Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Case Study

Opportunities for Investigations in Energy Efficiency

Imran Latif

March 18, 2024

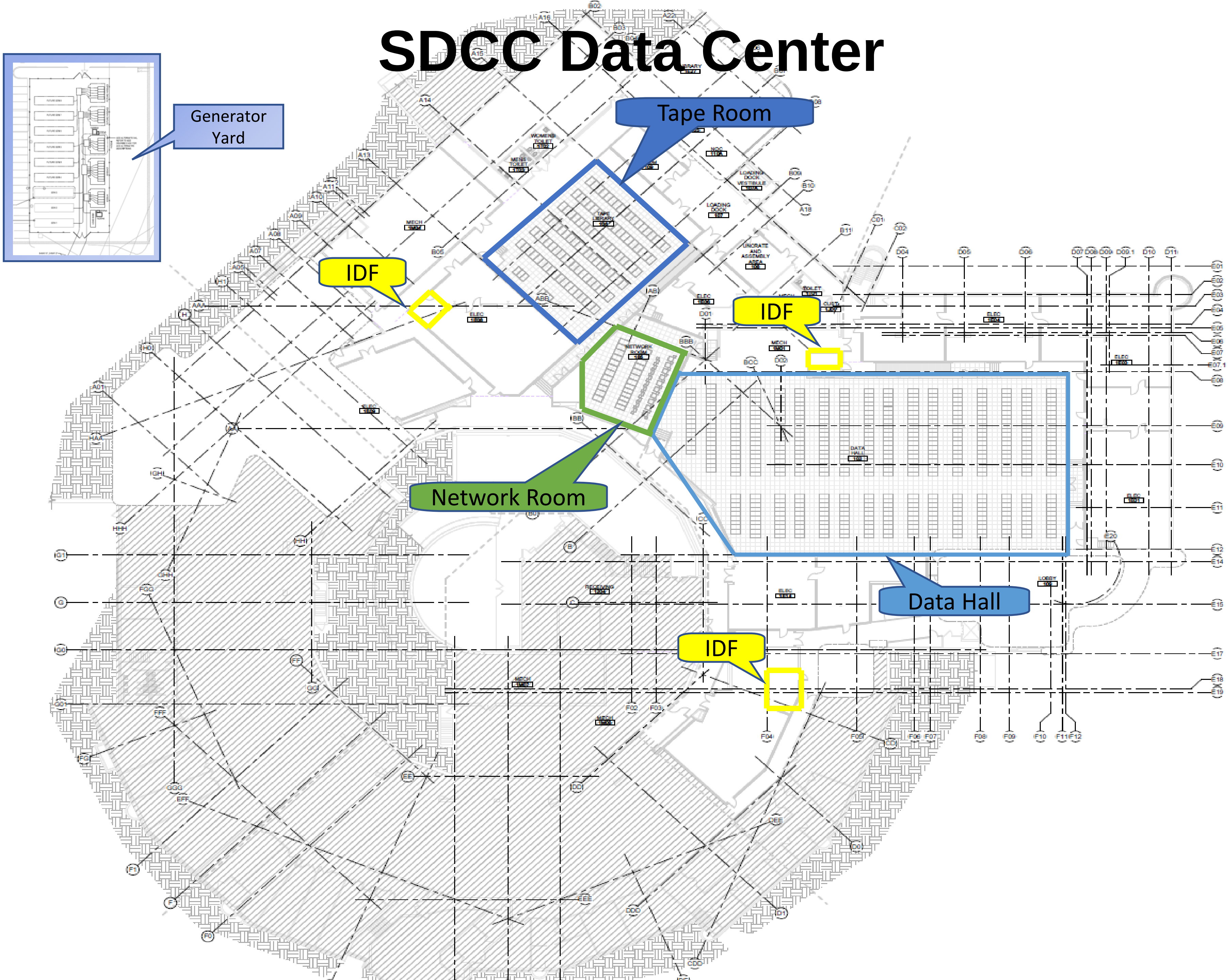
@BrookhavenLab

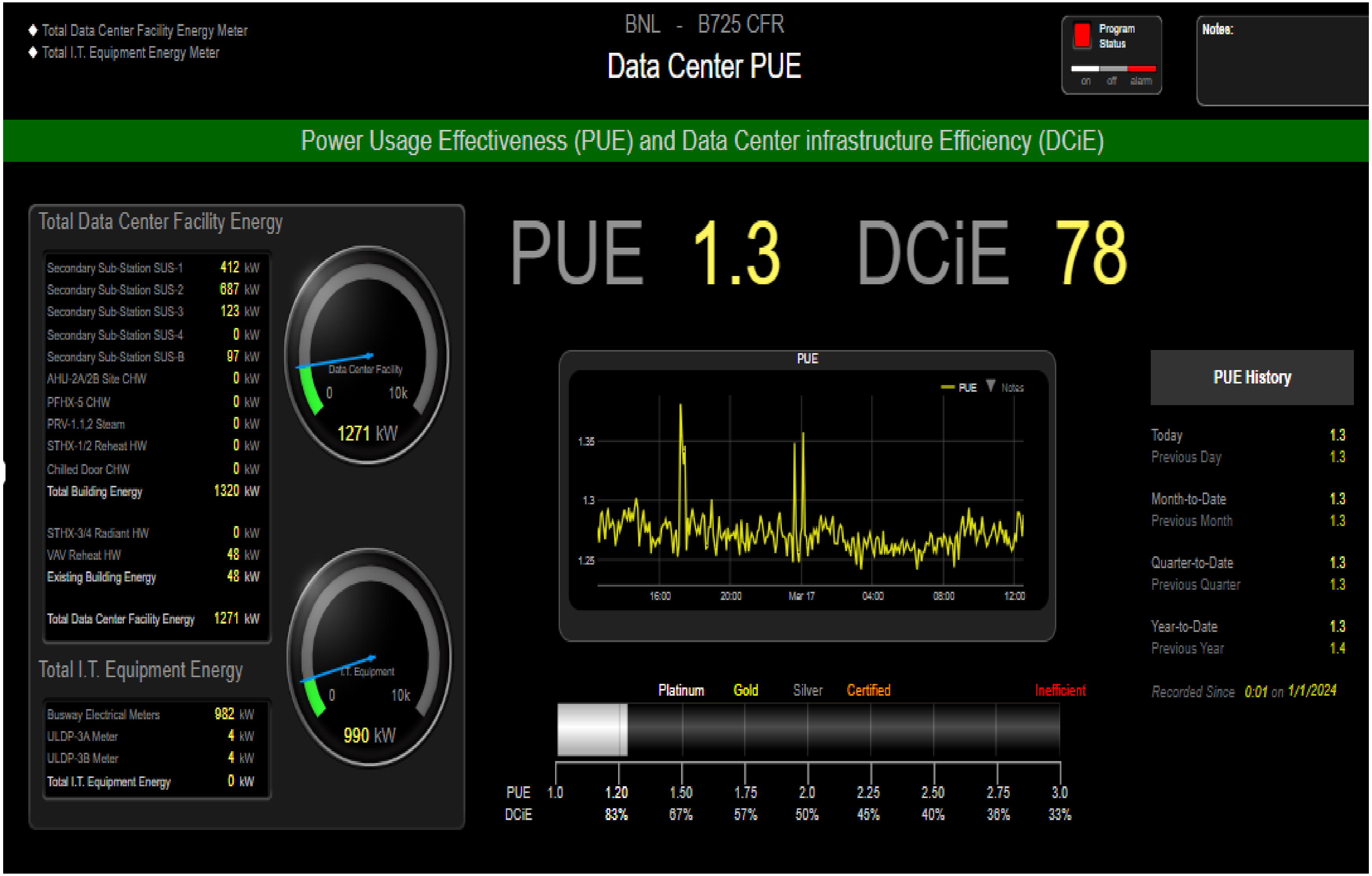
SDCC Data Center Building 725 (Features)

- ✓ 50,000 gross sq.ft. – Built in 2021 - $85M cost to build
- ✓ Energy efficient with 1.2 target PUE
- ✓ 18,000 sq.ft IT space for computing/storage
- ✓ Power and cooling infrastructure outside of IT rooms
- ✓ ~500 physical rack capacity, standard 42U, 19 in racks
- ✓ 3.6MW current power available with 9.6MW ultimate build out
- ✓ 1.2MW of power and cooling blocks installation- scalable approach
- ✓ Chilled water available for high density CPU/GPU



SDCC Data Center



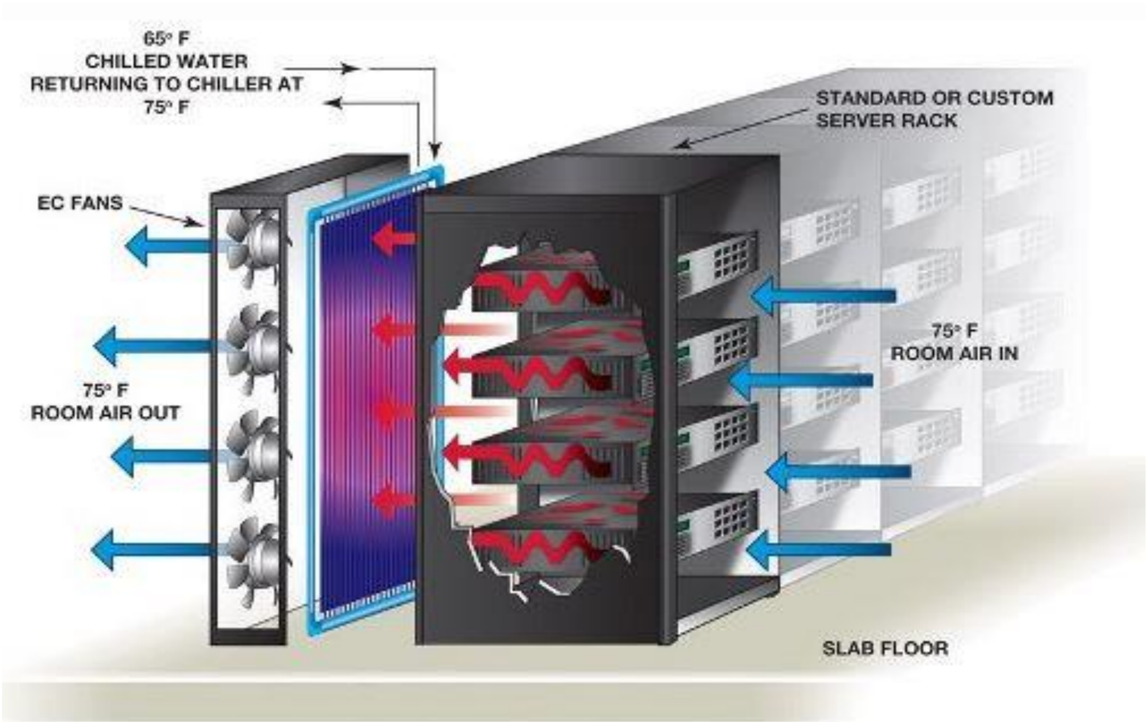

Total Data Center Facility Energy Meter
Total I.T. Equipment Energy Meter
BNL - B725 CFR
Data Center PUE
Program Status
on off alarm
Notes:
Power Usage Effectiveness (PUE) and Data Center infrastructure Efficiency (DCiE)
Total Data Center Facility Energy
Secondary Sub-Station SUS-1 412 kW
Secondary Sub-Station SUS-2 687 kW
Secondary Sub-Station SUS-3 123 kW
Secondary Sub-Station SUS-4 0 kW
Secondary Sub-Station SUS-B 97 kW
AHU-2A/2B Site CHW 0 kW
PFHX-5 CHW 0 kW
PRV-1.1,2 Steam 0 kW
STHX-1/2 Reheat HW 0 kW
Chilled Door CHW 0 kW
Total Building Energy 1320 kW
STHX-3/4 Radiant HW 0 kW
VAV Reheat HW 48 kW
Existing Building Energy 48 kW
Total Data Center Facility Energy 1271 kW
Data Center Facility
0
10k
1271 kW
Total I.T. Equipment Energy
Busway Electrical Meters 982 kW
ULDP-3A Meter 4 kW
ULDP-3B Meter 4 kW
Total I.T. Equipment Energy 0 kW
I.T. Equipment
0
10k
990 kW
PUE 1.3
DCiE 78
PUE
PUE Notes
1.35
1.3
1.25
16:00
20:00
Mar 17
04:00
08:00
12:00
PUE History
Today 1.3
Previous Day 1.3
Month-to-Date 1.3
Previous Month 1.3
Quarter-to-Date 1.3
Previous Quarter 1.3
Year-to-Date 1.3
Previous Year 1.4
Recorded Since 0:01 on 1/1/2024
Platinum Gold Silver Certified Inefficient
PUE 1.0 1.20 1.50 1.75 2.0 2.25 2.50 2.75 3.0
DCiE 83% 67% 57% 50% 45% 40% 36% 33%

RDHx – Opportunities for Investigations in Energy Efficiency

RDHx turns a 19” rack into a miniature datacenter enables experimentation with cooling infrastructure and environmental conditions

Simulate higher ambient room temperature

- Effects on server performance and power consumption
- Effects on the cooling system operating conditions and ultimately system efficiency



Typical Rear Door Heat Exchanger RDHx

Case study Setup

- Standard 42U 19” racks with up to 30KW load per rack
  - (26) 1U Dell Power Edge R640 Nodes and one (1U) Networking Switch
- Bulk of the sensible cooling provided by rear door heat exchangers 60°F chilled water input
- 75°F ambient dry bulb temperature and 40%-50% relative humidity in the MDH
- Controlled RDHx fan speed to modulate server temperature (simulate increased ambient temperature)
- ATLAS HEPScore23Beta benchmark workload generator
- Monitored
  - Rack power consumption (server+RDHx)
  - Server air inlet temperature and RDHx air inlet and outlet temperatures
  - Rack water supply control valve (controls water flow)
  - Server benchmark performance

Dell EMC PowerEdge R640
Technical Specs for the Allowable Ambient Temp

Table 31. Standard operating temperature specifications

Standard operating temperature	Specifications
Continuous operation (for altitude less than 950m or 3117ft)	10°C to 35°C (50°F to 95°F) with no direct sunlight on the equipment.

Table 32. Expanded operating temperature specifications

Expanded operating temperature	Specifications
Continuous operation	5°C to 40°C at 5% to 85% RH with 29°C dew point. NOTE: Outside the standard operating temperature (10°C to 35°C), the system can operate continuously in temperatures as low as 5°C and as high as 40°C. For temperatures between 35°C and 40°C, de- rate maximum allowable temperature by 1°C per 175 m above 950 m (1°F per 319 ft).
≤ 1% of annual operating hours	-5°C to 45°C at 5% to 90% RH with 29°C dew point. NOTE: Outside the standard operating temperature (10°C to 35°C), the system can operate down to -5°C or up to 45°C for a maximum of 1% of its annual operating hours. For temperatures between 40°C and 45°C, de- rate maximum allowable temperature by 1°C per 125 m above 950 m (1°F per 228 ft).

Table 2.1 2021 Thermal Guidelines for Air Cooling— SI Version (I-P Version in Appendix B)

Equipment Environment Specifications for Air Cooling							
	Product Operation[b,c]					Product Power Off[c,d]	
Class[a]	Dry-Bulb Temp.[e,g], °C	Humidity Range, Noncond.[h,i,k,l,n]	Max. Dew Point[k], °C	Max. Elev.[e,j,m], m	Max. Rate of Change[f], °C/h	Dry-Bulb Temp., °C	RH[k], %
Recommended (suitable for Classes A1 to A4; explore data center metrics in this book for conditions outside this range.)							
A1 to A4	18 to 27	–9°C DP to 15°C DP and 70% rh[n] or 50% rh[n]					
Allowable							
A1	15 to 32	–12°C DP and 8% rh to 17°C DP and 80% rh[k]	17	3050	5/20	5 to 45	8 to 80[k]
A2	10 to 35	–12°C DP and 8% rh to 21°C DP and 80% rh[k]	21	3050	5/20	5 to 45	8 to 80[k]
A3	5 to 40	–12°C DP and 8% rh to 24°C DP and 85% rh[k]	24	3050	5/20	5 to 45	8 to 80[k]
A4	5 to 45	–12°C DP and 8% rh to 24°C DP and 90% rh[k]	24	3050	5/20	5 to 45	8 to 80[k]

ASHRAE TC9.9 Thermal Guidelines

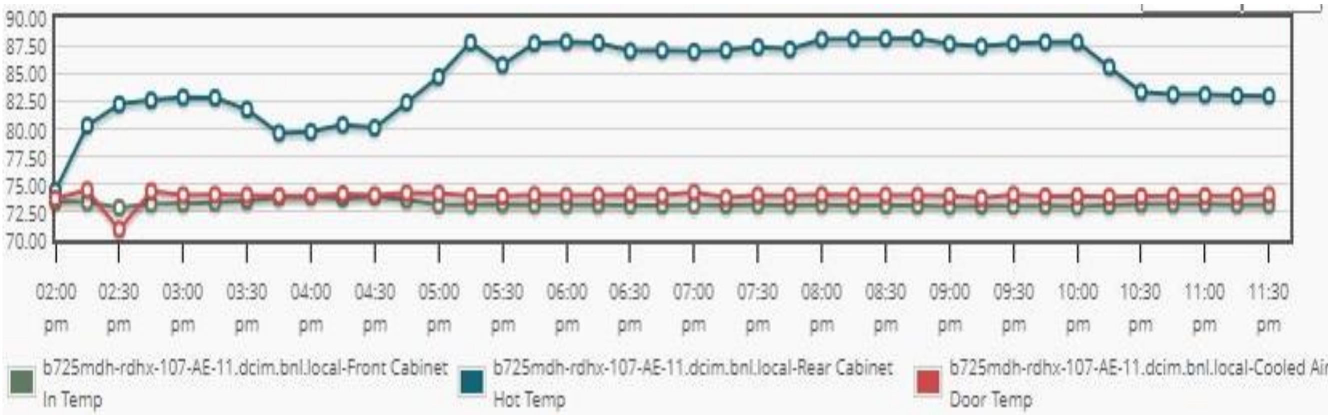
Rack 48-1	
39	
38	
37	
36	
35	
34	
33	spool0670.sdcc.bnl.gov
32	spool0671.sdcc.bnl.gov
31	spool0672.sdcc.bnl.gov
30	spool0673.sdcc.bnl.gov
29	spool0674.sdcc.bnl.gov
28	spool0675.sdcc.bnl.gov
27	spool0676.sdcc.bnl.gov
26	spool0677.sdcc.bnl.gov
25	spool0678.sdcc.bnl.gov
24	spool0679.sdcc.bnl.gov
23	spool0680.sdcc.bnl.gov
22	spool0681.sdcc.bnl.gov
21	spool0682.sdcc.bnl.gov
20	spool0683.sdcc.bnl.gov
19	spool0684.sdcc.bnl.gov
18	spool0685.sdcc.bnl.gov
17	spool0686.sdcc.bnl.gov
16	spool0687.sdcc.bnl.gov
15	spool0688.sdcc.bnl.gov
14	spool0689.sdcc.bnl.gov
13	spool0690.sdcc.bnl.gov
12	spool0691.sdcc.bnl.gov
11	spool0692.sdcc.bnl.gov
10	spool0693.sdcc.bnl.gov
9	spool0694.sdcc.bnl.gov
8	spool0695.sdcc.bnl.gov
7	spool0696.sdcc.bnl.gov
5	

Test rack with
(26) 1U
Dell Power Edge
R640 nodes
Front view

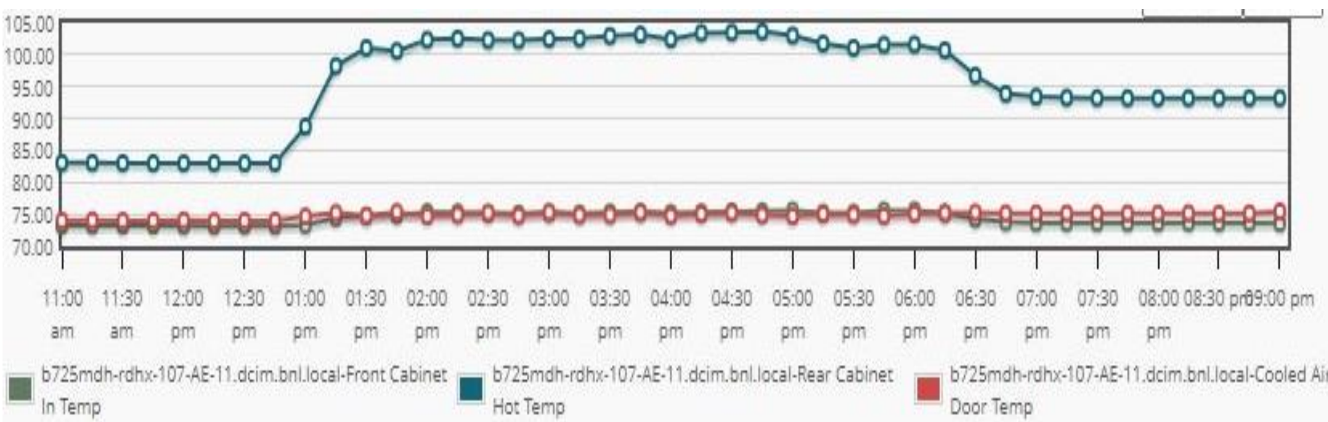
U Systems – Rear
Door Heat
Exchanger (RDHx)
Rear view

Simulating Higher Ambient Air Temperature

Reducing RDHx fan speed increases RDHx air inlet temperature (server output temperature)
Rack air inlet and RDHx air outlet temperatures roughly unchanged



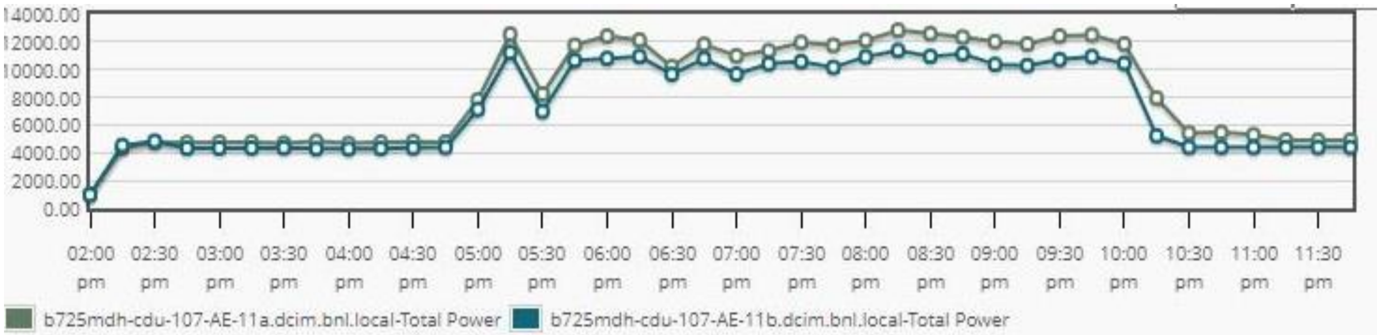
Normal RDHx mode
Rack Inlet and RDHx discharge temp <76F
RDHx coil inlet temp <90F



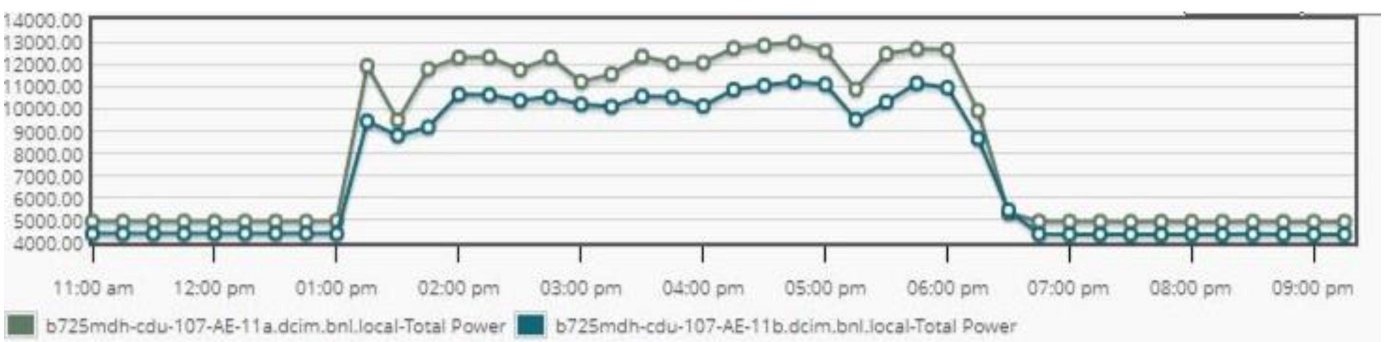
20% Fixed RDHx Fan Speed mode
Rack Inlet and RDHx discharge temp <76F
RDHx coil inlet temp **<u>100F +</u>**

Effects on Total Rack Power Draw (cont'd)

Total rack power consumption roughly unchanged



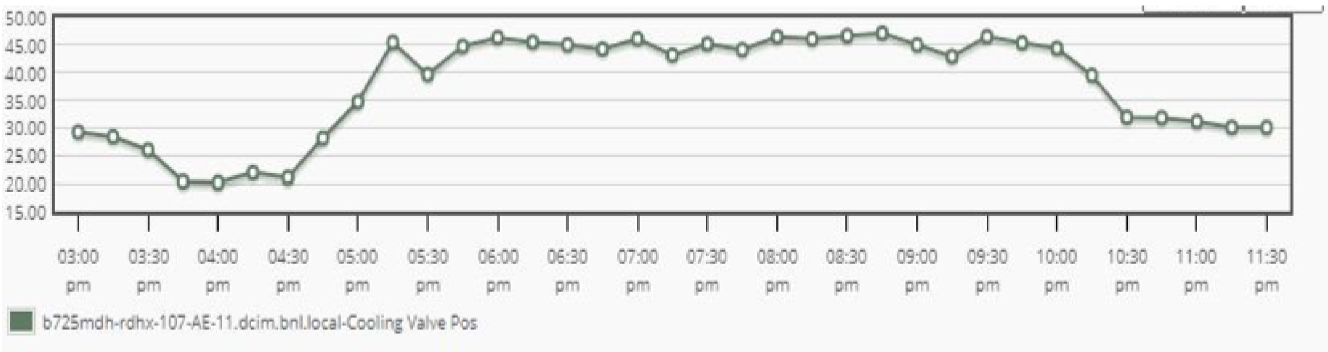
Normal RDHx mode
Overall power draw on servers + RDHx ~ 13kW



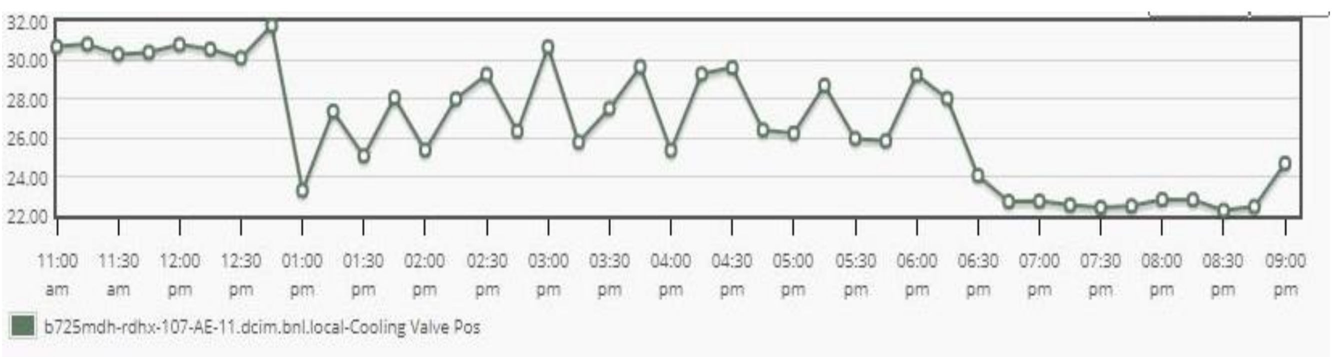
20% Fixed RDHx Fan Speed mode
Overall power draw on servers + RDHx ~ 13kW

Effects on Chilled Water Consumption

Decrease in chilled water consumptions with hotter servers

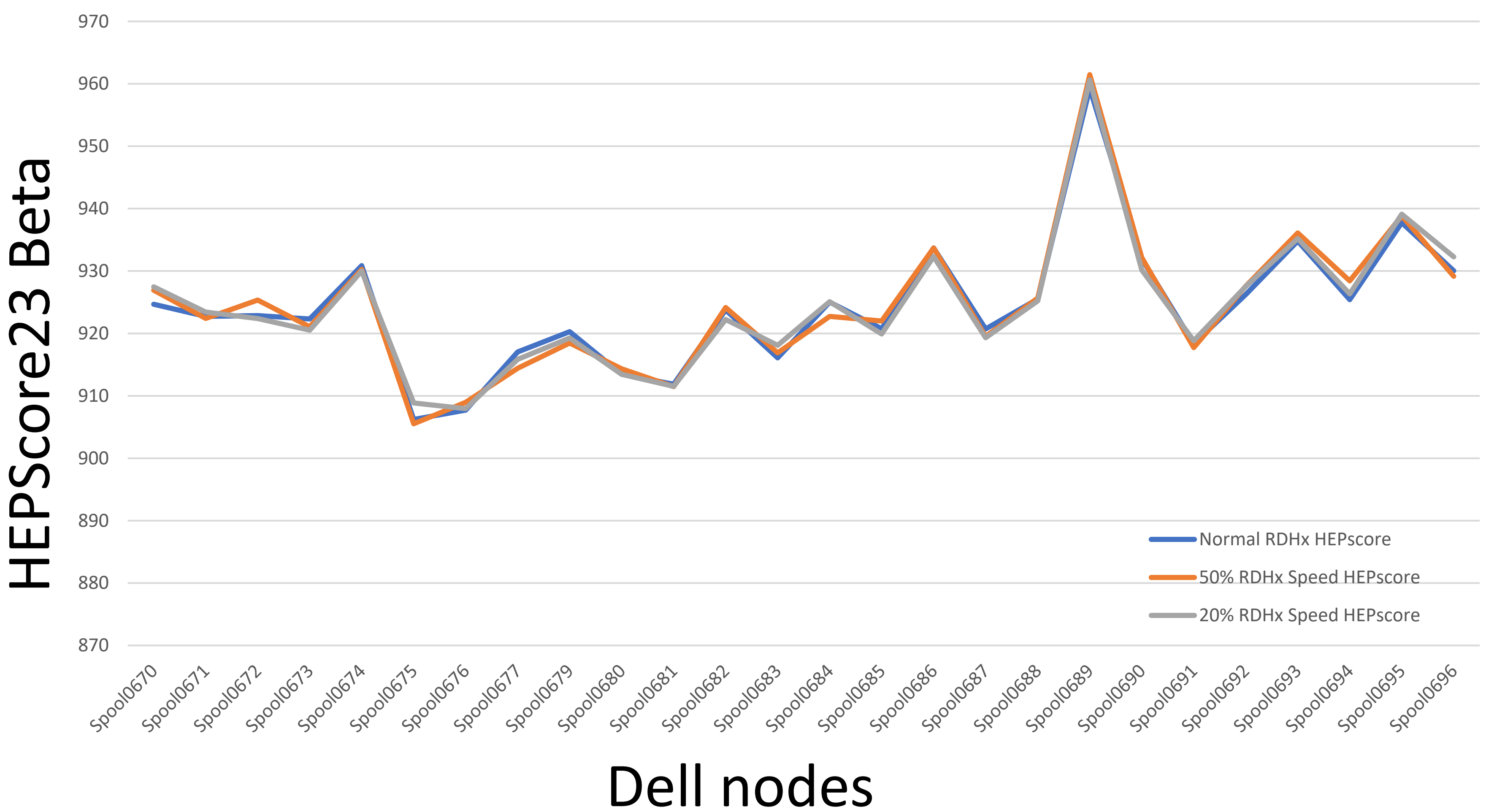


Normal RDHx mode
Chilled Water Valve opened ~45% on average



20% Fixed RDHx Fan Speed mode
Chilled Water Valve opened ~30% on average
Less chilled water consumption

Effects on Server HEPScore23



- HEPScore invariant to server temperature
- Some variability seen in HEPScore between servers of the same model/specs

Study Outcomes

- For a given server, HEPScore23 basically unchanged (1%-2%) over the tested temperature range.

- Some variation in HEPscore23 seen between servers of the same model/specs - this is suspected to be due to CPU manufacturing variability.

- At the lowest (20% fixed) fan speeds, server exceeded vendor defined "standard operating temperature specification" by 5°F, but still within the "extending operating temperature" envelope.

- Rack inlet and RDHx outlet air temperatures remained roughly constant for the test instances, suggesting ambient room temperature will remain unchanged and adjacent rack RDHx units were not picking up the load.

- Lowering the RDHx fan RPM resulted in reduced electric consumption for the RDHx, this will increase the duty life of the RDHx . But this is offset by relatively higher server fan power consumption due to increased RPM.

Future Research Work

- Instrumentation of RDHx chilled water outlet temperature
  - Would shed light on decreased chilled water consumption at high RDHx air inlet temperatures
  - Enable estimation of impact of higher ambient temperatures and higher chilled water supply temperature on chiller, circulating pumps and cooling tower efficiencies.

- Additional testing can be performed, by varying Chilled water supply temperature and chilled water system flow, to find the optimized ‘sweet spot’ with respect to the allowable server inlet temperature

- Obtain Data from building monitoring system and CPU usage. Using ML algorithm based on the workload intensity or carbon aware forecast, automate the cooling setpoint which may result in optimizing the chilled water system, lowering OPEX and PUE

QUESTIONS