LIGHTNING INTRODUCTIONS

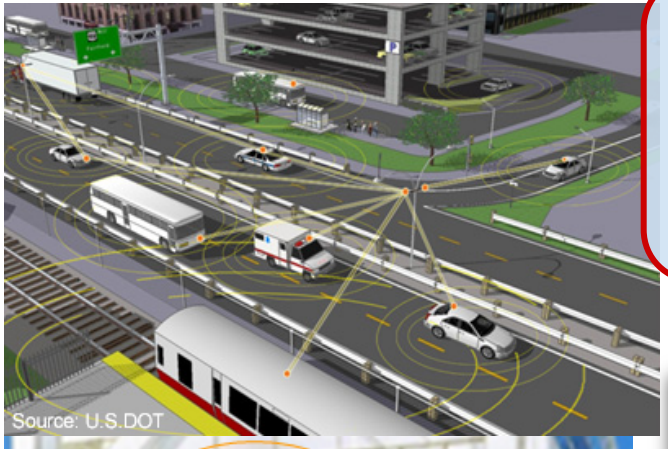
ARPA-E Mini-workshop

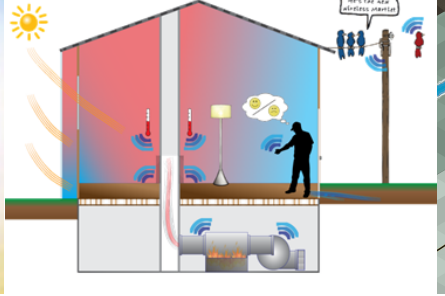
Reducing CAPEX for Energy-Efficient Building Controls

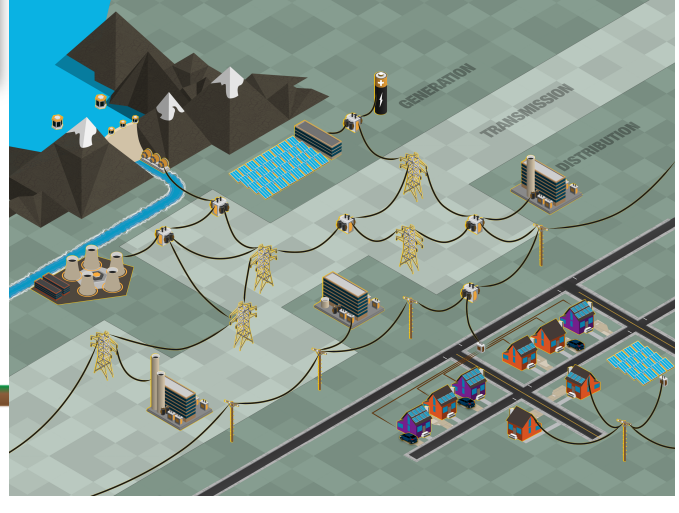
October 23rd, 2014 -- Washington, DC

Michael Kane

Autonomous control systems for energy efficient infrastructure







Michael Kane

BREAKTHROUGH

YOU ALL

The Community Unites!

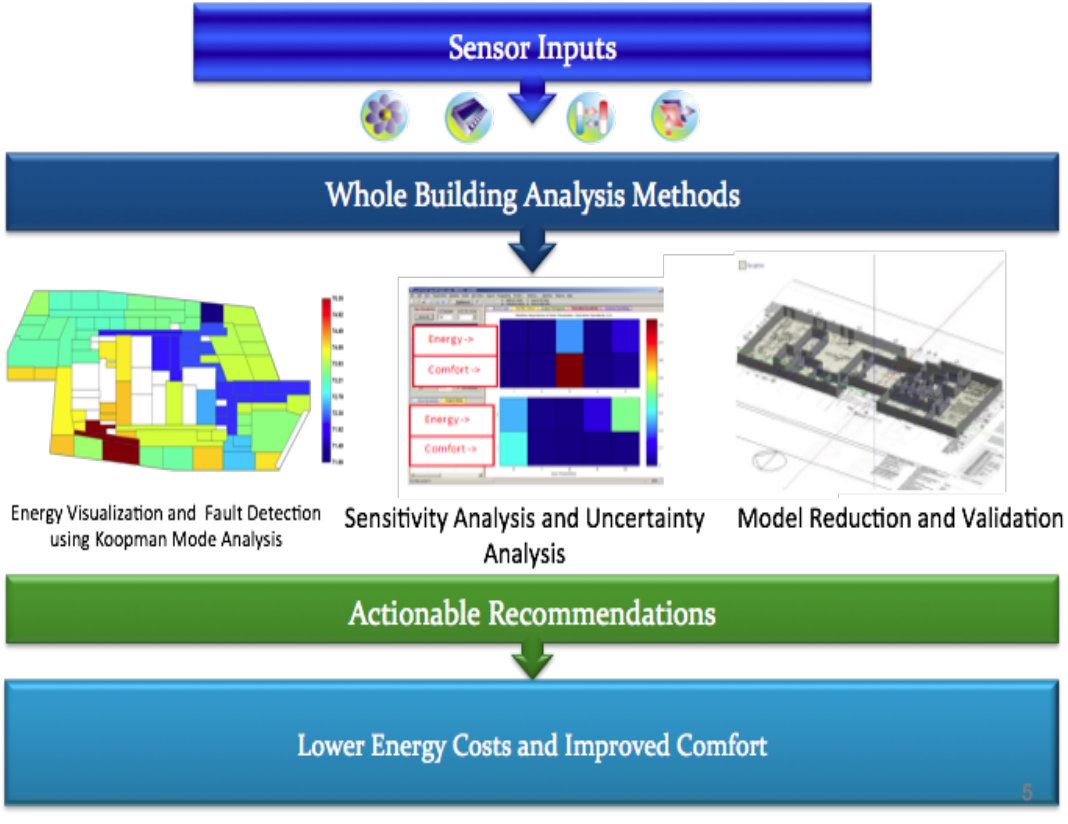
- Building Science Matures
- Theoretical algorithmic dev.
- HW & SW developments align
- 1st markets - sensing & analytics
- Controls ‘leaving aerospace’
- New R&D efforts leaving lab

CHALLENGE

Making ‘New Tech’ Feel Normal

- How to have evolution in high CAPEX markets like buildings
- Ensuring safety (physical & cyber), yet reduce margins

Igor Mezic



Small and Medium

Scale

City (IoT)

Enterprise

Igor Mezic

Breakthrough

- Comprehensive approach for whole building diagnostics, optimization and control with high ROI.
- One algorithmic platform that serves AFDD, optimization and control needs for a building, enterprise or a city within a cloud computing environment .
- Seamless integration of model-based (as in EnergyPlus) and data-based approach.

Challenges

- Many small and medium size buildings do not have a data-rich BMS. More data=more accuracy, less uncertainty.
- For better implementation results, building engineer needs to grasp elements of IT, automatic control and thermal engineering.
- Standardization of protocols, name conventions.

Gabriel Peschiera

ECORITHM

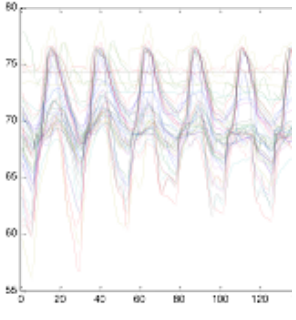
AFDD and Comfort Performance

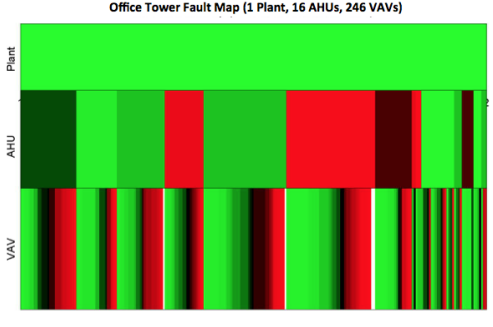
Tabularized Reporting

#	Equipment	Summary	Recommendation
1	Heat Pumps	7 heat pumps are exhibiting high frequency (on/off) fan cycling	Fans need attention to prevent smoking. Check for broken fans and control sequences.
2	Heat Pumps	49 heat pumps are exhibiting high frequency (on/off) compressor cycling	Confirm control sequence for equipment.
3	Heat Pumps	11 heat pumps detected exhibiting low cooling capacity	Ongoing monitoring for more detailed assessment
4	Heat Pumps	11 heat pumps are exhibiting unstable room temperature control	Ongoing monitoring for more detailed assessment
5	Heat Pumps	16 spaces served by heat pump are persistently above programmed set-point & upper comfort limit (79F).	Comfort may be increased by lowering room set-point temp. Check for broken equipment.
6	Heat Pumps	22 spaces served by heat pump are persistently below programmed set-point & lower comfort limit (74F).	Unnecessary energy use may be caused by overcooling. Confirm control sequence of equipment.
7	Air Handling Units	3 air handling units are exhibiting intermittent high frequency (on/off) cycling	Confirm control sequence for equipment.
8	Air Handling Units	Operation of 6 air handling units appear to not be connected to building CO2 concentration. Potential for demand based control by implementing CO2 schedules.	Confirm control sequence for equipment.

Floor Plan Visualization

Building Data Ingestion and Algorithmic Analysis





VAV14_2 exhibiting stuck damper

Commercial Deployment

Gabriel Peschiera

Breakthrough

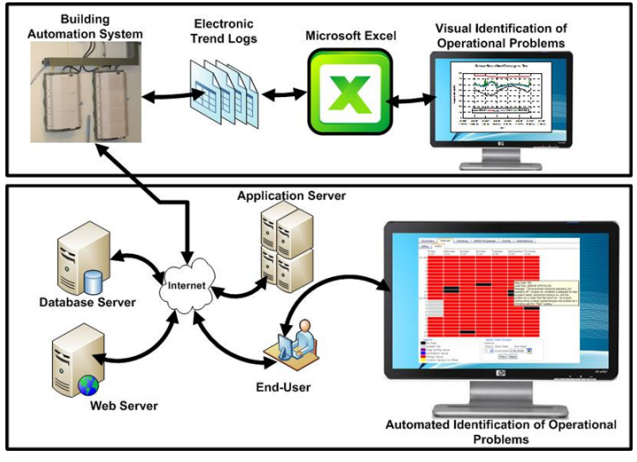
- Commercial customer facing AFDD web interface
- Highly specific, actionable insights to building operators
- Collaborative process with building engineers: integrated feedback and learning
- Accelerating deployment process with new batch of large commercial office buildings coming online around the world

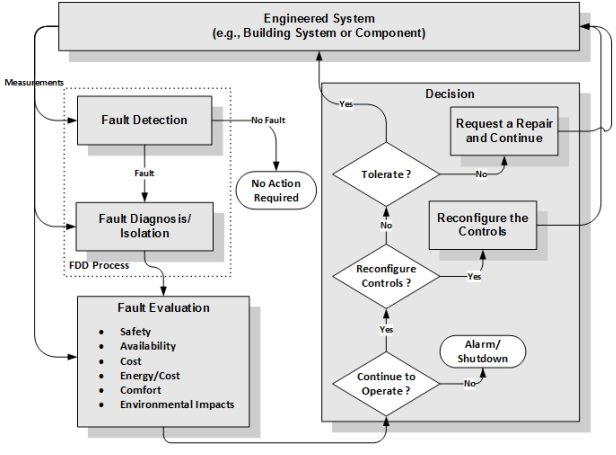
Challenges

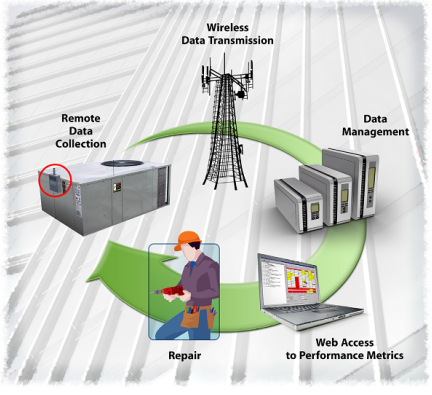
- Onboarding new buildings: handling inconsistent BMS point names, streamlining absorbing non-BMS building information
- Managing multiple interests: controls vendor, building operator, property owner, and property manager.
- Proving value: verifying energy savings, preventative maintenance benefits, and comfort improvements

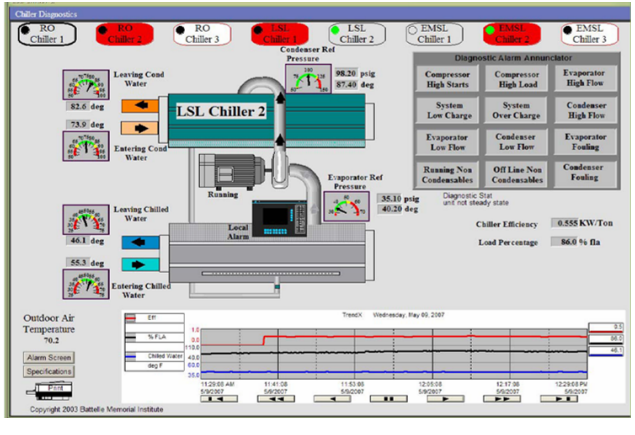
Srinivas Katipamula

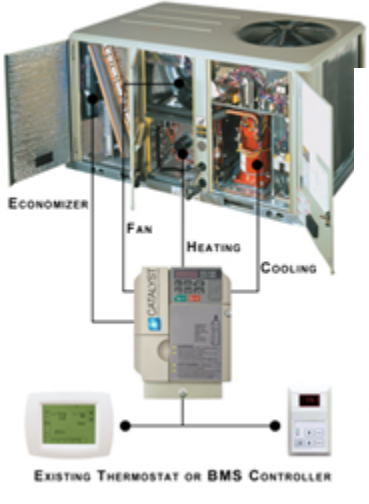
Pacific Northwest
NATIONAL LABORATORY

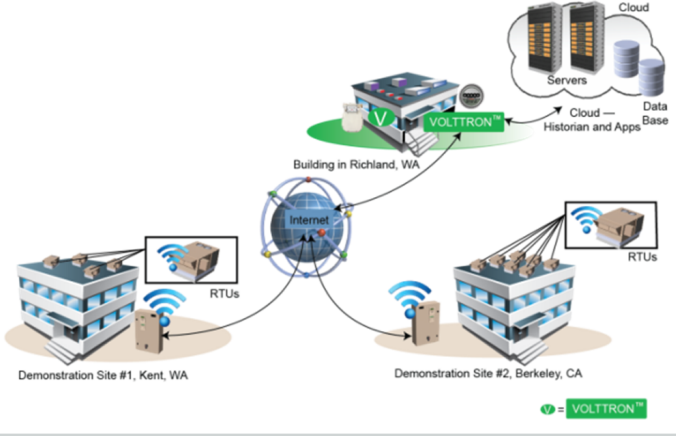












Srinivas Katipamula

Pacific Northwest
NATIONAL LABORATORY

Breakthrough

- Cost-effective control solutions for small and medium sized commercial buildings
- Self-correcting controls for large buildings
- Autonomous building operations - self-diagnosing, self-correcting, self-healing and self-optimizing

Challenges

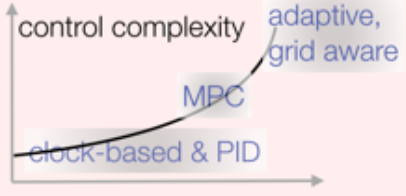
- Cost
- Overcoming split-incentives
- Industry reluctant to lead
- Not enough R&D investments in both private and public sector
- Lack of standard, open, scalable controls
- Lack of automated solutions

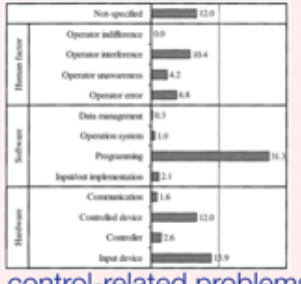
Michael Wetter

Problems:
No means for performance quantification that caries from design to operation.

Building controls are broken, yet their complexity increases for ZEB.

Lack of formalism and tool-chain despite increased complexity.





control-related problems (Ardehali, Smith 2002)

New generation computing tools for design & operation of buildings

Buildings library

EBC

IEA EBC Annex 60

$F(\dot{x}, x, y, u, \Theta) = 0$

Automatic code generation from Modelica to Niagara

design

Modelica/ C++

Modelica/ C++

FMU

FMU

$O(n)$

simulation

Spawn of EnergyPlus

logical

FMU

API

vendor-specific algorithms

operation

comm.

communication layer

physical

hardware

databases

web service

Michael Wetter

Breakthroughs

SW for design and operation on embedded HW and legacy building automation systems built on industry-developed standards.

Controls-oriented building modeling that integrates into design flows & product development process, used by major control vendors.

Built open-source community around open Modelica & FMI standards for buildings and community energy systems (IEA EBC Annex 60: 38 institutes, 16 countries, 5 years, around $25 million).

Challenges

Integrating workflow into the fragmented building industry.

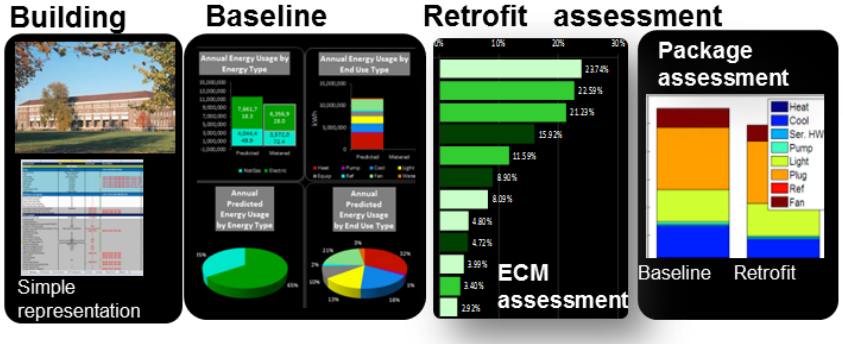
Have approaches to solve problem, but few universities teach model-based design methodology.

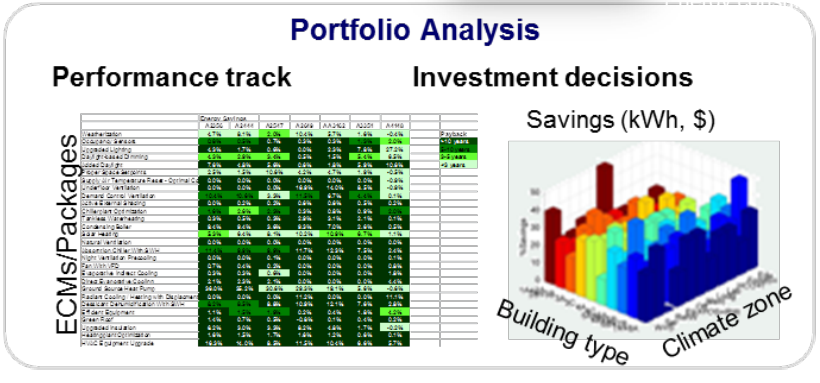
Scale computations from few rooms to 100s of rooms (generated from BIM) combined with HVAC & controls (cyber-physical systems).

BACnet disrupted building controls communication, how can modularity of Modelica & FMI standards disrupt design and deployment of control algorithms?

Marija Trcka

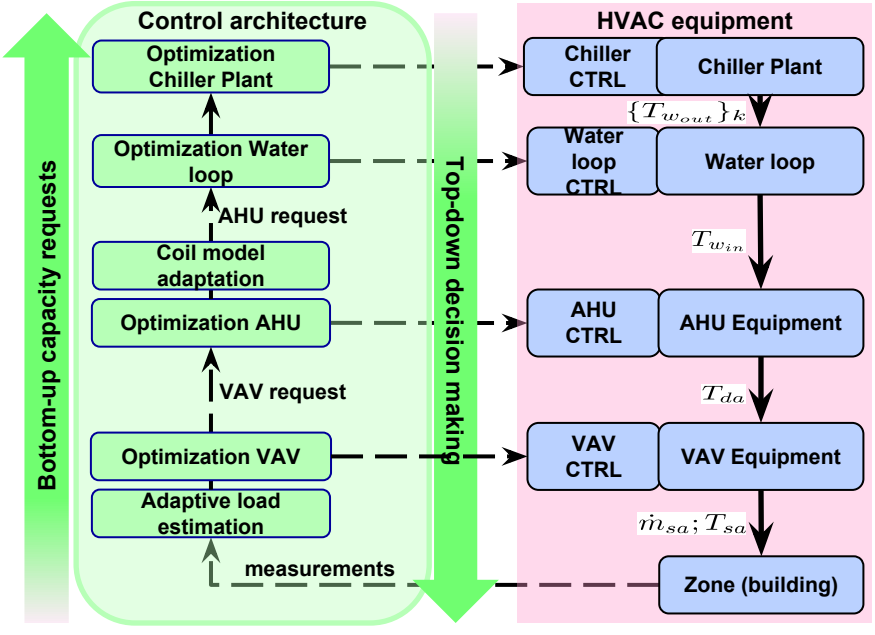
United Technologies Research Center





Retrofit assessment tool including investment and control measures

- Scalable: Approach based on a few data points
- Deployable: Automatic model calibration



Decentralized optimal control (Draguna Vrabie)

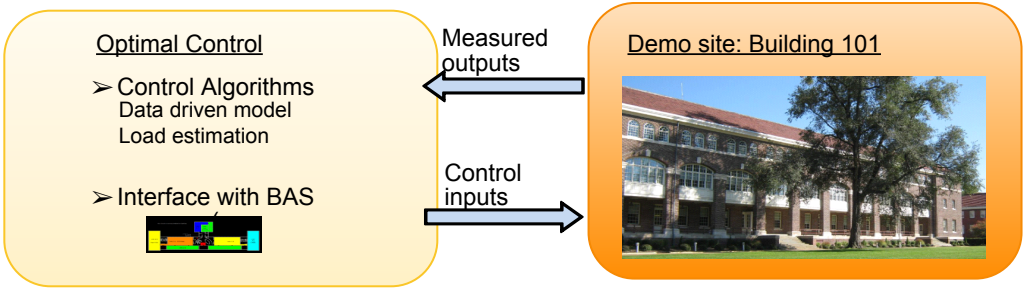
- Scalable: Approach mirrors current control architecture and hardware structure
- Deployable: Adaptive self-deployed online estimation models eliminate the need for manual model calibration and (re)tuning

Marija Trcka

United Technologies Research Center

Breakthrough

- Accurate retrofit and operational optimization screening potential
- Energy saving demonstrated in real buildings based on hybrid adaptable decentralized control

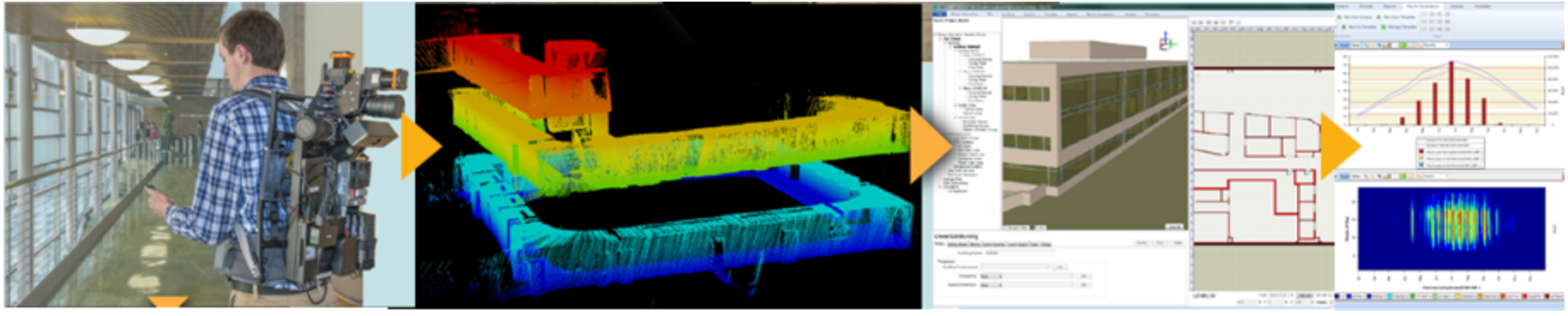


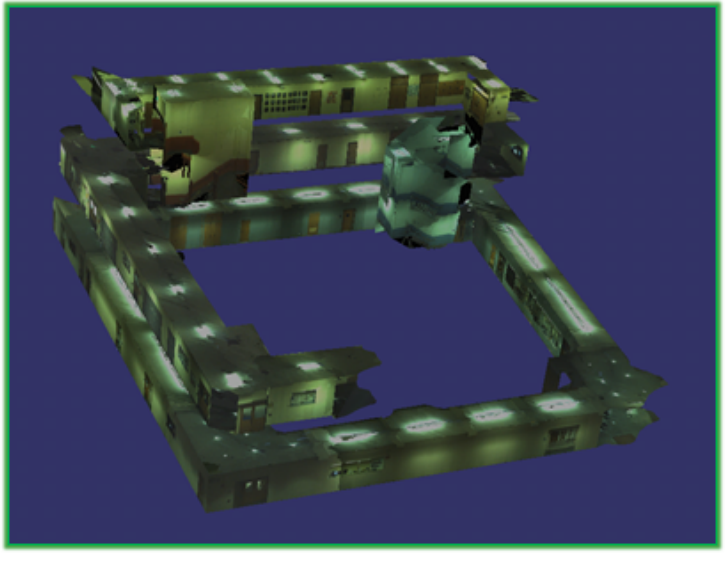
~17.5% energy savings

Challenges

- Ease of deployment of analytics on top of building automation / management systems (cost)
- Lack of common ontologies (semantics) for operational data points
- Lack of standardized approach to quantify achieved benefits

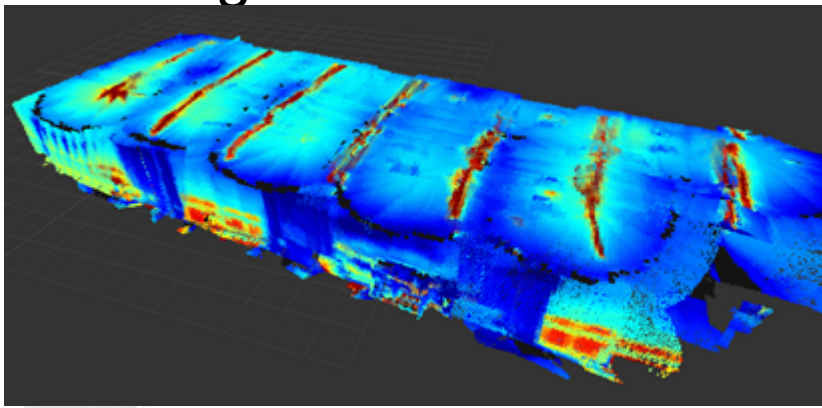
Avideh Zakhor

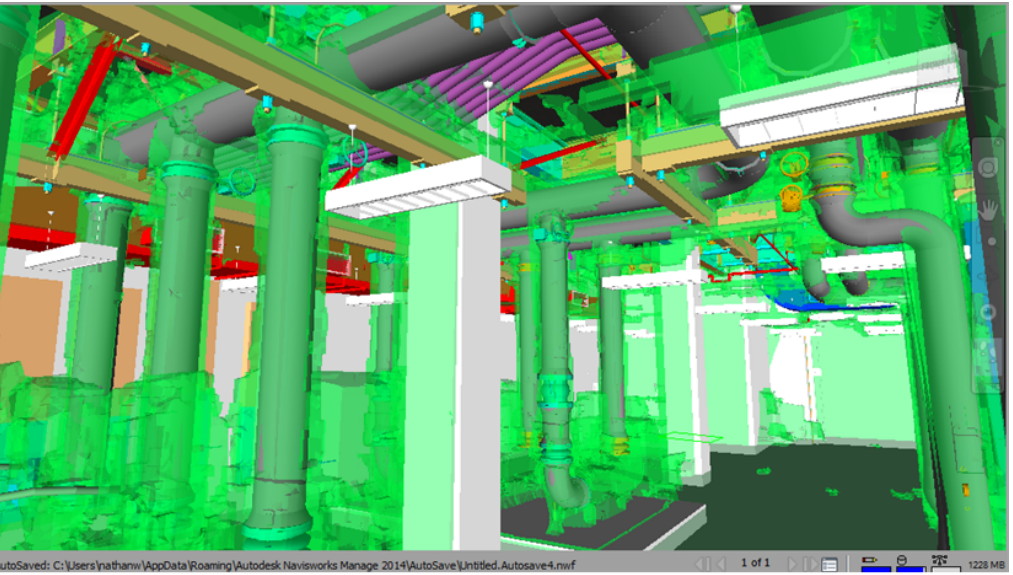




Avideh Zakhor

- Breakthrough: Fast, automated, capture and analysis of data for a pain-free energy audit for existing and new buildings
- Challenge: Reduce form factor





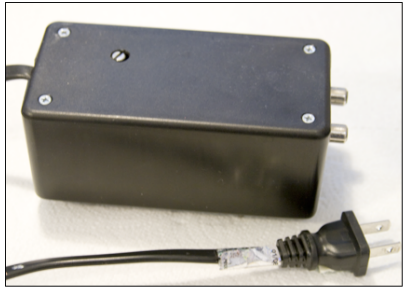
scan to BIM model comparison

Eric Schiff

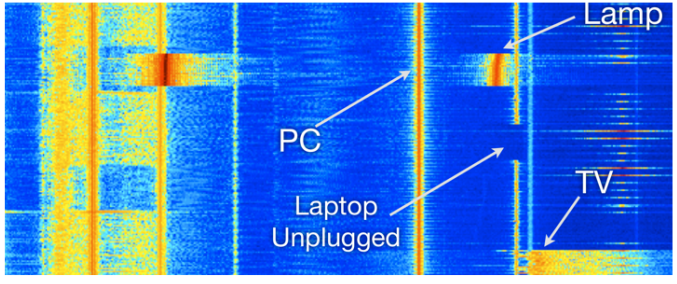
- 950 L'Enfant Plaza (1968)
- Rented by ARPA-E
- Legacy single pane windows: an intransigent problem.
- Workshop in early November

- On assignment to ARPA-E from Syracuse University
- Research on semiconductor and solar cell device physics

Sidhant Gupta



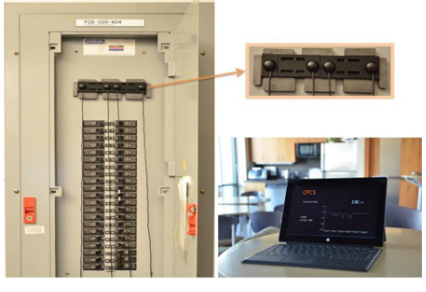
Single plug-in sensor capture EMI from appliances in building



Sample EMI observed over a home's power line. Notice distinct EMI from different appliances

Feature Extraction and **Machine Learning** Analytics

Automatic Appliance Usage Estimation



Novel **CT replacement sensor** for power measurement. Consumer deployable.

Real-time **disaggregated energy feedback**

Sidhant Gupta

Breakthroughs

- Developed novel easy-to-install sensing techniques for **retrofitting** buildings and homes for **fine-grained disaggregated energy** monitoring.
- Algorithms and systems for sensing and feedback of everyday human activities for promoting environmental behaviors. Giving consumers **actionable feedback**.
- Appliance's **internal electrical modes and failures** could be detected.

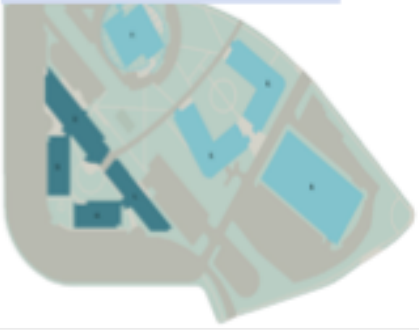
Challenges

- Hard machine learning and inference challenges to be addressed.
- Certain appliances with complex load pattern pose a problem.

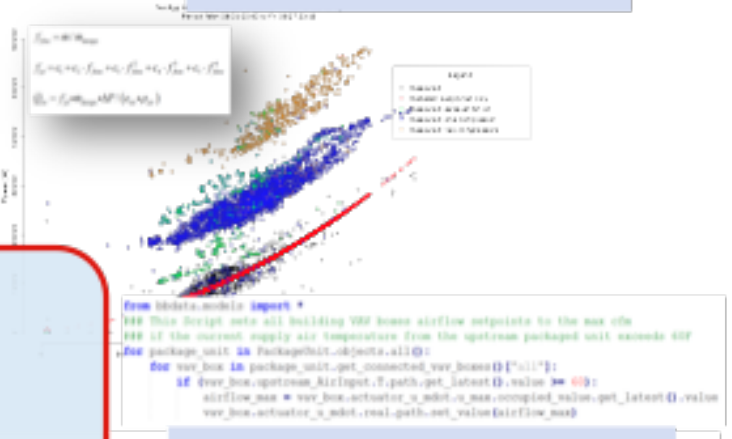
Yudong Ma

BrightBox Technologies

Connect Securely



Learn Models From Data



Autonomous
Real-time Cloud
Building Optimization

Optimize with Feedback

Deliver Savings and Comfort

Yudong Ma

BrightBox Technologies

Breakthroughs

•Secure, modular, modern, hosted, IT platform enables scalability
•Modularized Data Driven Modeling with Dynamic Learning
•Embedded integration with controls platforms (e.g., ALC) speeds deployment
•Customized optimization language for Large scale optimization problems (>500k variables >1M constraints)
•Compact platform for step-testing learning, control and verification
•Fast installation time
•Currently deployed in >1M sqf

Challenges

•Energy savings verification
•Market attraction
•Interface and transparency with facility operators

Alexis Abramson

Case Western Reserve University | Great Lakes Energy Institute

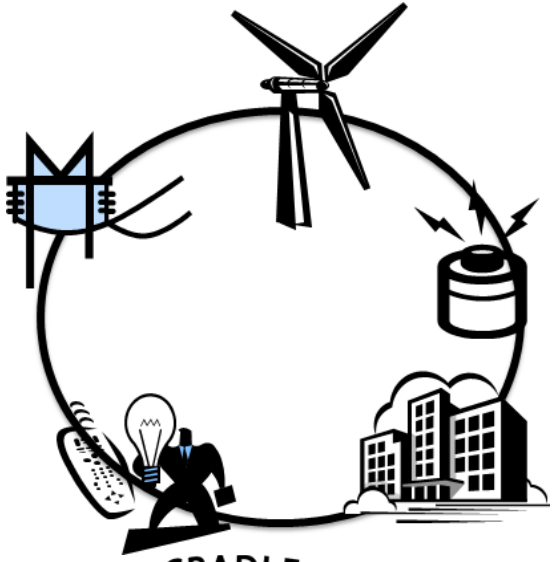
Prioritizing… *identifying areas of strength and growth*

Connecting… *across stakeholders to encourage partnerships and opportunities*

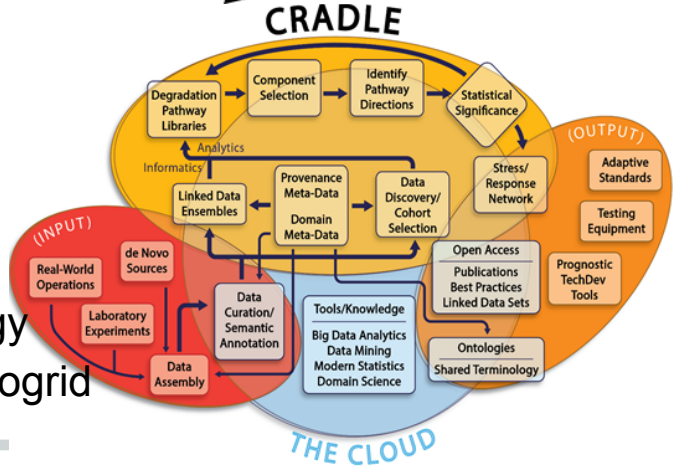
Empowering… *supporting stakeholders with core services that break down barriers to success*

GLEI

- Educational impact
- Breakthrough discoveries



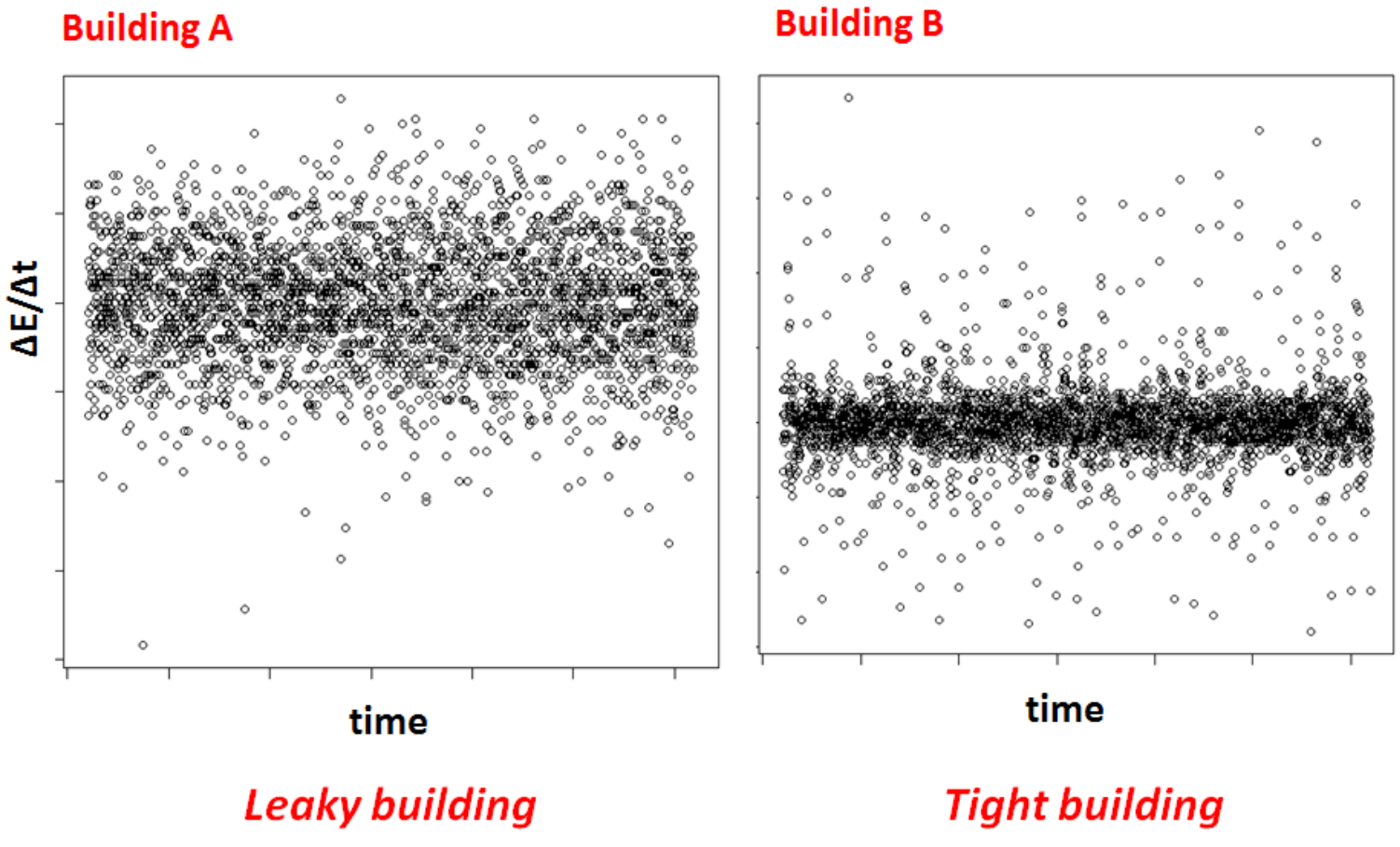
GLEI Faculty Director… empowering our faculty, students and partners to catalyze breakthroughs in energy sustainability.



Research… using data analytics to investigate building energy efficiency; transactive energy demonstration on campus microgrid

Alexis Abramson

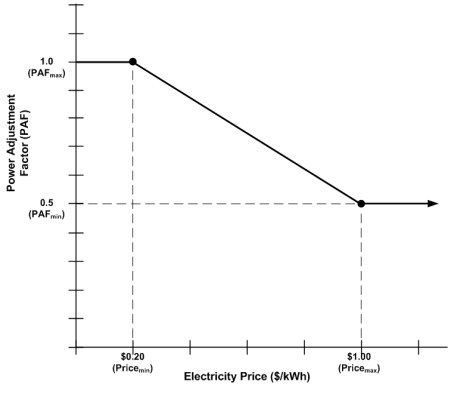
CASE WESTERN RESERVE UNIVERSITY | GREAT LAKES ENERGY INSTITUTE

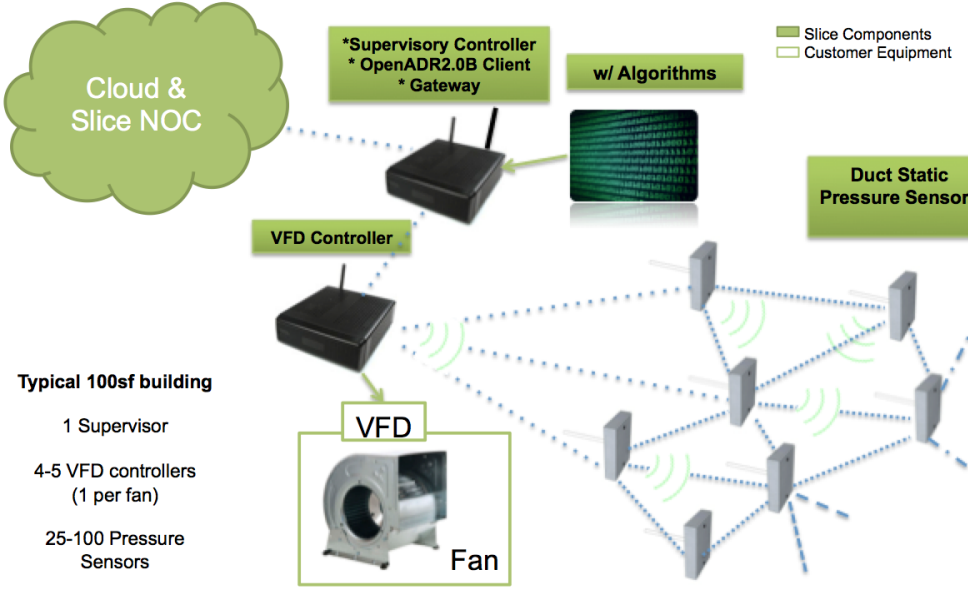


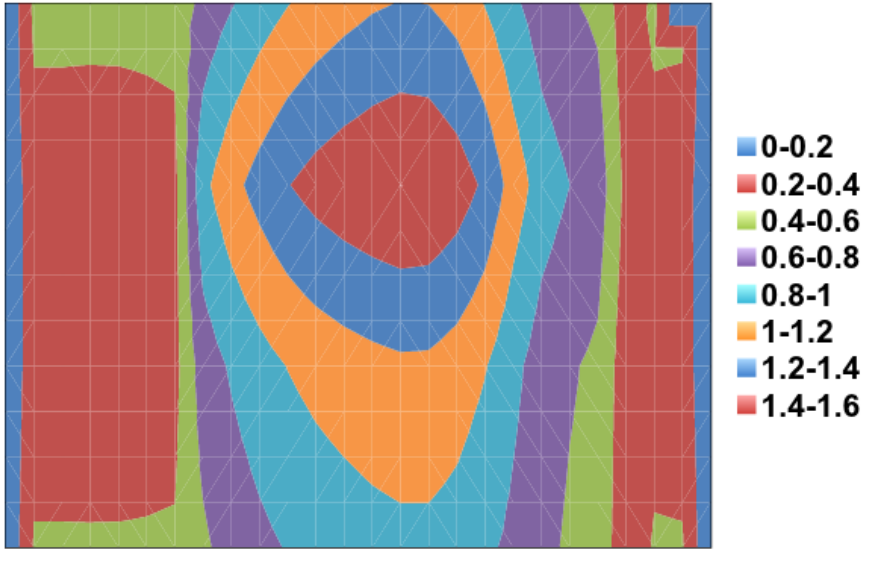
Dave Watson

SLICE DATA SYSTEMS

- Continuous dispatchable EE + Fast DR (24 x 7 x 365) = transactive energy
- Finding best loads in Buildings and connecting them with no loss of service
- Retrofits for existing building stock
- Economic, scalable with existing HVAC techs
- Left LBNL and co-founded Slice Data Systems 2012







Dave Watson

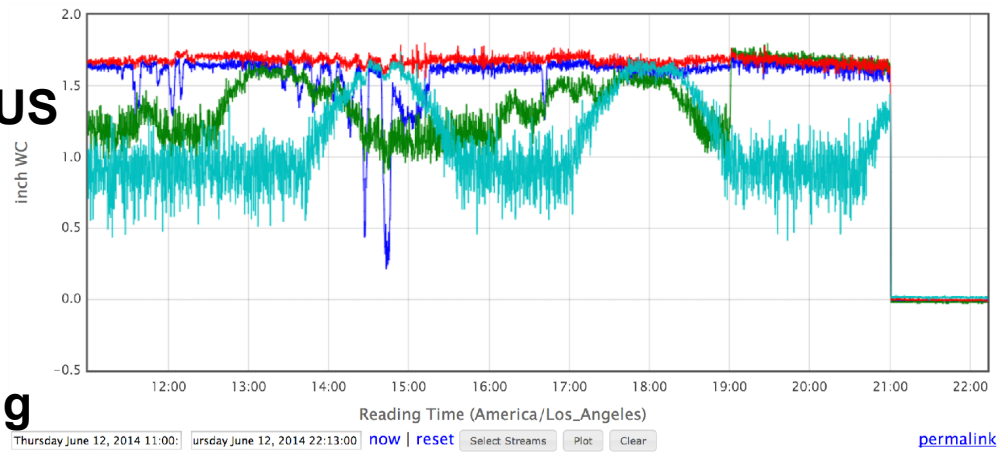
SLICE
DATA SYSTEMS

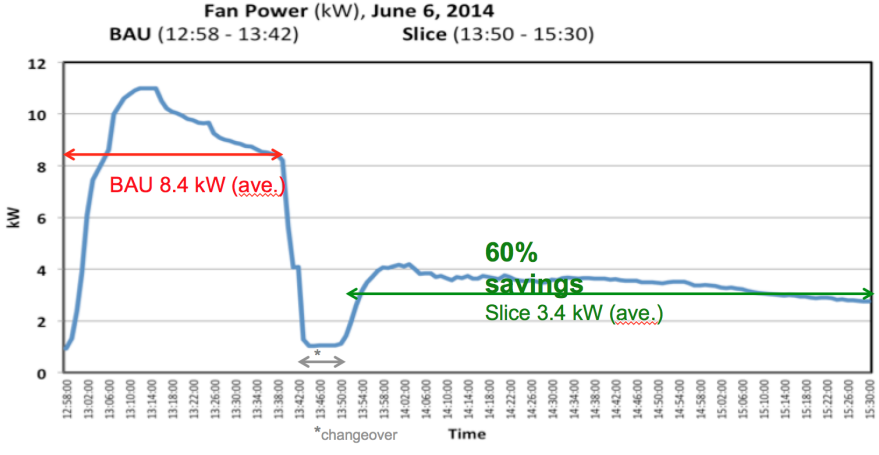
Breakthrough:

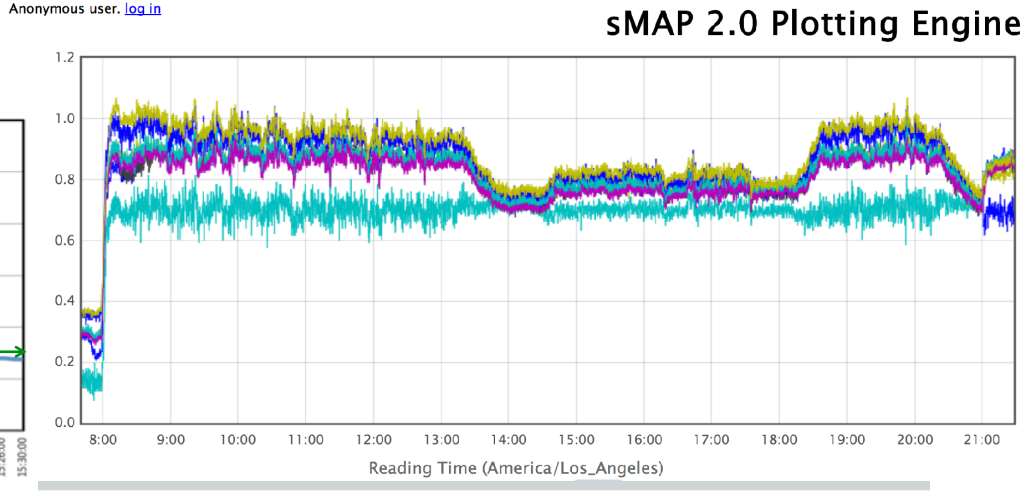
30-60% fan savings (EE) = $6B / yr. in US
Add'l value for ancillary services

Challenges:

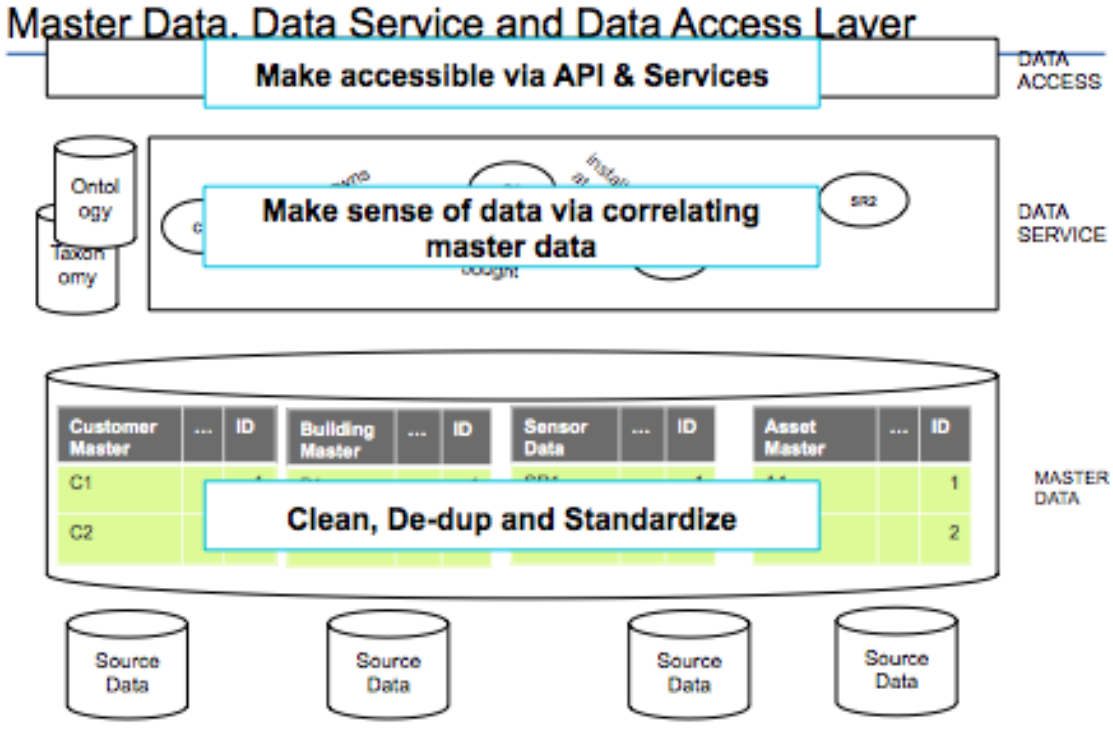
- **Low cost Submetering & Telemetry**
- **Utility programs that value balancing resources**
- **"Grid needs" signal to track**







Youngchoon Park & Abu



Youngchoon Park & Abu

Johnson Controls

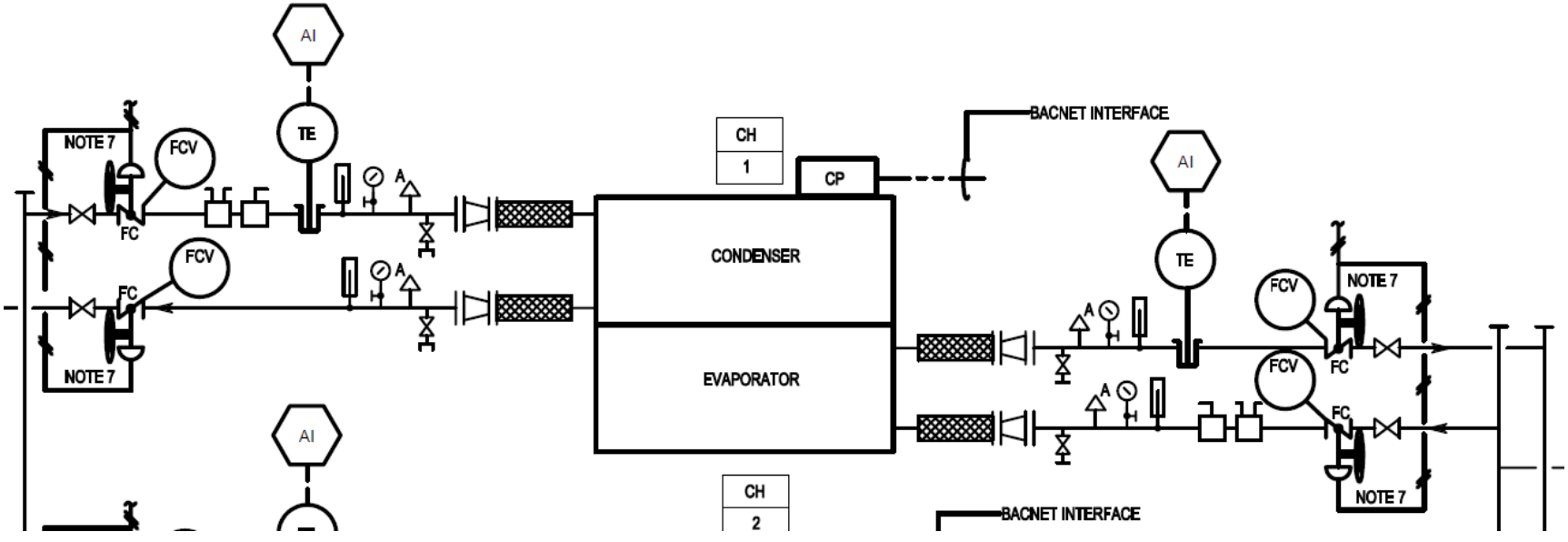
Partially automated configuration mediation

Self configuration and commissioning

peel and stick sensors...

Ryan Lee

A/E/C Industry



Commercial Building HVAC Design

Ryan Lee

A/E/C Industry

Breakthrough

- Designed HVAC systems and associated Building Automation Systems for highly complex Science & Technology projects
- Implement HVAC controls measures to optimize and reduce building energy consumption

Challenge

- Implementation - predictable and reliable operation
- Creating systems that are “user-friendly” for both the installer and the owner
- Measurement & verification of building energy performance
- Improving building owner incentives and interest in high performance systems

[Name] [Logo]

Image(s) w/ Captions (s)

Representing what you currently do

Go Here

Name [Logo]

Image(s) (w/ optional caption) representing

(Your) Latest Breakthrough
AND / OR
Biggest Technical Challenge To Overcome (In Your Area)

In The Area of Building Energy Management