Pushing the boundary conditions of data centers facilitates innovative circular economy approaches

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Abstract. Data are the new fuel. We call it *'Energy to Data, Data to Heat'*. Placing data centers at locations where both the demands for information technology and heat coincide with server virtualization and load-optimization allows circular economy approaches. We investigate the effect of direct hot-liquid cooling characteristics on the energy reusage factor. Depending upon the location, 85 % to slightly less than 100 % values are achievable. Optimized servers and components significantly contribute to the objective.

Introduction

- Tremendous electrical energy consumption of data centers (DC) worldwide (200 TWh/a in 2018) [1] in contrast to energy consumption reduction [2]
- Conversion of all electrical energy into heat, extra energy required for cooling [3]
- Direct hot-liquid cooling (DHLC) captures server waste heat directly in the server
- DHLC with server virtualization and smart load-balancing for circular economy concepts [4, 5]
- Investigation of optimized chips and servers for DHLC

Simulations

- Annual simulations with TRY* data and hourly time step, evaluation of per-time step i:

$$E_{\mathrm{IT},i} = E_{\mathrm{Computing},i} + E_{\mathrm{Storage},i} + E_{\mathrm{Network},i} \quad (1)$$

$$E_{\mathrm{Periphery},i} = E_{\mathrm{UPS},i} + E_{\mathrm{el,losses},i} + E_{\mathrm{RAC},i} + E_{\mathrm{DHLC},i} + E_{\mathrm{MON},i} + E_{\mathrm{ICA},i} + E_{\mathrm{HR},i} + E_{\mathrm{HRC}} \quad (2)$$

$$Q_{\mathrm{recoverable},i} = Q_{\mathrm{DHLC},i} + Q_{\mathrm{RAC2DHLC},i} - Q_{\mathrm{HR},i} - Q_{\mathrm{int.losses},i} \quad (3)$$

- Annual energies by summation (i.e., over 8,760 hours)
- Energy reusage factor [3]:

$$\mathrm{ERF} = Q_{\mathrm{recoverable,an}} / (E_{\mathrm{IT,an}} + E_{\mathrm{Periphery,an}}) \quad (4)$$

- Parameters: 1 MW DC, average part-load factor 50 %, free cooling, variable heat capture rate (HCR, ratio of heat captured in liquid vs. server waste heat)
- Results:
  - Strong relation between ERF and HCR for Stockholm, high ERF fur Dubai due to less free cooling (**Fig. 1**)
  - High ERF values (85 % until almost 100 %) worldwide for a Cloud&Heat DC (**Fig. 3**)

Experiments

- Measurements of DHLC server fluid outlet temperature and CPU/GPU chip temperature
- Set-up: insulated and air-conditioned chamber
- High-demanding LINPACK benchmark computations until thermal steady-state
- 30 recordings per measurement for statistics [6], temperature uncertainty ± 1 K
- Results:
  - Trend: outlet temperatures between 43 °C and 72 °C (**Fig. 2**)
  - High degree of dispersion in data in multi-CPU/GPU systems → disadvantageous small calorific mean temperature of the liquid in those systems

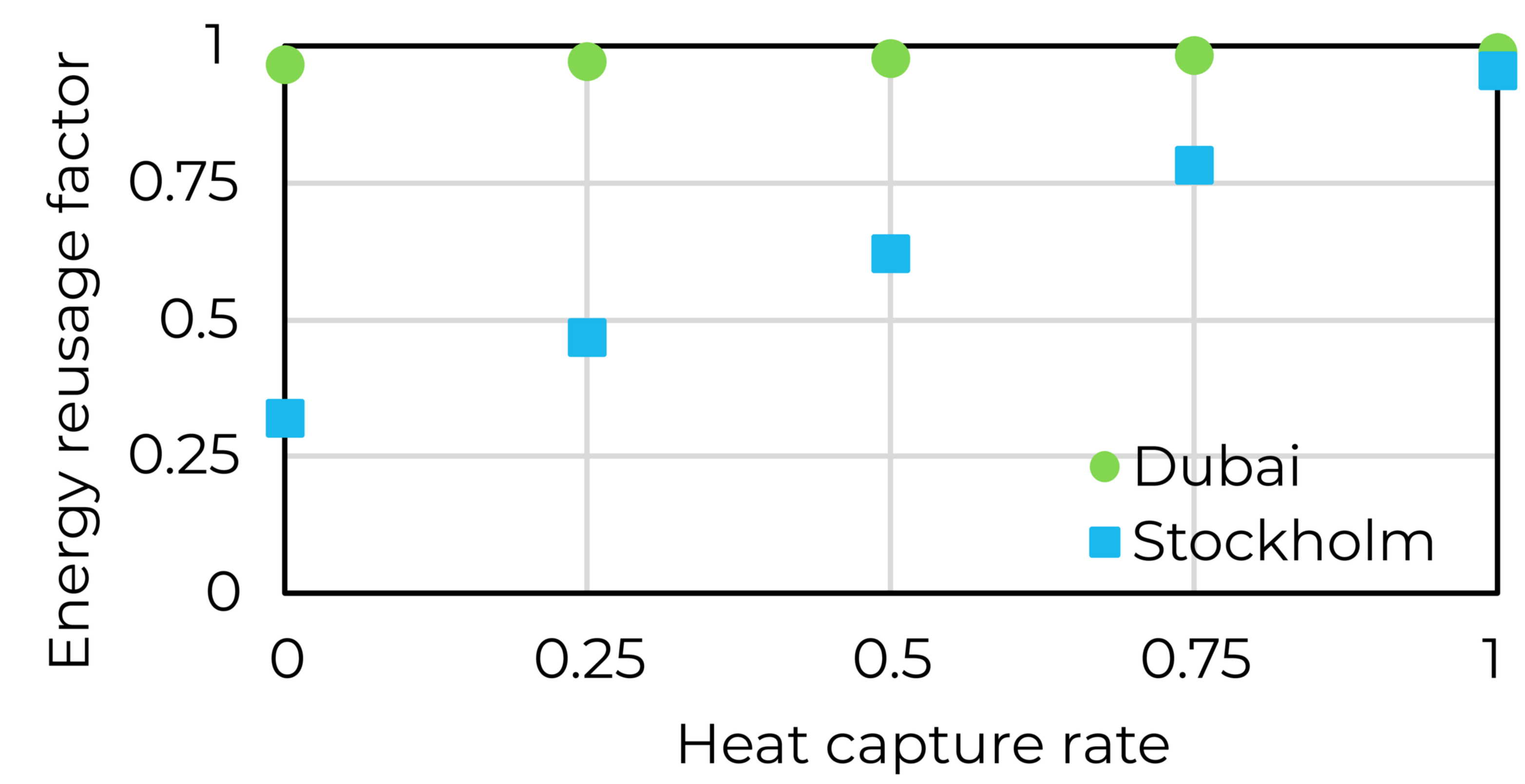

Fig. 1 Simulation: Energy reusage factor depending upon heat capture rate for cold (Stockholm, Sweden) and hot climate (Dubai, United Arab Emirates).

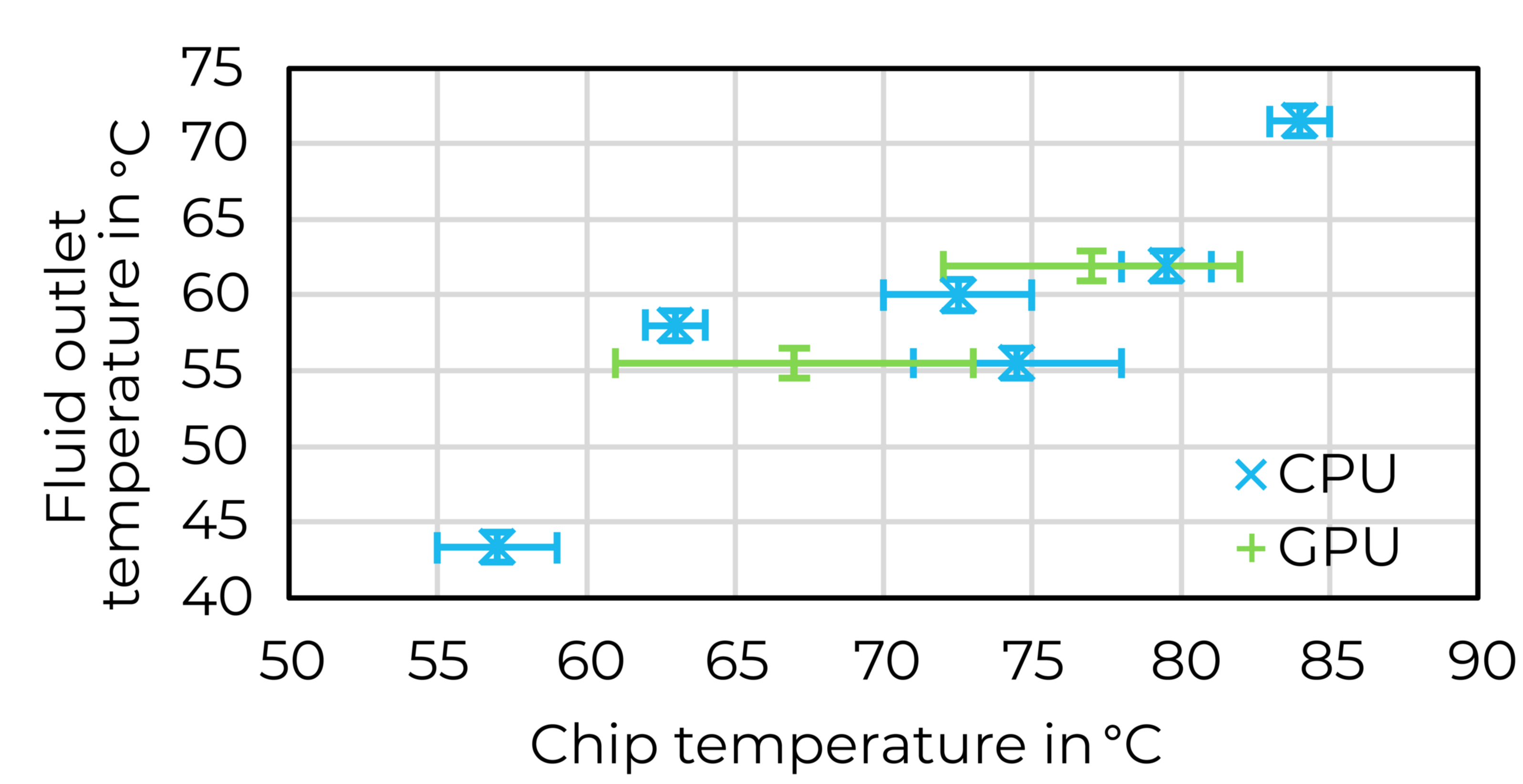

Fig. 2 Experiment: Coolant outlet temperature depending upon chip temperature for various servers.

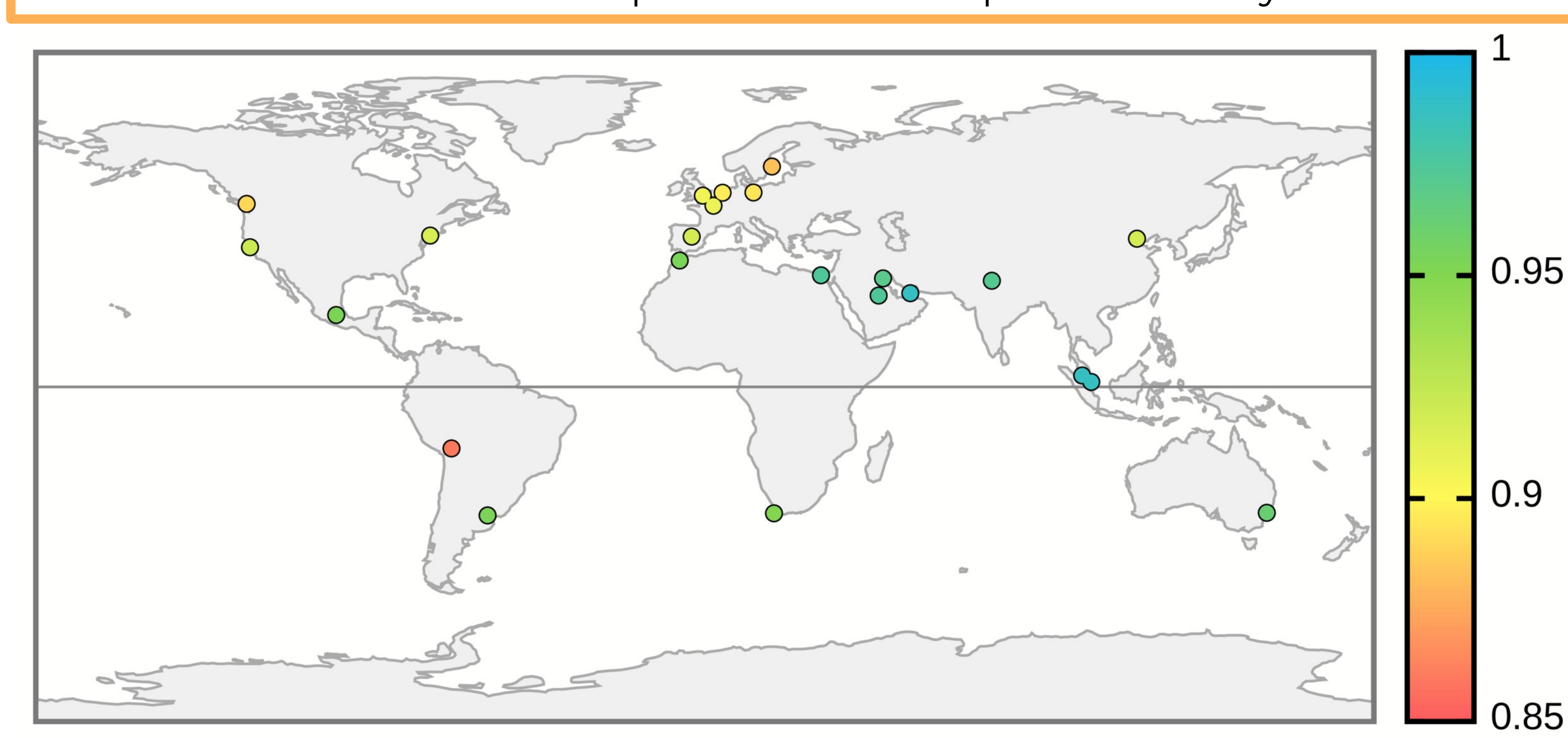

Fig. 3 Simulation: Energy reusage factor of a Cloud&Heat data center.

Summary and Outlook

- Annual simulations and experiments show positive effects of DHLC with server virtualization and load-optimization
- High HCR in the server yield high ERF of 85 % to almost 100 %
- Max. coolant outlet temperature (43 °C to 72 °C) depends strongly upon the server system

- Chips and servers should be optimized for DHLC.
- **Enormous potential: When we use the waste heat of the DC to produce potable water from seawater, a 40 MW DC installation would be sufficient to supply all residents of the United Arab Emirates [7] with the annual bottled water consumption.**

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* Test reference years (TRY) are statistically prepared climatic data with hourly time-steps of temperature, humidity, wind, and the like.

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