Grid Heating

Managing Thermal Loads with Grid Engine

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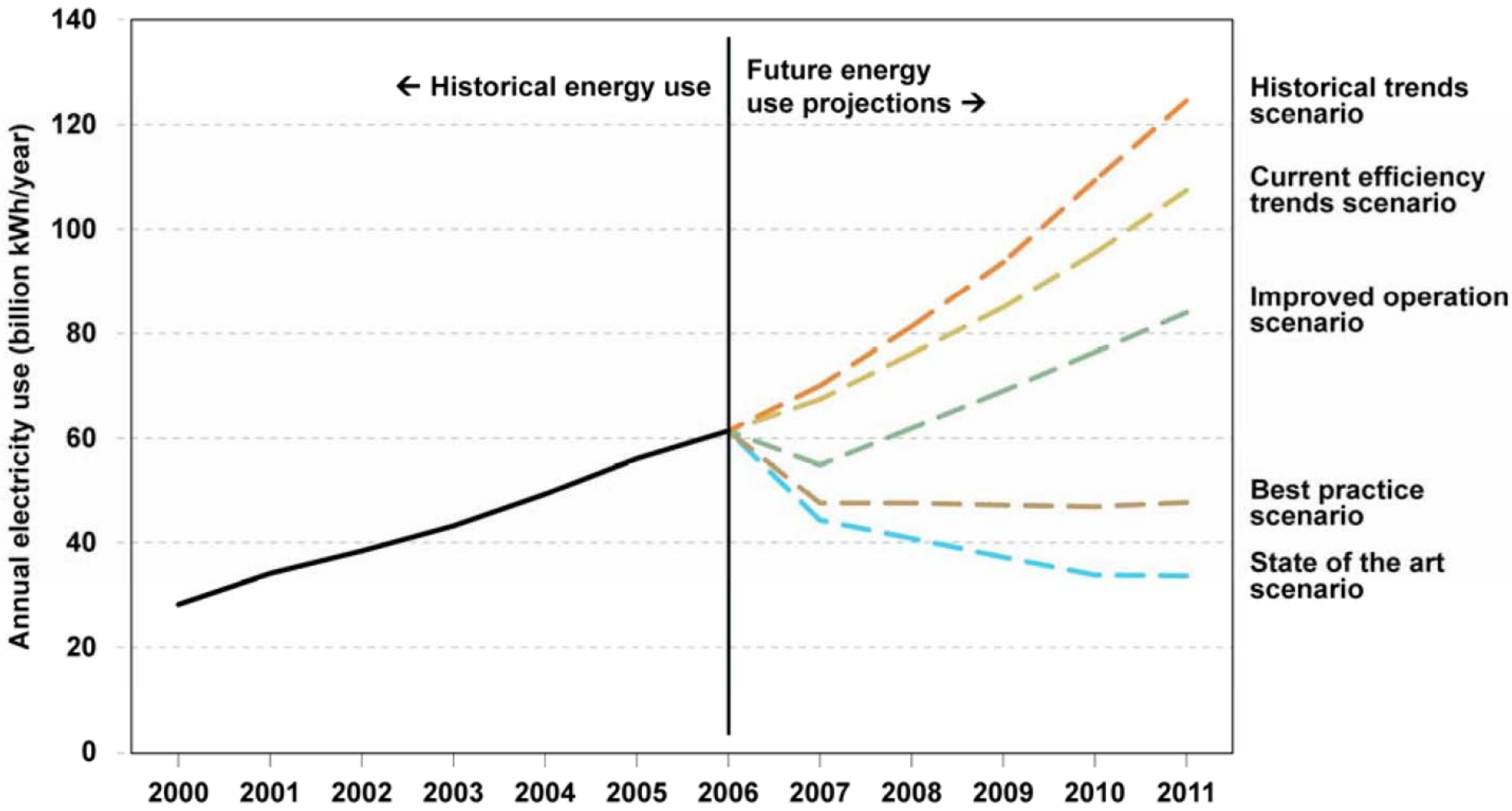
Motivation

- Utility costs for US Servers to grow from 4.5 billion in 2006 to 7.4 billion in 2011



Ref: US EPA 2007

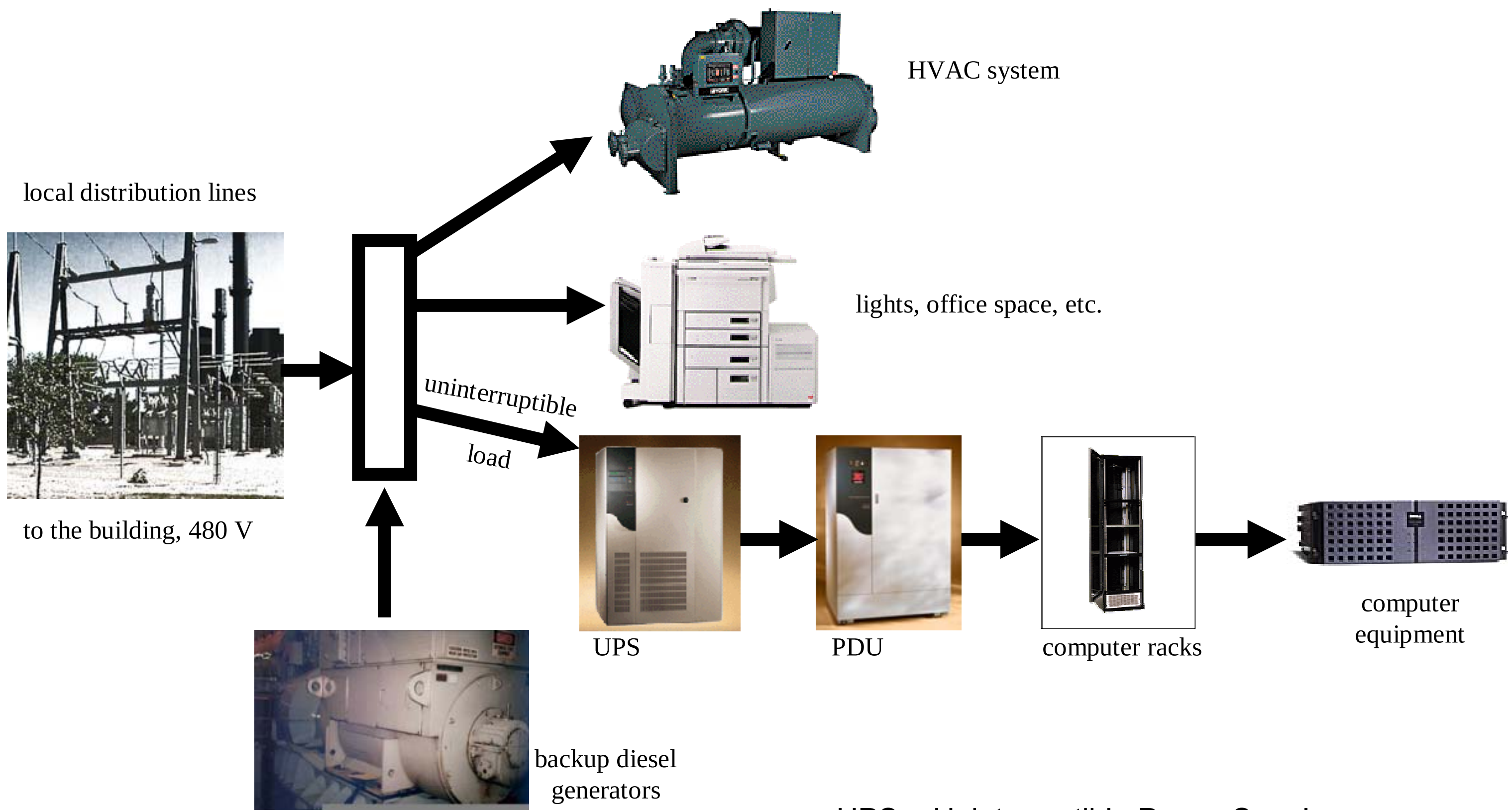
Motivation

- Power Requirements in Context

Typical AMD/Intel CPU	60-120 W
1U Server	300 W
Air Cooled Comp Rack	5-25 kW
Water Cooled Comp Rack	25-50 kW
CRC load at Union Station	150 kW
ND Data Center load	250 kW
NCSA PetaScale Facility	25 MW
Microsoft Facility *(Unpublished)*	125 MW
7.4 Billion Dollars in 2011	11.4 GW

Challenges

Electricity Flows in Data Centers

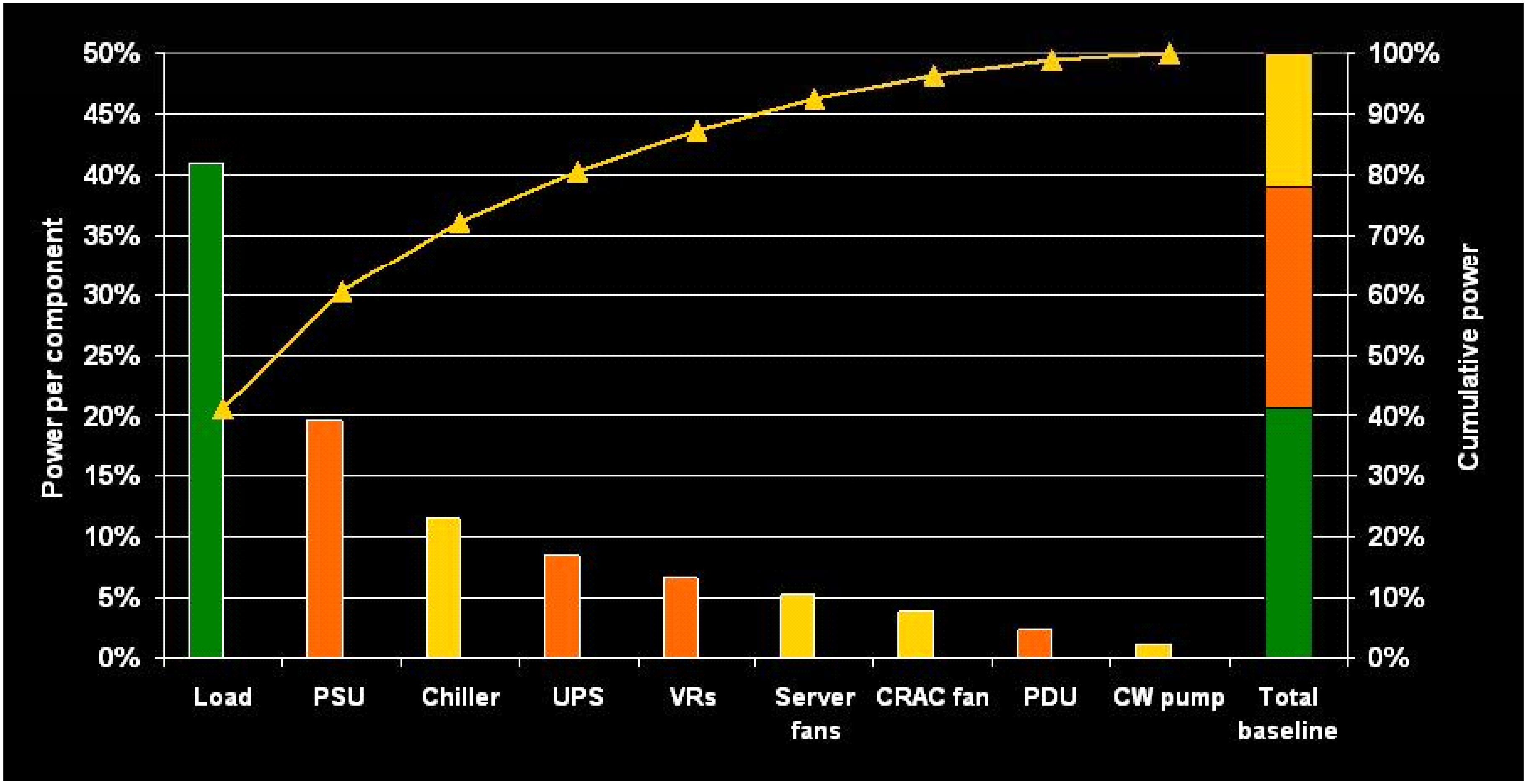


UPS = Uninterruptible Power Supply

PDU = Power Distribution Unit;

Ref: William Tschudi LBNL

Challenges



Ref: Michael Patterson, Intel Corporation *& William Tschudi LBNL*

A New Framework

- ***Grid Heating***
  - Design and deploy the IT infrastructure in correlation with target industrial and municipal heat sinks … ***"Bring the Heat"***
  - Reduce or remove operational and capital IT cooling costs
  - Provide thermal benefit to industrial/municipal partner at a shared economic savings
  - Direct environmental through reduction in thermal waste

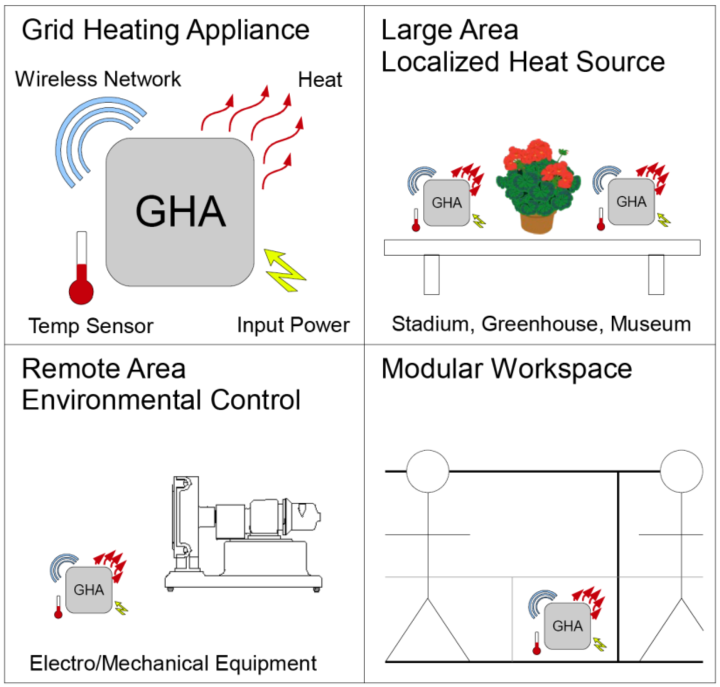
Deployment

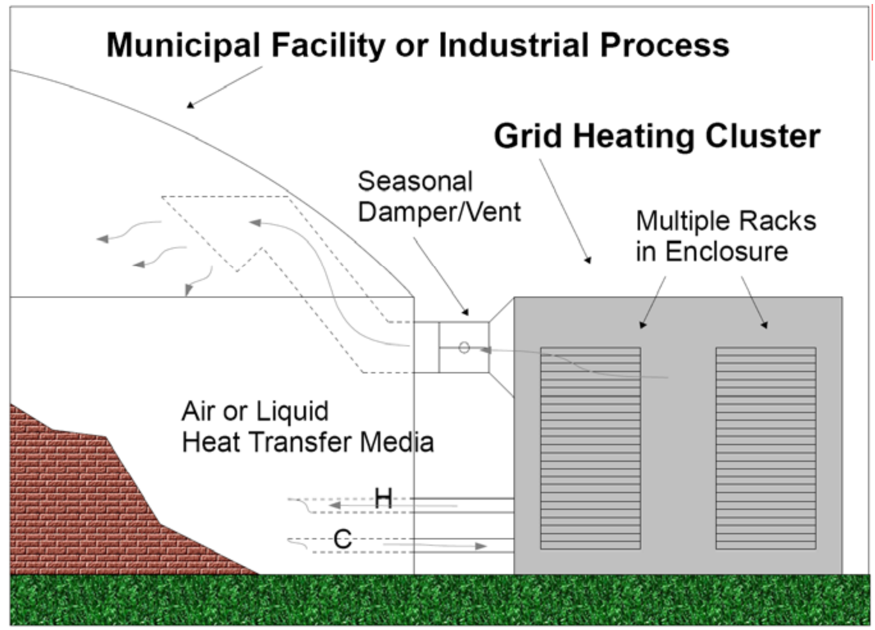
- Must address operational IT considerations
  - Physical
    - Temperature, Humidity, Particulate
  - Practical
    - Security, Bandwidth, Access, Acoustics
    - Reliability/Redundancy/Disaster Recovery
- Utilization relative to hardware capital costs
  - 365 x 24 designs preferred
  - Minimize energy transformation/transport
  - Select granularity of grid distribution accordingly

Two Example Models

- High Granularity

Grid Heating Appliances





- Coarse Granularity

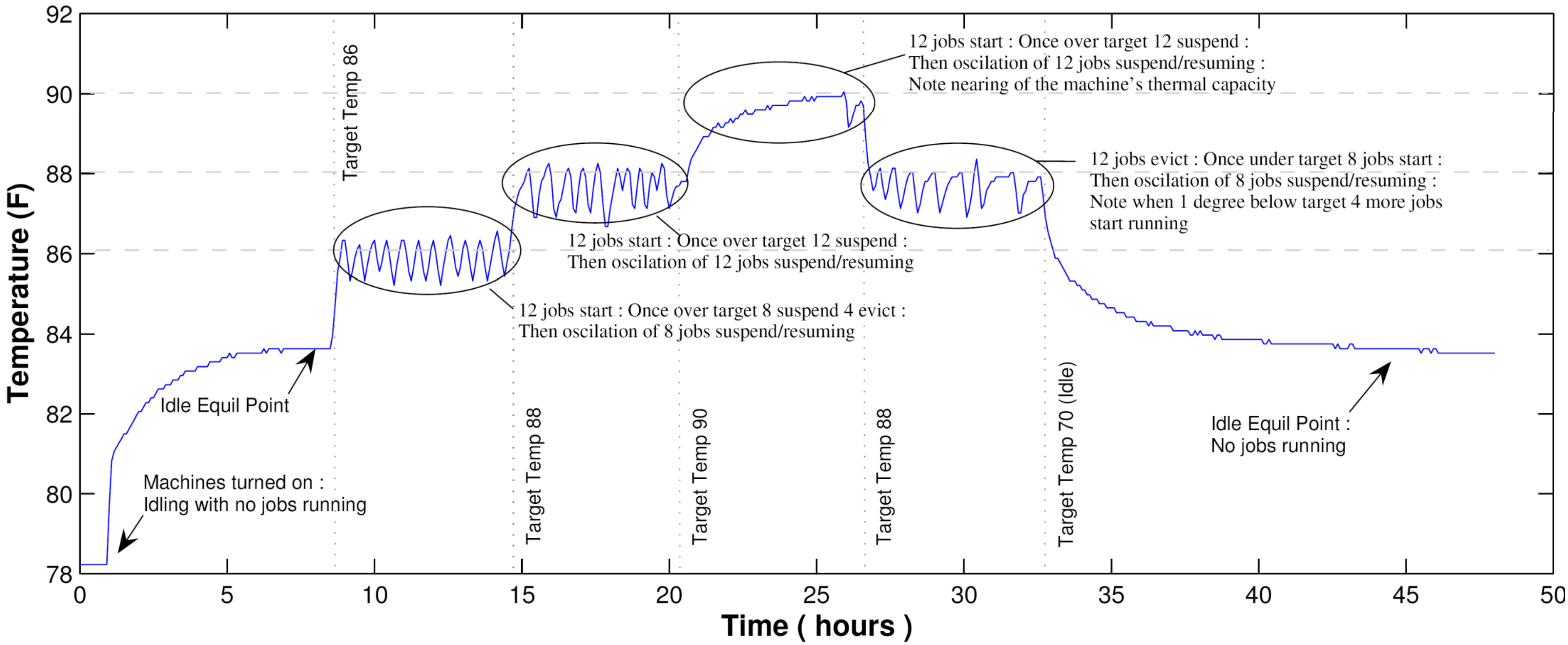
Grid Heating Clusters

Grid Engine at ND

- ND Campus Grid
  - Sun Grid Engine (5.3)
    - Central production environment
      - Bound to Distributed Storage (NFS & AFS)
    - Serial and Parallel Jobs
    - Replacing PBS on faculty clusters
  - Condor (7.x)
    - Serial Job Submissions
    - OSG Integration
    - Serial Cycle Scavenging

Experimental Results

- Fine Grained Temperature Control



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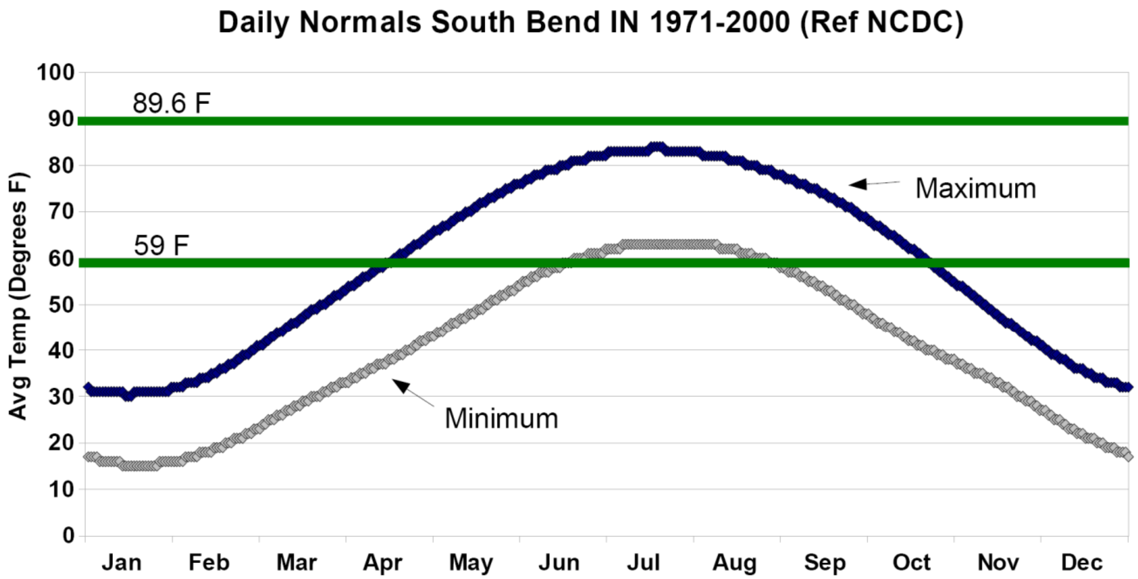
Experimental Results

- GHC and GHA in the South Bend Greenhouse and Botanical Garden (SBG)
  - SBG struggles to retain sufficient funding. Annual heating costs are a primary factor (over 100K in 2005 & 2006, forced closure of some sections in 2007).


Dayton

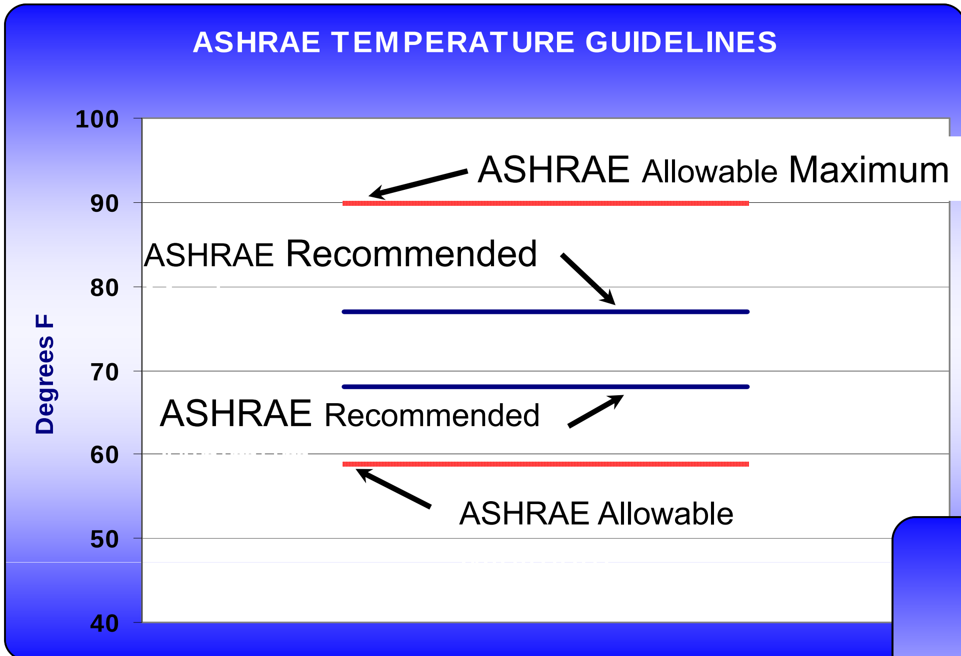
Greenhouse Factors *(Physical)*

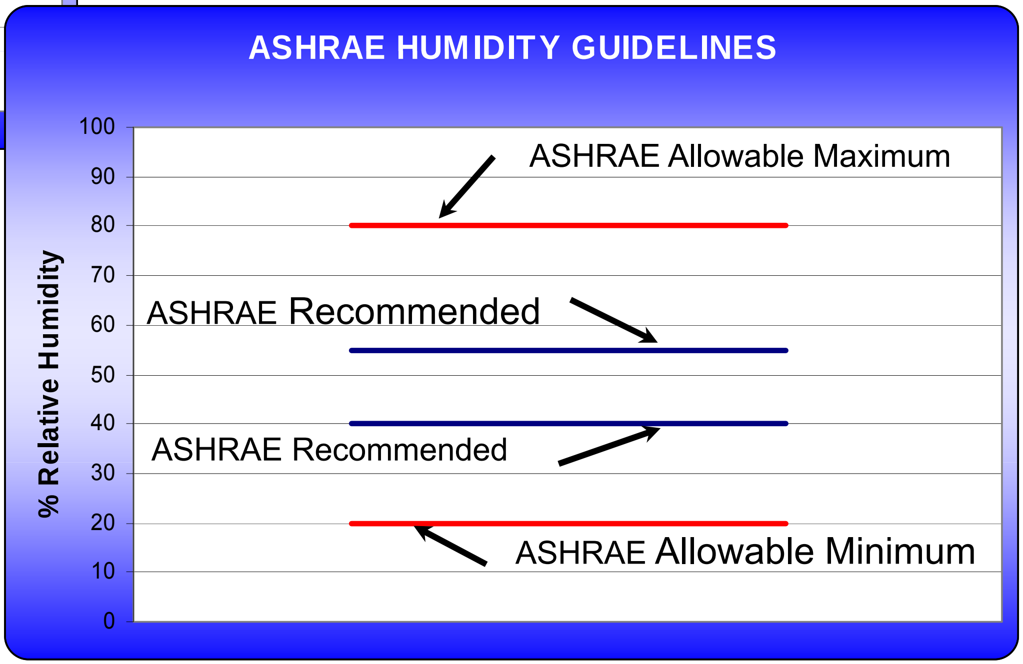
- Temperature
  - Louvered Outside Air Vents and Exhaust Fan



- Humidity
  - Existing Steam Humidification for Plants
- Particulate
  - Under Investigation

Temperature and Humidity





Ref: ASHRAE & William Tschudi LBNL

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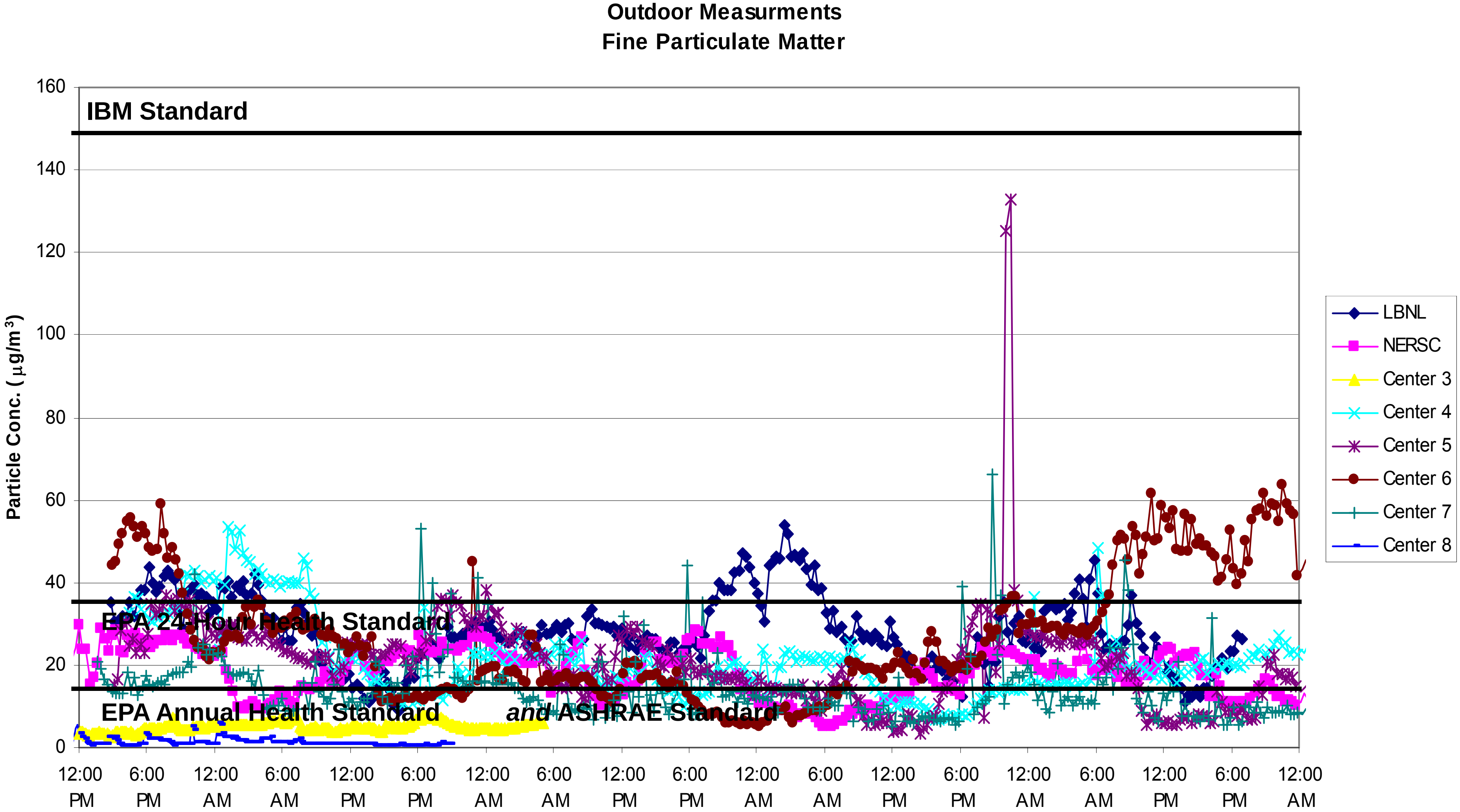
Particulate



Ref: William Tschudi LBNL

Greenhouse Factors *(Practical)*

- Security
  - Public facility open daily
  - Monitored/Paid admission
  - Hardware locked in compute rack
  - Power and network cable into rack, exposed
- Network
  - Cyberlink wireless broadband 4-15MB
  - Ownership… VPN in hindsight
  - Security
    - Firewalls everywhere: clients, routers, servers

Greenhouse Factors *(Practical)*

- Reliability/Redundancy/Disaster Recovery
  - SPF secured against accidental interruption
  - Need power backup (battery)
  - Susceptible to public vandalism
  - Provides decentralized of resources for DR
- Access
  - 10min drive from CRC offices (~distance to US)
- Acoustics
  - Significant echo in the dome. Sustained white noise is not magnified.

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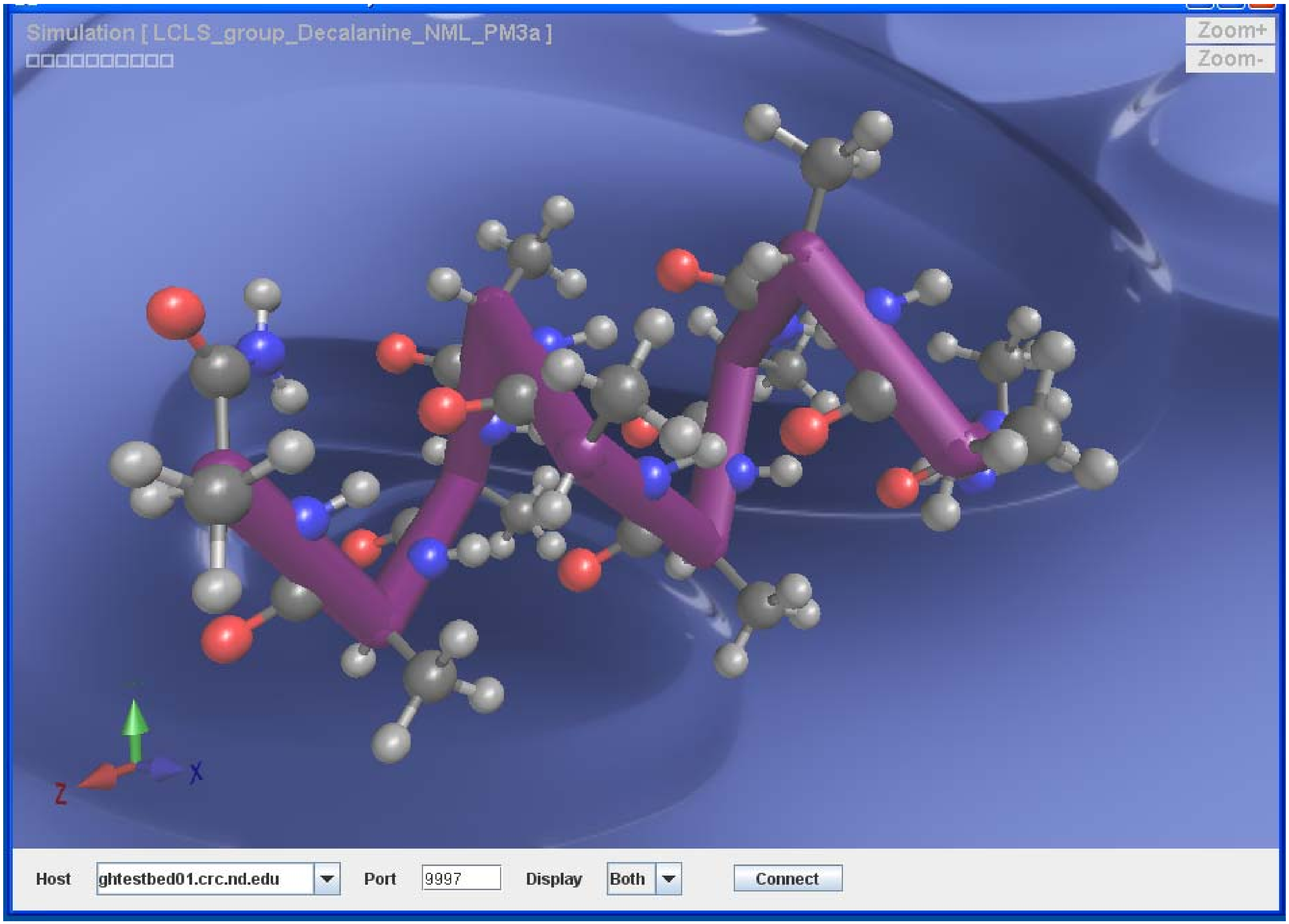
Phase 1 Complete



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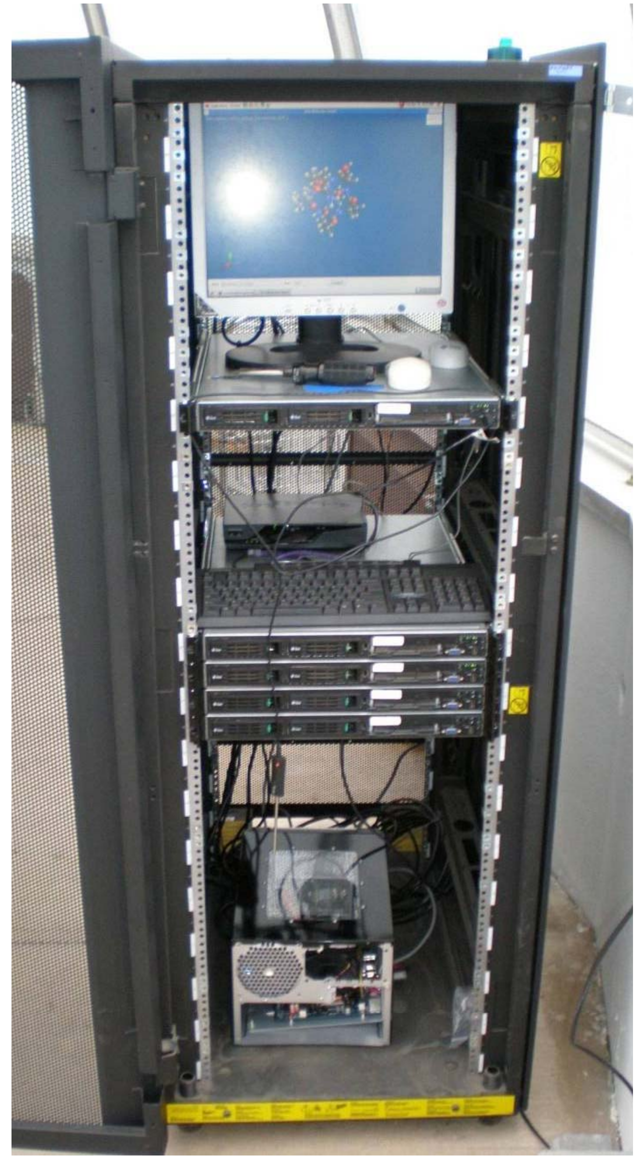
Phase 1 Complete



Grid Engine for Grid Heating

Mandate a user environment identical to our production grid

- Requires suitable bandwidth for distributed storage

Summer 2008 upgrade of production grid software stack

- RHEL5 (currently 4), Grid Engine 6.1, New ND CRC AFS Cell

Implementation Plans:

A

- Grid Heating *queue(s)* each mapped to a target and max temperature. Incremental change in resource provision

B

- Grid Heating Resources/Complexes.

Grid Heating Appliance

- No data persistence
  - Transmit, compute, transmit, forget
  - Appliance OS in 'Firmware'
- Rugged
  - Minimal components: No hard drive
- Mobile
  - Wireless networking
- Invisible
  - Small and Quiet (Special fan/heat sink)

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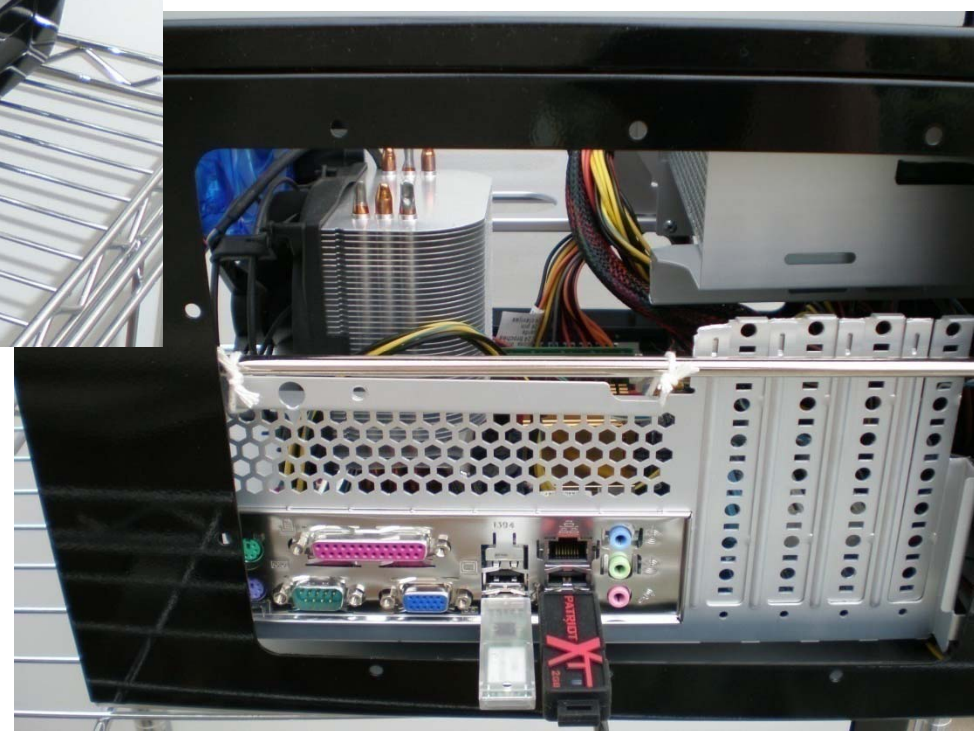
Grid Heating Appliance



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  - Curt Freeland
  - Mike Kelly and Mike Lammie (ND CSE Undergrads)
- DOE NWICG Grant


Questions?


Energy Conversions

- Power and Energy
  - 1 kWh = 3.6 Megajoules
  - 1 Therm (100,000 BTU) = 105.5 Megajoules
  - 1 Therm = 29.3 kWh
- What does it cost?
  - $0.086 /kWh (US DOE EIA commercial)
  - $0.013 /cubic ft ~ $ 1.30 /therm
- *Resolve Unit Cost into MJ*
  - *$23.89 /1000 MJ (electric)*
  - *$12.32 /1000 MJ (natural gas)*

Energy At The Greenhouse

- Annual heating costs are a primary factor
  - over 100K in 2005 & 2006, closed some buildings in 2007 due to heating costs
- Strong seasonal dependence
  - 18,000 therm natural gas load in Jan 08
    - 527,400 kWHr → *732.5 kW Max Seasonal Load*
    - *Not practical to size for maximum load*
    - *Select optimal baseline, supplement with nat gas*
  - Desert Dome ~8% of sqft → 59 kW

Related Work *(Data Centers)*

- Lawrence Berkeley National Lab
  - High-Performance Buildings for High-Tech Industries
  - http://hightech.lbl.gov
- NCSA
  - Building the Data Center of the Future, 2008 Symposium
- Uptime Institute
  - Green Enterprise Computing, 2008 Symposium
- ASHRAE TC 9.9
  - Mission Critical Facilities, Technology Spaces & Electronic Equip
- Green Grid
  - Global consortium to advance energy efficiency in data centers

References

- US EPA Tech Report 109-431
  - Report to congress on server and data center energy efficiency
- 24x7 Energy Efficiency Presentation
  - William Tschudi Lawrence Berkley Nat Lab
- ASHRAE TC9.9
  - Thermal Guidelines for Data Processing Equipment
- Condor High Throughput Computing
  - www.cs.wisc.edu/condor

Related Work *(Grid Arch)*