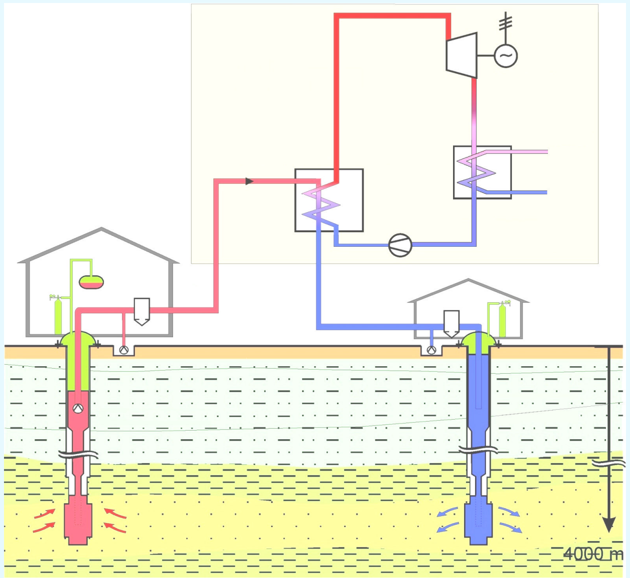
DESIGN OF GEOTHERMAL POWER PLANTS

holistic approach considering auxiliary power



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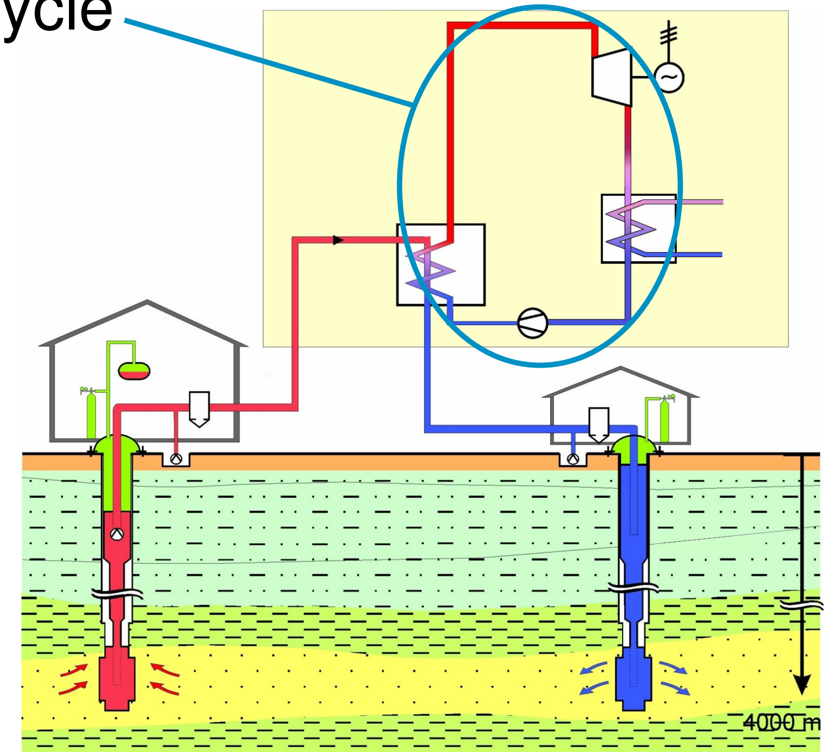
Introduction

- Power plants serve for net power production
- Net power = gross power - auxiliary power
- Auxiliary power { conversion cycle

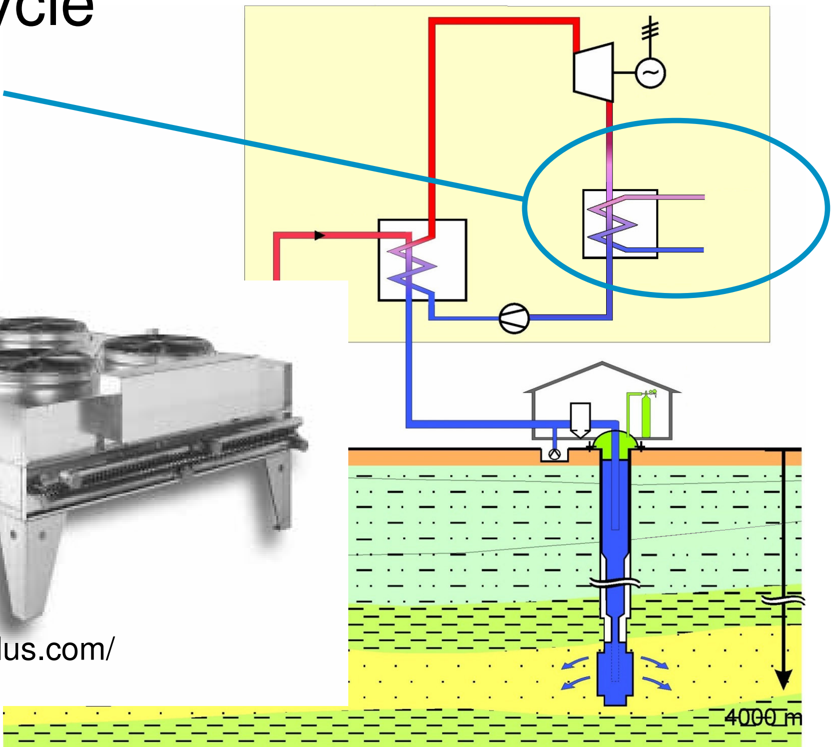


Introduction

- Power plants serve for net power production
- Net power = gross power - auxiliary power
- Auxiliary power { conversion cycle, cooling cycle }

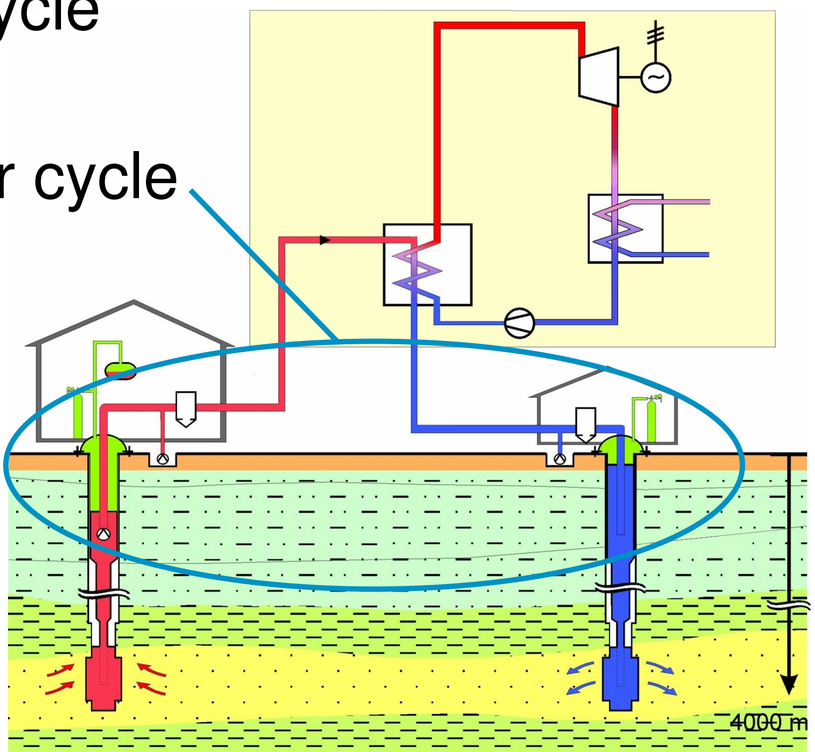
source: http://www.erdwaerme-kraft.de/

source: http://www.refplus.com/



Introduction

- Power plants serve for net power production
- Net power = gross power - auxiliary power
- Auxiliary power
  - conversion cycle
  - cooling cycle
  - thermal water cycle



Introduction

- Power plants serve for net power production

- Net power = gross power - auxiliary power

- Auxiliary power { conversion cycle; cooling cycle; thermal water cycle }

➡ For geothermal power plants, a maximum net power output can‘t be reached by maximising the gross power

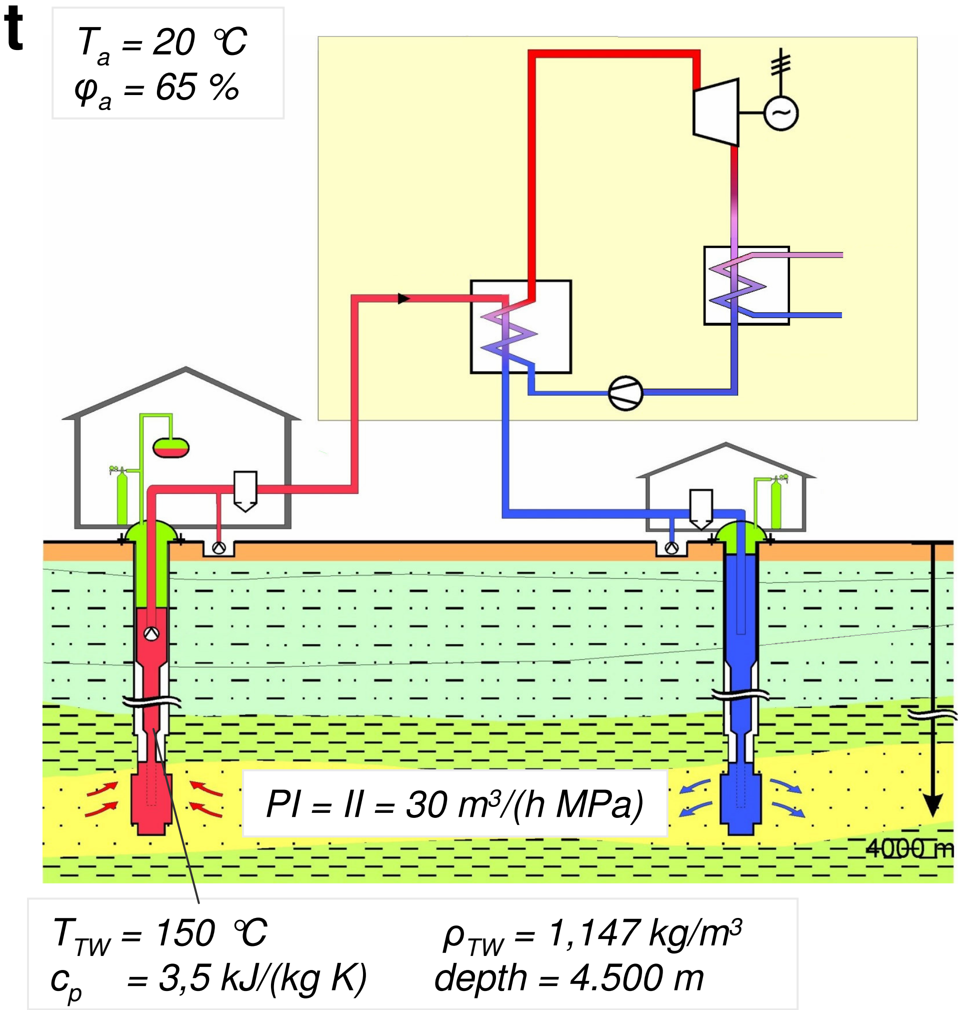
➡ Geothermal power plant design needs a holistic approach

Overview

- Methodical approach to power plant design
- Gross power characteristics
- Auxiliary power characteristics
- Practical approach to power plant design
- Conclusions & Outlook

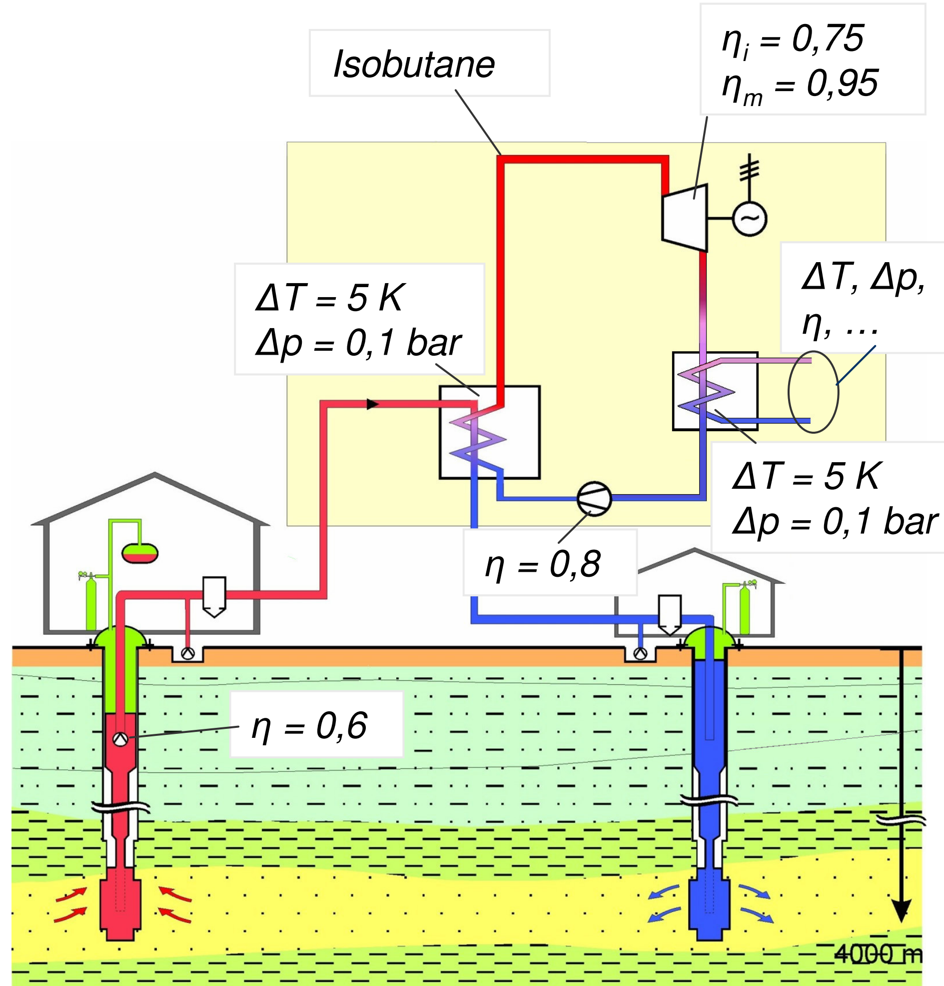
Methodical approach

- **site-specific reservoir characteristics and ambient conditions**
  (→ boundary conditions)



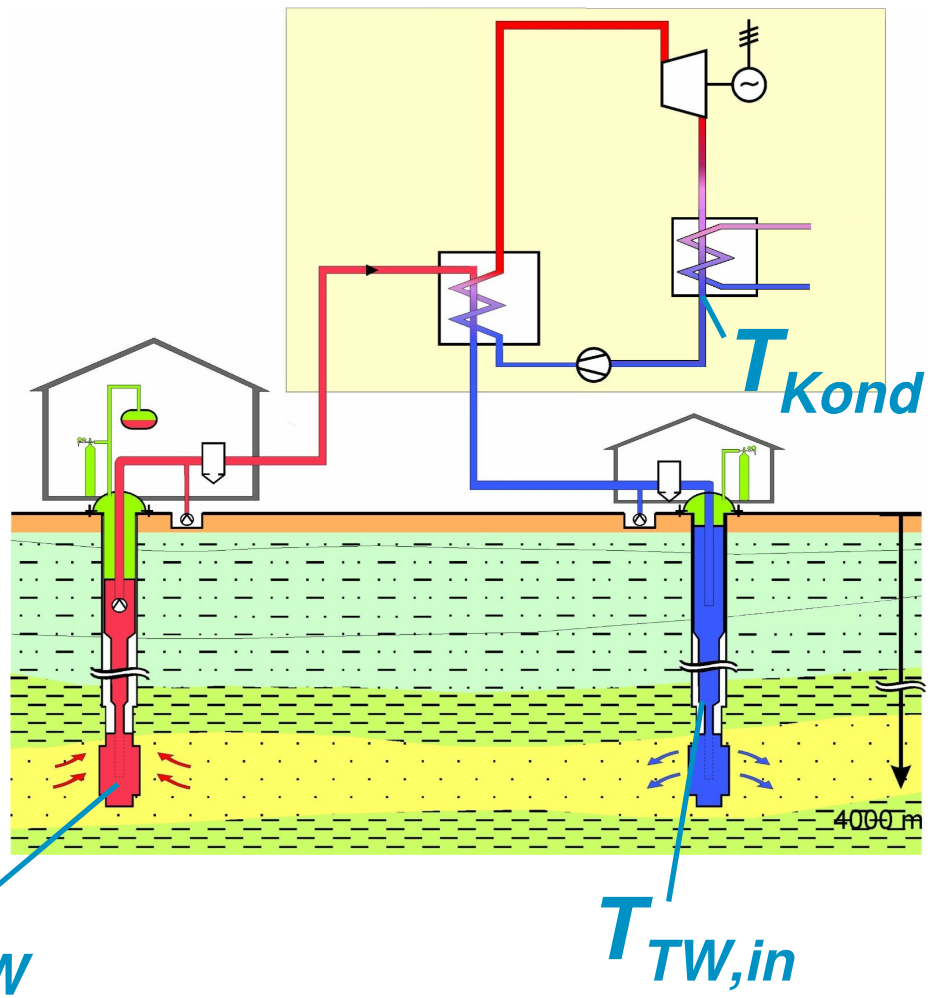
Methodical approach

- site-specific reservoir characteristics and ambient conditions (→ boundary conditions)
- **plant-specific parameters** (→ component quality)



Methodical approach

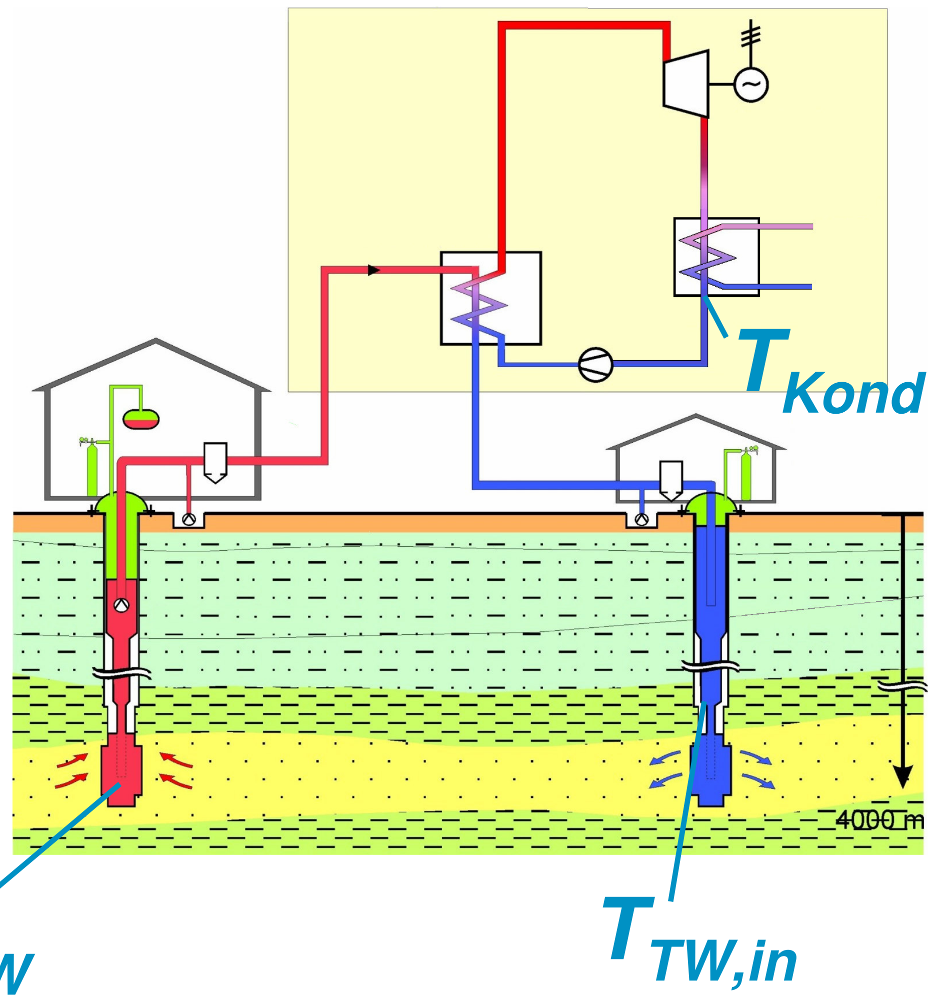
- site-specific reservoir characteristics and ambient conditions
  (→ boundary conditions)
- plant-specific parameters
  (→ component quality)
- **design parameters**:
  condensation temp. T_{Kond}
  injection temperature $T_{TW,in}$
  thermal water mass flow $\dot{m}_{TW}$



Methodical approach

- site-specific reservoir characteristics and ambient conditions (→ boundary conditions)
- plant-specific parameters (→ component quality)
- **design parameters**:

What influence have the design parameters on power plant performance?



Methodical approach

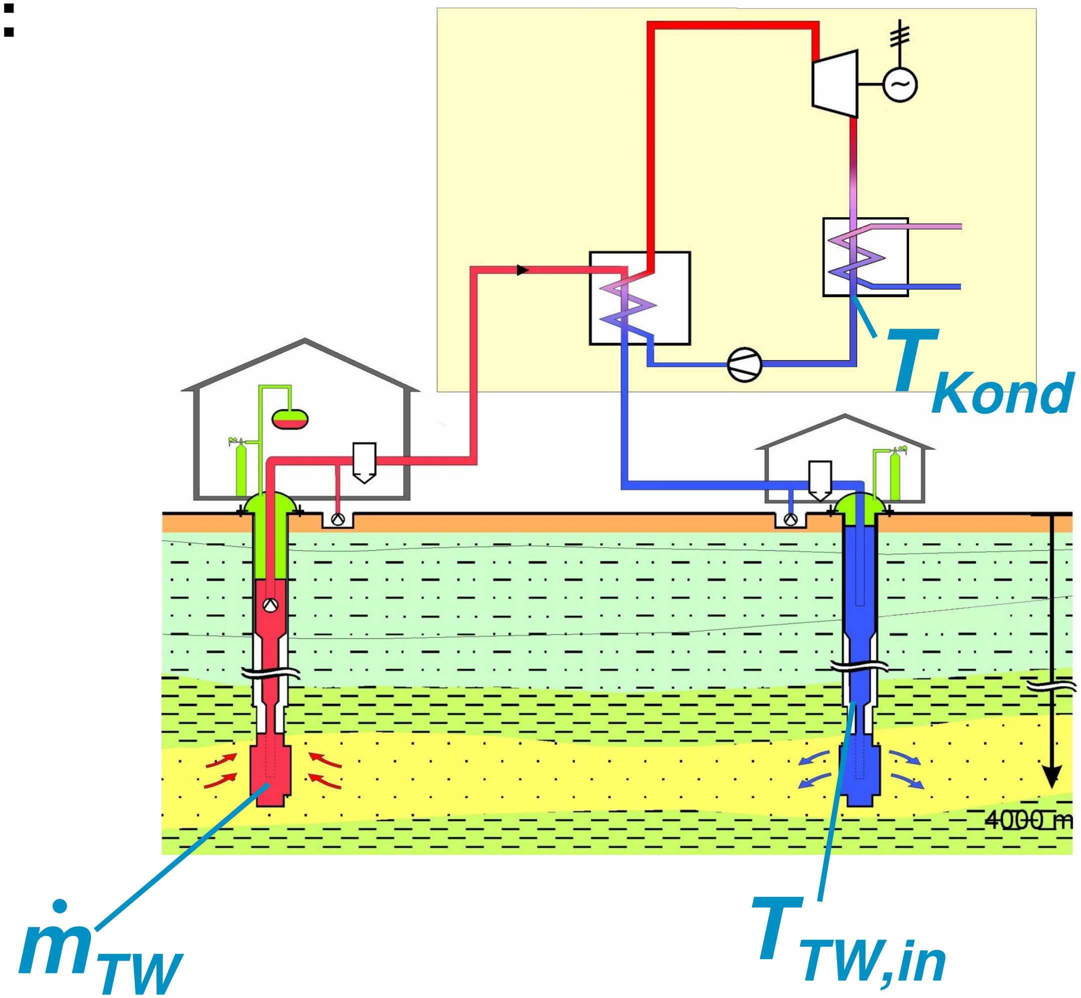
Exemplary power plant in the North German Basin:

$T_{TW} = 150\ °C$

$PI = 30\ m^3/(h\ MPa)$

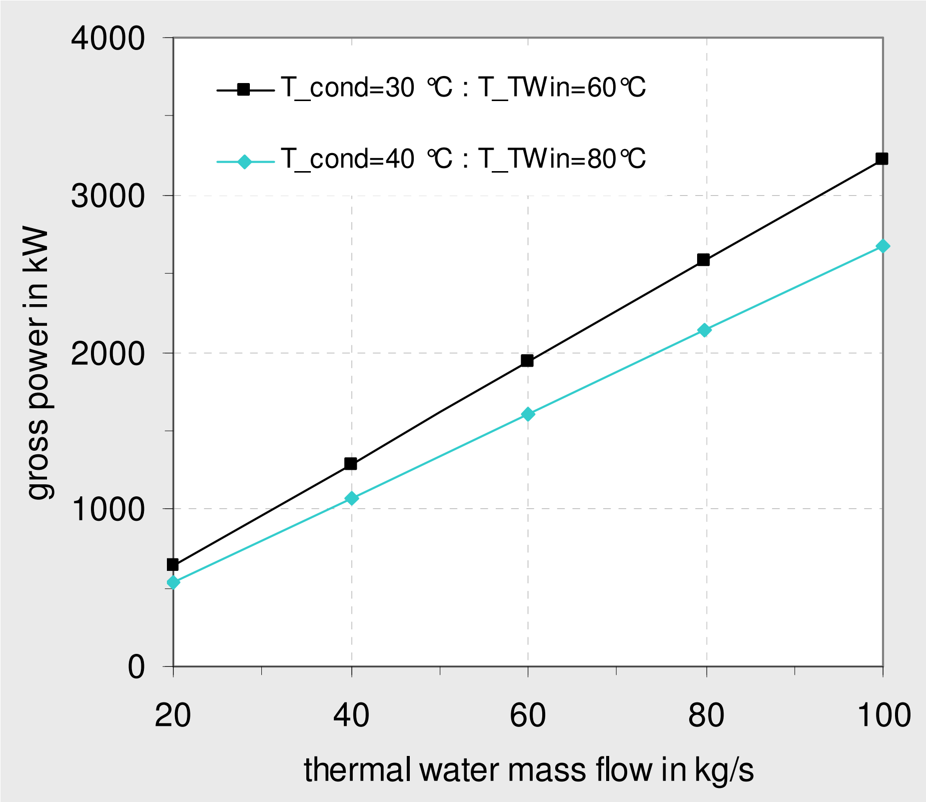
...

other parameters see slide 13



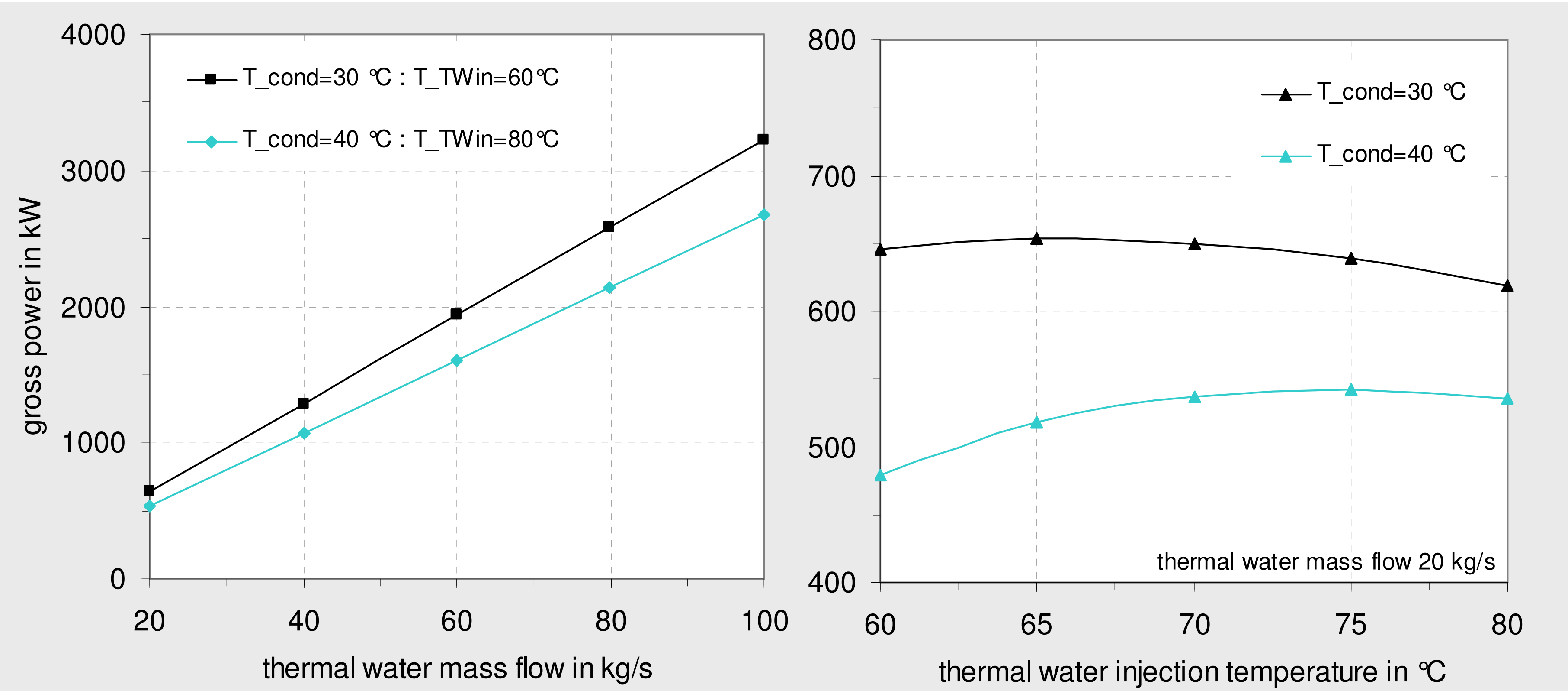
Gross power characteristics

Plant-specific parameters, reservoir and ambient conditions = const. (see slide 13)



Gross power characteristics

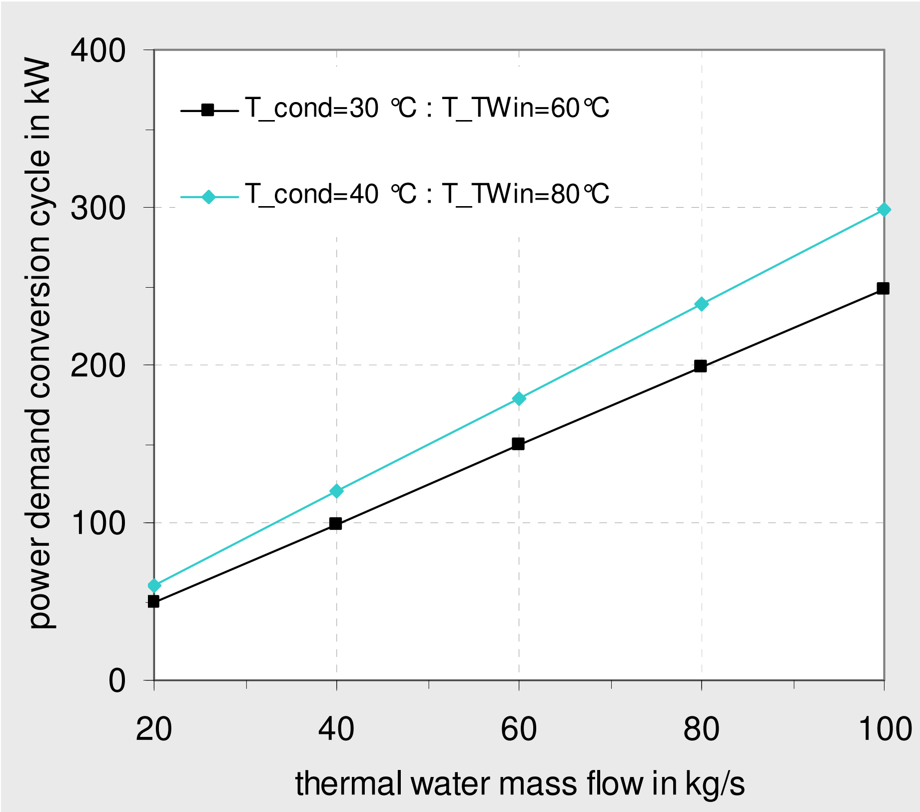
Plant-specific parameters, reservoir and ambient conditions = const. (see slide 13)



$$\text{gross power} = f\,(T_{cond}, T_{TW,in}) \cdot \dot{m}_{TW}$$

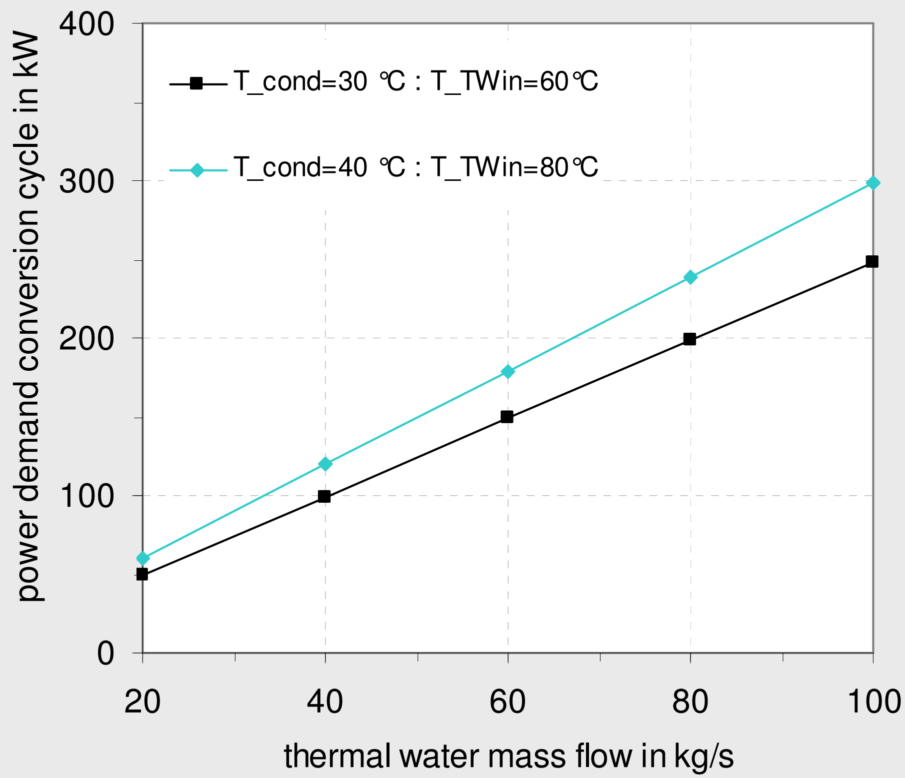
Auxiliary power characteristics
Conversion cycle

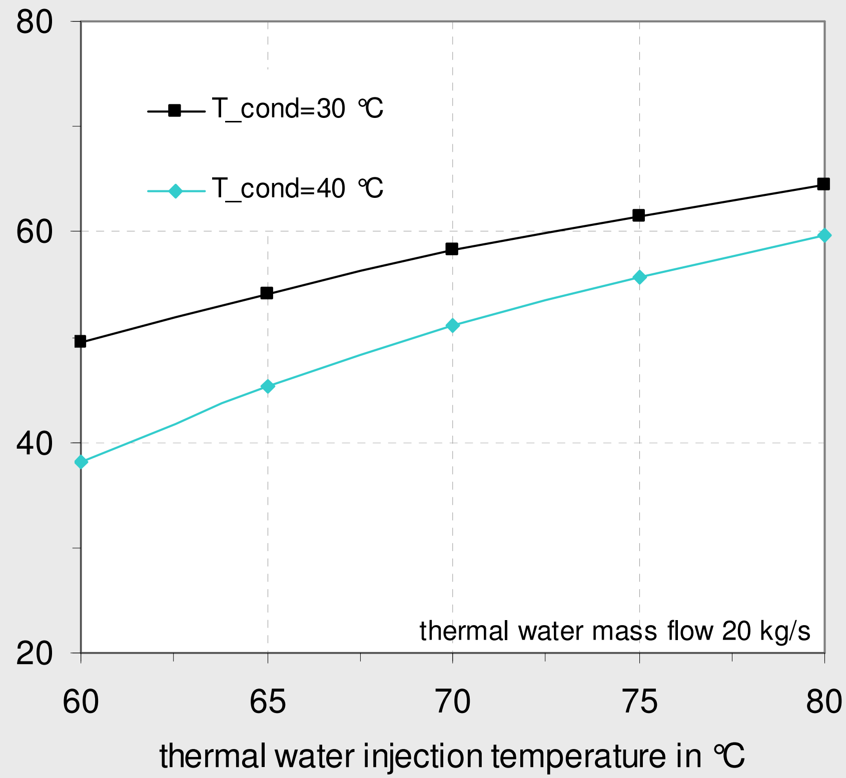
Plant-specific parameters, reservoir and ambient conditions = const. (see slide 13)



Auxiliary power characteristics
Conversion cycle

Plant-specific parameters, reservoir and ambient conditions = const. (see slide 13)



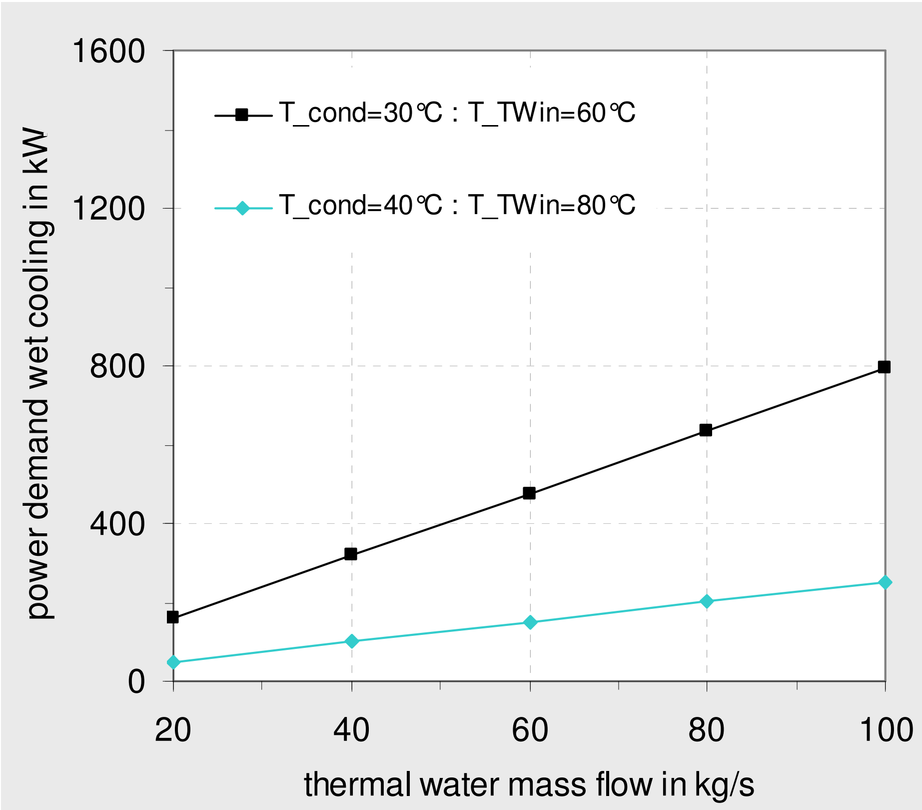


$$\Rightarrow \text{Power demand}_{\text{conversion cycle}} = f\,(T_{cond}, T_{TW,in}) \cdot \dot{m}_{TW}$$

Auxiliary power characteristics

Cooling cycle (wet cooling tower)

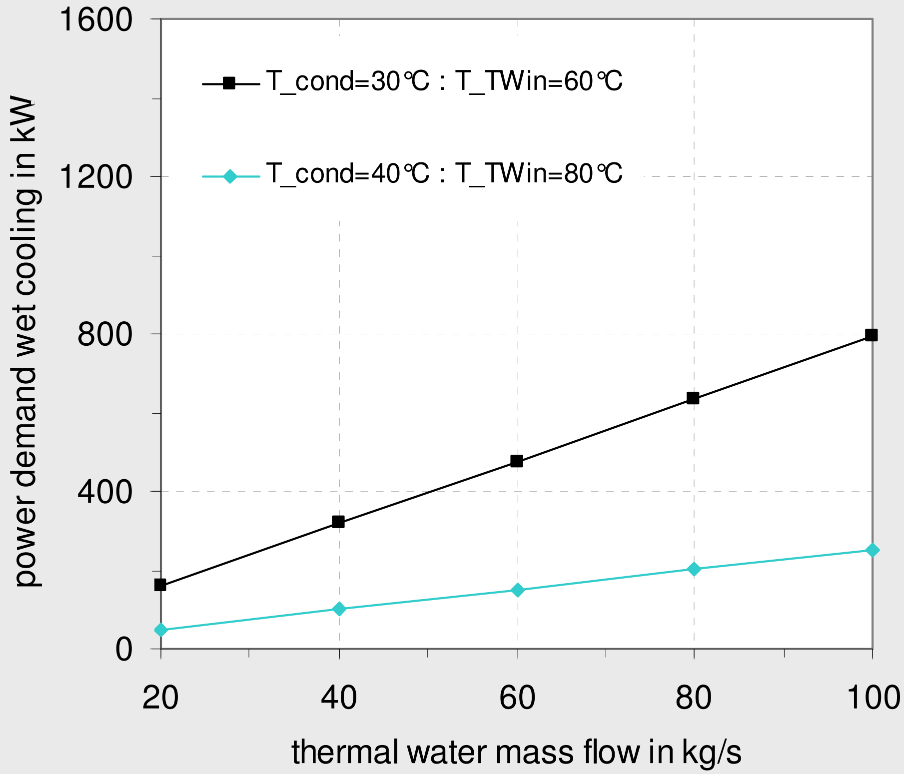
Plant-specific parameters, reservoir and ambient conditions = const. (see slide 13)

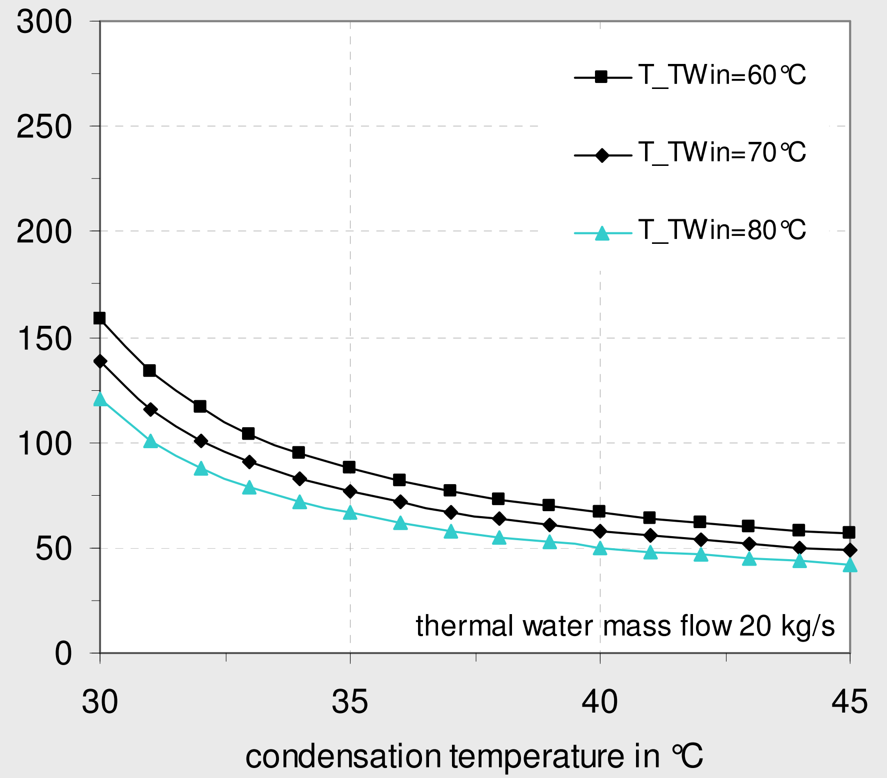


Auxiliary power characteristics

Cooling cycle (wet cooling tower)

Plant-specific parameters, reservoir and ambient conditions = const. (see slide 13)

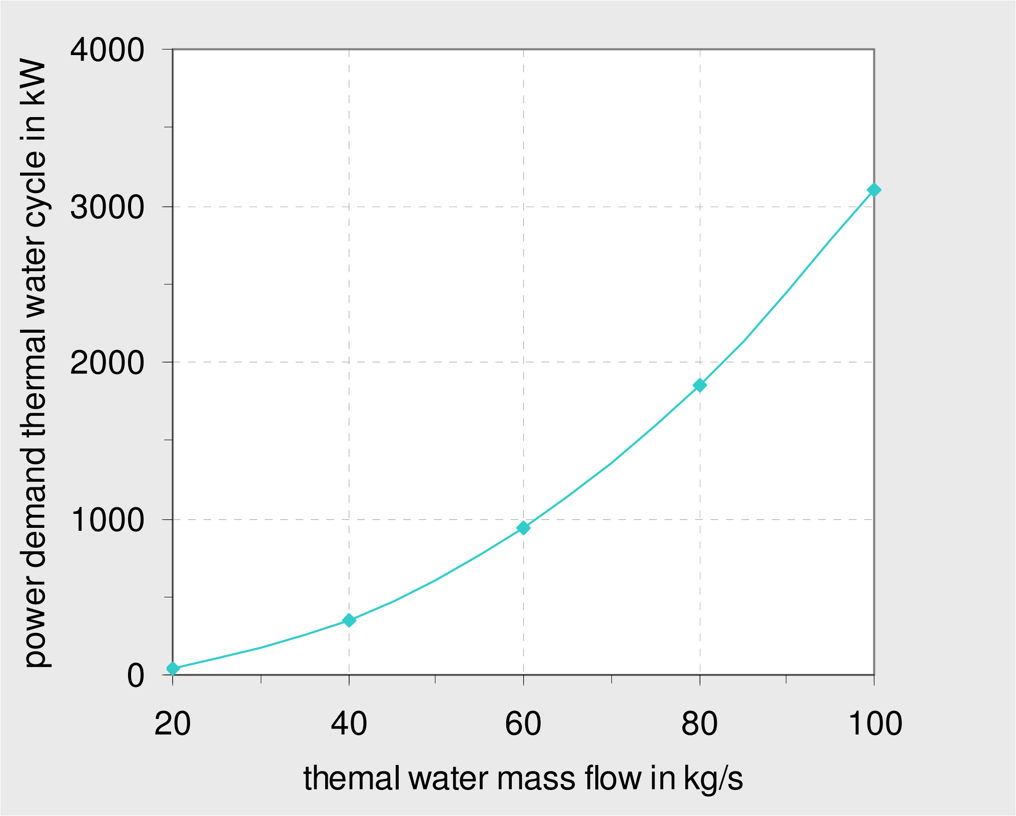




$$\text{Power demand}_{\text{cooling cycle}} = f\,(T_{cond}) \cdot T_{TW,in} \cdot \dot{m}_{TW}$$

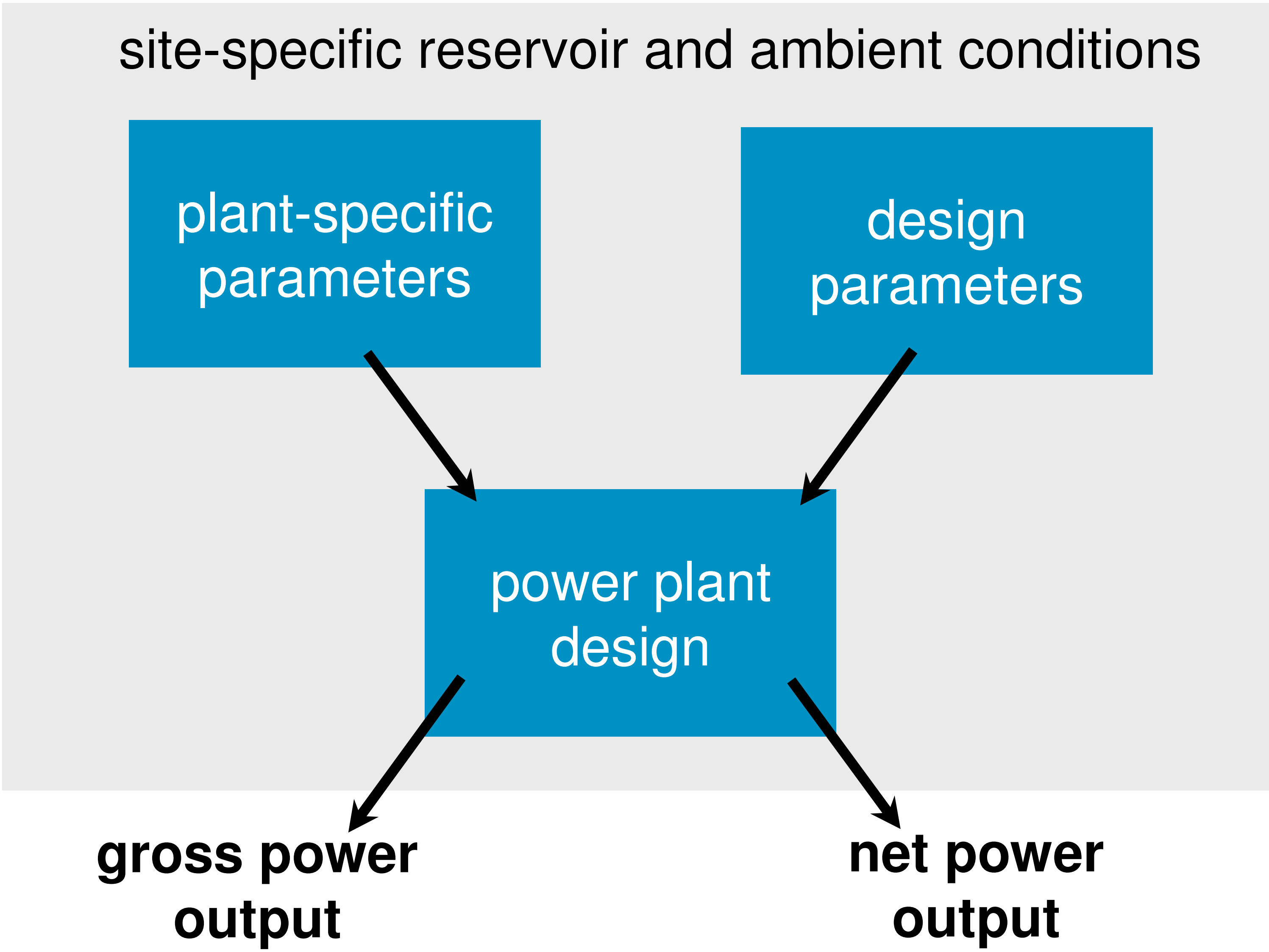
Thermal water cycle

Plant-specific parameters, reservoir and ambient conditions = const. (see slide 13)

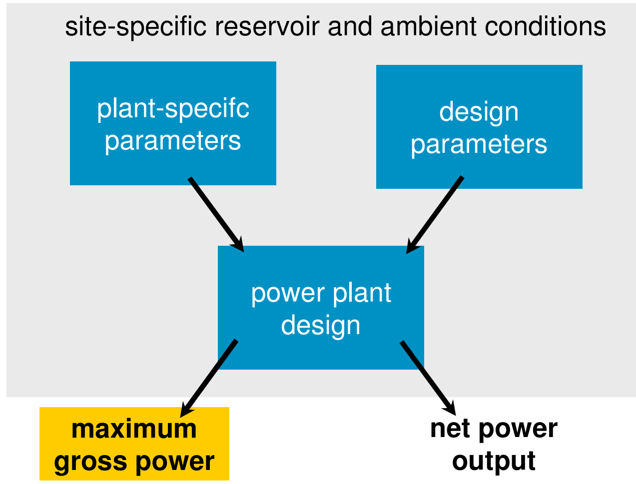


Power demand $_{\text{thermal water cycle}} = f\ (\dot{m}_{TW})$

Practical approach



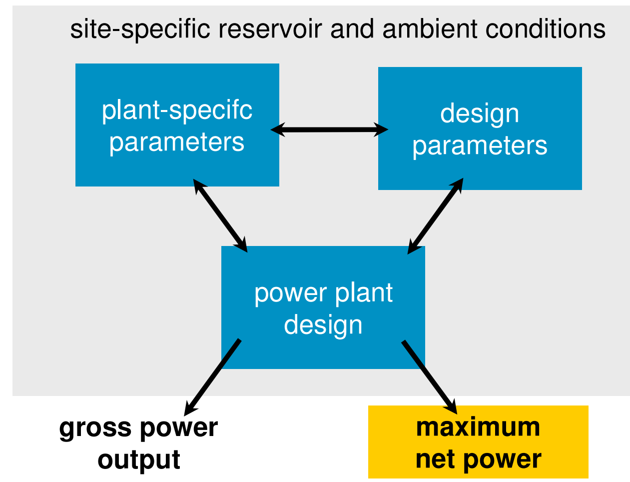
Exemplary power plant design



	maximum gross power (wet cooling)	maximum net power (wet cooling)
reservoir conditions	T_{TW} = 150 °C, PI = 30 m^3/(h MPa), $depth_{reservoir}$ = 4,500 m	
thermal water mass flow	56 kg/s	
th. water injection temp.	66 °C	
condensation temp.	30 °C	
gross power	1,8 MW	
net power	460 kW	

Plant-specific parameters, ambient conditions = const. (see slide 13)

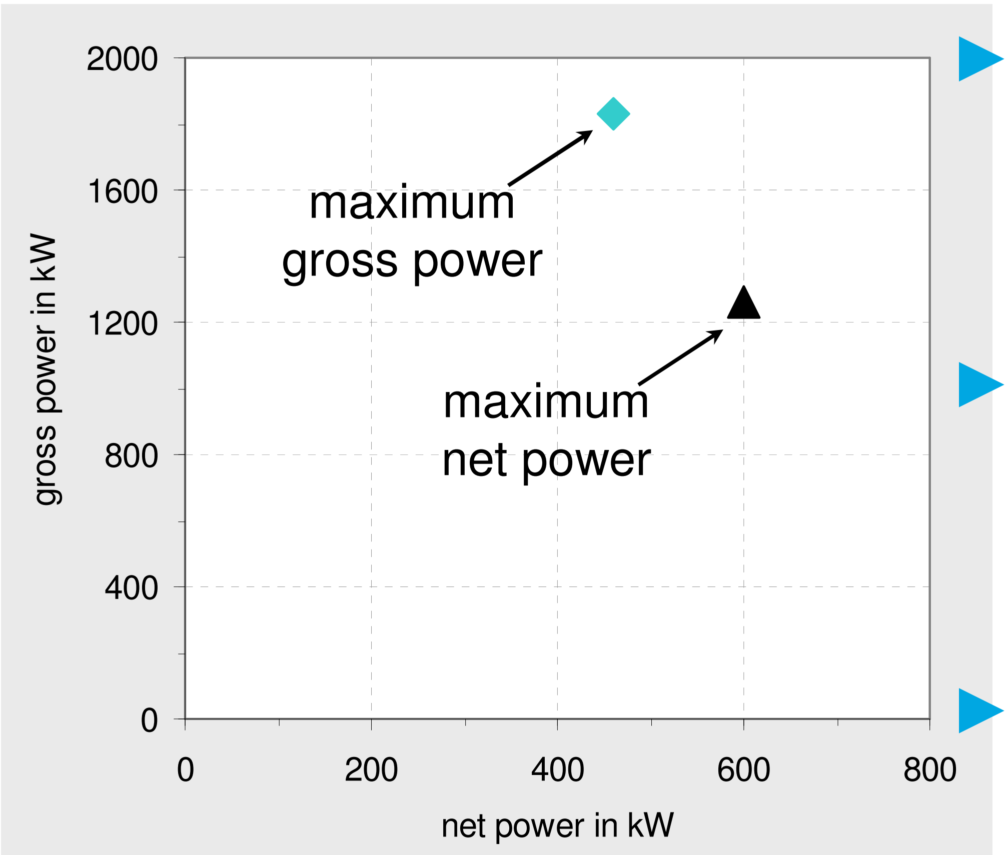
Exemplary power plant design



	maximum gross power (wet cooling)	maximum net power (wet cooling)
reservoir conditions	T_{TW} = 150 °C, PI = 30 m^3/(h MPa), $depth_{reservoir}$ = 4,500 m	
thermal water mass flow	56 kg/s	41 kg/s
th. water injection temp.	66 °C	71 °C
condensation temp.	30 °C	33 °C
gross power	1,8 MW	1,3 MW
net power	460 kW	600 kW

Plant-specific parameters, ambient conditions = const. (see slide 13)

Conclusions



- *Choice of* $\dot{m}_{TW}$, $T_{TW,in}$ and T_{cond} has a decisive impact on power plant performance
- A maximum net power output can‘t be reached by maximising the gross power!
- Geothermal power plant design needs a holistic approach

Outlook

- Successful geothermal project development needs a detailed and site-specific analysis
- Further technical constraints need to be considered
- Possible combination with other energy carriers to hybrid-plants (…please have a look at the poster "The combined use of geothermal and biomass for power generation - drawbacks and opportunities –")

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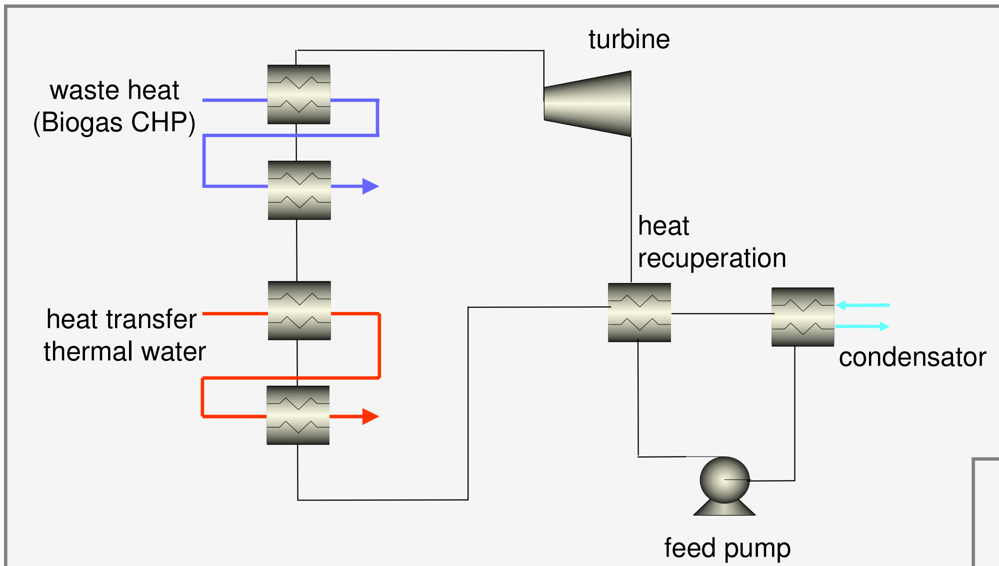
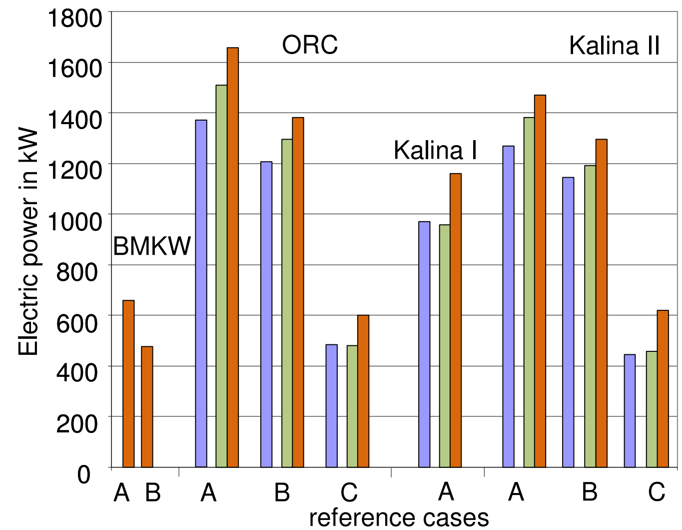
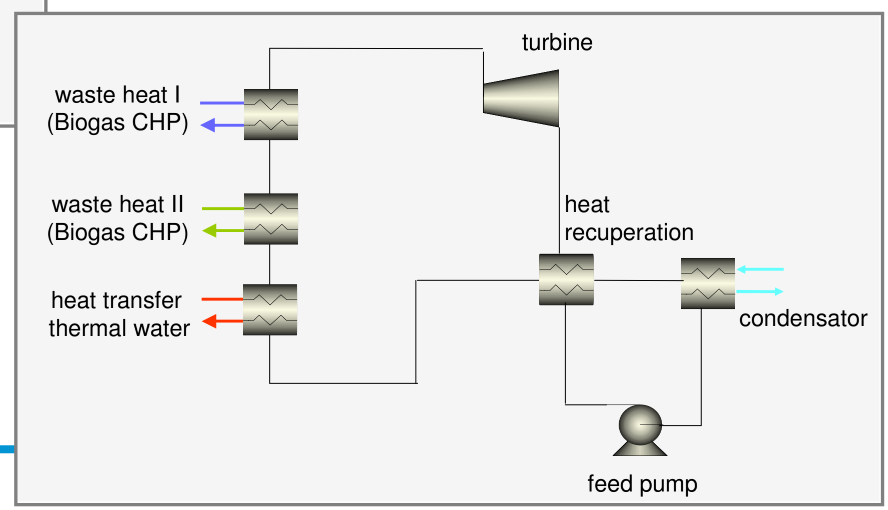
The combined use of geothermal and biomass for power generation - drawbacks and opportunities -

ENGINE Final Conference poster session

Jan Wrobel [a], Martin Kaltschmitt [a,b]







[a] Institute for Environmental Technology and Energy Economics, Hamburg University of Technology

[b] Institute for Energy and Environment

Outlook

- Successful geothermal project development needs a detailed and site-specific analysis
- Further technical constraints need to be considered
- Possible combination with other energy carriers to hybrid-plants (…please have a look at the poster "The combined use of geothermal and biomass for power generation - drawbacks and opportunities –")
- Non-technical aspects can be further limiting factors
- Successful geothermal development needs integrating, holistic planning tools

Thank you very much for your attention!

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Plant-specific parameters & site-specifc conditions

	plant-specific parameters	reservoir and ambient conditions
conversion cycle	turbine isentropic efficiency 75% turbine mechanical efficiency 95% heat exchanger temp. gradients 5K heat exchanger pressure losses 0,1 bar working fluid Isobutane	
cooling cycle	*wet cooling:* water-sided pressure losses 1 bar air-sided pressure losses 0,002 bar cooling range 6K approach 3K cooling tower constant 0,8 cooling pump efficiency 80% fan efficiency 80% *dry cooling:* air-sided pressure losses 0,002 bar fan efficiency 80%	ambient temperature 20℃ relative humidity 60%
thermal water cycle	down-hole pump efficiency 60% misc. parameter see [Legarth, 2005]	thermal water temperature 150℃ reservoir depth 4,500 m thermal water heat capacity 3,5 kJ/(kg K) thermal water density 1,147 kg/m^3 productivity-/injectivity index 30 m^3/(h MPa)

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Exemplary run of power output against thermal water injection temperature

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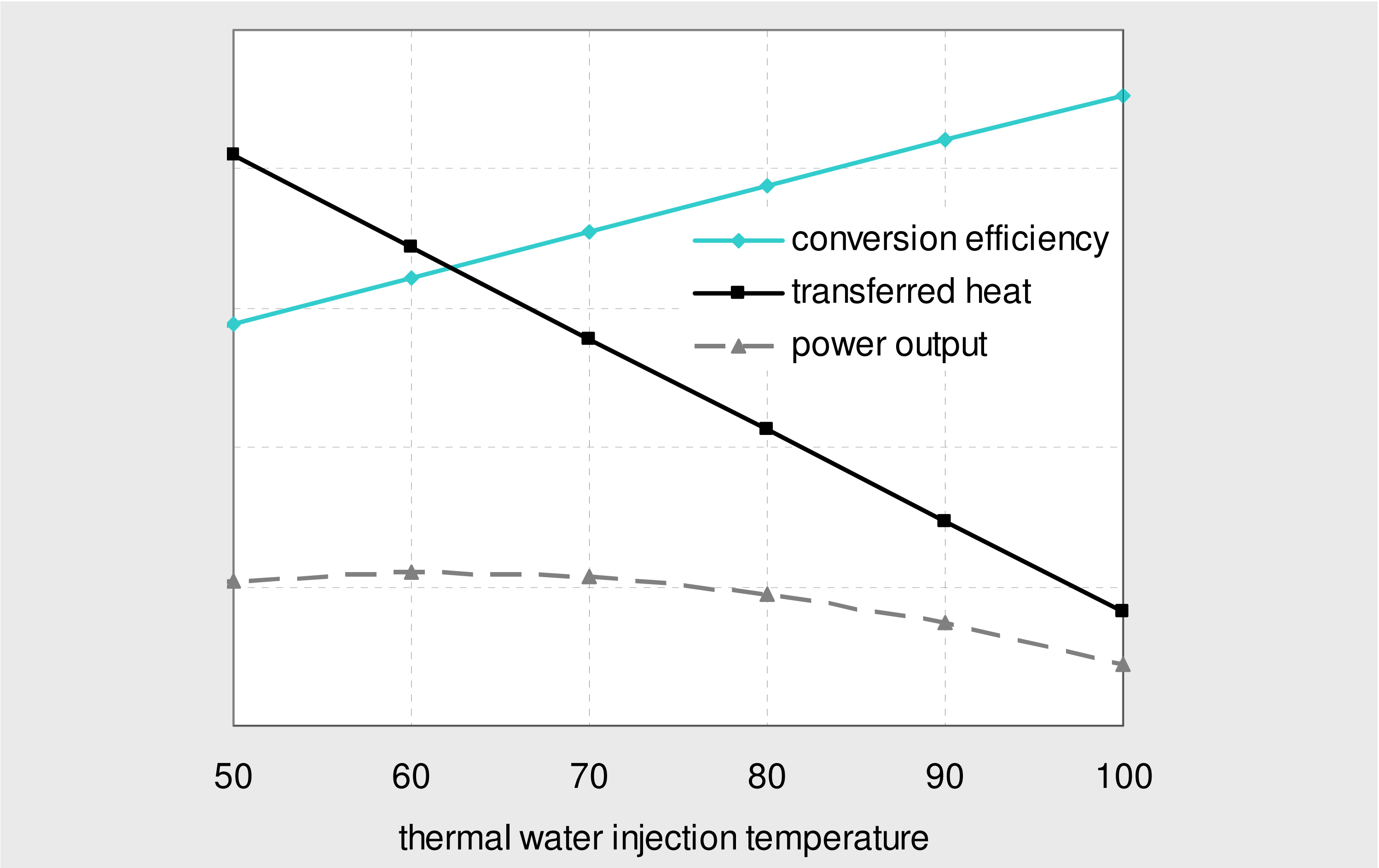
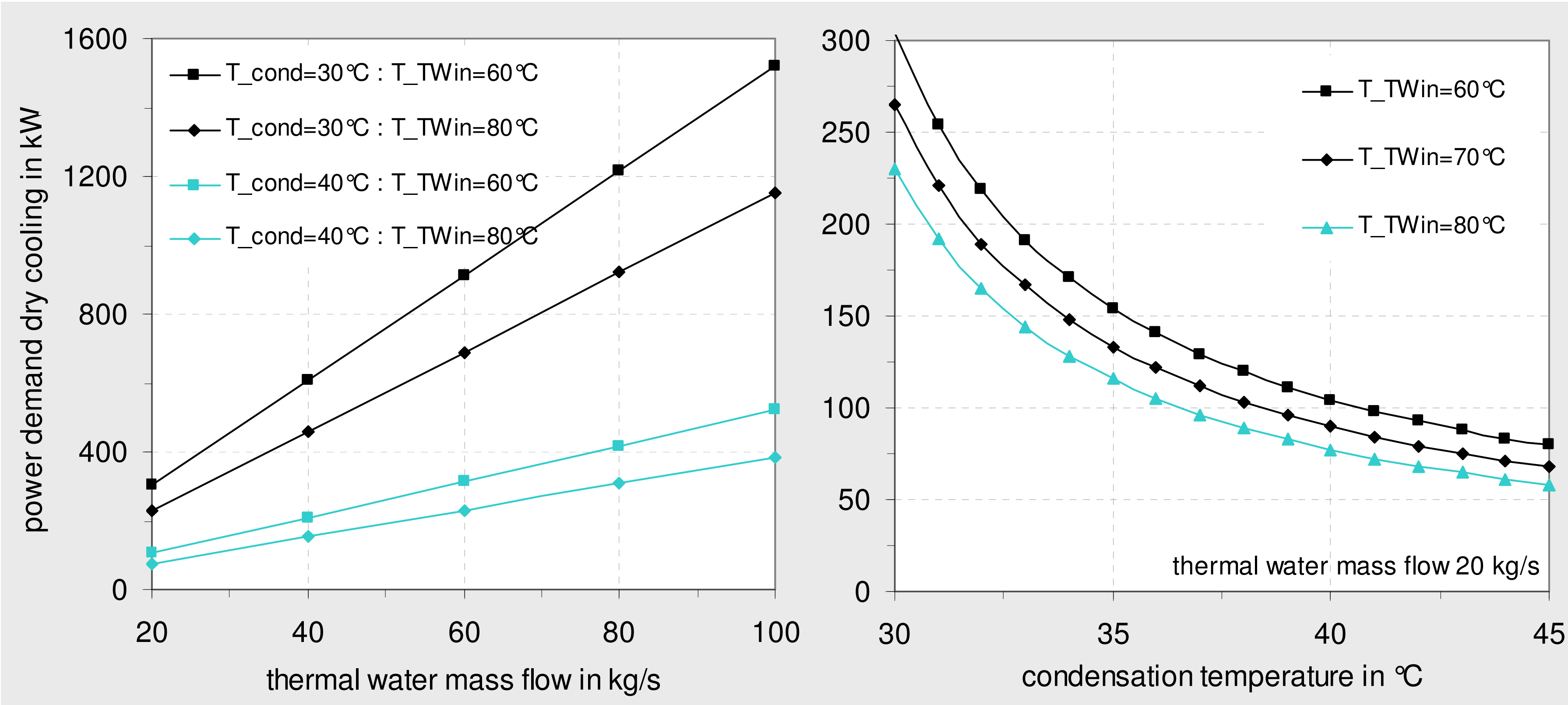


Power output = transferred heat x conversion efficiency

Auxiliary power characteristics

Cooling cycle (dry condensation)

Plant-specific parameter, reservoir and ambient conditions = const. (see slide 13)



$$\text{Power demand}_{\text{cooling cycle}} = f\,(T_{cond}) \cdot T_{TW,in} \cdot \dot{m}_{TW}$$

Exemplary power plant design

	maximum gross power (wet cooling)	maximum gross power (dry cooling)	maximum net power (wet cooling)	maximum net power (dry cooling)
reservoir conditions	T_{TW} = 150 °C, PI = 30 m^3/(h MPa), $depth_{reservoir}$ = 4,500 m			
thermal water mass flow	56 kg/s	56 kg/s	41 kg/s	37 kg/s
th. water injection temp.	66 °C	66 °C	71 °C	73 °C
condensation temp.	30 °C	30 °C	33 °C	36 °C
gross power	1,8 MW	1,8 MW	1,3 MW	1,1 MW
net power	460 kW	100 kW	600 kW	485 kW