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U.S. DEPARTMENT OF ENERGY

PUE Baselining: Methods and Resources

Better Buildings Summit

May 27, 2015

U.S. DEPARTMENT OF ENERGY

Data Center Metering and Resource Guide

Steve Greenberg
Lawrence Berkeley National Laboratory

Better Buildings Summit

Washington, DC

May 27, 2015

Agenda

- **Definitions, including the Power Usage Effectiveness (PUE)**
- **Discussion of data center types**
- **Anticipated scenarios of metering systems and how they integrate with data center types**
- **Metering methods, including leveraging existing meters, starting from scratch**
- **Challenges to installing meters and gathering data**
- **Resources**

Definitions

PUE
Power Usage Effectiveness

- The ratio of total energy use to that of the information technology (IT) equipment.

$$\text{PUE} = \frac{\textbf{Total Data Center Facility Annual Energy Use}}{\textbf{IT Equipment Annual Energy Use}}$$

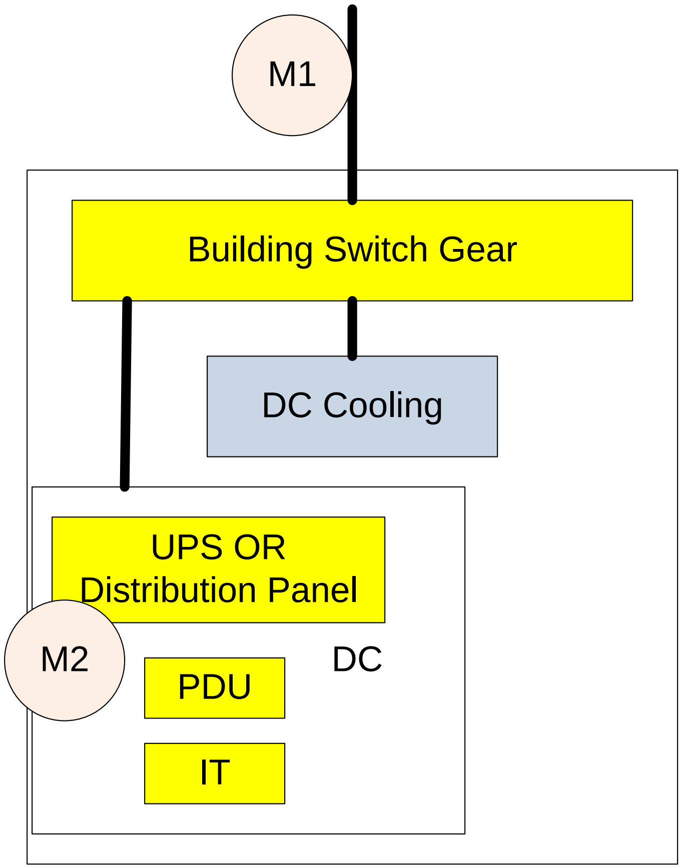
- A measure of how efficiently the data center infrastructure uses energy.

- Three levels (1=Basic, 2=Intermediate, 3=Advanced)

- Focus on Level 1

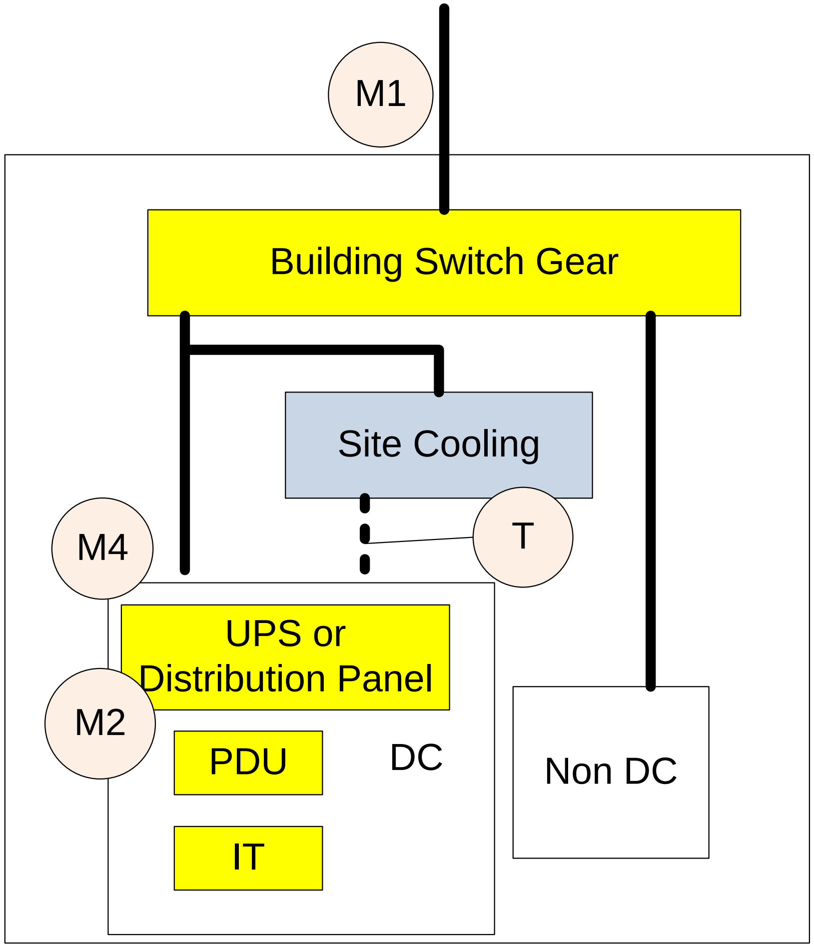
What PUE is good for (infrastructure overhead)

Data Center Types
1. Stand-alone



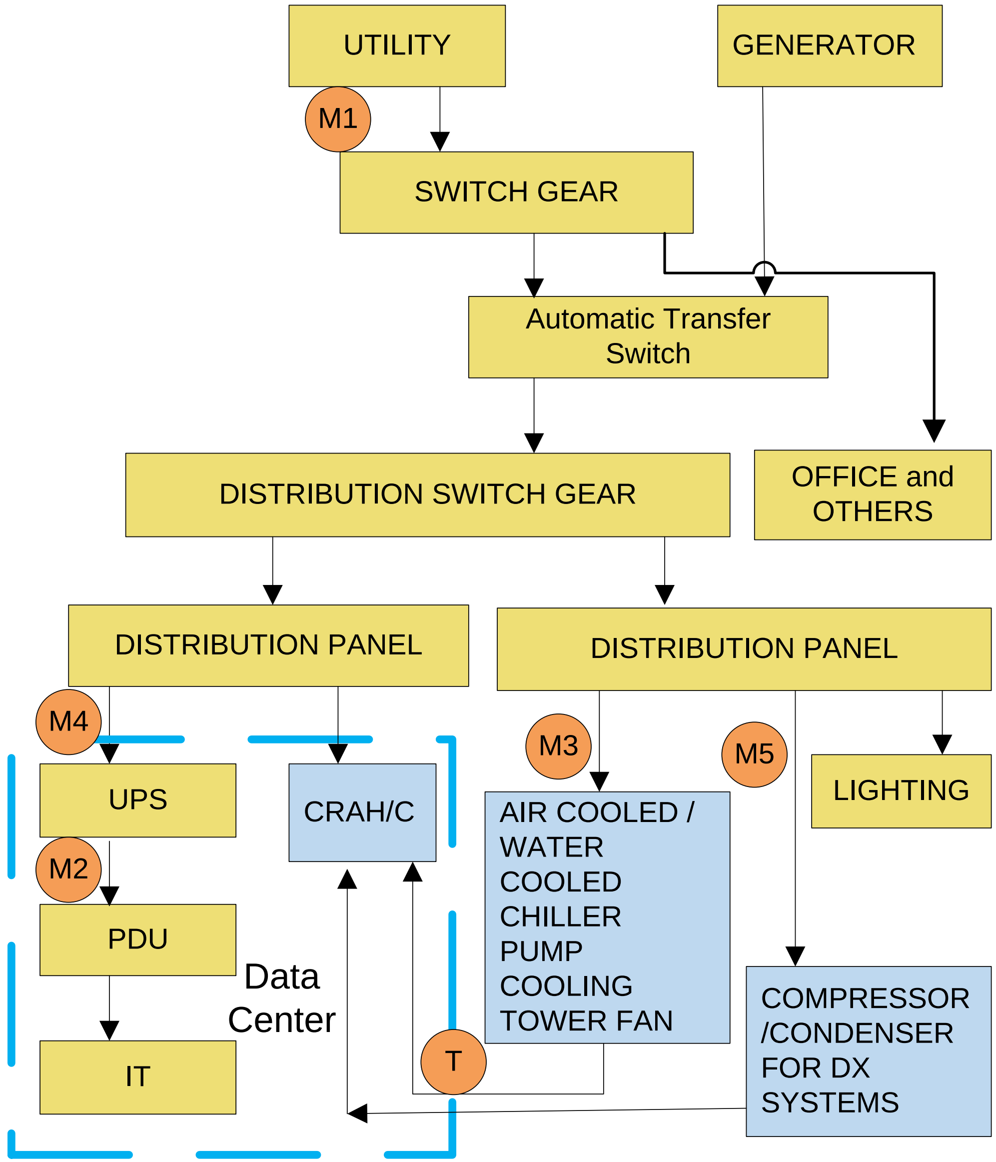
PUE = M1/M2

Data Center Types
2. Embedded



PUE = (M4 + data center cooling) /M2

Data Center Types
2. Embedded, con't



PUE calculation varies, depending on metering

Steps in Metering

1. Planning
    - Determine data center type
    - Determine existing metering
    - Review drawings
    - Interview staff/visit site
    - Decide on PUE calculation approach

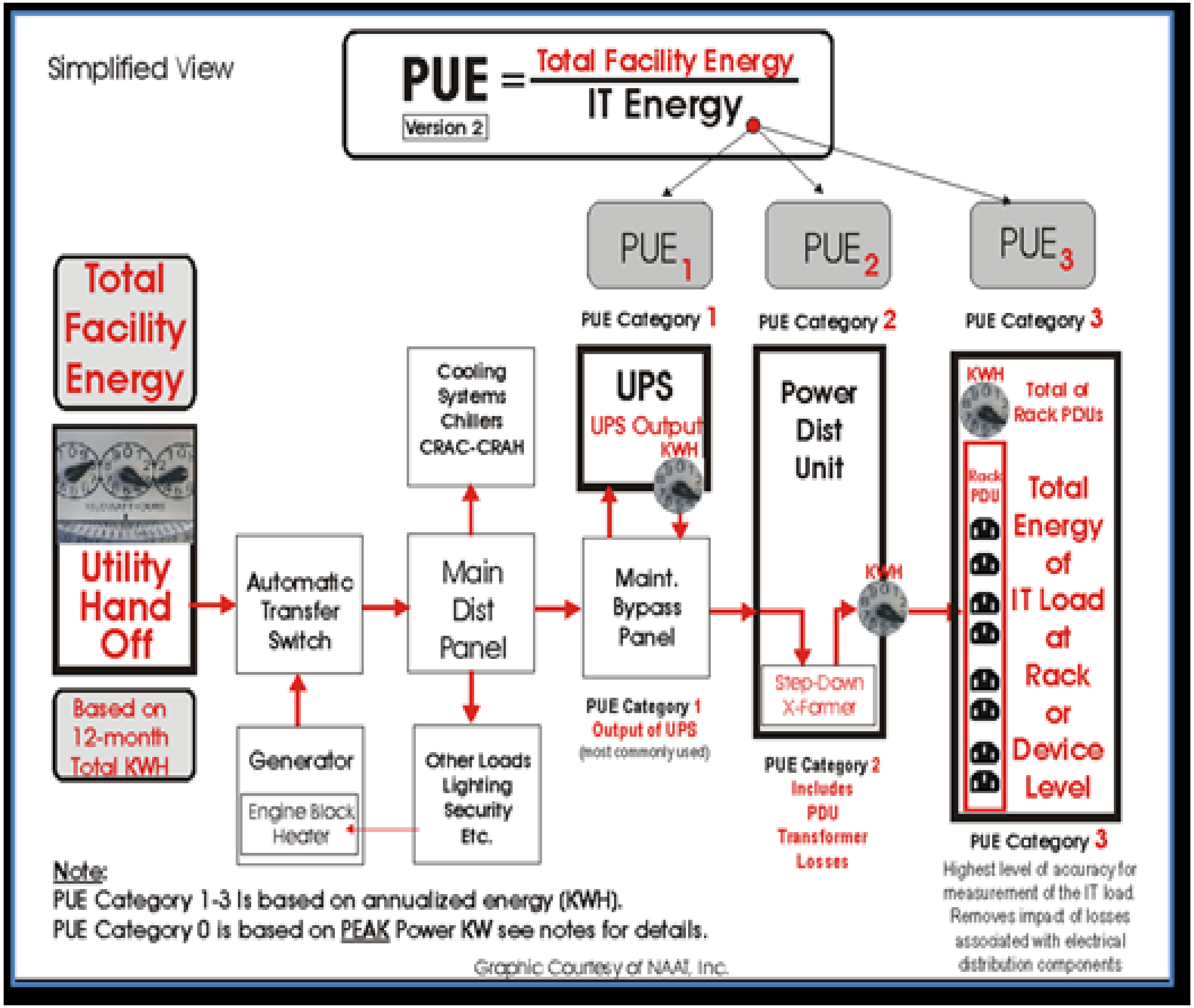
Steps in Metering, con't

2. Implementation
   - project initiation
   - defining needs and expectations
   - obtaining buy-in from all stakeholders
   - design (including review cycles)
   - installation
   - integration and configuration
   - Commissioning
     - ~ end-to-end
     - ~ sum-checking
   - training

Challenges to Meter Installation and Possible Solutions

- **Electrical metering: Shut down one system at a time in N+x systems**
- **Electrical metering: Wait for system maintenance**
- **Thermal metering: Use hot-taps or ultrasonic meters**

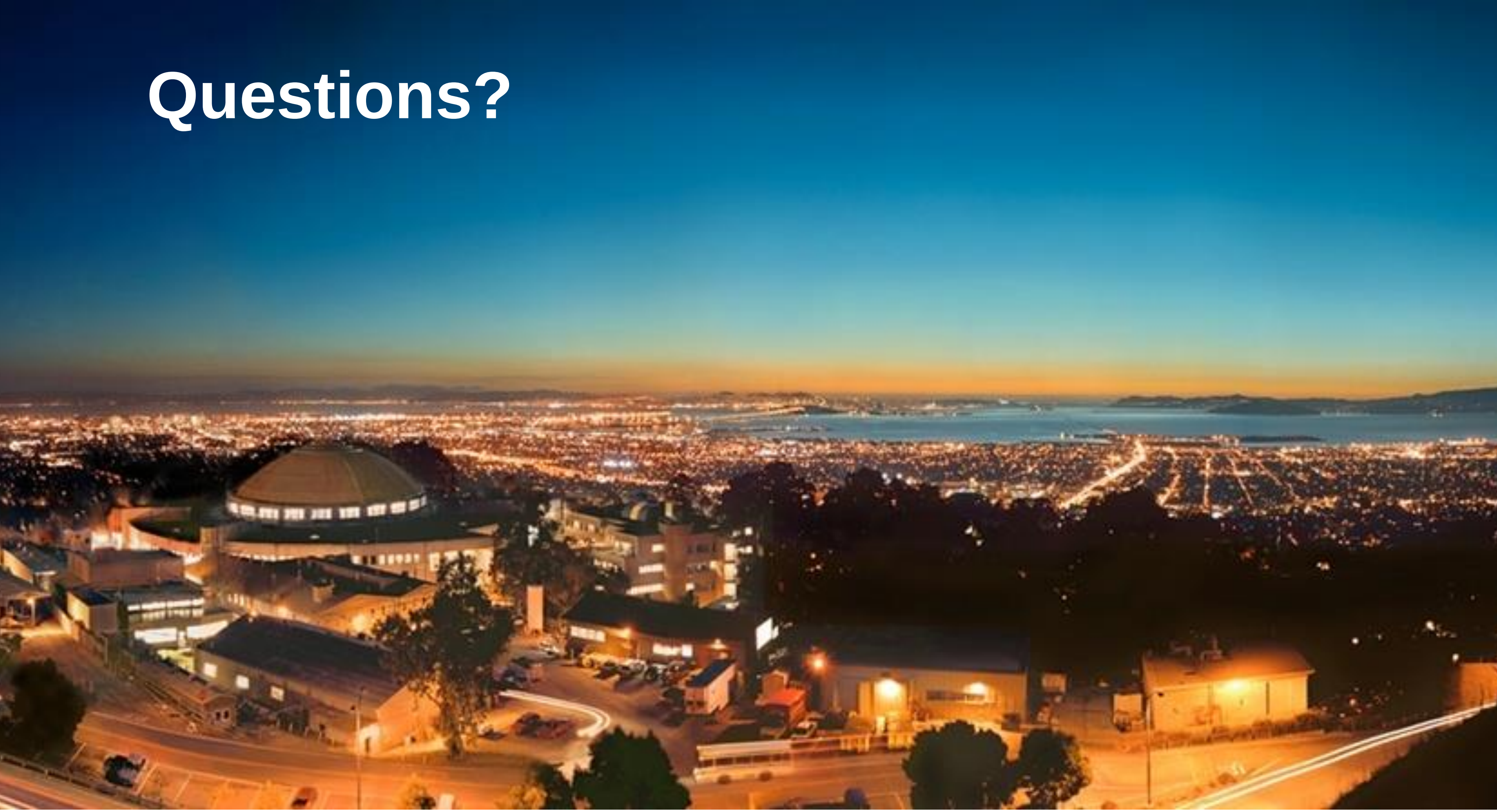
PUE level diagram



Resources

- **Data Center Metering and Resource Guide:**
  https://datacenters.lbl.gov/resources/data-center-metering-and-resource-guide
- **PUE: a Comprehensive Examination of the Metric:**
  https://www.thegreengrid.org/en/Global/Content/white-papers/WP49-PUEAComprehensiveExaminationoftheMetric
- **Center of Expertise for Energy Efficiency in Data Centers:**
  https://datacenters.lbl.gov/
- **Data Center Energy Practitioner (DCEP) Program:**
  https://datacenters.lbl.gov/dcep

Questions?



Steve Greenberg, P.E.
Lawrence Berkeley National Laboratory
(510) 486-6971
segreenberg@lbl.gov

Approaches to PUE at the Lawrence Berkeley National Lab: Three Case Studies

Steve Greenberg
Lawrence Berkeley National Laboratory

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Examples of getting to PUE at LBNL data centers

- **Building 50A-1156: the hodgepodge**
- **Building 50B-1275: the case-study king**
- **Building 59: the many-megawatt supercomputer center**

LBNL site map

Lawrence Berkeley National Laboratory
Room 50A-1156: “the hodge-podge”

- decades old, embedded data center in office building
- 2450 square feet
- ~100 kW IT load
- shared AHU for primary cooling on house chilled water
- standby CRAC with remote air-cooled condenser
- 2’ raised floor
- combination of telecom, house services, and high-performance computing
- mix of UPS and direct power distribution

Lawrence Berkeley National Laboratory

Room 50A-1156, con't

Approach to PUE:

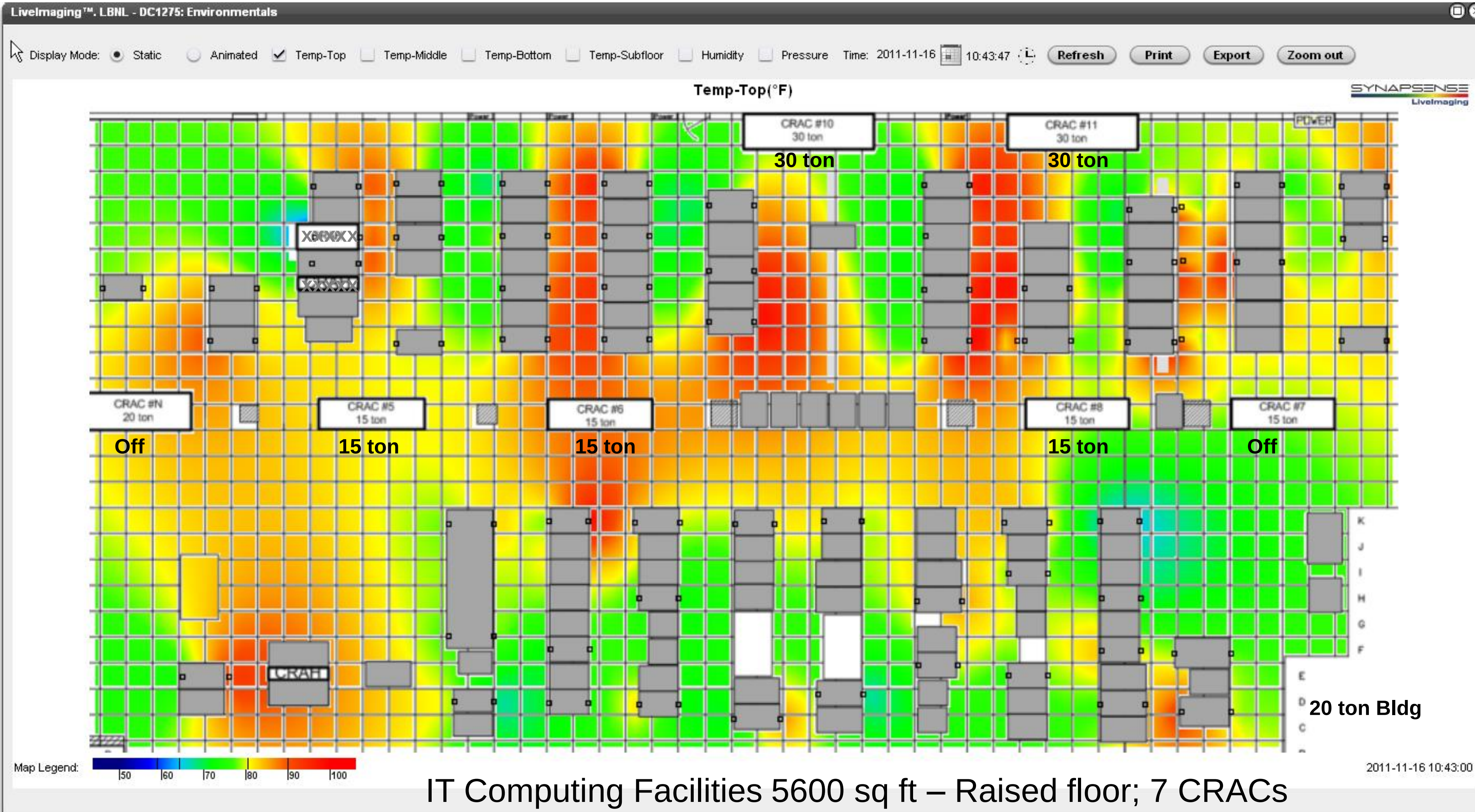
- **Level 1**
- **Measured IT**
- **Data center is embedded with multiple power and cooling feeds**
- **There are some existing meters on IT loads**
- **Identify meter additions needed**
- **Triage based on cost vs. effect on PUE**
- **Implement changes**
- **Calculation will use IT load and estimate HVAC based on system ratings and one-time readings**

Lawrence Berkeley National Laboratory
Room 50B-1275 “the case-study king”

45-year-old data center
5600 square feet
~450 kW IT load
7 CRACs 15 to 30 tons of cooling each in 2-4 stages
Down-flow units (raised floor)
Water-cooled
Other cooling including rear doors, enclosed racks, AHU

Numerous case studies

LBNL Room 50B-1275



IT Computing Facilities 5600 sq ft – Raised floor; 7 CRACs

Lawrence Berkeley National Laboratory
Room 50B-1275, con’t

Approach to PUE:

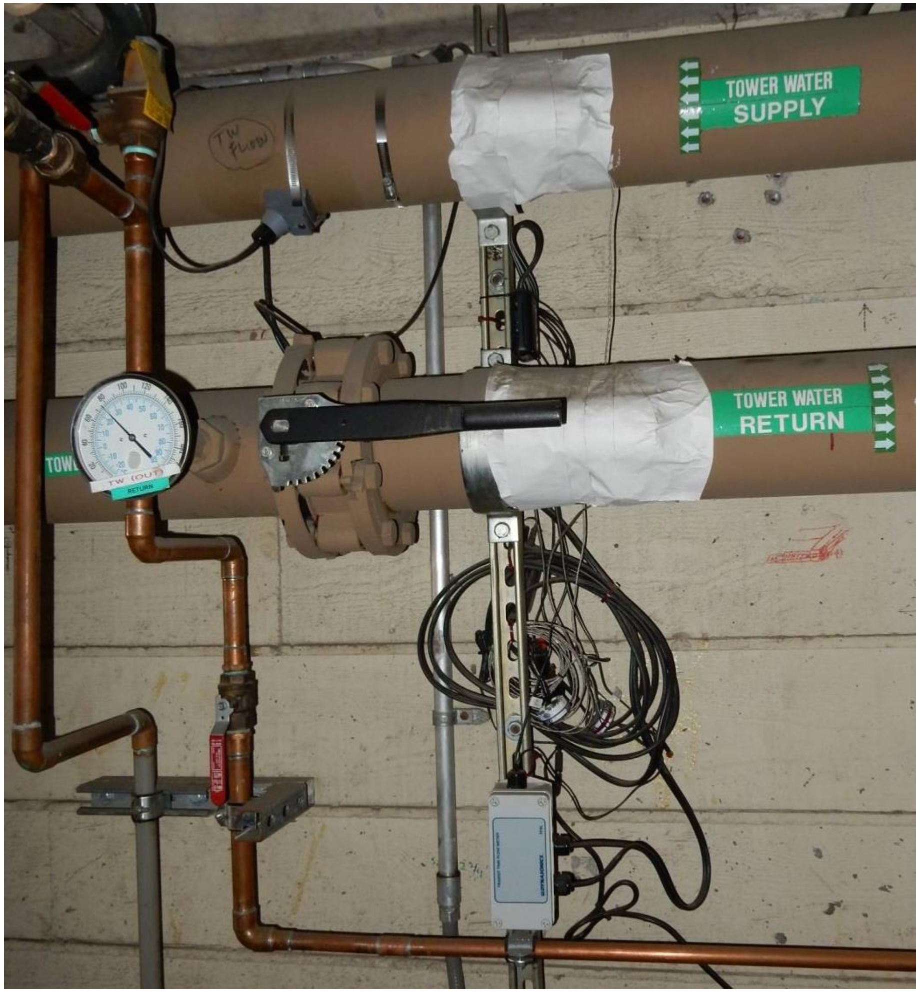
- Level 2 (transformer losses measured or estimated)
- Measured IT, HVAC, lighting
- Data center is embedded and has multiple power and cooling feeds
- PUE is already tracked in real time (~1.4) using numerous meters
- Metering needs update to reflect changes in power and cooling
- Identify meter additions, deletions, and moves needed
- Triage based on cost vs. effect on PUE
- Implement changes

LBNL Room 50B-1275, con't

Electric metering

LBNL Room 50B-1275, con't

Thermal metering



Lawrence Berkeley National Laboratory
Building 59: the Computational Research and Theory Facility
“the multi-megawatt supercomputer center”

- Brand-new supercomputer center, embedded
- 142,000 square feet total
- 7 MW IT load to start, then up to 17, then ???
- IT load will dominate building
- 2 large AHUs for air-cooled loads
- 4 cooling towers with heat exchangers for water-cooled loads
- Water-cooled supercomputers
- Air and water side economizers
- Air-side heat recovery for heating offices
- IT loads cooled without compressors

LBNL Building 59

Lawrence Berkeley National Laboratory
Building 59, con't

Approach to PUE:

- Level 2 (PDU outputs for IT)
- Measured IT, HVAC, lighting
- Data center is embedded with multiple power and cooling feeds
- PUE will be tracked in real time (~1.06) using hundreds of meters
- Meter location, accuracy, and reporting capability in review and commissioning
- Identify meter additions needed
- Triage based on cost vs. effect on PUE
- Implement changes

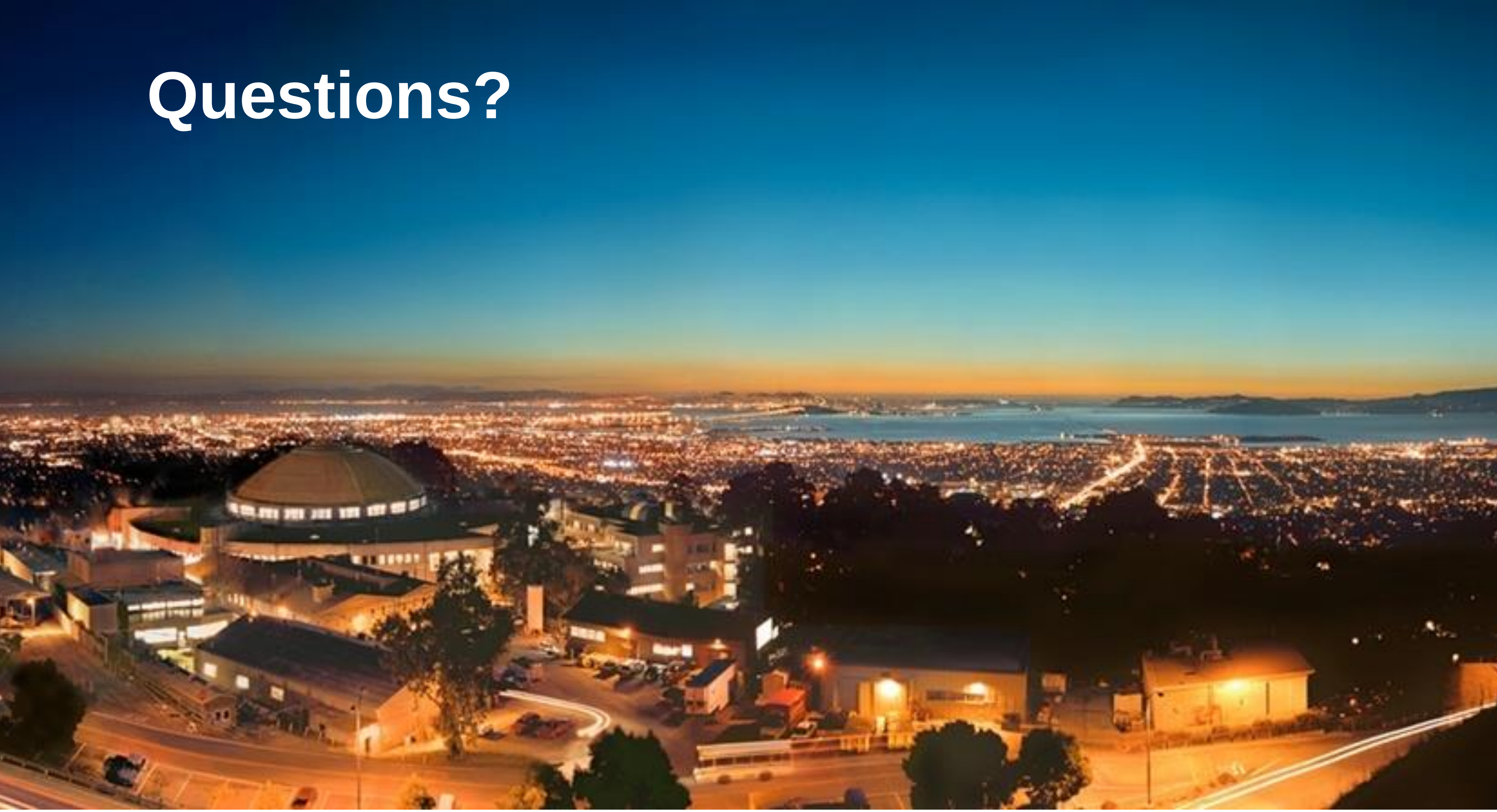
Lawrence Berkeley National Laboratory

Building 59, con't

Conclusions: PUE determination at LBNL

- Is case-by-case—every center is different
- Takes advantage of existing meters
- Minimizes estimation
- Typically involves numerous meters to resolve energy flow in embedded spaces

Questions?



Steve Greenberg, P.E.
Lawrence Berkeley National Laboratory
(510) 486-6971
segreenberg@lbl.gov

Metering for PUE

NATIONAL RENEWABLE ENERGY LABORATORY

Steve Hammond **May 2015**

NREL – Two Data Center Use Cases

RSF - Enterprise Air Cooled

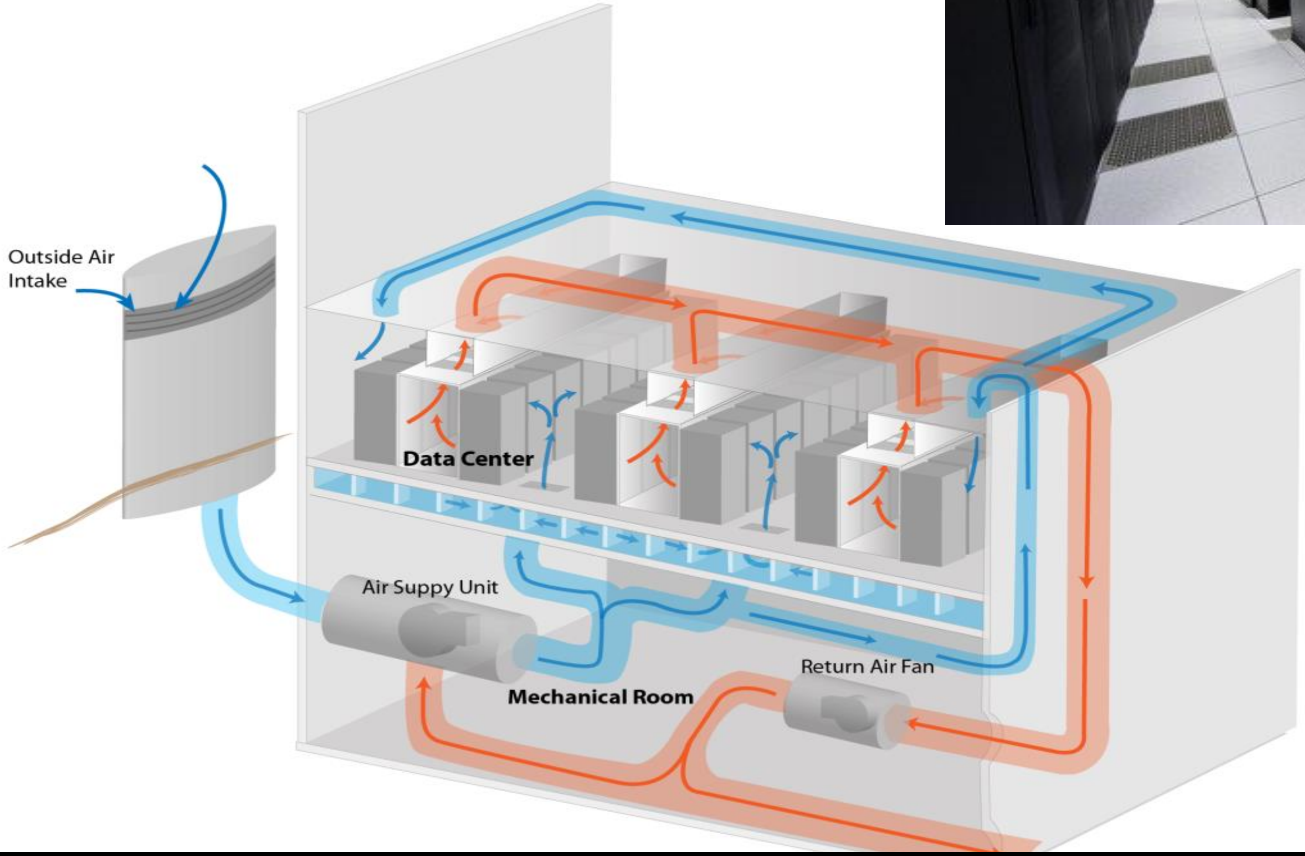
- Fully contained hot aisle
  - Server fans pull cold air into servers and exhaust heat to hot aisle.
- 1.1-1.2 PUE Winter, Spring, Fall
- 1.2-1.4 PUE Summer
- Waste heat used to heat building
- Economizer and Evaporative cooling
- Low fan energy design
- ~200kW, ~2,000 Sq Ft.

ESIF – HPC Liquid Cooled Data Center

- 95% of IT heat load directly to liquid.
- 1 fully contained hot aisle for lower power, low density air cooled equipment.
- Annualized average PUE 1.06
- Waste heat used to heat building
- Evaporative cooling
- VFD motors, Low fan energy design
- 10MW, 10,000 Sq Ft.

http://www.nrel.gov/docs/fy12osti/52785.pdf

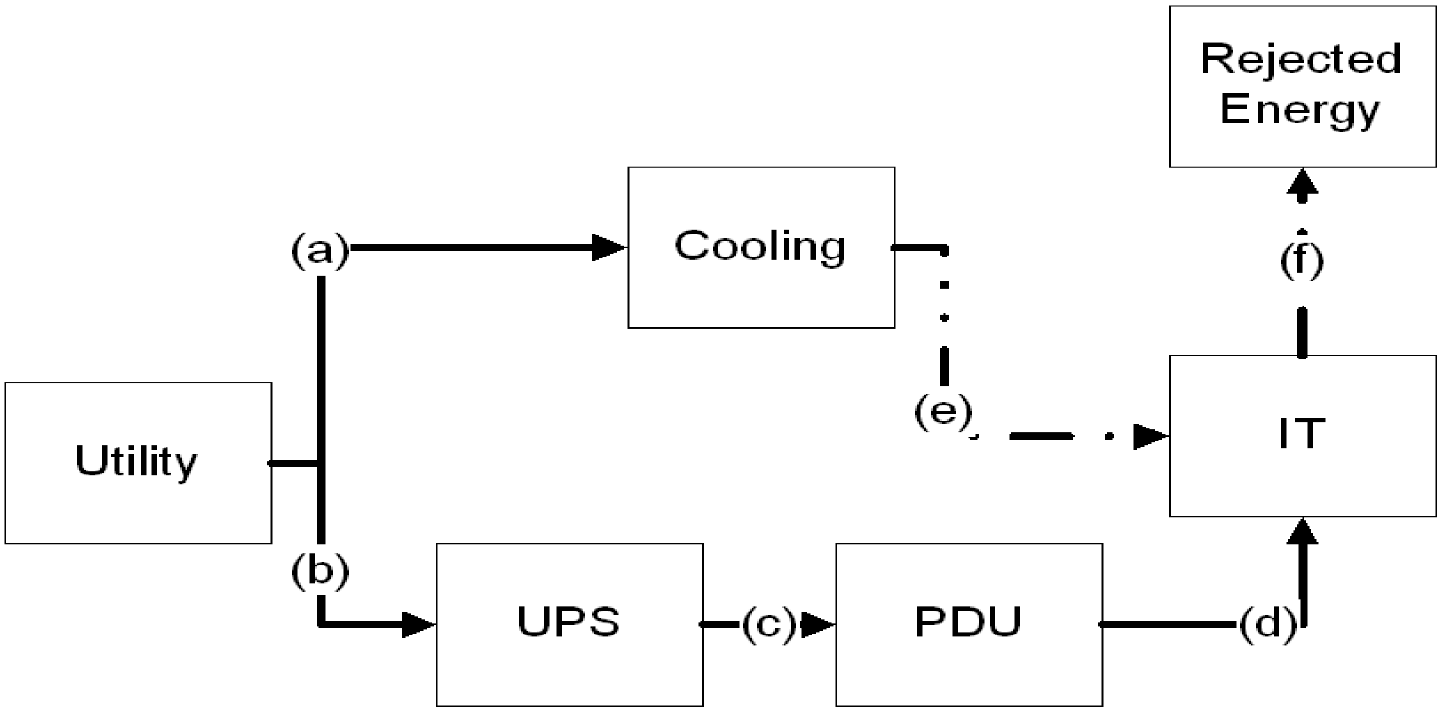
RSF Enterprise “Air Cooled” Data Center



RSF Enterprise “Air Cooled” Data Center

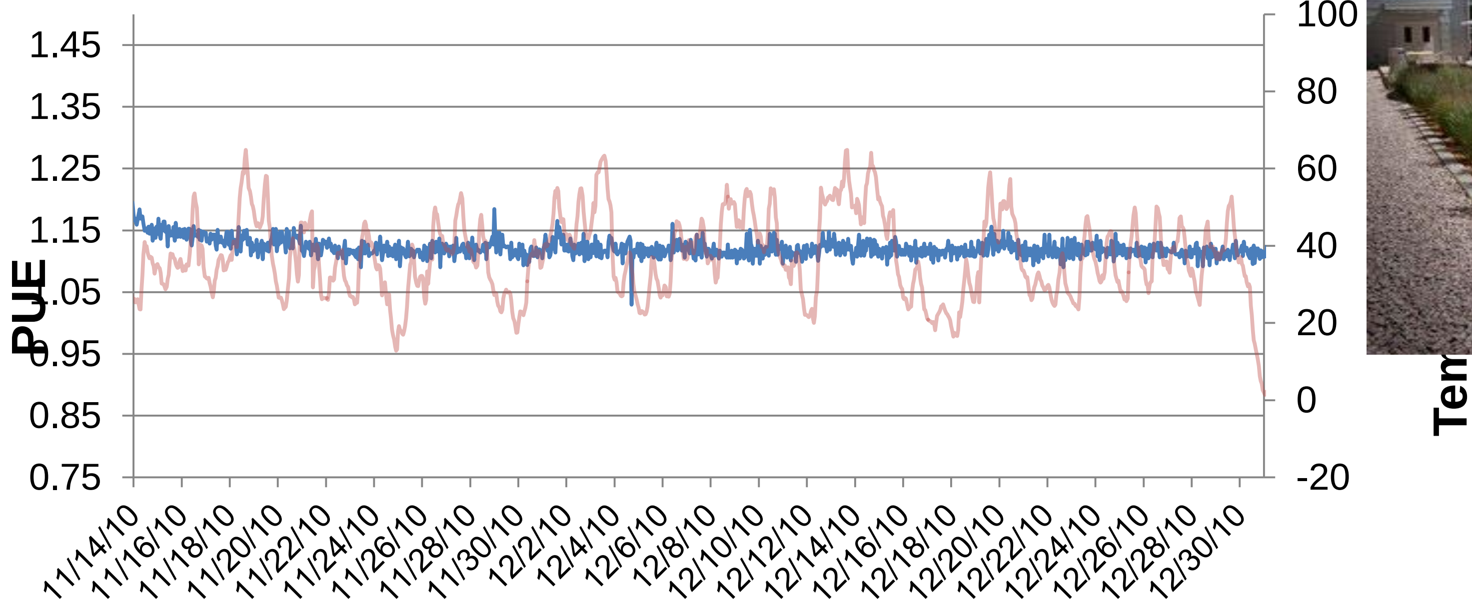
Dehumidification	for hours when the outdoor air was more humid than the acceptable supply air criteria. Some form of mechanical cooling or dehumidification would be required for these hours.	44 hours/year
Economizer	for hours when the outdoor air can satisfy the supply air criteria with no additional conditioning	559 hours/year
Evaporative Cooling	for hours when adiabatic humidification/cooling (70% effectiveness) of outside air can meet the supply air criteria	984 hours/year
Mixing	for hours when the outside air can be mixed with hot aisle air to meet the supply air criteria	1063 hours/year
Mixing and Humidification	When the outside air is cool and dry, outdoor air can be mixed with hot aisle air, then adiabatically humidified to the supply air criteria.	6110 hours/year

PUE Metering– simple & effective



$$PUE = \frac{Total\ Energy}{IT\ Energy} = \frac{Cooling + PowerDistribution + Misc + IT}{IT} = \frac{a+b}{d}$$

Air Cooled Data Center PUE



6 week data: mid-November to end of December

NREL ESIF Liquid Cooled Data Center

Showcase Facility

- ESIF 182,000 s.f. research facility
- Includes 10MW, 10,000 s.f. data center
- LEED Platinum Facility, PUE 1.06
- NO mechanical cooling (*eliminates expensive and inefficient chillers*).
- Use evaporative cooling only.

Utilize the bytes and the BTUs!

Data Center Features

- Direct, component-level liquid cooling (75F cooling water).
- 95-110F return water (waste heat), captured and used to heat offices and lab space.
- Pumps more efficient than fans.
- High voltage 480VAC power distribution directly to compute racks (*improves efficiency, eliminates conversions*).

Compared to a typical data center:

- *Lower CapEx – cost less to build*
- *Lower OpEx – efficiencies save ~$1M per year in operational expenses.*

Integrated "chips to bricks" approach.

Key HPC Data Center Specs

- Warm water cooling, 24C (75F)
  - ASHRAE “W2” category
  - Water much better working fluid than air - pumps trump fans.
  - Utilize high quality waste heat, +35C (95F).
  - +95% IT heat load to liquid.

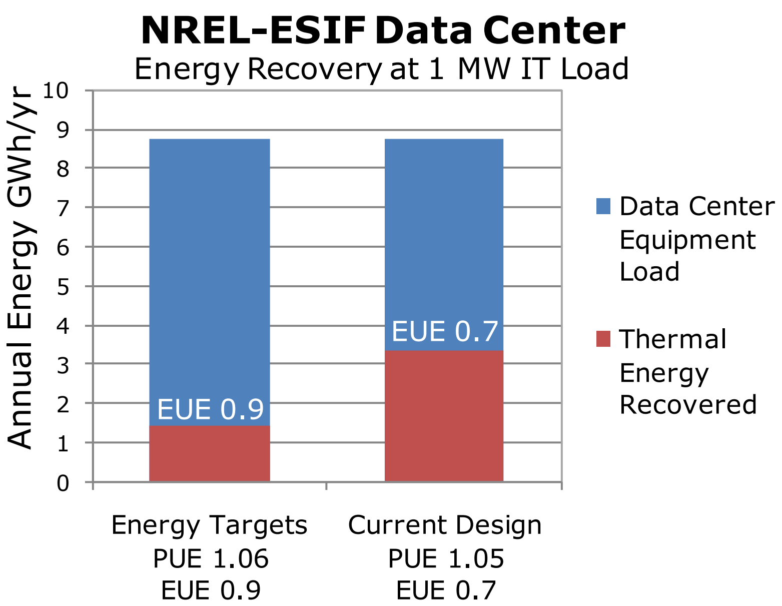
- Racks of legacy equipment
  - Up to 10% IT heat load to air.

- High power distribution
  - 480VAC, Eliminate conversions.

- Think outside the box
  - Don’t be satisfied with an energy efficient data center nestled on campus surrounded by inefficient laboratory and office buildings.
  - Innovate, integrate, optimize.

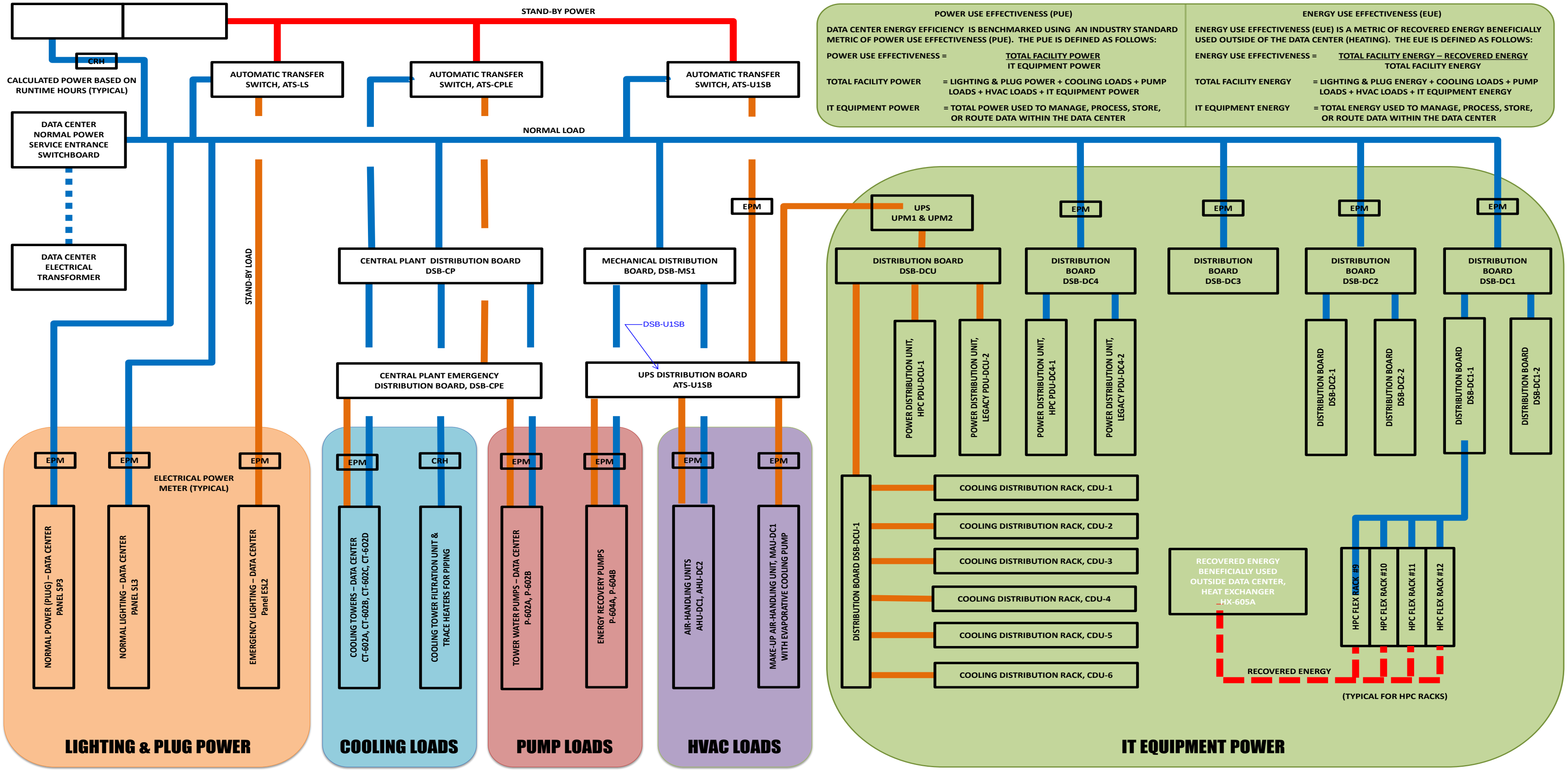
Direct Liquid Cooling & Energy Recovery On Display

"We want the bytes AND the BTU's!"



ESIF HPC Datacenter PUE Calculation

NREL ESIF – DATA CENTER ENERGY EFFICIENCY METRICS



Initial HPC Datacenter PUE metering*

POWER USE EFFECTIVENESS (PUE)

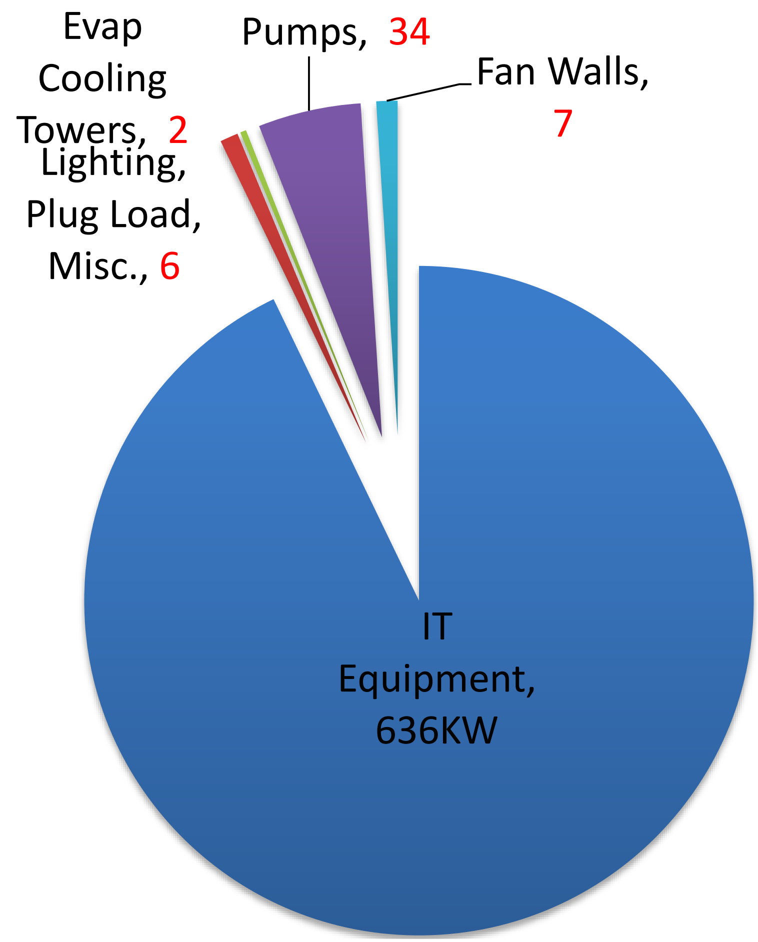
DATA CENTER ENERGY EFFICIENCY IS BENCHMARKED USING AN INDUSTRY STANDARD METRIC OF POWER USE EFFECTIVENESS (PUE). THE PUE IS DEFINED AS FOLLOWS:

POWER USE EFFECTIVENESS = $\frac{\text{TOTAL FACILITY POWER}}{\text{IT EQUIPMENT POWER}}$

TOTAL FACILITY POWER = LIGHTING & PLUG POWER + COOLING LOADS + PUMP LOADS + HVAC LOADS + IT EQUIPMENT POWER

IT EQUIPMENT POWER = TOTAL POWER USED TO MANAGE, PROCESS, STORE, OR ROUTE DATA WITHIN THE DATA CENTER

$$\frac{6 + 2 + 34 + 7 + 636}{636} = 1.077$$



*Very first meter readings, November 2013.

Questions?