Delivering Energy Efficient Buildings: Deploying Advanced Computing In Industry

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Key Points

- Substantial energy use reductions in built infrastructure can be realized using an integrated systems approach (70-80% reductions possible)
- *Simulation-based design* is prevalent and being practiced in buildings industry. This is inadequate for decision making and of limited value
- Building industry has different needs for computation
  - Multi-physics, multi-scale (~O(10^6) range) dynamics encountered
  - Optimize among design choices at system level (100's-1000's of components, controls, sensors…)
  - Assess performance uncertainty and robustness of system choices
  - On-line estimation, filtering, optimization, control, data assimilation
- Transformative impact achievable by directing advances in computing to create algorithms and toolboxes that can be used by buildings industry
  - Productivity: Reduce design cycle time from months → days/weeks
  - Quality: Reduce performance uncertainty from >30% → <5%
  - Cost: Cut commissioning and O&M costs by 2-5x (reduce from months → days)

Delivering Energy Efficient Buildings: Industry Drivers

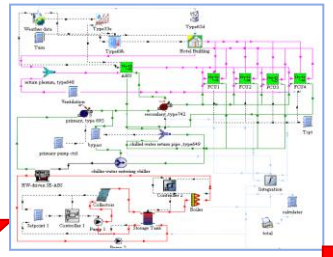
	Concept & Design	Build	Operations & Maintenance
Industry Players	A & E Firms	Contractors, OEM's	Property Managers & Operations Staff

100kwh/m²/y

Low Energy

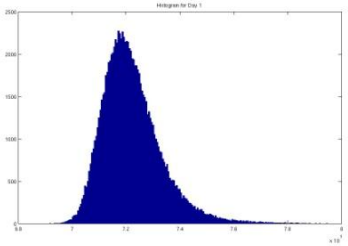
Savings Potential

Unaware

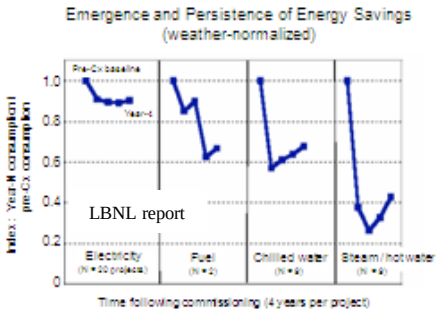


Design Not Scalable

Miss



Systems Not Robust



Loss

Benefits Do Not Persist

Current State

300kwh/m²/y

Industry Situation	EEB's can take up to 1 year to design & optimize	Delivered system performance vary by >30%	>20% energy wasted in operations
Industry Impact	O($M's) spent for each building!	Huge "untapped" margins in delivered performance	Energy spend 5-10% of operating cost Up to 30% spend on O&M cost

Industry Needs Tools That Improve Decision Making

Need computational environments that support design methodology throughout delivery

Industry Value Chain

Plan

Select system architectures

Design

System & component performance analysis and specification

Control & software definition

Robustness & risk assessment

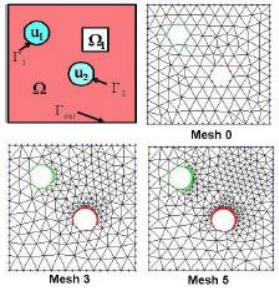
Build

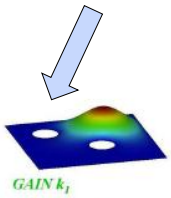
System verification testing, installation & commissioning

Operate

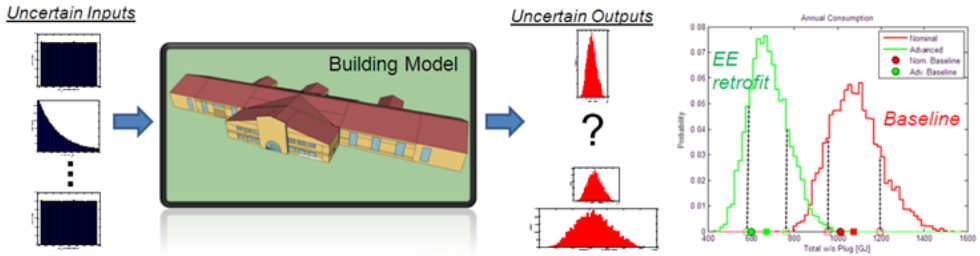
Performance monitoring, optimization, diagnoses

Tools for optimization





Uncertainty management tools

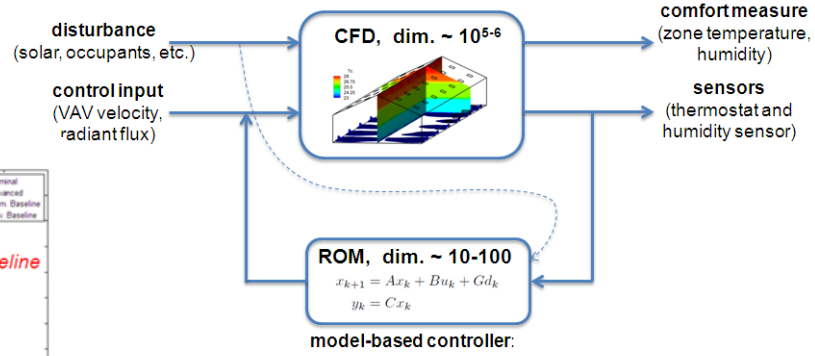


100's-1000's Computationally Efficient Sampling **10's**

Monte Carlo requires ~10^4-10^5 simulations!

Improve quality of model-based design decisions

Toolboxes for control design



Reduced-order models with valid dynamics for control design and testing/verification

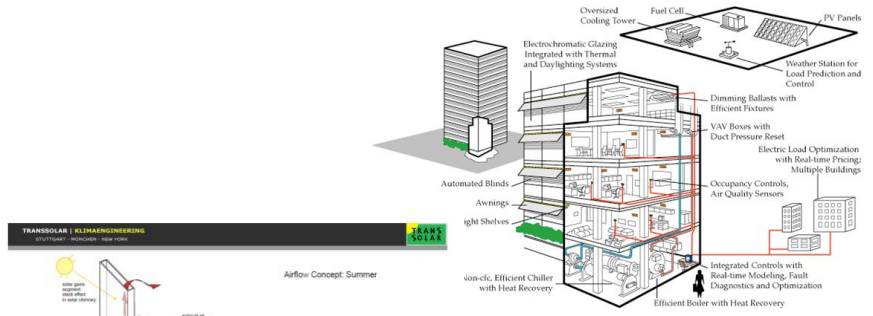
Back Up

Forward Simulations for Building Scale Problems

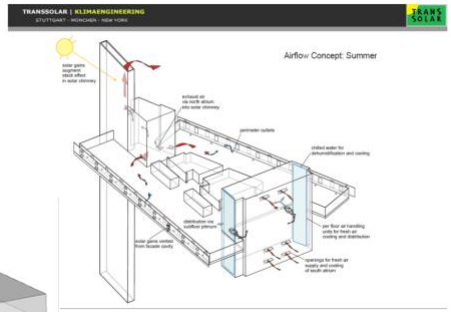
Whole Building Simulations (complex geometry, multiple sub-systems, and realistic indoor/external uncertainties)

Multi-zone Building Simulation (simplified geometry and boundary conditions)

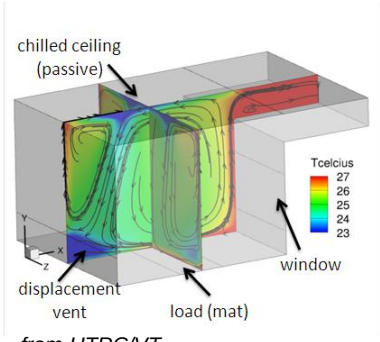
Isolated Thermal Environment in an Individual Zone/Room



from LBNL



from Transolar Engineering



from UTRC/VT

10 TFlops → 10 Pflops Computation Capability*

Key concerns to industry are with "decision making" *not* just prediction
Higher fidelity simulations will not do!

* Assuming less than 1hour turnaround for practical design calculations (J. Borgaard, VT)

Vision

We need to do more transformational research at DOE … including **computer design tools** for commercial and residential buildings that enable reductions in energy consumption of up to 80 percent with investments that will pay for themselves in less than 10 years

Dr. Steven Chu, House Science Committee Testimony, March 17, 2009

We will nurture a **system integration approach to building design, aided by computer tools with embedded energy analysis.** It was the system integration of the automobile engine, transmission, brakes and battery that enabled Toyota to create the Prius. With computer control of ignition timing and fuel mix, today's automobile engines operate at 20 percent higher efficiency. With computer monitoring and continuous, real-time control of HVAC systems, lighting, and shading, far more spectacular efficiencies can be realized in buildings. There is a growing realization that we should be able to build buildings that will decrease energy use by 80 percent with investments that will pay for themselves in less than 15 years. Buildings consume 40 percent of the energy in the U.S., so that energy efficient buildings can decrease our carbon emissions by one third.

Secretary Chu, Caltech Commencement, June 12, 2009