies.

  Dry cooling with water usage during time periods with peak ambient temperatures.

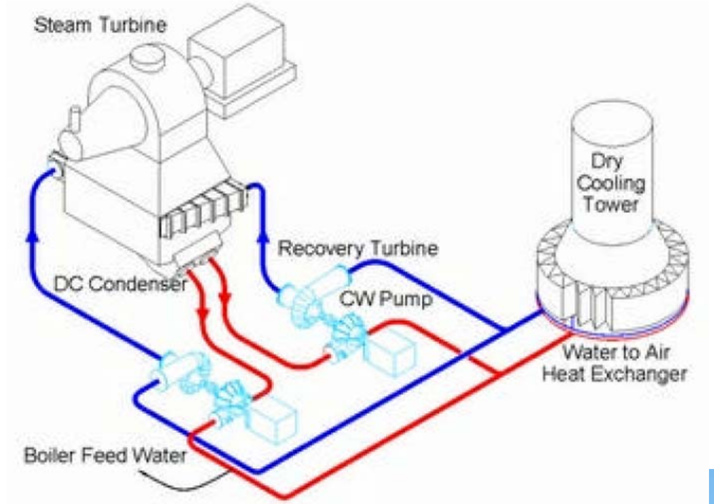
Wet Cooling Tower

- Ambient wet bulb temperature defines the condenser pressure (less fluctuations than dry bulb temperature)
- Surface condenser (TTD~3K)
- Cooling water and boiler feed water are separated
- Natural draft or cooling towers with fans are possible



Heller System

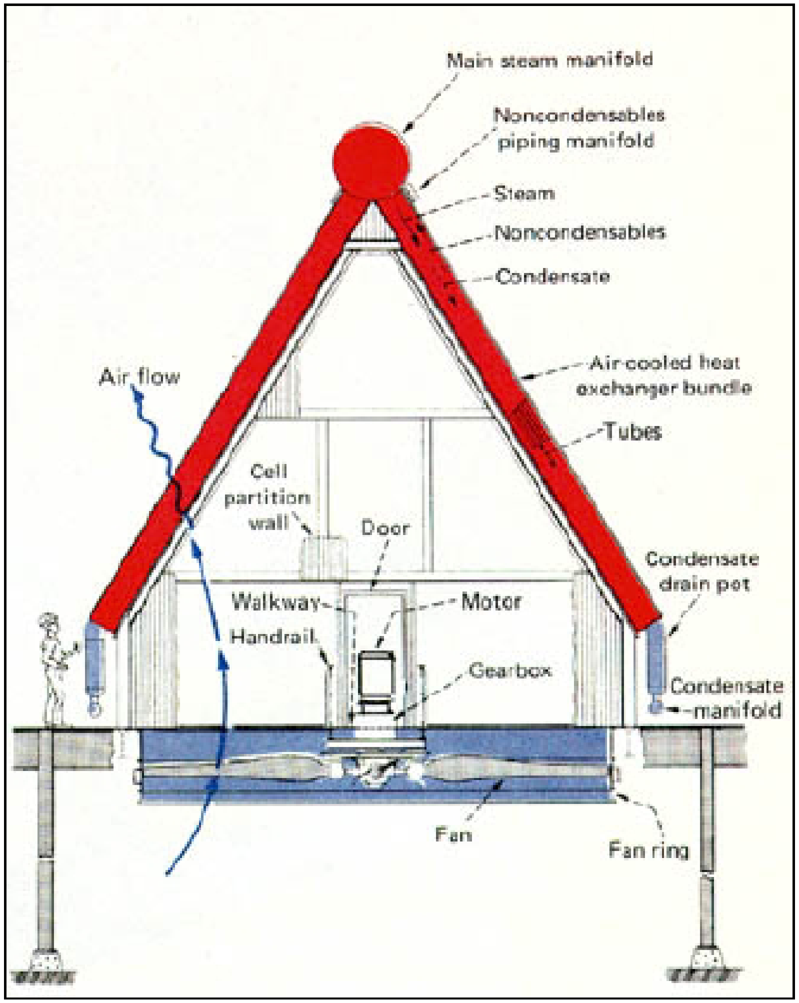
- Dry bulb temperature defines the condenser pressure
- Direct contact jet condenser (TTD~0.5K)
- Cooling water and boiler feed water are mixed
- Large underground storage tanks are used to drain the system
- Ratio cooling water flow / boiler feed water appr. 50
- Natural draft or cooling towers with fans are possible



Air Cooled Condenser

- Dry bulb temperature controls the condenser pressure
- Steam is condensed without the usage of an intermediate medium
- Large cooling surfaces are necessary
- The ACC should be located close to the turbine
- Typically forced draft A-frame configurations

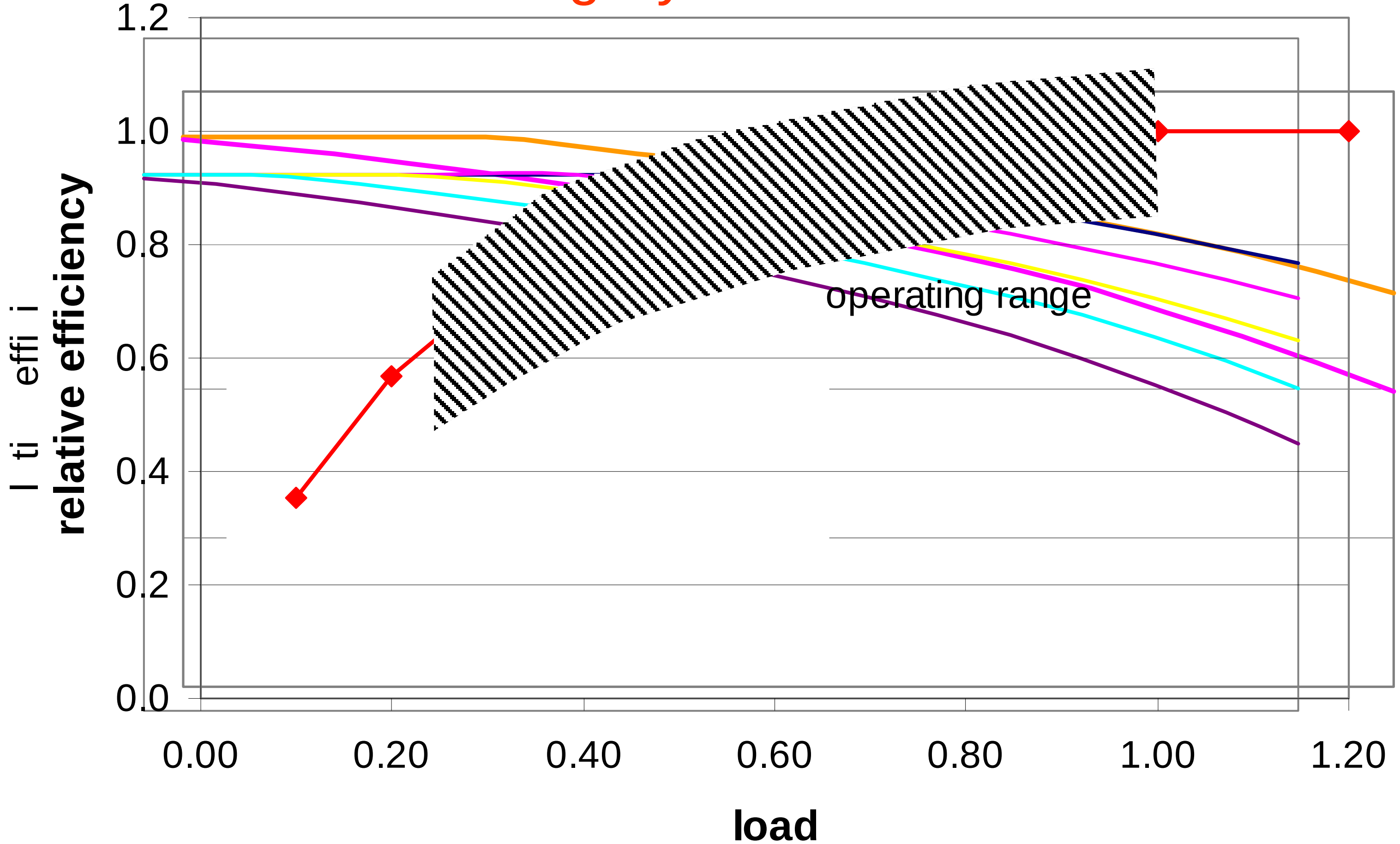
TU



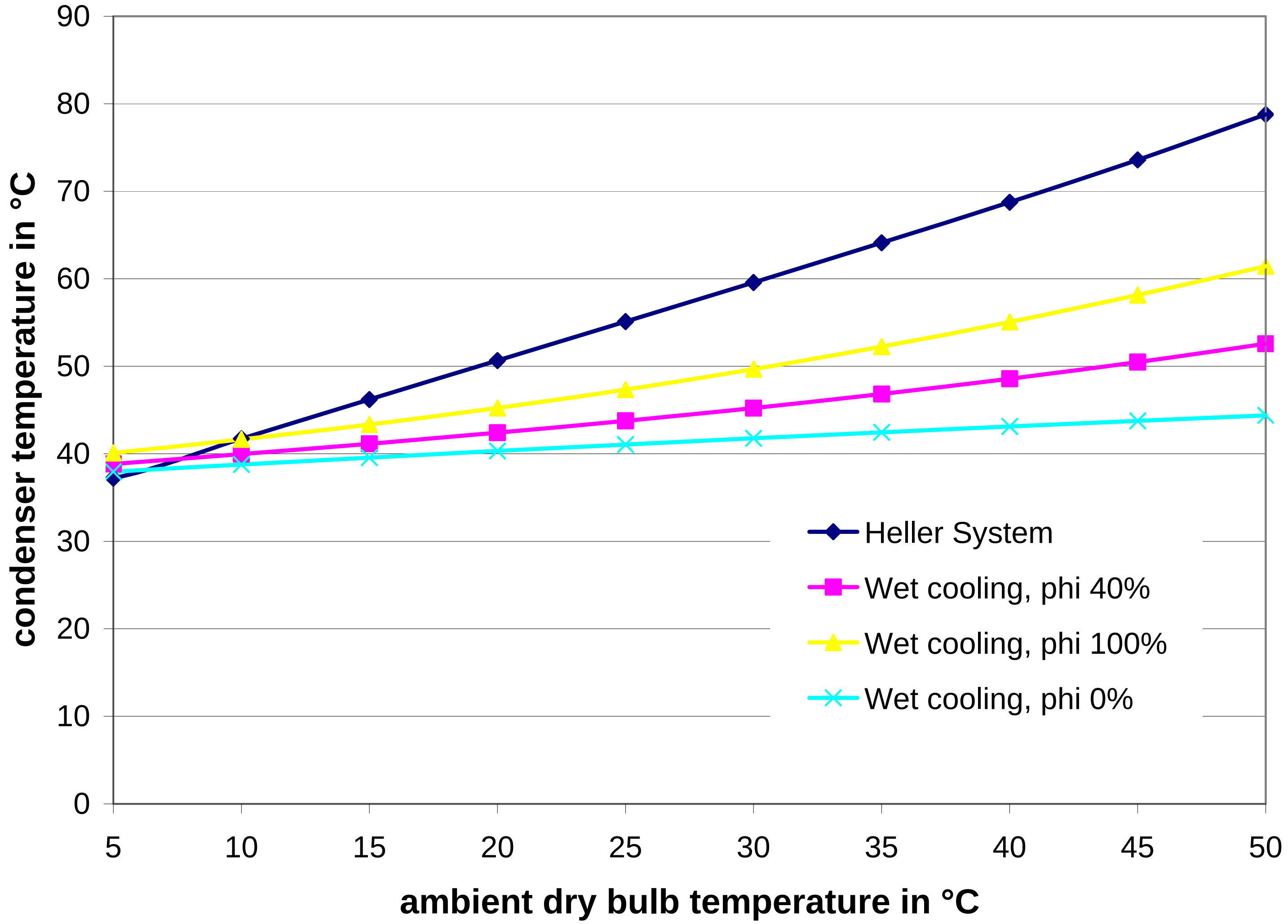
The Annual Simulation Tool

- **Steady state models in MS Excel**
- **Based on empirical equations or performance maps generated by other more sophisticated tools or delivered by suppliers**
- **Part load characteristics are considered**
- **Levelized electricity cost (LEC) calculation using the simplified IEA method**
- **Hour by hour calculation with meteo data for different sites**

Examples of the Performance Maps



Condenser Temperatures and Ambient Conditions



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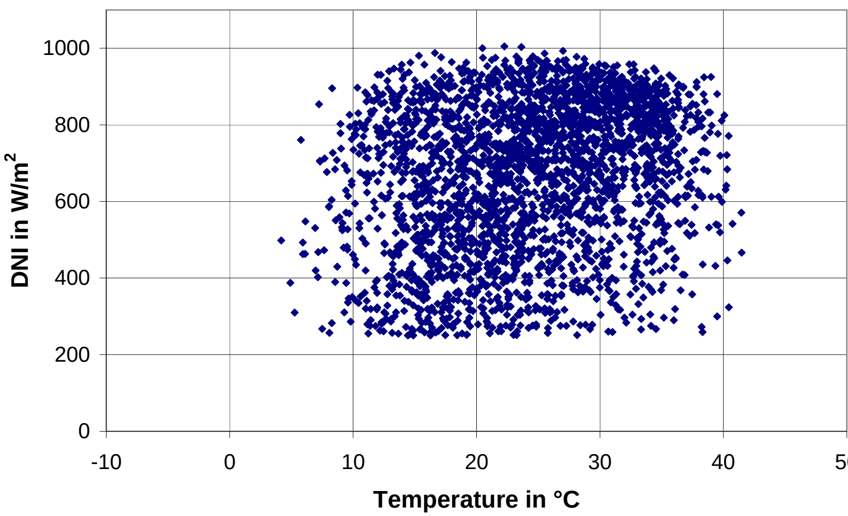
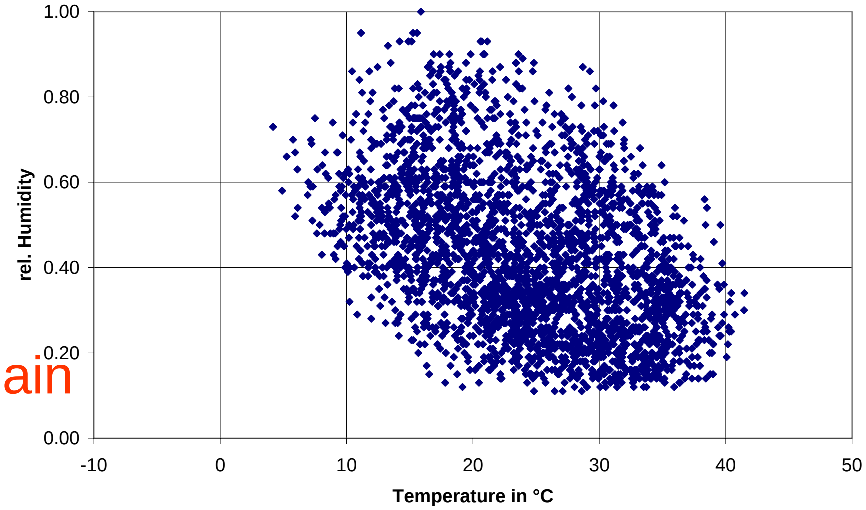
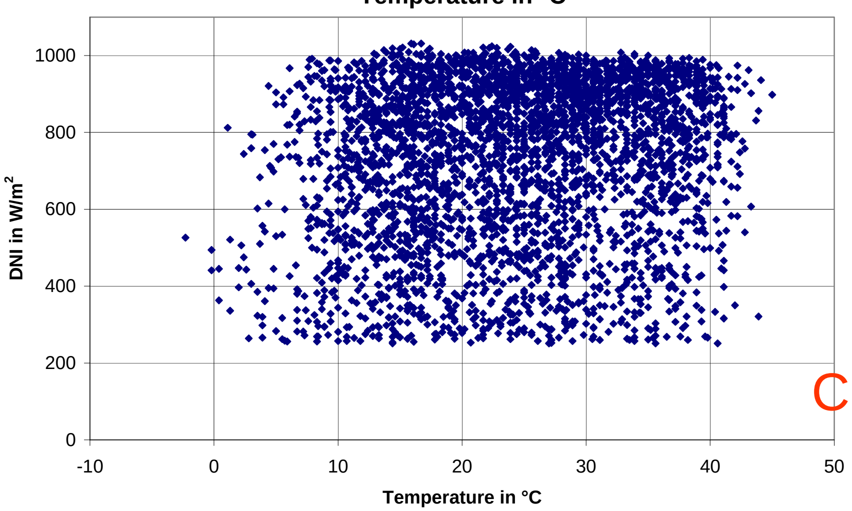
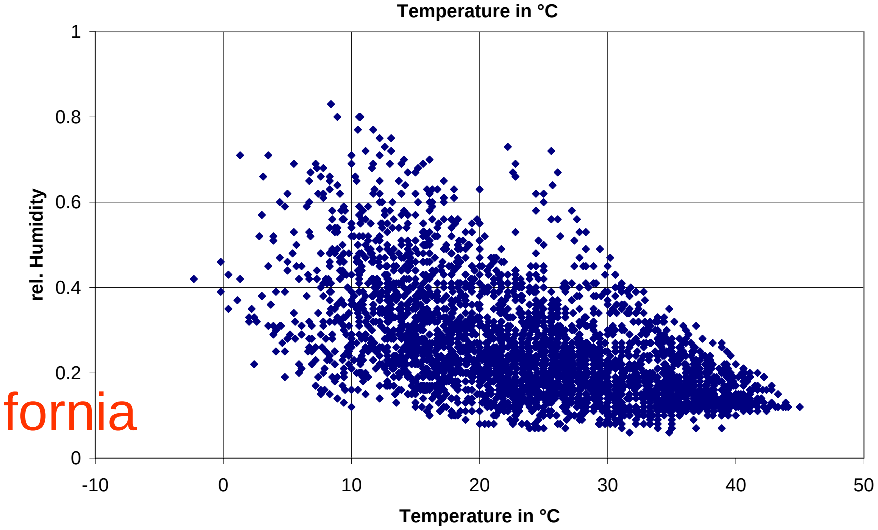
Meteo Data of Different Sites (DNI > 250W/m²)





Spain





California

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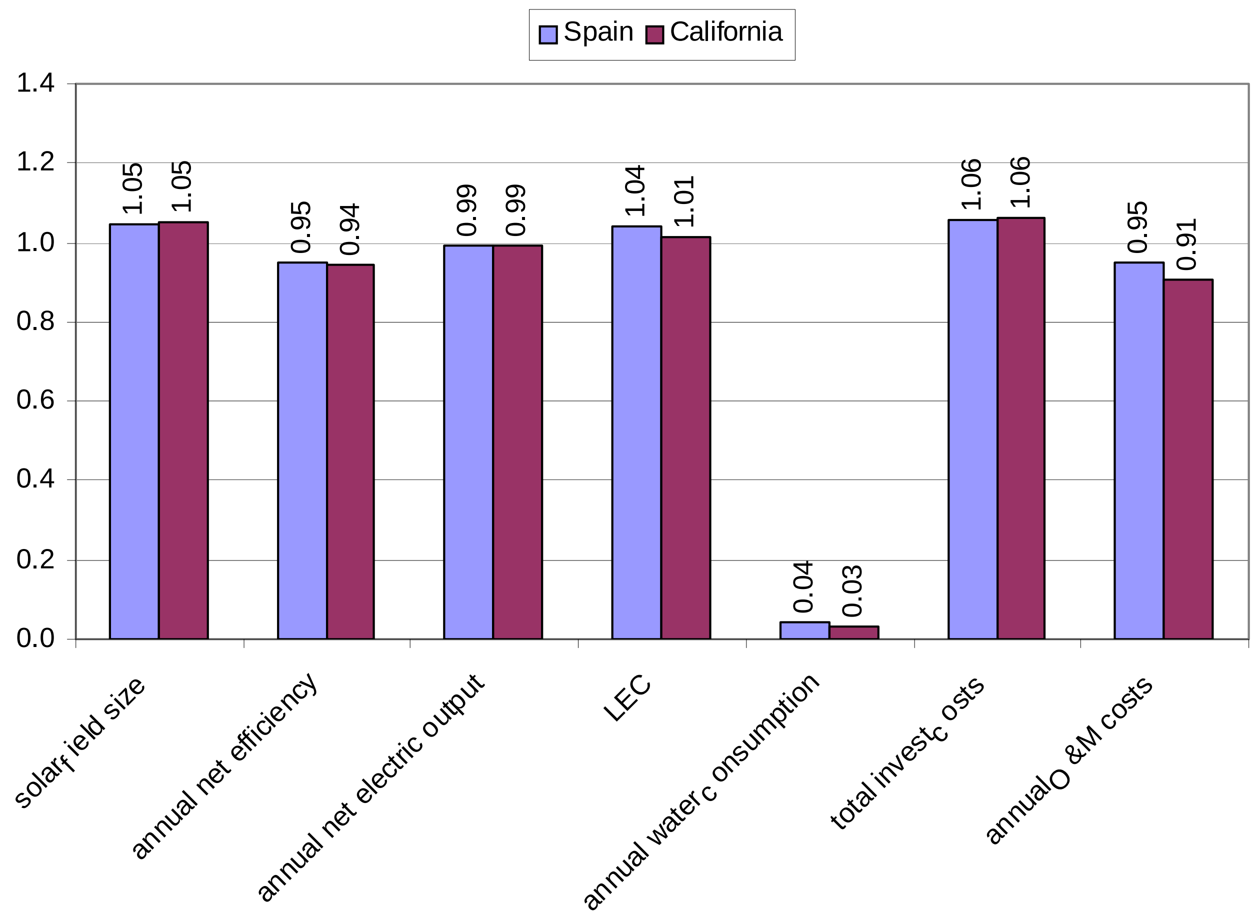
Results of Annual Calculation (Heller System compared to Wet Cooling)



Reference is the same plant at the same site with wet cooling tower

Gross output 55 MW

Water costs 1.0 €/m^3

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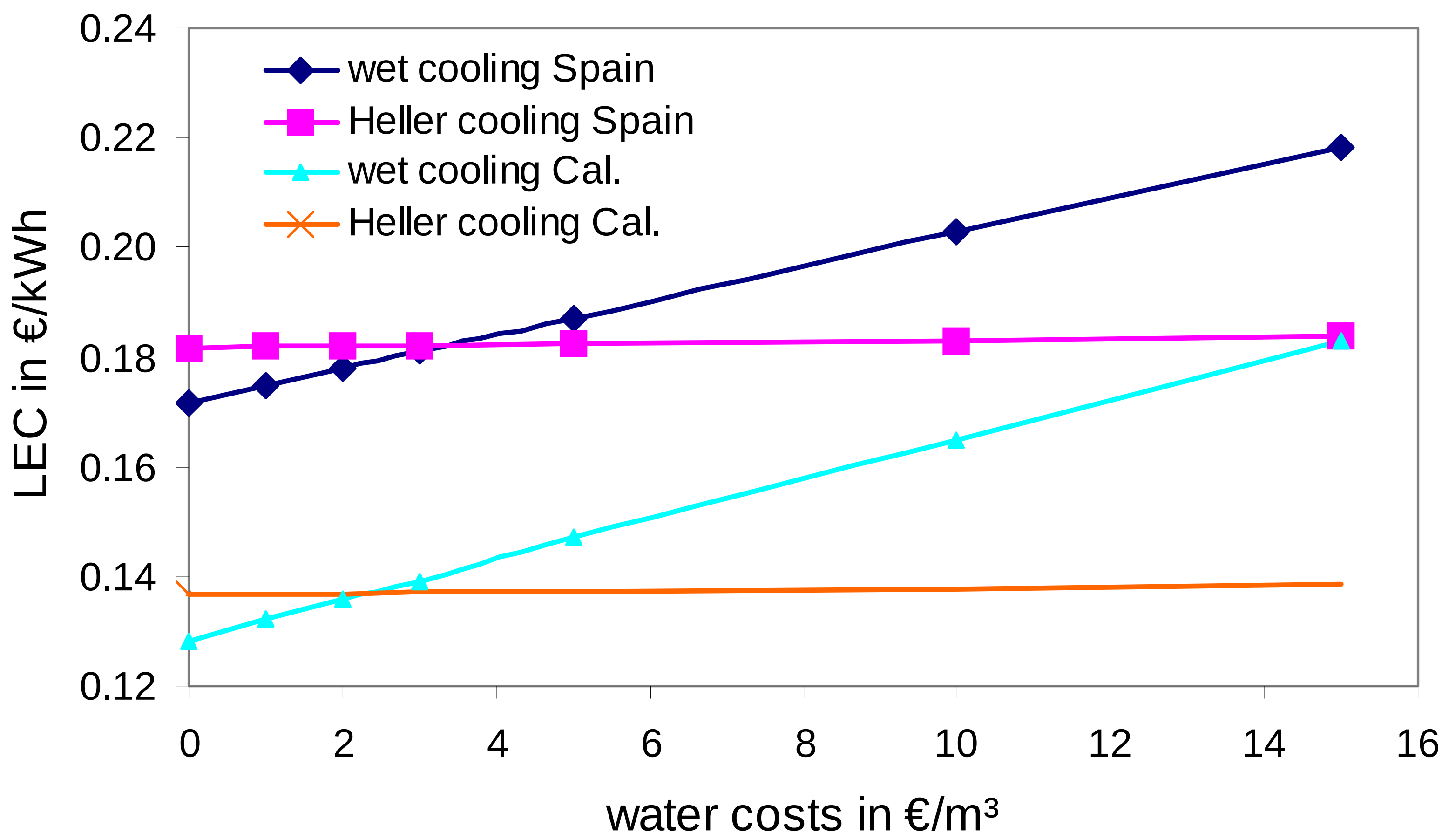
Sensitivity of LEC on Water Costs



Conclusions and Next Steps

- Change-over to dry cooling for STPP would reduce the water demand significantly (>95% reduction)
- The electricity generation costs will increase by up to 5% (depending on water cost) compared to evaporative cooling

- Hybrid cooling technologies to enhance the cooling at high dry bulb temperatures
- Usage of storage technologies to shift the cooling loads partly to times with lower ambient temperatures

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