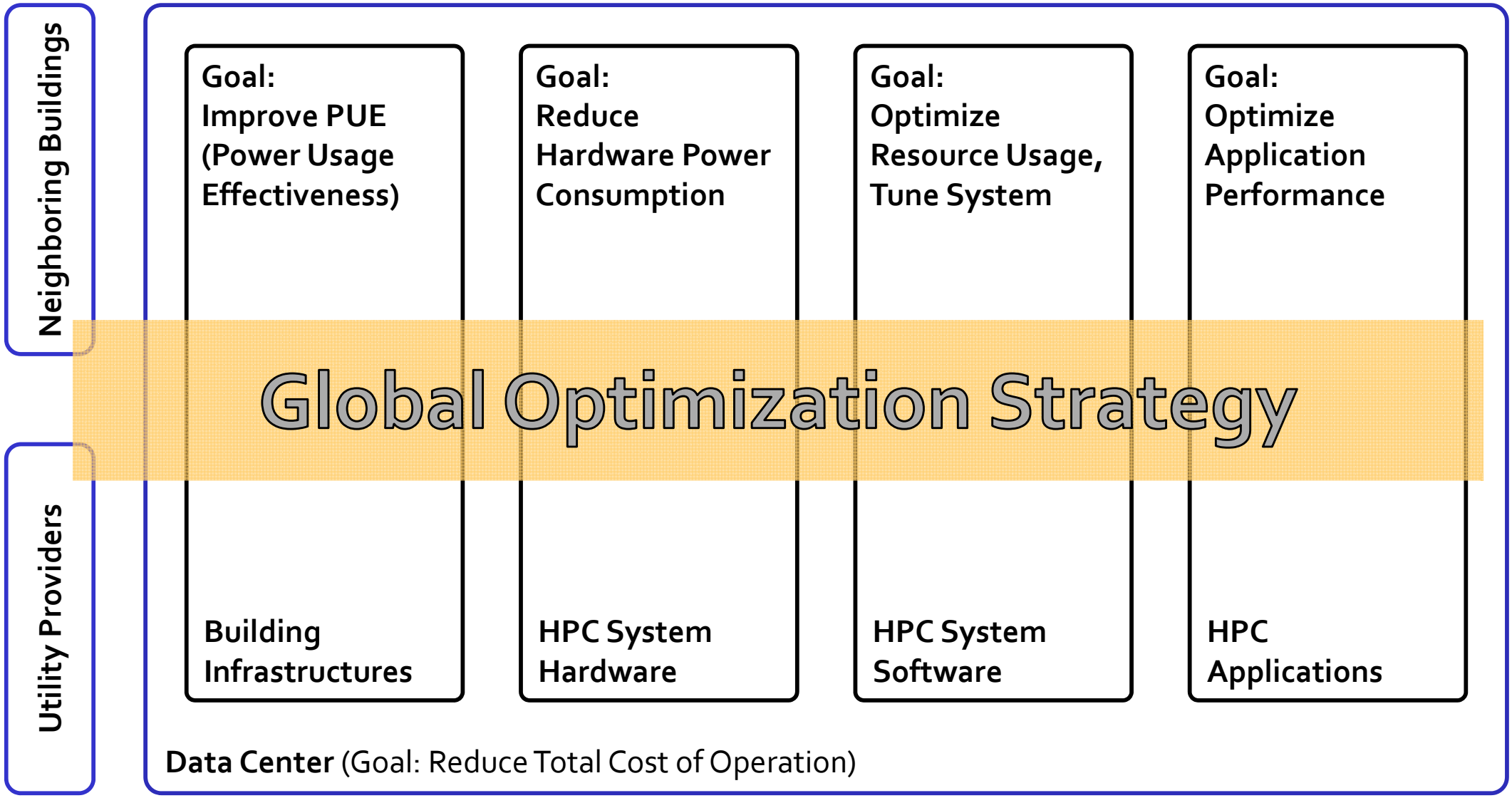
Energy Efficient HPC
An Integrated View

Energy Efficient HPC: The Four Pillar Model



Energy Efficient HPC @ LRZ

Motivation: we pay 17.8 € Cents per KWh (100% Renewable Energy Contract)

Research on Energy Efficiency:

- Hardware Architectures
- Programming Models & System Software
- Energy Efficient HPC Centre Infrastructures
  - Re-Use of Waste Heat

„Zero Emission" Supercomputing Centre

$$ERE = \frac{Cooling + Power + Lightning + IT - Reuse}{IT}$$

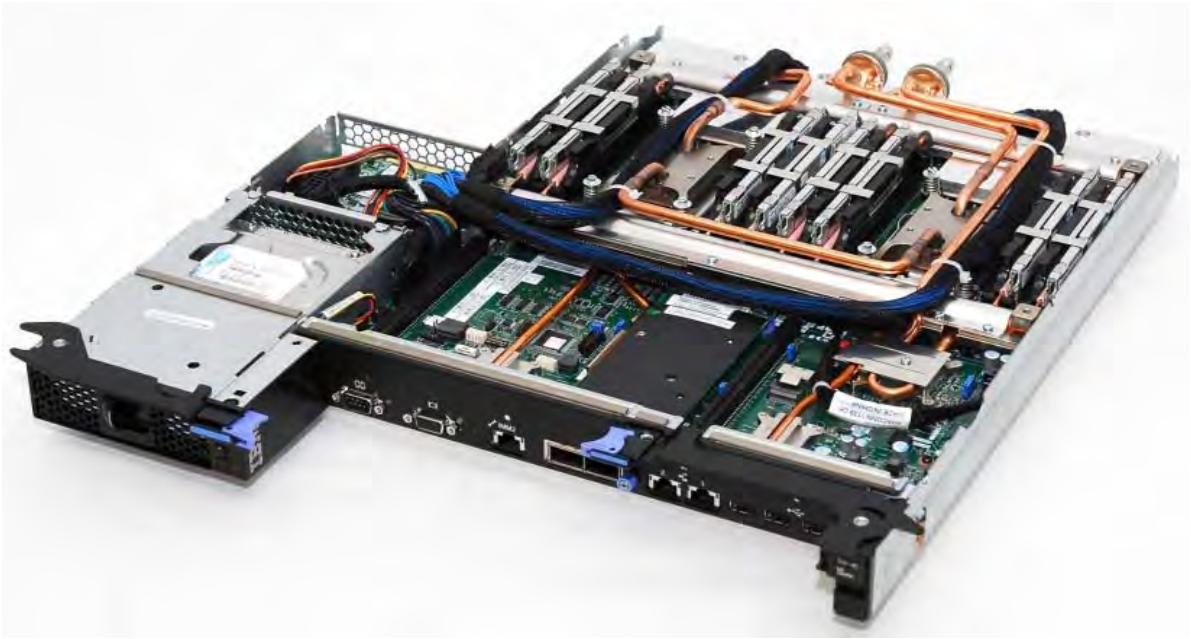
SuperMUC

TOP500® SUPERCOMPUTER SITES

2897 TFlop/s HPL Performance

Rank 4 (June 2012)
Rank 6 (November 2012)
Rank 9 (June 2013)

SuperMUC: Warm Water Cooling

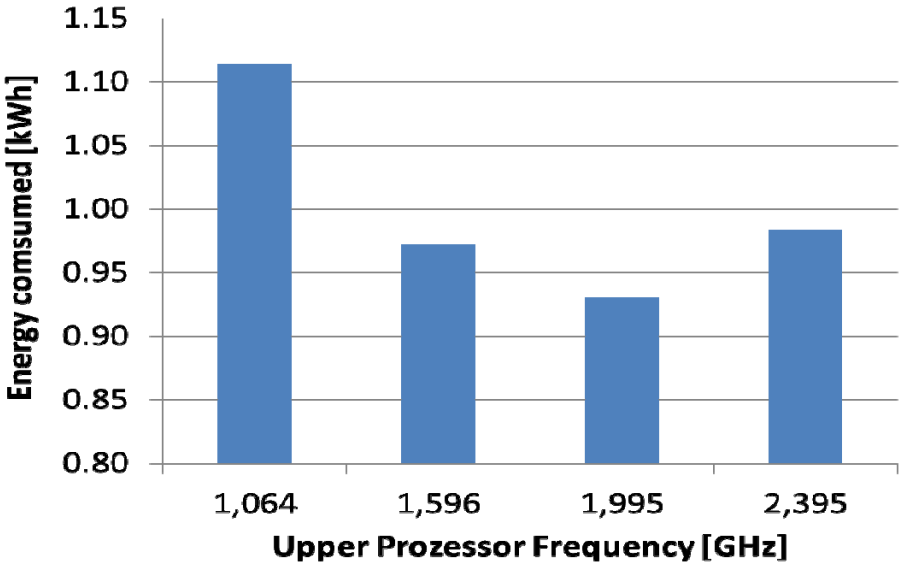


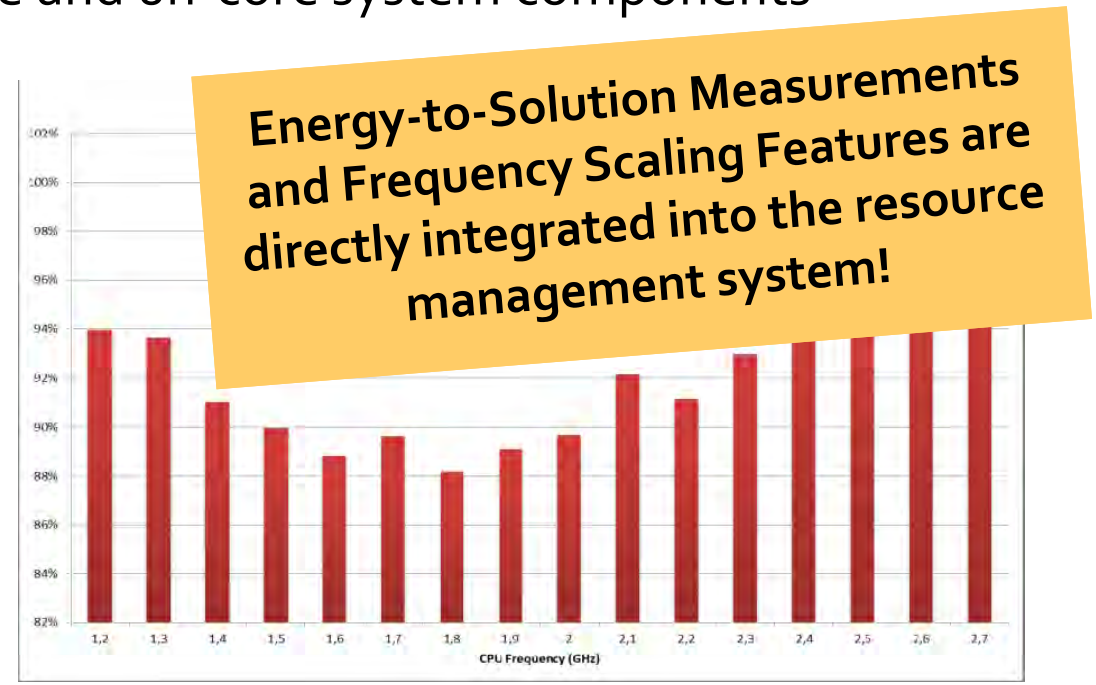
- **Heat flux > 90% to water; very low chilled water requirement**
- **Power advantage over air-cooled node:**
  - Warm water cooled ~10%
    (cold water cooled ~15%)
  - due to lower $T_{components}$ and no fans
- **Typical operating conditions: T_{air} = 25 – 30°C, T_{water} = 18 – 45°C**

Energy-aware System Software: Minimizing Energy to Solution for Parallel Applications

For minimum Energy to Solution:

Energy Saving due to frequency scaling must be greater than Energy consumed by unused processors in lowest energy state and un-core system components





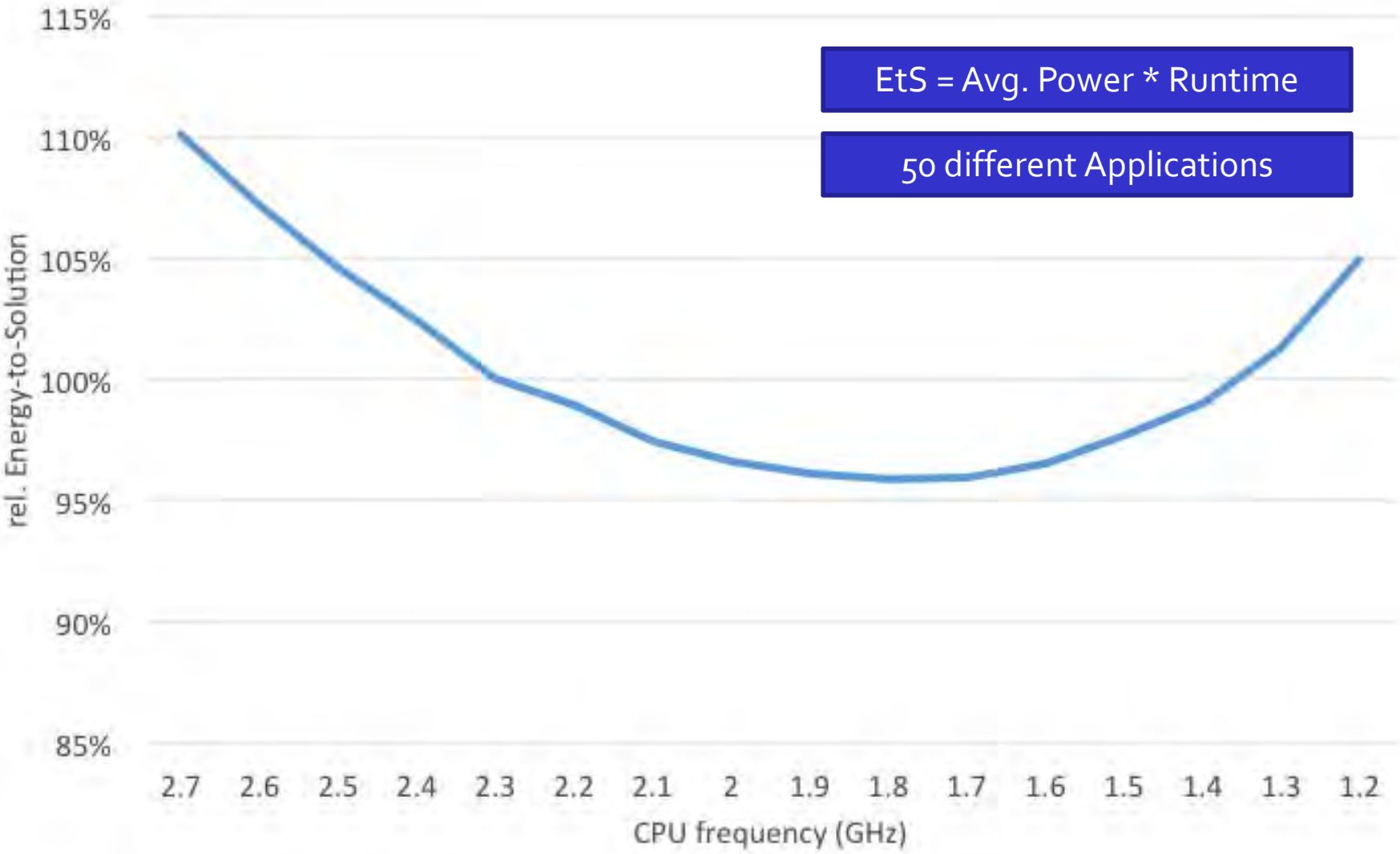
Example 1: Geophysical Application SeisSol

- 40 E7-4870 cores (one node)
- MPI
- On demand Linux governor

Example 2: CFD Application HYDRO

- 256 Intel E5-2680 cores (16 nodes)
- MPI
- On demand Linux governor

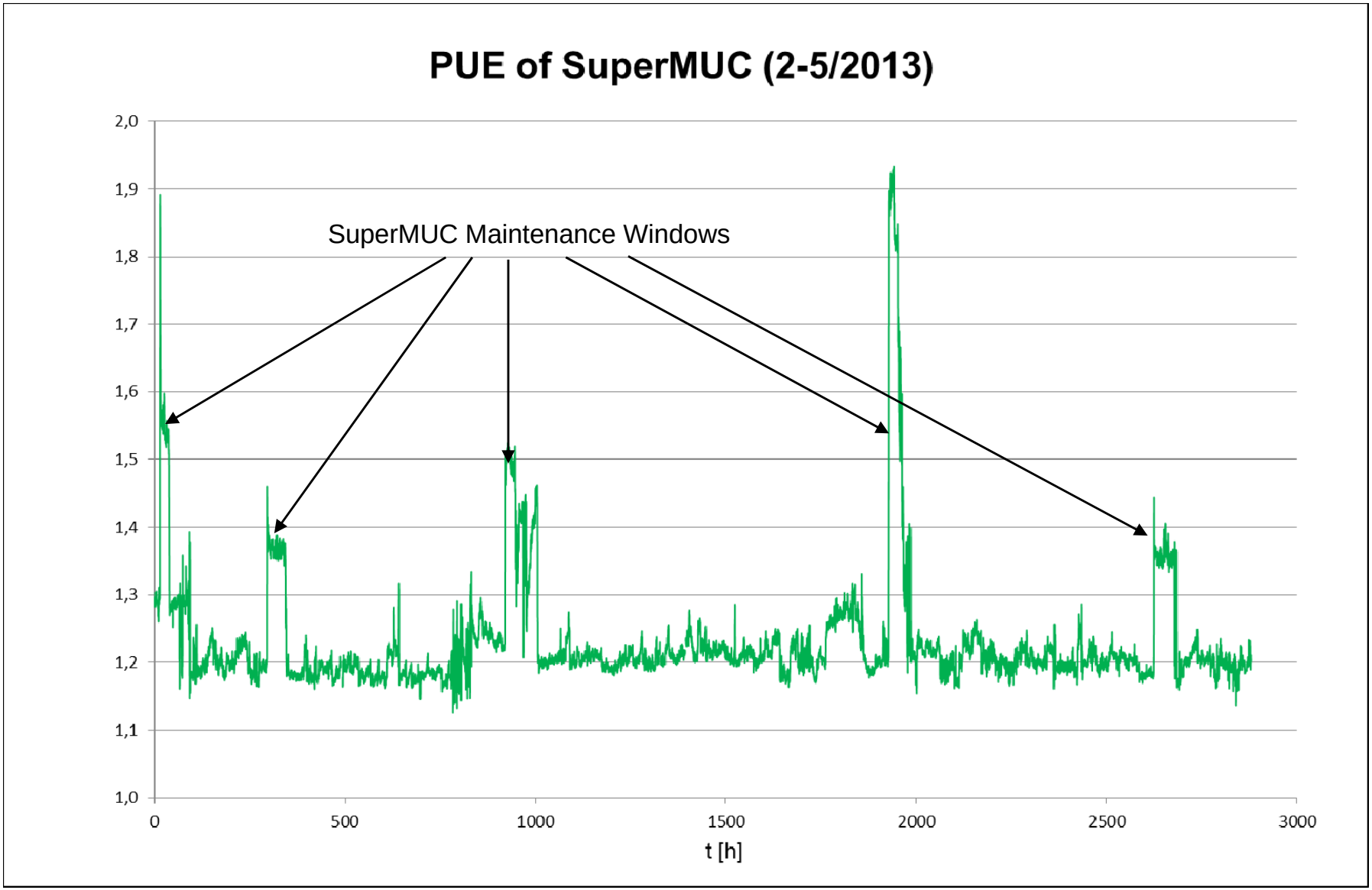
Average Energy-to-Solution Profile on SuperMUC



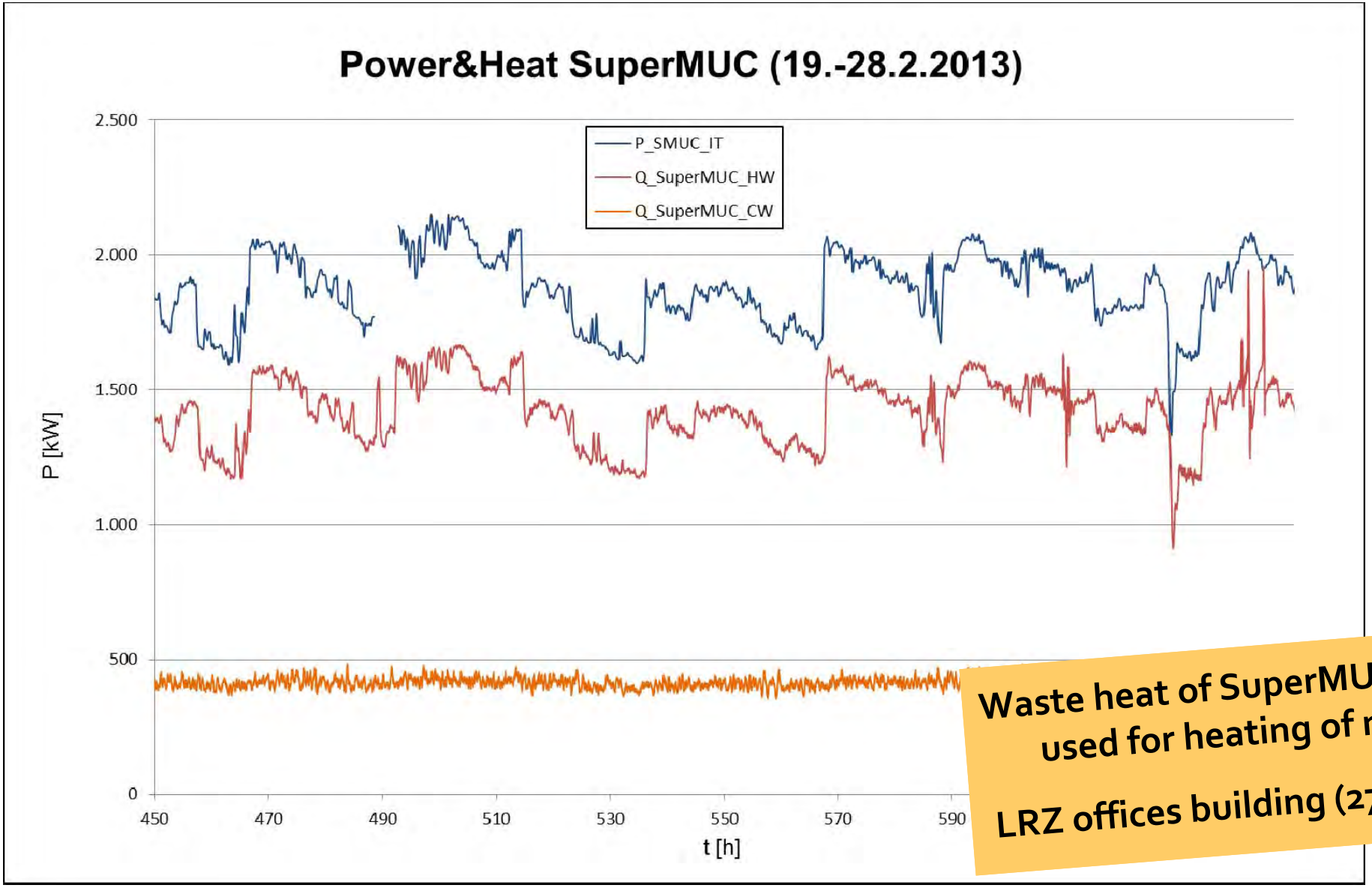
EtS = Avg. Power * Runtime

50 different Applications

Measured PUE of SuperMUC



SuperMUC Power and Heat Output Balance



Waste heat of SuperMUC is re-used for heating of new LRZ offices building (2700 m²)

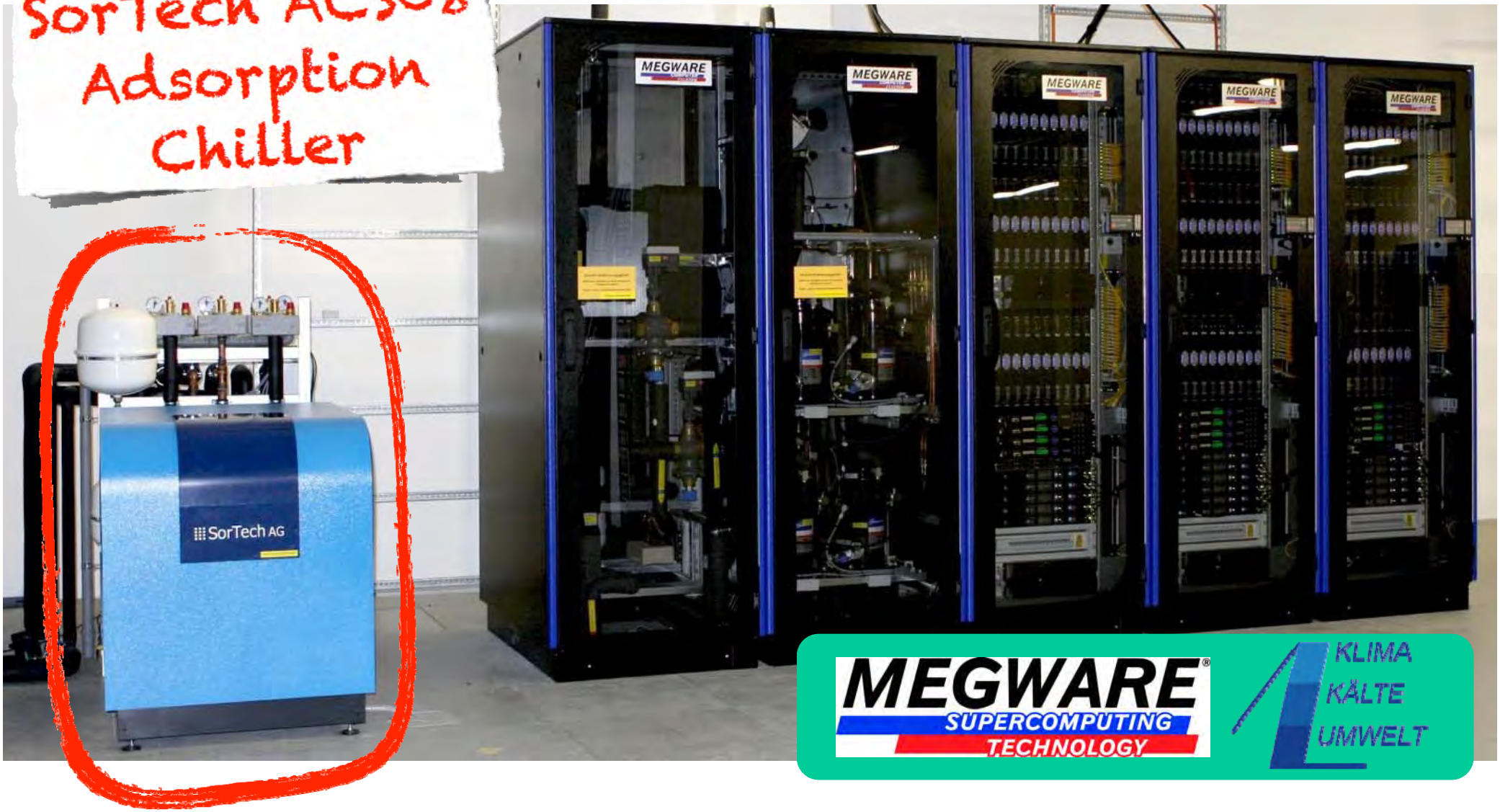
The Problem with Heat Re-Use

- New buildings in Germany are very good thermally isolated: Standard heat requirement of only 50 W/m² (~ 4,7 W/Ft²)

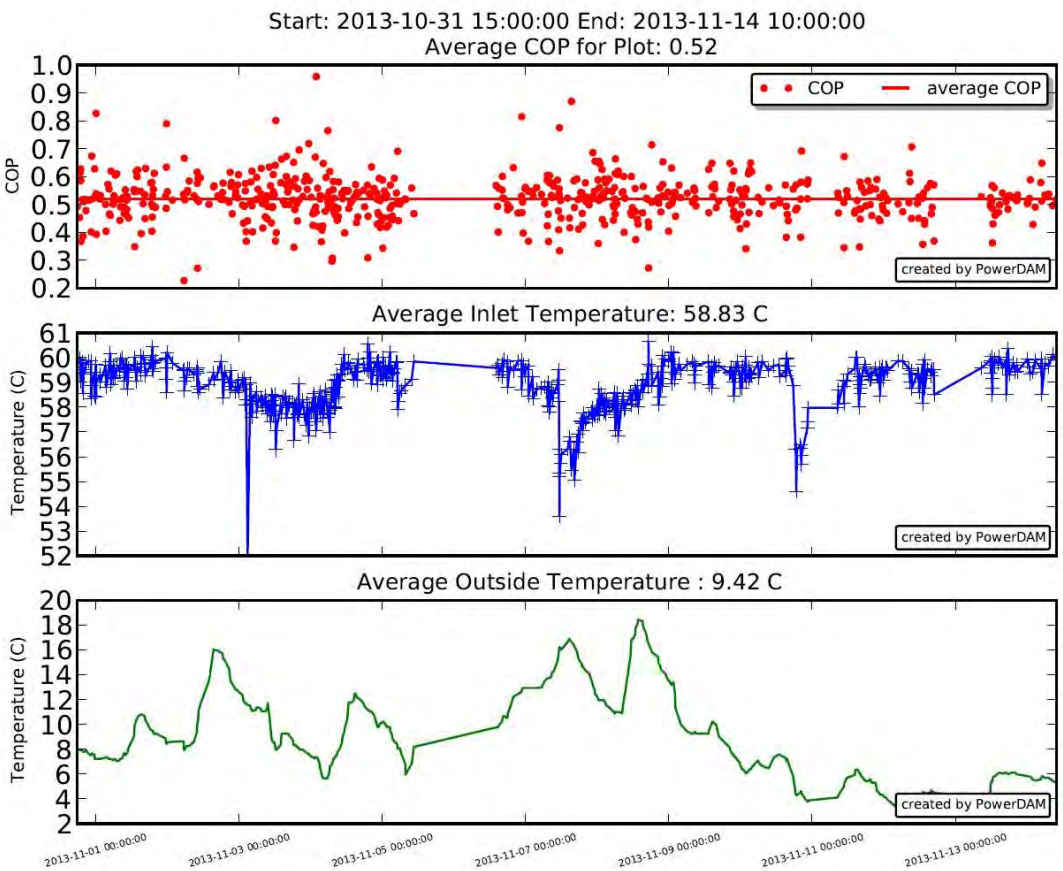
  → SuperMUCs waste heat would be sufficient to heat 26 000 m² of office space (10 x)

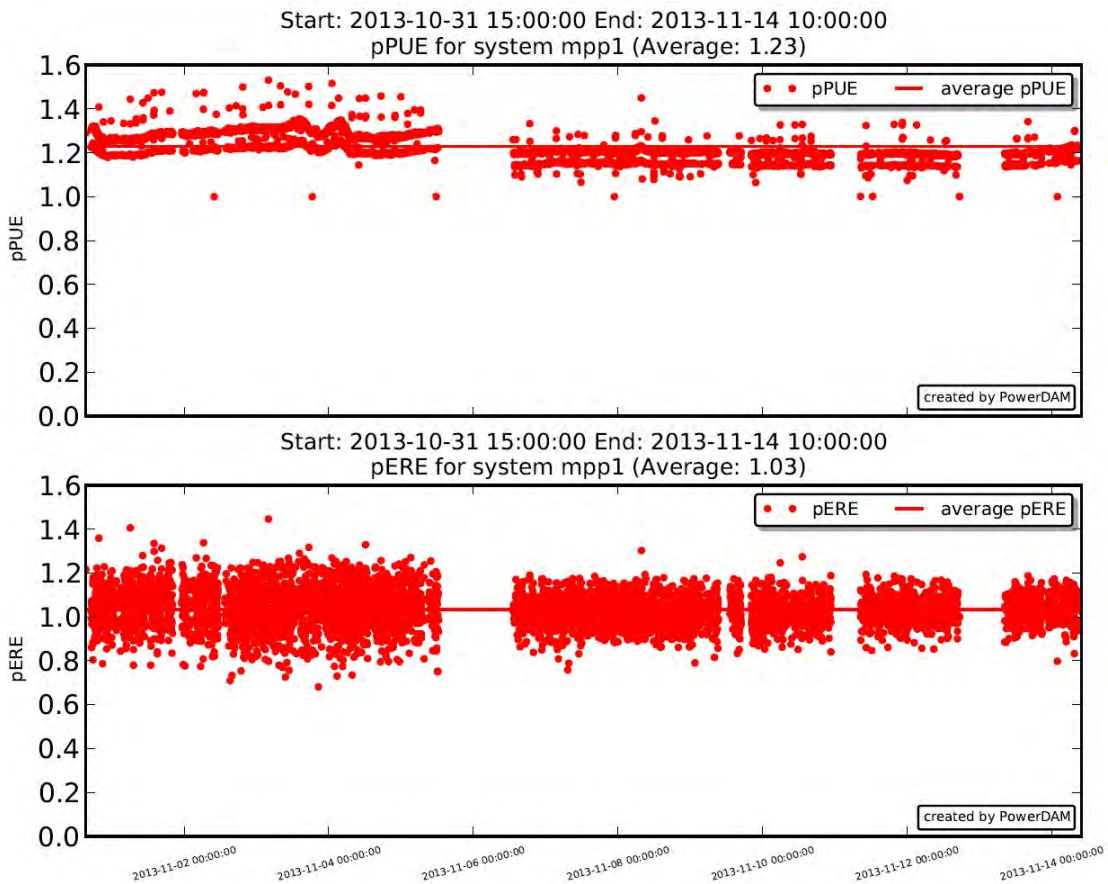
- We've just started negotiations with the Galileo planners

- What to do with the waste heat during summer?


SorTech ACS08
Adsorption
Chiller
SorTech AG
MEGWARE
MEGWARE
MEGWARE
MEGWARE
MEGWARE
MEGWARE
SUPERCOMPUTING
TECHNOLOGY
KLIMA
KÄLTE
UMWELT

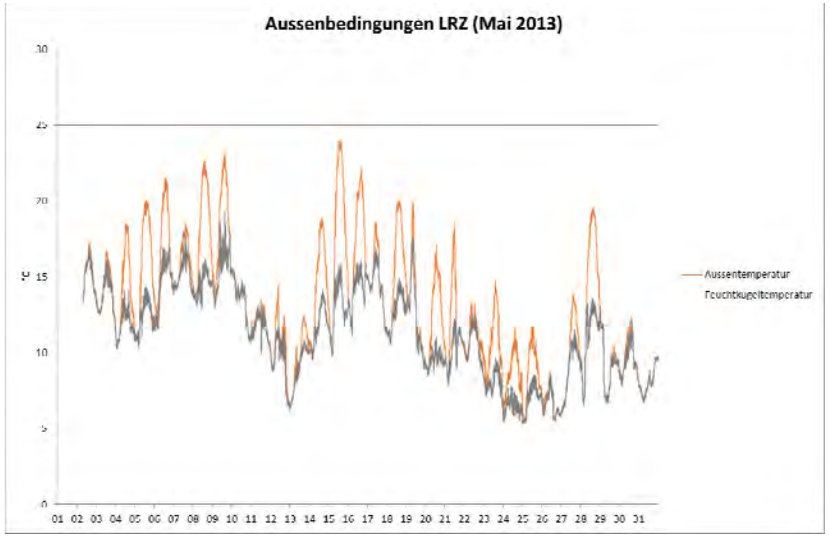
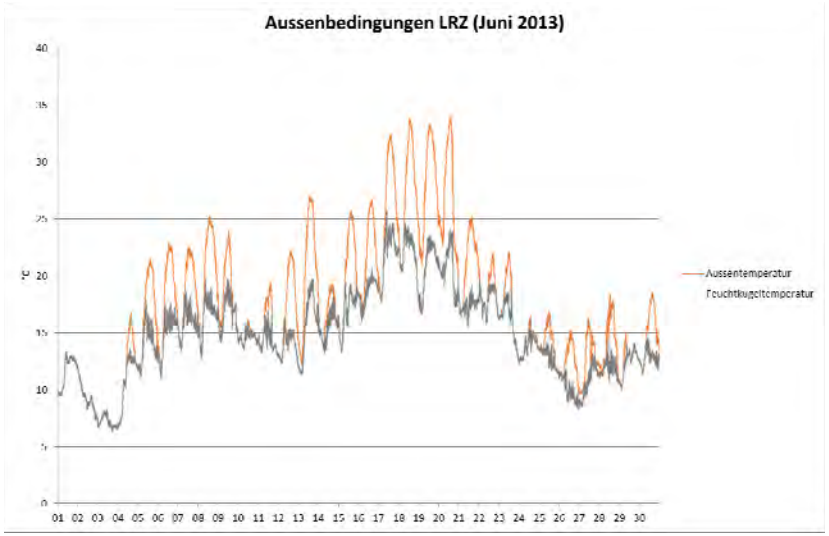
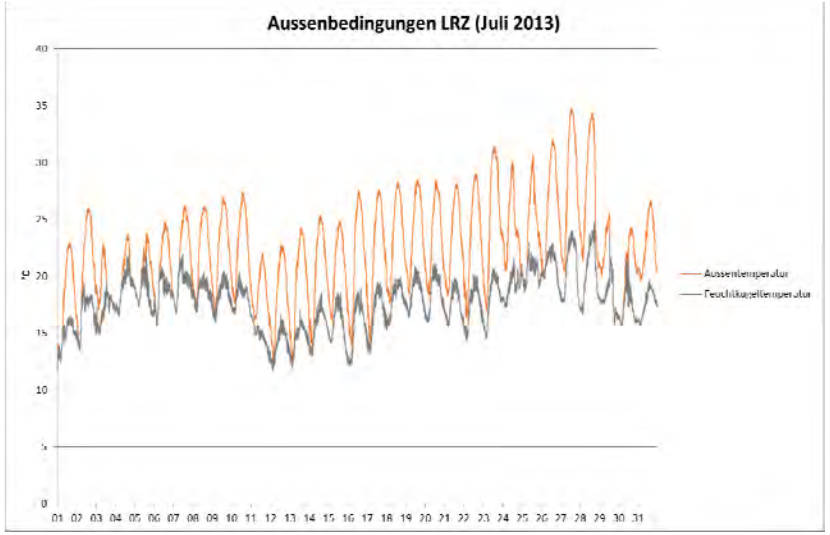
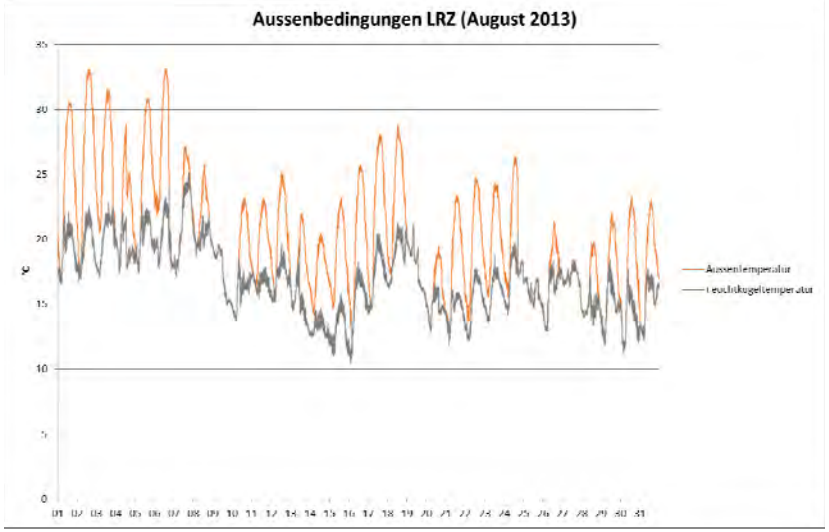
First Results on the Re-Use of HPC System Waste Heat for Chilled Water Production





Summary

- **PUE is a good metric for site managers to check the sites Progress in cooling efficiency**
- **Ask vendors about the Total Energy Effectiveness (TUE) to be informed about the cooling overhead of their HPC solutions**
- **ERE should be the future focus area**
  - Re-use concepts for system waste heat need a sound planning and often structural modifications
  - Don’t forget to implement the required sensor system
  - Explore new concepts for heat re-use

Backup Slides

Environmental Conditions in the Munich Area