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:
  \[
  E_{\text{IT,i}} = E_{\text{Computing,i}} + E_{\text{Storage,i}} + E_{\text{Network,i}} \]
  \[
  E_{\text{Peripheral,i}} = E_{\text{UPS,i}} + E_{\text{AC,i}} + E_{\text{DHLC,i}} + E_{\text{HR,i}} + E_{\text{HC,i}} \]
  \[
  E_{\text{coolable,i}} = Q_{\text{coolable,i}} - Q_{\text{f,l.o.s.s.,i}} \]
  \[
  E_{\text{coolable,i}} = E_{\text{IT,i}} + E_{\text{Peripheral,i}} \]
- Annual energies by summation (i.e., over 8,760 hours)
- Energy reusage factor [3]:
  \[
  \text{ERF} = \frac{Q_{\text{coolable,annual}}}{E_{\text{IT,annual}} + E_{\text{Peripheral,annual}}} \]
- 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 caloric mean temperature of the liquid in those systems

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.

References

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

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