DR Sense: *Automated and Scalable Assessment of Demand Response for Green Building Portfolios*

Ram Rajagopal, Abbas El Gamal
and Amit Narayan

Dept. of Civil and Environmental Engineering

Dept. of Electrical Engineering

DR Sense

Low-cost automated self assessment tool for building managers to evaluate DR potential and DR strategies for their building portfolio, to achieve greening goals.

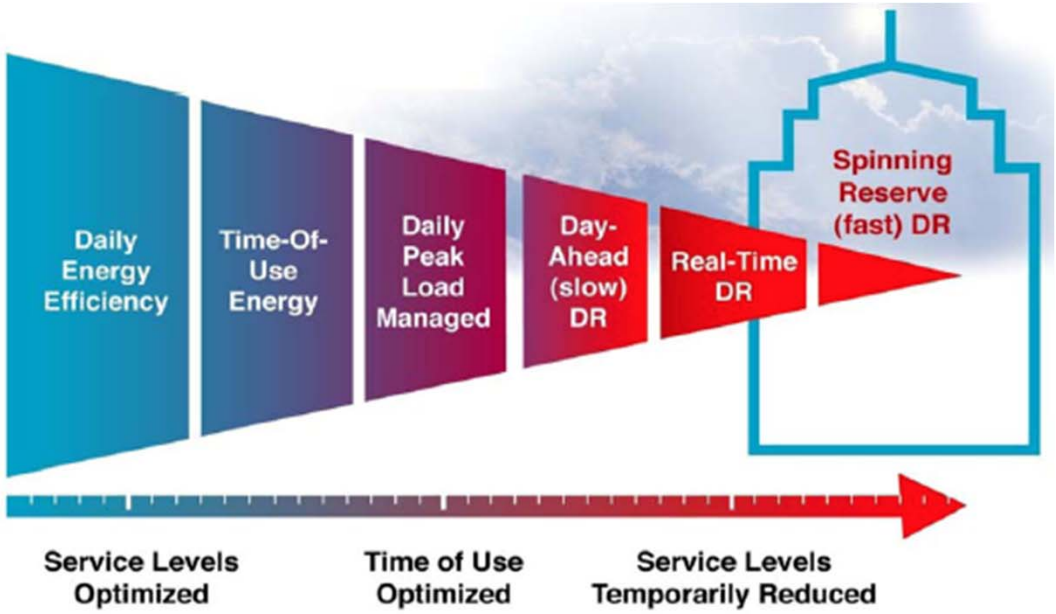
It enables scalable, data driven, real-time evaluation and management of facilities in DR.

Who are we?

- *Prof. Ram Rajagopal specializes in sensing and operation of built environment systems relying on massive data driven models. He currently directs the Stanford Sustainable Systems lab.*
- *Prof. Abbas El Gamal's is a world leader in sensing and communication systems and infrastructure. He* has authored or coauthored over 200 papers and holds 30 patents in these areas.
- *Dr. Amit Narayan is a leader in developing systems simulation and evaluation tools for very large scale systems. He currently directs the Stanford Smart Grid Simulation efforts.*

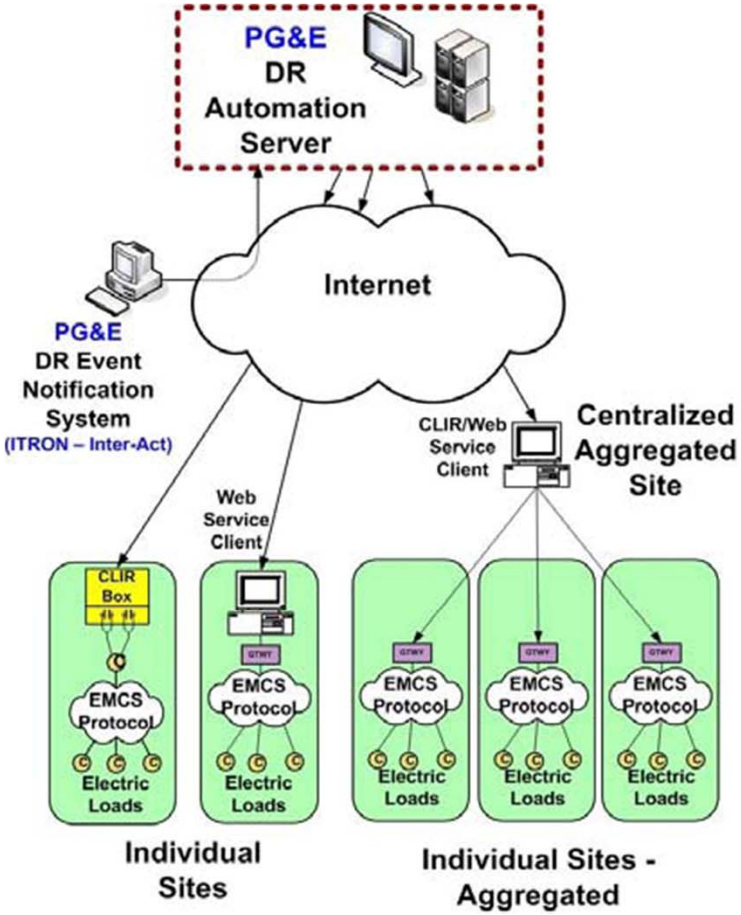
Demand Response

- *Greening a building requires measures at different time scales*



- *Demand response is profitable greening due to utility incentives and* **peak pricing of energy**

Utilities offer programs and infrastructure



DR Option	Data Source(s)	Eligible Customers (peak demand)
Optional hourly pricing	Central and Southwest (CSW) Utilities' (now American Electric Power) two-part RTP rate	<1500 kW
Default hourly pricing	Niagara Mohawk Power Corporation (NMPC), a National Grid Company, SC-3A tariff	> 2000 kW
Short-notice emergency program	NYISO Emergency Demand Response Program (EDRP)	> 100 kW
	ISO-NE Real-Time Demand Response (RTDR) Program	> 100 kW
Price-response event program	ISO-NE Real-Time Price Response (RTPR) Program	> 100 kW
Critical-peak pricing	California Utilities[1] Critical Peak Pricing Program	> 200 kW; > 100 kW for SDG&E

[1] Pacific Gas & Electric (PG&E), Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E)

Various programs

PG&E Auto-DR program

Building manager needs to know

- How much **DR is available for a building**?
- How much **DR is available for a portfolio**?
- What DR strategies are best suited for each building? **What strategy to use when?**
- For which buildings is it profitable to incorporate DR? **Which program should it be enrolled in?**
- How to **maximize DR potential for entire portfolio** given cost/benefit analysis?

Assessing DR today

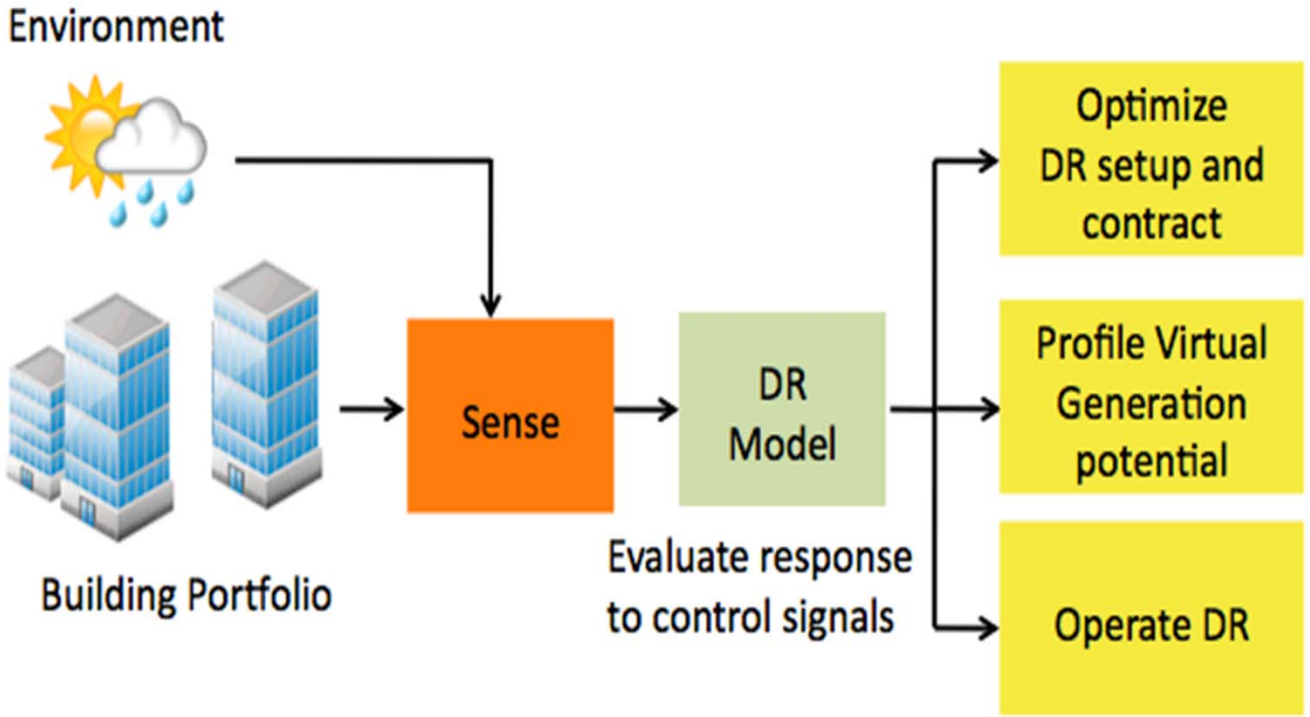
- *Requires expensive audit:* ***not profitable nor feasible for most buildings***
- *One-time only and does not account for* ***real-time*** *changes in building use and operations:* ***it is not continuous commissioning***
- *Dynamic sensing available in buildings is not exploited:* ***does not benefit from dynamic BIM***
- *Building portfolio is not considered simultaneously:* ***failure to exploit complementarity***

Project Goal

- *Develop DR Sense - a low-cost automated self assessment tool for building managers to evaluate DR potential and DR strategies for their building portfolio:*
  - **Integrates** *existing audit information by using building* **simulators**
  - *Uses sensors to* **self-calibrate** *data-driven DR assessment models*
  - **Clusters** *and compares multiple buildings in a* **portfolio** *to assess joint potential*
  - **Forecasts** *Virtual Generation characteristics of each building and of portfolio in* **real-time**

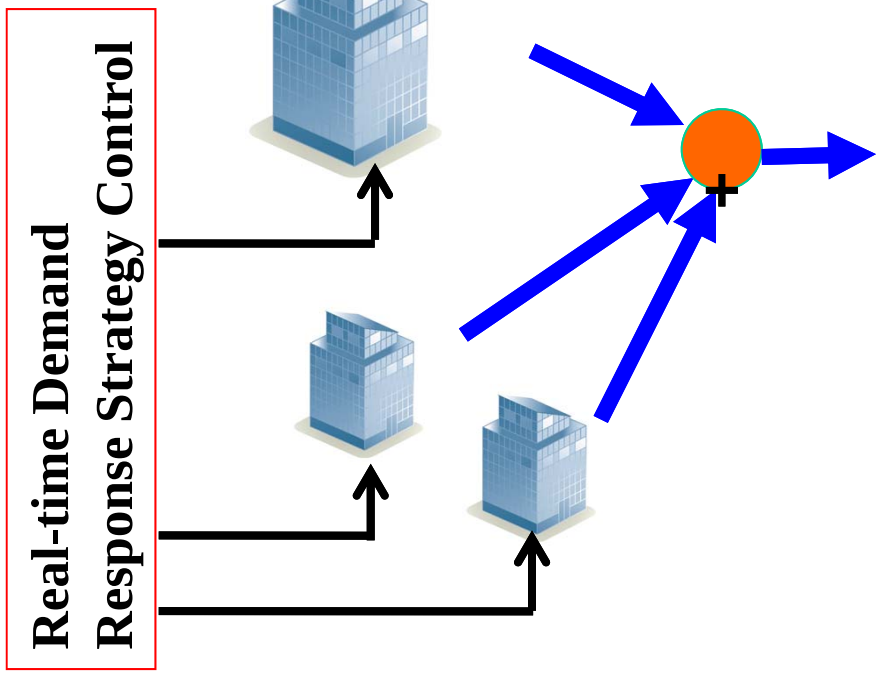
- *DR Sense can turn energy consumption flexibility into profit*

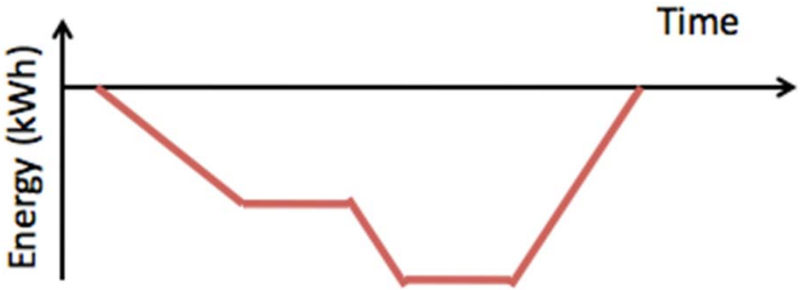
DR Sense



- *DR Model includes data-driven DR models and building simulators*
- *Model is executed in a high performance data mining cloud system*
- *Information is aggregated from a building using energy management systems*

Building Portfolio is a **Virtual Generation** *Asset*



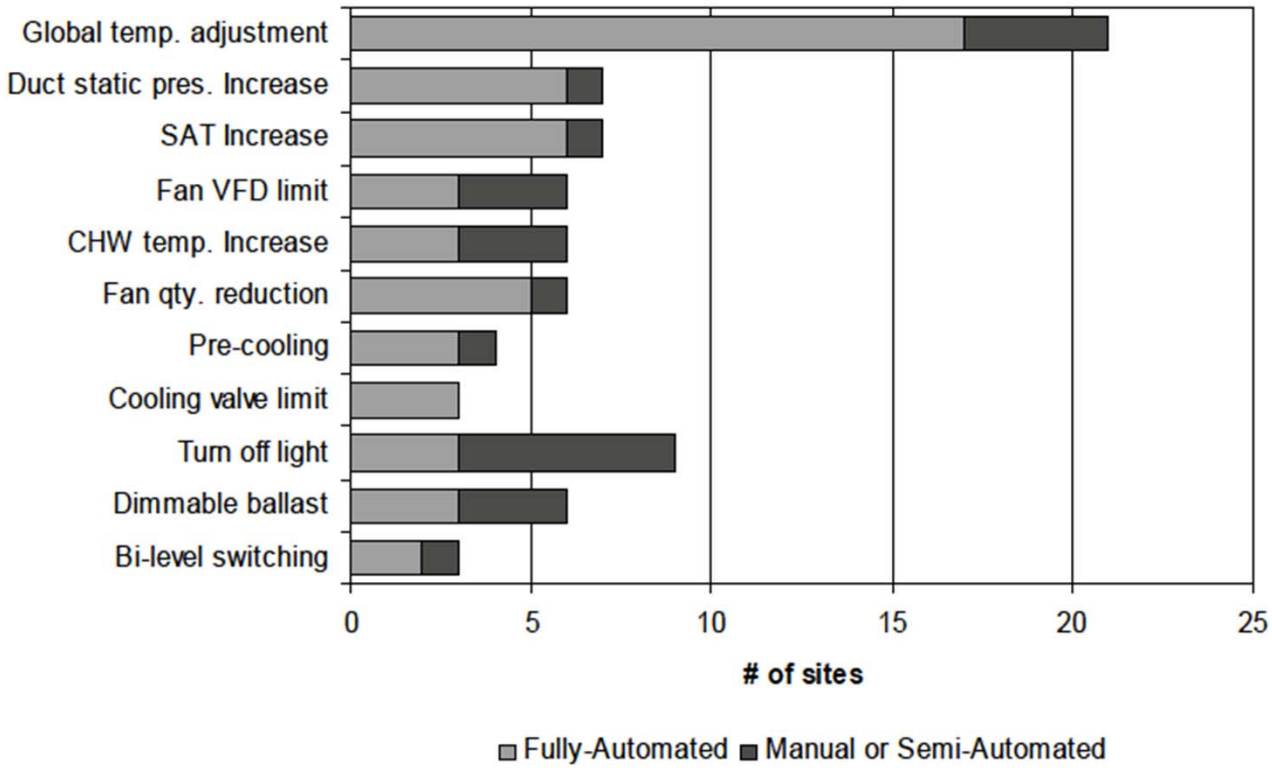


Virtual Generator Profile to offer in the market

Accurate real-time prediction of DR from building is needed to provide VGP in actual operations

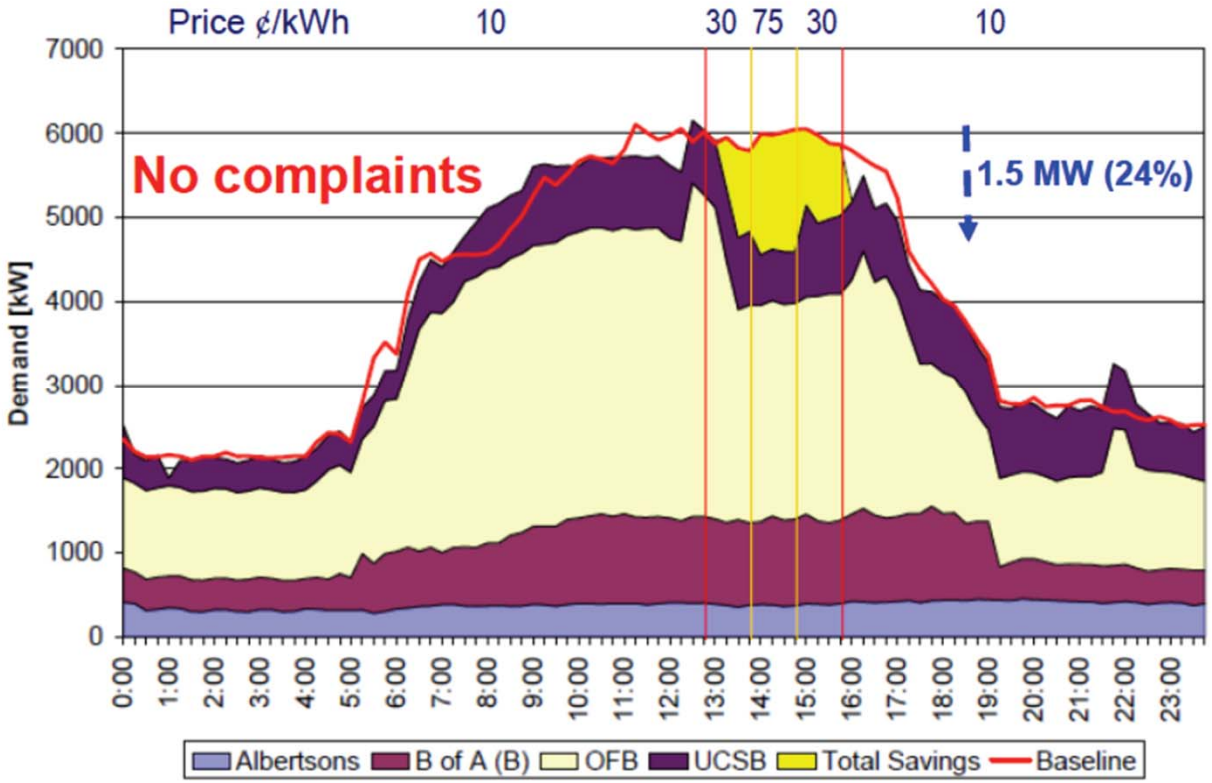
- *Information technology and smart grid advances turn buildings from passive energy consumers to active (virtual) generators*

DR Strategies: what are they?



- *Strategies are parameterized building system settings and procedures that result in changes in energy consumption*
- *Forecasting effect of a strategy consists in evaluating energy increase/reduction profiles when parameters are chosen*

*Strategies matter and **what if** matters even more*



- *Wrong strategy fails to achieve any response*
- *Strategy works now but not tomorrow*
- **Forecasting** *is key to provide VGP for a building*

Existing approach does not scale

- Models are complex and evaluate all internal building dynamics requiring extensive audit and manual calibration: need an approach that scales
- Forecast actual energy consumption- actually only need energy difference for DR strategies
- Massive data is available: leverage across buildings

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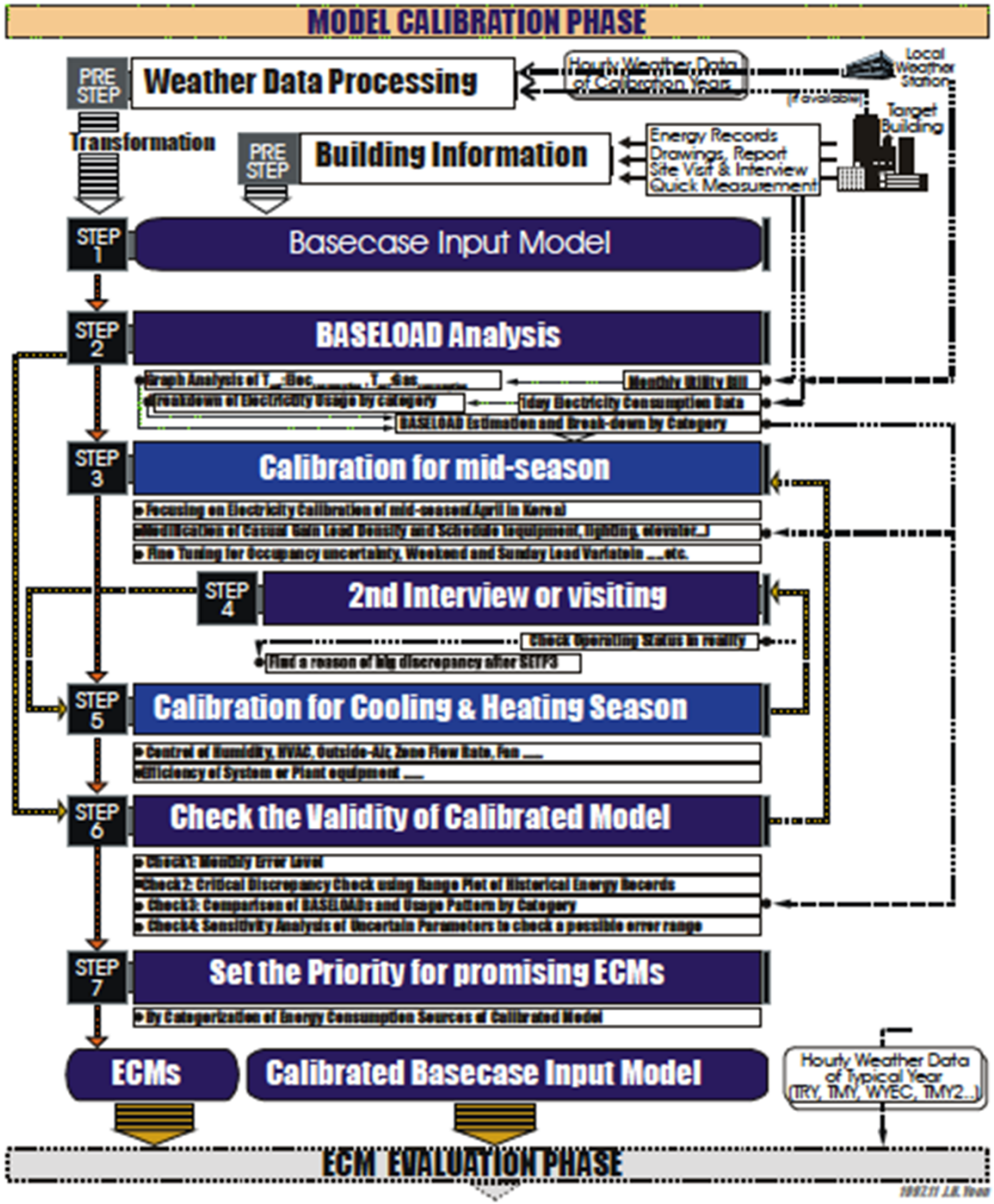
Typical "Seven Step" Calibration



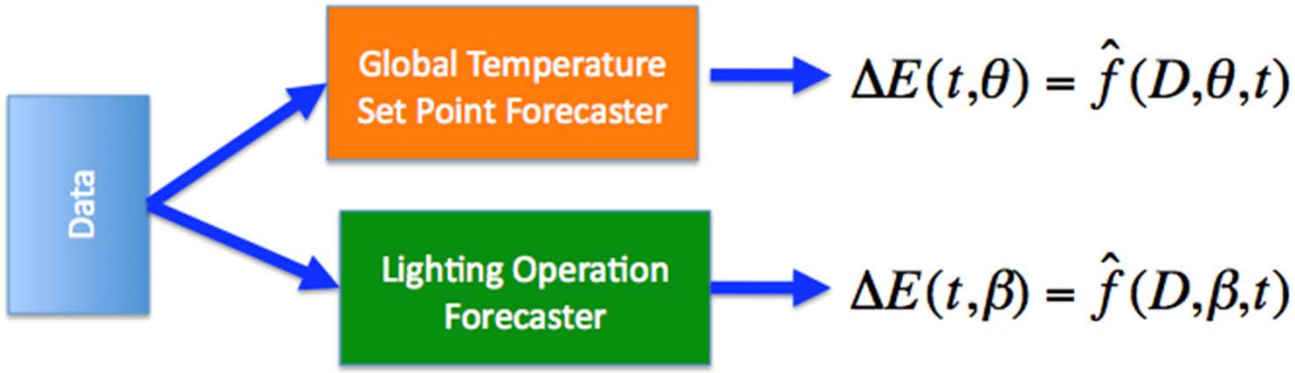
CIFE TAC 2011

One time calibration accuracy is not great in real-time

- Actually modeling all building dynamics
- Some DR benefits are of the order of 1-3%...

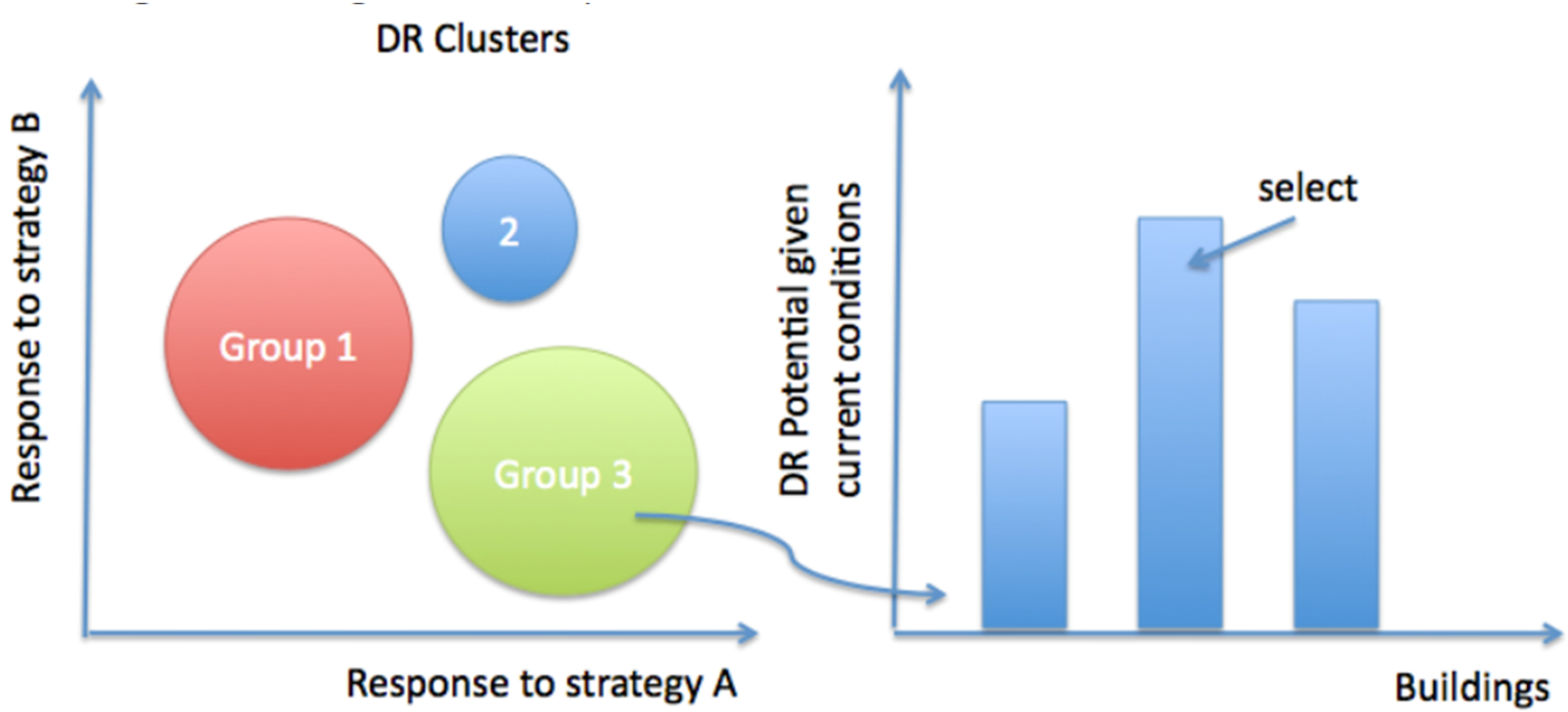
DR Sense Forecaster

- *Ensemble data-driven forecast algorithms*
- *Each algorithm focuses on one strategy alone*



- *Advantages: can perform sensor variable selection, can leverage data across buildings*
- *(1) Use simplified technical models for each system: time-series approach*
- **(2) Use high performance data mining algorithms: SVM, Bayesian Nets, Ensemble Kalman Filters**

DR Sense Cluster



- *Evaluate the DR potential in real-time using DR Sense Forecaster*
- *Cluster buildings by response profiles to one or more strategies*
- *Identify individual best response building*

Platform challenges

- Massive data being generated by buildings: Y2E2 alone, 1Gb per year => easily grow to TB in large portfolios
- Communication and data collection setup is usually adhoc and very difficult for building managers that manage large portfolios
- Scalable evaluation requires processing enormous amounts of data (even larger if you are an utility!)

DRSense Platform

- *Cisco Building Mediator for interfacing building systems and data stores*

- *Massively parallel and distributed data computing using Hadoop and Map-Reduce*

- *Scalable low cost storage using cloud computers*

- ***We leverage technologies that have enabled large scale web-data analysis to buildings.***

Data availability and industry

- Extensive high resolution data collected from **Y2E2** building systems with calibrated EnergyPlus model and other buildings on campus
- DR data provided by **PG&E and LBNL** for thousands of commercial buildings in Auto-DR program
- Building Mediator data for selected deployments provided by **Cisco**
- **Palo Alto Utility** data from commercial buildings for their DR rollout in 2011/2012

Project plan

- **Milestone 1:** *Use EnergyPlus model for Y2E2 to rank multiple DR strategies and evaluate DR savings prediction (First 4 months)*
- **Milestone 2:** *DR Forecaster model for Y2E2 for HVAC control and/or lighting control strategies using time-series analysis (First 4 months)*
- **Milestone 3:** *Change building set points according to simple strategies and validate the models above (First 6 months)*
- **Milestone 4:** *Advanced DR Forecaster model for HVAC using simplified heat dynamics. Compare to previous model. Only partially achievable in year 1. (Second 6 months)*
- **Milestone 5:** *Build software tool incorporating DR Forecaster and a DR Cluster to group and analyze multiple buildings (Second 6 months) to deliver a prototype of our research*

Project Risks

- *EnergyPlus model for Y2E2 is not well calibrated*
- *Sensors in Y2E2 do not provide adequate coverage for desired problems*
- *Models do not translate across buildings*

Future steps

- *Continued development of software tool for real-time DR assessment and provide it as an open source tool*
- *Add additional DR strategies*
- *Add interfacing with building energy management systems (including Building Mediator) to enable continuous commissioning*
- *Build a Virtual Generation model for each building based on DR Forecaster characterizing capacity, cost, ramp-rates, etc*
- *Use VG models for buildings to perform full grid scale simulation using GridSpice*

Seek DOE and NSF funding

Questions?

Thank you!