Transforming Institutional Infrastructure for Research

Linking Knowledge with Action

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- Associate Director, California Institute for Telecommunications & Information Technology

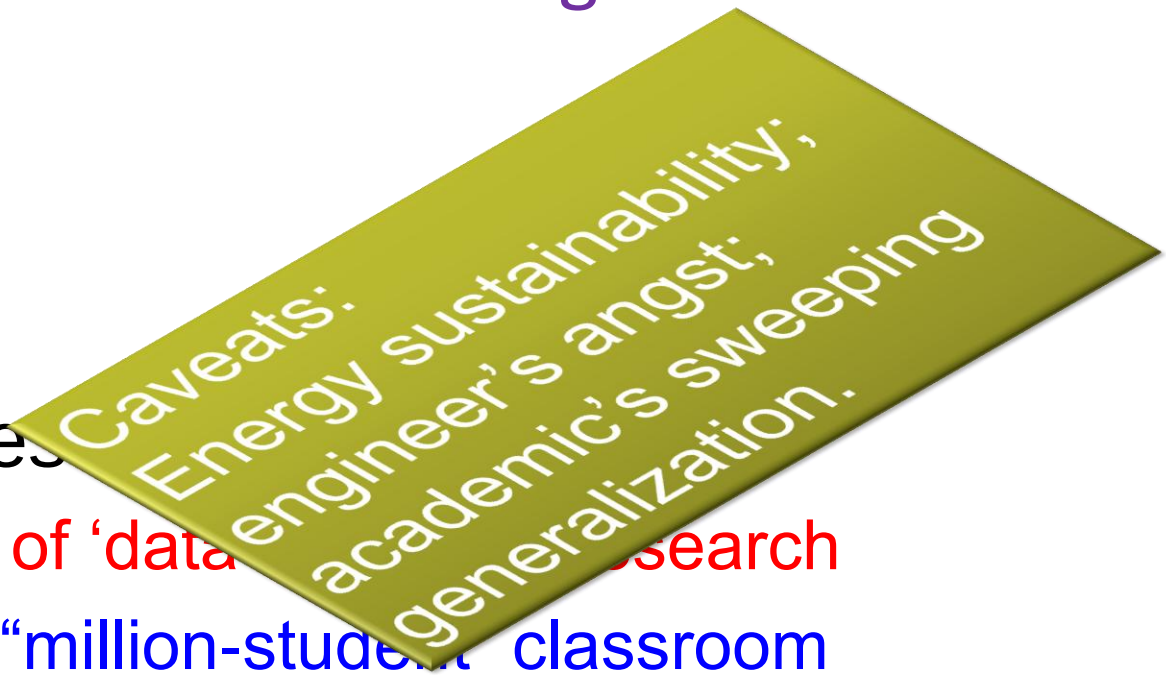
Sustainability Solutions Institute

UC San Diego

Outline: Sustainability is about Future

Stable Institutions Plan for the Long Term

- The University
  - The Convent
- Sustainability Res
  - The Dominance of 'data search
  - Hyperscaling: a "million-student" classroom
- A Compelling Infrastructure
  - The City and The Corporation



Universitas magistrorum et scholarium

a community of teachers and scholars

- a unibody of people, place and piety
  - pursuit of knowledge intimately tied to living

- Modern university
  - Unbundling of “uni” into a multi-verse of
    - Knowledge specialization
    - Imported workflows and systems that constitute the basic infrastructure for conducting scholarly activities
      - Printing press, laboratories, transportation networks
  - “a corporation” of ideas, skills?

- **Not Really**. It is a also a place for natural expression of a society’s aspirations.

The Princeton Review

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The Princeton Review's
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The Princeton Review's Guide to 322 Green Colleges
higher education in the United States and two in
strong commitment to sustainability in their
infrastructure, activities, and career pre
free, comprehensive, annually upd

To produce this book we par
outstanding national no
green building ratin
2010 to increa
designed

Green Facts

% food budget spent on local/organic food	3
Available transportation alternatives: free bus pass, universal access transit pass, restricted parking, bike share/rent, car share, carpool parking, vanpool, market based pricing (hourly parking costs), guaranteed ride home	
School has formal sustainability committee	Yes
New construction must be LEED-certified or comparable third-party rating system	Yes
Waste diversion rate (%)	51
Environmental studies degree available	Yes
Public GHG inventory plan	Yes
% of school energy from renewable resources	2
School employs a sustainability officer	Yes
School provides guidance on green jobs	Yes
% sch… …eaning products that are green certified	76
… maintained organically	50
	23,663
	48,093
	3.98
	38
	540–670
	610–720
	560–690
…on	$10,152
…-state tuition	$33,030
…d fees	$1,976
…oom and board	$11,684
% of students receiving need-based scholarship or grant aid	62

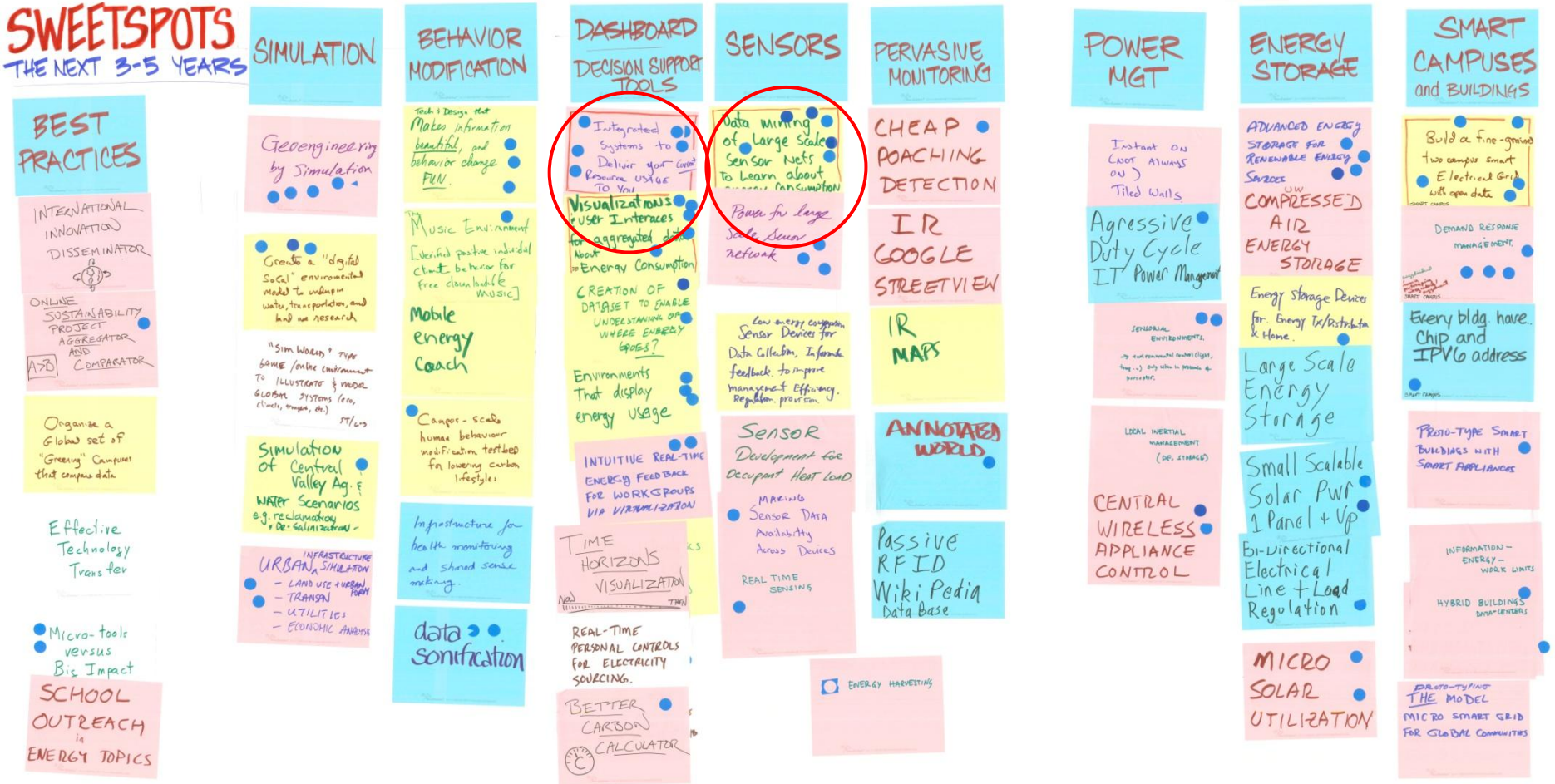
65% of 12,000 surveyed applicants wanted information on college's commitment to sustainability! 24% decide using this info.

83,000 College buildings , 3.48 billion

Universities enable Learning & Living in Future

A Weekend Discussion in April 2009.

Identify


SWEETSPOTS
THE NEXT 3-5 YEARS
BEST PRACTICES
INTERNATIONAL INNOVATION DISSEMINATOR
ONLINE SUSTAINABILITY PROJECT AGGREGATOR AND COMPARATOR
Organize a Global set of "Greening" Campuses that compare data
Effective Technology Transfer
Micro-tools versus Big Impact
SCHOOL OUTREACH in ENERGY TOPICS
SIMULATION
Geoengineering by Simulation
Creates a "digital SoCal" environmental model to underpin water, transportation, and land use research
"Sim World" type GAME /online environment TO ILLUSTRATE & MODEL GLOBAL SYSTEMS (eco, climate, transpo, etc.)
Simulation of Central Valley Ag. & WATER Scenarios e.g. reclamation, De-Salinization
URBAN INFRASTRUCTURE SIMULATION
- LAND USE + URBAN FORM
- TRANSP
- UTILITIES
- ECONOMIC ANALYSIS
BEHAVIOR MODIFICATION
Tools & Design that Makes information beautiful, and behavior change FUN.
Music Environment [Verified positive individual climate behavior for free downloadable MUSIC]
Mobile energy Coach
Campus-scale human behavior modification testbed for lowering carbon lifestyles
Infrastructure for health monitoring and shared sense making.
data sonification
DASHBOARD DECISION SUPPORT TOOLS
Integrated Systems to Deliver your Current Resource Usage TO You
Visualizations & User Interfaces for aggregated data about Energy Consumption
CREATION OF DATASET TO ENABLE UNDERSTANDING OF WHERE ENERGY GOES?
Environments That display energy usage
INTUITIVE REAL-TIME ENERGY FEEDBACK FOR WORKGROUPS VIA VIRTUALIZATION
TIME HORIZONS VISUALIZATION
NOW
THEN
REAL-TIME PERSONAL CONTROLS FOR ELECTRICITY SOURCING.
BETTER CARBON CALCULATOR
SENSORS
Data Mining of Large Scale Sensor Nets To Learn about
Power for large Scale Sensor network
Low energy consumption Sensor Devices for Data Collection, Informed feedback, to improve management Efficiency, Regulation, provision
Sensor Development for Occupant Heat Load
MAKING Sensor Data Availability Across Devices
REAL TIME SENSING
PERVASIVE MONITORING
CHEAP POACHING DETECTION
IR GOOGLE STREETVIEW
IR MAPS
ANNOTATED WORLD
Passive RFID Wiki Pedia Data Base
ENERGY HARVESTING
POWER MGT
Instant ON (NOT ALWAYS ON) Tiled Walls
Agressive Duty Cycle IT Power Management
SENSORIAL ENVIRONMENTS
LOCAL INTERTIAL MANAGEMENT (DR. STORAGE)
CENTRAL WIRELESS APPLIANCE CONTROL
ENERGY STORAGE
ADVANCED ENERGY STORAGE FOR RENEWABLE ENERGY SOURCES
COMPRESSED AIR ENERGY STORAGE
Energy Storage Devices for Energy Tx/Distribution & Home
Large Scale Energy Storage
Small Scalable Solar Pwr 1 Panel + Up
Bi-Directional Electrical Line + Load Regulation
MICRO SOLAR UTILIZATION
SMART CAMPUSES and BUILDINGS
Build a fine-grained two campus smart Electrical Grid with open data
DEMAND RESPONSE MANAGEMENT
Every bldg. have Chip and IPV6 address
PROTO-TYPE SMART BUILDINGS WITH SMART APPLIANCES
INFORMATION-ENERGY-WORK LIMITS
HYBRID BUILDINGS DATA-CENTERS
PROTOTYPING THE MODEL MICRO SMART GRID FOR GLOBAL COMMUNITIES

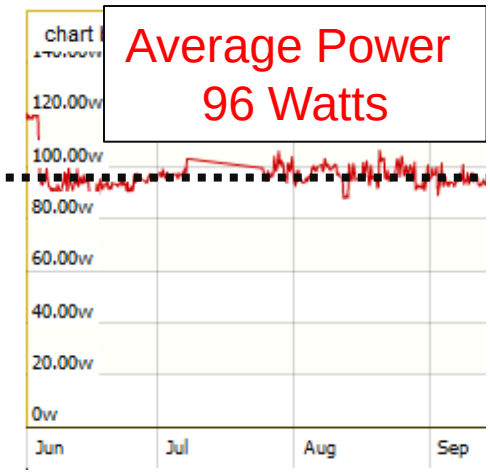
Making Buildings Energy Efficient

Increasing bandwidth of use, decreasing granularity of response.

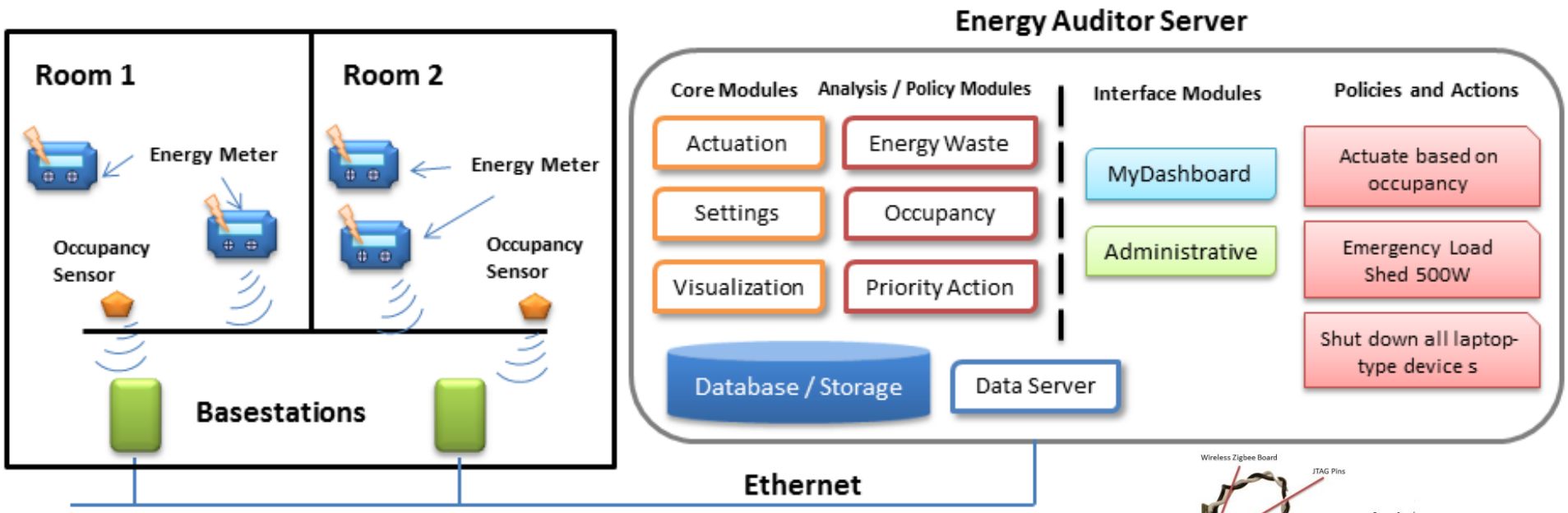
1. Reduce energy consumption by IT equipment
   - Servers and PCs left on to maintain network presence
   - Key: "Duty-Cycle" computers aggressively maintaining availability
   - *Somniloquy [NSDI '09]* and *SleepServer [USENIX '10]*
2. Reduce energy consumption by the HVAC system
   - Energy use is not proportional to number of occupants
   - Key: Use real-time occupancy to drive HVAC at fine spatial scales
   - *Synergy occupancy* node *[BuildSys '10], HVAC Control [IPSN '11]*
3. Reduce energy consumption by Plug-Loads
   - "Dark-loads" distributed over a building, diverse types
   - Key Idea: Measure and actuate based on "policies" at fine temporal scales *[BuildSys'11].*

1. IT

SleepServers: Enable Aggressive Duty Cycling



68% energy savings since *SleepServer* deployment



2. HVAC

Occupancy-driven HVAC

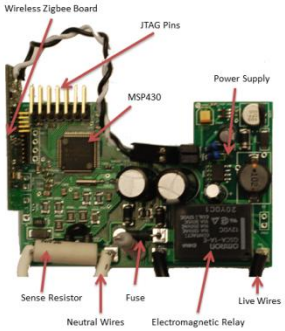
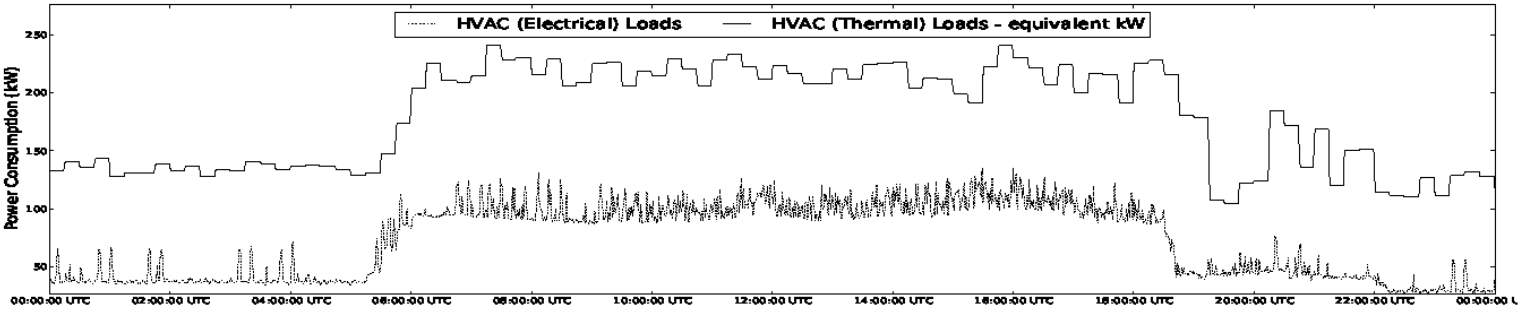
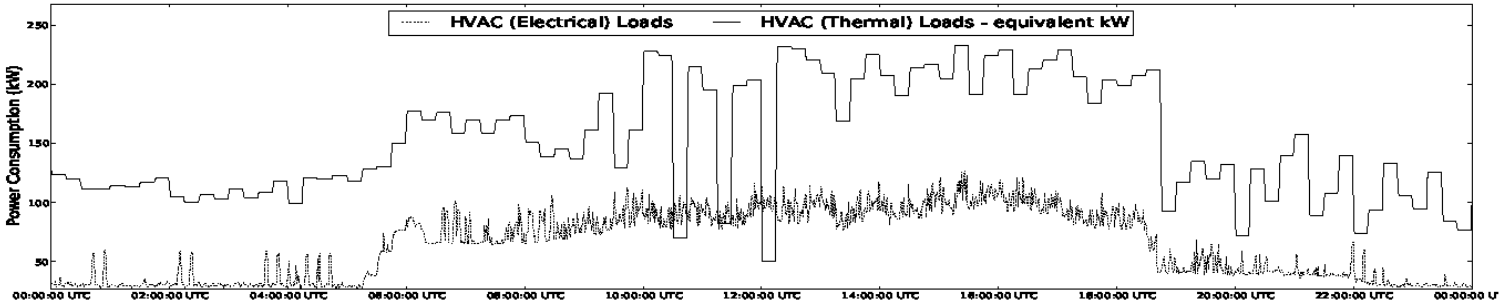


Figure 4. Picture of our energy meter (a, b) along with our SheevaPlug base station (c) that is deployed in the hallways. The CC2530 based wireless module that are in both the base station and the energy meters is also shown (d).

2. HVAC Energy Savings



HVAC Energy Consumption (Electrical and Thermal) during the baseline day.



HVAC Energy Consumption (Electrical and Thermal) for a test day with a similar weather profile. HVAC energy savings are significant: over 13% (HVAC-Electrical) and 15.6% (HVAC-Thermal) for just the 2nd floor

Estimated 40% savings across entire building. Detailed occupancy can be used to drive other systems.

Demand Response

3. Plug Loads

- 54 HVAC zones including 1 kW corridor each floor
  - 15-20 kW per floor, 260-358 W per zone
  - DREM for plug loads with device type and priority levels
  - Actuation classes: Off (PL 1), Occ_low (PL 2), Occ_hi (PL 3), On (PL 10).

	Subsystem Type	DR Priority-1 (P1)	DR Priority-2 (P2)
		Plug Load Devices	
1	Class: `always-off` Space heater, fans Laptops, Chargers	Occ: Load=OFF | NotOcc: Load=OFF Inconvenience=1pt/10min Savings -> Device Load(Occ) Savings -> Device Load(NotOcc)	Occ: Load=OFF | NotOcc: Load=OFF Inconvenience=1pt/10min Savings -> Device Load(Occ) Savings -> Device Load(NotOcc)
2	Class: `Occupancy-Based-Low` PC Speakers, Room Printers	Occ: Load=ON | NotOcc: Load=OFF Inconvenience=0pt Savings -> Device Load(Occ) Savings -> No Savings (NotOcc)	Occ: Load=OFF | NotOcc: Load=OFF Inconveni /10min Savings ce Load Savin oad (NotOcc)
3	Class: `Occupancy-Based-High` Lamps	Occ: Load=ON | NotOcc: Load=OFF Inconvenience=0pt Savings -> No Savings (Occ) Savings -> Device Load (NotOcc)	Occ NotOcc: Load=OFF onvenience=0pt ngs -> No Savings (Occ) vings -> Device Load (NotOcc)
		Desktop Computers and ens	
4		Active | NotOcc: Sleep if CPU < 10% Inconvenience=0pt Savings -> No Savings(Occ) Savings -> Desktop + LCD (NotOcc)	Occ: Sleep if no input for 5mins | NotOcc: Sleep Inconvenience=1pt Savings -> Desktop+LCD if allowed to sleep(Occ) Savings -> Desktop+LCD (NotOcc)
		Heating Ventilation and Air Conditioning (HVAC) System	
5		Occ: ON | NotOcc(all rooms in zone): OFF Inconvenience=1pt/room, 3pt/shared zone* Savings -> 260W-358W per zone shutdown	Occ: ON | NotOcc(at least 1 room in zone): OFF Inconvenience=2pt/10min room, 6pt/10min shared Savings -> 260W-358W per zone shutdown

Building OS?

OpenBuildings

30 Room Deployment

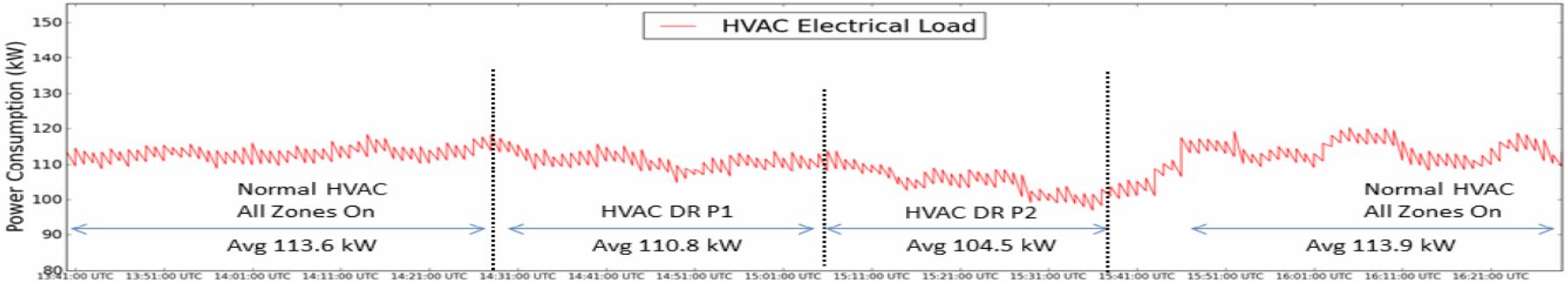


Figure 8: The energy consumption of our HVAC experiment. Occupancy information is gotten prior to DR P1, and held constant for the duration of the DR event.

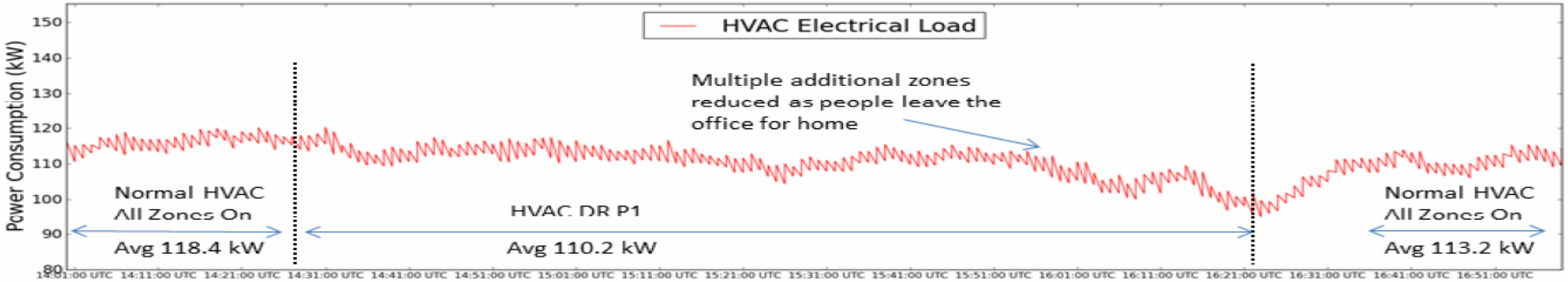
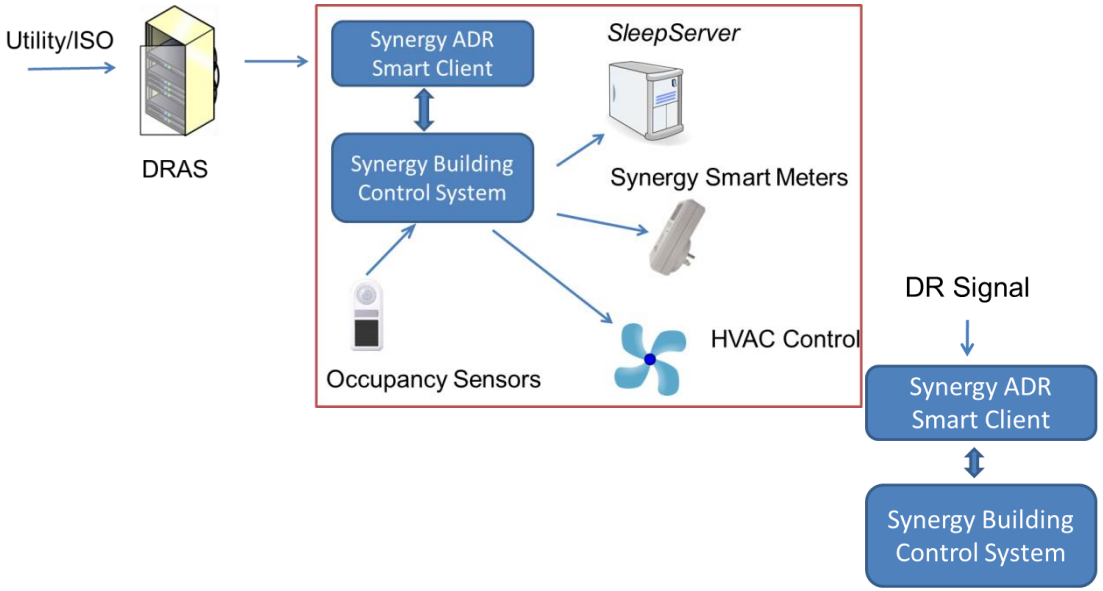


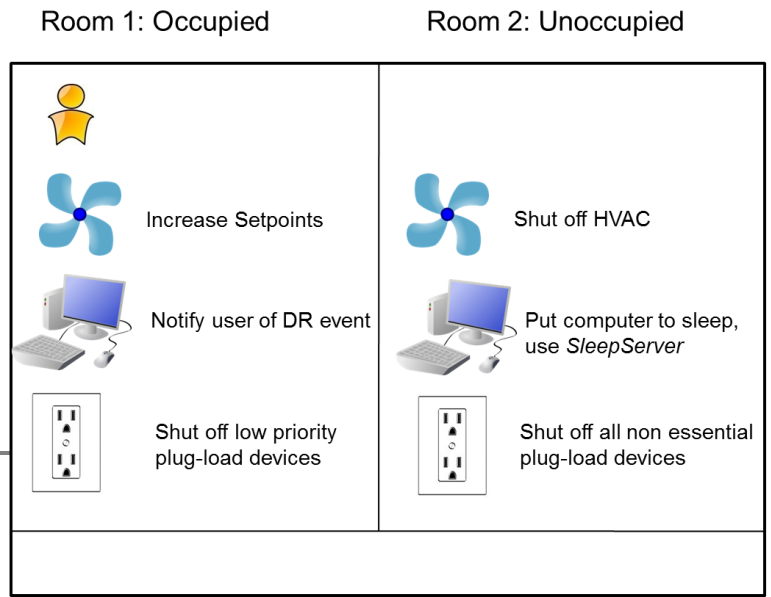
Figure 9: The energy consumption of HVAC for the actual occupancy-based deployment. HVAC zones controlled as occupancy changes.

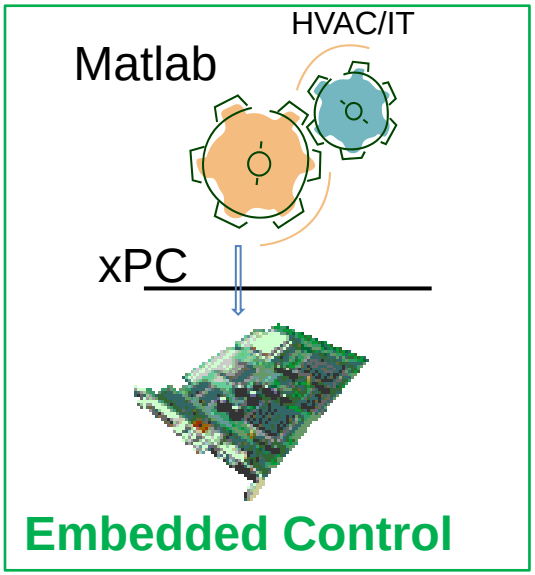
36.9% lower energy use over 8-hour work day. DR response in minutes.

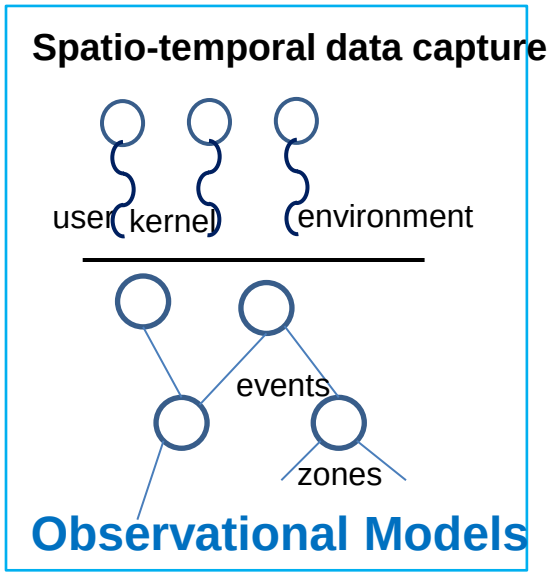
There is a 10X reduction as a LHF

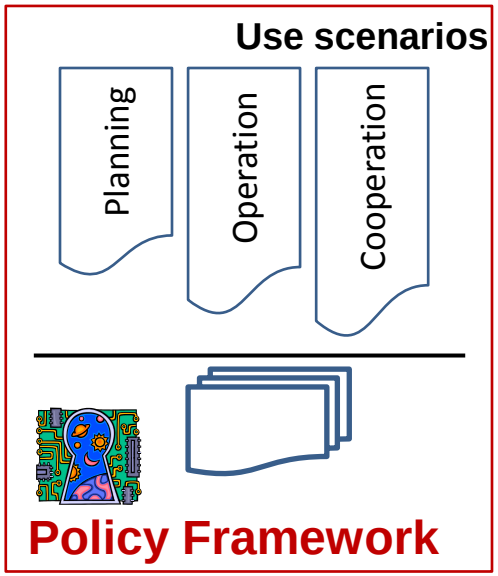
- Interfacing with smart grid:
  - An emerging communication plane over the electrical grid
  - Demand Response is key to this interface
  - From day-ahead planning to hour-ahead DR

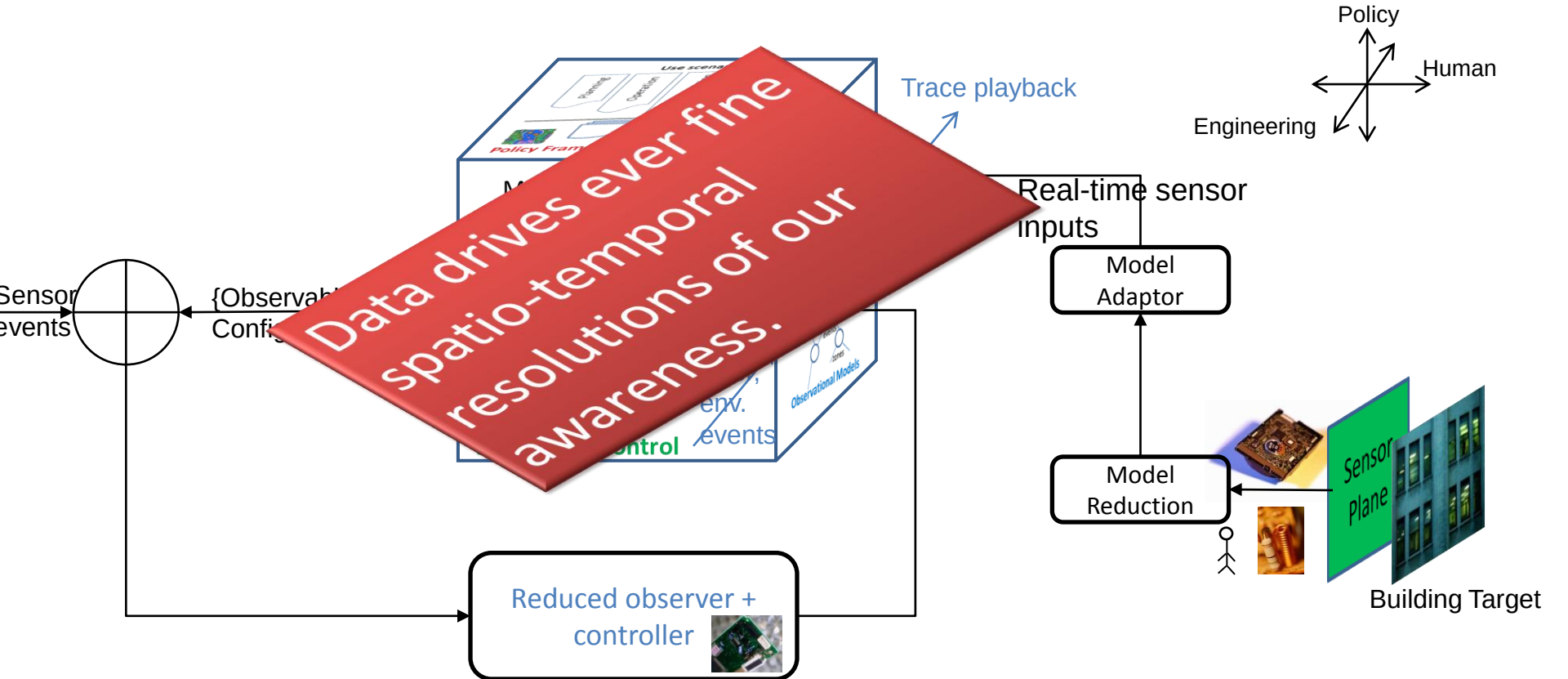




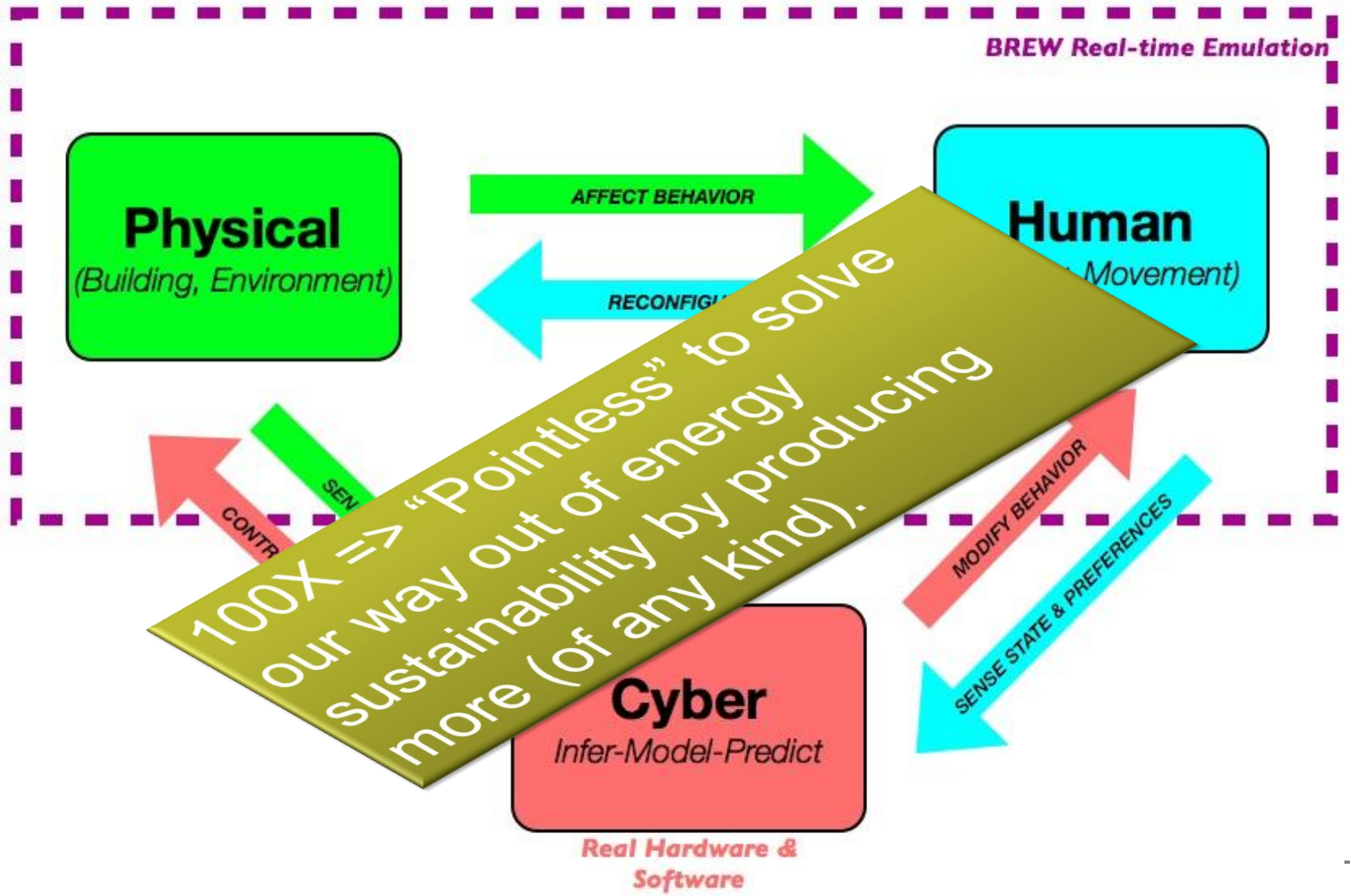

HVAC/IT
Matlab
xPC
Embedded Control


Spatio-temporal data capture
user
kernel
environment
events
zones
Observational Models

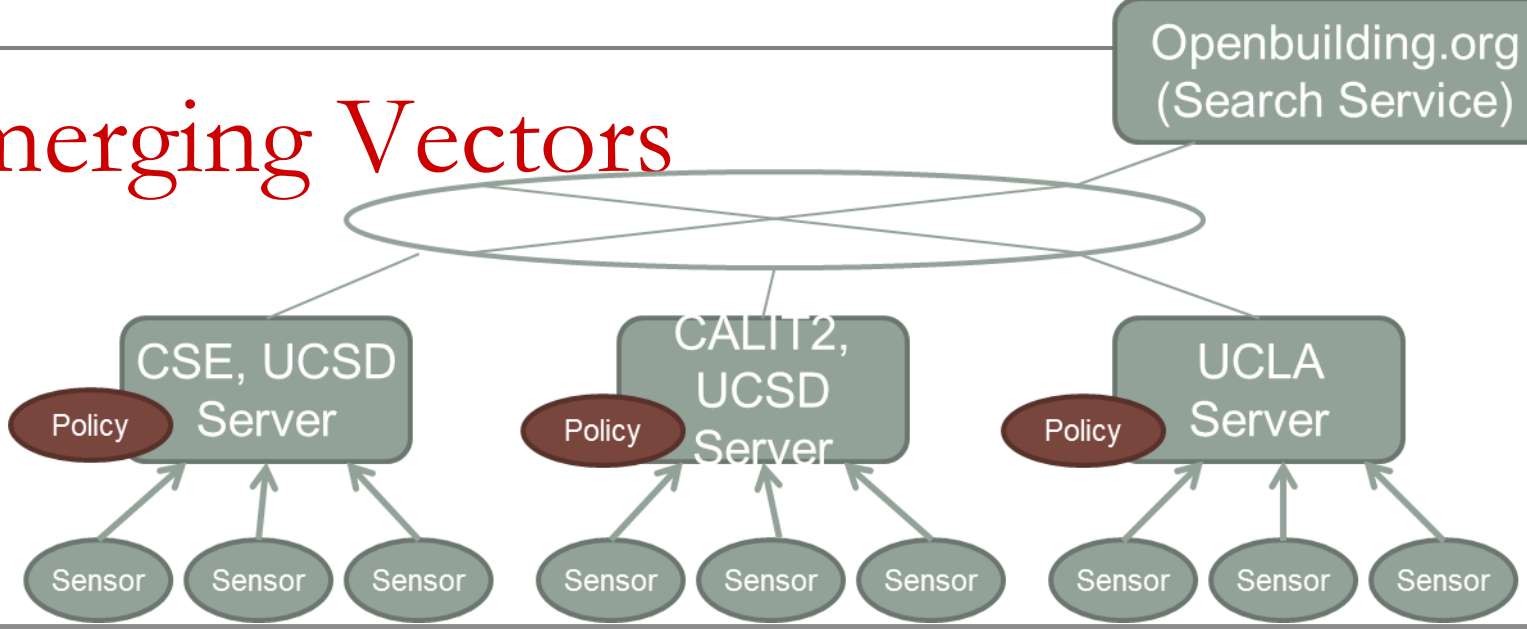

Use scenarios
Planning
Operation
Cooperation
Policy Framework


Policy
Human
Engineering
Trace playback
Real-time sensor inputs
Model Adaptor
Model Reduction
Sensor Plane
Building Target
Reduced observer + controller
Data drives ever fine spatio-temporal resolutions of our awareness.

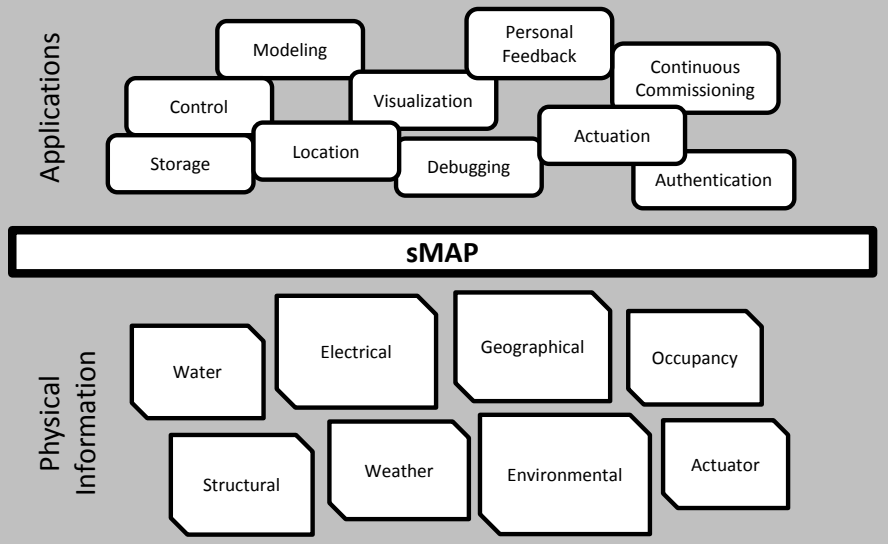
And a 100X in a coupled system!



Emerging Vectors



sMAP Architecture



Horizontal Architecture

Vertical Protocol Layering


Enter The Corporation
photographed by
Jeff Park, 2009

A "compelling" place for practice in living as a community

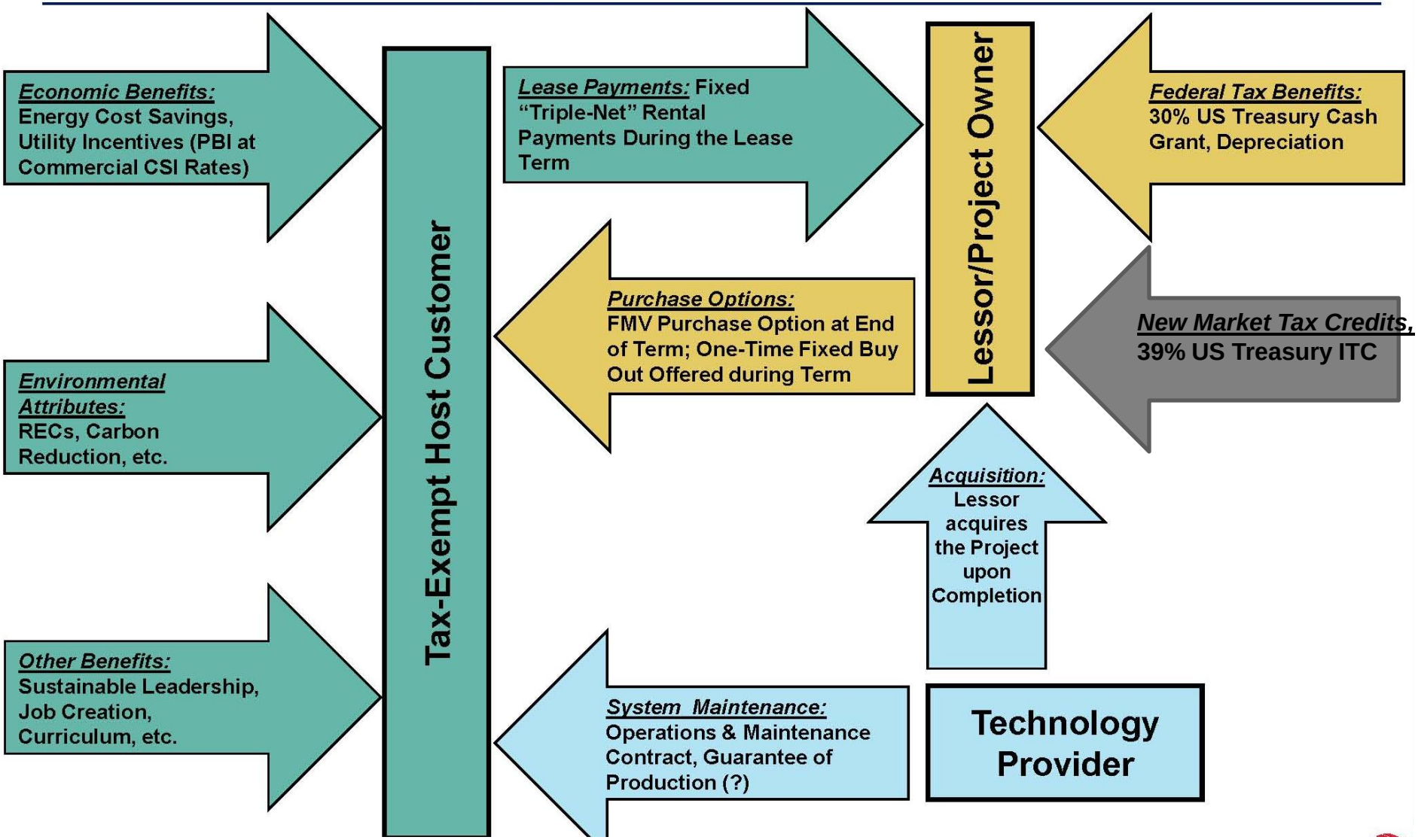
- 12,000 acres, 45,000 occupants, 8,000 residents
- 2 hospitals (with local generation), 15 restaurants
- 450 buildings, 11 million square fee of building space
- Over $250M in capital construction/year
- Generates 80% of its own electricity usage including
  - 2.8 MW fuel cells, >2 MW PV, Wind, 15% of daily energy stored
- Meters & Monitors everything:
  - 50K meters, 4.5K thermostats
- 16 weather stations, real-time monitoring,
  - tracks moving clouds across the campus to drive dynamic PV load shifts from 50 kW/sec to 1 kW/sec.
- Self-regulating entity, its own police.

"The Corporation" under "True Lease" Rules

- Section 1603 of the Tax Code
  - Originally enacted under ARRA as "cash grants in lieu of tax credits" for clean energy projects struggling for financing since the tax shelter market had dried up, 30% cash grants to lessor
  - 100% funding for PV projects, 2.8 MW Biogas Fuel Cell project
- An example of where modern corporation meets researchers in the middle
  - 11:1 leveraging of donor funds by ensure 5% start of construction in 2011.

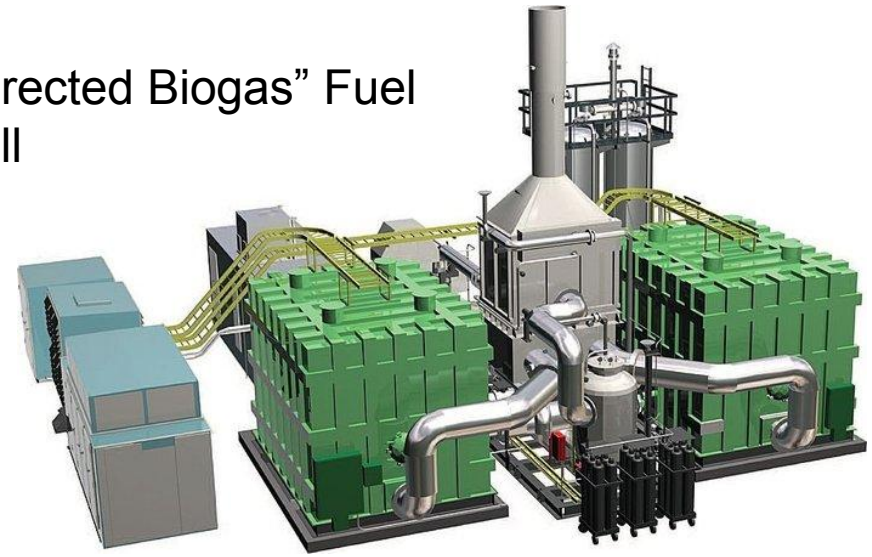
True Tax Lease for California Solar PV Projects

Diagram of True Lease Transaction Structure



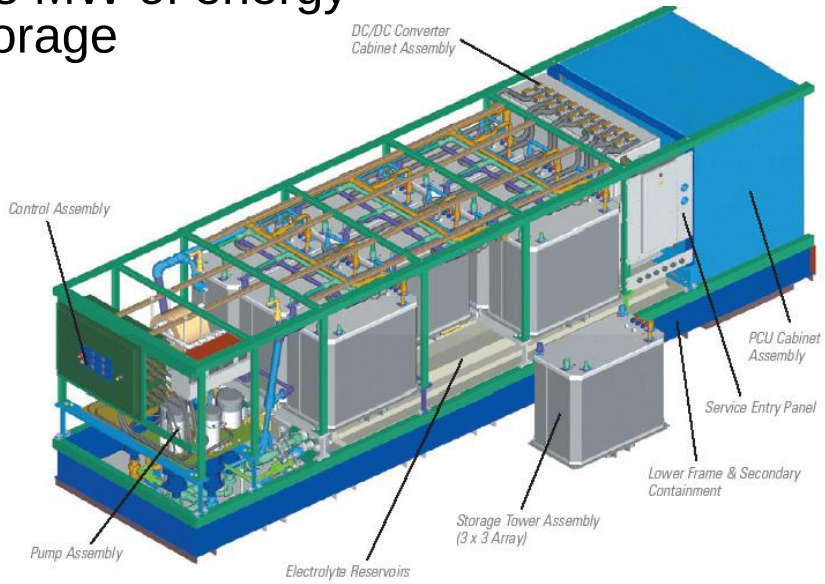
An Explosion of "Corporate Projects"

"Directed Biogas" Fuel Cell



Access to DC Power

2.8 MW of energy storage



Campus As A Living Laboratory of Localized Co-Generation and Storage

Roadmap to a green campus, USGBC.

Campuses as Living Laboratories for the Greener Future

By Bill St. Arnaud, Larry Smarr, Jerry Sheehan, and Tom DeFanti

We enter 2010 at a turning point in the debate on global climate change, in which the focus is rapidly moving from a scientific analysis of how human activity affects climate to a political discussion on how best to regulate greenhouse gas (GHG) emissions so as to lessen the human and environmental toll of global climatic disruption. Policymakers in many countries are actively engaged in drafting legislation at the local, state/province, and federal levels to enact substantial regul... limits on GHG emissions. Colleges and universiti... swept up in this legislation, will soon have to ... sure and abate campus GHG emissions or ... repercussions.

Bill St. Arnaud is Chief Research Officer at CANAR... the UCSD Jacobs School's Department of Co... of the California Institute for Telecomm... California, San Diego, and University o... at Calit2. Tom DeFanti is a Senior Research Sc...

We can not talk our way out of the sustainability challenges: even basic science will require deployments, gathering and understanding data.

Since college and university ... effectively small cities, they are an ideal scale for exploring ...vative approaches to the reduction of carbon footprints.

Computer Science As A Discipline

- CS favorite preoccupations now go beyond data
  - Ballots, Equity, Access, Health
- Special role of NSF in driving this change.