A "CS Systems View" of the real world

Vision and strategy for tomorrow's challenges

CITRIS/INRIA joint workshop

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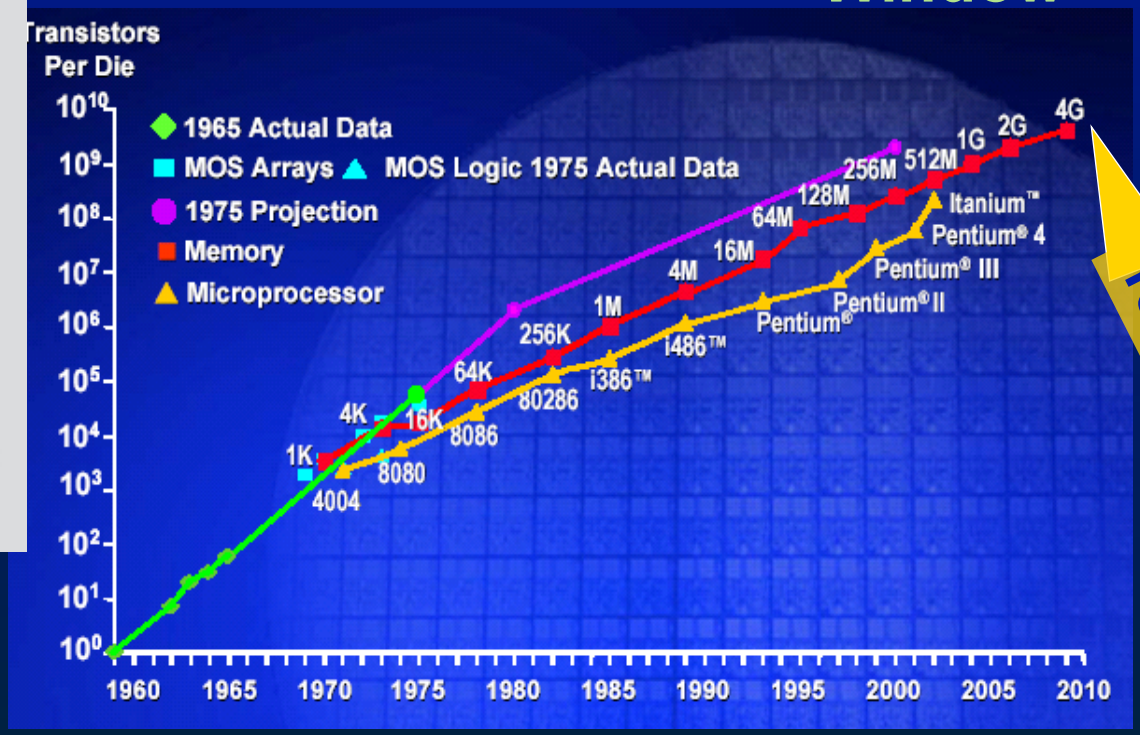
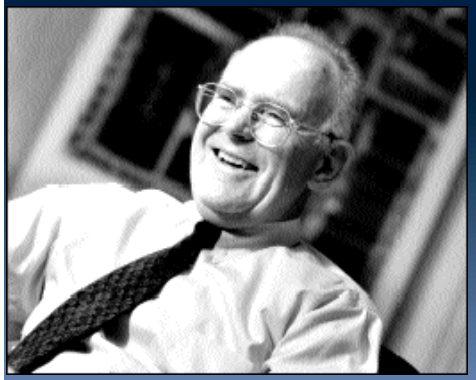
University of California, Berkeley
May 23, 2011

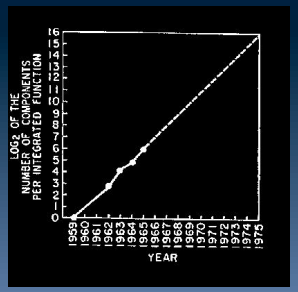
Where we are… an inward view

Grad Window



You are here!





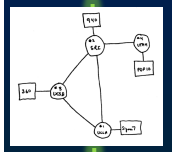
Where we are… an outward view

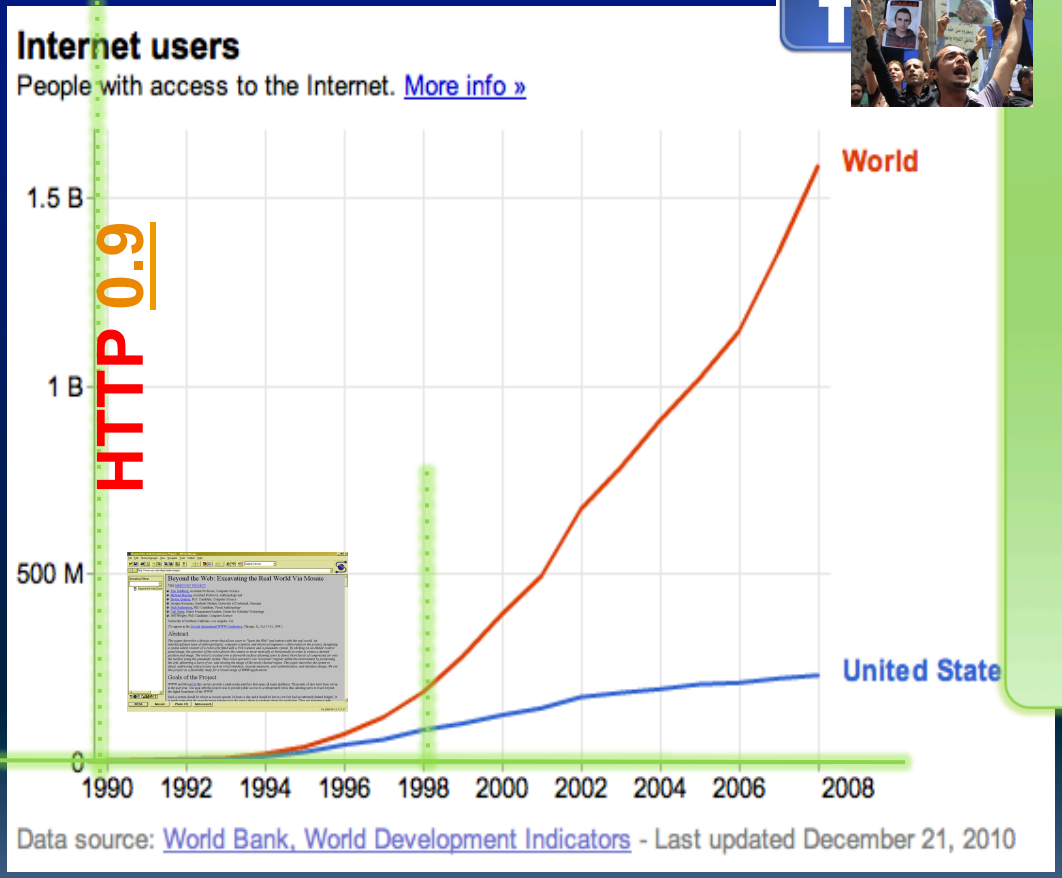
2.0 B 1/26/11

Internet **WWW**

ARPANet

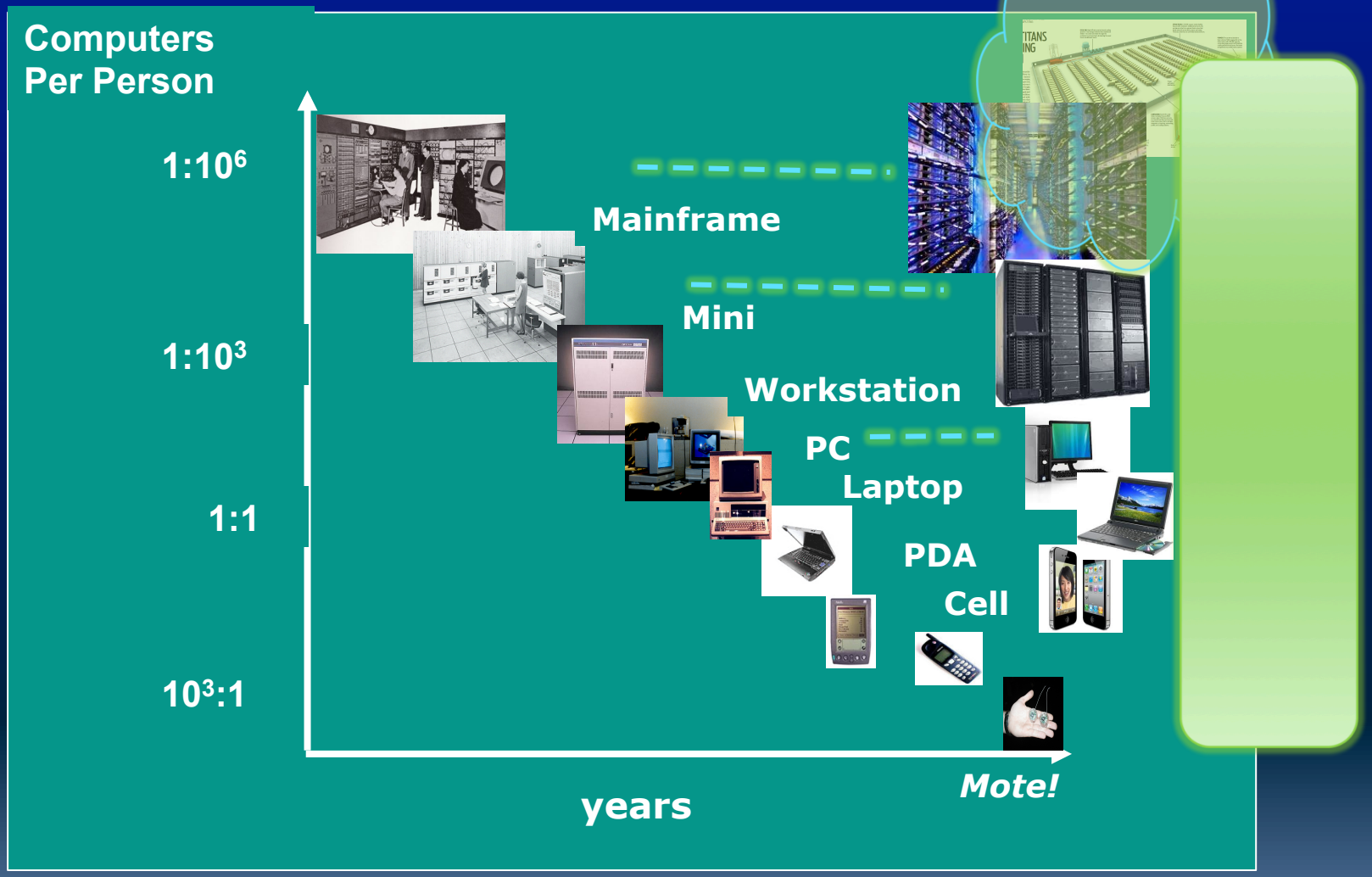
RFC 675 TCP/IP





1969 **1974** **1990** **2010**

Confluence across immense scale



Bell's Law: new computer class per 10 years

System innovation perspective

- Pace and form of innovation driven by emergence of computer classes
  - 70's shared server
  - 80's personal, networked, workstation, SMP & MPP
  - 90's cluster, 00's internet service, data center
- Hugely effective research community turned inward toward highly competitive conferences
- So far has missed the personal mobile revolution
  - If it looks like a mid-80's PC "Unix will run on it" and always did
- Industry led the Cloud / Analytics revolution, but research community running fast to catch up
- Just begun to really look at the real world

A different "Graduation Window"

Global temperature change (relative to pre-industrial era)

0°C | 1°C | 2°C | 3°C | 4°C | 5°C

Food — Crop yields fall

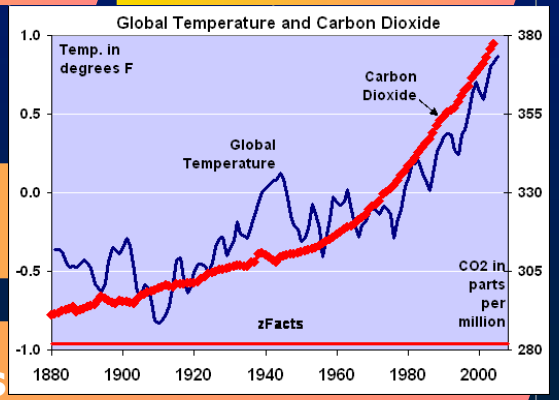
Water — Glaciers melt → Water shortages → Rising seas

Ecosystems — Reefs damaged → Species extinction

Weather — Storms, droughts, fires, heat waves

Feedback — Abrupt climate change

Today



The Industrial Age Grid

Baseline + Dispatchable Tiers **Oblivious Loads**

Towards an "Aware" Energy Infrastructure

Baseline + Dispatchable Tiers

Oblivious Loads

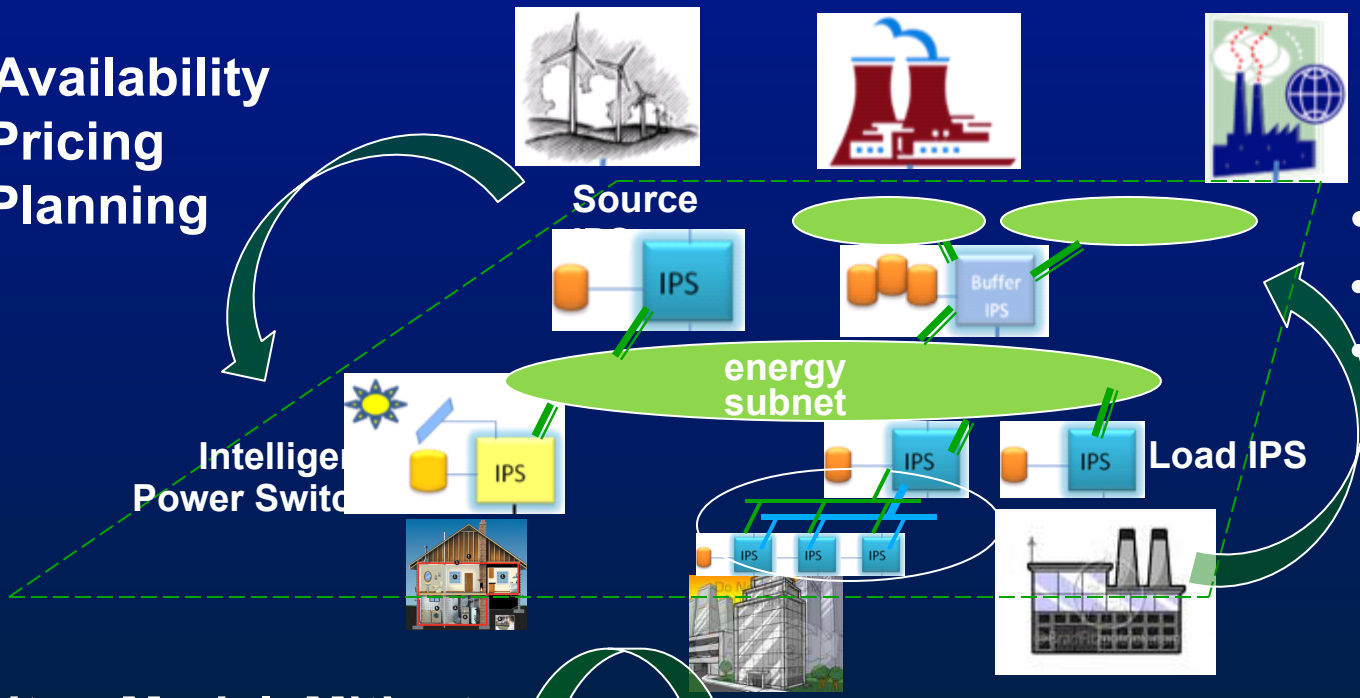
LoCal

Non-Dispatchable Sources

Aware Interactive Loads

Cyber-Physical Systems: A Cooperative Grid

- Availability
- Pricing
- Planning



- Forecasting
- Tracking
- Market

- Monitor, Model, Mitigate
  - Deep instrumentation
  - Waste elimination
  - Efficient Operation
- Shifting, Scheduling, Adaptation

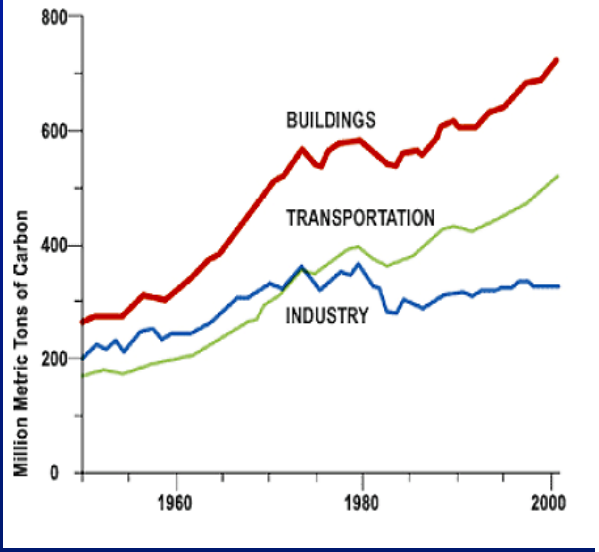
Where to Start?

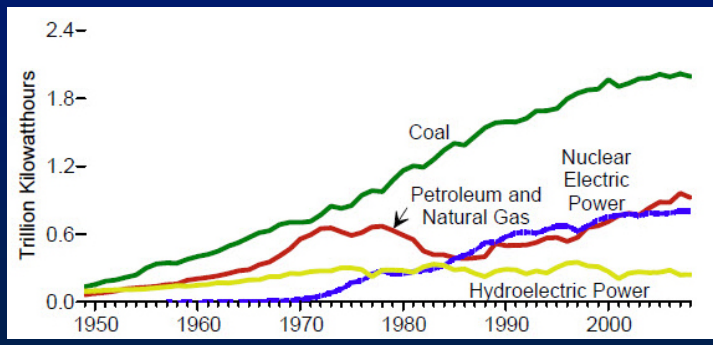
Buildings

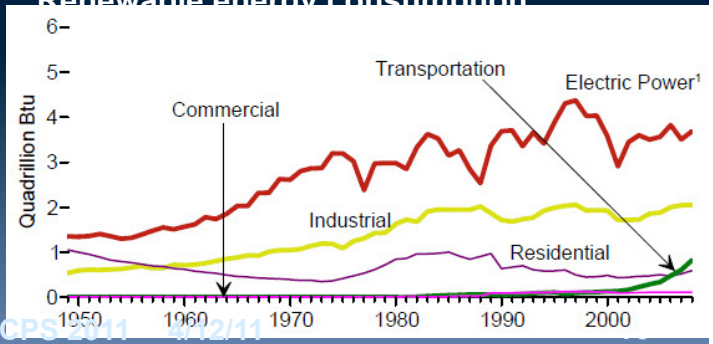
- 72% of electrical consumption (US),
- 40-50% of total consumption,
- 42% of GHG footprint
- US commercial building consumption doubled 1980-2000, 1.5x more by 2025 [NREL]

Where Coal is used

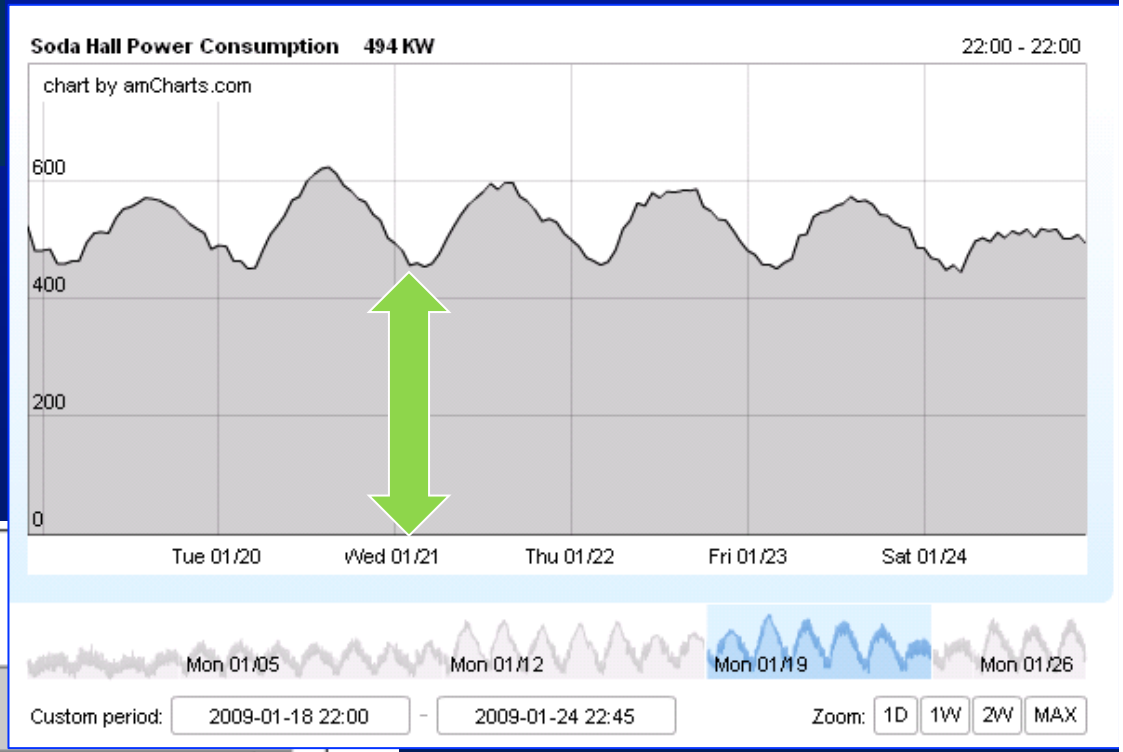
Prime target of opportunity for renewable supplies

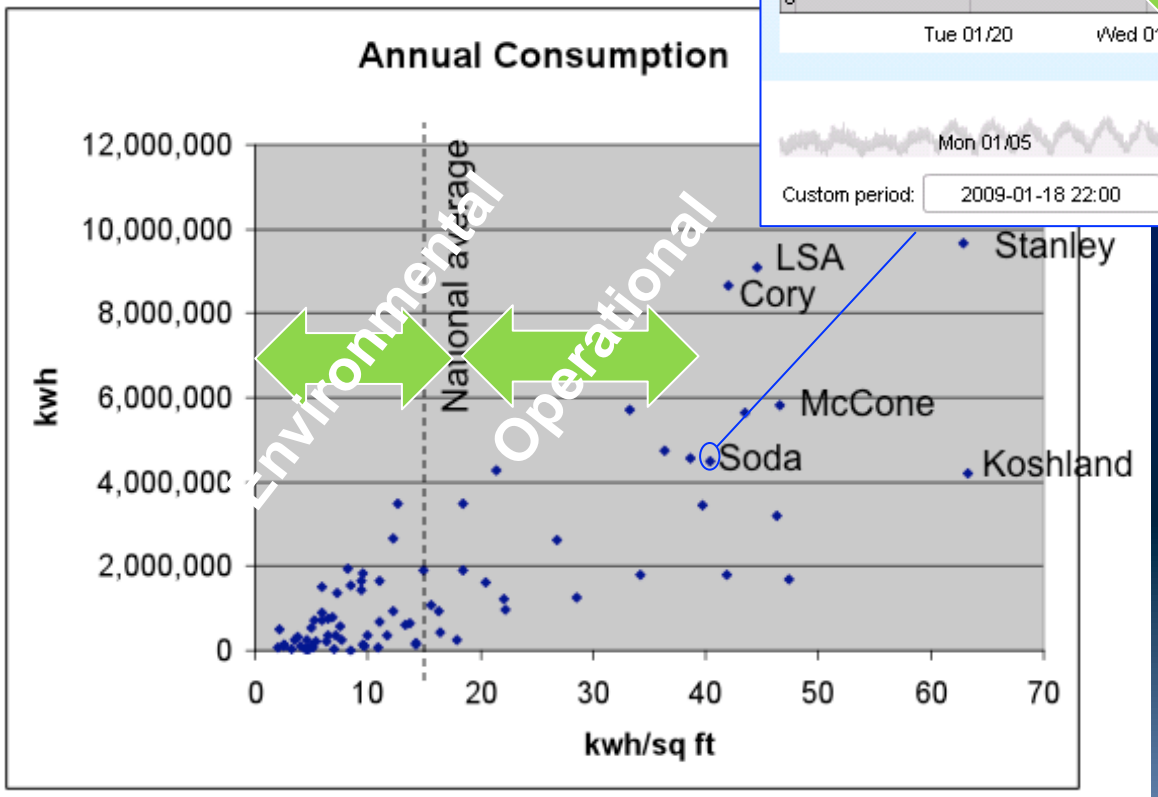




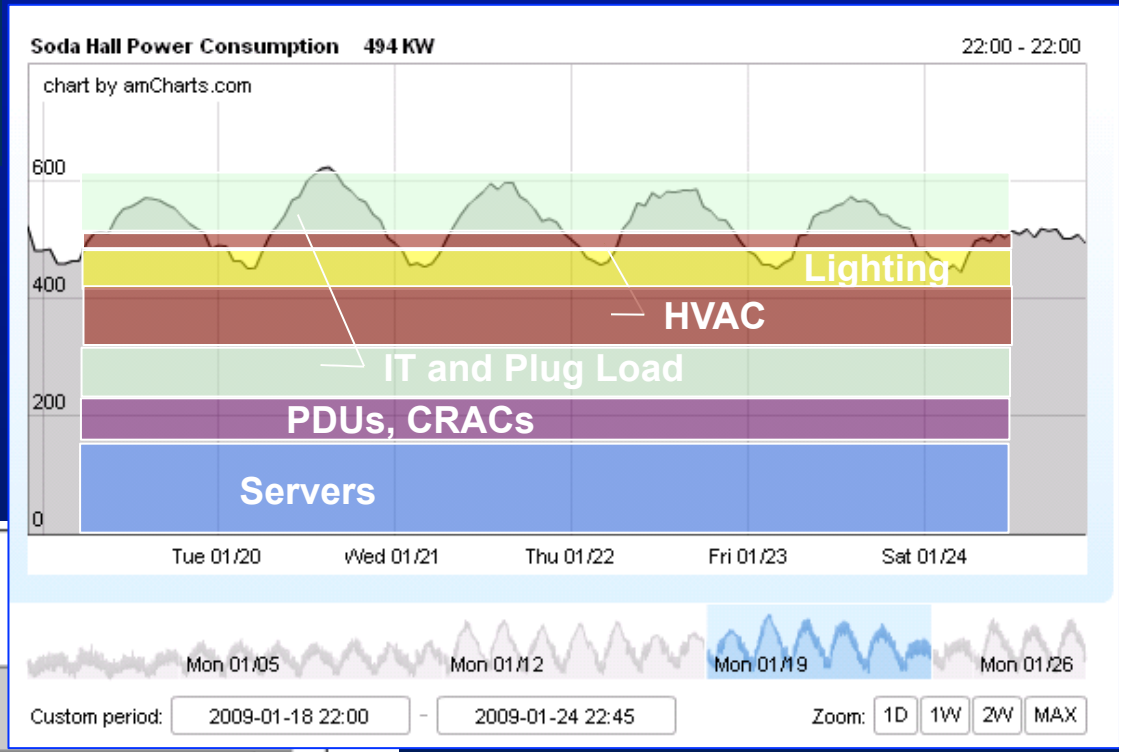


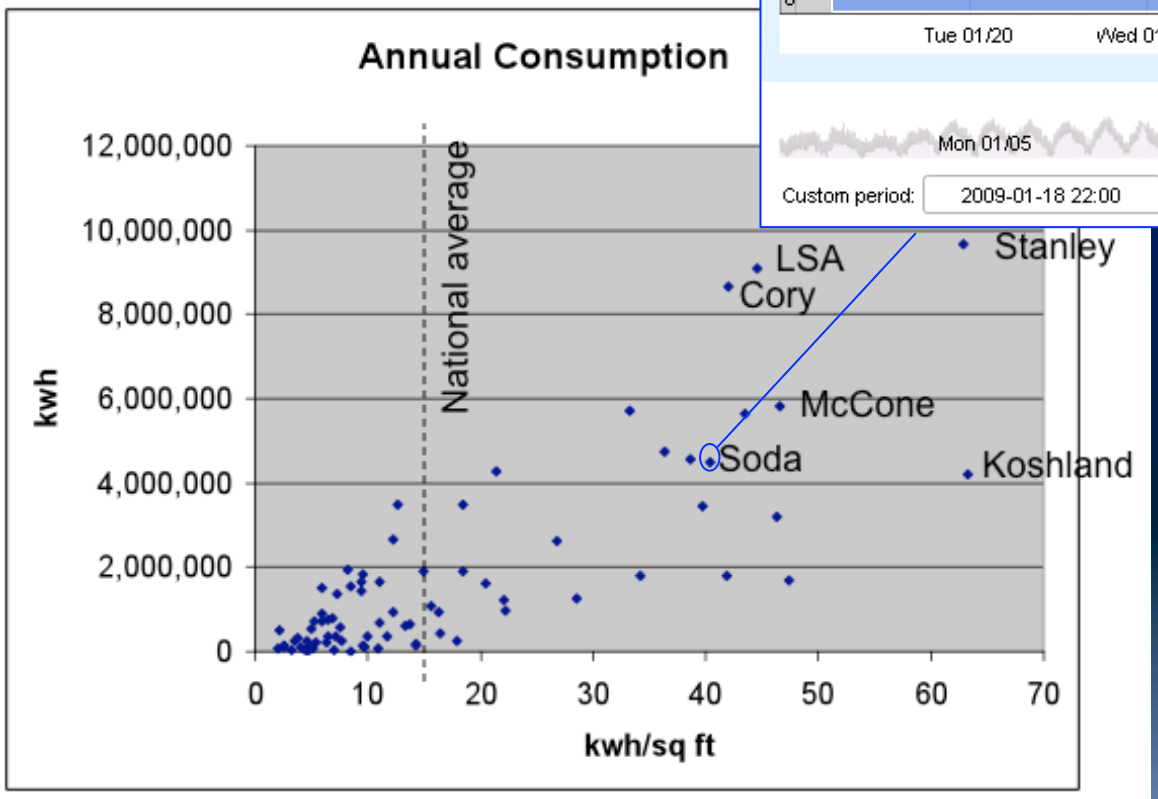
Our Buildings





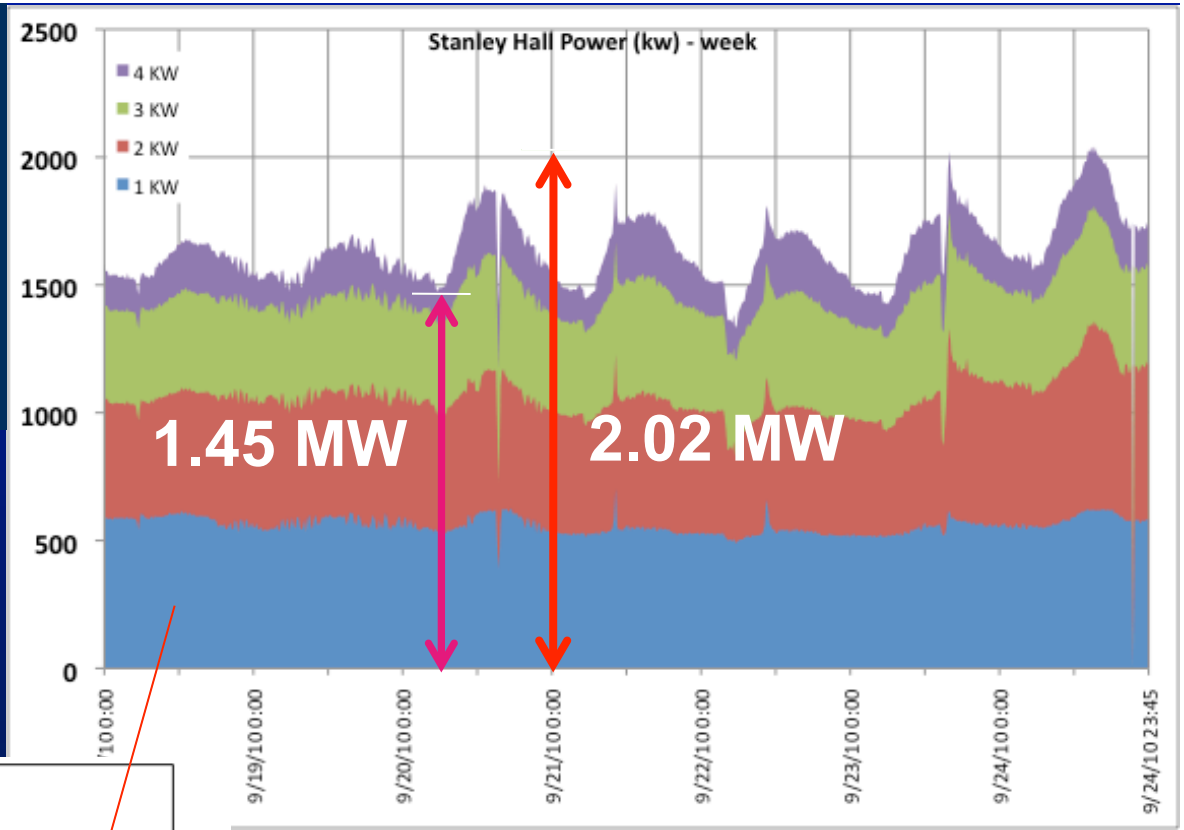
Soda Hall

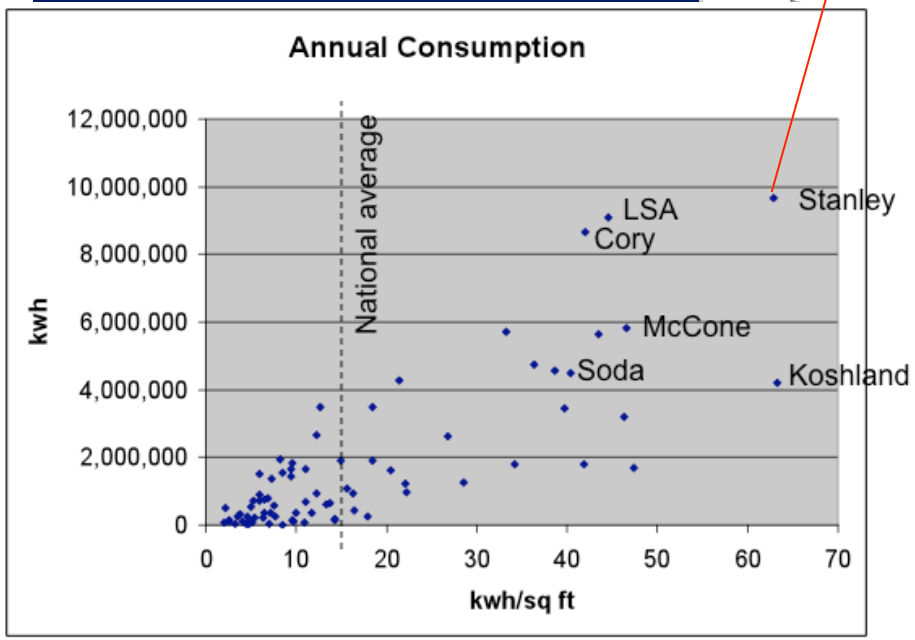

Soda Hall Power Consumption 494 KW
22:00 - 22:00
chart by amCharts.com
600
400
200
0
Lighting
HVAC
IT and Plug Load
PDUs, CRACs
Servers
Tue 01/20
Wed 01/21
Thu 01/22
Fri 01/23
Sat 01/24
Mon 01/05
Mon 01/12
Mon 01/19
Mon 01/26
Custom period:
2009-01-18 22:00
2009-01-24 22:45
Zoom:
1D
1W
2W
MAX


Annual Consumption
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
kwh
National average
LSA
Cory
Stanley
McCone
Soda
Koshland
0
10
20
30
40
50
60
70
kwh/sq ft

Power-Proportional Buildings ?

Stanley Hall:
Office + BioScience
- 13 NMRs

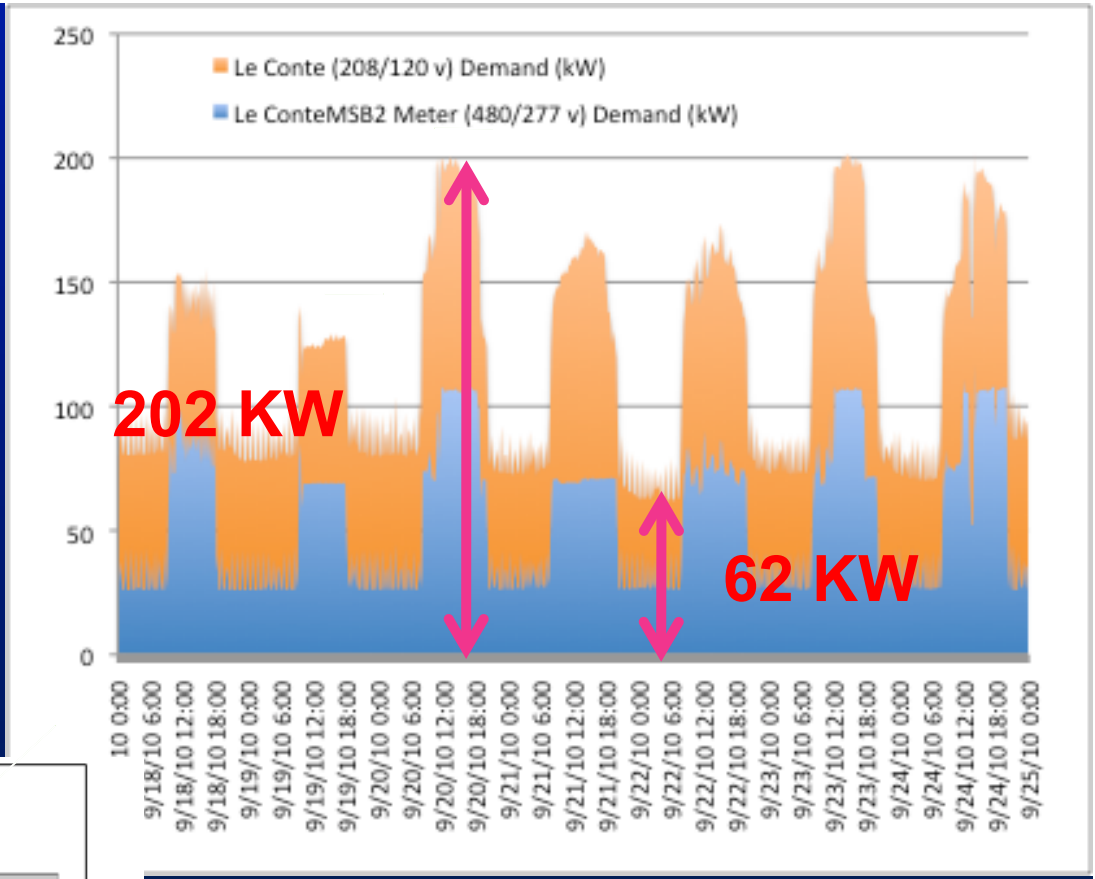


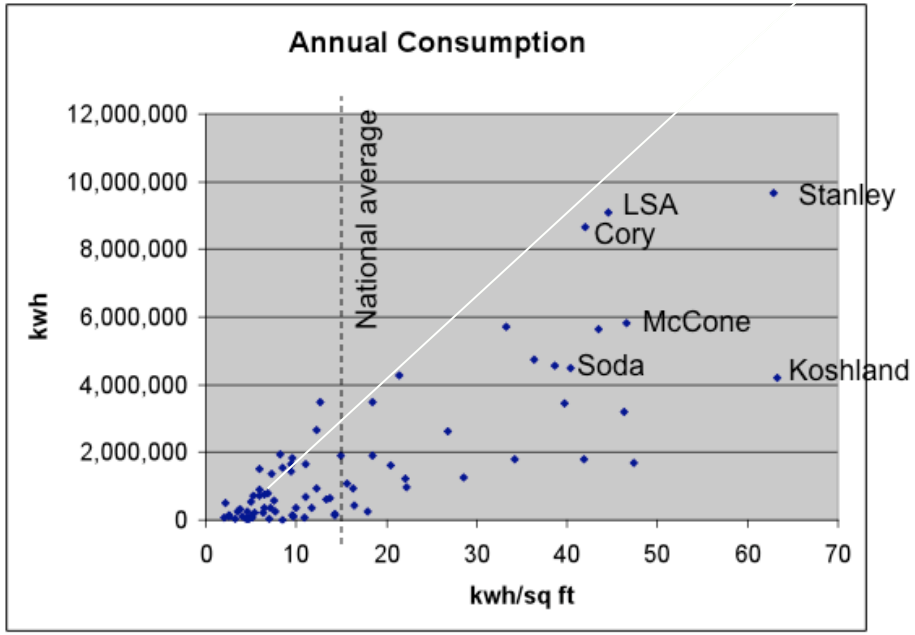


Min = 72% of Max

Power-Proportional Buildings ?

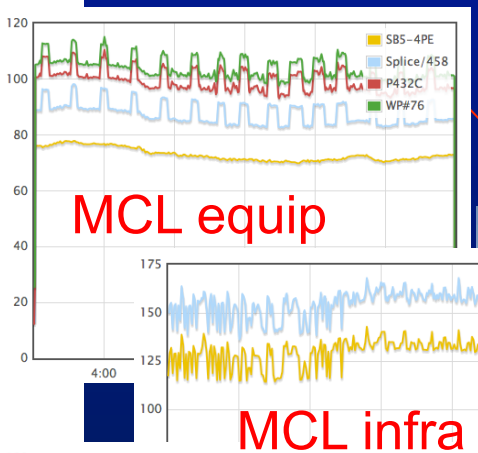
LeConte Hall: Office

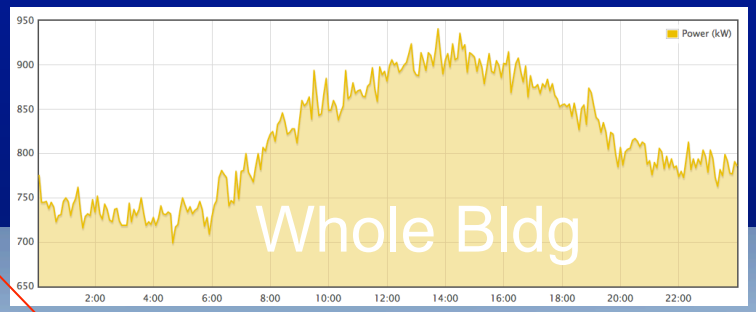


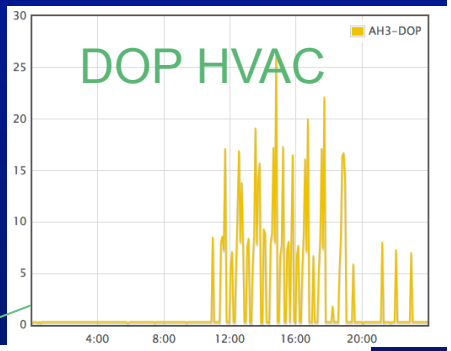


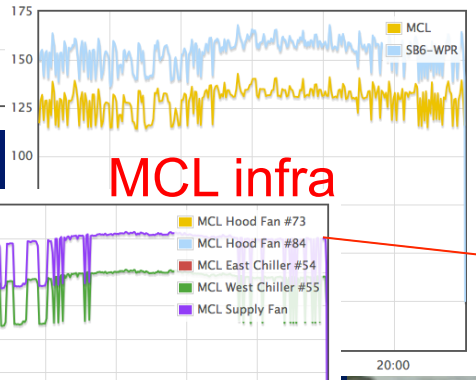
Min = 31% of Max

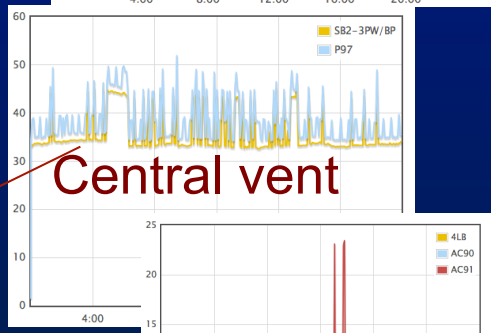
Energy Transparent Building

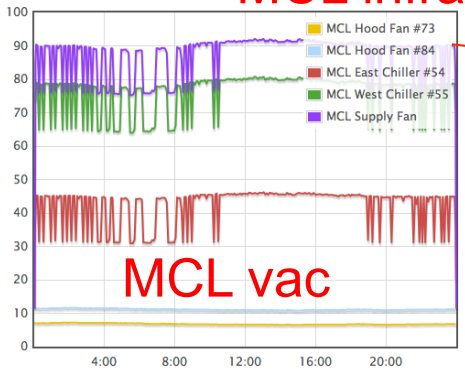


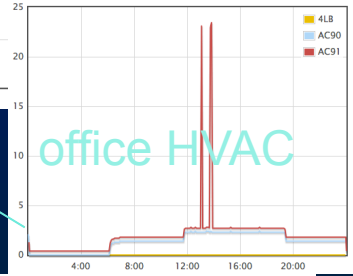


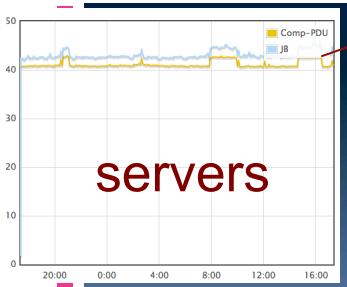


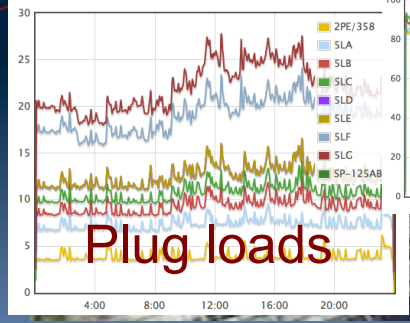


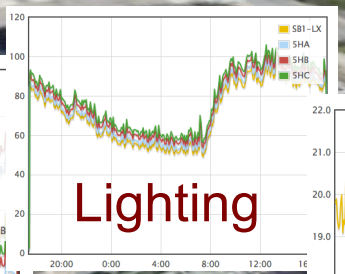


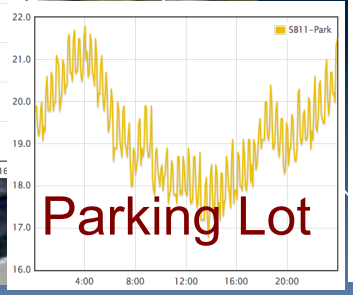


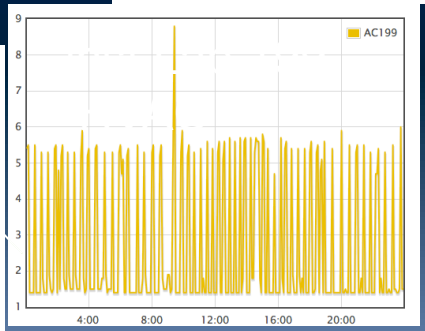




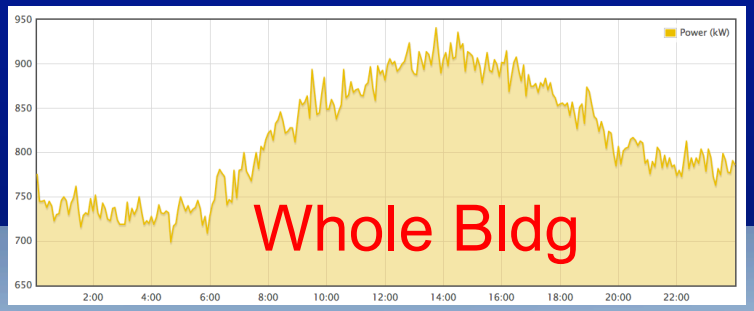


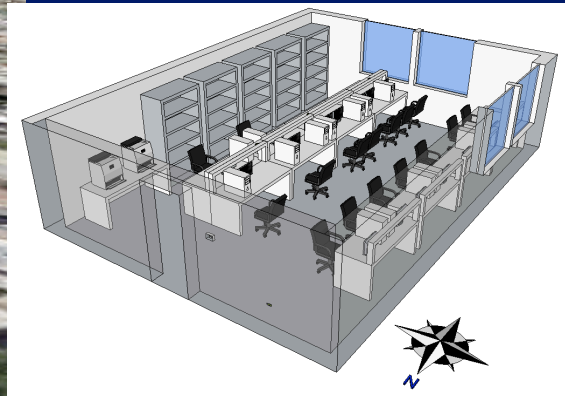


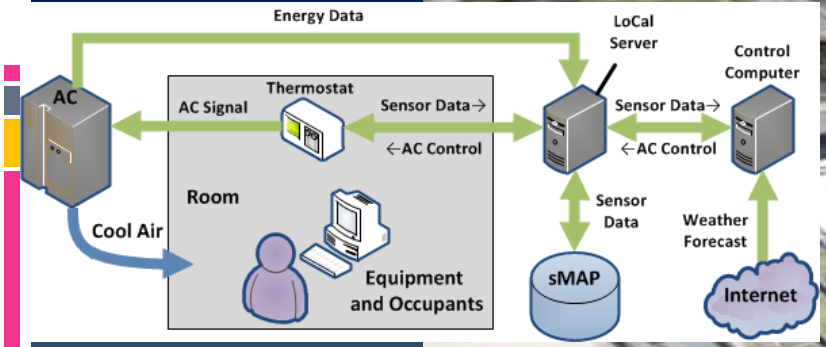




Intelligence in lo-tech places



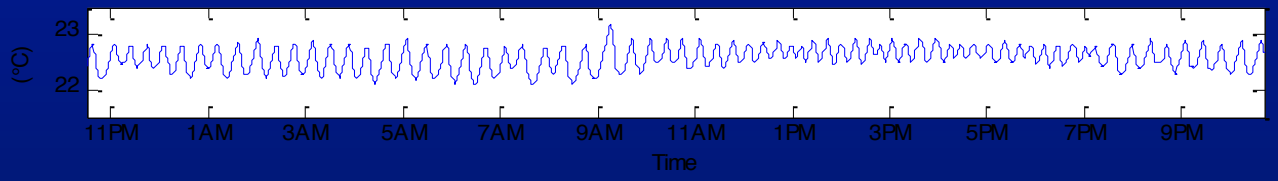




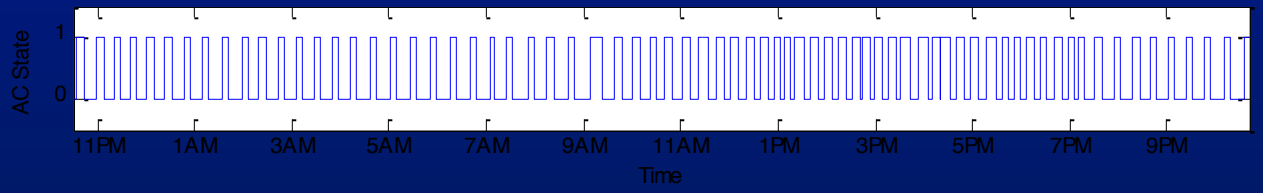
Learning-Based Model Predictive Control

Experimental Hysteresis Control: 31.7 kWh Consumed

Temperature

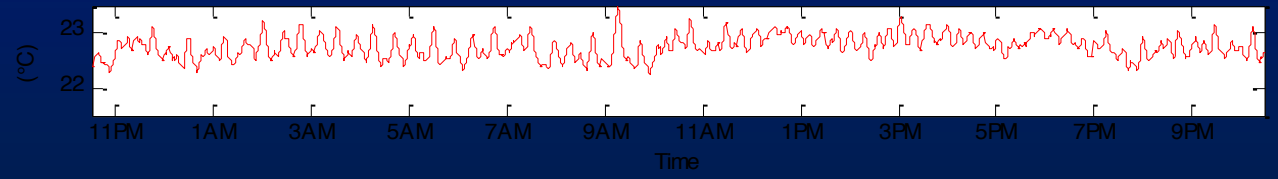


Control Action



Simulated LBMPC: 19.0 kWh Consumed (estimated)

Temperature



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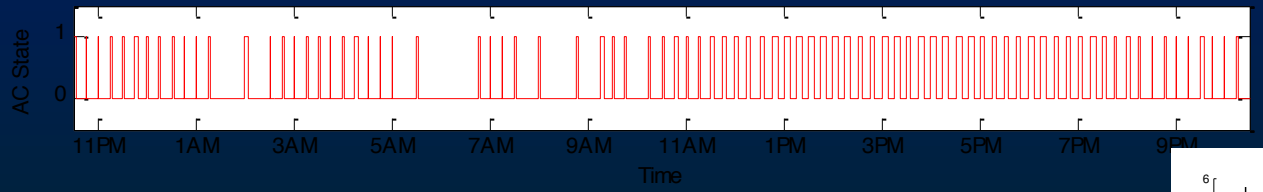
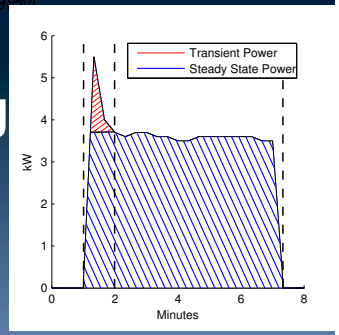
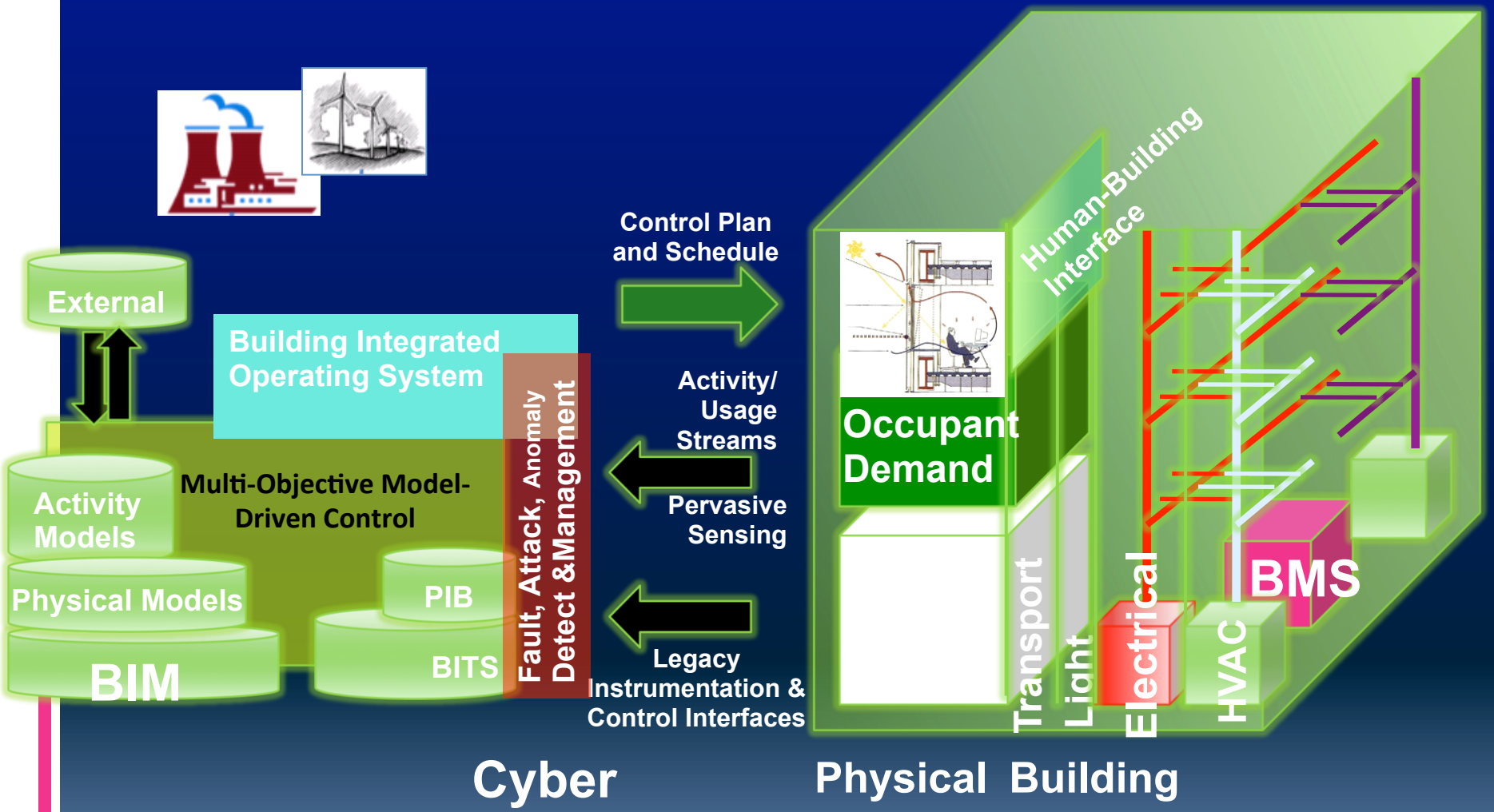


LBMPC adjusts for internal dynamics, avoids over-cooling, trades off duty cycle and switching frequency



(Aswani, Master, Taneja, Culler, Tomlin, 2011, submitted)

Cyber / Physical Buildings



CPS contributions … ???

- Pervasive Embedded Monitoring Networks
- Power Proportional Design Techniques
- Application Independent Physical Information Representation
- Modeling and Analysis
- Multi-objective Intelligent Control
- Human-Centric Optimization
- Robust, Scalable Infrastructure Archit

Research as "Time Travel" - the secret formula

- **Imagine** a technologically plausible future
- **Create** an approximation of that vision using technology that exists.
- Discover what is **True** in that world
  - Empirical experience
    - Bashing your head, stubbing your toe, reaching epiphany
  - Quantitative measurement and analysis
  - Analytics and Foundations
- Courage to 'break trail' and discipline to do the hard science on problems that matter