50th HPC User Forum

DC Microgrid-Powered HPC

Going Green to Save Green

September 9-11, 2013
Boston, Massachusetts

Speaker

Michael Thompson
Lead Systems Software Engineer
Computing and Information Technology
Wayne State University
Michael@wayne.edu

Data Centers and Power Consumption

EPA Report 2007

Data Centers consume ~**1.5-2%** of total U.S. electricity consumption

Power consumption more than doubled 2000-2007

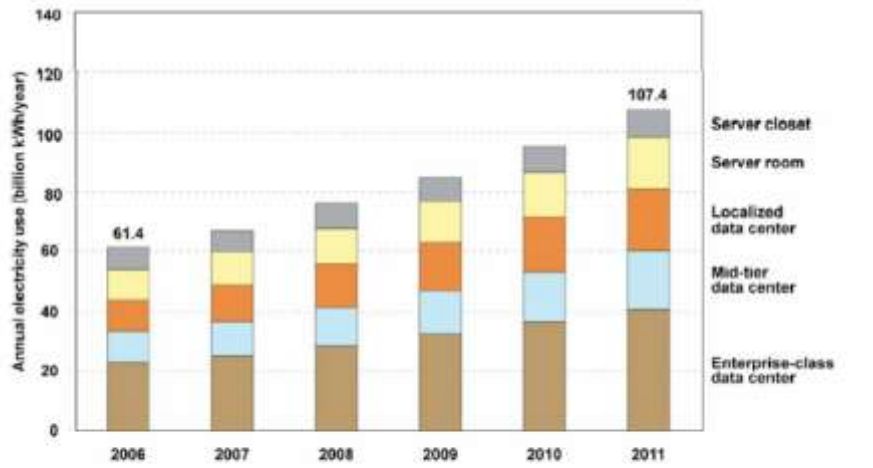
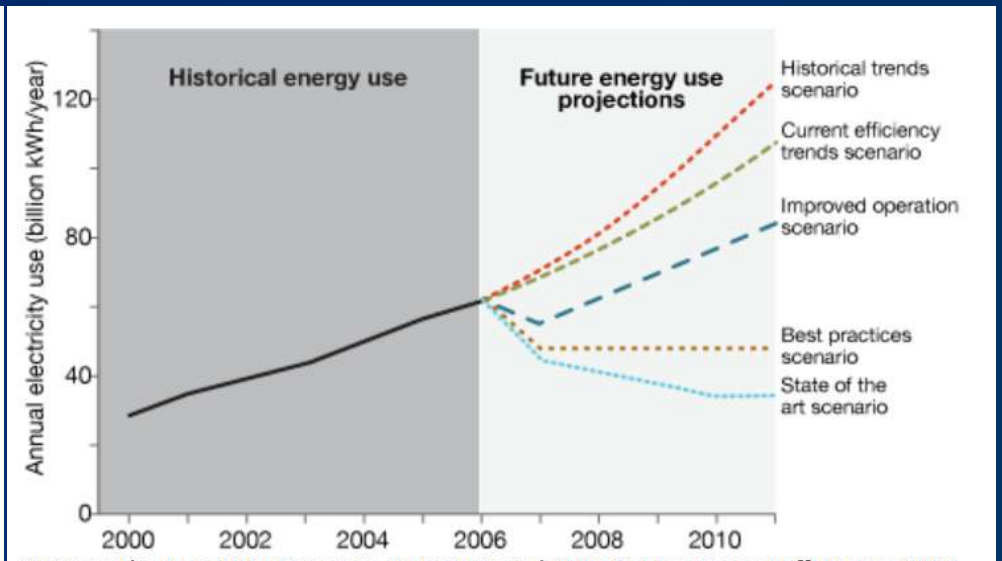


Figure 3: Projected 5-Year Electricity Consumption Growth in Data Centers by Market Segment, Assuming Continuation of Current Energy Trends

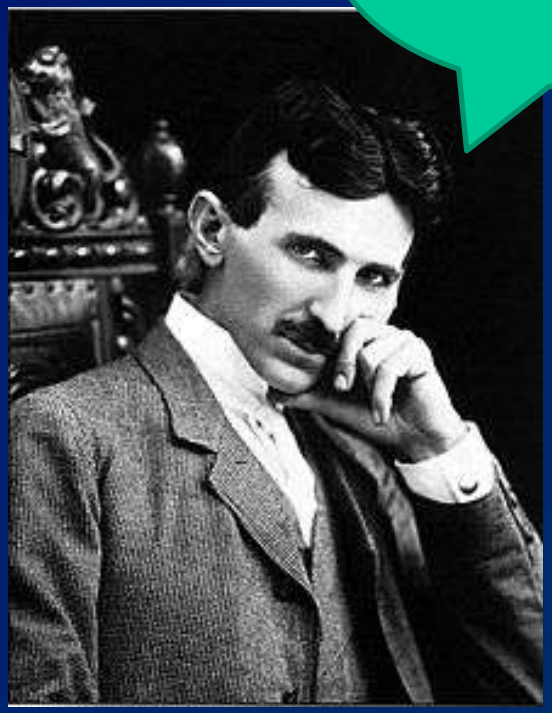


Source: The Report to Congress on Server and Data Center Energy Efficiency, 2007

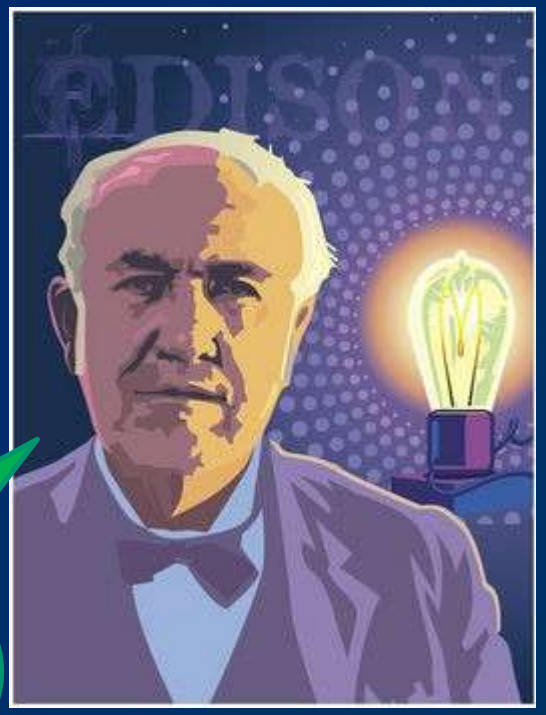
The "War of the Currents"

Late 1800s

AC!!



DC!!



Nikola Tesla: held several instrumental patents in the Westinghouse AC system.

Thomas Edison: Argued AC was deadlier than DC

Some DC History…

Centralized Generation (Power Plants)

Long Distance Transmission

Site Based Renewable Energy – Distributed Generation

Zero Energy Buildings

Electric Vehicles (Bi-Directional)

DC Power Use

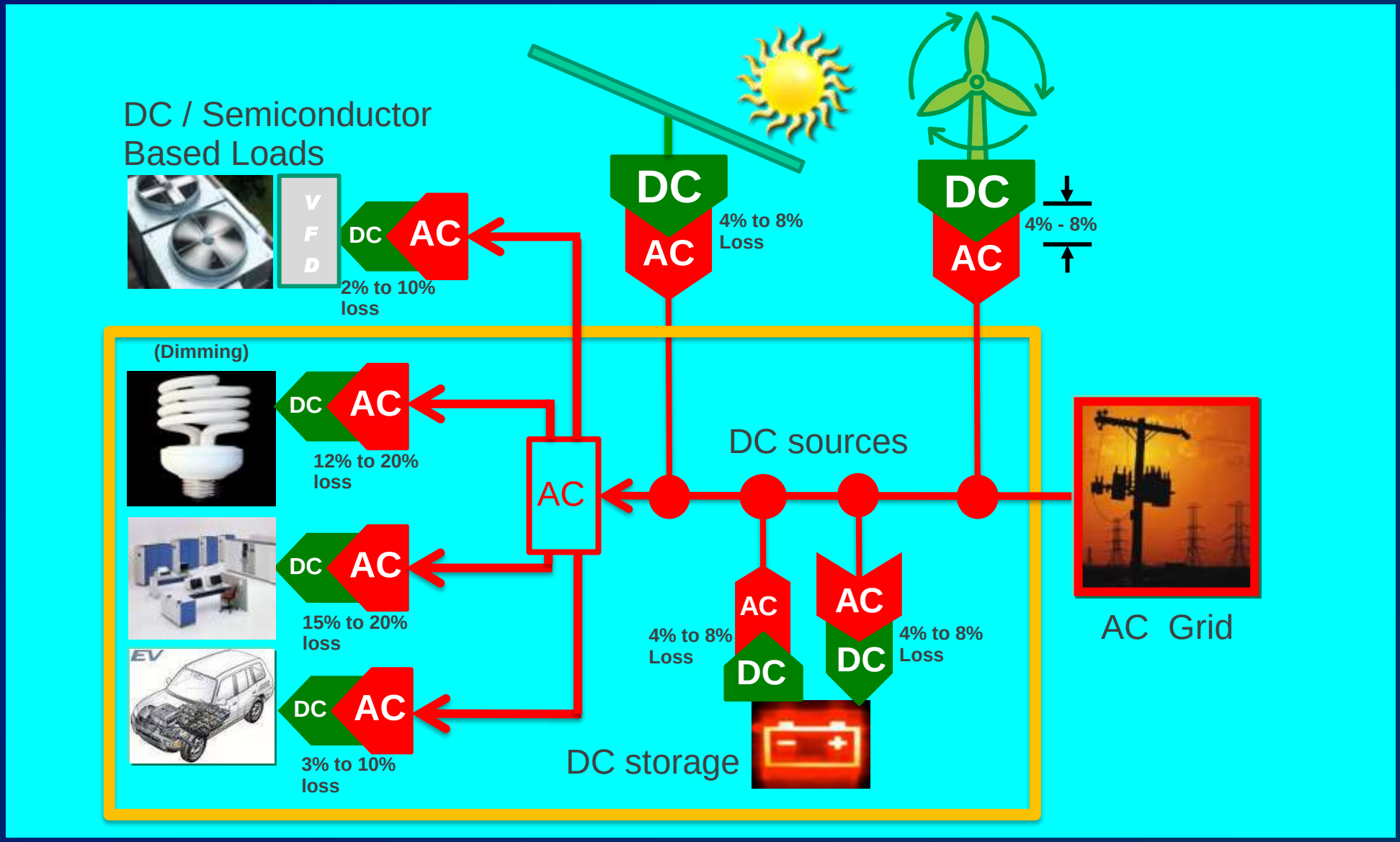
1860's **1950's** **1960's** **1970's** **1980's** **1990's** **2000's**

Initial Electrical Loads: Simple Inductive & Resistive

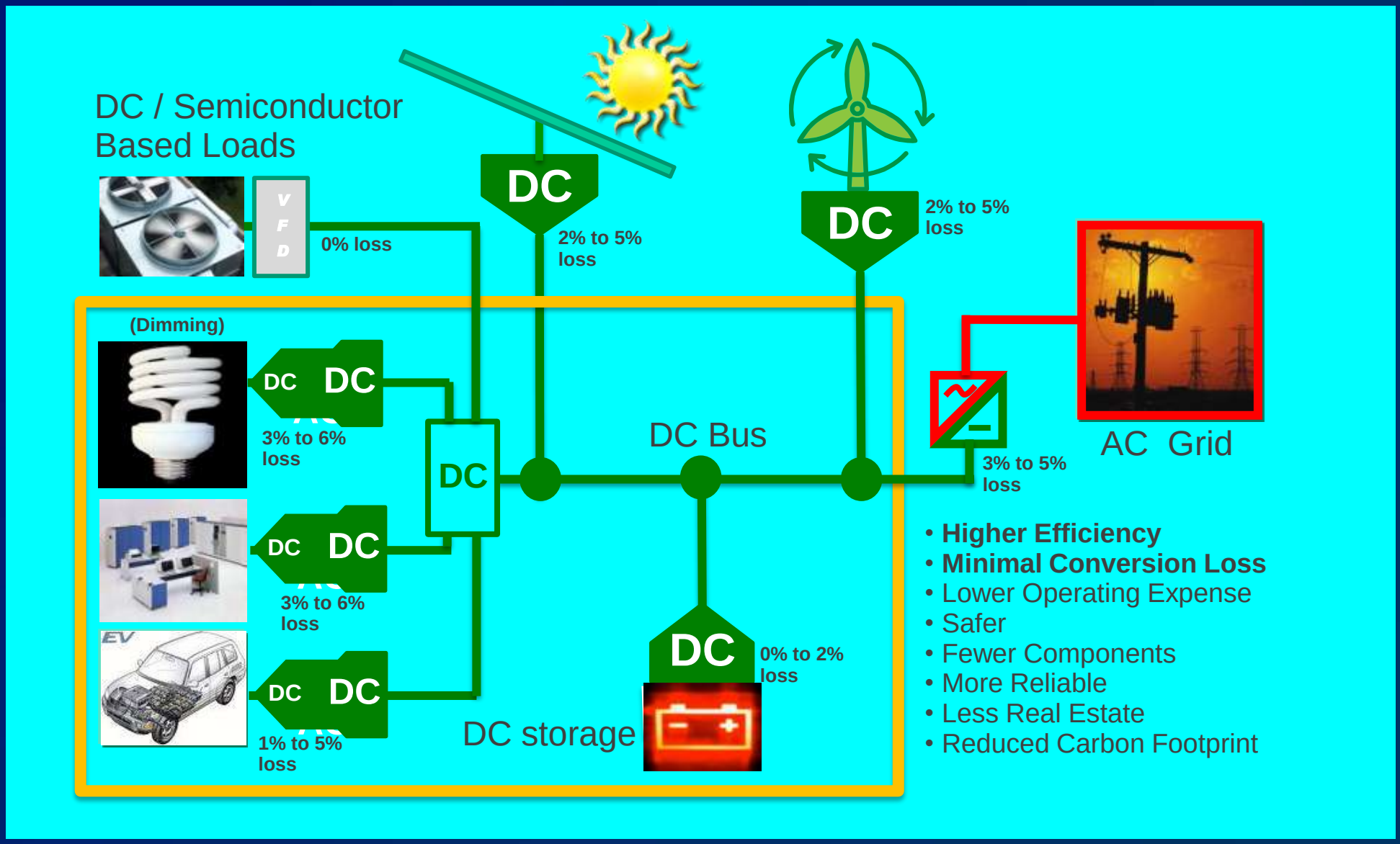
DC Semiconductors / Power Electronics

80% of all AC electricity is used by DC based power electronics

Status Quo

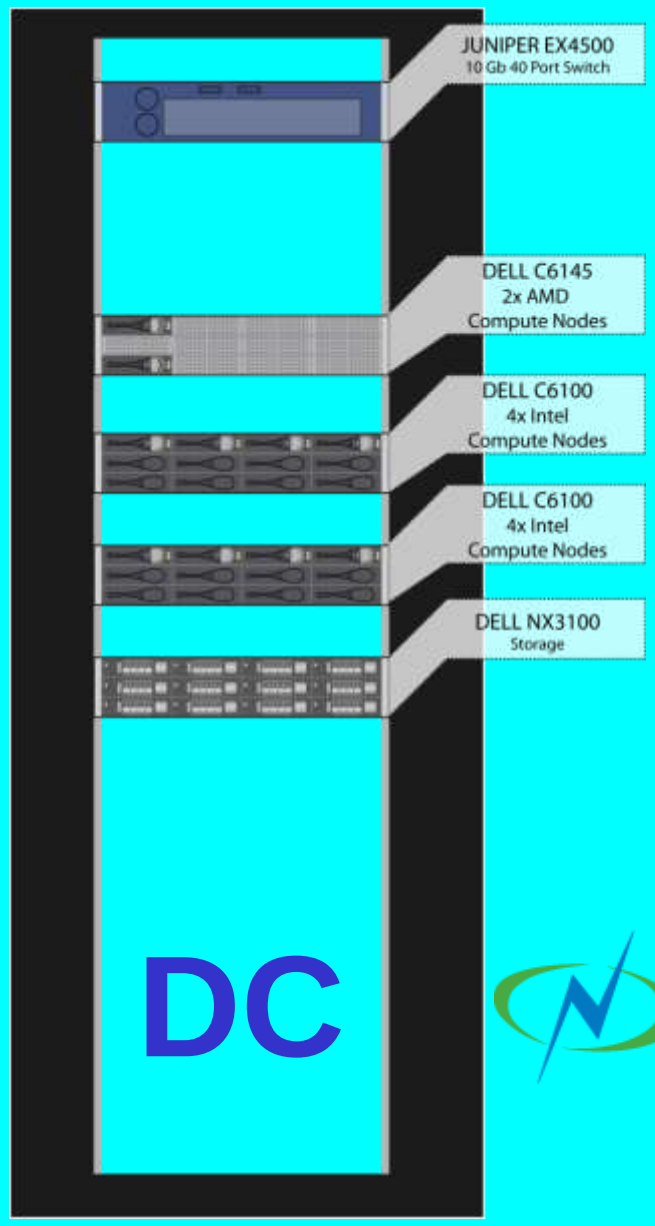

DC / Semiconductor
Based Loads
V
F
D
DC
AC
2% to 10%
loss
DC
AC
4% to 8%
Loss
DC
AC
4% - 8%
(Dimming)
DC
AC
12% to 20%
loss
DC
AC
15% to 20%
loss
DC
AC
3% to 10%
loss
AC
DC sources
AC
AC
DC
AC
DC
4% to 8%
Loss
4% to 8%
Loss
DC storage
AC Grid

A Better Way
DC Microgrids



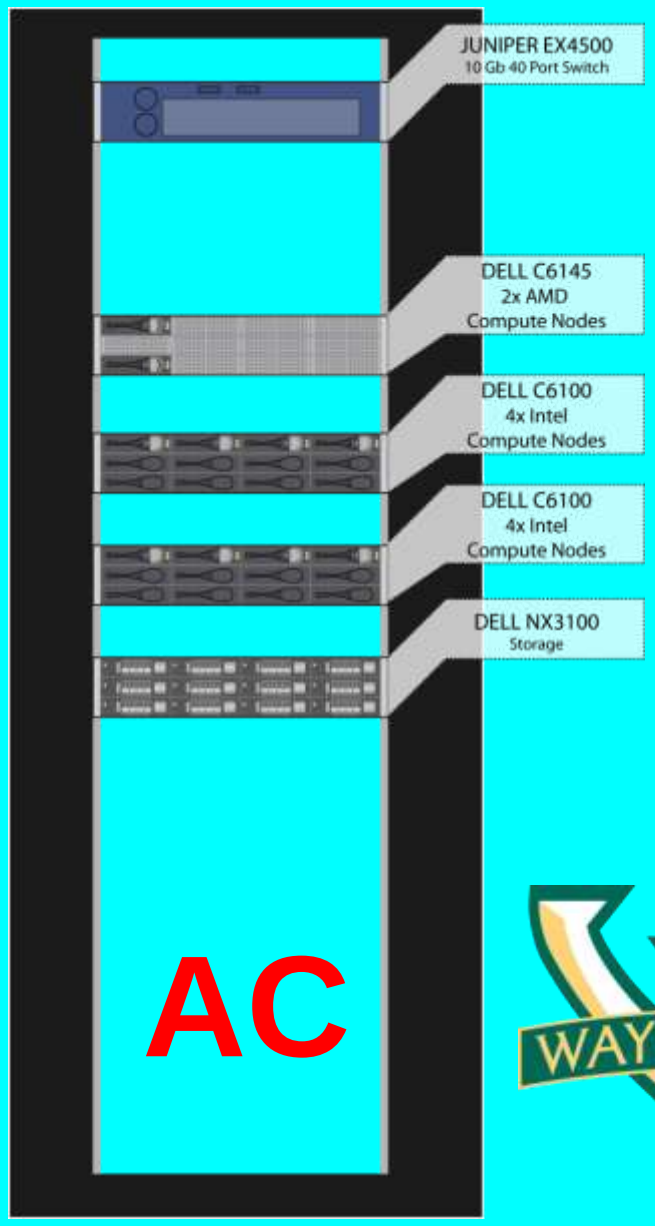
DC Data Centers Around The World… A Growing List!

Racks



DC

NEXTEK
Power Systems



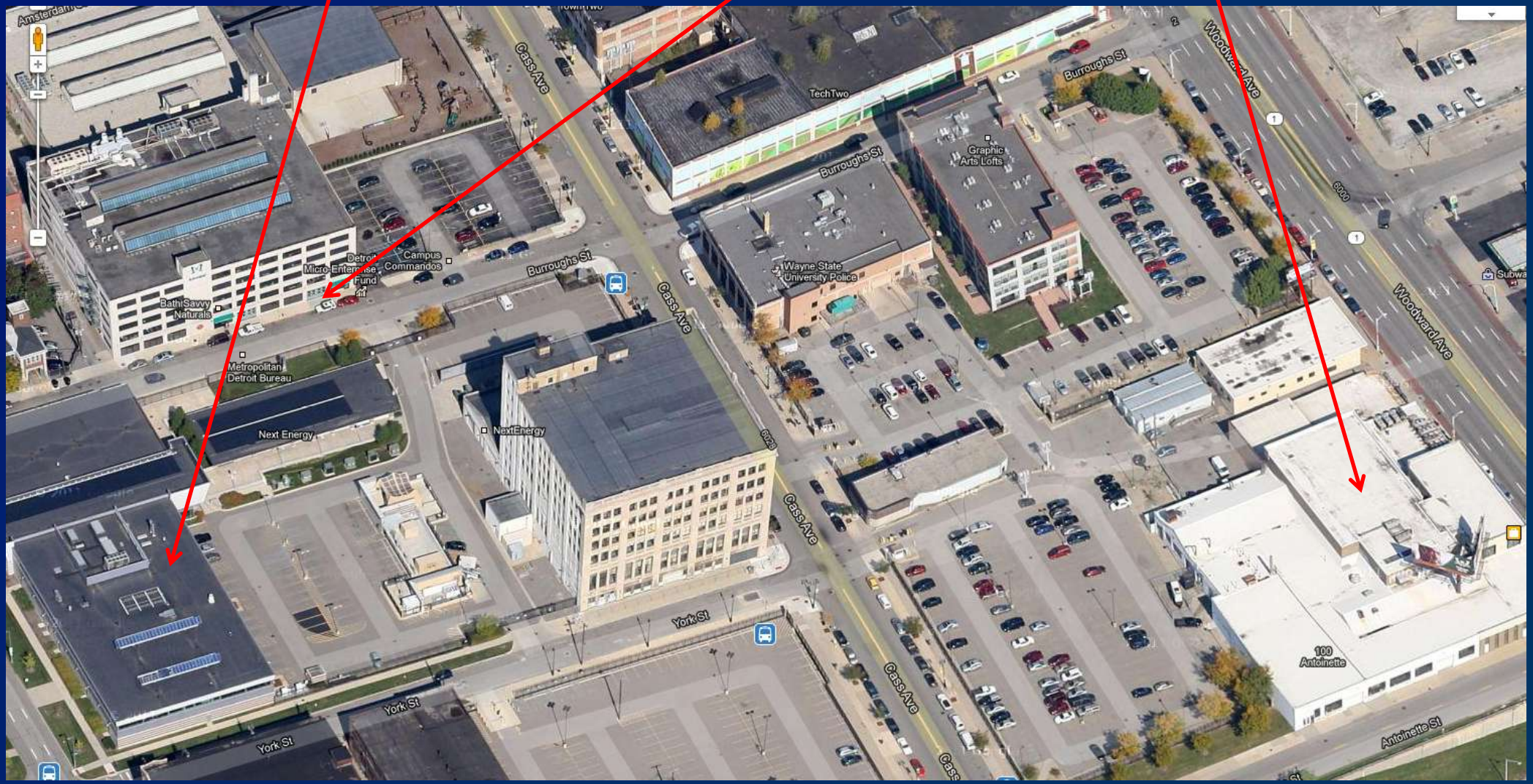
AC

How it all started: A great cup of coffee

NextEnergy and Nextek

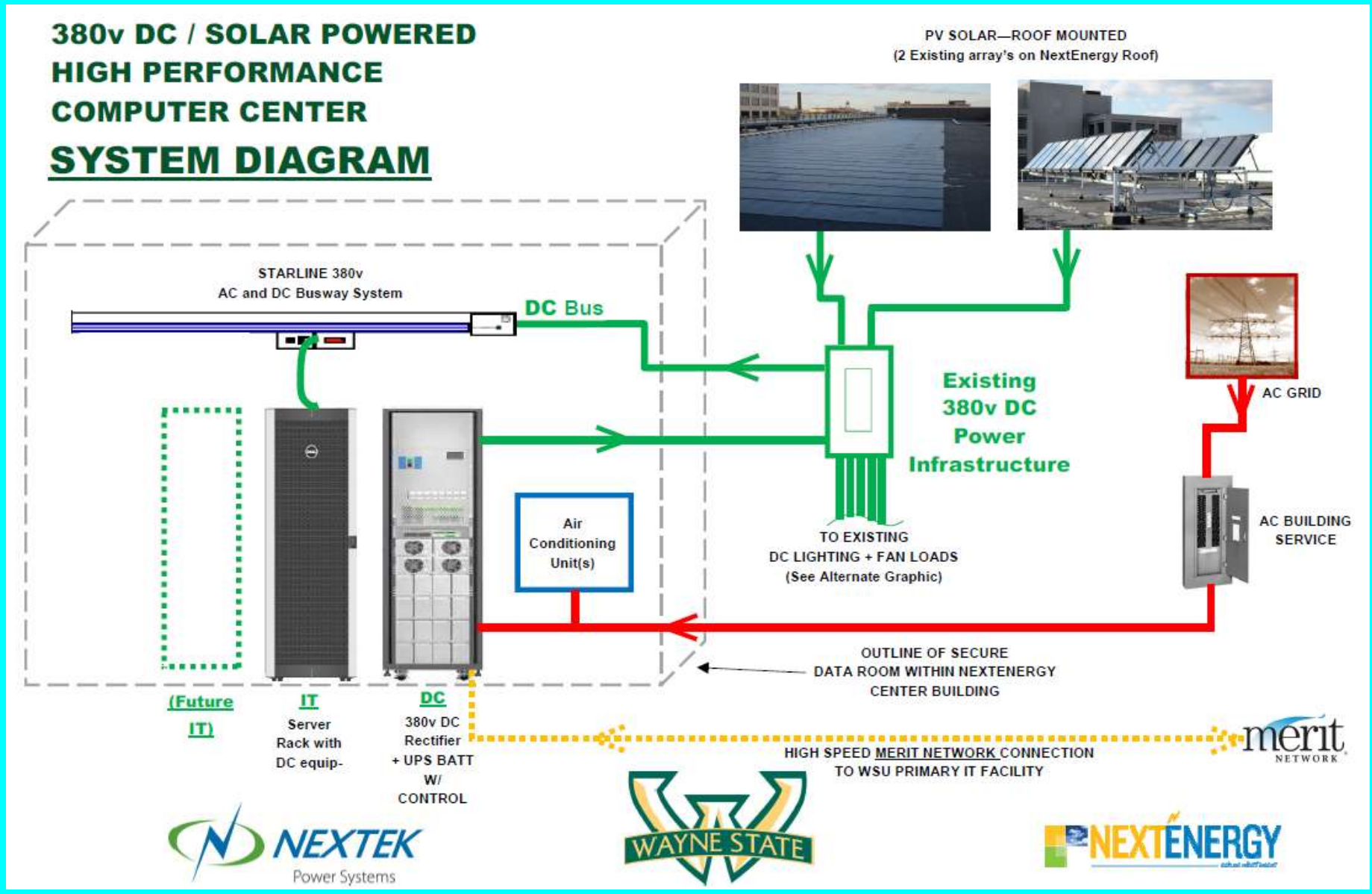
Tech Town and Java Cafe

WSU Datacenter

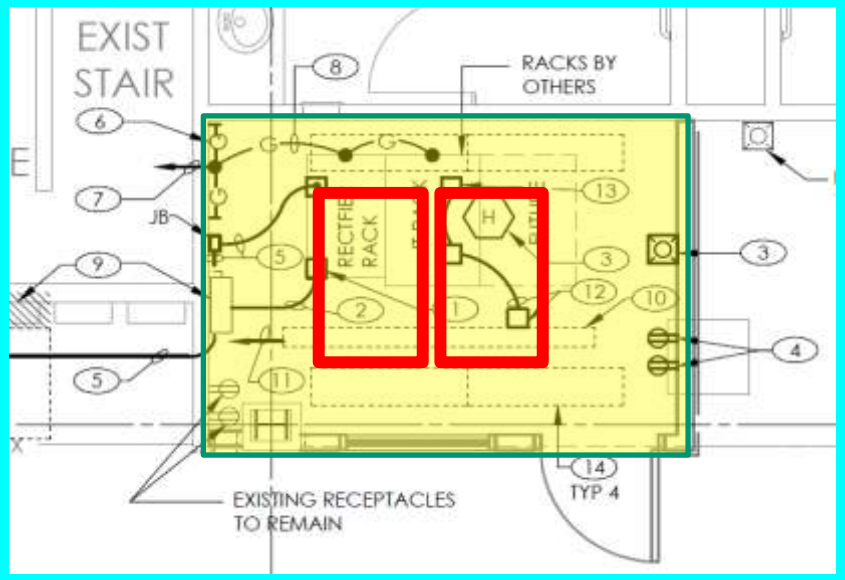


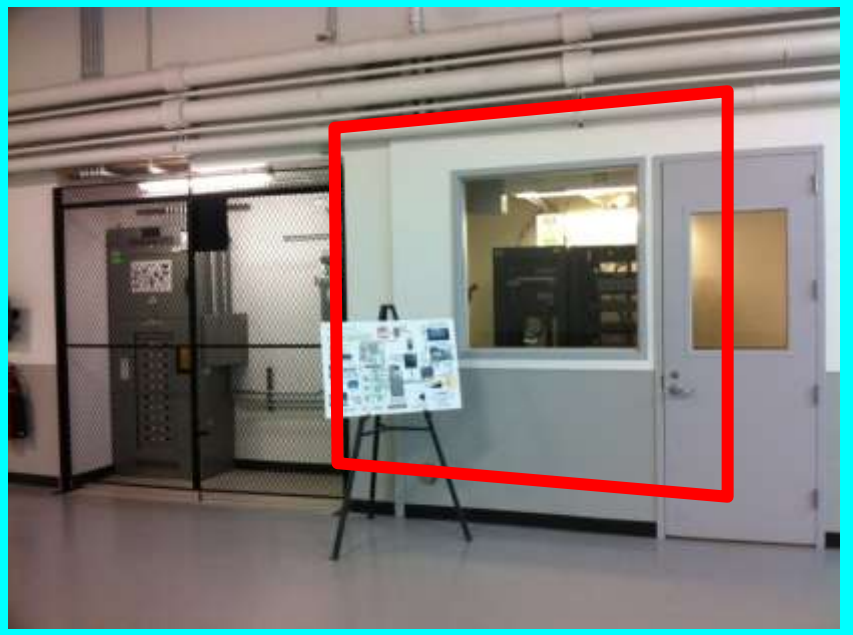
NextEnergy's mission is to accelerate energy security, economic competitiveness, and environmental responsibility through the growth of advanced energy technologies, businesses, and industries.

The NextEnergy Data Room Detail



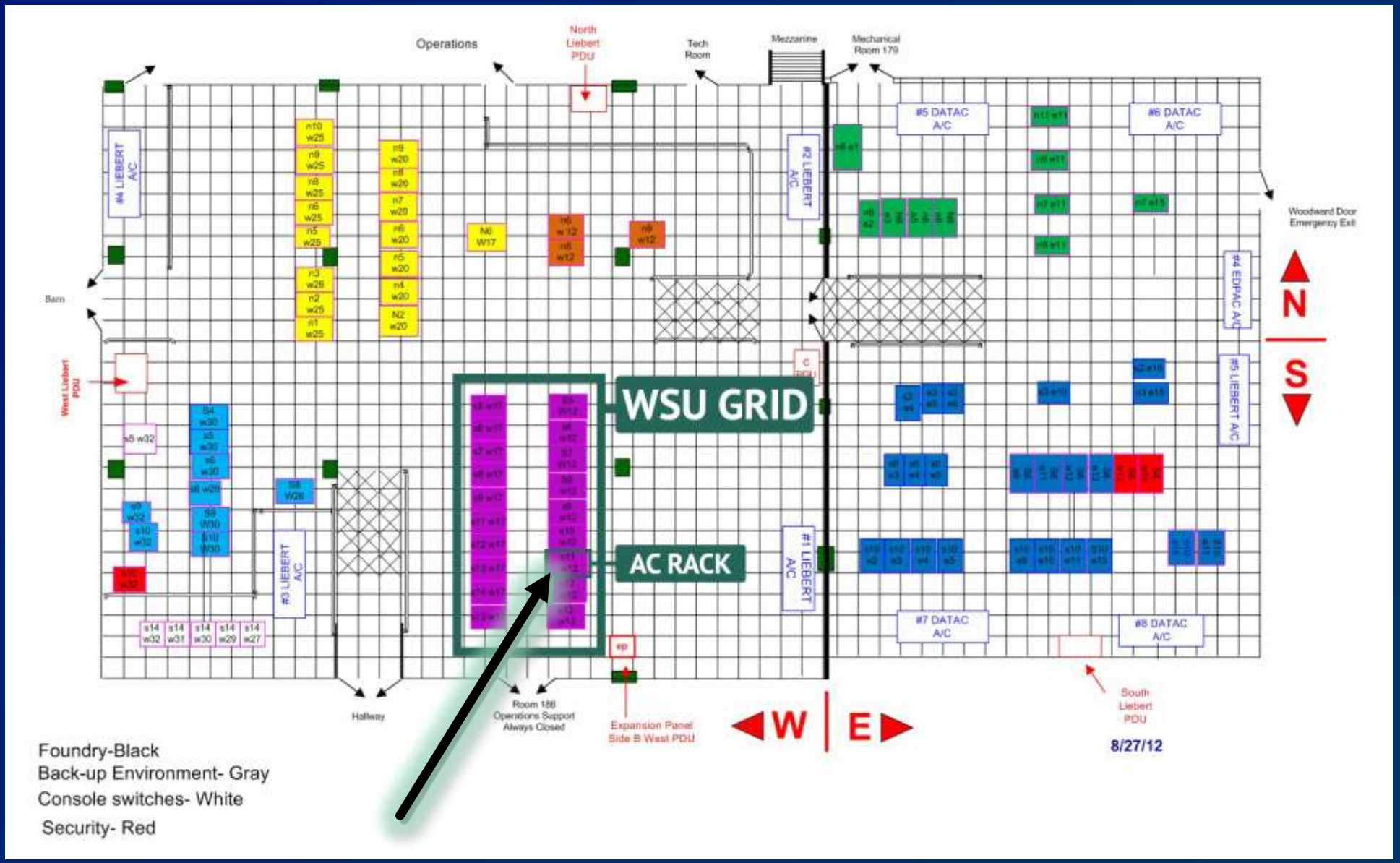
The NextEnergy Data Room Detail



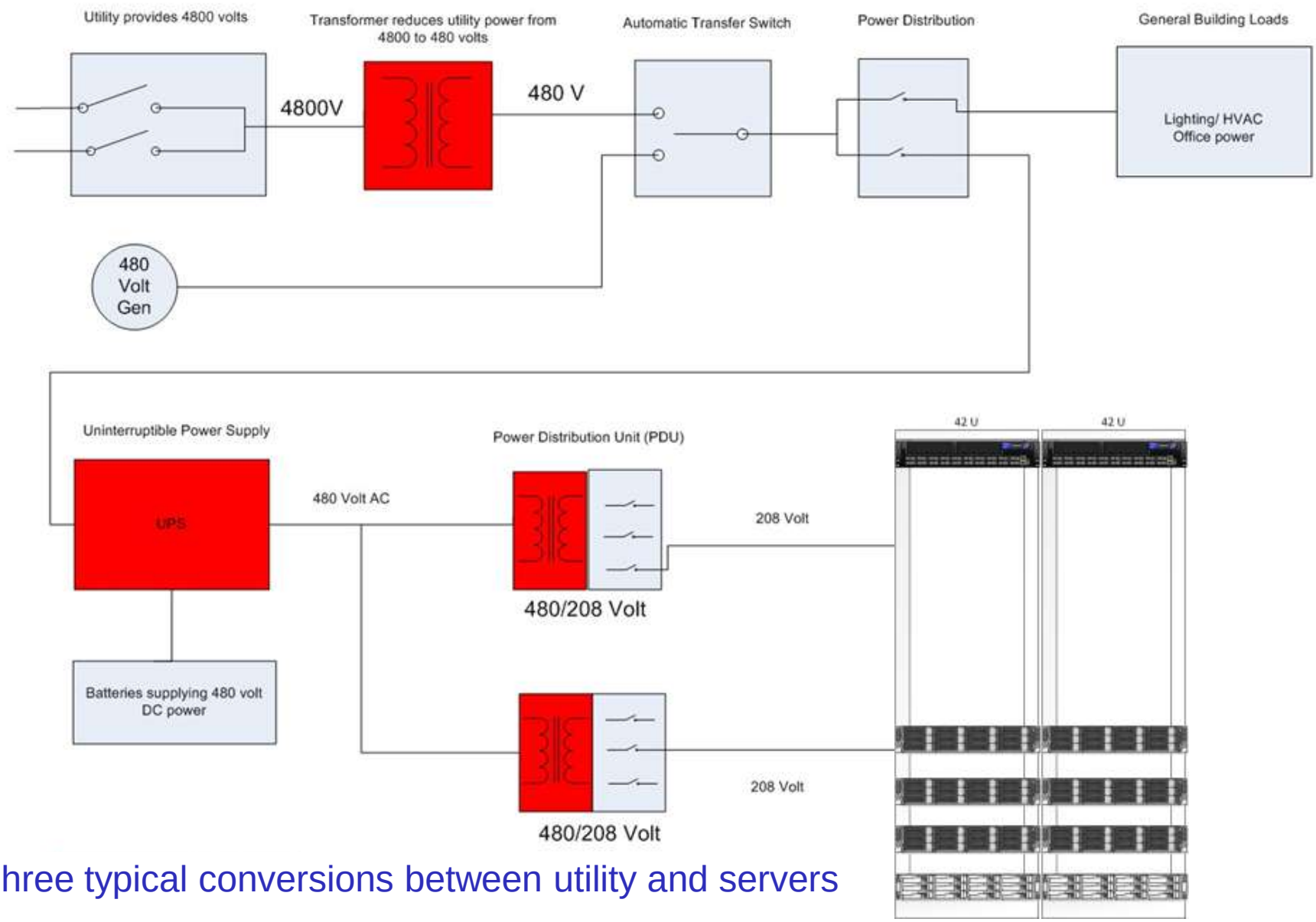


30kW Rectifier + Batteries

C&IT AC Site


Operations
North Liebert PDU
Tech Room
Mezzanine
Mechanical Room 179
#5 DATAC A/C
#6 DATAC A/C
#4 LIEBERT A/C
#2 LIEBERT A/C
Woodward Door Emergency Exit
#4 EDPAC A/C
#5 LIEBERT A/C
Barn
West Liebert PDU
WSU GRID
AC RACK
#3 LIEBERT A/C
#1 LIEBERT A/C
#7 DATAC A/C
#8 DATAC A/C
N
S
W
E
Hallway
Room 188 Operations Support Always Closed
Expansion Panel Side B West PDU
South Liebert PDU
8/27/12
Foundry-Black
Back-up Environment- Gray
Console switches- White
Security- Red

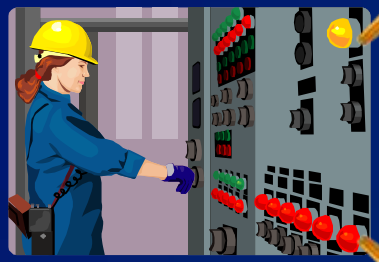
AC Power Diagram



Three typical conversions between utility and servers

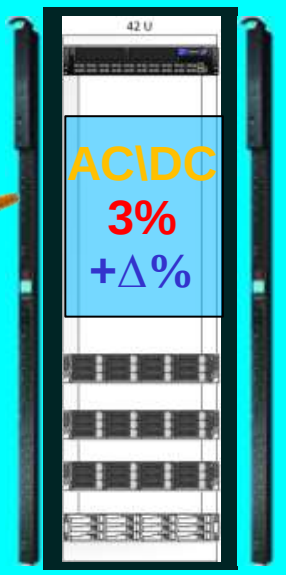
Power Loss

480 volt AC



480V AC

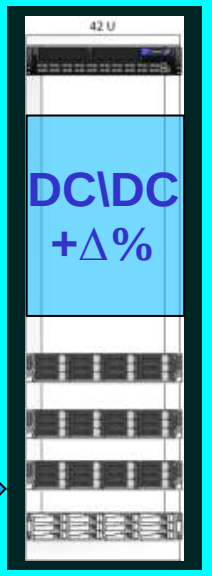
208V AC



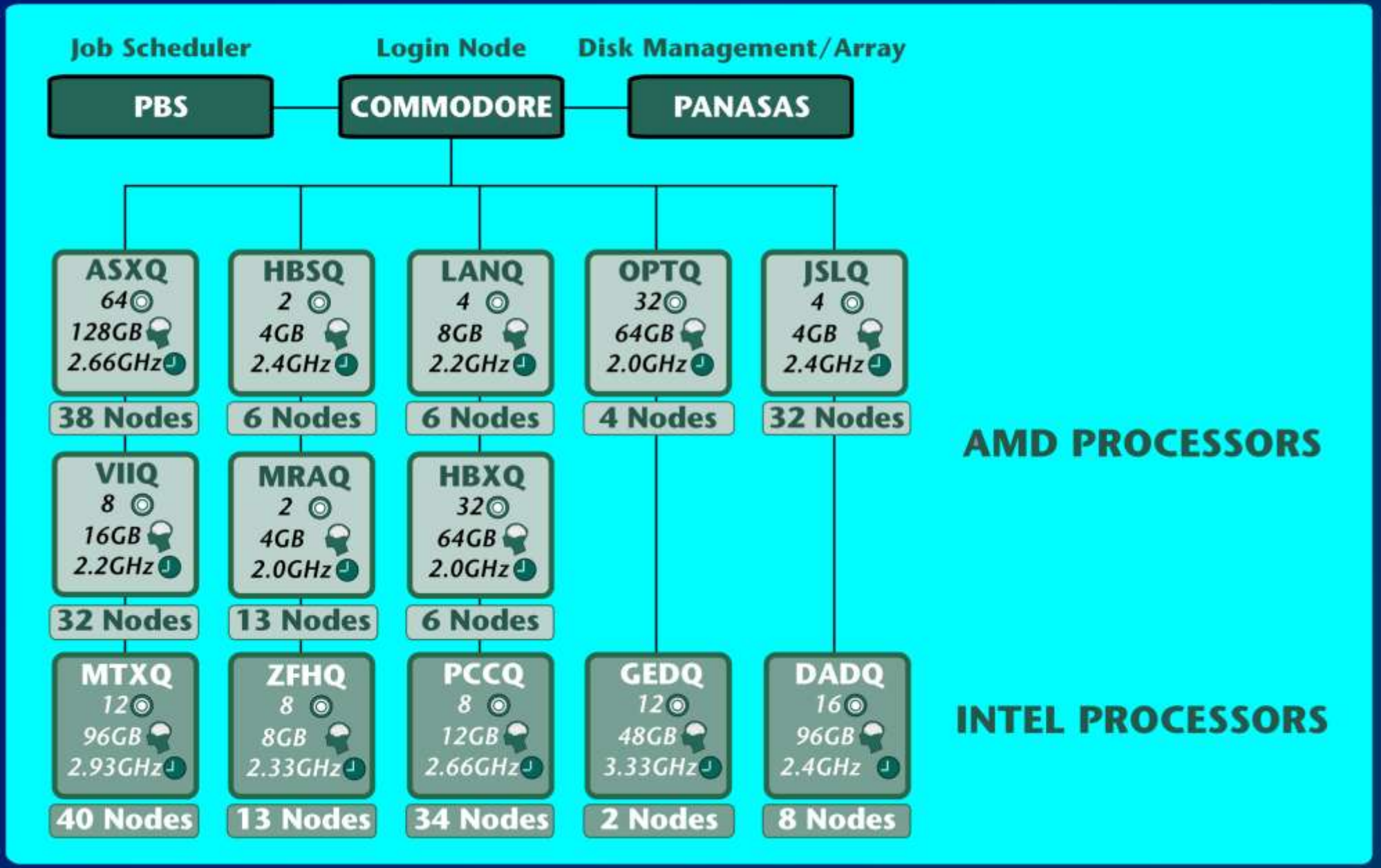
AC TOTAL~25-28%+Δ%

DC TOTAL ~3%+Δ%

380V DC BUS



Grid Layout


Job Scheduler
Login Node
Disk Management/Array
PBS
COMMODORE
PANASAS
ASXQ
64
128GB
2.66GHz
38 Nodes
HBSQ
2
4GB
2.4GHz
6 Nodes
LANQ
4
8GB
2.2GHz
6 Nodes
OPTQ
32
64GB
2.0GHz
4 Nodes
JSLQ
4
4GB
2.4GHz
32 Nodes
AMD PROCESSORS
VIIQ
8
16GB
2.2GHz
32 Nodes
MRAQ
2
4GB
2.0GHz
13 Nodes
HBXQ
32
64GB
2.0GHz
6 Nodes
MTXQ
12
96GB
2.93GHz
40 Nodes
ZFHQ
8
8GB
2.33GHz
13 Nodes
PCCQ
8
12GB
2.66GHz
34 Nodes
GEDQ
12
48GB
3.33GHz
2 Nodes
DADQ
16
96GB
2.4GHz
8 Nodes
INTEL PROCESSORS

HPC Job Scheduling & Workload Management

Faster time-to-results, better throughput and utilization

- Scalability and Reliability
- Policy-driven Scheduling
- Accelerator Scheduling
- Green Provisioning™ for Power Management
- Topology-aware Scheduling
- EAL3+ Security Certified
- Extensible Plugin Framework
- Mature and Reliable Technology

PDU Data Collection

DC Data Collection
(amatis AM-SCADA Meter and Monitor)

Disk Array A
Disk Array B

Juniper Switch A
Juniper Switch B

AMD Compute 1-A
AMD Compute 1-B

Intel Compute 1-A
Intel Compute 1-B

Intel Compute 2-A
Intel Compute 2-B

AC Data Collection
(APC AP8641 Rack PDU)

Disk Array A
Disk Array B

Juniper Switch A
Juniper Switch B

AMD Compute 1-A
AMD Compute 1-B

Intel Compute 1-A
Intel Compute 1-B

Intel Compute 2-A
Intel Compute 2-B

IPMI & Ganglia Readings

C6145 - 48 Readings Total	
16	RAM Temperature Readings
4	CPU Temperature Readings
4	Main Logic Board Temperature Readings
2	Northbridge Board Temperature Readings
1	Fan Controller Board Temperature Reading
8	Fan Speed Readings
5	Power Supply Voltage Readings
1	Standby Voltage Reading
4	CPU Core Voltage Readings
2	Power Supply Amperage Readings
1	Mother Board 12V Amperage Reading

C6100 - 19 Readings Total	
2	CPU Temperature Readings
3	Main Logic Board Temperature Readings
2	Fan Control Board Temperature Readings
4	Fan Speed Readings
2	Power Supply Voltage Readings
1	Standby Voltage Reading
2	CPU Core Voltage Readings
3	Power Supply Currents

Ganglia Readings

CPU Load, Memory, Bytes In, Byte Out, Disk Free

Data Collection and Storage

Intelligent Platform Management Interface

IPMI

Amatis AM-SCADA Meter and Monitor

APC AP8641 Rack PDU

Summary

- DC Microgrids save money
- Less electricity
- Less cooling
- Less space
- Less maintenance *(reliability)*
- Minimal AC-DC conversion losses
- Flexible, whole-building use of 380VDC power
- Applicable to existing IT equipment
- Fully scalable to meet demand

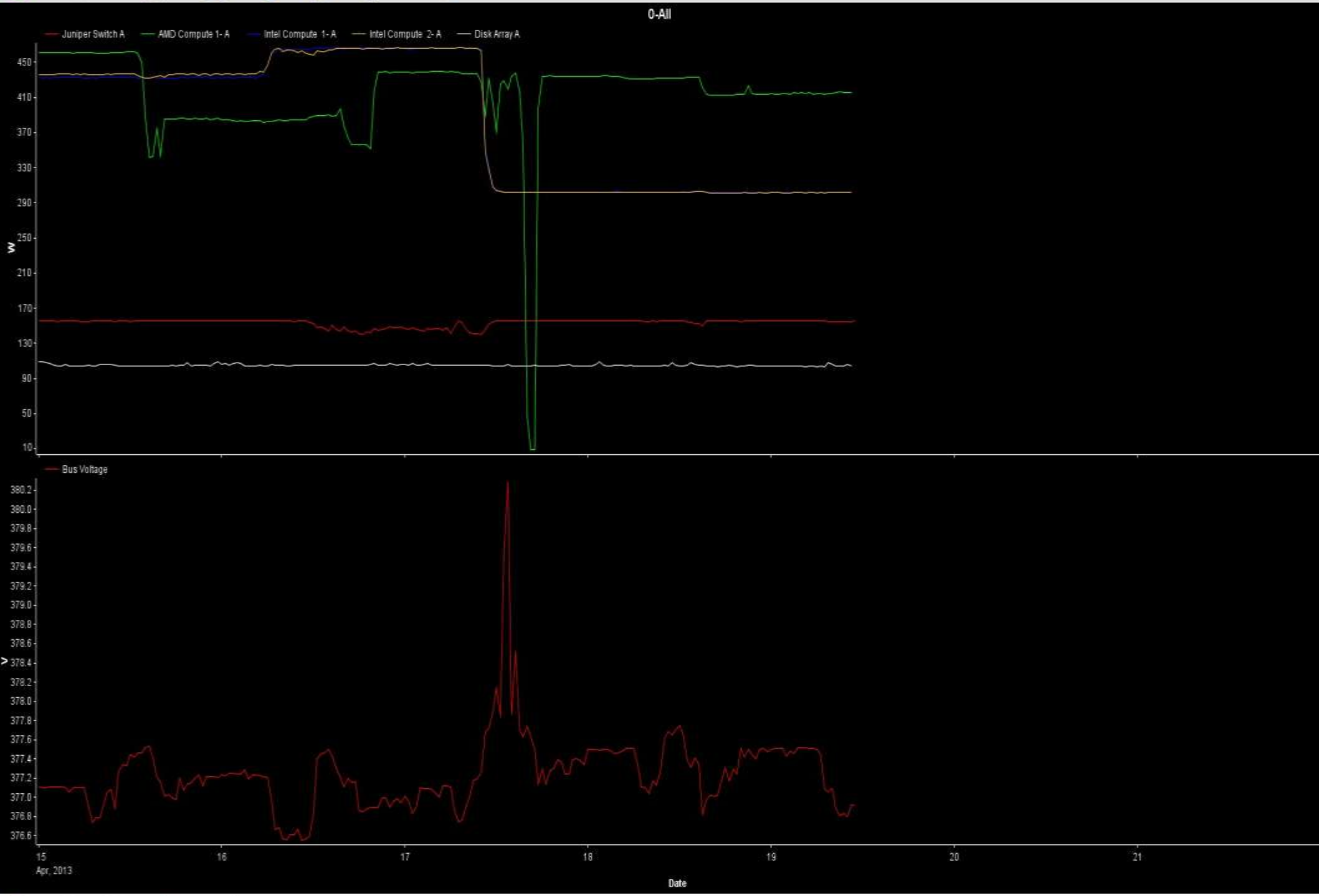
Acknowledgements

Michael Thompson – *Michael@wayne.edu*

Graph - 0-All - PowerStudio Scada

Options Views General

Previous Next Devices Graph Table Events Properties Print



Back Next Go to Grouped by Period

Table - Date/time, 0-All.Juniper Switch A (W), 0-All.AMD Compute 1- A (W), 0-All.Intel Compute 1- A (W), 0-All.Intel Compute 2- A (W), 0-All.Disk Array A (W), 0-All.Bus Voltage (V) - PowerStudio Scada

Options Views General

Previous Next Devices Graph Table Events Properties Print

Week 16, 15 April 2013 - 21 April 2013

Date/time	0-All.Juniper Switch A (W)	0-All.AMD Compute 1- A (W)	0-All.Intel Compute 1- A (W)	0-All.Intel Compute 2- A (W)	0-All.Disk Array A (W)	0-All.Bus Voltage (V)
Monday 15 00:00:00	155.231	460.576	432.555	436.128	108.817	377.105
Monday 15 00:30:00	155.470	460.494	431.994	435.877	108.674	377.101
Monday 15 01:00:00	155.190	460.436	432.621	435.822	108.283	377.103
Monday 15 01:30:00	155.233	460.526	431.989	435.794	106.759	377.109
Monday 15 02:00:00	155.584	461.190	432.767	435.995	104.840	377.106
Monday 15 02:30:00	155.057	461.254	433.011	436.358	104.438	377.107
Monday 15 03:00:00	155.377	461.024	432.862	436.377	104.285	377.109
Monday 15 03:30:00	155.349	460.826	433.095	436.240	106.445	377.099
Monday 15 04:00:00	155.319	460.670	432.866	436.214	104.426	377.053
Monday 15 04:30:00	155.344	460.388	432.778	435.911	104.374	377.099
Monday 15 05:00:00	155.216	460.561	432.651	436.184	104.104	377.101
Monday 15 05:30:00	154.964	460.654	432.611	436.170	104.230	377.098
Monday 15 06:00:00	154.947	461.257	432.181	436.196	104.091	377.101
Monday 15 06:30:00	154.988	460.732	432.294	435.851	105.567	376.909
Monday 15 07:00:00	155.132	460.465	432.504	435.520	104.676	376.735
Monday 15 07:30:00	155.235	460.331	432.265	435.826	104.351	376.792
Monday 15 08:00:00	155.317	460.228	432.362	435.778	105.899	376.792
Monday 15 08:30:00	155.278	460.396	432.999	436.136	106.414	376.910
Monday 15 09:00:00	155.376	460.390	432.365	436.387	106.006	377.052
Monday 15 09:30:00	155.247	460.488	432.502	435.923	105.884	377.080
Monday 15 10:00:00	154.784	460.787	432.874	436.246	104.864	376.889
Monday 15 10:30:00	155.360	461.050	433.175	436.346	104.258	377.269
Monday 15 11:00:00	155.156	461.194	432.878	436.436	104.270	377.341
Monday 15 11:30:00	155.302	461.513	432.585	436.296	104.352	377.333
Monday 15 12:00:00	154.935	461.678	432.484	436.264	104.068	377.442
Monday 15 12:30:00	155.110	461.763	432.916	436.192	104.254	377.418
Monday 15 13:00:00	155.150	460.259	431.868	434.421	104.102	377.466
Monday 15 13:30:00	155.580	448.979	432.181	432.521	104.082	377.468
Monday 15 14:00:00	155.755	386.809	431.719	432.043	104.252	377.521
Monday 15 14:30:00	155.804	341.668	431.823	432.064	103.914	377.539
Monday 15 15:00:00	155.469	342.588	432.325	432.704	104.043	377.409
Monday 15 15:30:00	155.402	374.924	431.888	434.232	103.929	377.202
Monday 15 16:00:00	156.053	343.206	431.711	434.277	103.938	377.162
Monday 15 16:30:00	155.881	385.442	431.455	433.171	104.022	377.011
Monday 15 17:00:00	155.789	385.237	432.085	436.157	104.609	377.031
Monday 15 17:30:00	155.470	385.240	432.212	435.914	104.702	376.996
Monday 15 18:00:00	155.665	385.564	432.142	436.377	104.631	376.971
Monday 15 18:30:00	155.584	386.245	432.696	436.525	104.924	377.198
Monday 15 19:00:00	155.366	386.468	432.574	436.723	105.291	377.072
Monday 15 19:30:00	155.278	385.409	432.201	435.674	107.925	377.139
Monday 15 20:00:00	155.660	385.254	432.424	436.469	104.538	377.153
Monday 15 20:30:00	155.667	385.819	433.078	437.028	104.853	377.198
Monday 15 21:00:00	155.469	385.237	432.740	435.081	104.729	377.234
Monday 15 21:30:00	155.279	385.155	432.530	436.738	104.902	377.121
Monday 15 22:00:00	155.693	386.132	433.362	436.908	104.968	377.212
Monday 15 22:30:00	155.320	384.792	432.102	435.197	104.610	377.218
Monday 15 23:00:00	155.537	385.580	432.204	436.739	107.122	377.212
Monday 15 23:30:00	155.722	386.051	432.460	436.236	109.458	377.208
Tuesday 16 00:00:00	155.503	384.620	431.583	435.487	105.969	377.235
Tuesday 16 00:30:00	155.671	384.583	432.573	436.596	106.718	377.220
Tuesday 16 01:00:00	155.430	384.002	432.696	437.044	104.959	377.250
Tuesday 16 01:30:00	155.557	382.956	432.196	435.622	106.770	377.253
Tuesday 16 02:00:00	155.569	382.578	432.625	436.476	108.304	377.239
Tuesday 16 02:30:00	155.733	383.644	432.963	436.717	107.037	377.241
Tuesday 16 03:00:00	155.473	382.520	432.622	435.785	104.450	377.285
Tuesday 16 03:30:00	155.583	382.579	432.876	436.614	104.604	377.192

Back Next Go to Grouped by Period

Drivers of WSU's Interest in More Efficient Data Centers

- Institutional IT strategy: co-location, server hosting and IT consolidation
- Declining budgets
- Units being asked to pay electricity bills
- Environmental benefits
- Alternative energy and microgrids
- Detroit's Public Lighting Department: reliability
- Research

AC vs. DC

- Energy loss in every AD/DC conversion
  efficiencies generally range from 75%-95%
- Three typical conversions between power plant and servers in a data center
- Energy lost typically as heat
  adding to cooling problems in data center
- Inside servers: DC already

Other DC Data Center Pilots…

EPRI/LBNL - Electric Power Research Institute Lawrence Berkeley National Lab, California

Ernest Orlando Lawrence Berkeley National Laboratory

EPRI Electric Power Research Institute

Duke Energy data center in Charlotte, North Carolina

Duke Energy®

Calit2 - California Institute for Telecommunications and Information Technology , UC San Diego

Sustainability Resource Center Equity-Environment-Economy UCSanDiego Local Impact, National Influence, Global Reach

Full Scale 1MW DC Data Center

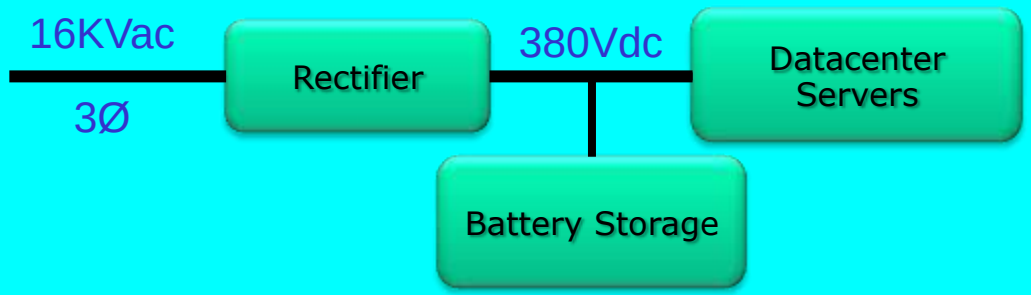
Green.ch-ABB Zurich-West 380Vdc Data Center

ABB/Validus Power Distribution
- In: 16KV AC
- Out: 1MW @ 380Vdc
- Battery Backup: 10 mins
- Backup Generation

1,100m^2 of 3,300m^2 Vdc

HP 2U, Blades & Storage Servers

Demonstrated Benefits
- **10% Better Energy Efficiency**
- **15% Lower Capital Cost**
- **25% Smaller Footprint**
- **20% Lower Installation Costs**



Photos courtesy of ABB* and HP*

Benchmarking

TPCW

HiBench

YCSB