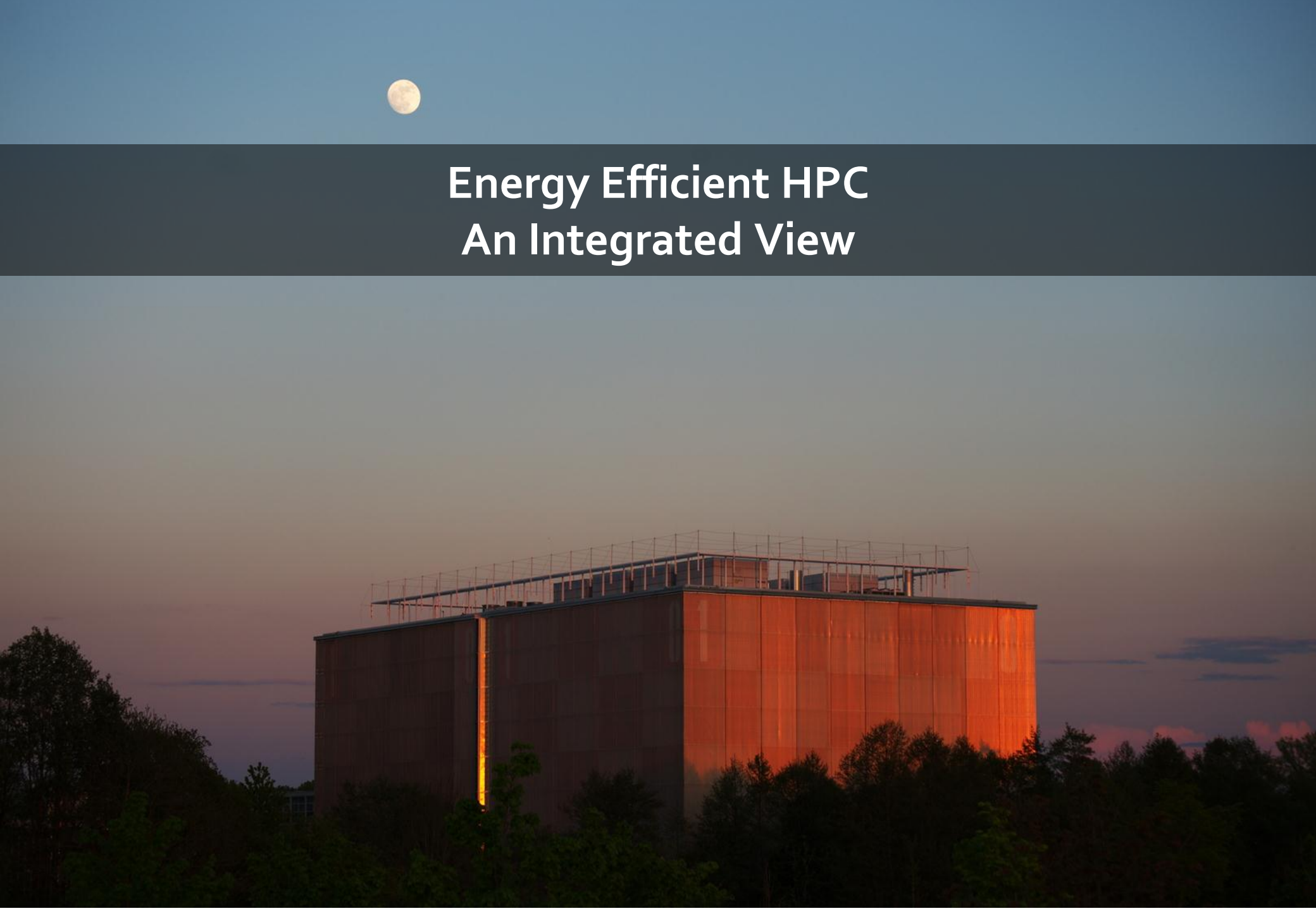
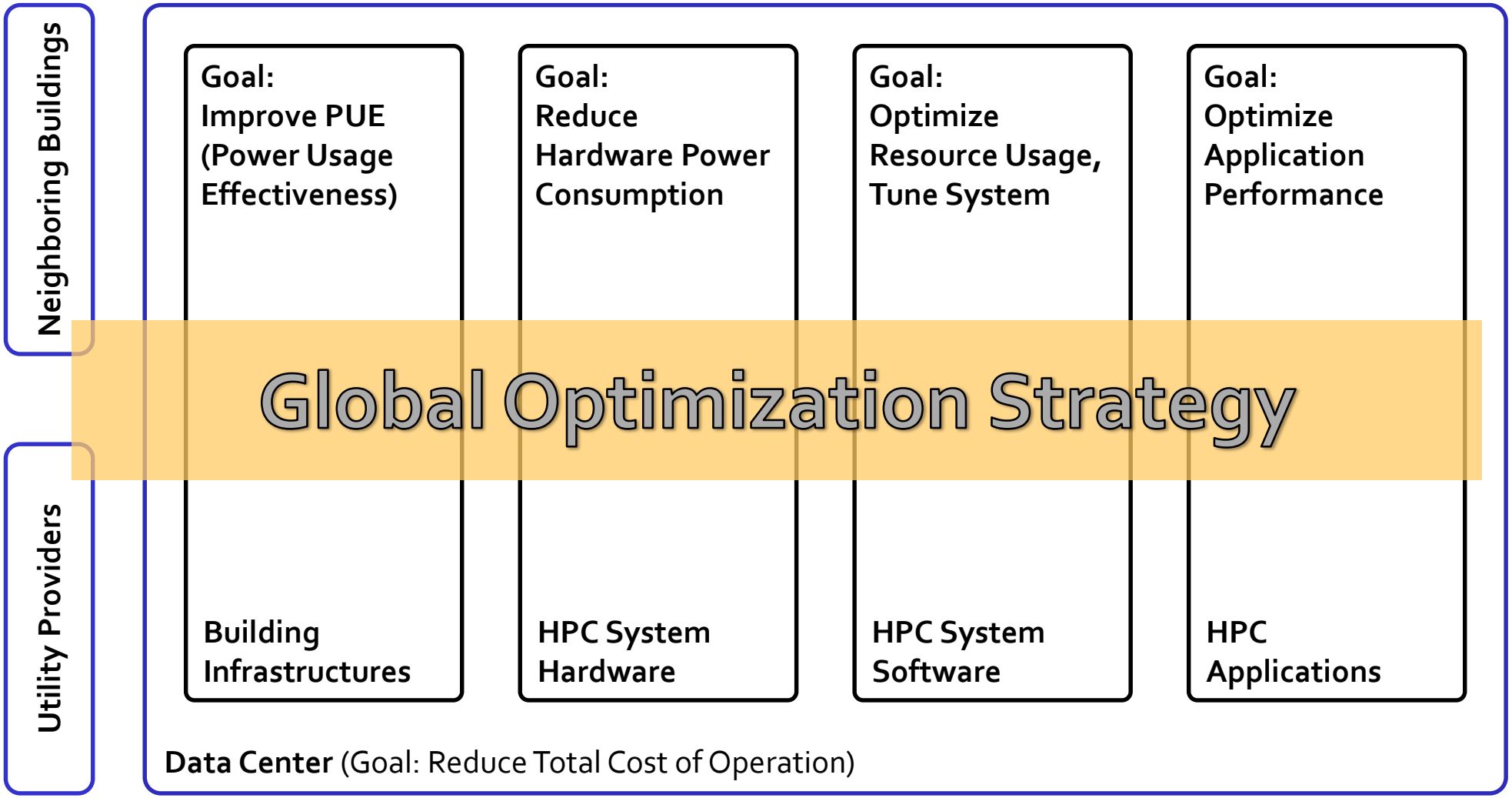
Energy Efficient HPC
An Integrated View



Energy Efficient HPC: The Four Pillar Model

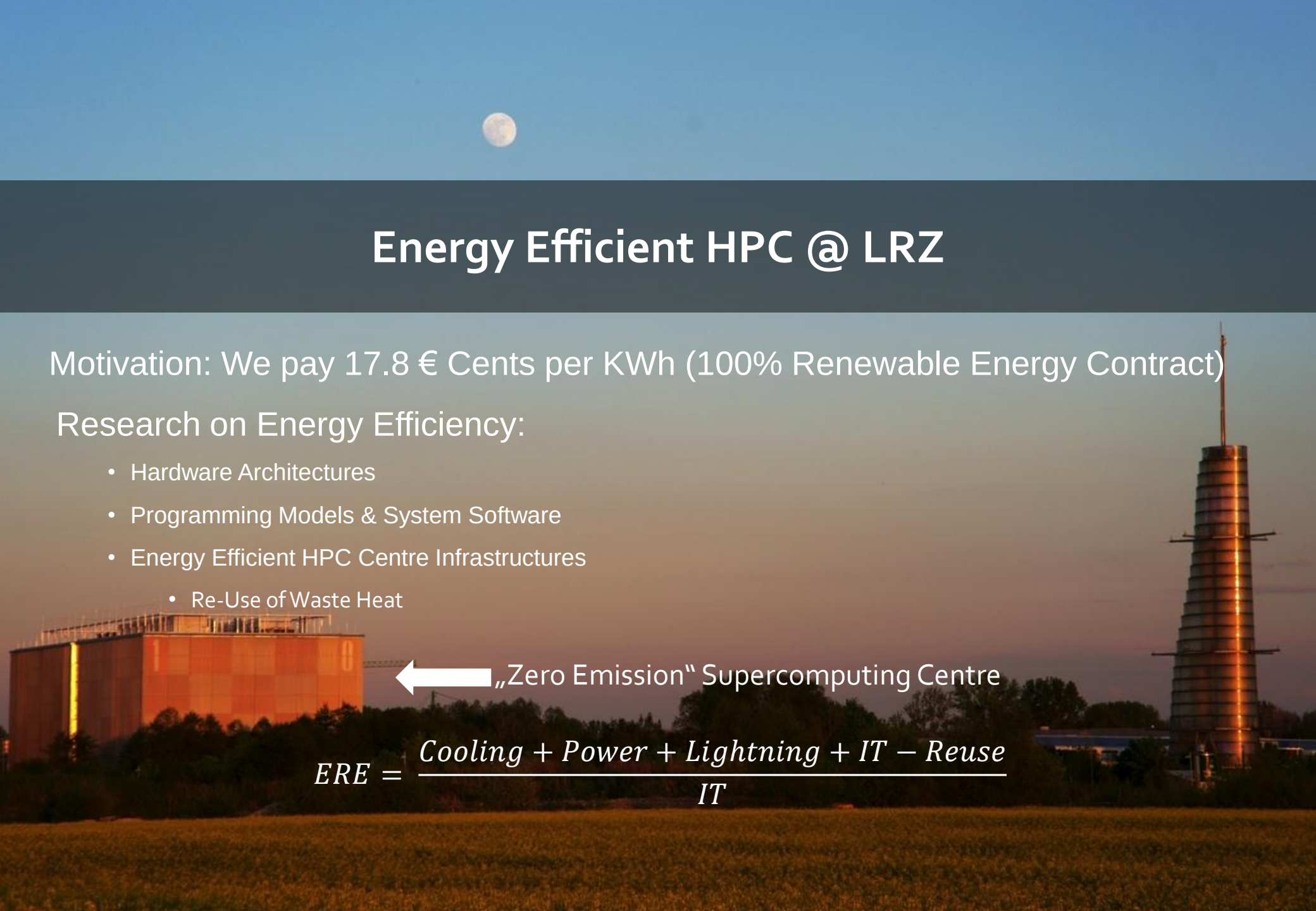


Energy Efficient HPC @ LRZ

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)

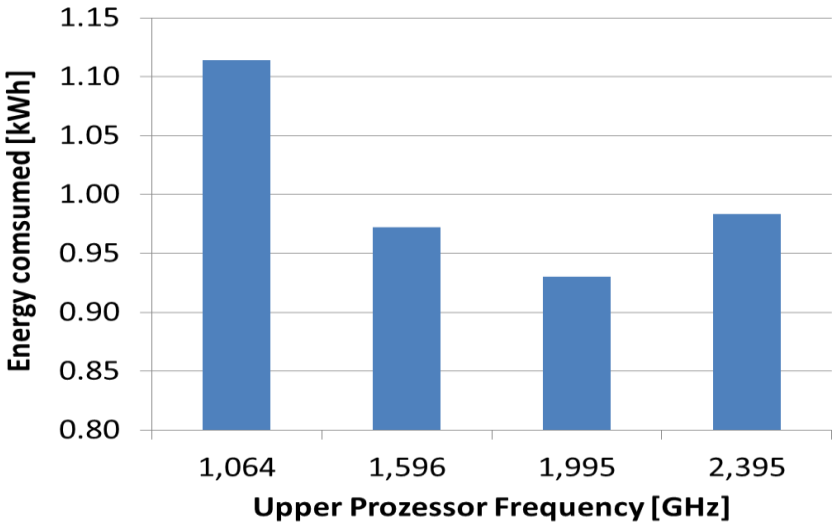
SuperMUC: Warm Water Cooling

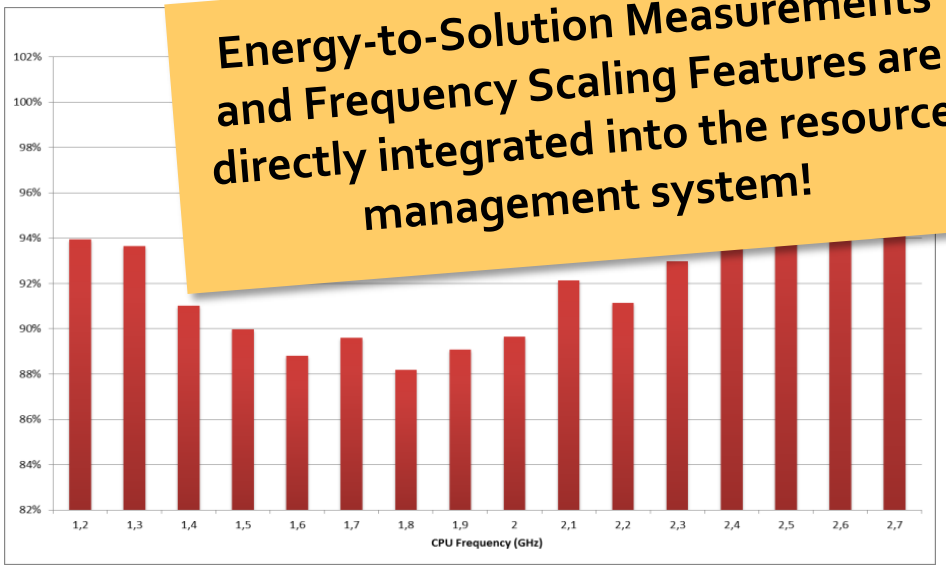
- **Heat flux > 90% to water; very low chilled water requirement**
- **Power advantage over air-cooled node:**
  - Warm water cooled ~10%
    (cold water cooled ~15%)
  - due to lower $T_{components}$ and no fans
- **Typical operating conditions: T_{air} = 25 – 30°C, T_{water} = 18 – 45°C**

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





Energy-to-Solution Measurements and Frequency Scaling Features are directly integrated into the resource management system!

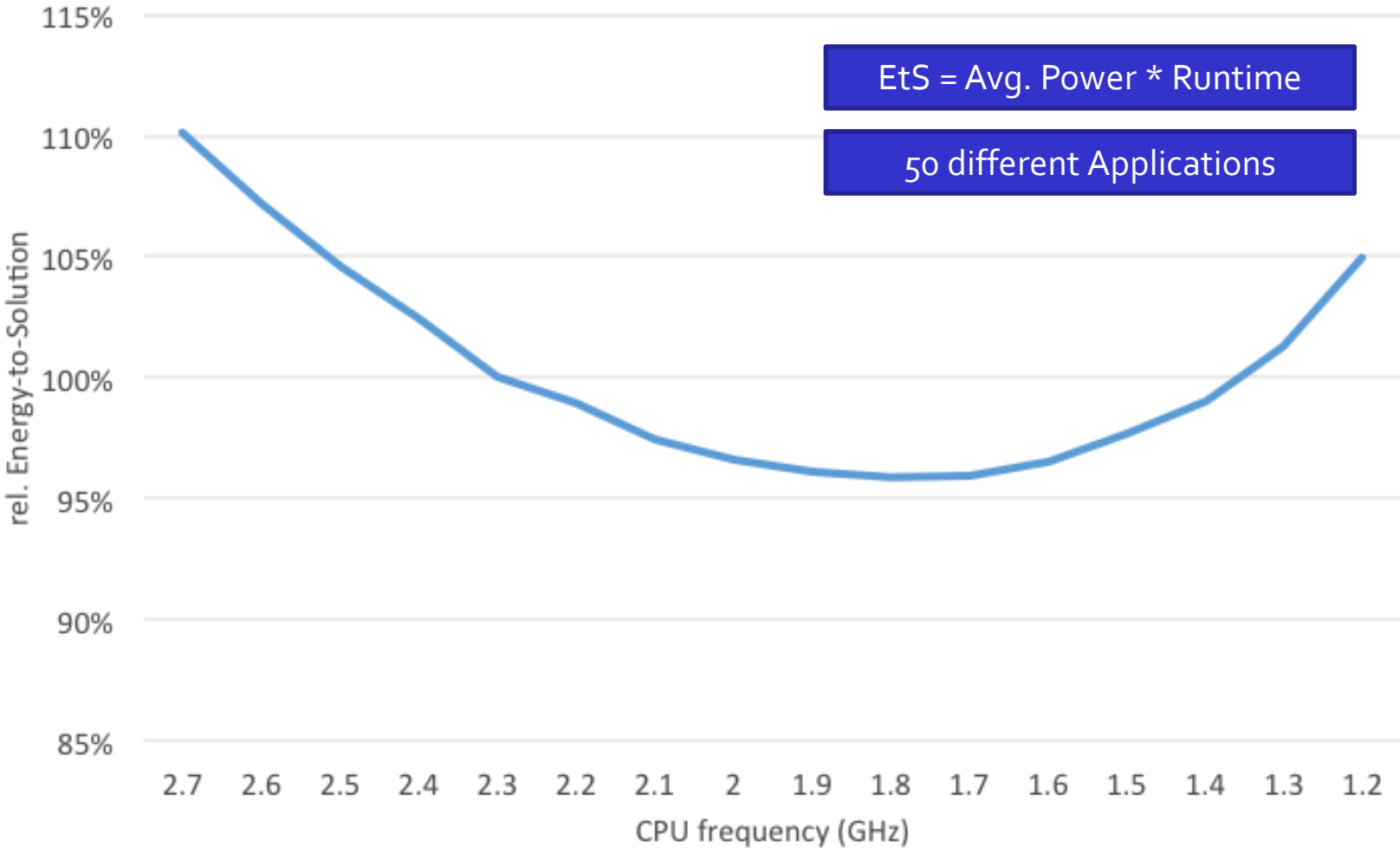
Example 1: Geophysical Application SeisSol

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

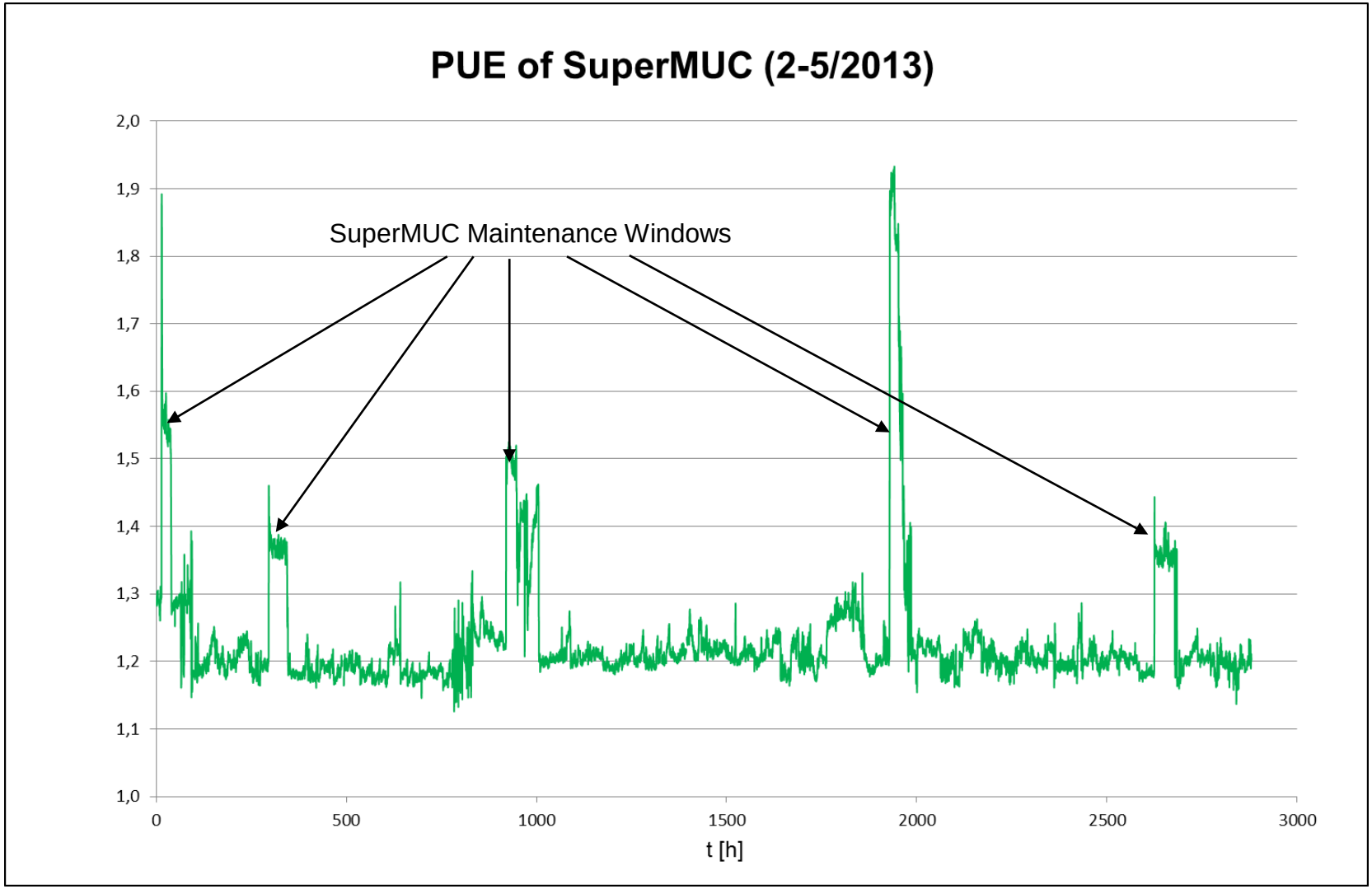
Example 2: CFD Application HYDRO

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

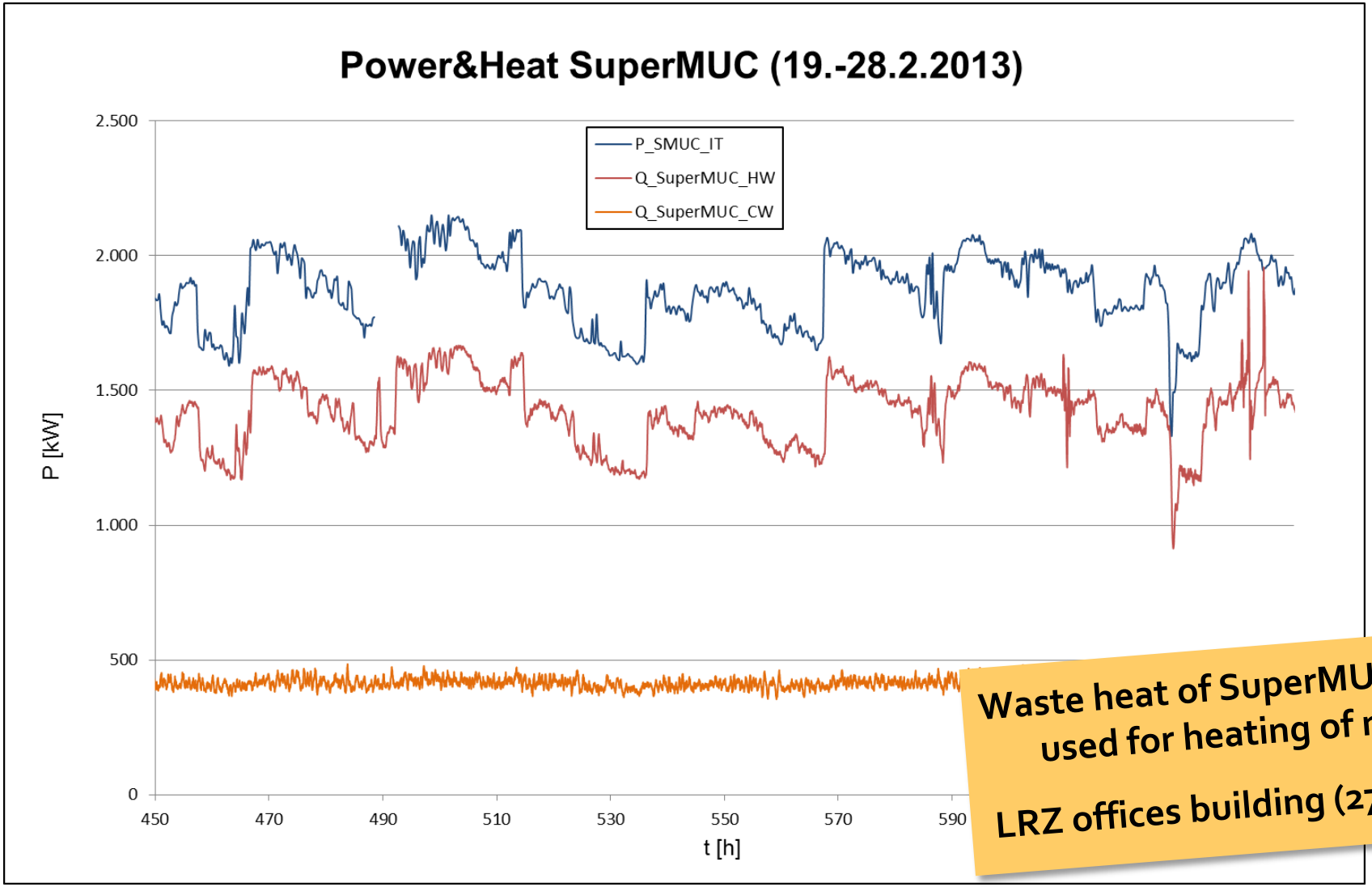
Average Energy-to-Solution Profile on SuperMUC



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)

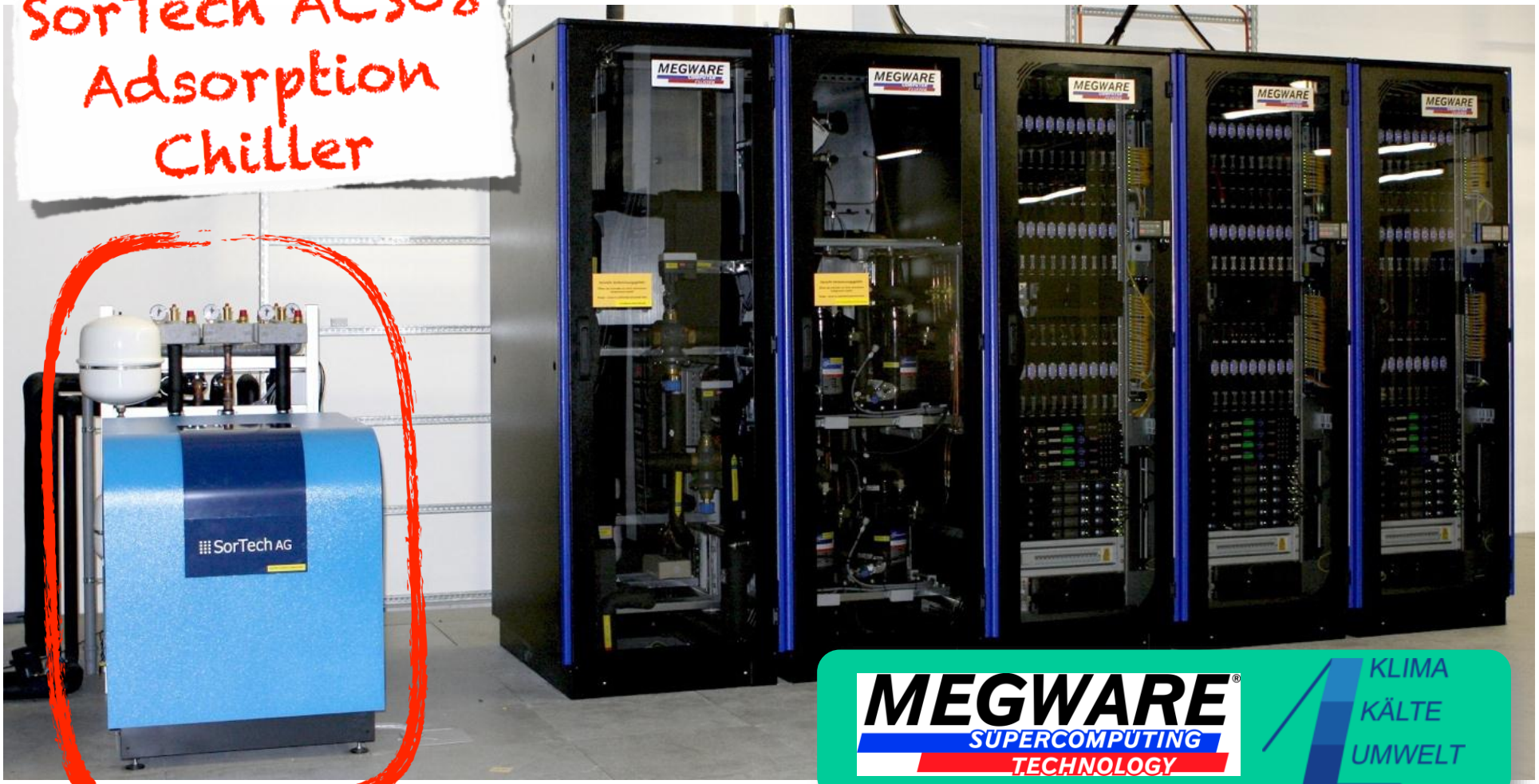
  → SuperMUCs waste heat would be sufficient to heat 26 000 m² of office space (10 x)

- We've just started negotiations with the Galileo planners

GALILEO
LEARNING : LIVING : GARCHING : TUM

- What to do with the waste heat during summer?

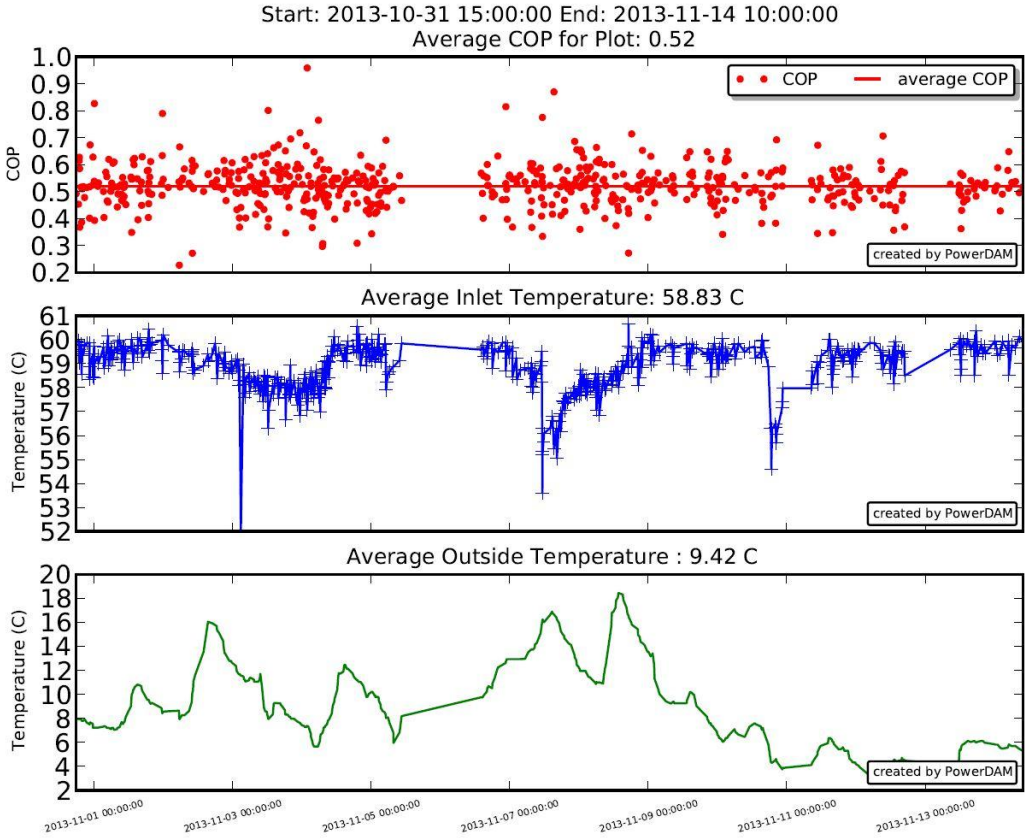
SorTech ACS08 Adsorption Chiller

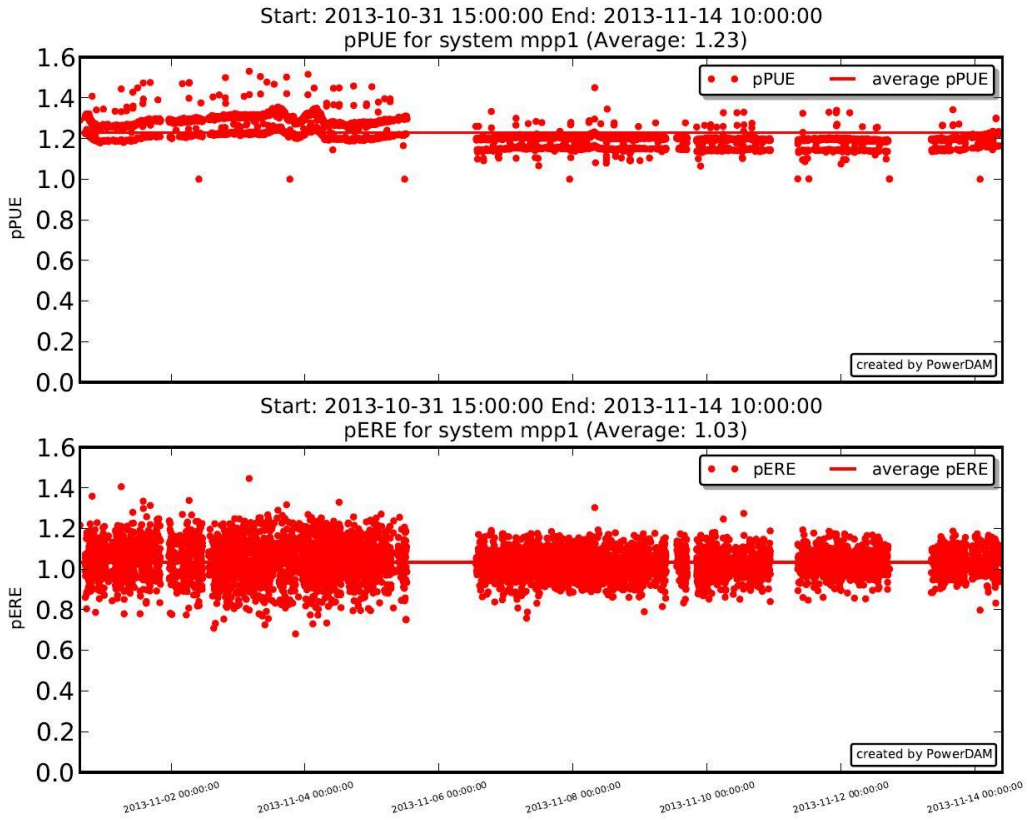


MEGWARE® SUPERCOMPUTING TECHNOLOGY

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 Power Usage 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