# ICT Energy Reuse

## Updates from the University of Notre Dame

Paul Brenner PhD, PE
Associate Director - Center for Research Computing

SC13 EE HPC Workshop

# Environmentally Opportunistic Computing

*Paul Brenner, David Go, Doug Thain, Aimee Buccellato, Patrick Raycroft, Ryan Jansen, Garrett McGrath, Eric Ward, Matt Godeke, Mateusz Jarus, Curt Freeland, Rich Sudlow, Steve Bogol, Michal Witkowski*

# An Alternative Framework

- ***Environmentally Opportunistic Computing (EOC)***

  ***Two Examples:***

  - ***Grid Heating***
    - Design and deploy the IT infrastructure in correlation with target industrial and municipal heat sinks . ***"Bring the Heat"***
    - Direct environmental benefit through waste heat utilization
    - Shared economic savings via reduction is core heat costs
  - ***Symbiotic Cooling***
    - The ICT resources are deployed inline with the host facility's available relief/exhaust air streams
    - Year round free cooling via existing preconditioned air
    - *"Fresh air must come in, cool with the air stream headed out."*

# Grid Heating Greenhouse Prototype

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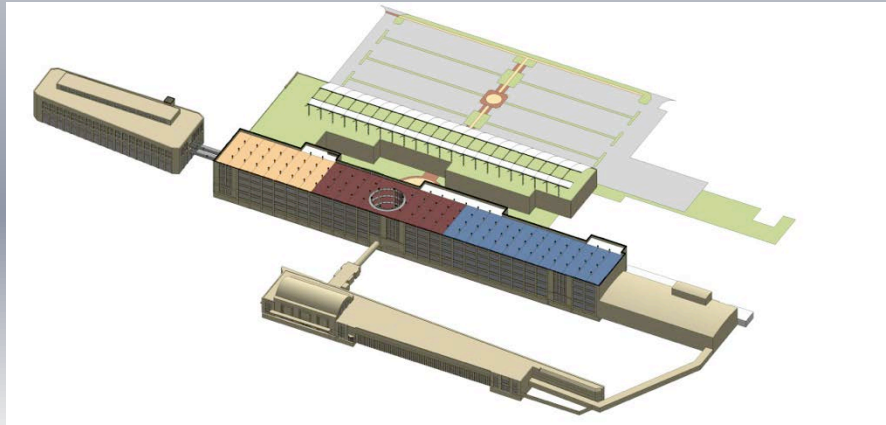
**SDDC**

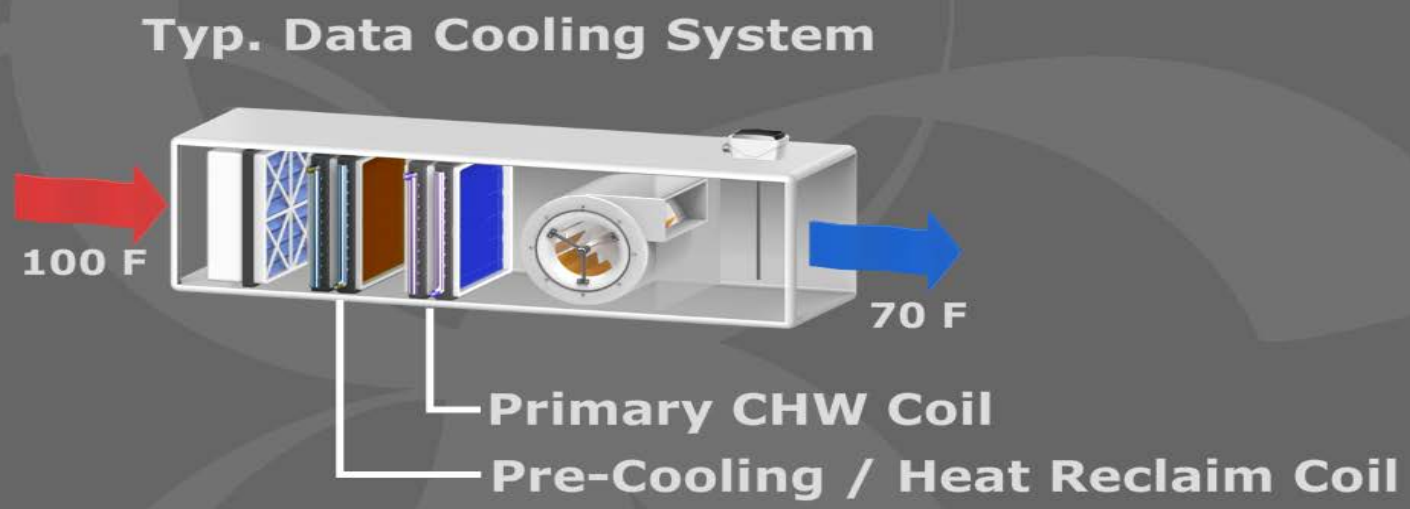
Sustainable Distributed Data Center

# ITC Waste Heat Reutilization at Union Station Tech Center

Kevin Smith, Shane Fimble, James Krolikowski



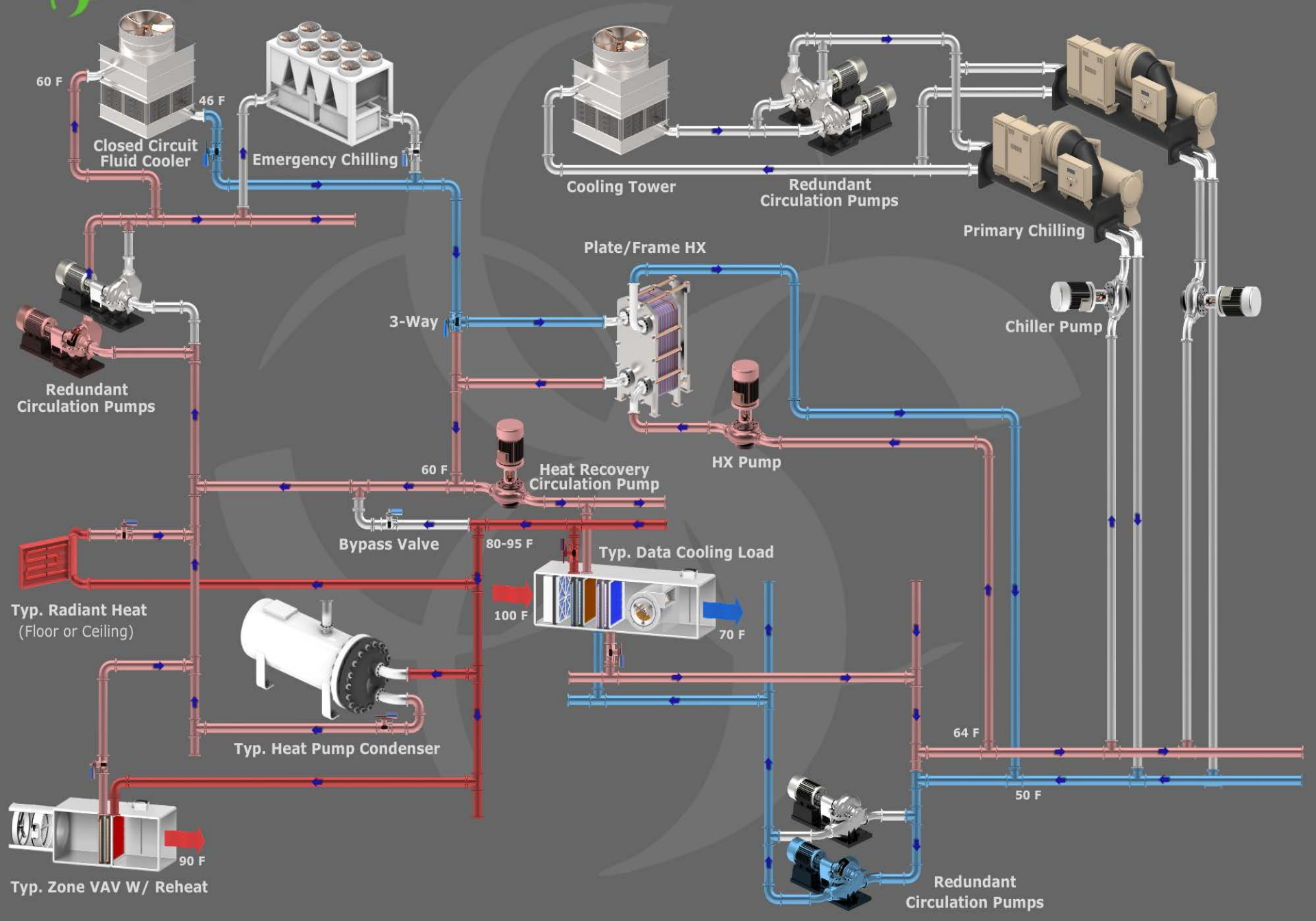
Union Station
Technology Center



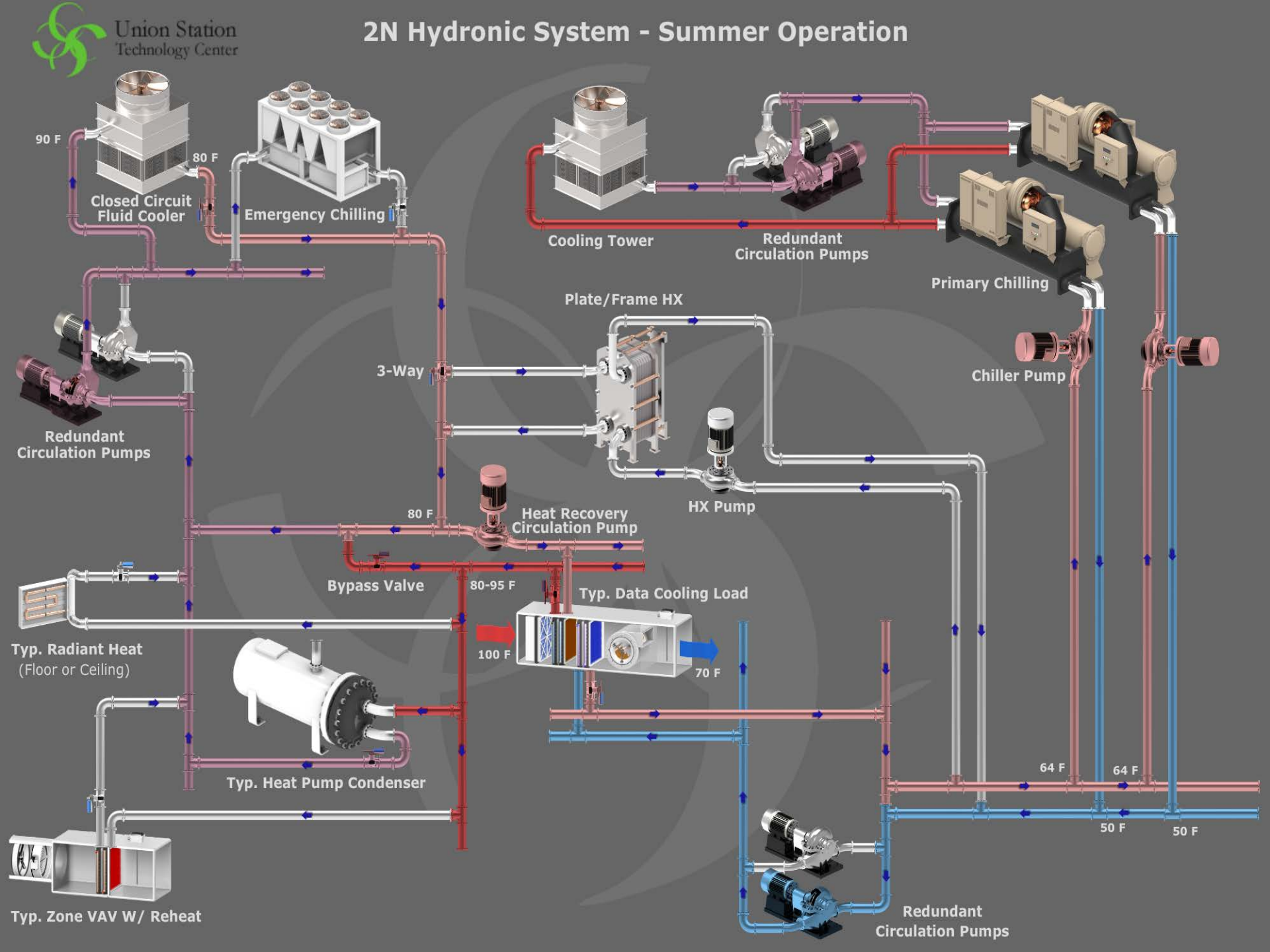

- USTC designs and constructs custom air handling systems for all cooling solutions implemented at the facility
  - All air-to-water cooling systems employ heat recovery
  - All air-to-water cooling systems employ multiple redundant EC fans
  - Heat recovery coils are completely independent from primary coils, and provide 100% cooling if the primary system is down
- USTC's newest modular air-to-water systems are pre-engineered for easy upgrade to water-to-water data cooling solutions

Union Station Technology Center

# 2N Hydronic System - Winter Operation



# 2N Hydronic System - Summer Operation



# A Distributed Waste Heat Reutilization Approach to Energy-Efficient Buildings and Data Centers

J.Z. Woodruff, P. Brenner, A.P.C. Buccellato, D.B. Go, Environmentally Opportunistic Computing: A distributed waste heat reutilization approach to energy-efficient buildings and data centers, *Energy and Buildings* (2013), http://dx.doi.org/10.1016/j.enbuild.2013.09.036

# Effective Thermal Reuse

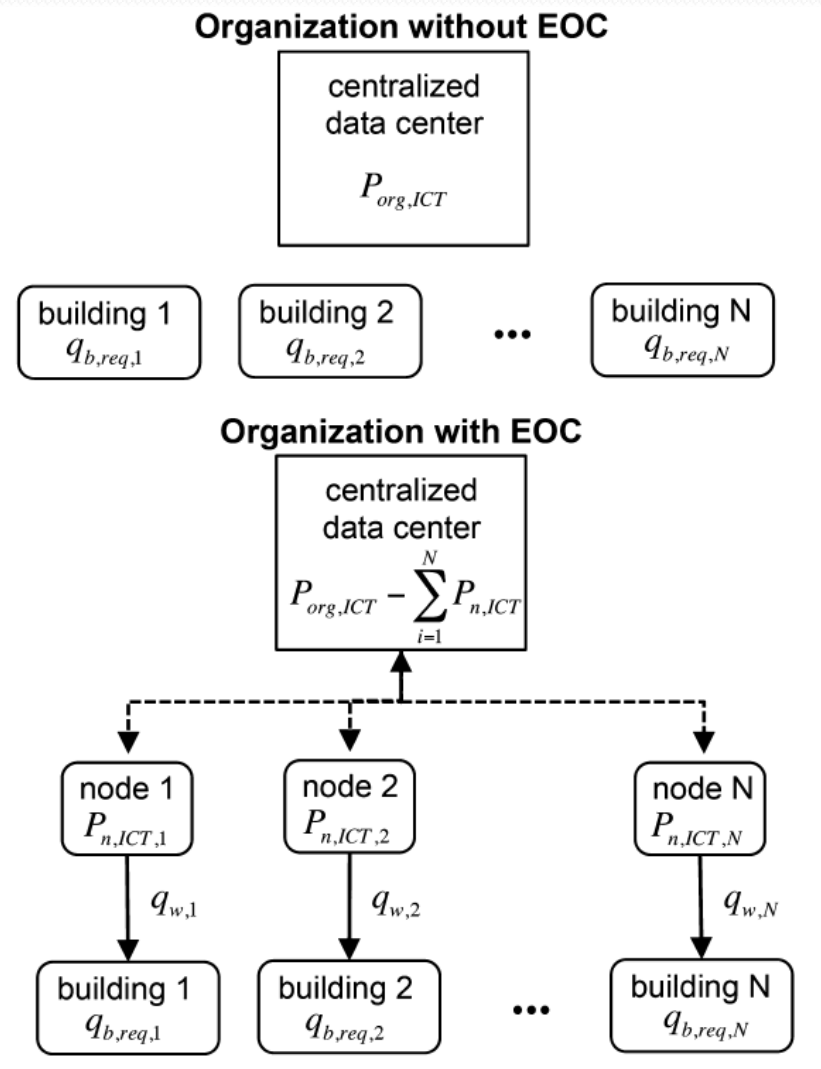
- If we consider that the energy used for ICT equipment will be spent regardless of whether the waste heat is utilized, then one perspective is that any utilization of the waste heat is a successful deployment of EOC.

- However, in order to evaluate an effective deployment of EOC, how much the EOC deployment actually reduces the overall energy consumption of the organization needs to be evaluated.

- From ERE Paper* - "However, the benefits of that reuse energy and the efficiency of that energy are outside the scope of ERE. While these concepts are important to a data center's overall energy use, they are too complex to try to define or measure in the context of what ERE is attempting to do, which is primarily based on the energy use and efficiencies of the data center itself."

*Patterson, M., Tschudi, B., Vangeet, O., Cooley, J., & Azevedo, D. (2010). ERE: A Metric for Measuring the Benefit of Reuse Energy from a Data Center. *The Green Grid, Beaverton*.

# Benefits to the Organization

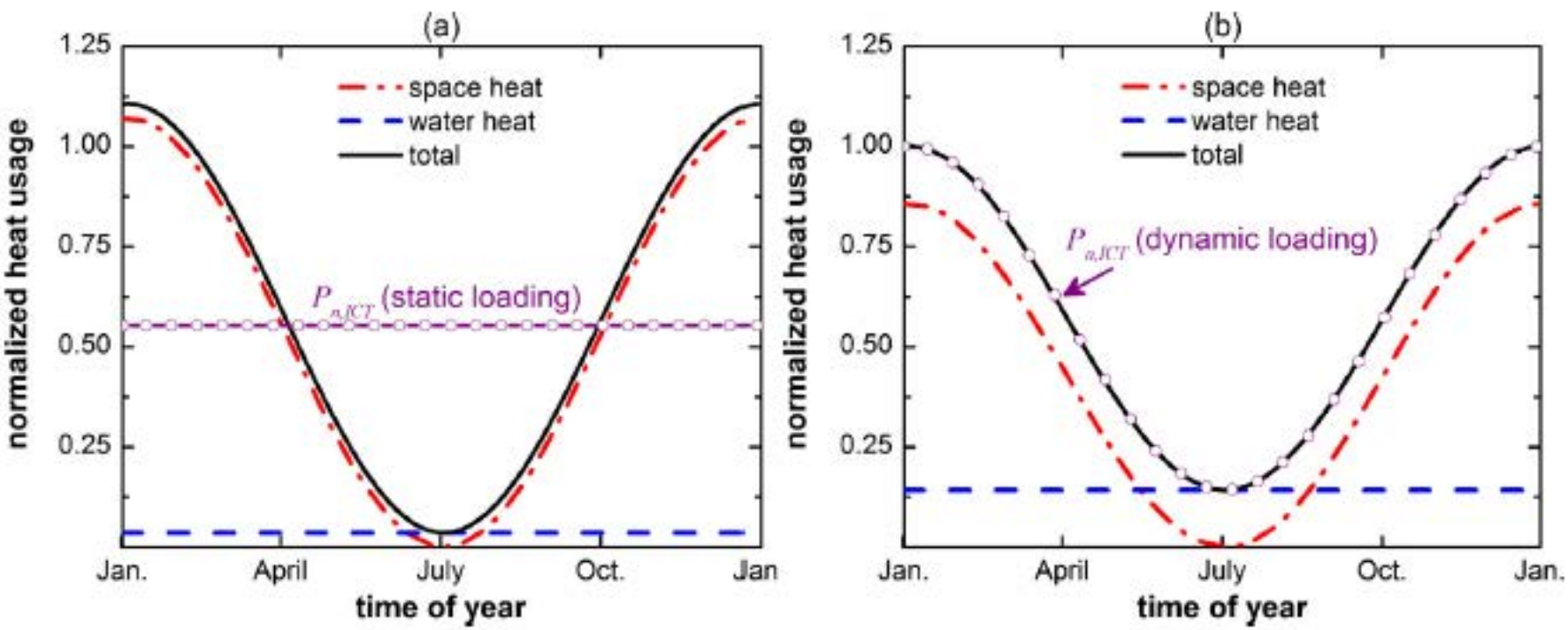



$$\varepsilon_{\text{bldg}} = \frac{P_{\text{b}} - P_{\text{b, EOC}}}{P_{\text{b}}}$$

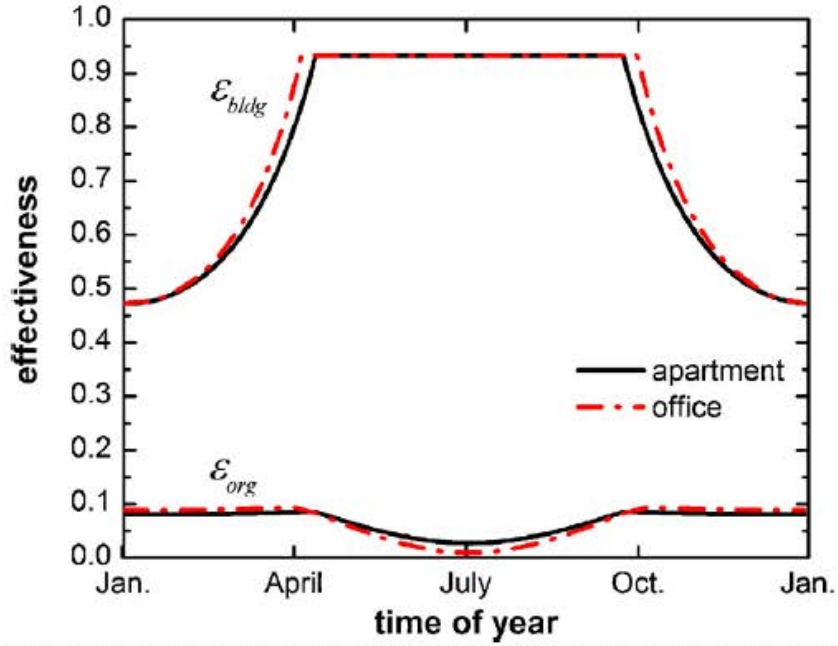
$$\varepsilon_{\text{org}} = \frac{(P_{\text{org}} - P_{\text{org,ICT}}) - (P_{\text{org,EOC}} - P_{\text{org,ICT}})}{P_{\text{org}} - P_{\text{org,ICT}}}$$

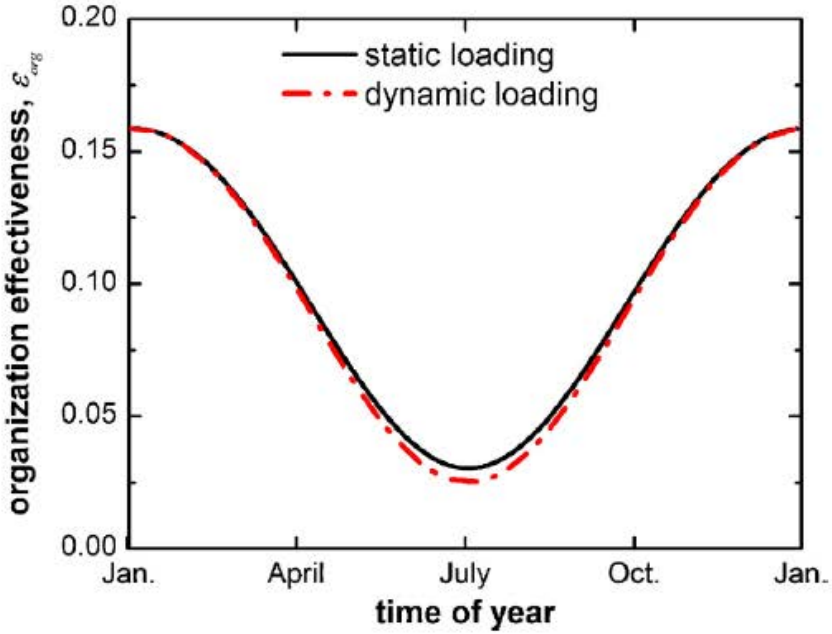
# Reference Building Models

## Office and Apartment



# Balancing Building, Org, and Peak



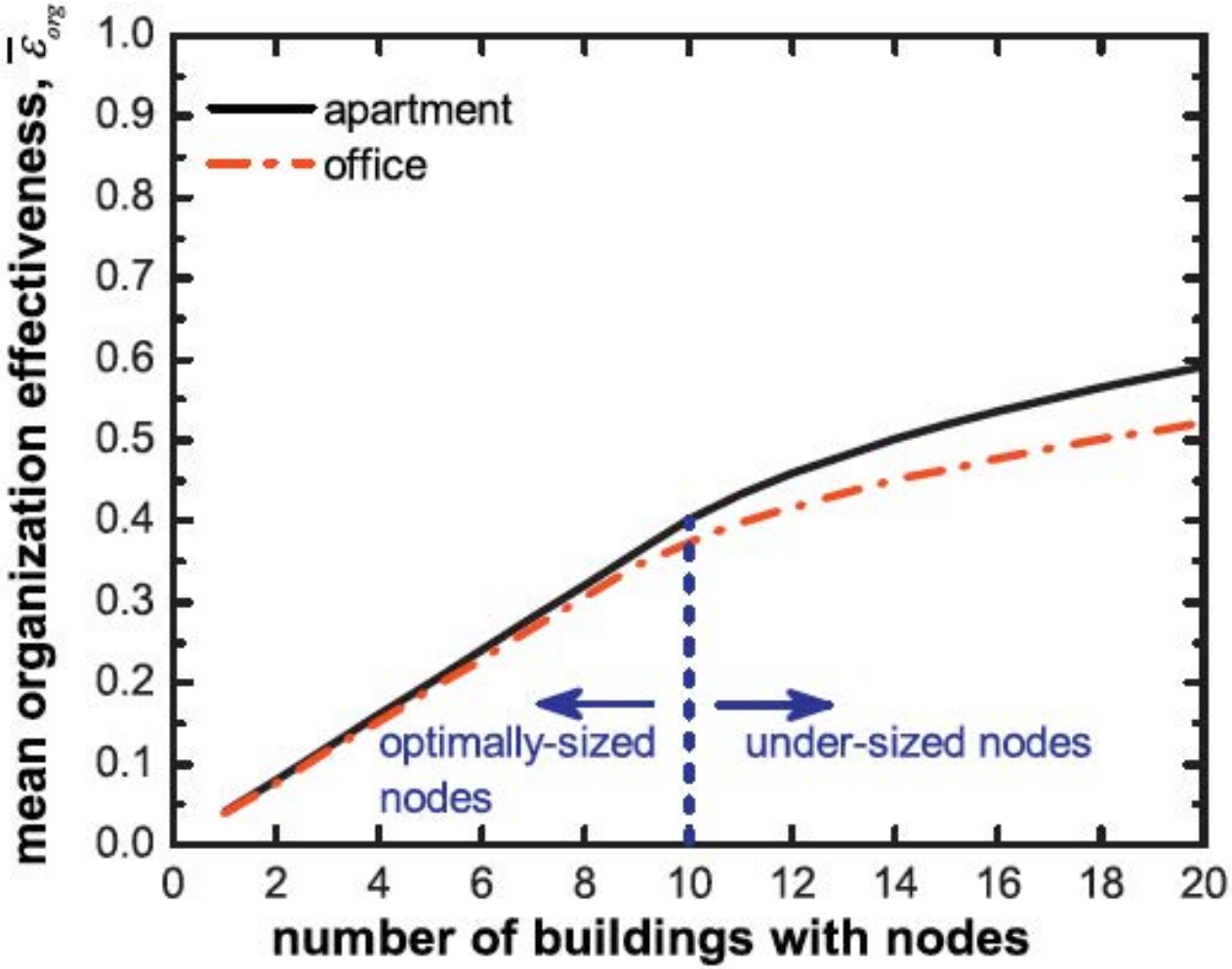
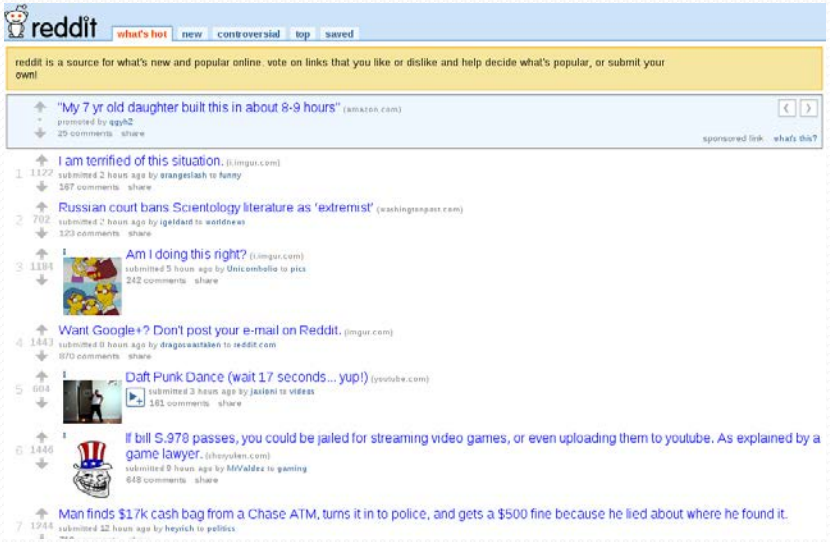


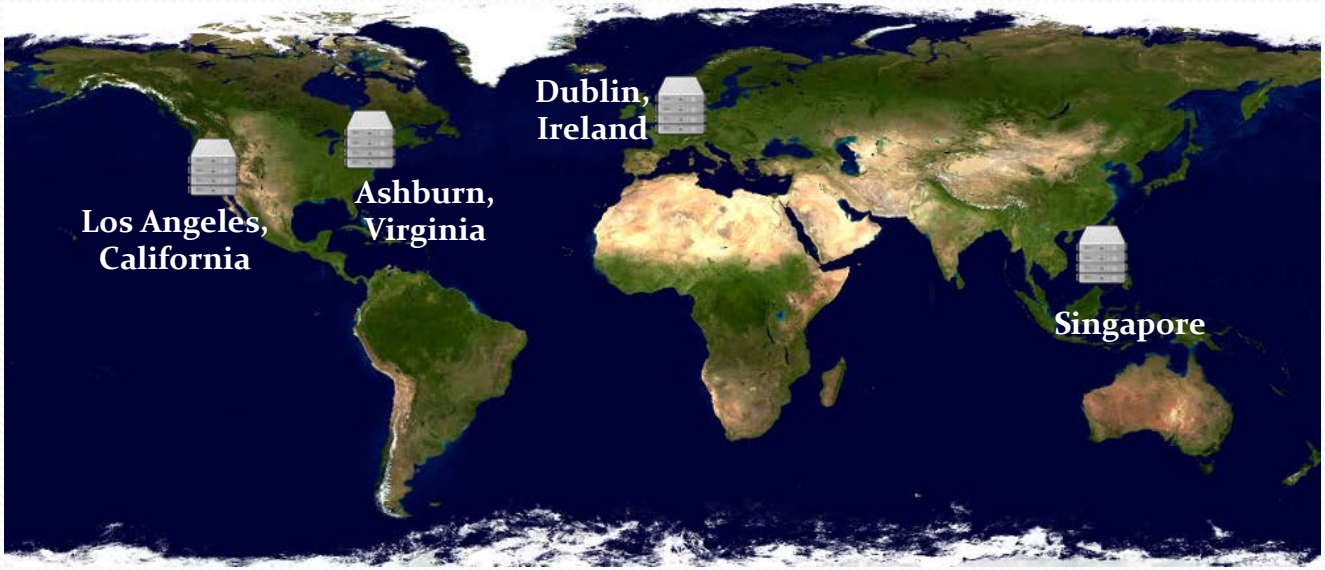

**Fig. 7.** Time-averaged $\bar{\varepsilon}_{org}$ as a function of the number of buildings with nodes in an organization. The analysis used an organization with 20 identical buildings, each sized with heating requirements to be 10% of the ICT power in the organization ($q_{b,req} = 0.1\ P_{ICT,org}$), and the nodes underwent static loading.

# Energy Efficient Virtual Machine Allocation in the Cloud

# Simulation Scenario

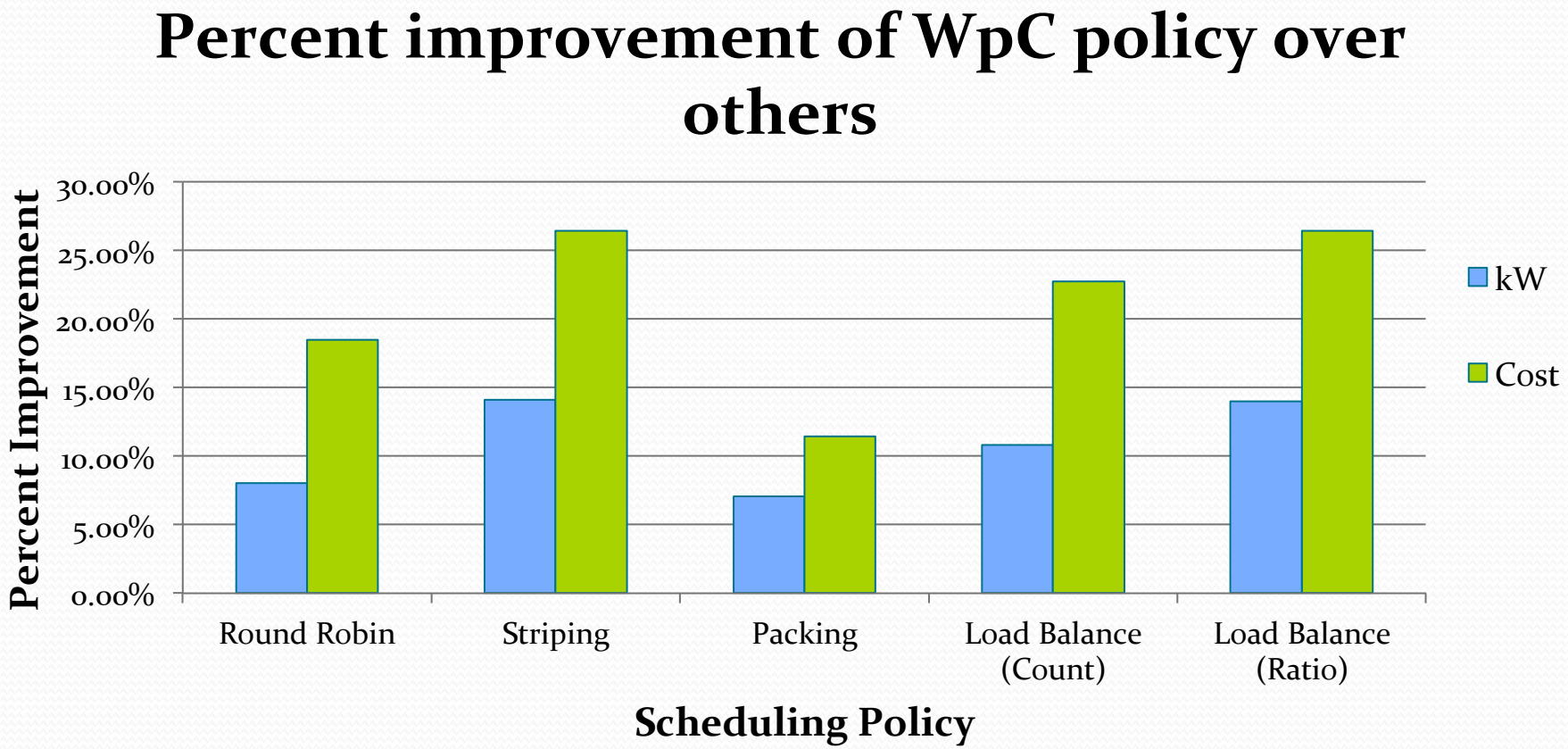
- Real world basis
  - Reddit® cloud load
  - Amazon® VM sizes
  - IBM® hardware
  - Published power prices
  - Global Distribution



# Watts per Core Policy

- Most energy efficient policy – Watts per Core (WpC)



Questions?