



# 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

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- A/E 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

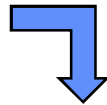


# So Where Do Buildings Come From?

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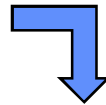
## Developer/Owner

- May Be Public or Private
- Defines Baseline Requirements



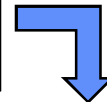
## Architect

- Designs General Building Form
- Insures Livability, Usability



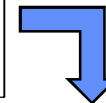
## Structural Engineer

- Designs Structural Systems
- Insures Building Stands Up



## EE/ME/CEs

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



## Construction Engineer

- Designs Construction Plan
- Oversees Building Realization

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

## Impacts of computational science:

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



# Risk Quantification

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- **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

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- **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

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- **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

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- **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

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- **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

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- **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**

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- **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

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- **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**