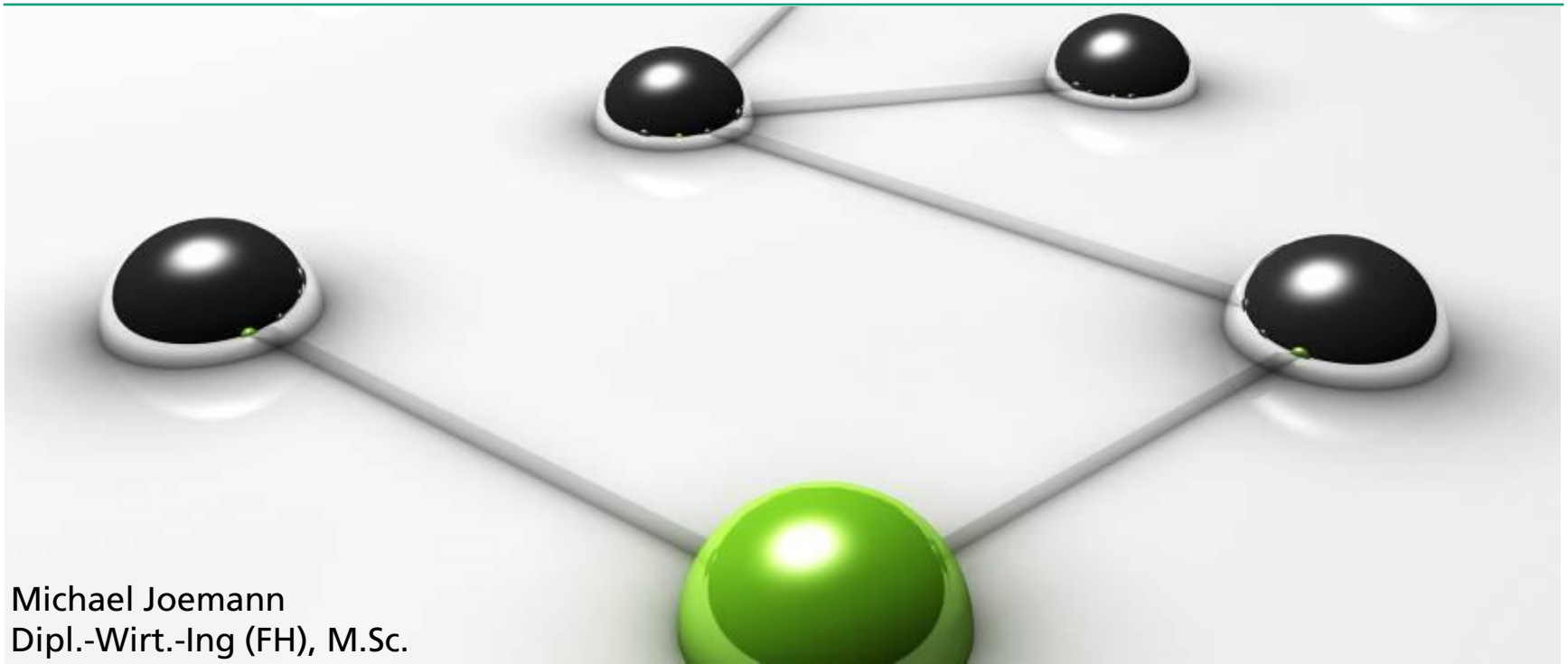

Static analysis of heat rejection systems for solar cooling applications

30 September 2013



Michael Joemann
Dipl.-Wirt.-Ing (FH), M.Sc.

Design parameters

→ Investigations for a location in Germany

Heat rejection system

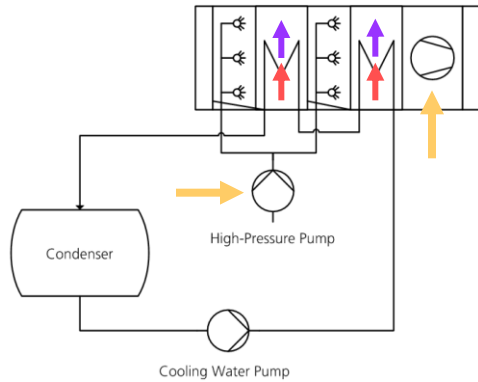
- Heat rejection capacity: 350 kW
- Cooling water flow: 50.2 m³/h
- Water inlet temperature: 31°C
- Water outlet temperature: 25°C

Climate conditions (design point)

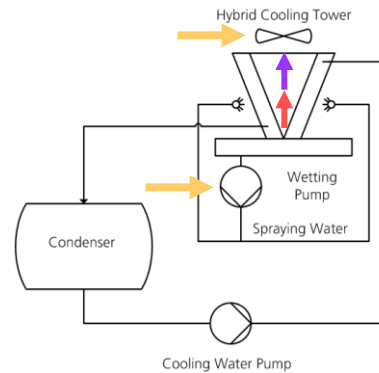
- Ambient temperature: 33.5°C
- Wet bulb temperature: 22°C
- Rel. humidity ambient air: 37 %

Heat rejection systems

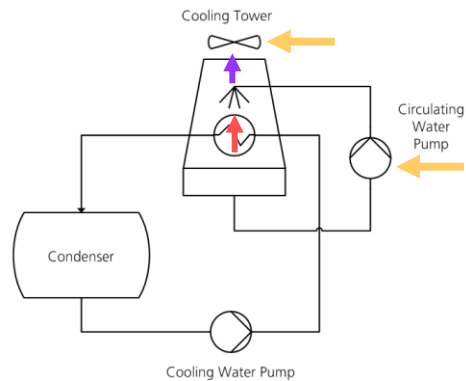
Concept I
Adiabatic cooling tower



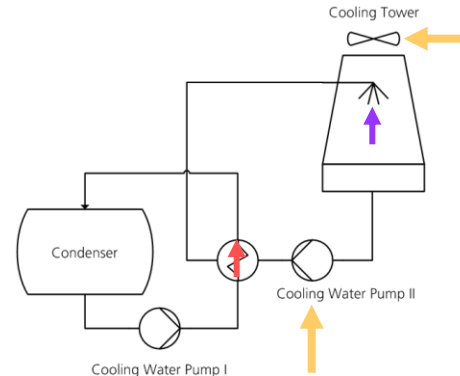
Concept II
Hybrid cooling tower



Concept III
Closed cycle wet cooling tower



Concept IV
Open cycle wet cooling tower



Simplification

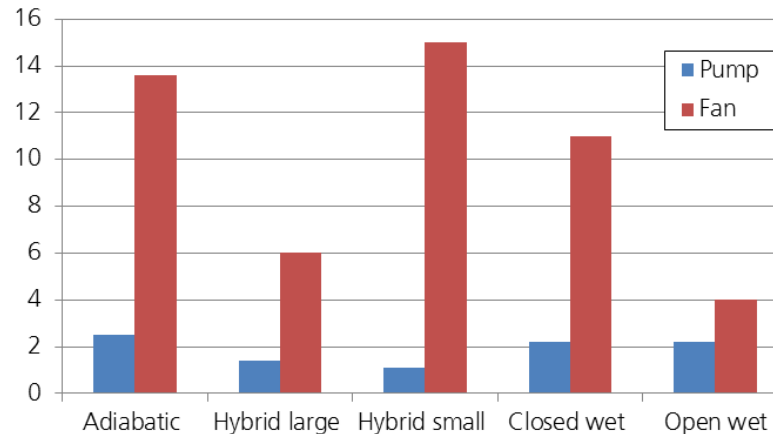
Cooling water pump not considered

- Heat exchanger
→ tube bundle or plate heat exchanger
- Pipe length
→ heat exchanger in machine room or in cooling tower

Technical data

		Concept I	Concept II a	Concept II b	Concept III	Concept IV
	Unit	Adiabatic cooling tower	Hybrid Large HE	Hybrid Small HE	Closed wet cooling tower	Open wet cooling tower
Water treatment	-	Reverse Osmosis	Desalination Unit	Reverse Osmosis	Desalination Unit	Desalination Unit
Water demand	m ³ /h	0.6	1.1	0.49	1.32	0.55
Switch-over dry/wet	°C	15.4	15 - 21	20	Only wet	Only wet
Share of wet cooling	%	60	58	69	100	100

Input power [kW]



Economic analysis

Comparison of heat rejection costs

- Quotations for German market
- Using annuity method

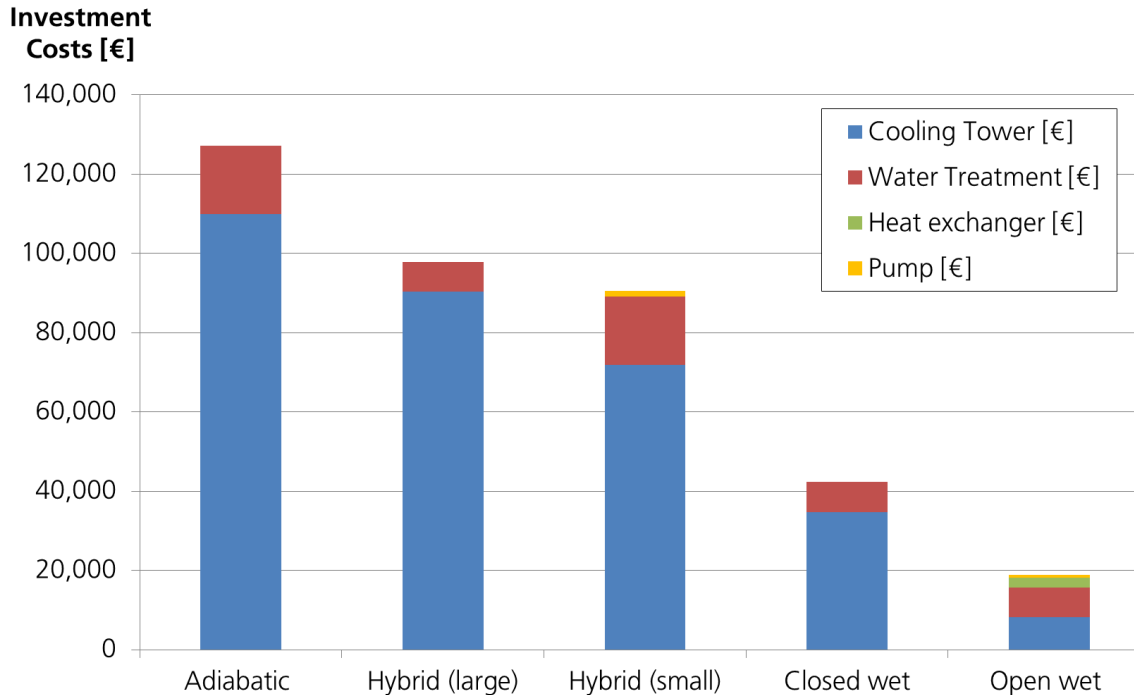
Operational costs

- Electricity costs (load dependent electricity consumption)
- Fresh water and waste water costs
- Costs for water treatment

Main parameters

- Interest rate: 2.5 %
- Economic life time: 15 years
- Electricity costs: 0.24 €/kWh

Investment costs



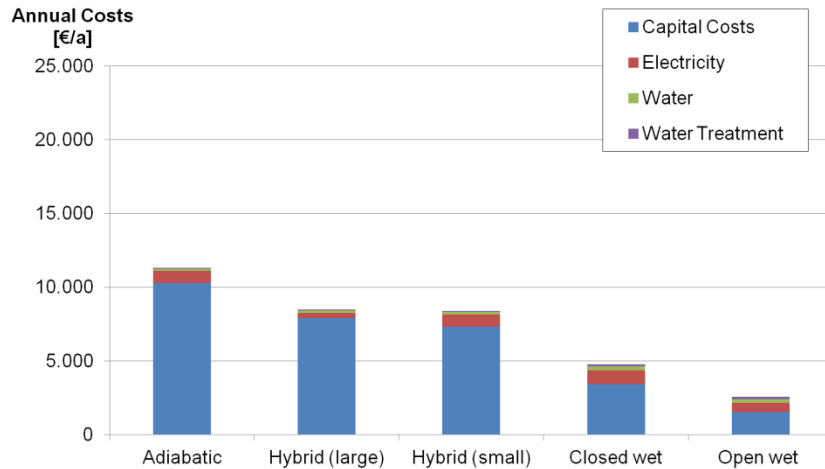
Specific investment costs

- Adiabatic: 360 €/kW
- Hybrid (large): 280 €/kW
- Hybrid (small): 260 €/kW
- Closed wet: 120 €/kW
- Open wet: 55 €/kW

Investigated scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cooling demand	Low	Moderate	High	Very high
Waste heat rejection	70 MWh/a	175 MWh/a	350 MWh/a	700 MWh/a
Full-load hours	200 h/a	500 h/a	1000 h/a	2000 h/a
Operating hours	800 h/a	2000 h/a	4000 h/a	4000 h/a
Ratio operating / full load hours	4	4	4	2

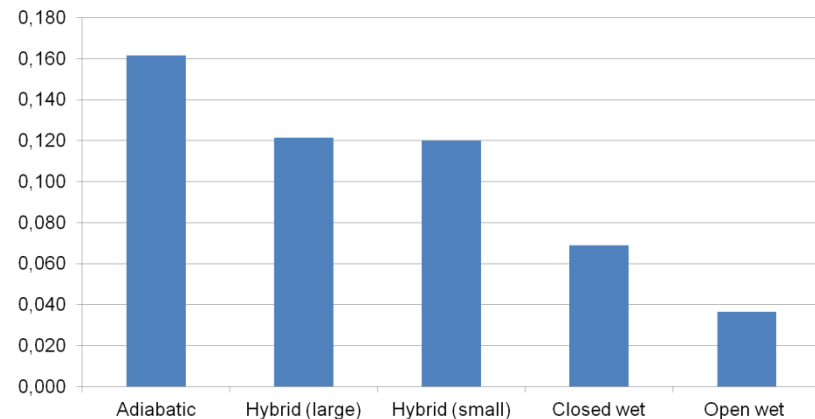
Scenario 1 – Low cooling demand



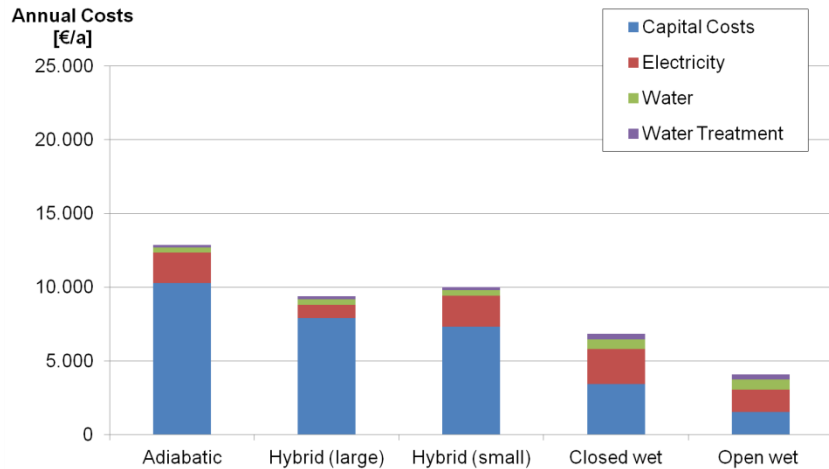
Waste heat rejection: 70 MWh/a
Full load hours: 200 h/a



Heat rejection costs [€/kWh]



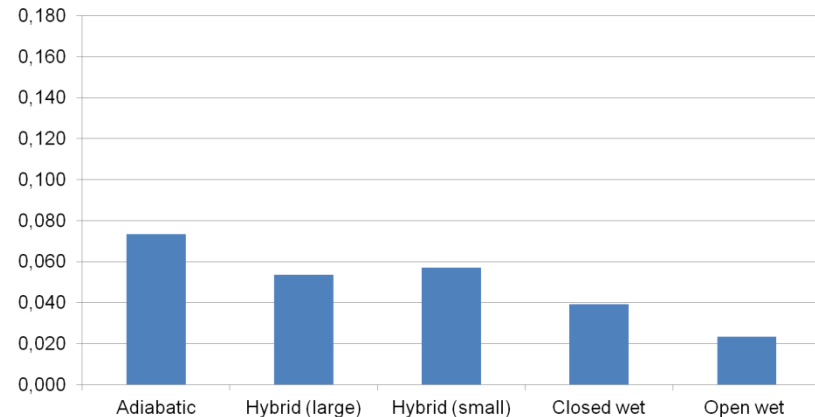
Scenario 2 – Moderate cooling demand



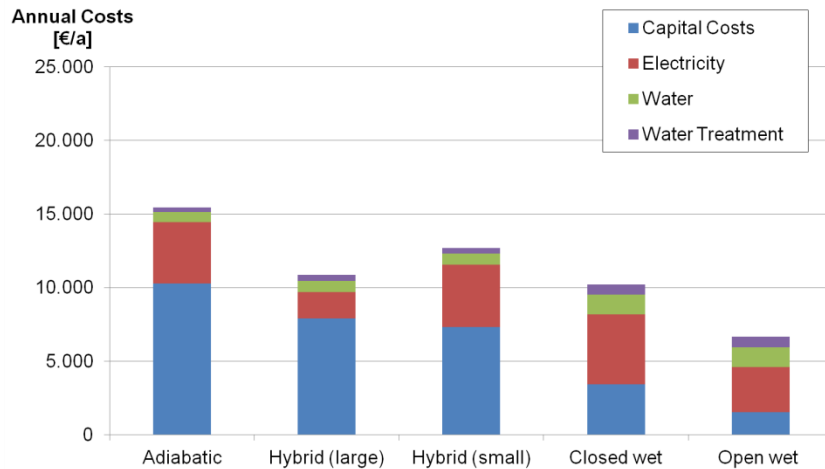
Waste heat rejection: 175 MWh/a
Full load hours: 500 h/a



Heat rejection costs [€/kWh]



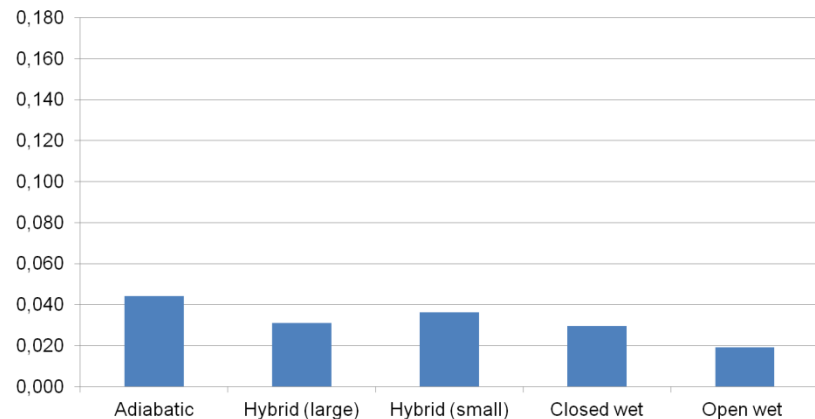
Scenario 3 – High cooling demand



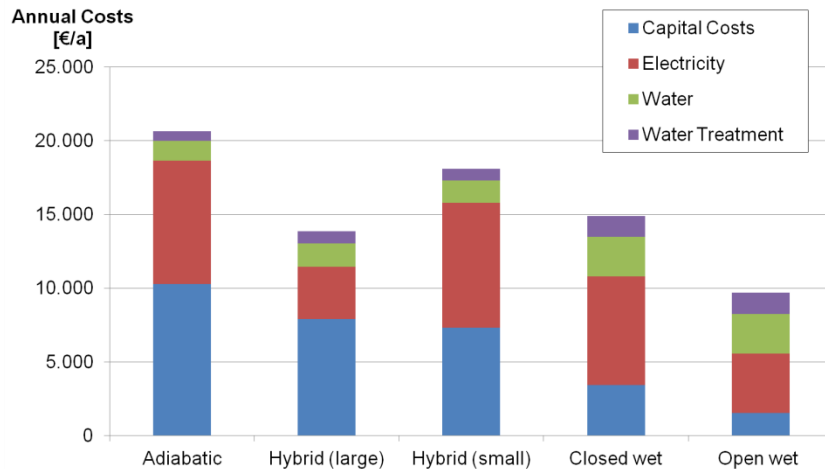
Waste heat rejection: 350 MWh/a
Full load hours: 1000 h/a



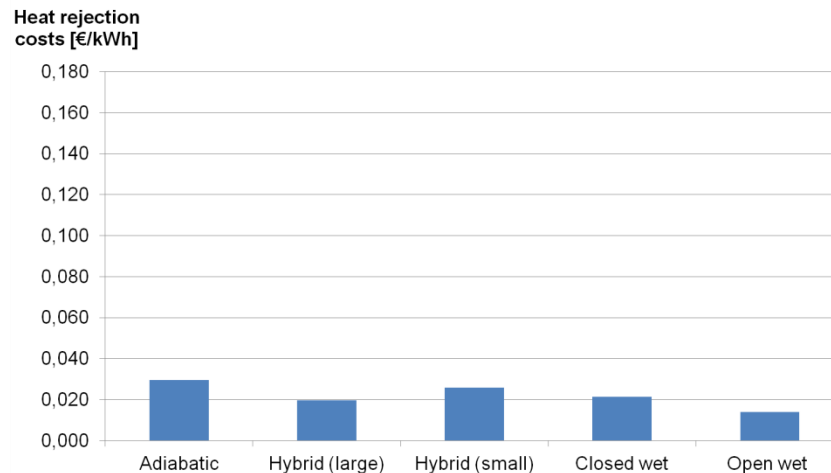
Heat rejection costs [€/kWh]



Scenario 4 – Very high cooling demand



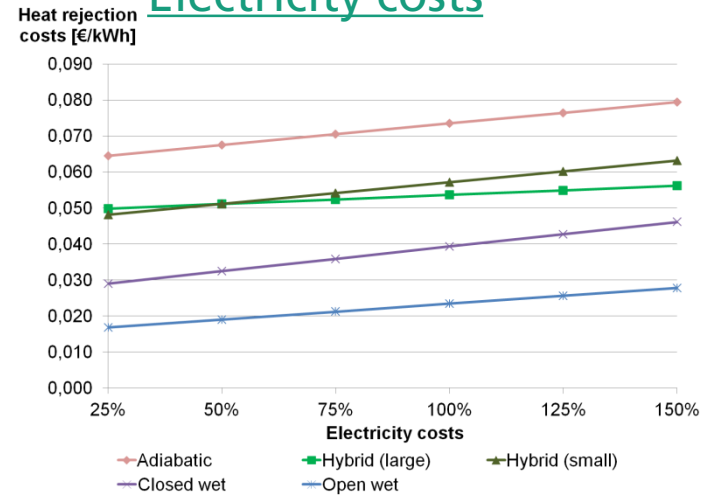
Waste heat rejection: 700 MWh/a
 Full load hours: 2000 h/a



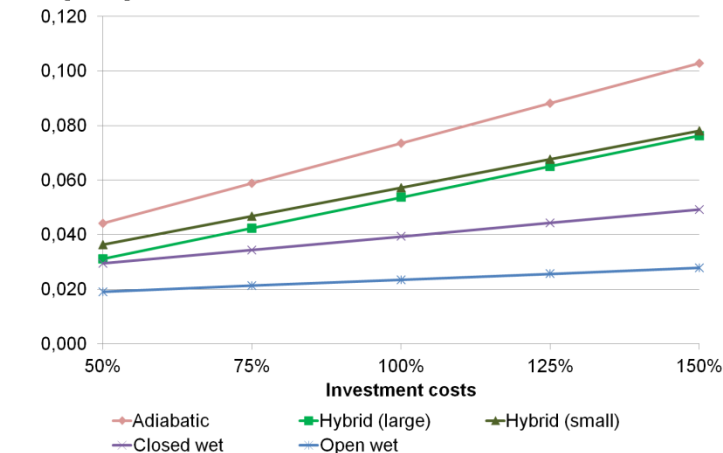
Sensitivity analysis: Scenario 2 – Moderate demand

Open wet cooling tower most economical
 → even under changing boundary conditions

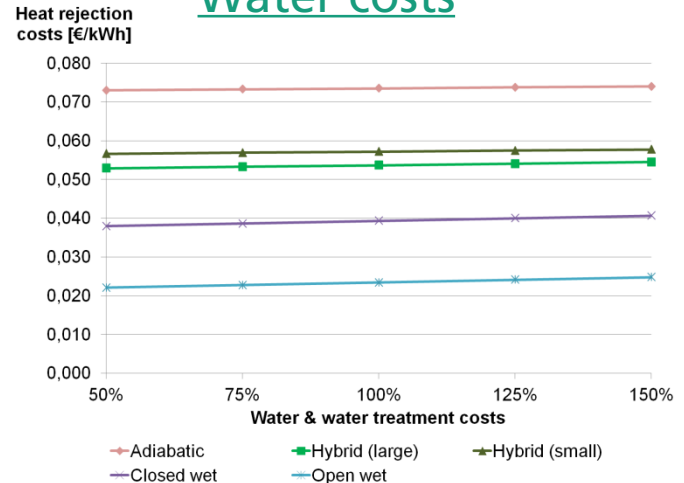
Electricity costs



Investment costs



Water costs



Acknowledgement

SPONSORED BY THE



Federal Ministry
of Education
and Research

The investigations presented here were embedded in the research project “Demonstration einer Prozessdampf- und Kälteerzeugung mit Solarkollektoren, Dampfstrahlkältemaschine und latenten Wärmespeichern” funded by the German Federal Ministry of Education and Research - BMBF and supported by the project manager DLR.

The beneficiary is grateful for the financial support.

Funding code: 1RI0908A



FRAUNHOFER UMSICHT

Thermal Energy Storage and Systems

Thank you for your attention!

Contact:

Fraunhofer UMSICHT

Osterfelder Str. 3
46047 Oberhausen
Germany

E-Mail: info@umsicht.fraunhofer.de
Internet: <http://www.umsicht.fraunhofer.de>



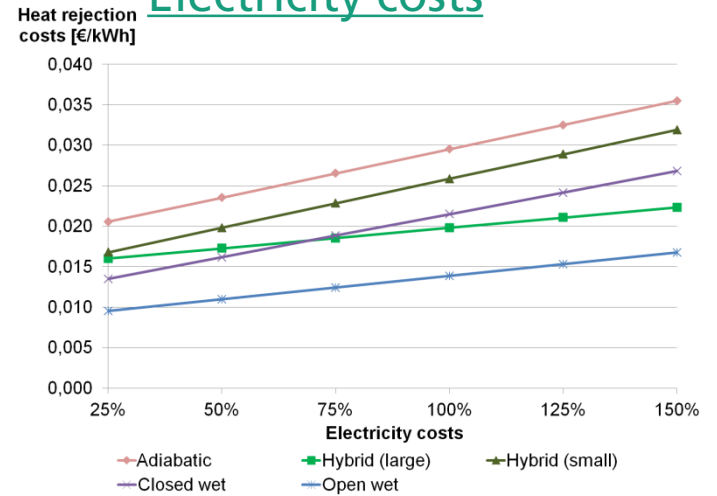
Foto: photocase.de

M.Sc. Michael Joemann

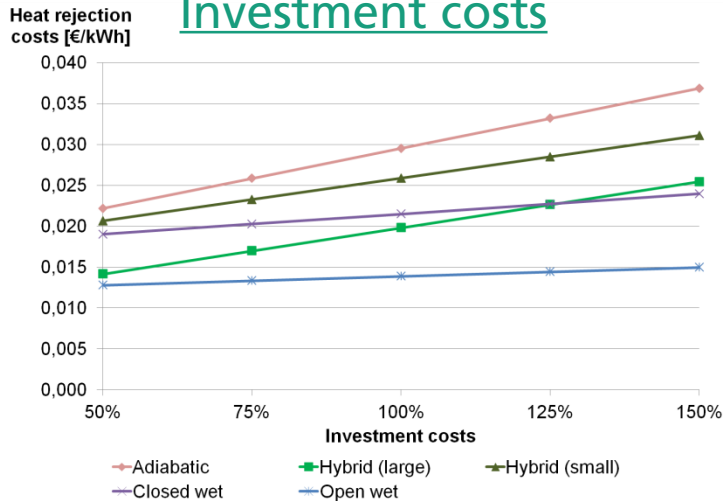
Telefon: +49 208-8598-1436
E-Mail: michael.joemann@umsicht.fraunhofer.de

Sensitivity analysis: Scenario 4 – Very high demand

Electricity costs



Investment costs



Water costs

