

Computational Needs for Design, Optimization, Control, and Analysis of Energy Efficient Buildings

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**Computational Science Needs in the Design, Optimization
and Operation of Energy Efficient Buildings**

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Stakeholders for Computation Impacting Building Efficiency

- AIE practitioners
- Policy makers
- Regulators
- Researchers
- Building occupants
- Industry
- Utilities
- Manufacturers

GOAL: Design and operate buildings for energy efficiency over lifespan, accounting for:

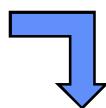
- Internal energy, air, water, occupant flows
- Building/building and building/environment interactions
- Building structure, usage, and energy supply system evolution
- Real-time forecasts and feedback on multiple time scales



So Where Do Buildings Come From?

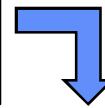
Developer/Owner

- May Be Public or Private
- Defines Baseline Requirements



Architect

- Designs General Building Form
- Insures Livability, Usability

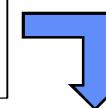


Impacts of computational science:

- **Shorten development time (currently years)**
- **Move toward a more iterative process, reducing late retrofits/recourse**

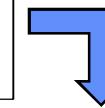
Structural Engineer

- Designs Structural Systems
- Insures Building Stands Up



EE/ME/CEs

- Designs Non-Structural Systems
- Lighting, HVAC, Water, etc.



**These are the professions of
*Architectural Engineering***

Construction Engineer

- Designs Construction Plan
- Oversees Building Realization



Risk Quantification

- **Target Audience: Developers and Owners**
- **Goals of Simulation Tools**
 - **Predict real-world building performance**
 - Permit evolution in use of building over lifespan
 - Include sensitivity to full range of expected conditions in computing estimated costs
 - **Convey building performance in relevant terms**
 - Quantify initial and operational costs
 - Provide accurate estimates of resource inputs



Optimal Building Design

- **Target Audience: Architects and Engineers**
- **Goals of Simulation Tools:**
 - **Provide for integrated design of buildings**
 - Remove artificial barriers between design stages so that more relevant design space can be considered
 - Facilitate incorporation of energy use as an equal partner to architectural and structural considerations
 - **Support optimal building design decision-making**
 - Compute financial and resource costs of trade-offs among architectural, structural, and environmental systems design decisions



Building Life-Cycle

- **Target Audience: Developers and Architects**
- **Goals of Simulation Tools:**
 - **Support agile response to evolution of building function over building's lifespan**
 - **Permit high-level design decision-making that will insure against costly side-effects developing as the function of a building evolves over time**



Model Reduction and Hierarchy

- **Target Audience: Architects and Engineers**
- **Goals of Simulation Tools:**
 - Reduce complexity of building models
 - Permit manageable set of parameters for control
 - Permit real-time management of building systems
 - Insure that reduced models are accurate
 - Create hierarchy of models to support adaptive error control in reduced models
 - Provide appropriate measures of uncertainty



Modular Software Design

- **Target Audience: All Stakeholders**
- **Goals of Simulation Tools:**
 - **Provide for rapid development and revision of all simulation tools used for building design**
 - Incorporation of new building technologies requires supporting software be rapidly redeployable
 - Supporting integrative building design will require integration of disparate software components
 - **Support appropriate computing platforms**
 - Need seamless migration to new HPC architectures
 - Tools must scale down (e.g. embedded intelligence)



Quantifying Optimal Performance

- **Target Audience: Developers and Engineers**
- **Goals of Simulation Tools:**
 - **Support optimal performance in engineering terms**
 - Continuously monitor and compare all aspects of building systems performance to theoretical ideals
 - **Support optimal performance in financial terms**
 - Aggregate systems-level performance data into relevant form for owners and operators
 - Provide financial and resource data to aid in optimal operational decision-making



Intelligent Control and Data Assimilation

- **Target Audience: Building Systems Engineers**
- **Goals of Simulation Tools:**
 - Improve accuracy of building systems models by fusion of simulation and data sources
 - Characterize actual usage patterns over time
 - Develop predictive capacity for resource use
 - Incorporate data into control programs
 - Improve reduced models via incorporation of data
 - Sensor placement to reduce model uncertainty



Energy Portfolio Management

- **Target Audience: Developers and Owners**
- **Goals of Simulation Tools:**
 - Aggregate building performance to larger scale
 - Facilitate informed decision-making by quantifying effects of trade-offs among building inventory
 - Support coordinated effort in portfolio management
 - Provide decision-support services for full range of financial and resource inputs
 - Provide for adaptive learning based on integration of performance history data over time