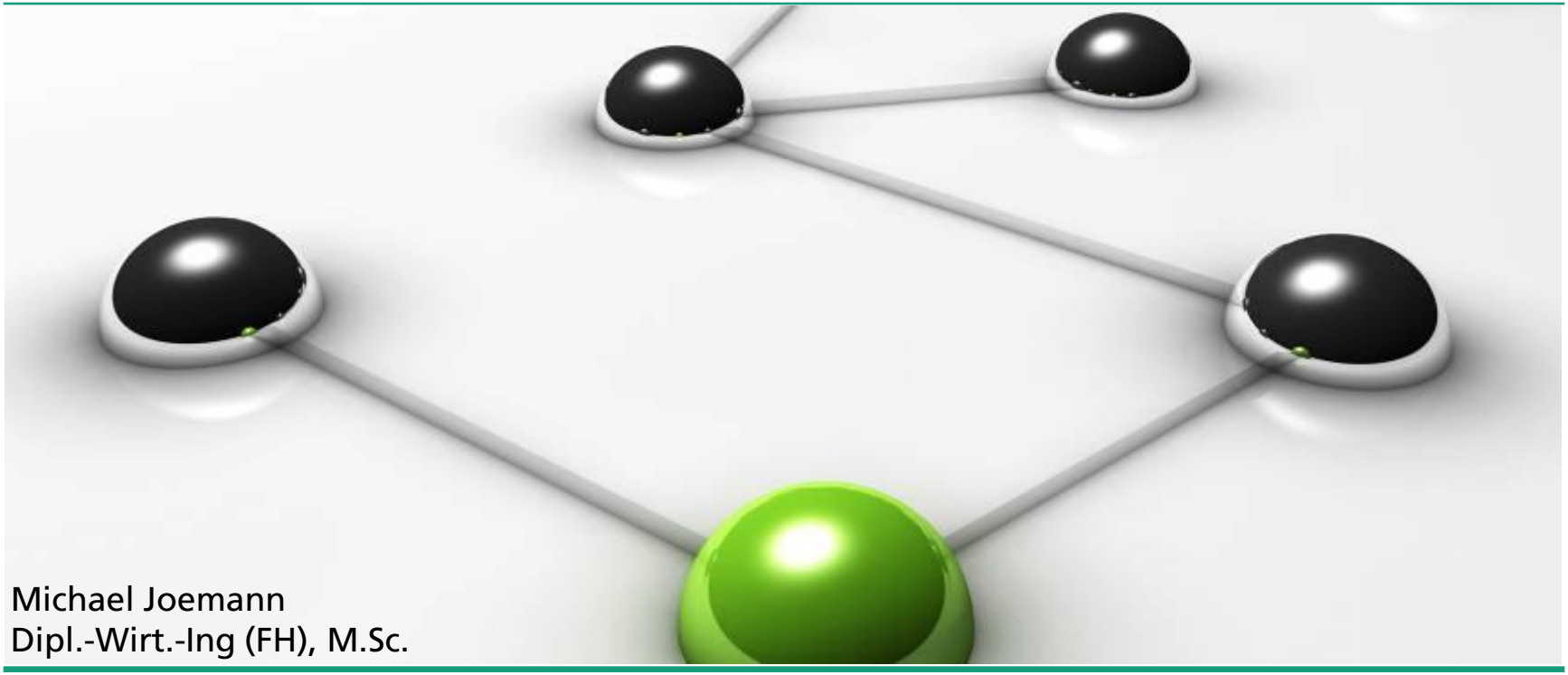
Static analysis of heat rejection systems for solar cooling applications

30 September 2013



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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 %

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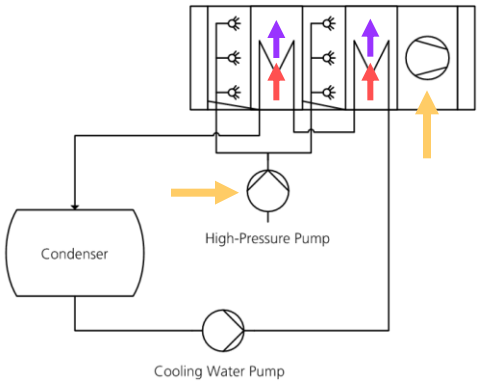
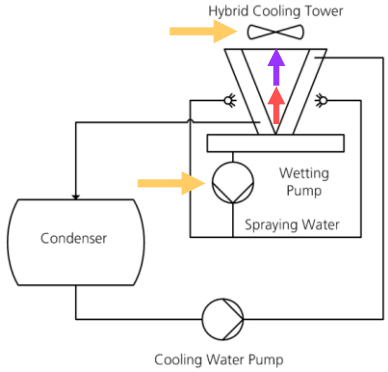
Heat rejection systems

Concept I
Adiabatic cooling tower

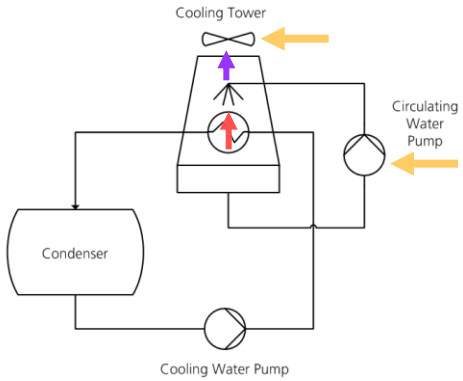


Concept II
Hybrid cooling tower

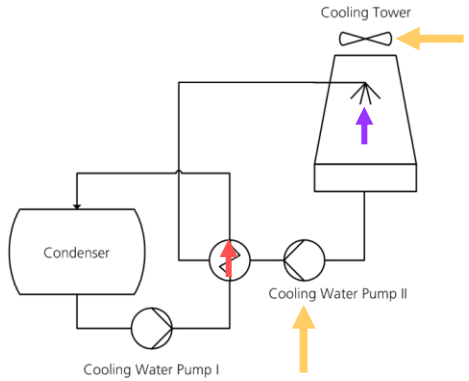


Heat transfer
Evaporation
Power

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

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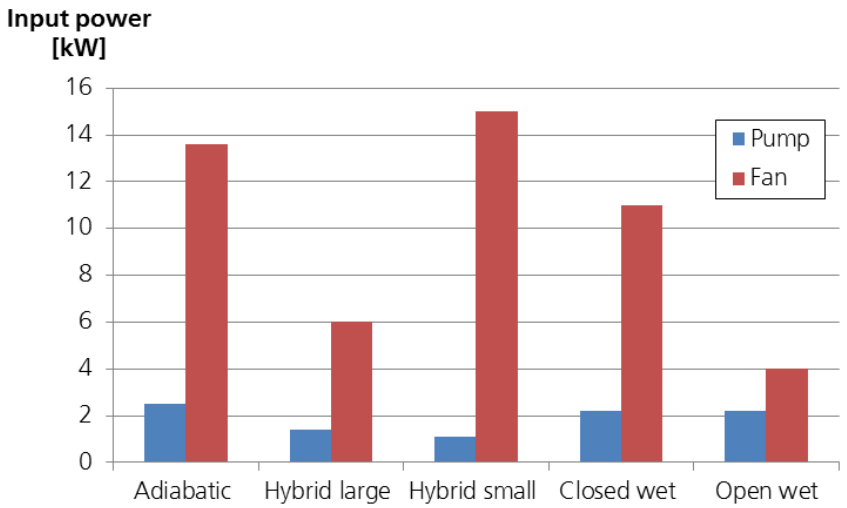
Technical data

		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	m³/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



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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

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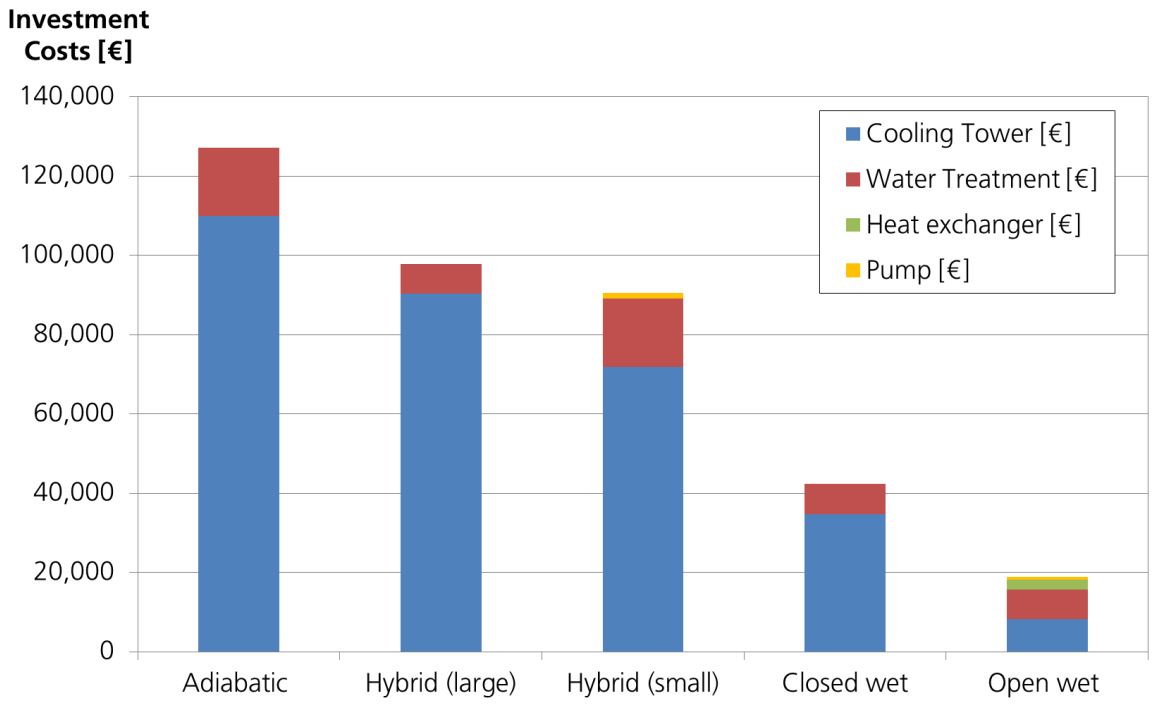
Investment costs



Specific investment costs

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

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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

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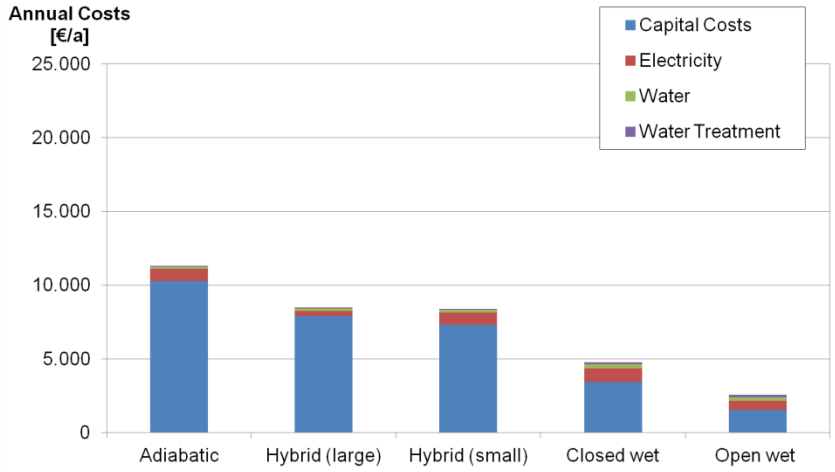
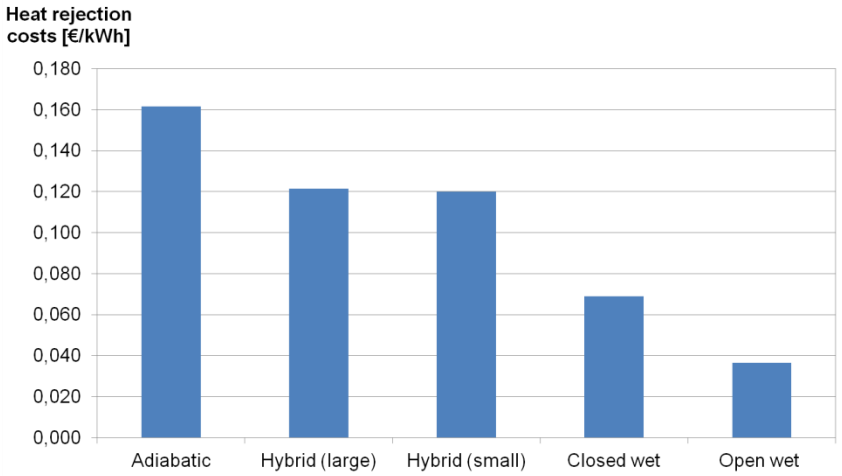
Scenario 1 – Low cooling demand



Waste heat rejection: 70 MWh/a

Full load hours: 200 h/a



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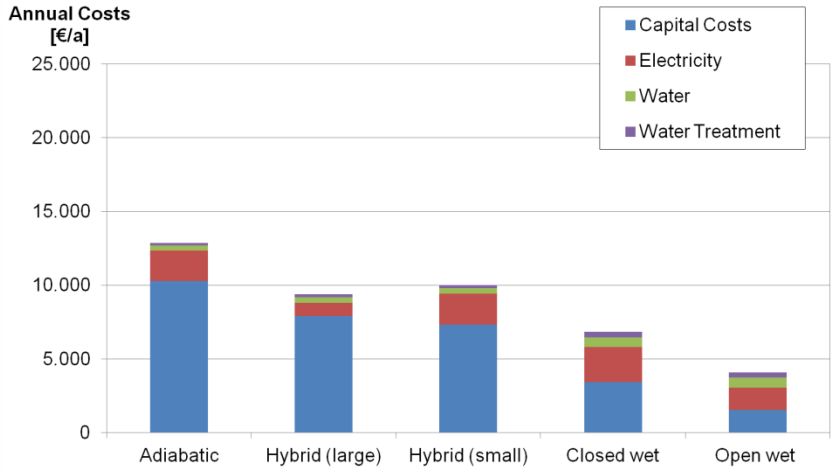
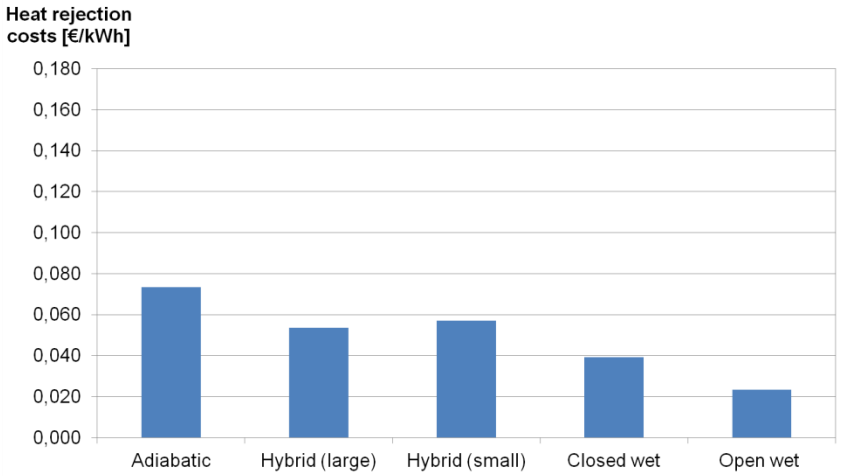
Scenario 2 – Moderate cooling demand



Waste heat rejection: 175 MWh/a

Full load hours: 500 h/a



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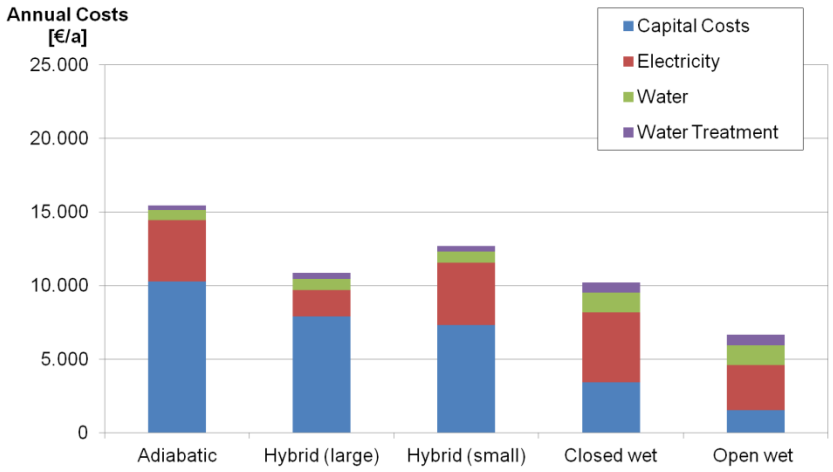
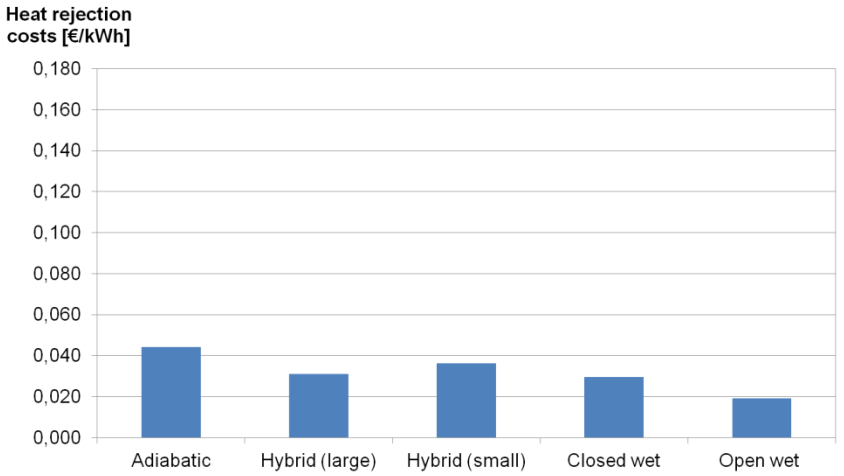
Scenario 3 – High cooling demand



Waste heat rejection: 350 MWh/a

Full load hours: 1000 h/a



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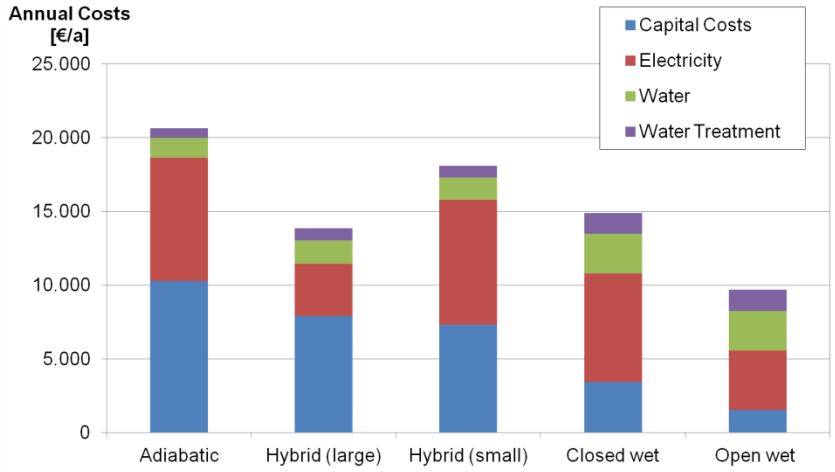
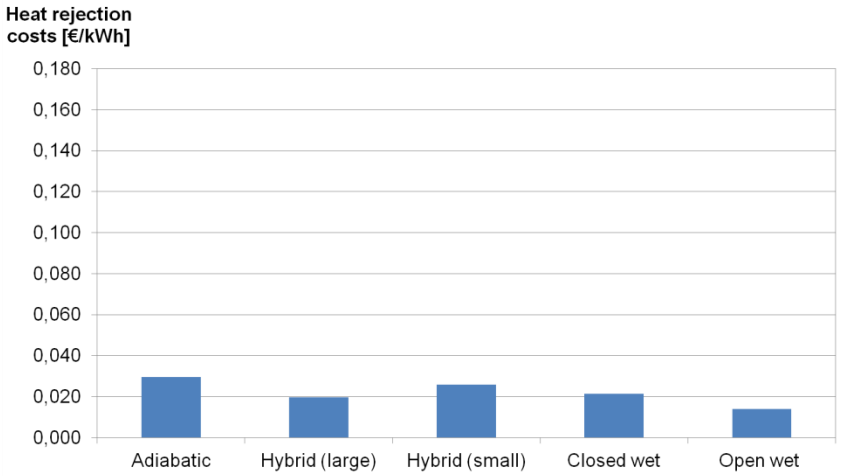
Scenario 4 – Very high cooling demand



Waste heat rejection: 700 MWh/a

Full load hours: 2000 h/a



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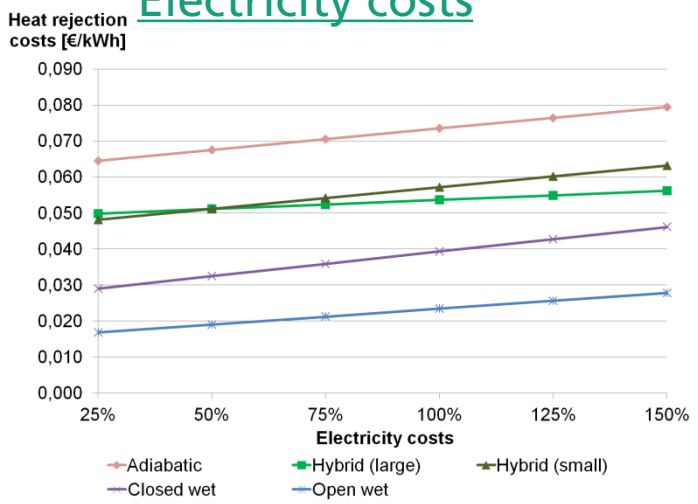
Sensitivity analysis: Scenario 2 – Moderate demand

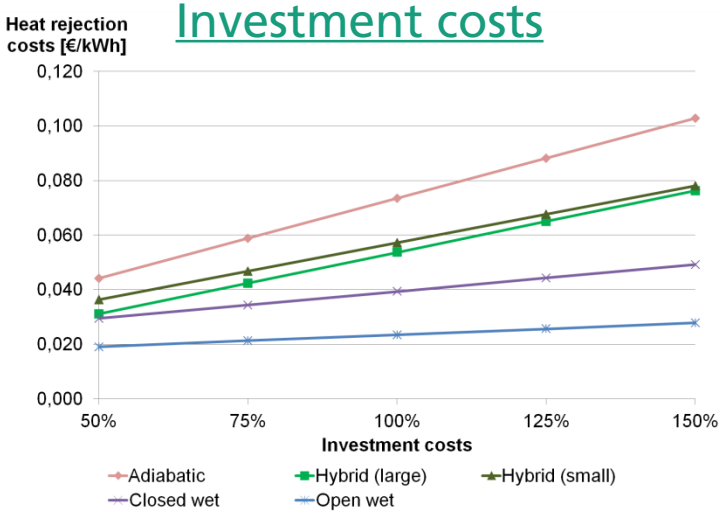
Open wet cooling tower most economical

→ even under changing boundary conditions

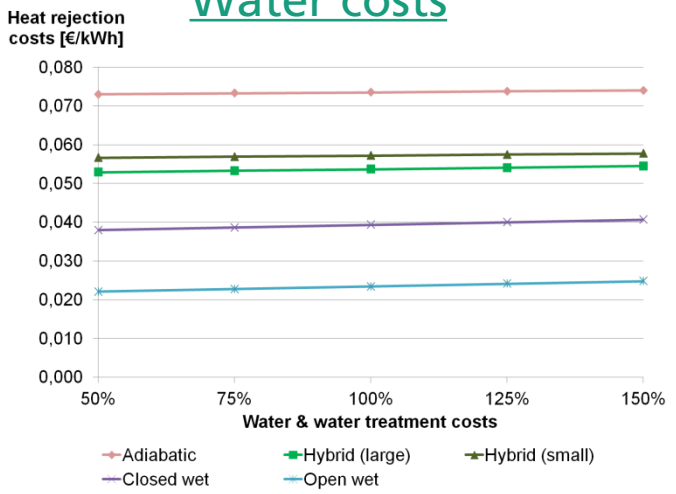
Electricity costs



Investment costs



Water costs



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Thermal Energy Storage and Systems

Thank you for your attention!

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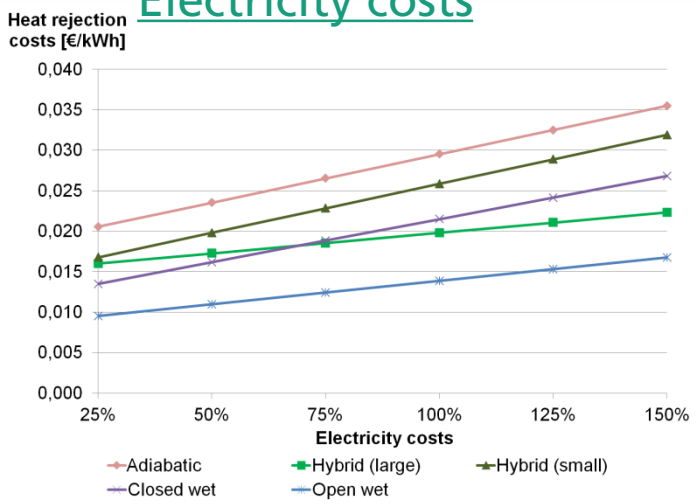
Sensitivity analysis: Scenario 4 – Very high demand

Electricity costs



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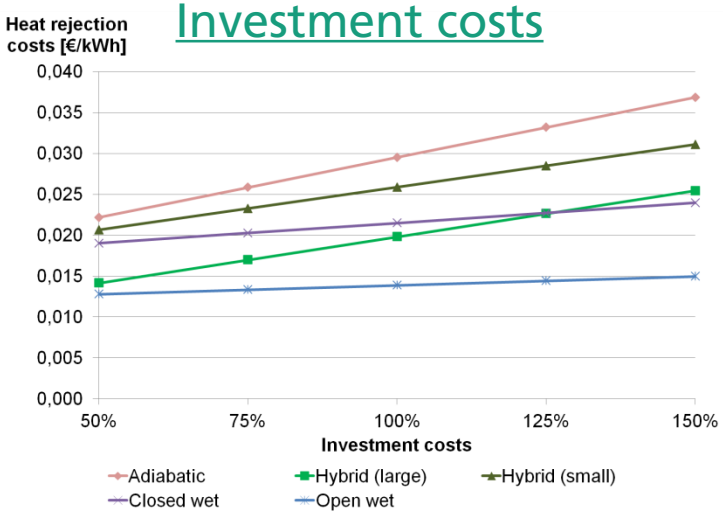
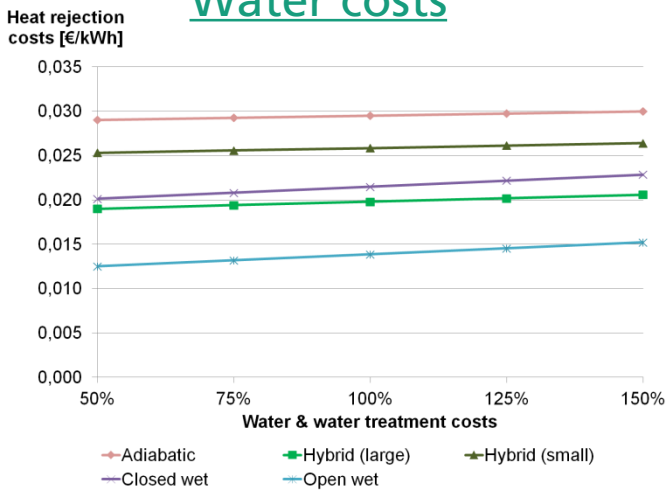


Water costs



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