Optimizing the Efficiency of the NCAR-Wyoming Supercomputing Center Facility

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Personal Information

Education:

- Mechanical Engineering Grad Student
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Project Goals

- Optimize NWSC Energy Usage
- Investigate and Identify Inefficient Energy System(s)
- Standardize Trends as a Diagnostic Tool Consistent with “The Green Grid™” Datacenter Metric System

CISL Computational & Information Systems Laboratory

NCAR

About NCAR-Wyoming Supercomputing Center (NWSC)

- Purpose: Constructed to house high performance supercomputers for atmospheric and geoscience modeling across the nation
- Official Opening[1]: October 15, 2012
- Location: 8120 Veta Drive, Cheyenne, Wyoming
- Awards & Recognition:
  - 2013 Green Enterprise IT (GEIT) Award

    Awarded First Place in the "Facility Design Implementation" category
  - Datacenter Dynamics - North American Green Data Center Design Award
  - Ranked 17th fastest supercomputer in the world[2]
  - LEED Gold Status

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The Green Grid™ Metric System

- The Green Grid™ energy metric system is the industry-wide accepted metric system for measuring and comparing information technology infrastructure energy efficiencies all over the world

- Metric Systems includes:
  - Performance Usage Effectiveness[3] (PUE)

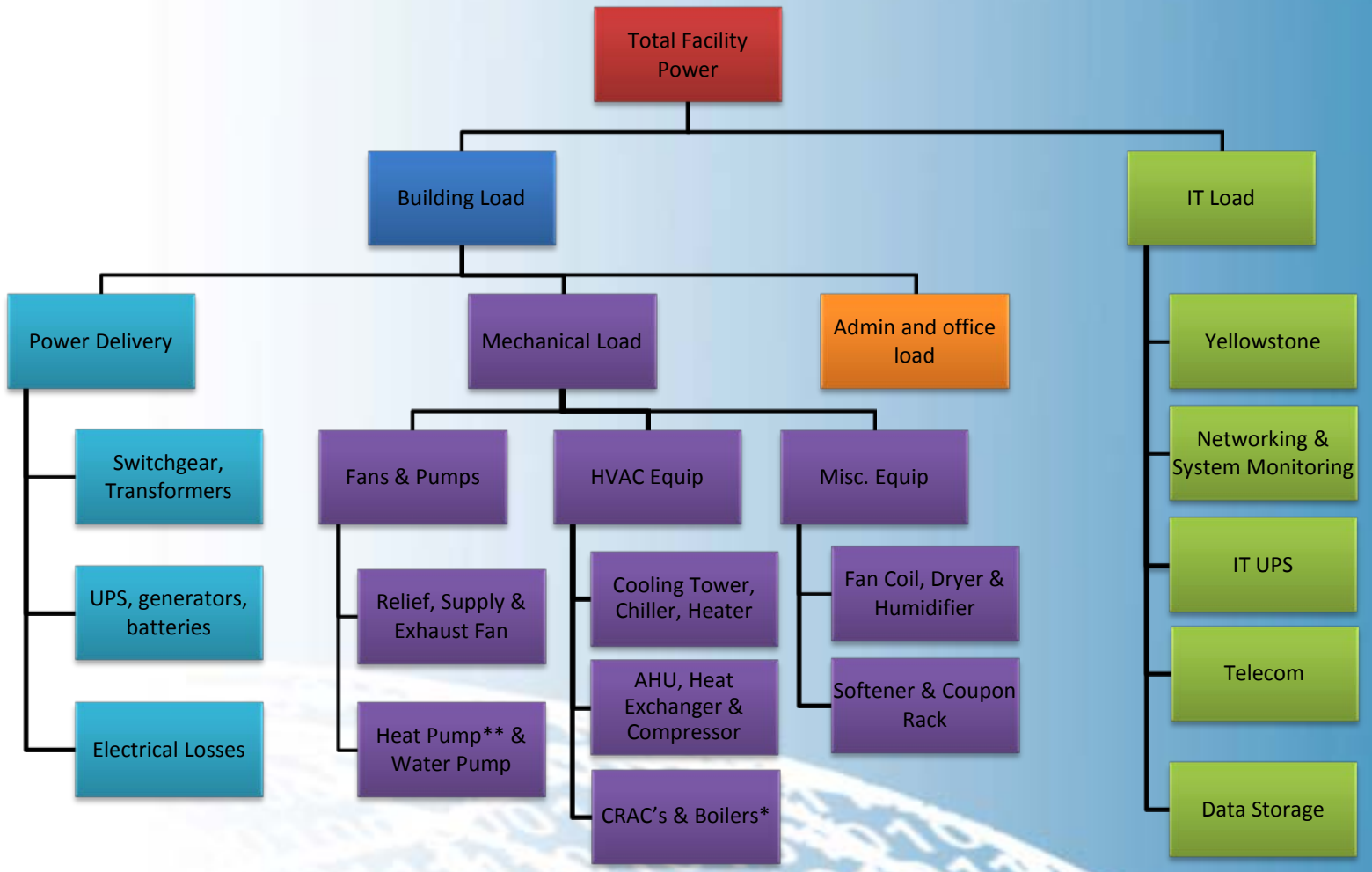
$$PUE = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}} \qquad 1.0 \leq PUE \leq \infty$$

  - Energy Reuse Effectiveness[4] (ERE)

$$ERE = \frac{\text{Total Facility Energy} - \text{Reuse Energy}}{\text{IT Equipment Energy}} \qquad 0 \leq ERE \leq \infty$$

  - Other metric systems investigated are Carbon Usage Effectiveness (CUE) [5] and Water Usage Effectiveness (WUE) [6]

Energy Subcomponents

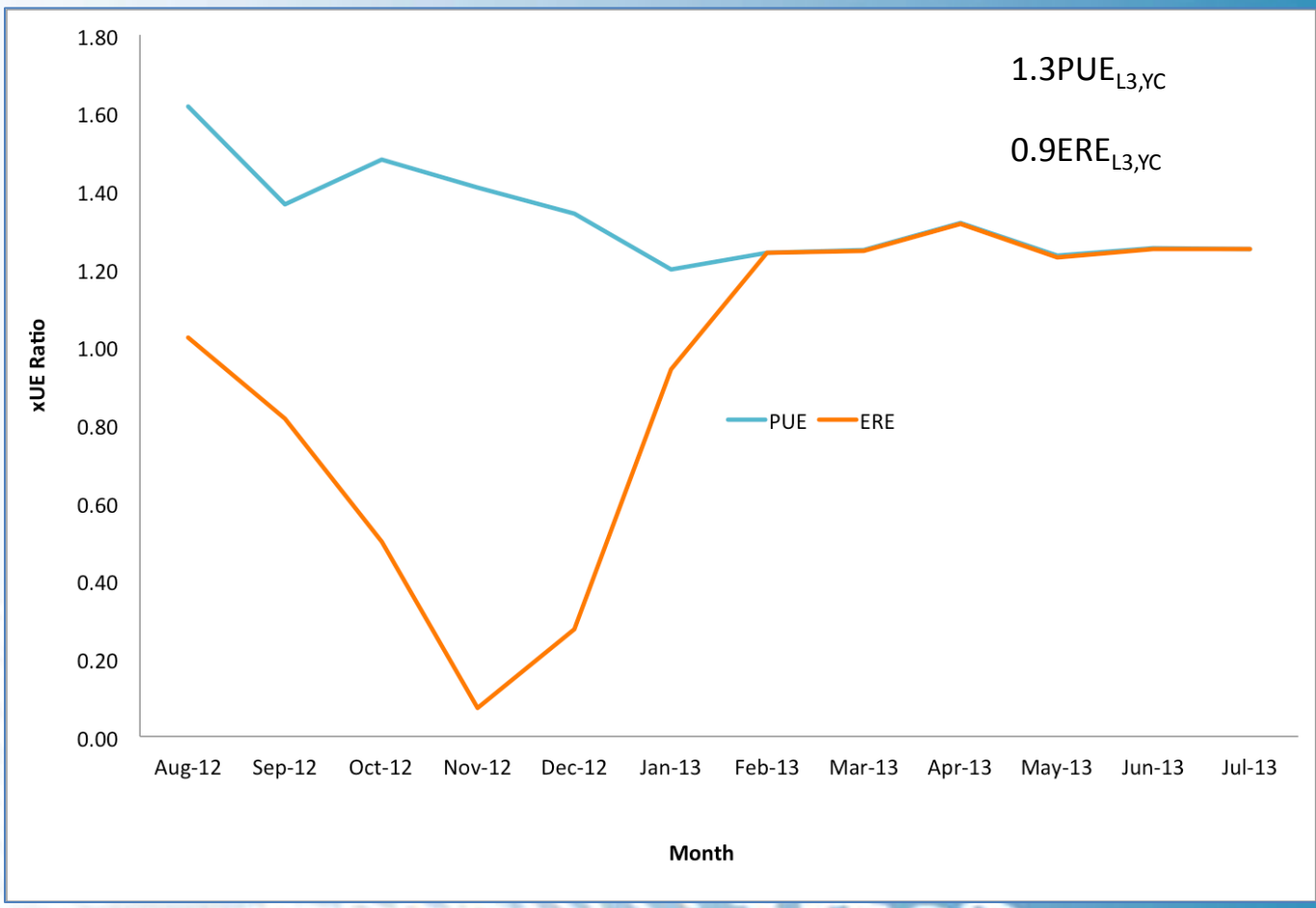


*Boiler is mainly operated on natural gas, all other components are powered by electricity

**ERE is computed from reused heat energy recovered from Yellowstone Supercomputers by Energy Recovery Heat Pumps

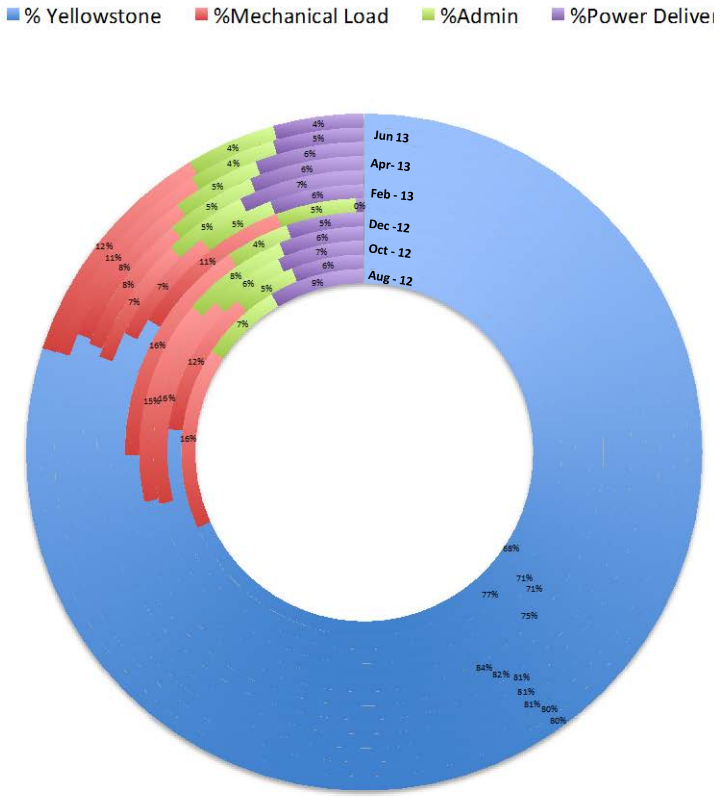
2012-2013 NWSC PUE & ERE

- $1.3PUE_{L3,YC}$ signifies, level 3 PUE 15 minutes, annual measurements
- Lower ERE trends before Feb is due to energy reuse within the data center



Monthly Energy Usage

- Yellowstone consumes over 80% of Total Facility Power
- Mechanical load accounts for 10% of Total Facility Power on average



*Increasing monthly concentric circle from Aug, 2012 to July 2013

Mechanical Systems

Investigated NWSC Mechanical Systems are:

- Heating Systems
- Humidification Systems
- Duplex Softener Systems
- Reverse Osmosis System
- Chilled Water System

Others include:

Cooling Towers, AHU, Fan Wall Air Handlers, Snow Melt System, Lighting System

Hydronic Evaporative System

- 65^0F Efficient Water Circulation

Utilizes 45^0 bends; Oversized Piping Network; and Smaller Pumps

- Cooling Tower

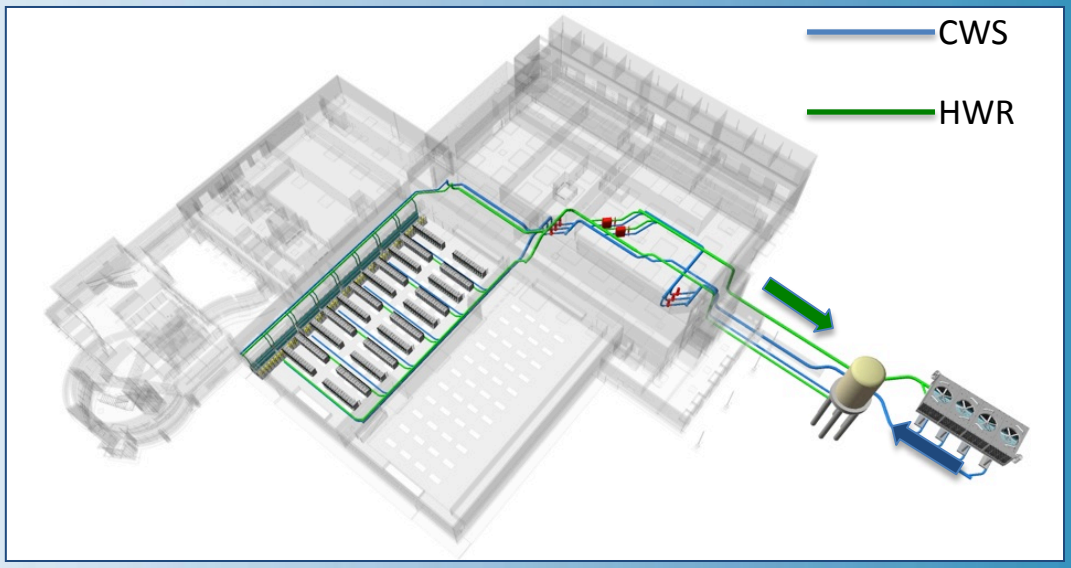
Very high efficient tower consuming less at 30^0F wet-bulb temp (46% of the year)

- Chiller

Back-up cooling alternative at high relative humidity conditions

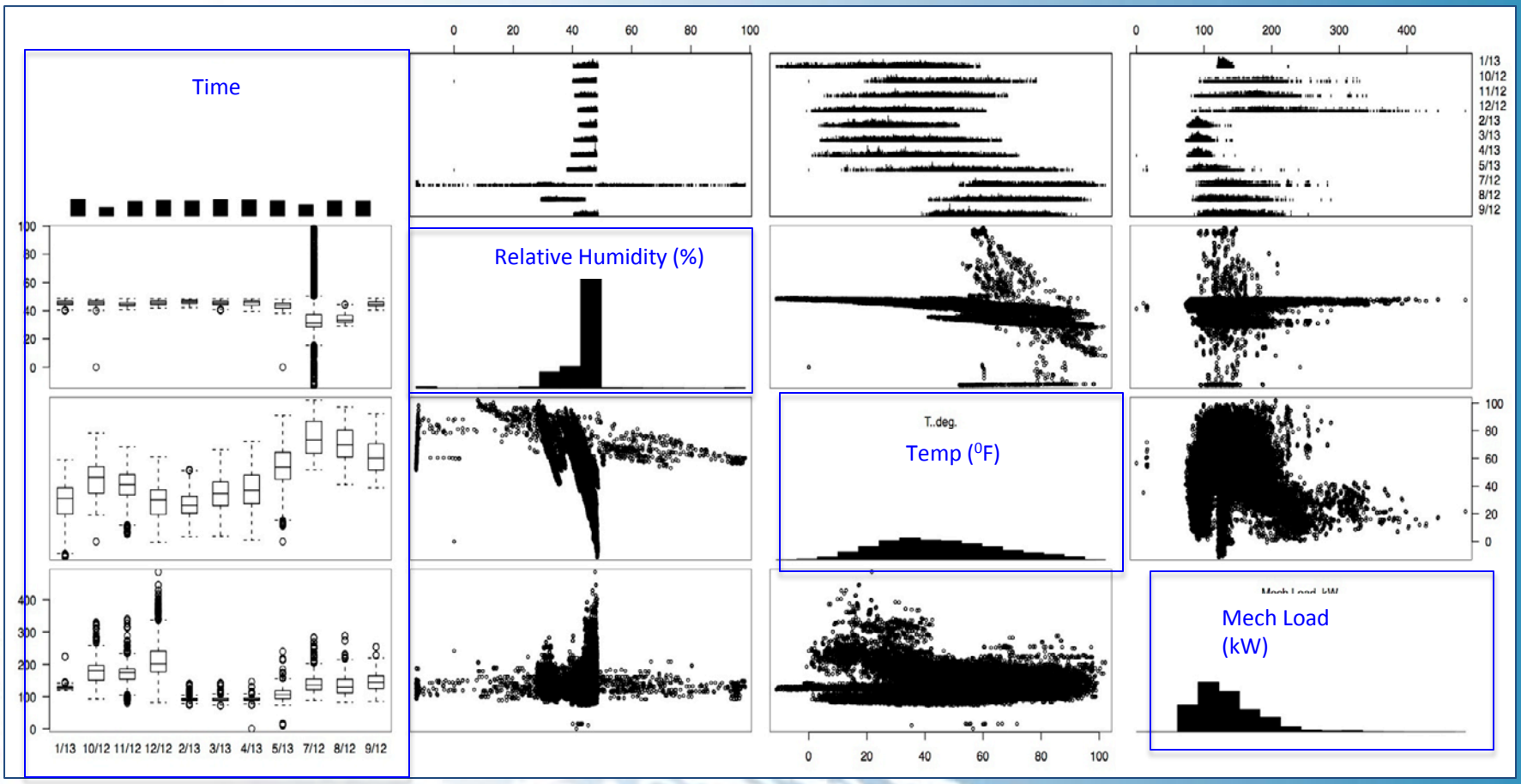
- Building Automation System

Water System; Electrical Management; Air Management



HWR – Hot Water Return
CWS – Chilled Water Supply

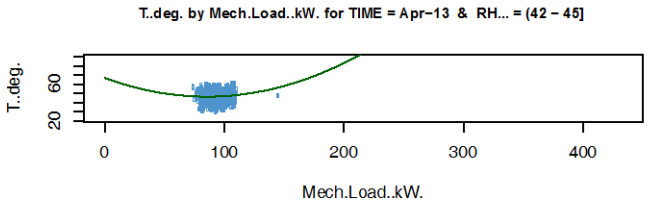
Building Response to Outside Weather Conditions

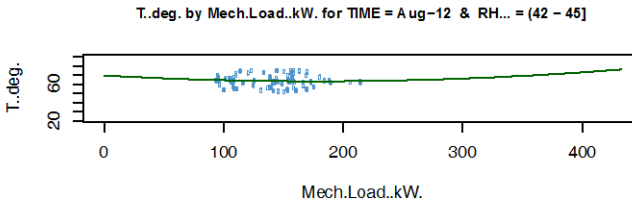


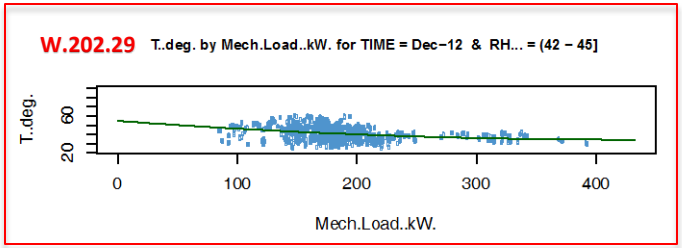
- RH distribution is fairly constant year round (i.e. 42% ≤ RH ≤ 45%)
- Mechanical Load is at it's peak within Oct-Dec, 2012

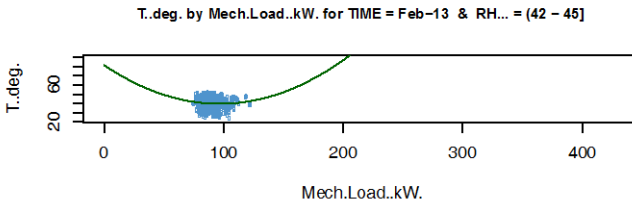
Autumn-Winter Trend

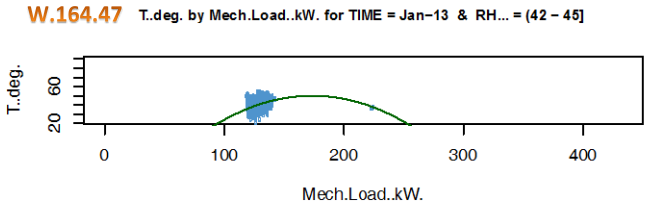
- RH Distribution (42≤RH≤45)
- December Mechanical Load negative trend in red

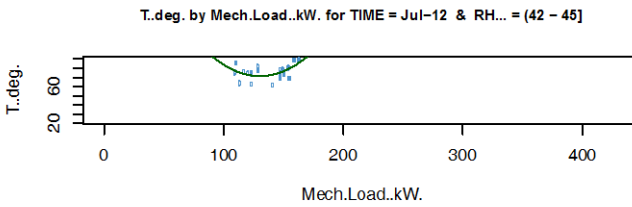


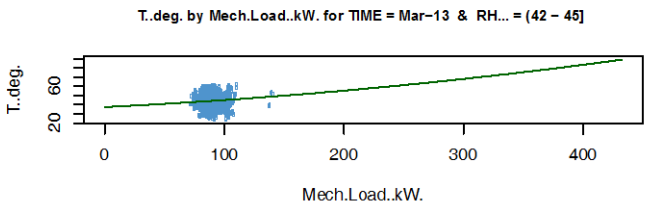


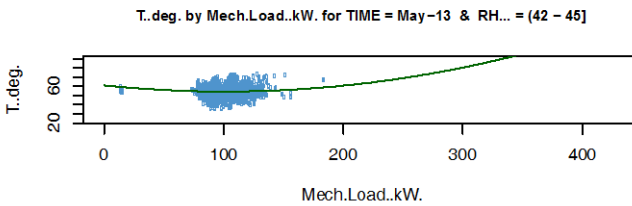


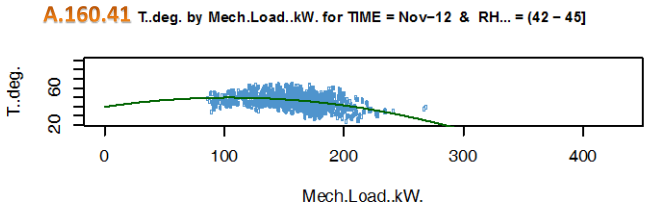


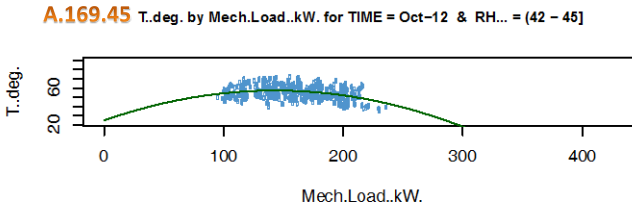


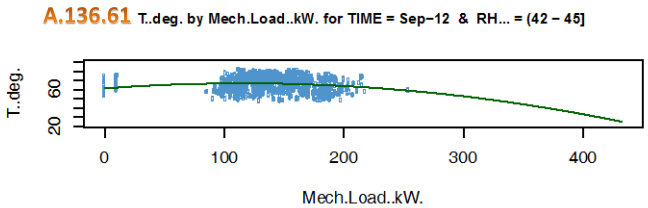






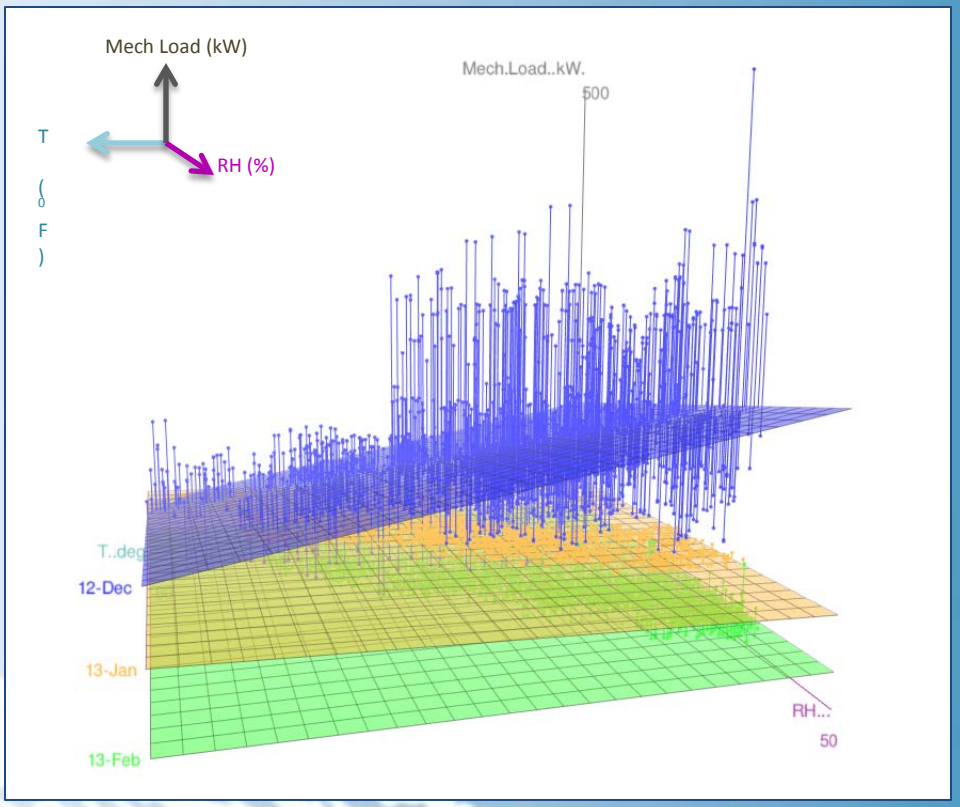




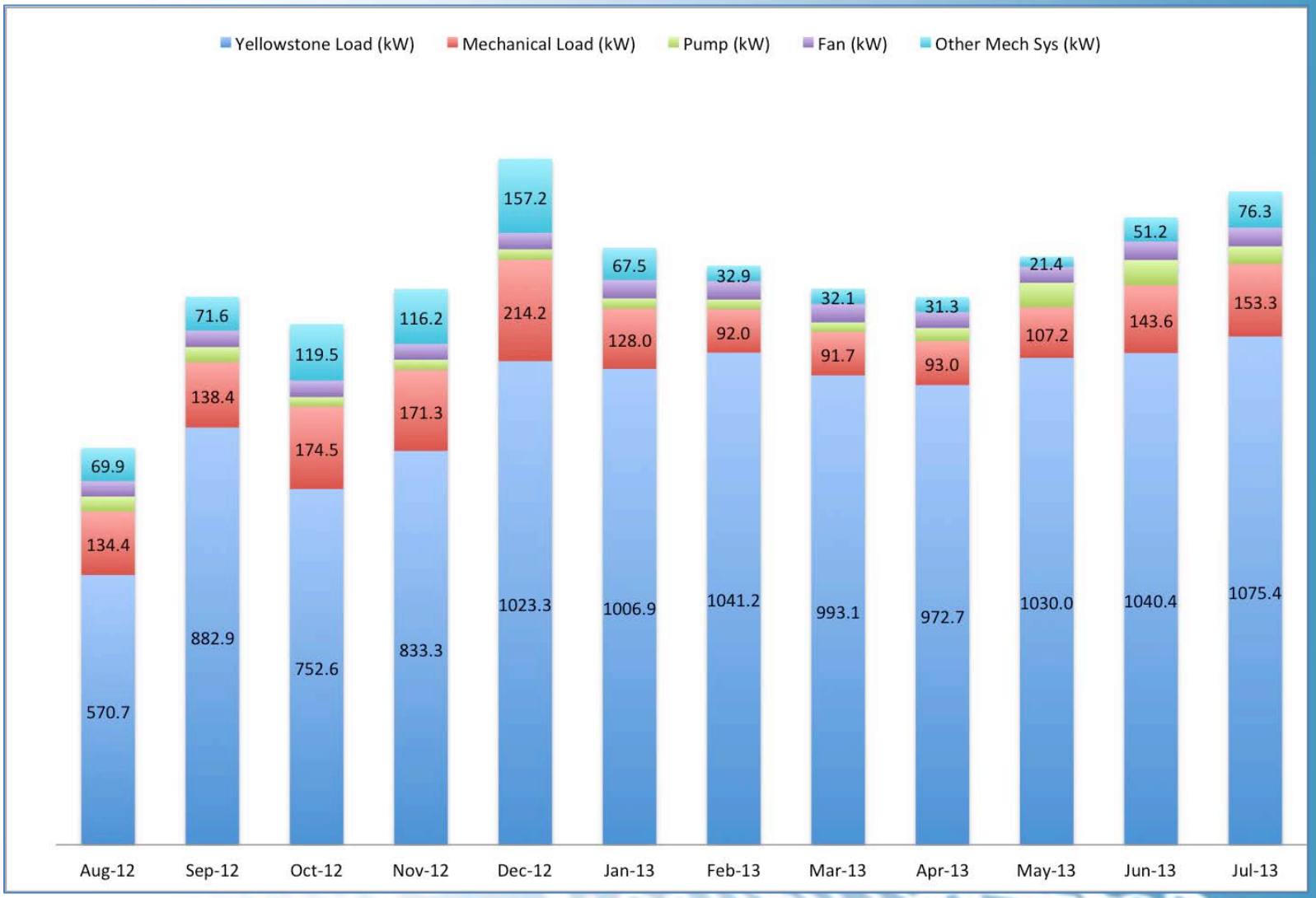


External Influence on Building Load During Winter

- Mech Load is highest at high RH and low T
- December and January plot reflects Energy Recovery Pumps inefficiency during winter



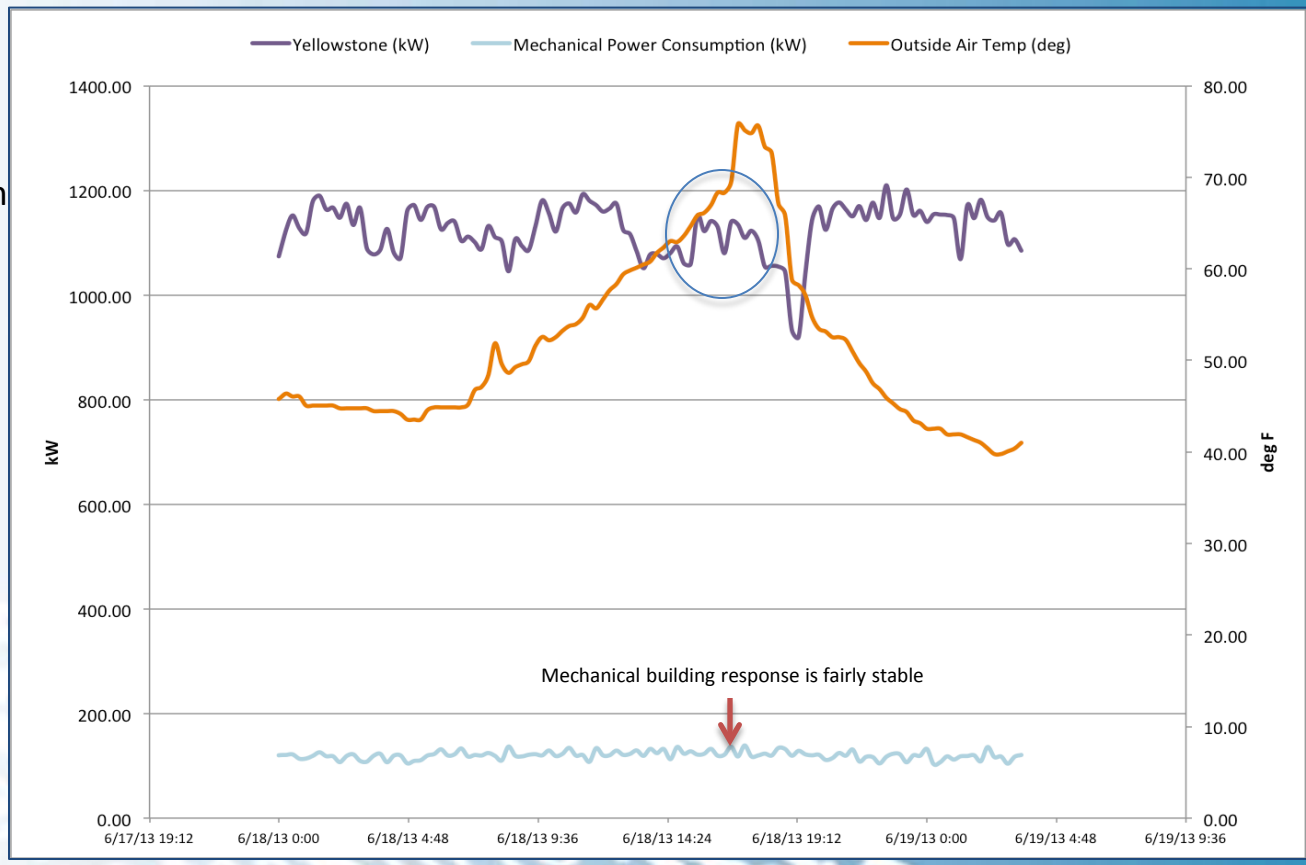
Building Response to Yellowstone Load



Building Response at Peak Computing Performance

- 4096 node cases (of 4518 nodes) was loaded on Yellowstone on June 18, 2013 at 17:23:53 (inset on chart in blue ring)
- Building response not modulating as much as Yellowstone load

Chart shows building response at 91% Yellowstone



Heating Systems

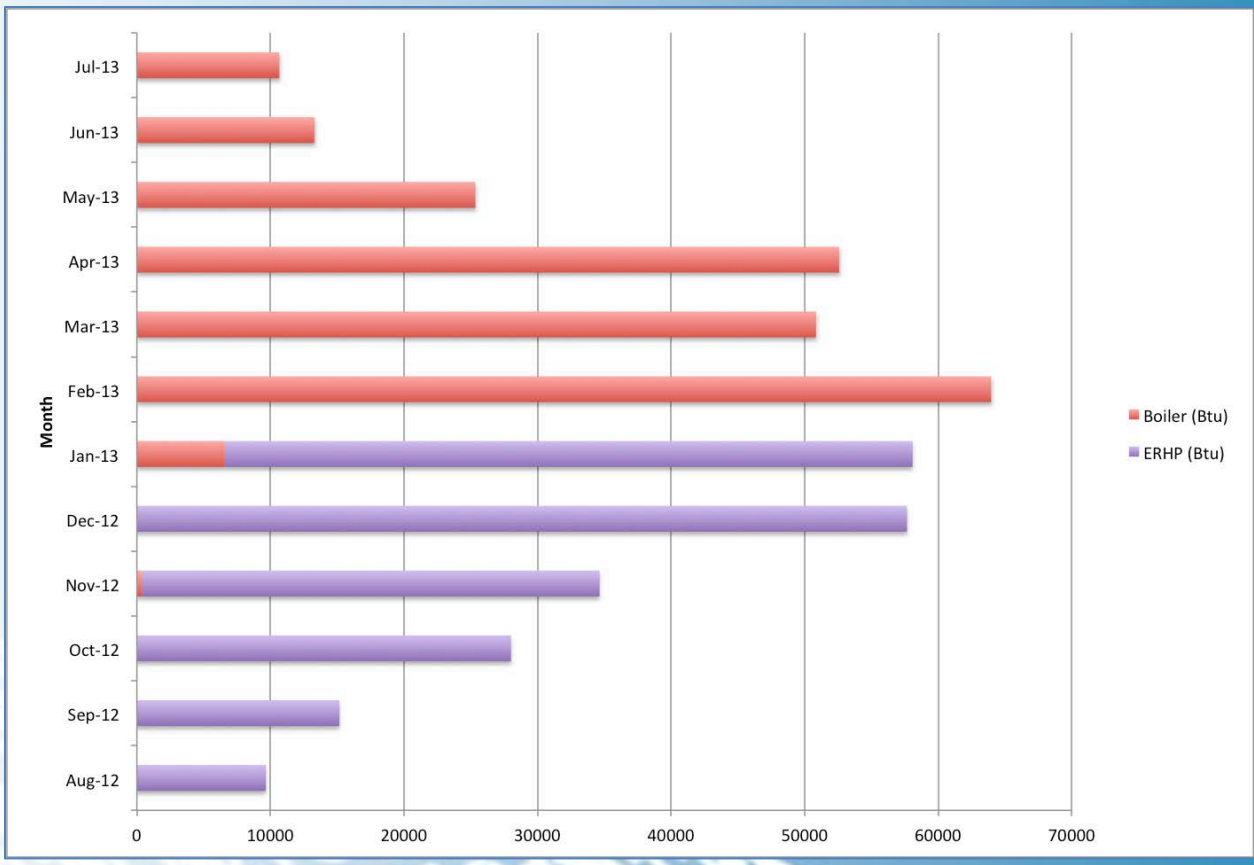
- NWSC operates Energy Recovery System (ERE)
- ERS involves the reuse of heat removed from cooling supercomputers elsewhere within the data center

Energy Recovery System	Heat Recovery Pumps (HRP)	Boiler System
Running Condition	• Enabled when AHU is energized • Temp Set-Point: - 140^{0}F at OAT*≤60^{0}F	• Back-up to HRP when HW supply temp is not maintained within 5^{0}F of temp set-point for longer than 5mins • When HPHW flow rate is greater than max allowable for all HRP's
Rating	180 HP water-to-water scroll heat pump/chiller (3 units)	Benchmark 2.0 Low NOx Gas Fired Boiler System (4 units)
Power Supply	Electricity	Natural Gas

*OAT – Outside Air Temp

Heating Load Performance

- Both systems provided adequate heat requirements
- Boiler modulates efficiently with heating demands and gas consumption



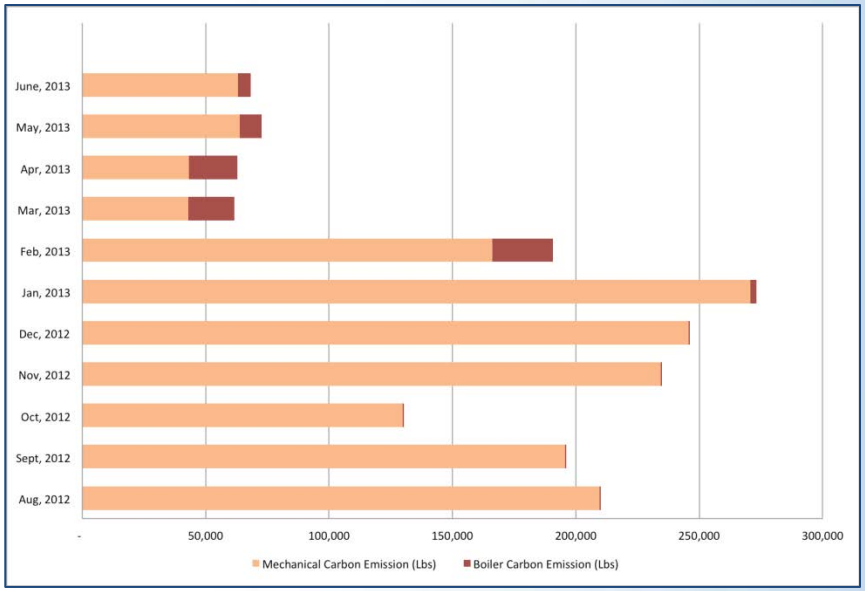
*Energy Recovery Heat Pump - ERHP

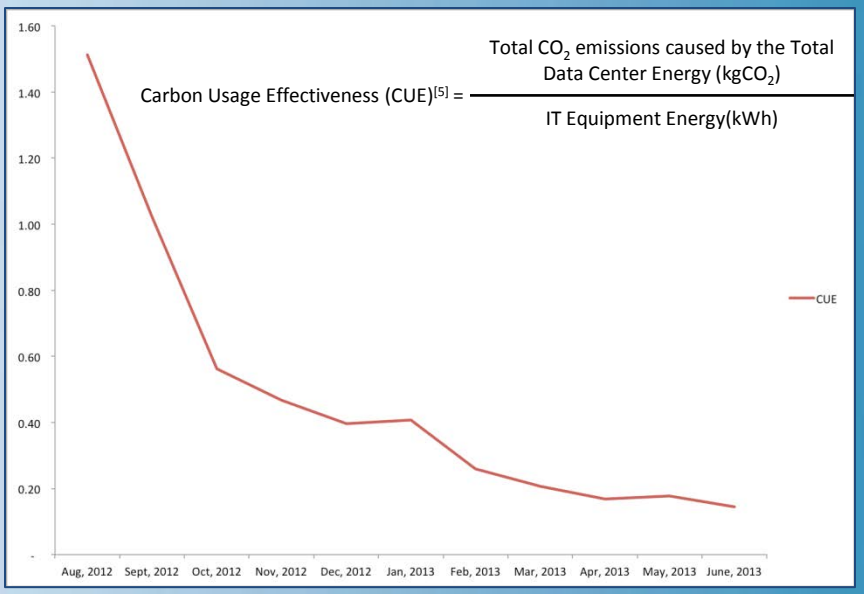
Cost Analysis

- $5,958.02 saved in the last 4 months
- Current unit cost of natural gas makes Boiler System more economical

	Aug, 2012	Sept, 2012	Oct, 2012	Nov, 2012	Dec, 2012	Jan, 2013	Feb, 2013	Mar, 2013	Apr, 2013	May, 2013	June, 2013
Electricity Usage (kW)	1872	1872	2232	1656	1872	1872	1656	1656	1656	1656	1728
Capacity Charge	$32,666.40	$32,666.40	$37,650.12	$28,887.20	$32,666.40	$32,666.40	$28,897.20	$28,897.20	$28,897.20	$28,897.20	$30,153.60
Gas Charge	$77.63	$88.58	$95.12	$116.02	$93.90	$425.82	$3,934.26	$2,722.73	$2,871.49	$1,333.77	$869.27
Gas Usage (Dth)	11.62	12.67	12.61	16.27	12.90	75.50	740.24	557.91	588.64	267.76	154.16

Carbon Emission



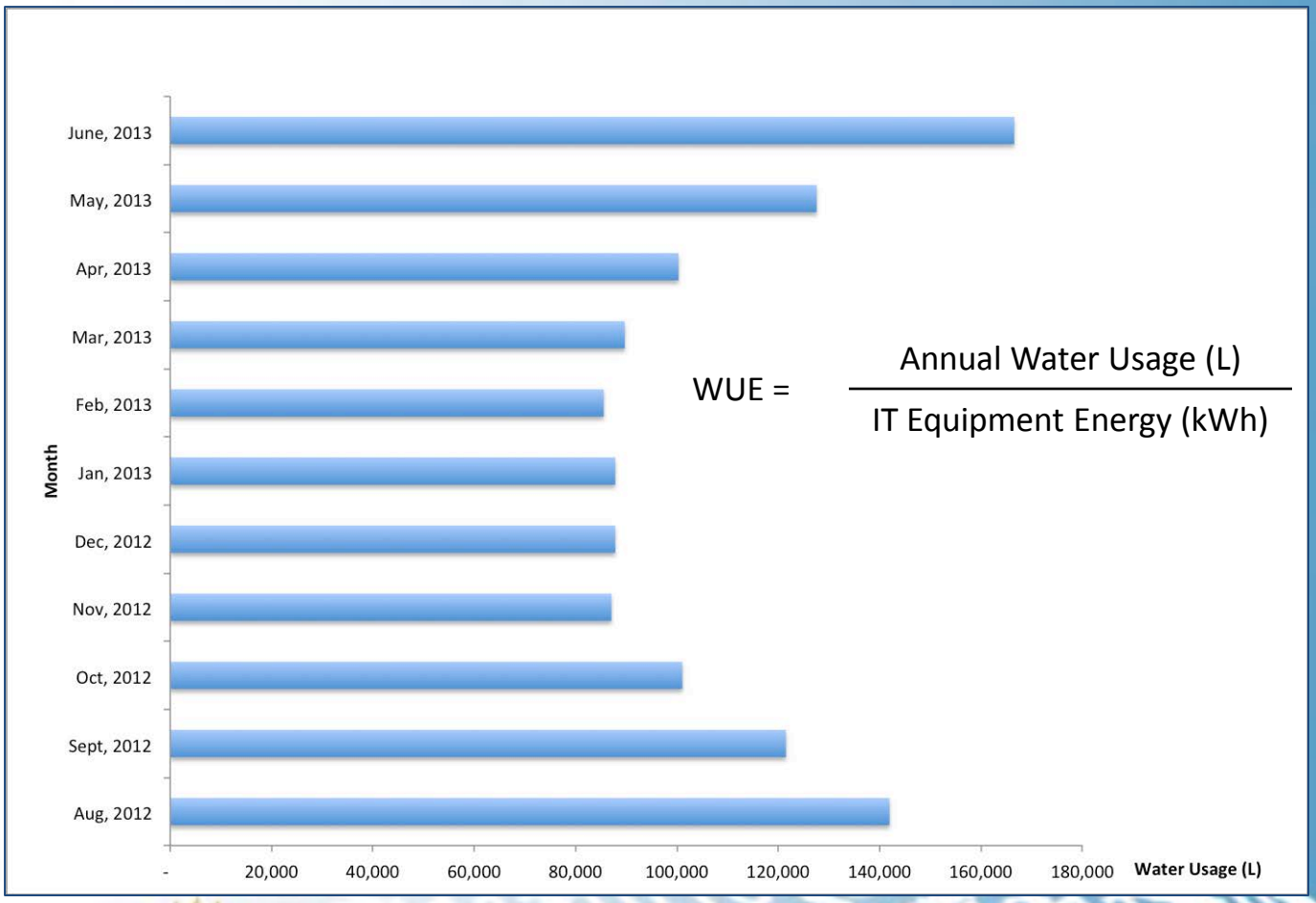


- Facility has shown consistent improvement to 0.14CUE since commissioning
- Running Boiler System reduced total carbon emissions

*Carbon Usage Effectiveness - CUE

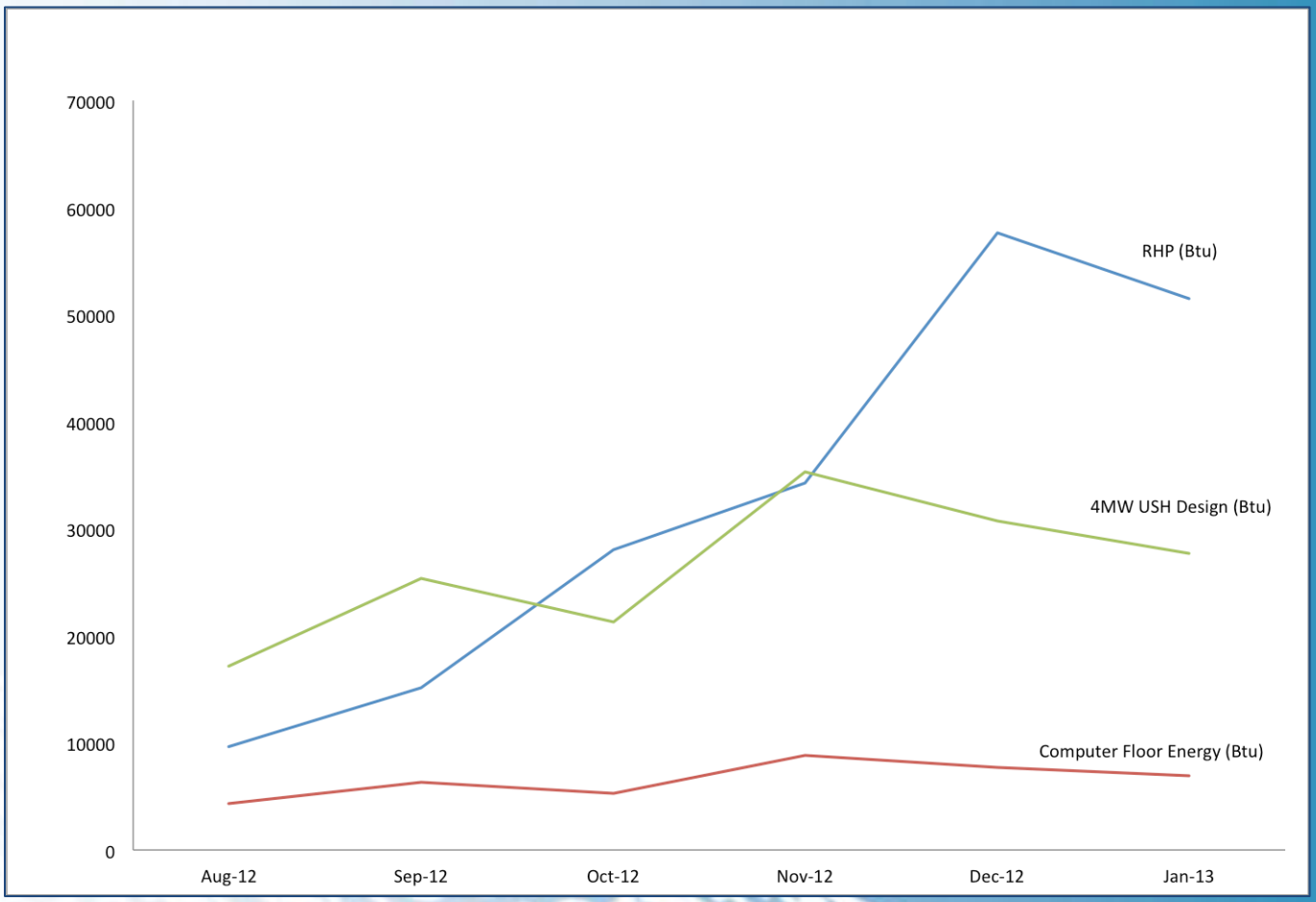
Water Usage Effectiveness (WUE)

- 0.10WUE
- Annual Water Usage = 1.1 million liters (Aug, 2012 – June, 2013)



Why is RHP inefficient?

- Yellowstone HW heat rejection is relatively too low for equivalent heating requirements
- RHP operates with 1.1 MW USH systems against 4MW design
- 4MW USH Simulation predicts RHP's adequacy in the NWSC heating requirements during Summer



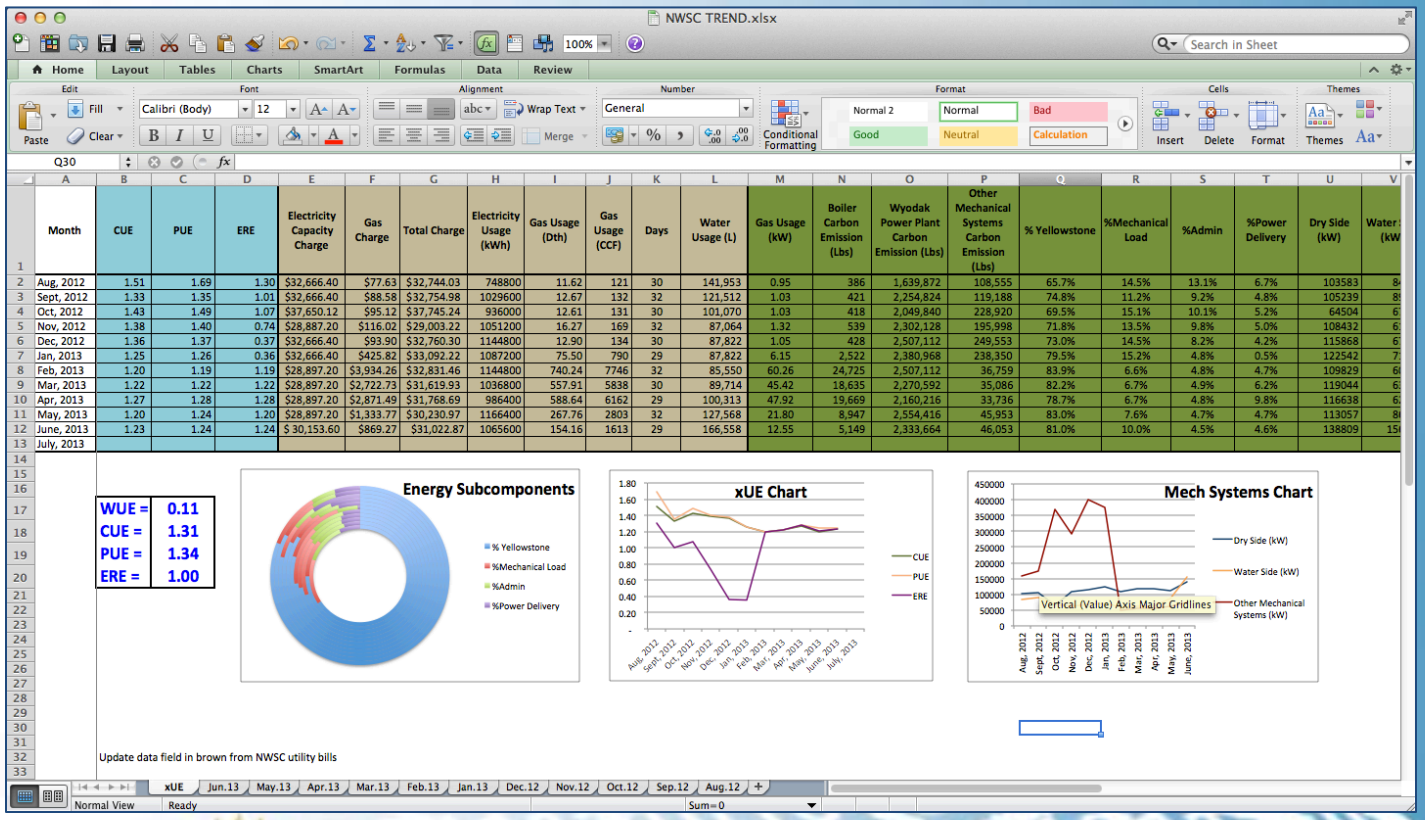
Utility Substation HPC – USH
High Performance Computing – HPC
Recovery Heat Pump – RHP
Hot Water - HW

Conclusion

- NWSC has shown steady improvements to $1.3PUE_{L3,YC}$ and $0.9ERE_{L3,YC}$ over the first year of operation
- Building responds more to outside weather conditions than Yellowstone load
- Running RHP proves competitive advantage during summer season (adequate, if preference is given to green technology over cost)
- Improving RHP pump sequencing is recommended
- Boiler is a preferred alternative at other seasons both economically, environmentally and with respect to energy usage
- Trend proves to be an efficient diagnostic tool

Future Work

- Software development can be designed to plot trends on a weekly basis, providing an analytical tool for routine maintenance and oversight of facility for Engineers
- UPS Firmware Software Upgrade Power Delivery Effect



Reference

[1] NCAR – Wyoming Supercomputing Center (NWSC) Fact Sheet. April 2013
http://www2.ucar.edu/atmosnews/news/nwsc-fact-sheet

[2] June 17, 2013 TOP500 Press Release at the opening session of the 2013 International Supercomputing Conference in Liepzig, Germany http://top500.org/blog/lists/2013/06/press-release

[3] the green grid™ "PUE™: A COMPREHENSIVE EXAMINATION OF THE METRIC" WHITE PAPER #49. 2012

[4] the green grid™ "ERE: A METRIC FOR MEASURING THE BENEFIT OF REUSE ENERGY FROM A DATA CENTER" WHITE PAPER #29. 2010

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[6] the green grid™ "WATER USAGE EFFECTIVENESS (WUETM): A GREEN GRID DATA CENTER SUSTAINABILITY METRIC" WHITE PAPER #35. 2011

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Questions

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