How Electrical System Monitoring Improves Facility Efficiency, Reliability and Safety

David G. Loucks

Manager, Power Systems and Advanced Solutions

Eaton Corporation

Gregory F. Reed

Director, Electric Power Initiative and Associate Professor, ECE Dept.

University of Pittsburgh

galvin center for electricity innovation
at ILLINOIS INSTITUTE OF TECHNOLOGY

IEEE PES
Power & Energy Society®

Building to Grid (B2G)

- Of all electricity generated in US:
  - Buildings consume 70%
  - Buildings pay > 80% of the cost to generate
  - Consequences of inefficiencies are high
  - Building loads are contributing to grid instability
    - Alternative energy (or worse, 1-phase AE)
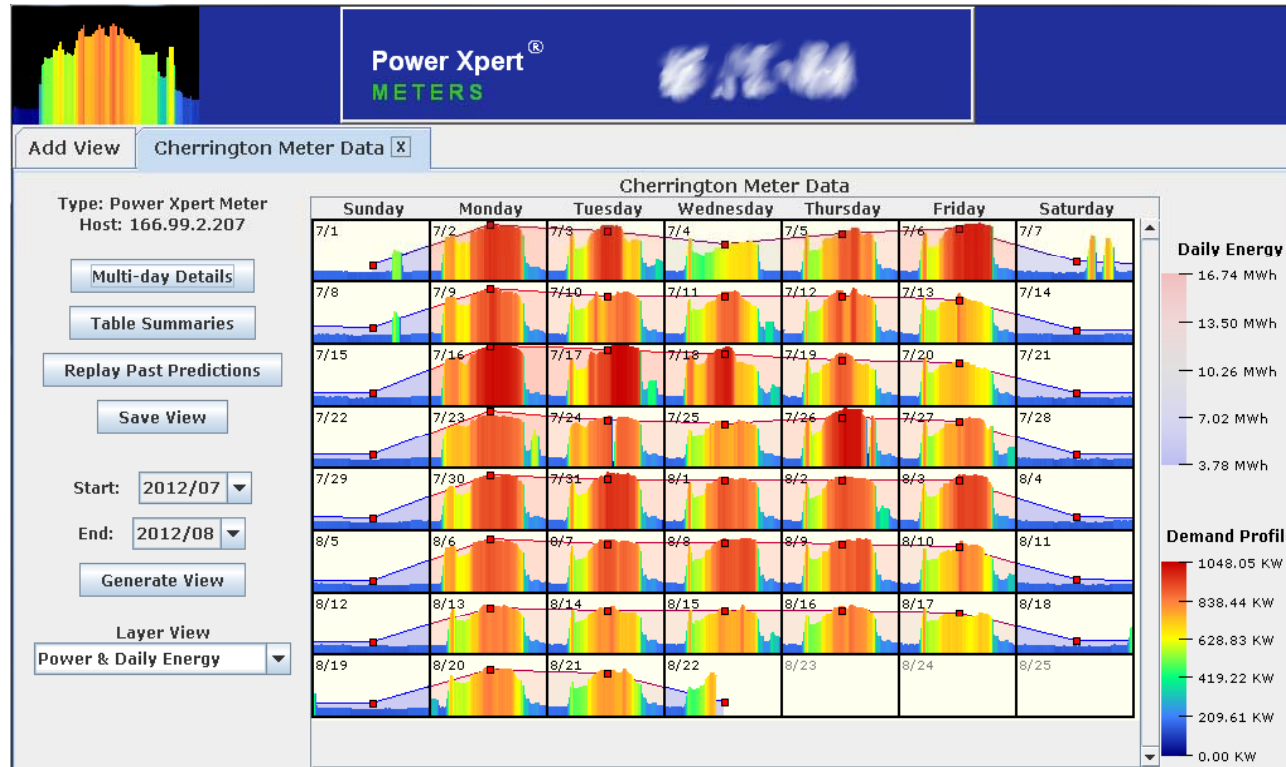   - Electric vehicle charging
    - FIDVR, etc

Consumption Patterns Tell a Story
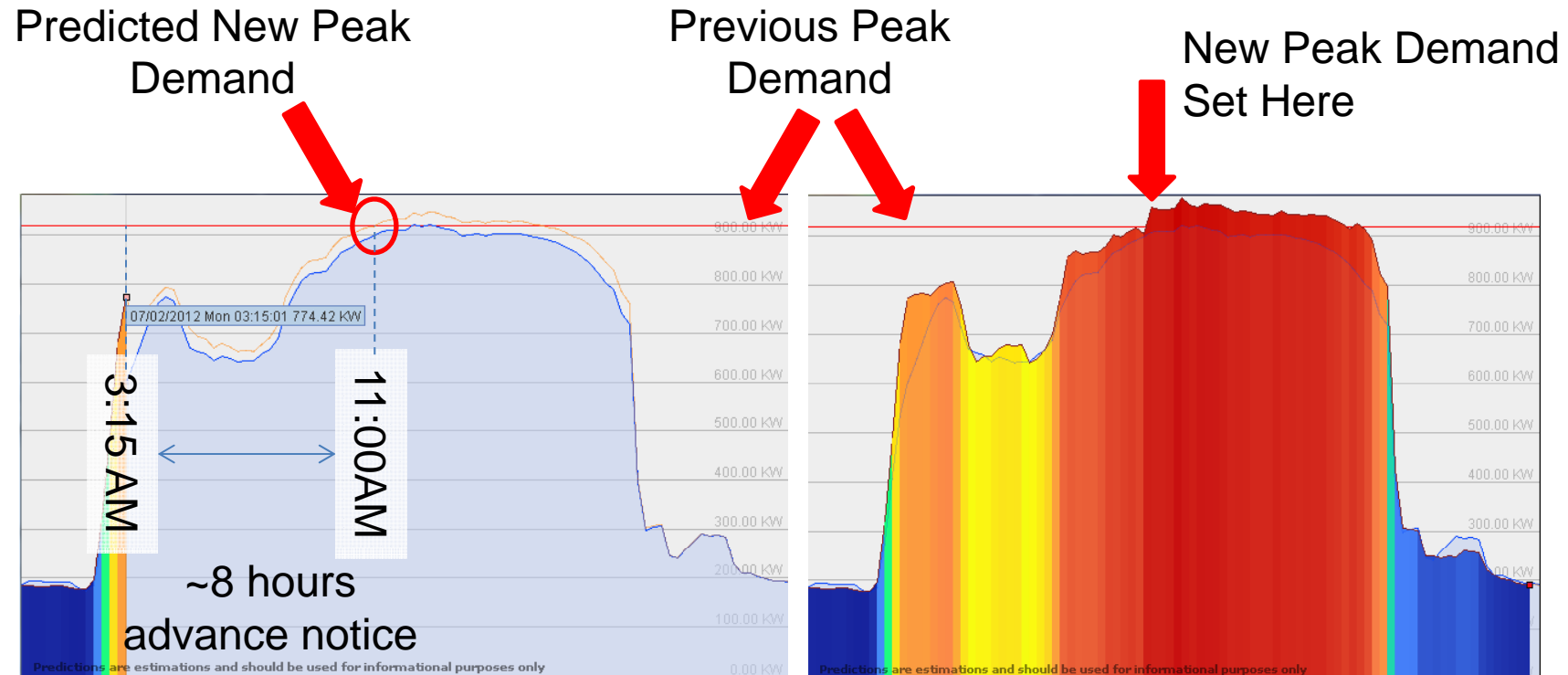
- Usage tends to follow a pattern
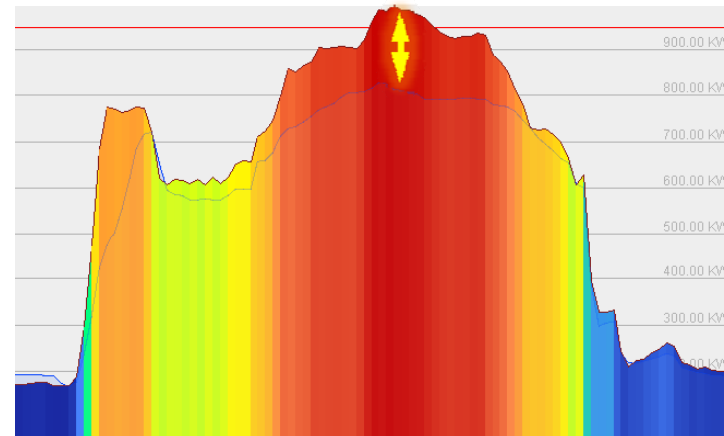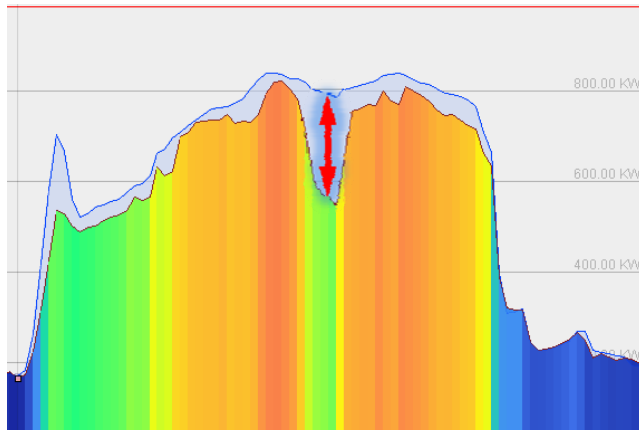
- Mathematical model can predict this pattern
- Deviations from pattern are interesting
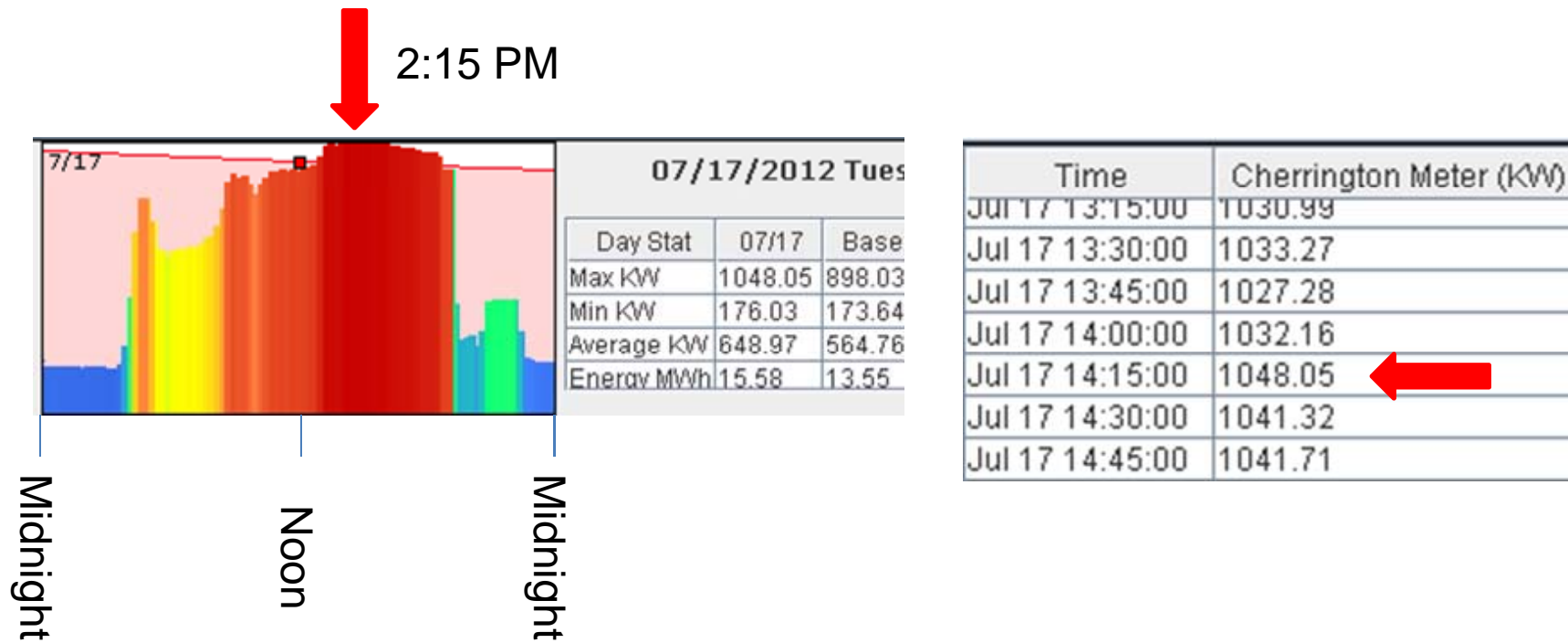
Anomalous Energy Consumption

- # Why do we have outliers?
  - ## – Which are important?

Excessive Consumption Prediction

Predicted New Peak Demand

Previous Peak Demand

New Peak Demand Set Here

07/02/2012 Mon 03:15:01 774.42 KW

3:15 AM

11:00AM

~8 hours advance notice

Predictions are estimations and should be used for informational purposes only

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- Must be sufficient time to take action

New Monthly Peak Demand Set

2:15 PM

Day Stat	07/17	Base
Max KW	1048.05	898.03
Min KW	176.03	173.64
Average KW	648.97	564.76
Energy MWh	15.58	13.55

07/17/2012 Tues

Time	Cherrington Meter (KW)
Jul 17 13:15:00	1030.99
Jul 17 13:30:00	1033.27
Jul 17 13:45:00	1027.28
Jul 17 14:00:00	1032.16
Jul 17 14:15:00	1048.05
Jul 17 14:30:00	1041.32
Jul 17 14:45:00	1041.71

Midnight   Noon   Midnight
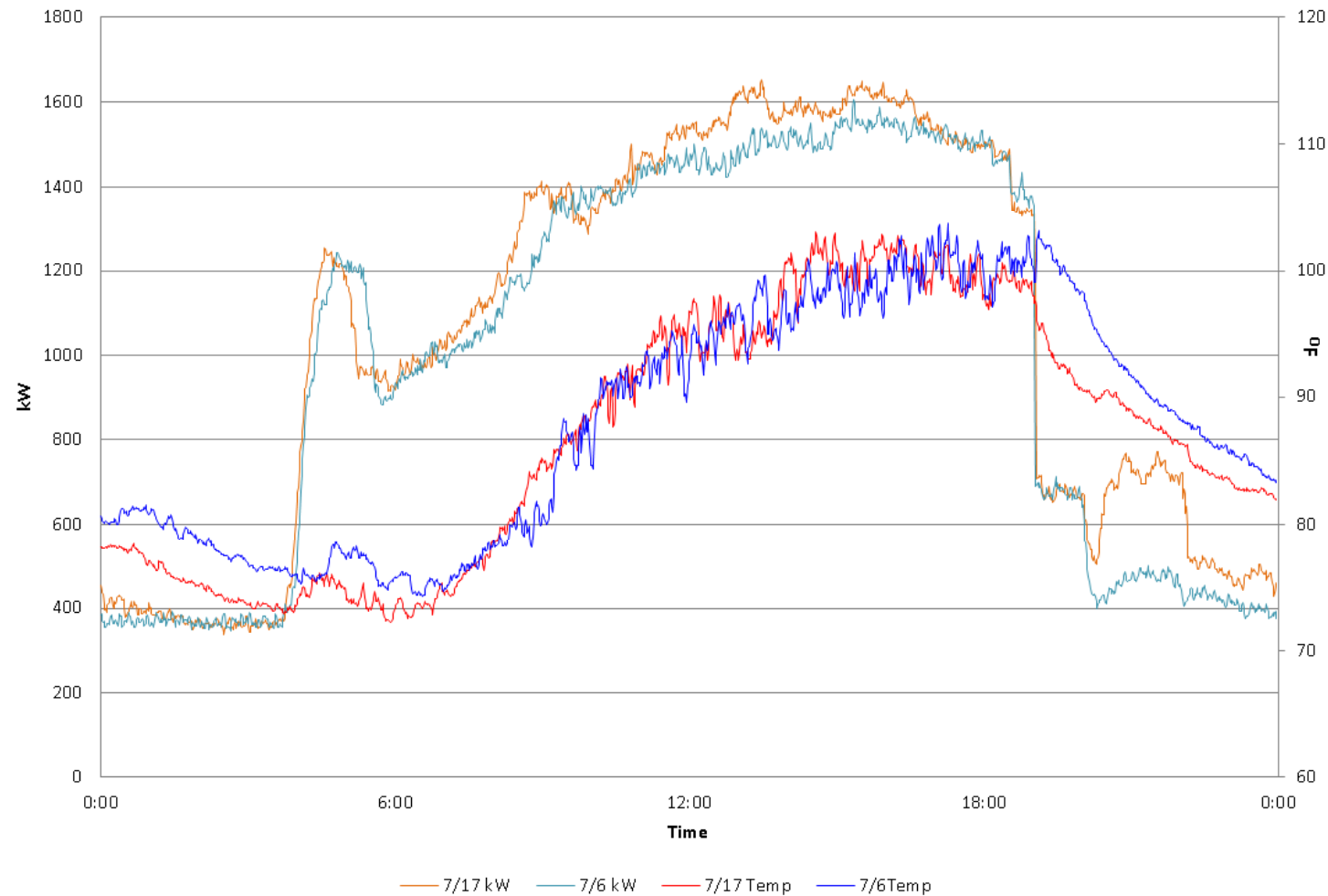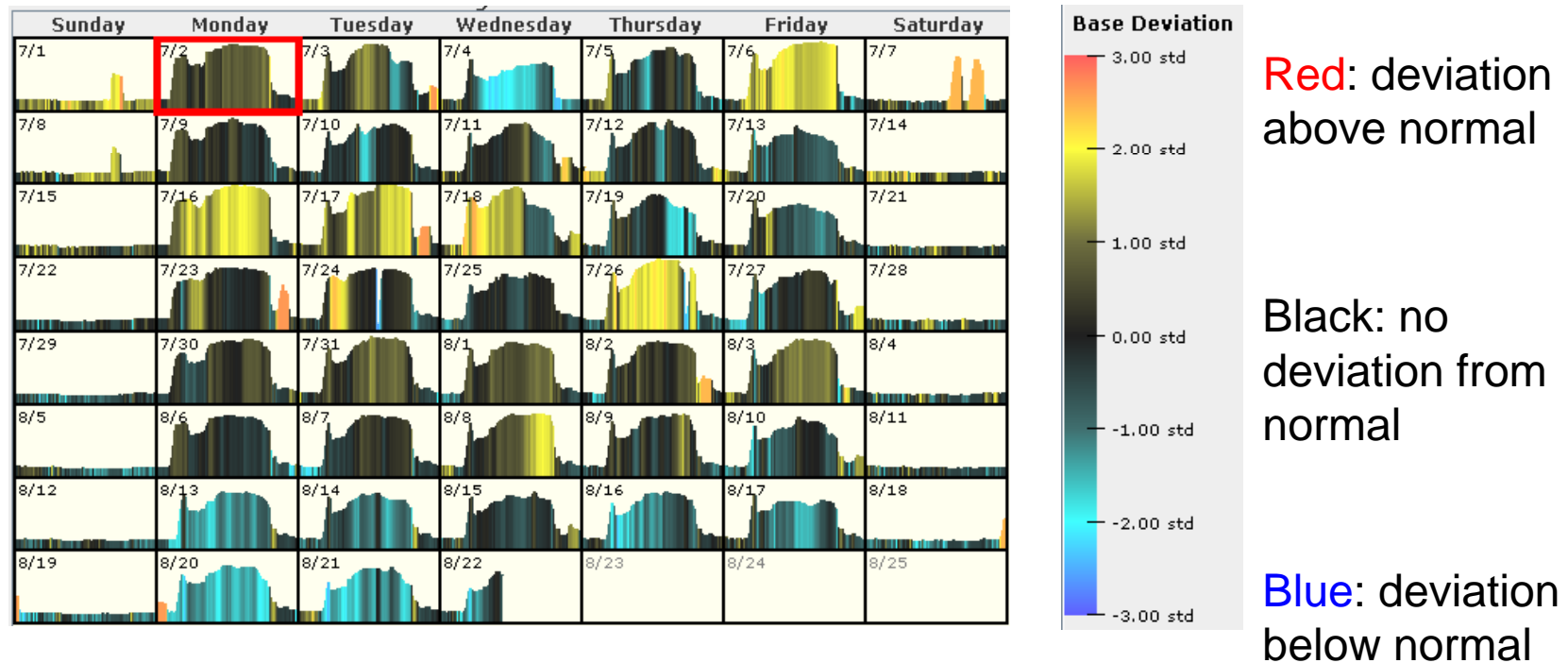
- High, but maybe not "abnormal"
  - Is it coinciding with hottest part of the day?

What is Abnormal Here?
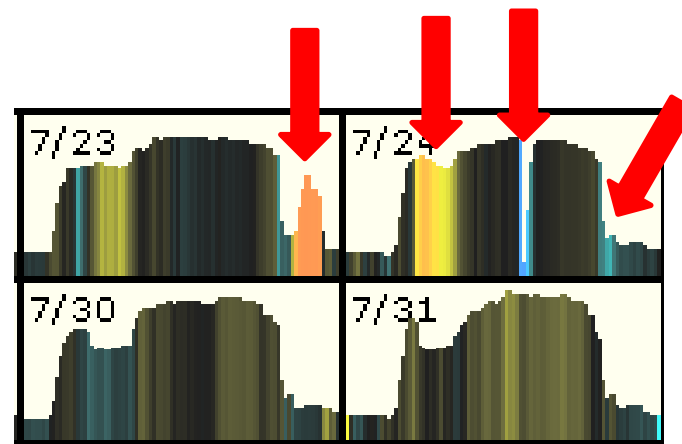
Cooling Energy Required Versus Outside Air Temperature

Legend: 7/17 kW — 7/6 kW — 7/17 Temp — 7/6 Temp

Deviation from Normal Usage

Base Deviation

Red: deviation above normal

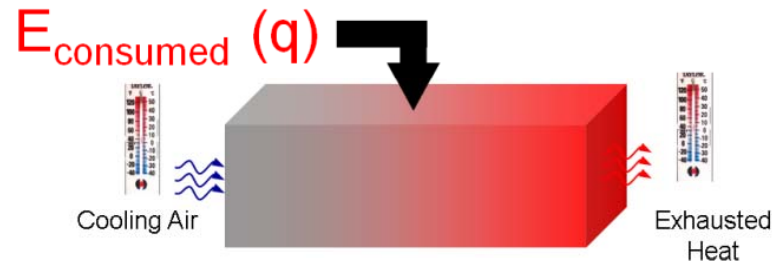Black: no deviation from normal

Blue: deviation below normal

- "Abnormal" usage different than peak usage

Time of Use Analysis

- TOU deviations can indicate anomalies
- Anomalous usage doesn't coincide with peak
- Almost always detects abnormal operations

Convection Heat Transfer

$$ave(\dot{q}_v) = ave(S\eta F(\Delta T))$$

Where:

$\dot{q}$	heat transfer rate via convection
S	Specific Heat of cooling media
η	Efficiency of heat exchanger
F	Flow rate of cooling fluid
ave(	distributed average operator

- Temperature differential and flow rate
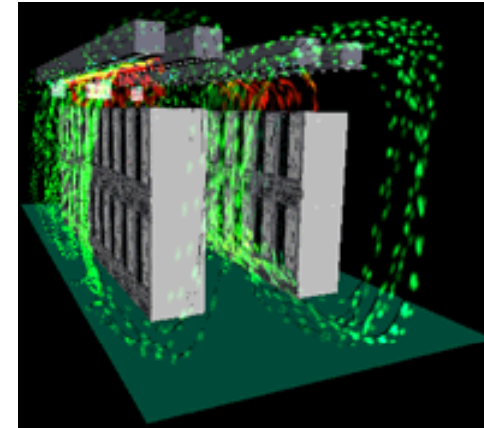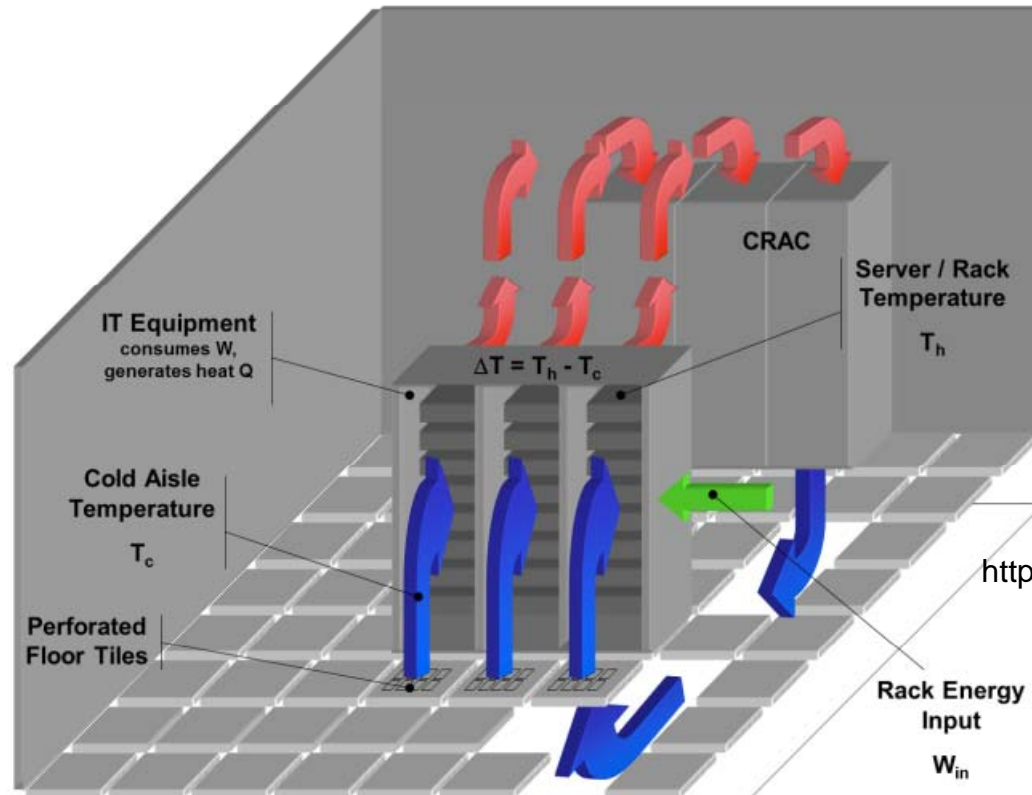
- Common heat transfer method in buildings

Building "Efficiency"

$$\varepsilon = S\eta F$$

$$ave(\varepsilon) = \frac{ave(\dot{q})}{ave(\Delta T)}$$

- Group unknowns and replace with new ε
- Acts like an efficiency
  - Larger: more energy transfer across smaller ΔT
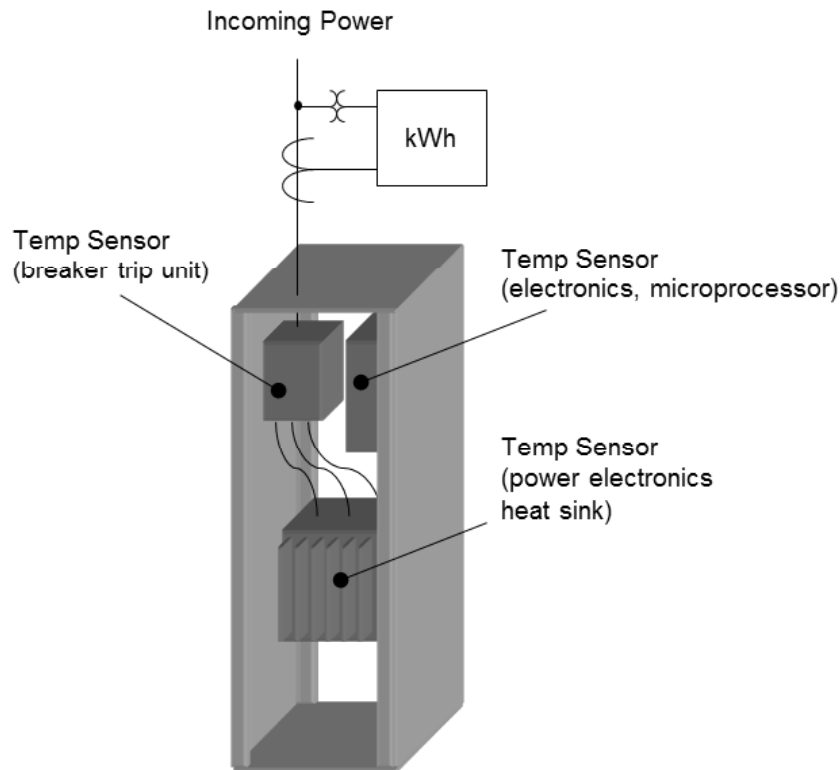 - Smaller: less energy transfer across larger ΔT

Can Subdivide and Isolate Problem

http://www.flomerics.com/flovent/data_center_animation.gif

- CFD-like studies can be performed continuously
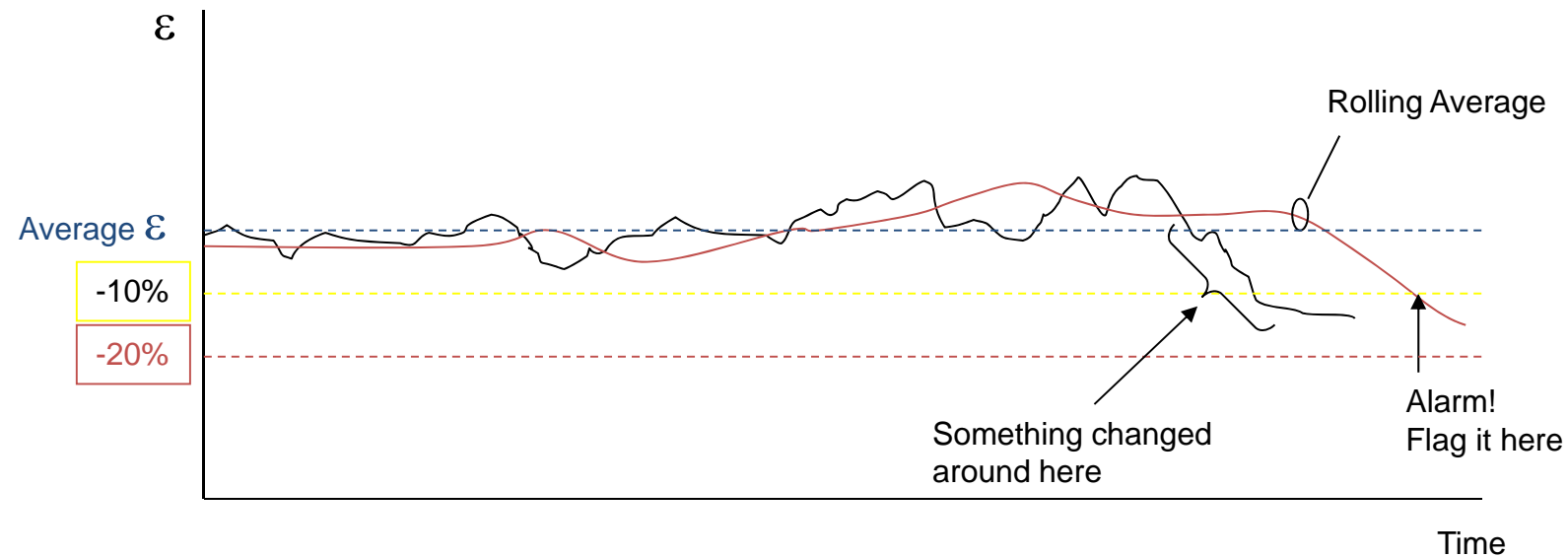- Flows and temperatures are predictable

Equipment Sensors Required

$$ave(\varepsilon) = \frac{ave(\dot{q})}{ave(\Delta T)}$$

- Rate of energy consumption and temperature gradient across enclosure, room or building

Trending ε

- Decreasing "efficiency" – is that a problem?
- Increasing "efficiency" – why?

Summary

- Buildings are an important grid connected load, consuming 70% of generated power

- Peak demand values may not be abnormal

- Unusual demand at unusual times normalized to temperature provides useful insight

- New patented method to "drill down" within a facility and find problem areas