

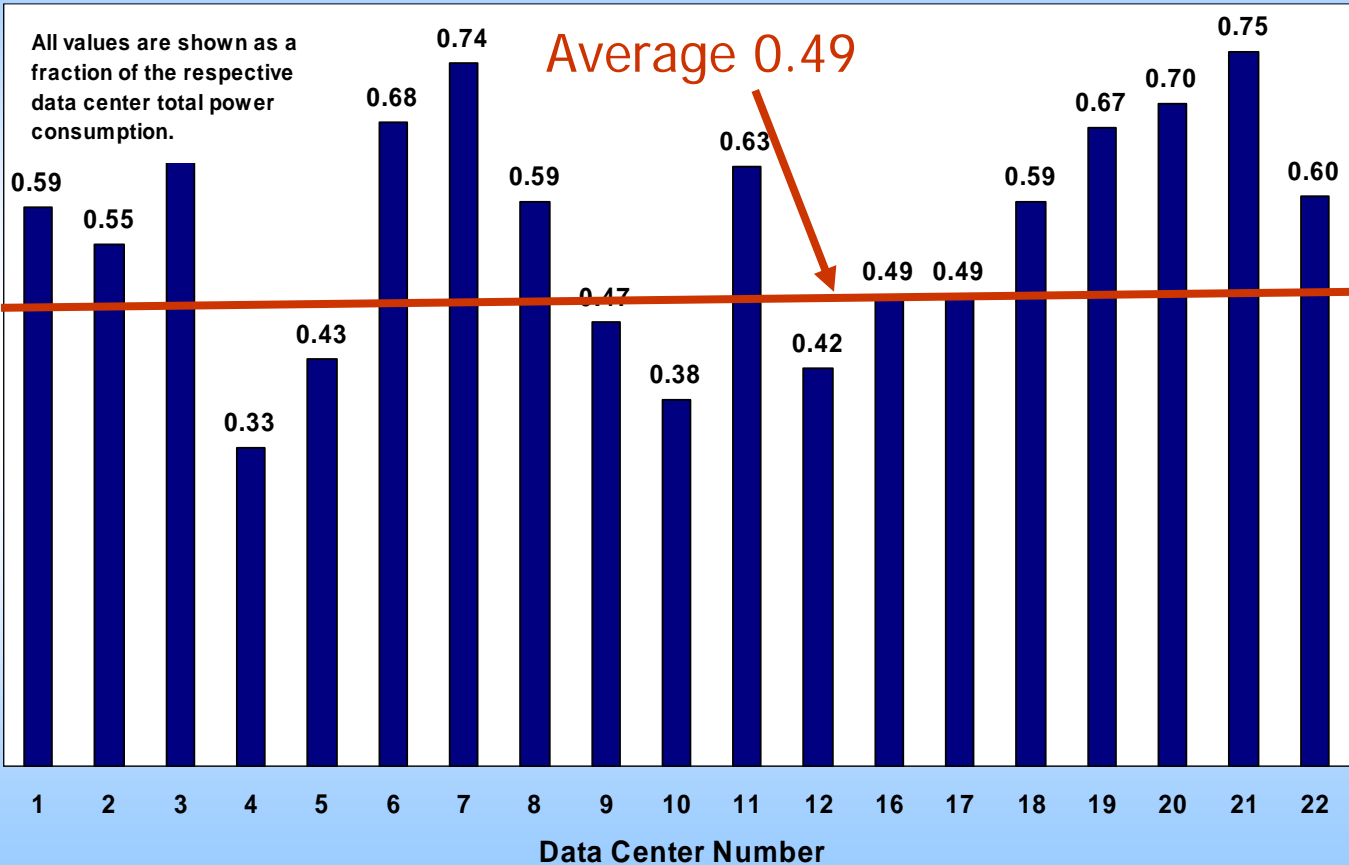
Data Center Power Distribution



July 19, 2007
William Tschudi
wftschudi@lbl.gov

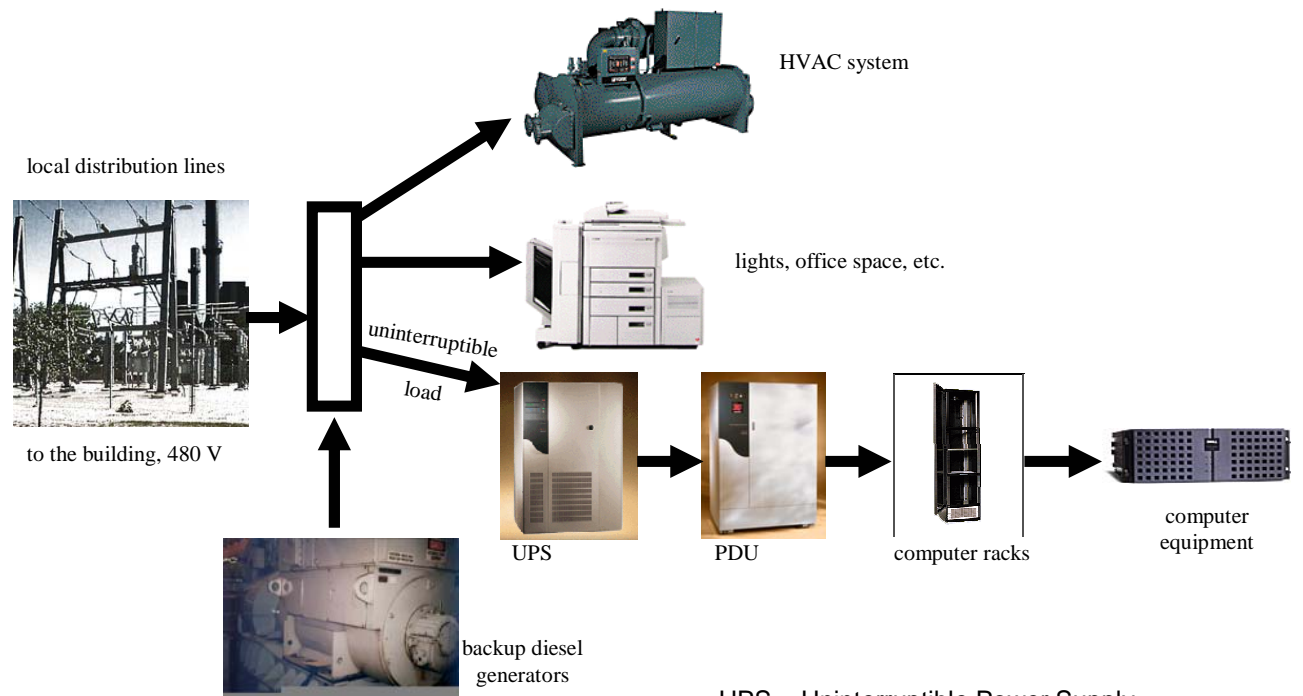
Percentage of power delivered to IT equipment

IT Equipment load Index



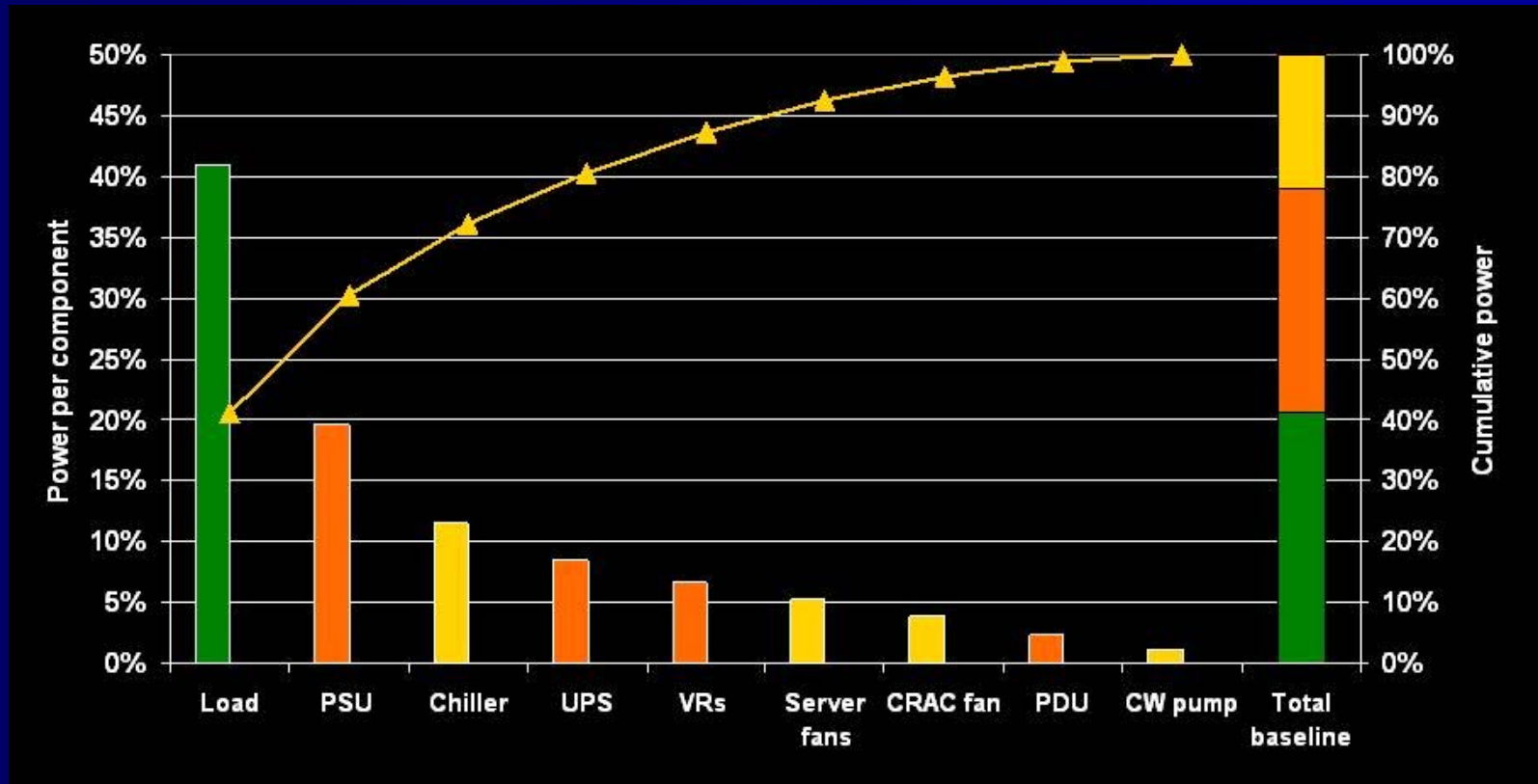
Benchmarking energy end use

Electricity Flows in Data Centers



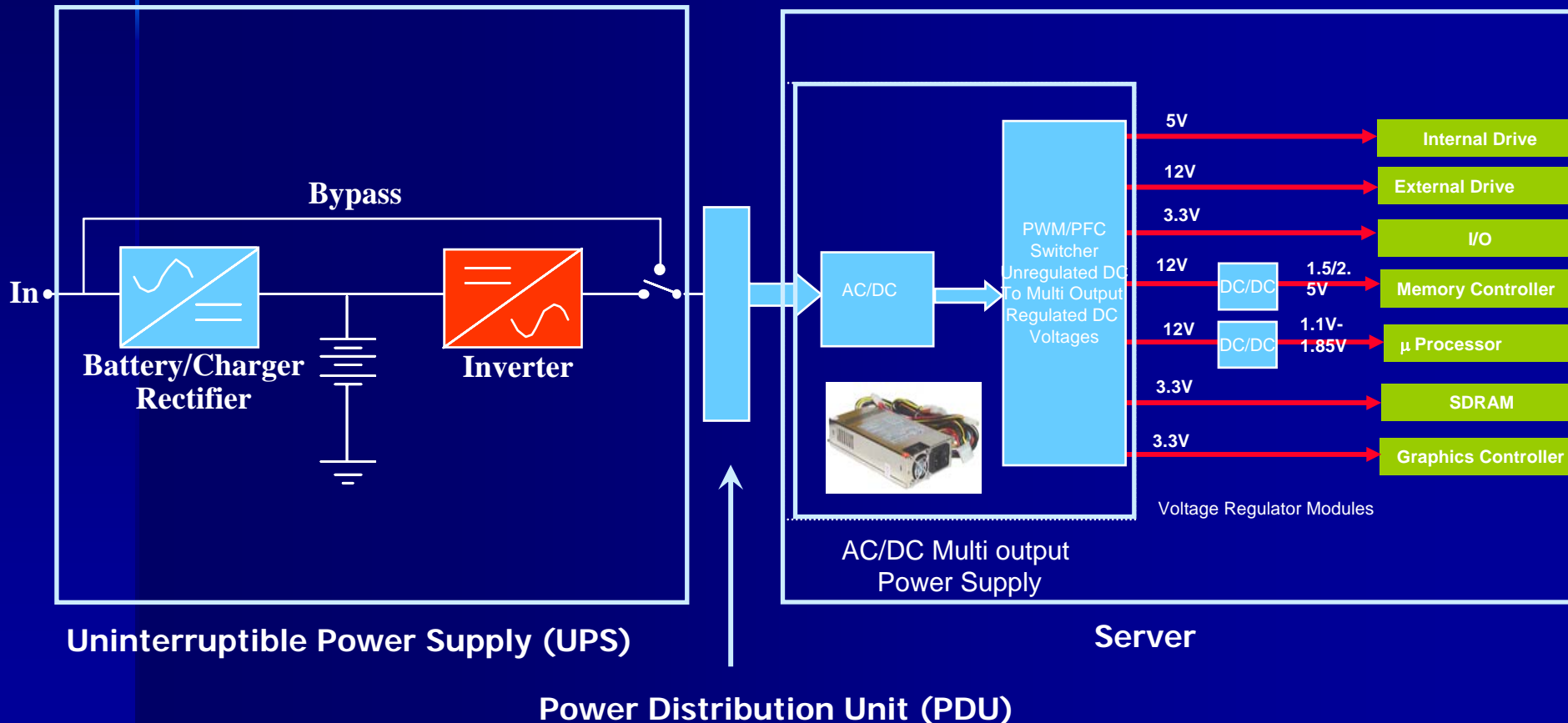
UPS = Uninterruptible Power Supply
PDU = Power Distribution Unit;

Overall power use in Data Centers



Courtesy of Michael Patterson, Intel Corporation

Data Center power conversions



Data Center Power Delivery System

UPS
85 - 92%



Power Dist
98 - 99%



Power Supply
68 - 72%



DC/DC
78 - 85%



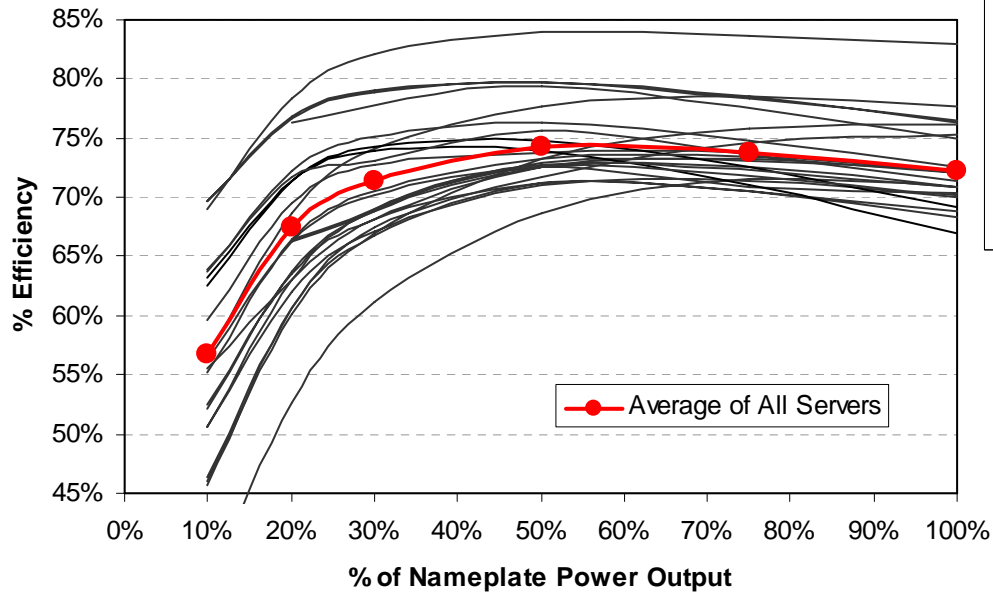
The heat generated from the losses at each step of power conversion requires additional cooling power



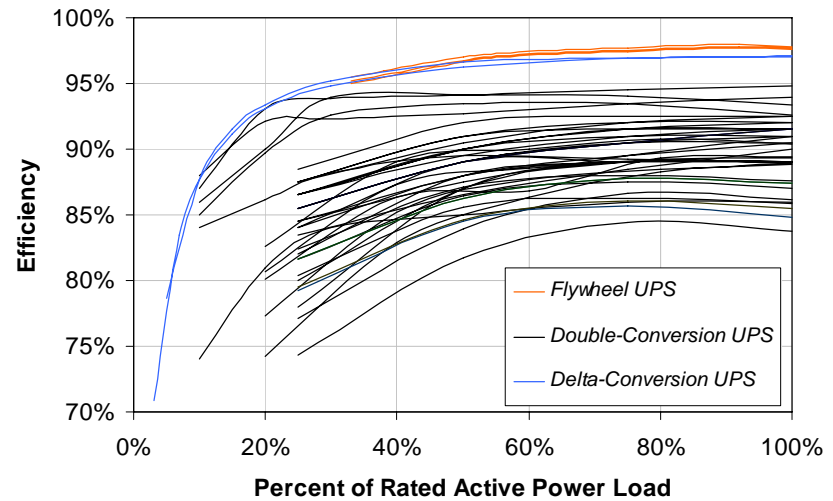
Power for cooling can equal or exceed the direct losses

Prior research illustrated large losses in power conversion

Power Supplies in IT equipment



Factory Measurements of UPS Efficiency
(tested using linear loads)



Uninterruptible Power Supplies (UPS)

UPS labeling

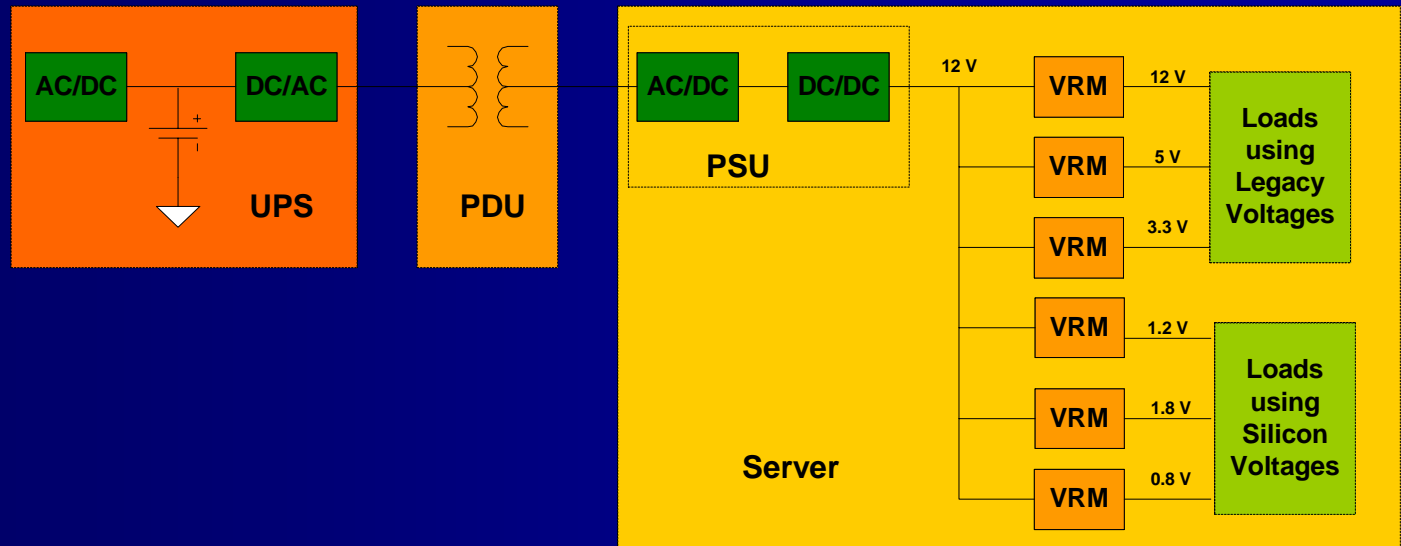
- ❑ Based upon proposed European Standard
- ❑ Possible use in Energy Star program
- ❑ Possible use in Utility incentive programs
- ❑ Possible use in Federal Procurement specs

UPS-System			
Manufacturer Model	SFOE USV1A		
Nominal power kW ¹⁾ / kVA ²⁾	XXX / XXX		
Mode of operation			
Low losses			
			A
			D
High losses			
Energy losses kWh / year ³⁾	xx.x		xx.x
Energy losses kWh at 2'000 h standby	xx.x		xx.x
Filtering of net disturbances	U _n = ⁴⁾		
Outage		✓	> X ms
Voltage interruption		✓	> X ms
Over- and undervoltages		✓	> X ms
Voltage sags/brownouts		✓	> X ms
Harmonic voltages		✓	
Frequency variations		✓	> X ms
Fast transients		✓	< XXX % U _n
Energy loaded transients		✓	< XXX % U _n
Power factor and harmonic distortion	λ / THD ⁵⁾		
<small>No declaration for UPS-systems with a nominal power higher than 10 kVA</small>			
at nominal power in kW ¹⁾	x.xx / xx.x %		x.xx / xx.x %
at nominal power in kVA ²⁾	x.xx / xx.x %		x.xx / xx.x %
at asymmetric nonlinear load ²⁾	x.xx / xx.x %		x.xx / xx.x %

¹⁾ at ohmic load
²⁾ at non-linear load according to EN 50051
³⁾ Energy losses at ohmic continuous load with 75 % of nominal power
⁴⁾ U_n = Nominal output voltage
 Filtering is sufficient, if the output voltage fulfills EN 50160.
⁵⁾ Power factor λ / Total harmonic distortion of the input current
 SFOE-Directors for UPS-Systems
 October 2002

Typical AC distribution today

480
Volt AC



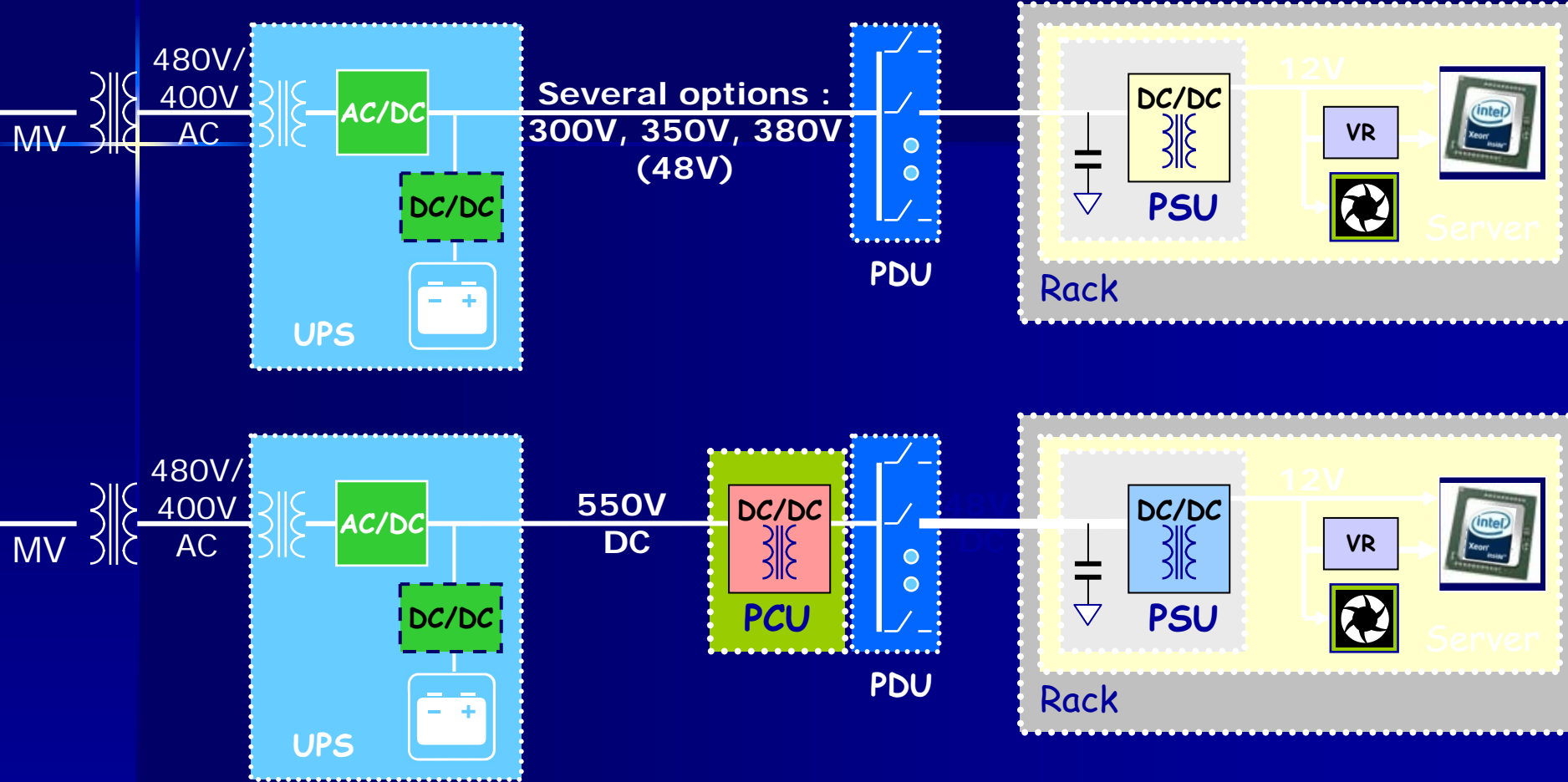
Distribution considerations

- Distributing higher voltage AC or DC to the load is more efficient
- Less copper at higher voltage – copper cost is very high
- Safety is key consideration
- Electricians are needed at higher voltages
- Disconnecting DC creates an arc
- UL rated equipment exists
- Equipment in use is rated to 600V. now.

Thomas Edison:

"My personal desire would be to prohibit entirely the use of alternating currents. They are as unnecessary as they are dangerous. I can therefore see no justification for the introduction of a system which has no element of permanency and every element of danger to life and property."

Various DC architectures



Courtesy of Annabelle Pratt, Intel

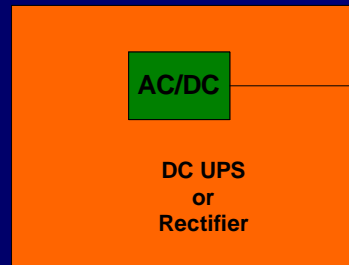
380 V. DC Demonstration



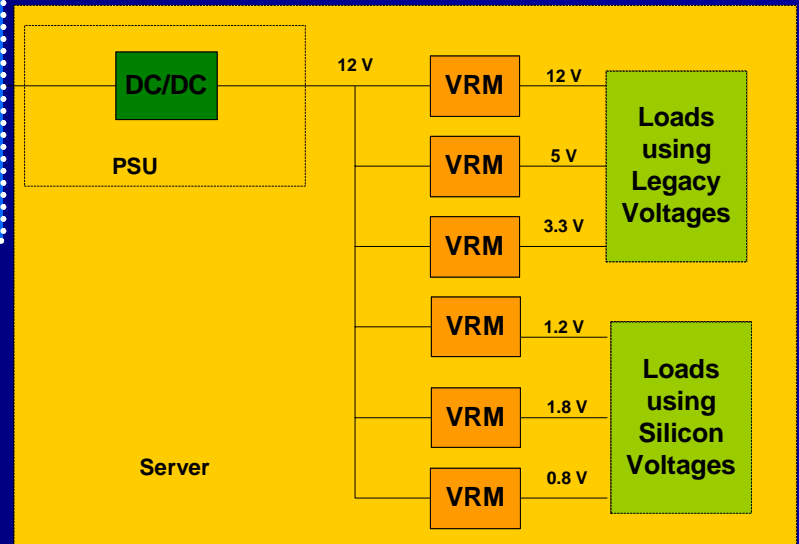
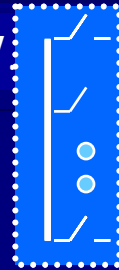
- Side-by-side comparison of traditional AC system with new DC system
 - Facility level distribution
 - Rack level distribution
- Power measurements at conversion points
- Servers modified to accept 380 V. DC
- Artificial loads to more fully simulate data center

Facility-level 380 V. DC distribution

480
Volt AC

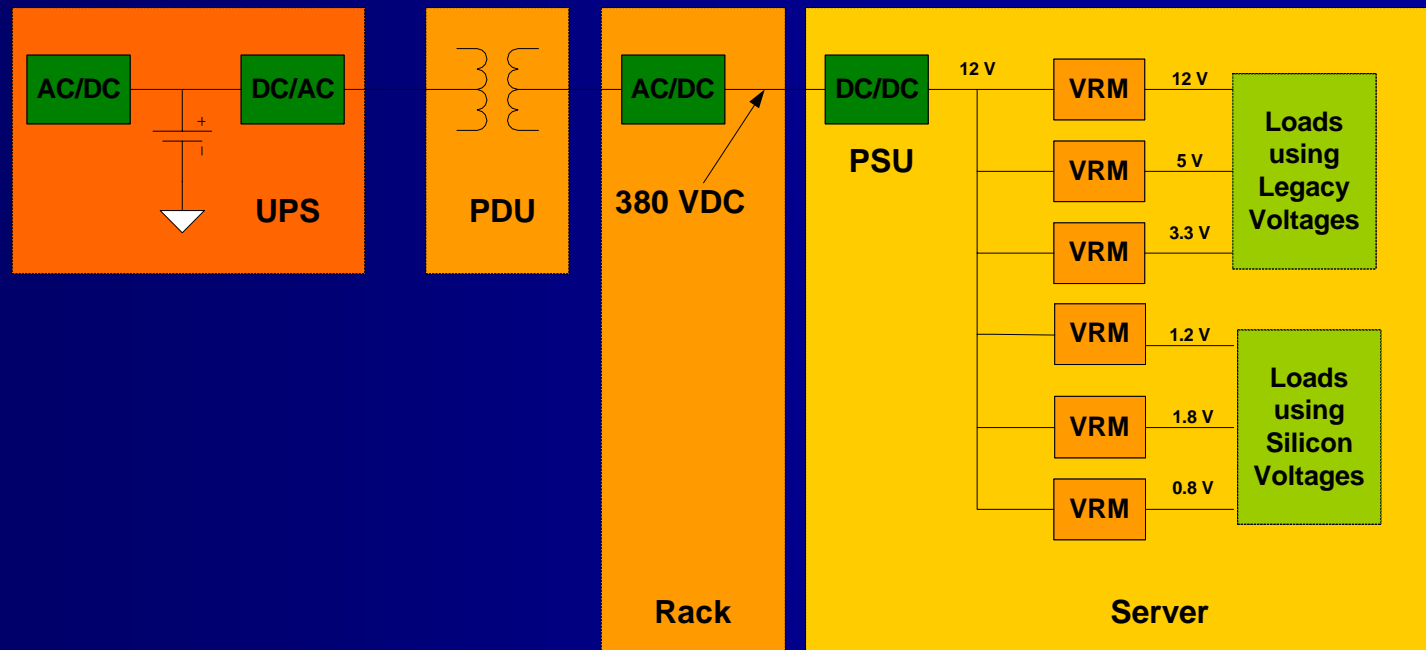


380V

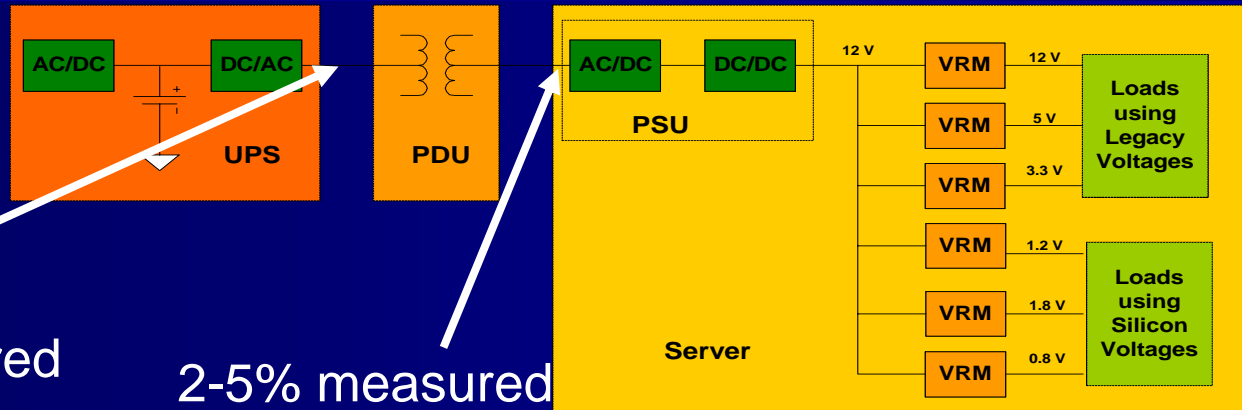


Rack-level DC distribution

480
Volt AC

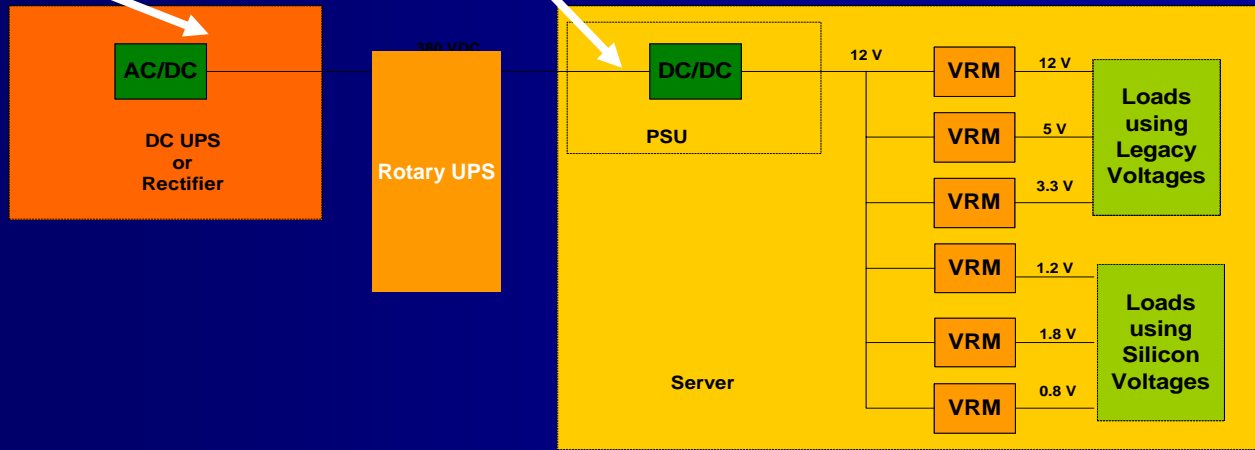


Measured Best in Class AC system loss compared to DC



7-7.3% measured improvement

2-5% measured improvement



Picture of demonstration set-up – see video for more detail



Demonstration Highlights

- All equipment was commercially available and UL rated.
- Connectors at the IT equipment need to be standardized
- Typical energy savings can be 20% or more
- Reliability is expected to be improved – fewer points of failure
- In the long term, first cost could be lower

Most of the Center Can Operate on DC

- DC lighting was included



Most of the Center Can Operate on DC

- Lighting



- HVAC



On-Site Power Production (DG)



Implications could be even better for a typical data center

- Redundant UPS and server power supplies operate at reduced efficiency
- Cooling loads would be reduced.
- Both UPS systems used in the AC base case were “best in class” systems and performed better than benchmarked systems – efficiency gains compared to typical systems could be higher.
- Further optimization of conversion devices/voltages is possible

Data Center Power Delivery

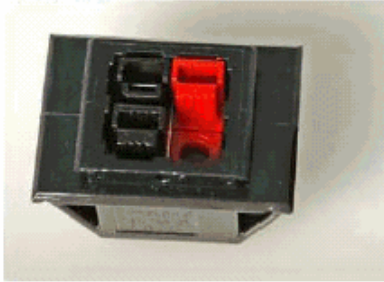
For a typical center energy savings
could exceed 20%

	UPS	XFMR	PS	Total Efficiency	
Typical Efficiency	85.00%	98.00%	73.00%	60.81%	
DC Option	92.00%	100.00%	92.00%	84.64%	
	Compute Load (W)		Input Load (W)		Difference
Typical Efficiency	10,000		16444.93		
Optimized DC Option	10,000		11814.74		28.16%

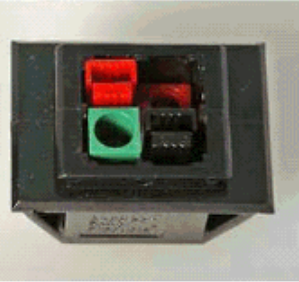
Connectors exist

PowerPak configurations for 400 VDC

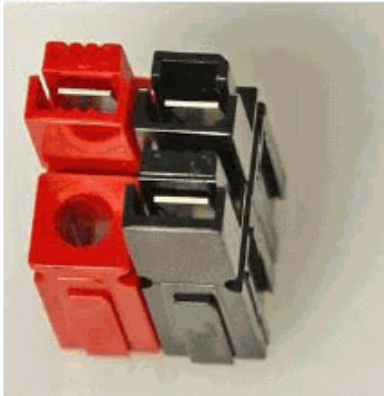
**30 amp Receptacle
Sun Micro**



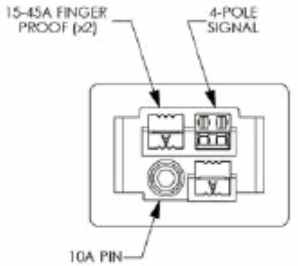
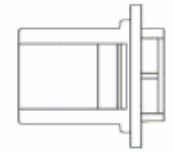
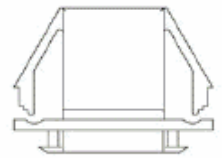
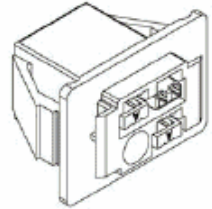
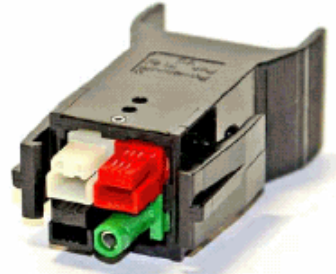
**10 Amp Receptacle
Intel**



**30 amp Plug w/latch
Sun Micro**



**10 Amp Plug w/latch
Intel**



Red spacer location will be replaced by future 4 circuit signal module

Connectors with the right form factor are being developed



DC Power – path forward:

- DC power pilot installation(s)
- Standardize distribution voltage
- Standardize DC connector and power strip design
- Server manufacturers develop power supply specifications (including disturbances)
- Power supply manufacturers develop prototypes
- UL and communications certification
- Address other types of IT equipment (storage, switches, etc.)

Industry Partners in the Demonstration

Equipment and Services Contributors:

Alindeska Electrical Contractors

APC

Baldwin Technologies

Cisco Systems

Cupertino Electric

Dranetz-BMI

Emerson Network Power

Industrial Network Manufacturing
(IEM)

Intel

Nextek Power Systems

Pentadyne

Rosendin Electric

SatCon Power Systems

Square D/Schneider Electric

Sun Microsystems

UNIVERSAL Electric Corp.

Other firms collaborated

Stakeholders:

380voltsdc.com

CCG Facility Integration

Cingular Wireless

Dupont Fabros

EDG2, Inc.

EYP Mission Critical

Gannett

Hewlett Packard

Morrison Hershfield Corporation

NTT Facilities

RTKL

SBC Global

TDI Power

Verizon Wireless

Additional Information

Lawrence Berkeley National Laboratory

- Bill Tschudi, Principal Investigator
wftschudi@lbl.gov

EPRI Solutions

- Brian Fortenbery
bfortenbery@eprisolutions.com

Ecos Consulting

- My Ton
mton@ecosconsulting.com

website:
<http://hightech.lbl.gov/datacenters/>

Discussion/Questions??