Analysis of a Data Center Using Liquid-Liquid CO_2 Heat Pump for Simultaneous Cooling and Heating

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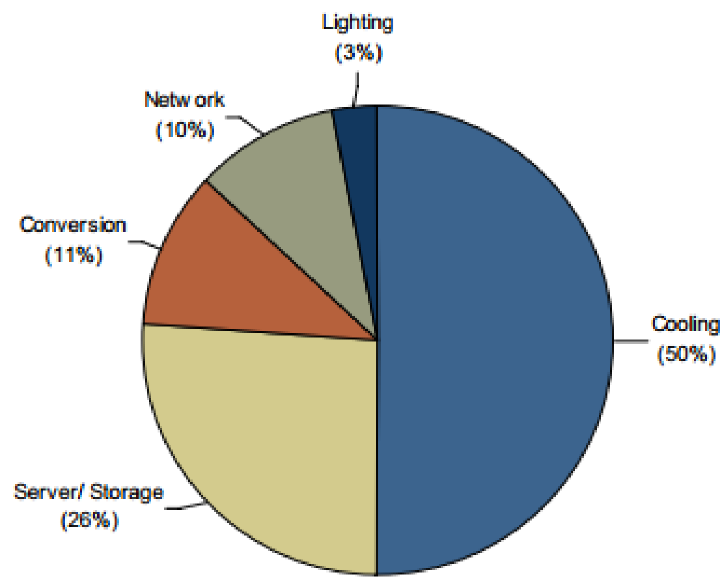
Motivation

- Heat from electrical equipment must be removed to prevent the equipment temperature from rising to certain level.

- Working Temperatures (Geet, 2014)
    - CPUs should always work under ~65ºC,
    - GPUs under ~75ºC
    - Memory chips under ~85ºC

Motivation



Typical break down of energy consumption in a Data Center (Info-tech Research Group, 2007)

Increasing power densities → More heat generation → Cooling becomes a challenge

Key Literature References

- Sarkar (2006) has studied CO_2 heat pump cycles for simultaneous cooling and heating loads in detail
- Stene (2005) proposed CO_2 heat pumps for residential applications
- Transcritical CO_2 refrigeration cycle shows a good performance in heat pump applications; however, the system performance is significantly influenced by ambient temperature (Sarkar et al., 2010), which limits the applications in domestic cooling through year
- Year round usage (Byrne et al., 2009). Blarke et al. (2012) shows how a 'thermal battery' system has the capability of simultaneous cooling and heating, which may reduce the seasonal temperature affects
- Houbak-Jensen et al. (2013) present an analytical model, which can be used for the study of dynamics of the system involving simultaneous supply of heating and cooling buildings..

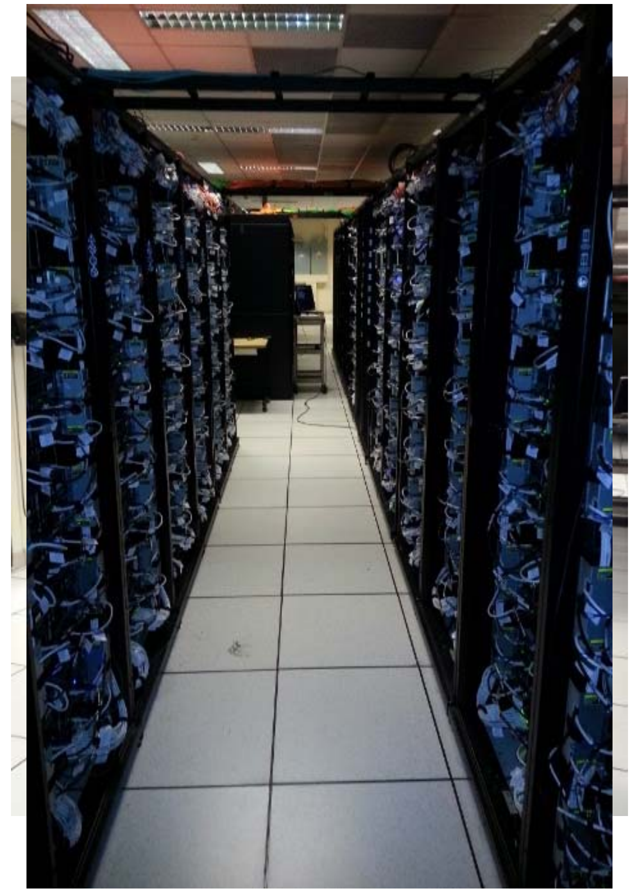
Objective

- Analyse CO_2 heat pump systems for commercial building applications, which require simultaneous heating and cooling
- Recently, direct water cooling systems are employed for IT computer racks
- Use model to evaluate advantages of simultaneous heating and cooling of liquid-liquid CO_2 heat pump in MATH data center on Purdue campus

Case Study- Data Center on Purdue Campus

MATH Data Center

CATEGORIES	UNIT	
Power consumption	MW	1.1-1.5
Cooling capacity	kW	700-800
No. of rear cooling door	/	101
Chilled water capacity (max)	kg/sec	65
Chilled water capacity (working condition)	kg/sec	30
CDU lines size	m	0.2
Chilled water source	/	Wade Utility plant
Chilled water supply temperature	C	~7º
Chilled water return temperature	C	~12º
No. of cooling distribution units	/	14



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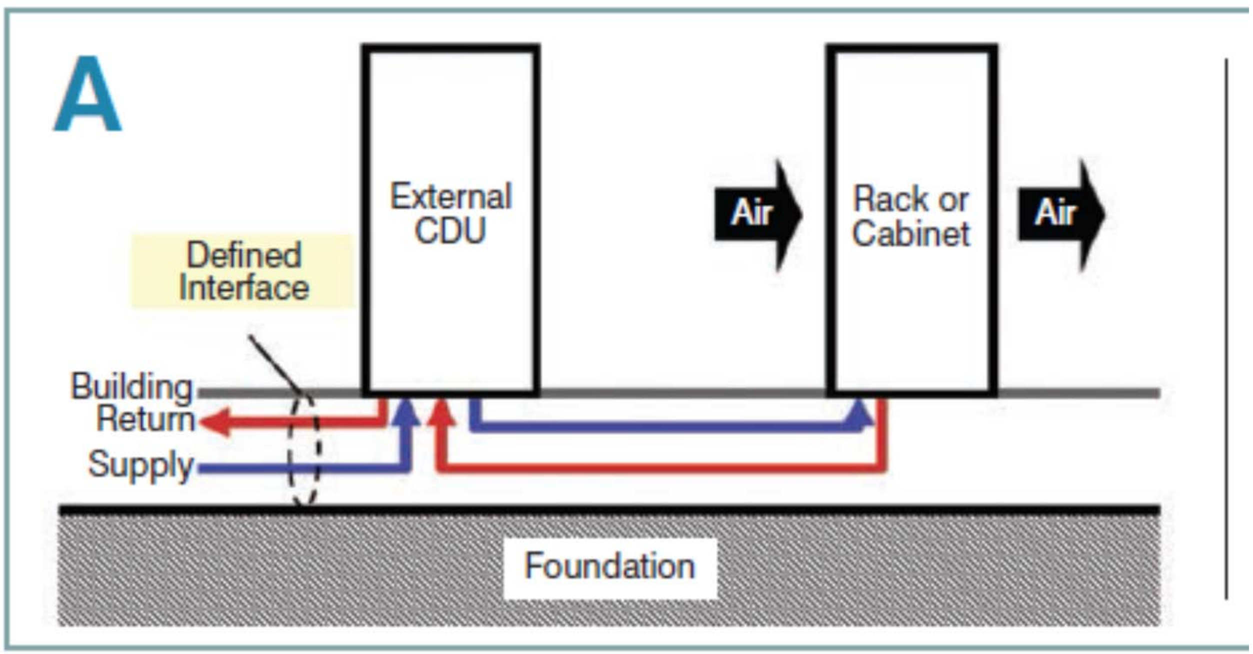

Schematic diagram showing the external CDU system (Steinbrecher, 2011)

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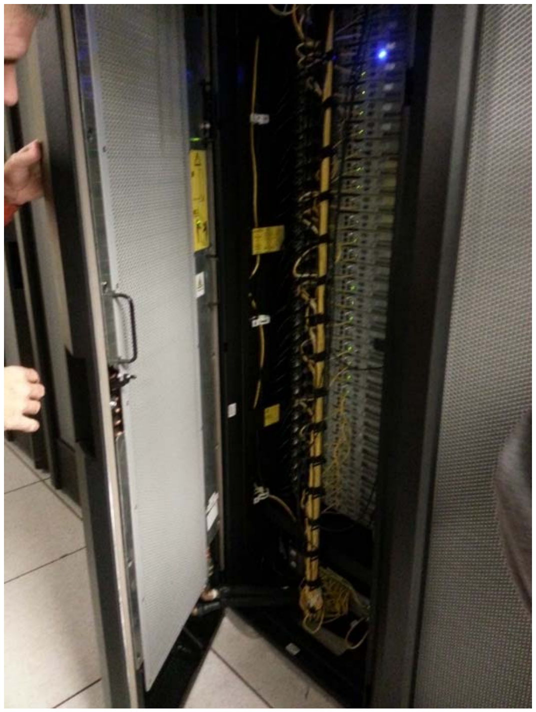

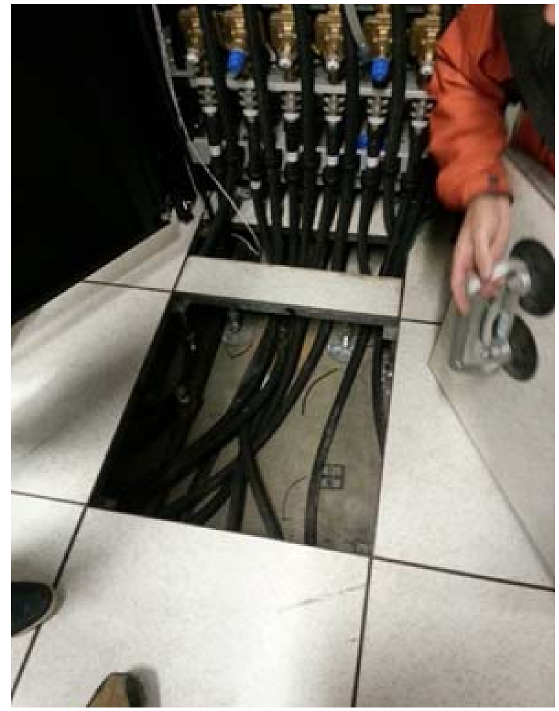

Actual Pictures of the MATH data center

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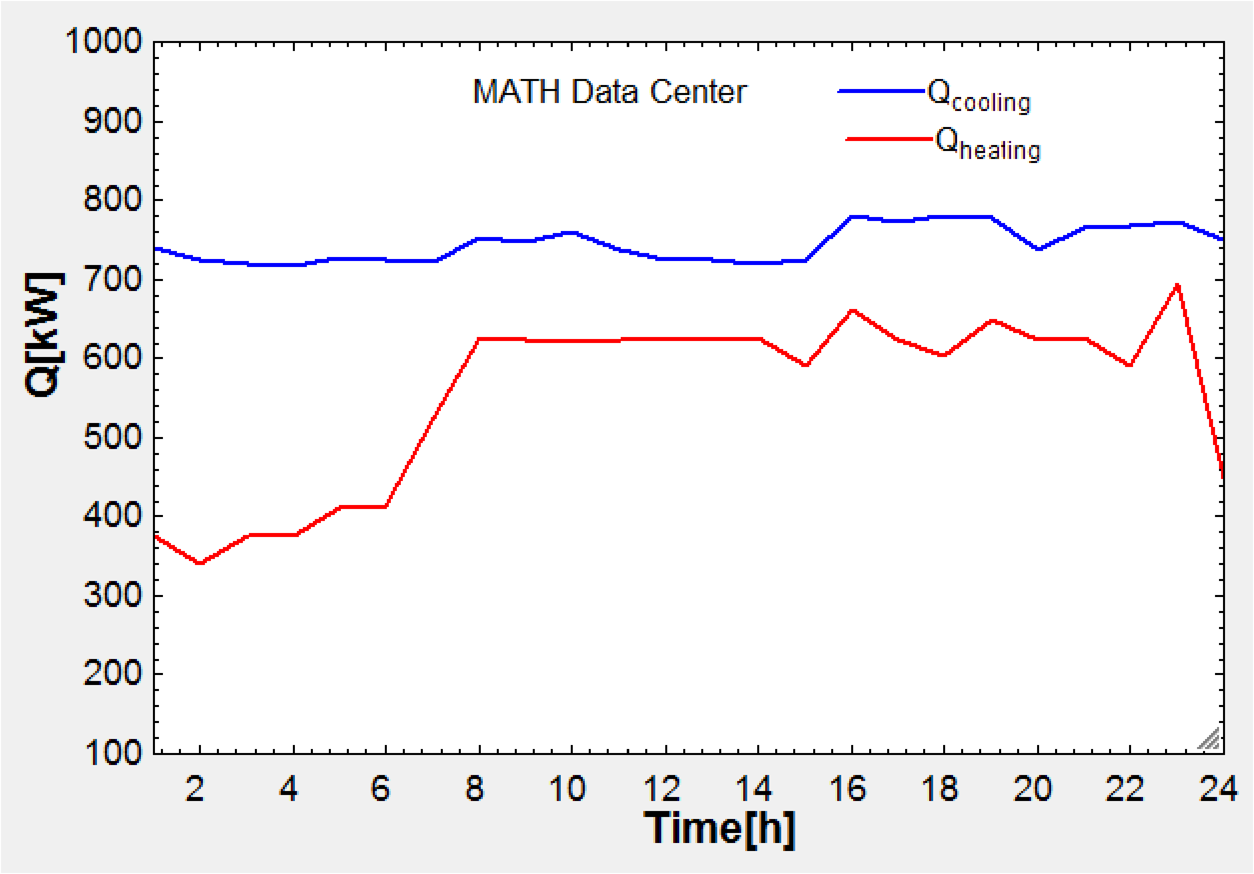
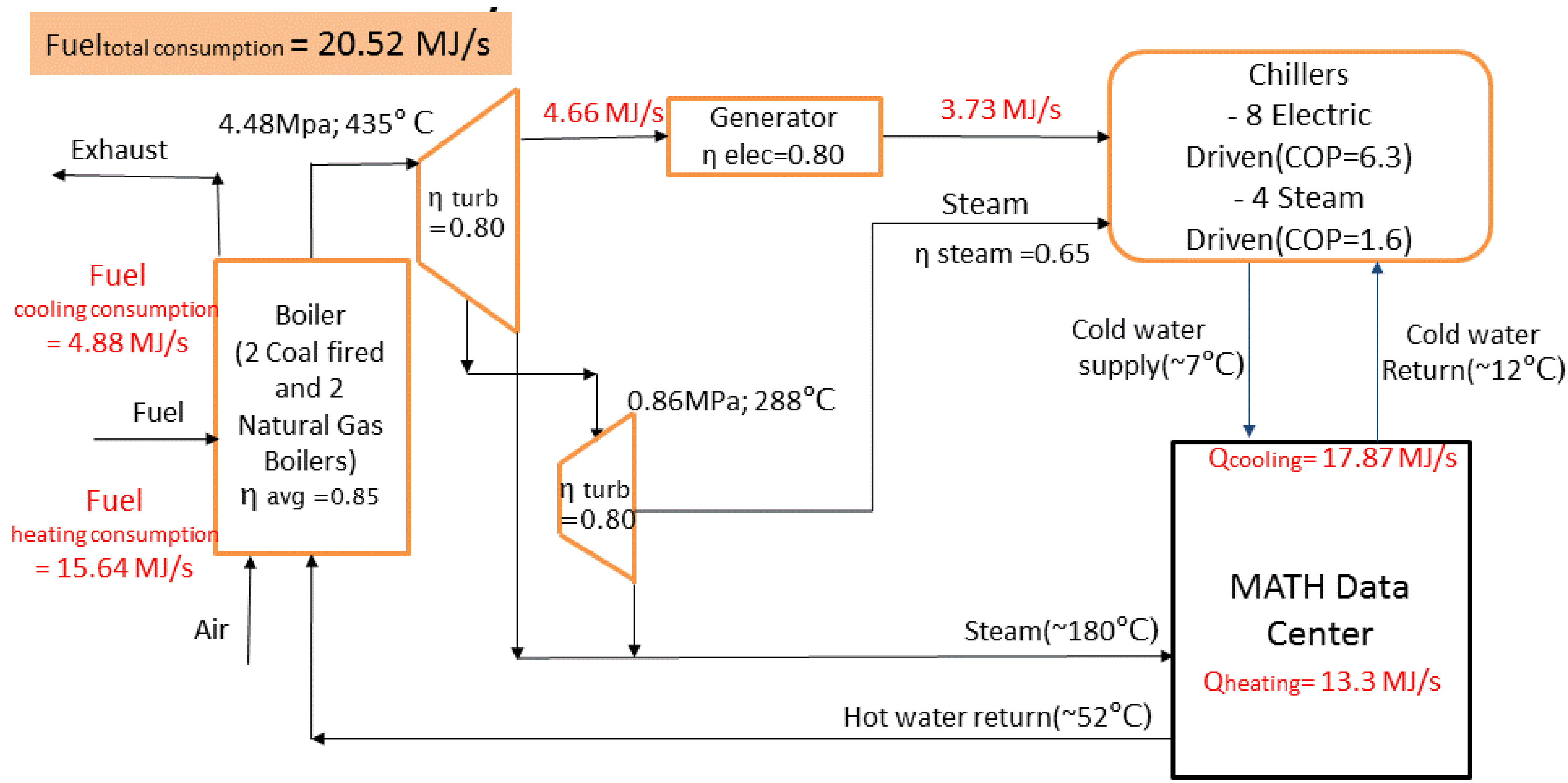
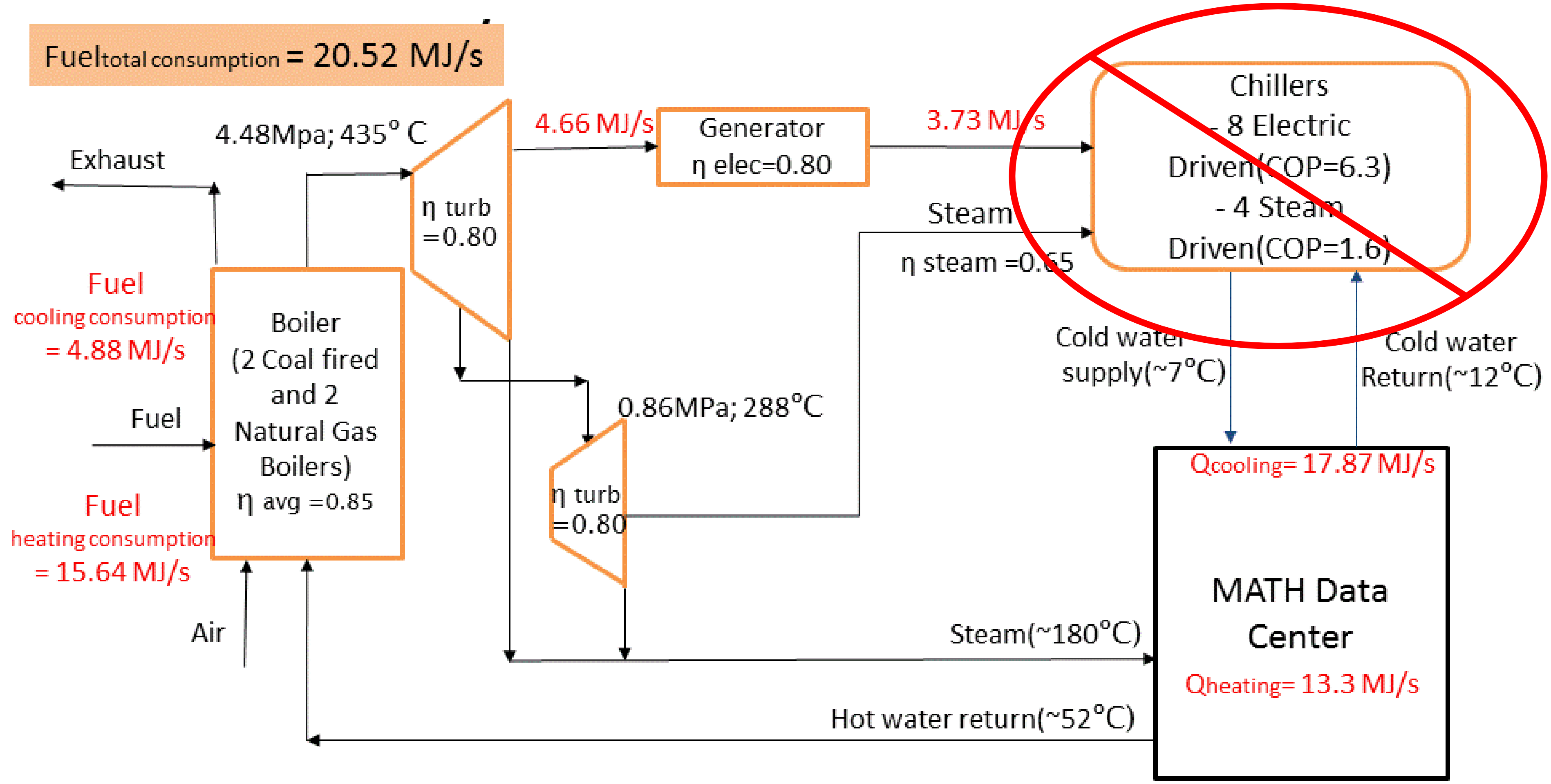


Variation of heating load of MATH building and cooling load of MATH data center

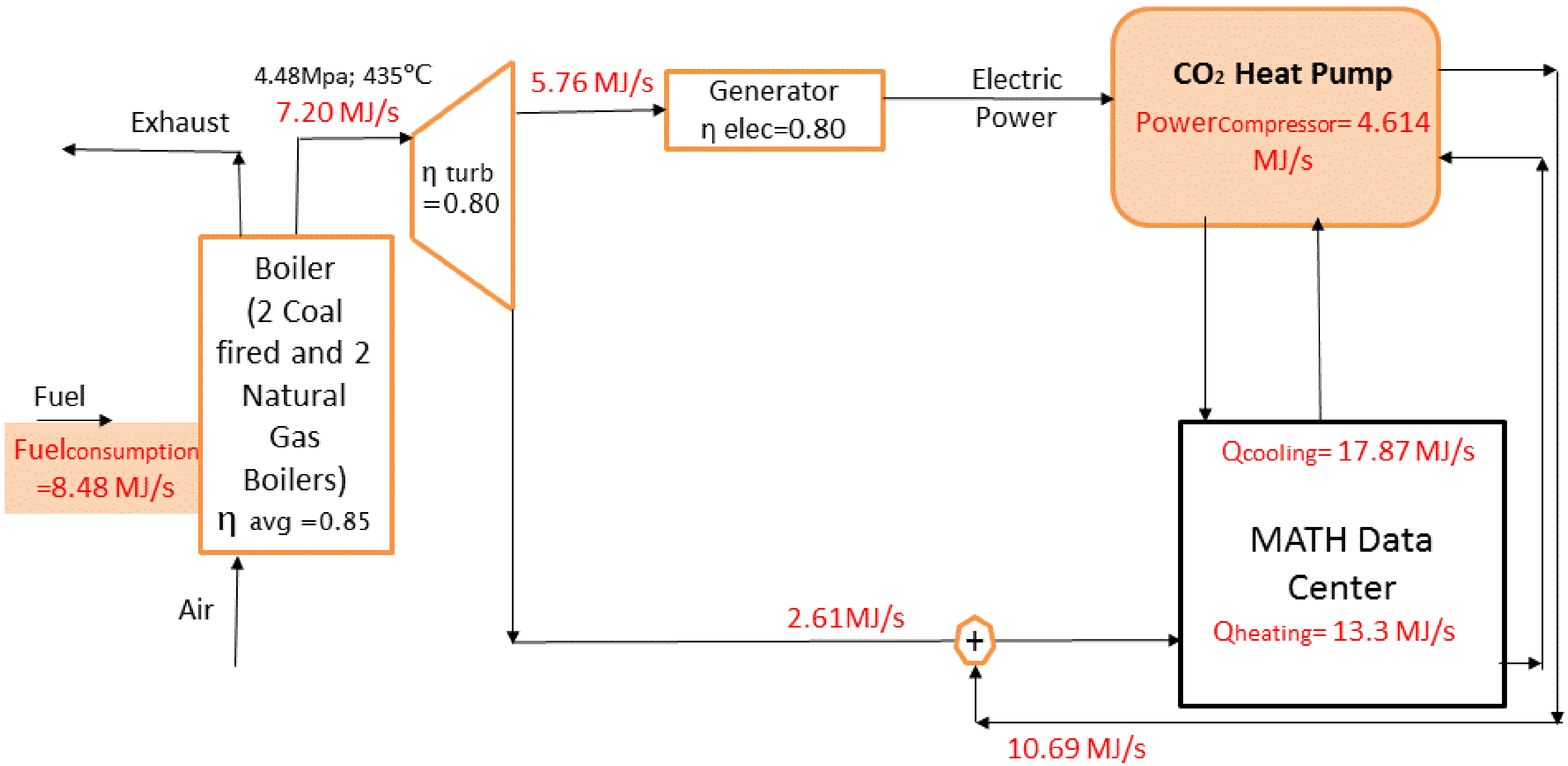
Energy flow diagram of the present system



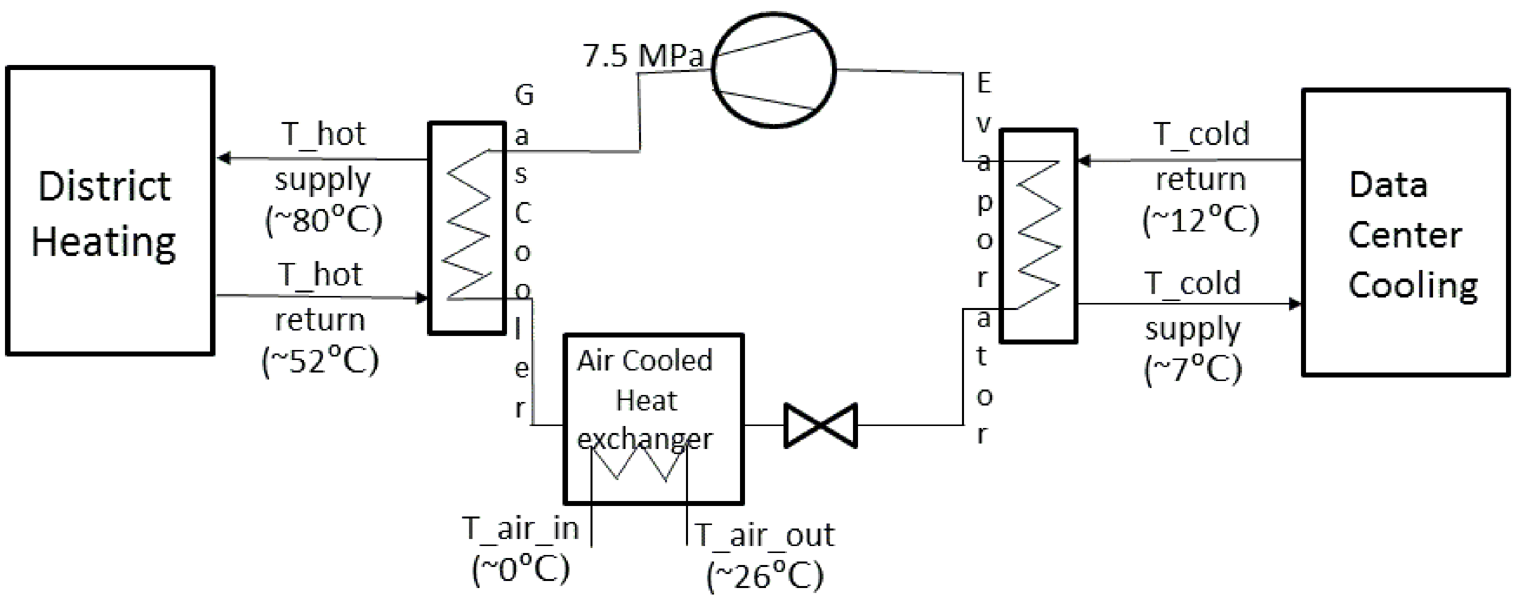
Proposed System



Energy flow diagram of the proposed sytem



Proposed heat pump system



Comparison between the existing and proposed system

The above table assumes

- Calorific value of coal = 20.4 MJ/kg ,
- Heating value of natural gas = 37.7 MJ/m^3
- CO_2 emission factor for coal = 87.3 kg/GJ
- CO_2 emission factor for natural gas = 50.3 kg/GJ

On January 2, 2014,

Savings= 59.6%

Further Work

- Annual energy calculations varying with the ambient temperature

- Determining optimum thermal storage capacity optimization for reasonable response of time-dependent demands at minimum electricity

- Improvement in the existing model in terms of pressure drop correlation and heat exchanger model

- Dynamic model with thermal storages is being improved and its prediction will be validated using experimental results

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Thank you!

Questions?