

# INTEGRATING ENERGY ENGINEERING & PERFORMANCE MODELING INTO THE DESIGN PROCESS



BETTERBRICKS

An initiative of the Northwest Energy Efficiency Alliance.



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# INTRODUCTION

In order to achieve highly energy efficient buildings (energy consumption more than 50% below baseline buildings), add an energy engineering function, including modeling capability, to the project team. This role is both analytical and synthetic, pushing and prodding the designers as part of an integrated design process.

This document provides a recommended scope of energy engineering and performance modeling services to support the development of very energy efficient, high performance buildings. The services described are more comprehensive than the energy modeling scope typically required to document project efficiency measures and to simulate the energy use of proposed and baseline buildings. Instead, this energy engineer/modeler will enhance the design team's understanding of project opportunities and constraints, challenge the design team to examine key questions, act as an advocate, and serve as a design team resource to improve a building's energy performance throughout each design step.

The energy engineering/modeling function is part of the project team, but not necessarily of the design team (a distinction made because the energy engineer may not be the designer of record). Energy engineering and modeling may be part of the mechanical engineer's scope or may be performed independently. Regardless of how the team is formed, the job of the energy engineer is to continuously advocate for better energy performance throughout the design, construction, and building start-up process. Modeling is key to the energy engineering function and should be performed early and iteratively to inform the design. With this role on your team, contributing to the integrated design process, your building has a much greater chance of meeting high performance energy targets.

## OVERVIEW OF SERVICES

There is a suite of performance modeling activities and tools that the energy engineer brings to the design table, including energy simulation, physical modeling techniques, and specialty software tools to analyze and document the performance of particular strategies or to fine tune the performance of specific systems.

The energy engineer/performance modeler will help the design team:

- Identify and understand the big issues related to building energy use and performance;

“When elements of a building take on different functions, that is a clue that we are doing integrated design.”

*Mike Hatten, SOLARC  
Architecture and Engineering*

- Develop project-specific design goals and directives;
- Use preliminary energy modeling to support setting energy use goals;
- Develop design strategies to reach the goals; and
- Update the energy model throughout the design process to evaluate strategies and to track progress against the goals.

The energy engineer/modeler should be an analytical and creative thinker who challenges the design team by posing questions like:

- What is an appropriate energy use target for the design?
- Can the project be a zero net energy building?
- What other energy-related performance goals should be established for the project? For example, can the project eliminate the need for mechanical cooling, provide sufficient ventilation without the use of ducts or implement daylighting to minimize energy use?
- Are there any design criteria inconsistent with a high performance building? What are those criteria? In what ways are the criteria different from what might be considered “state of the art” design practice? Is the building sited appropriately? If not, are there issues for future performance testing e.g, west-facing glass?
- What additional analysis is needed to challenge higher energy using “conventional” design assumptions such as the “need” for reheat?

To advance integrated design strategies, we have listed questions throughout this document that should be addressed by the design team with facilitation and support from the energy engineer. Answers to these questions should be provided (and updated) within major deliverables at each phase of the design.

We have also organized this document using a model of integrated design that was developed primarily by G.Z. “Charlie” Brown of the University of Oregon, with substantial support from NEEA’s BetterBricks initiative. Using this framework in an iterative way throughout each design phase, the team, with the energy engineer, can seek the required design strategy synergies that allow the design to achieve high levels of efficiency.

This construct of integrated design focuses on opportunities to increase building energy performance through four integrated design strategies:

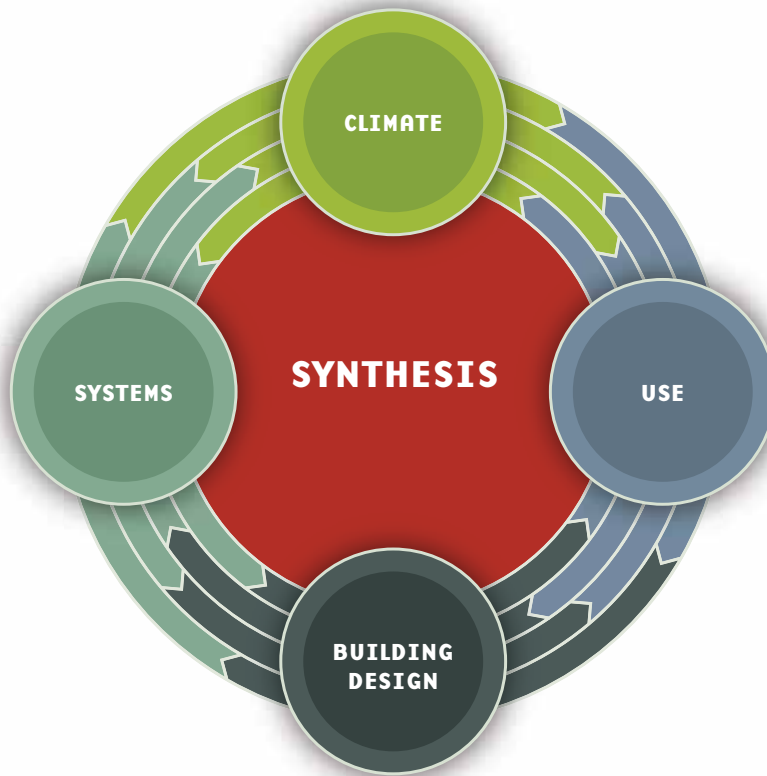
# INTEGRATED DESIGN SYNTHESIS

## CLIMATE

Climate is often considered a liability.  
View it instead as a resource.

## SYSTEMS

Systems designed to integrate climate and use strategies and sized to meet optimized loads.



## USE

Even small adjustments to operating schedules, comfort criteria and use patterns can make a significant difference in a building's energy consumption.

## BUILDING DESIGN

Design strategies (daylighting, natural ventilation, shading, and others) are related to decision about building site, form, organization, and major materials.

- Employing CLIMATE as a resource to enhance energy performance;
- Consideration of USE, schedule, and comfort criteria as malleable;
- Building DESIGN and site design (primarily building orientation and landscaping) to create small loads; and
- The design of efficient SYSTEMS.

This model of integrated design is not universally applied by design teams. The conventional definition of integrated design is that project team members from all disciplines work together early and often throughout the project design process. The enhanced definition presented here includes what goes on when the design team gets together to synthesize new design solutions by integrating climate, use, building design and systems strategies.

## CLIMATE

### Wind direction and velocity

Develop a series of wind roses that accurately represent the site's wind regime and consider the following:

- Research local wind data and ensure that the wind speed and direction data contained in hourly weather files (generally available for energy simulation) are correct for the project site.
- If appropriate local wind data cannot be located for the project site, it may make sense for the designer/owner to install an on-site weather station with anemometer and data archiving capability.
- Construction of the project itself will modify site wind, so CFD modeling and/or wind tunnel analysis can also be extremely helpful in exploring the effects of wind.
- An on site weather station will remain extremely useful after construction for continuous monitoring and for predictive control of building systems.

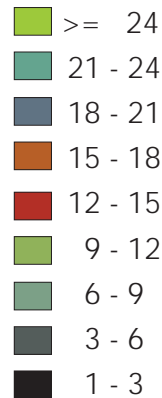
This wind data can help the design team answer the following questions:

- What facades are likely to need protection from winter winds to reduce infiltration?
  - This analysis may employ an infiltration algorithm that relates the wind pressure differential between inside and outside and the infiltration performance properties of the facade; representing a dynamic relationship.
  - A more common practice considers the static properties of the facade and uses an infiltration rate based on empirical testing under a given pressure differential.
- What site-specific natural ventilation strategies should be considered?
- Is there good potential for the use of building integrated wind turbines? (This analysis is a separate exercise from modeling the impact of wind on building performance.)

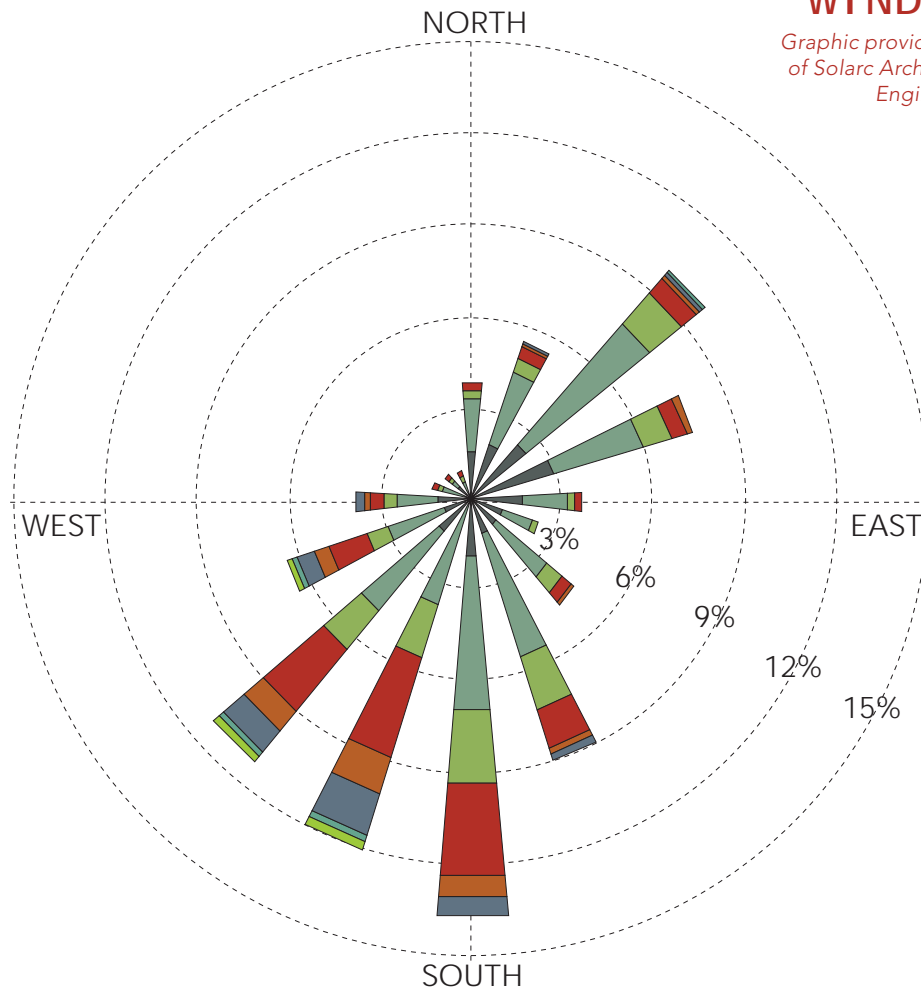
## WIND ROSE

Graphic provided courtesy of Solarc Architecture and Engineering, Inc.

### WIND SPEED (Knots)



Calms: 4.34%



- o The necessary information is typically presented as a frequency histogram, a common format for wind energy generation analysis. Once plotted, the data can be compared to “ideal” frequency distributions and/or used for energy generation predictions.

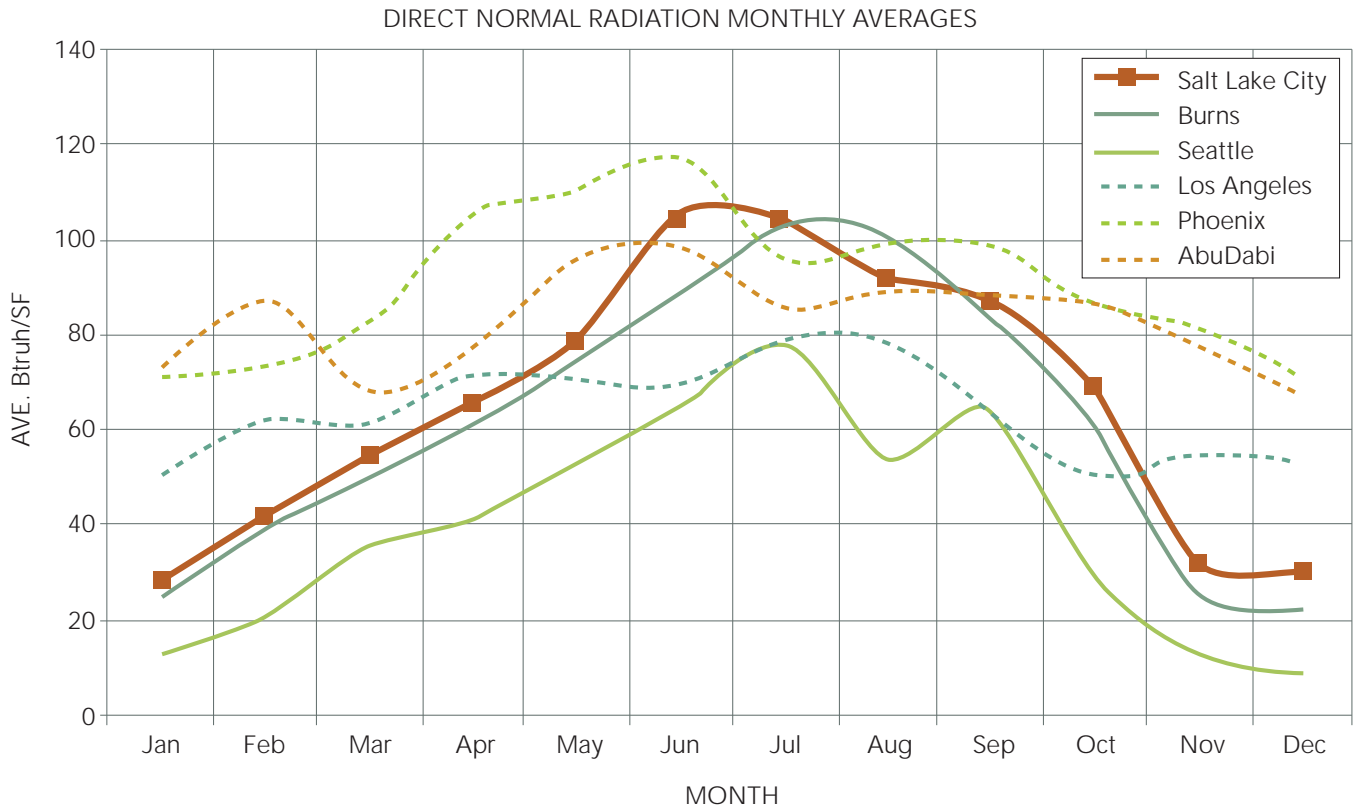
## Solar Radiation and Sun Path

Prepare graphic representation(s) of solar radiation and sun paths and include a written explanation of design implications. Initial versions of these materials should be delivered as early as the project kick off meeting for use during conceptual design and programming, with the information fully integrated into the design during the Schematic Design phase.

The solar radiation and sun path plot can help the design team answer many questions, such as:

# SOLAR RADIATION

Graphic provided courtesy of Solar Architecture and Engineering, Inc.



- What is the relationship between solar radiation and typical temperatures (conductive heat transfer)? Even where there may not be much solar radiation, mild temperatures may mean that solar is not needed as a resource.
- When are overcast and clear sky conditions predominant during the year?
- What are the implications for daylighting opportunities: skylight and window size, placement, and solar control?
- Should solar control options focus on control of direct radiation, glare from overcast sky conditions, or both?
- How many clear sunny days are typical during the winter season and what is the potential to use solar energy as a direct energy input to the building?

## USE

### USE

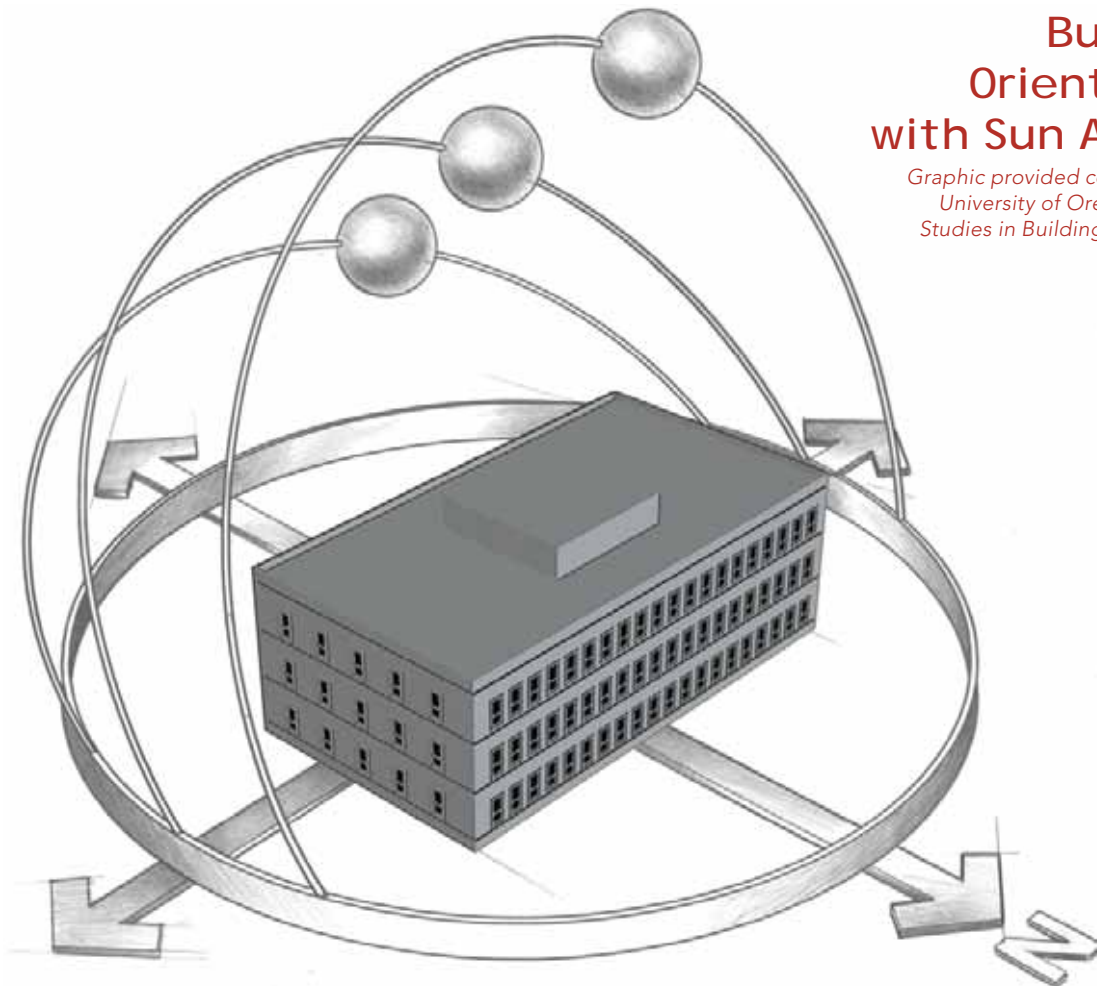
Compile and maintain documentation of projected occupant use, schedule, code-based requirements and other programming assumptions.

- Identify the key design criteria that can significantly impact heating, cooling, ventilation, and lighting loads: indoor design temperatures, horizontal illuminance levels, peak internal equipment gain, number of occupants during peak (and other) occupancies minimum ventilation rates, etc., and document how each criterion has been established.
- Consider how the boundaries and constraints imposed by these criteria might be extended and modified.

## DESIGN

### DESIGN

Use the sun path to determine the building orientation that is most likely to optimize daylighting while reducing solar gain.



## SYSTEMS

Consider whether there are passive heating, cooling, and ventilation systems that are likely to make sense for this project.

The scope of work for the energy engineer/performance modeler encompasses more than energy simulation modeling. It begins with Pre-Design analysis by providing recommendations to support project energy performance. The scope includes:

- Climate analysis report;
- Design criteria for indoor and outdoor design temperatures, indoor humidity, minimum ventilation rate (including air flow distribution and velocity), interior and exterior illuminance levels, and peak miscellaneous equipment heat gain densities.

Energy simulation modeling can be initiated during Pre-Design and carried through 100% Construction Documents. As design documentation progresses through the Conceptual, Schematic, Design Development and Construction Document phases, the energy model will be revised at critical stages of the design. It will be used to inform design decisions and to provide estimates of energy use to help assess the life cycle costs of various options.

The energy engineer should develop energy models for baseline analysis and the proposed project. The models are based on program and simplified geometric inputs—tall and skinny building, short and fat building, short and elongated, etc.—the so-called “shoebox” model. This simplified model illustrates the impacts and opportunities of climate resources, provides an initial overview of occupant use and the impact upon energy consumption, and considers how preliminary design assumptions affect performance. Start with a baseline model that complies with relevant existing standards (e.g., ASHRAE 90.1, local code requirements, or other definitions of minimum acceptable performance) and that can be used to test the implications of various design criteria on both loads and energy use.

From the baseline energy/loads simulation model, prepare a report that addresses integrated design strategies and informs design team decisions. It should:

- Identify potential problems related to excessive energy use;
- Identify potential problems, such as drafts, glare, and high levels of internal gains, which primarily impact occupant comfort;

## PERFORMANCE MODELING

## PERFORMANCE MODELING

- List energy efficiency design strategies to be incorporated into the project; (this list will be a deliverable that is updated at least once per design phase);
- Suggest pathways to carbon neutral and/or zero net energy performance;
- Use the shading calendar and, merging climate data with balance point calculations, provide a simple estimate of time of year and hour of day when exterior shading should keep direct solar gain from entering the building. (This will support time-specific analysis of the effectiveness of exterior shading during summer conditions, for cooling load reduction, and times during winter that direct solar gain is desirable, while maintaining acceptable daylighting conditions.)

# CONCEPTUAL DESIGN



## CLIMATE

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### CLIMATE

Questions to consider regarding climate in this phase:

- During what times of the year will the building need to be protected from solar radiation?
- How will winter winds influence the location of main entries and secondary entries?
- How will predominant wind direction(s) influence air intake and exhaust locations?
- How well will evaporative cooling work at the site?
- How cool are early morning hours on a design cooling day?
- What is the typical diurnal temperature swing?



## USE

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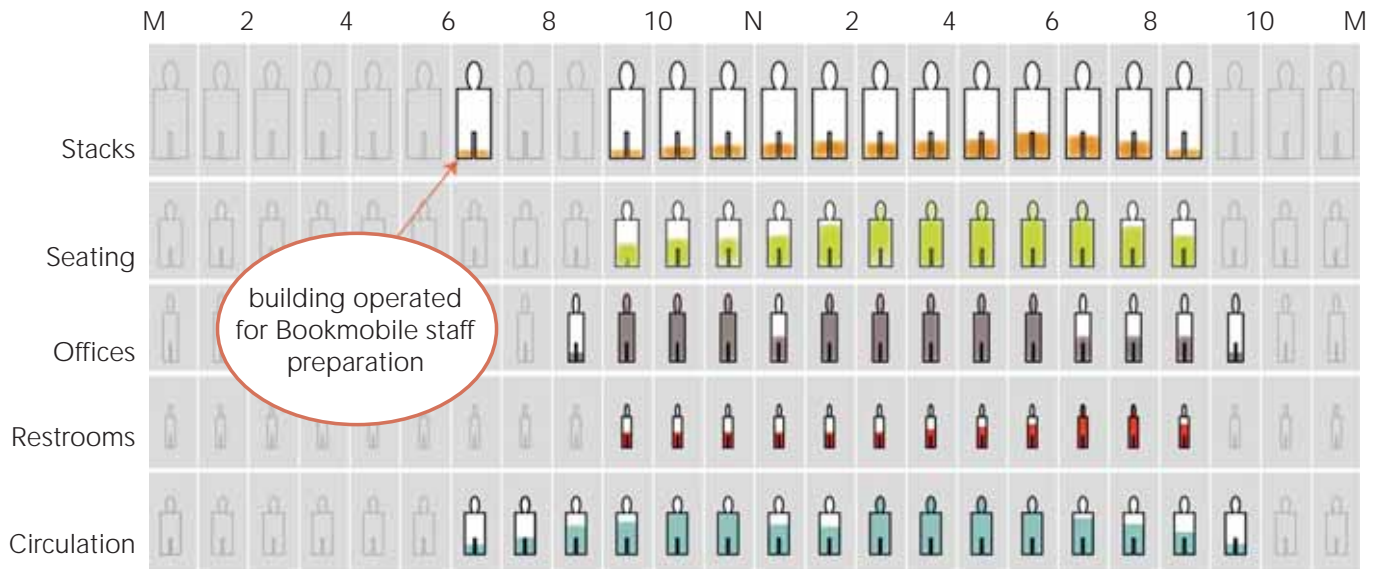
### USE

The owner/occupant program and performance criteria related to building occupancy and use often have a much bigger impact on the first cost of HVAC systems and operating energy use of a project than more narrowly focused decisions made by the design team. The performance modeler must be prepared to address the design impact of these criteria. Questions and strategies to consider:

- When will the building be occupied and unoccupied?
- What are the benefits from modifying occupancy schedules?
- What are the code-dictated requirements that might constrain design options (e.g., codes that specify a minimum ventilation rate)?
- How will thermal comfort criteria be determined for the project? What range of comfort conditions will be acceptable? (Most people are able to state, unequivocally, when they are comfortable, but have difficulty translating comfort into temperature and humidity values. Answers to the following questions about maximum and minimum acceptable temperature and humidity levels will identify metrics, but even when achieved, these metrics will not guarantee comfort.)

## OCCUPANCY ANALYSIS, LIBRARY

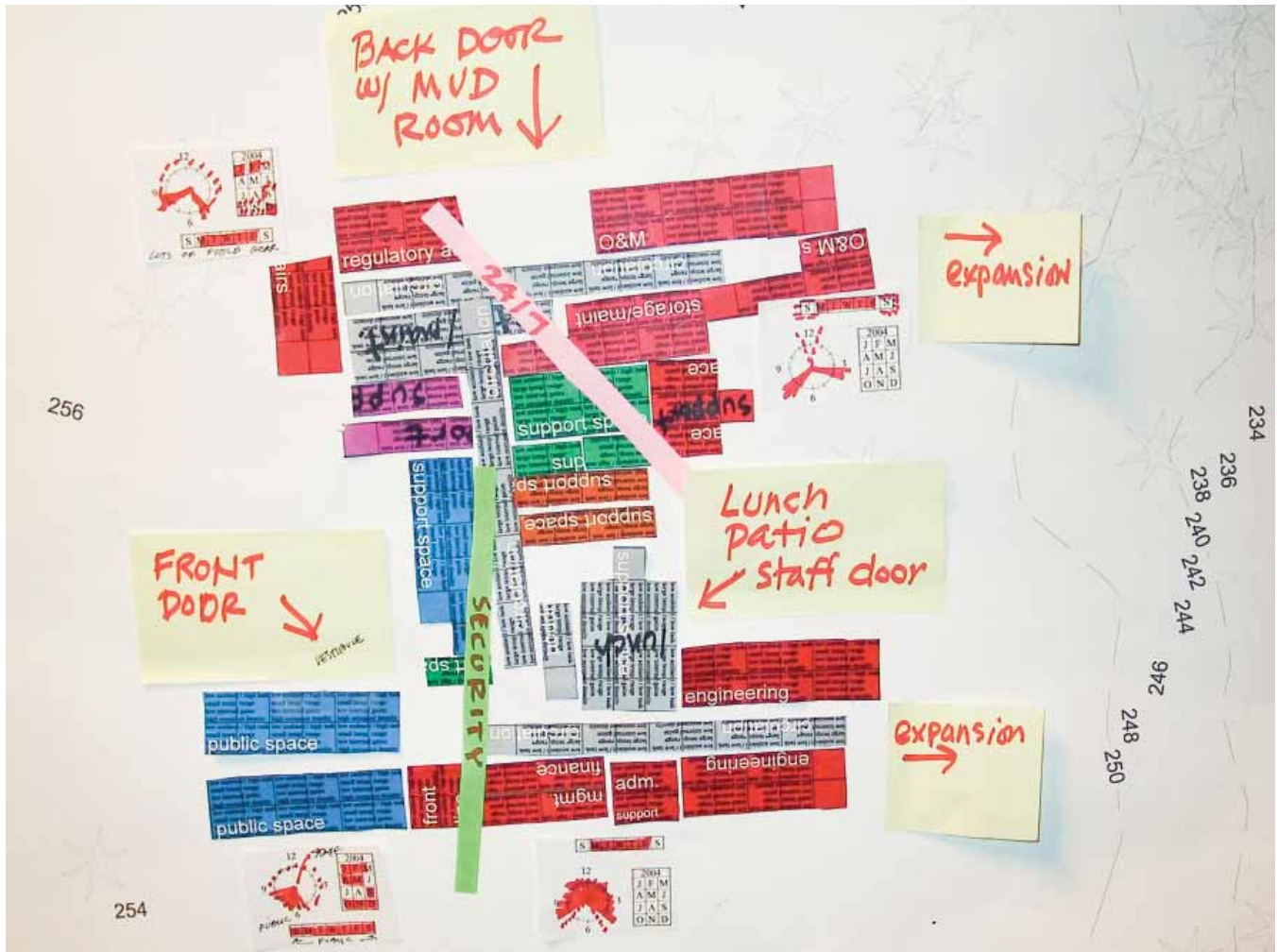
Graphic provided courtesy of the University of Oregon's Energy Studies in Buildings Laboratory.



- What is the maximum acceptable indoor space temperature and humidity during occupied conditions in the cooling season? Can this temperature be changed if enhanced air movement is provided? What is the maximum acceptable temperature during unoccupied conditions?
- What is the minimum acceptable indoor space temperature and humidity during occupied conditions in the heating season? What is the minimum acceptable temperature during unoccupied conditions?
- What are the desirable lighting levels, lighting power densities, thermal comfort criteria and ventilation requirements as they relate to occupant activities, for each project occupancy?
- How can this energy specific programming information be integrated, along with other design criteria, into a preliminary assessment of adjacencies? (G.Z. Brown, at the University of Oregon has developed a methodology of Energy Programming to facilitate this process.)
- What other programming requirements will have a meaningful impact on loads or energy use, i.e., redundant systems, requirements to size systems for future load growth, the perceived need for "flexibility" to meet potential future program changes, etc.?

# ENERGY PROGRAMMING

Graphic provided courtesy of Konstrukt.



## DESIGN

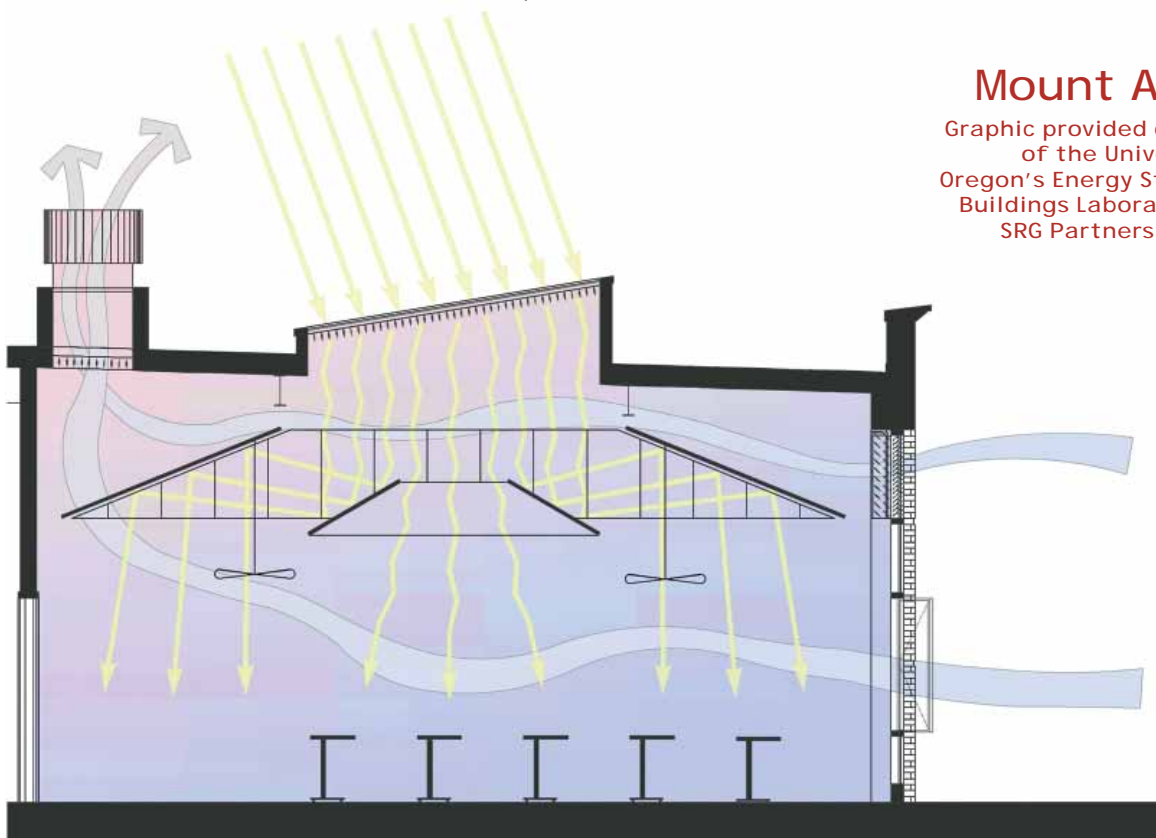
The loads analysis completed during the pre-design phase should be used by the energy engineer, working with the architect, to identify a range of load reduction strategies associated with site shading, the building envelope, and management of building internal heat gains. For example, how will site shading influence the contribution of solar gain to the peak cooling load? The impact of these various strategies can be tested using the energy simulation model.

Evaluate opportunities for the form and orientation of the building to take advantage of passive heating and/or cooling, natural ventilation, and daylighting.

## SYSTEMS

Formulate an overall HVAC strategy, including passive strategies, to reduce the HVAC load. Can passive strategies, e.g., shading/fenestration systems and their impact on heat gain, or the applicability of natural ventilation, eliminate the need for active systems? Strategies to consider:

- Identify heat recovery opportunities.
- Evaluate “cascading” energy streams.
- Expand typical efficiency discussions to include the 2nd law of thermodynamics: while a system option can be very efficient from a 1st law standpoint (i.e. a condensing water heater at 95% efficiency), it can be very inefficient from a 2nd law standpoint (i.e., natural gas combustion at 1800°F to make 120°F water).
- Consider solar hot water heating and potential benefits from cogeneration. What hybrid (integrated active/passive solutions) should be considered? Techniques such as air flow diagramming can help the project team evaluate how options such as a mixed-mode natural ventilation system could be incorporated into the design.
- Consider building-integrated renewable energy strategies, such as photovoltaics or wind turbines.



### Mount Angel

Graphic provided courtesy of the University of Oregon's Energy Studies in Buildings Laboratory and SRG Partnership, Inc.

## PERFORMANCE MODELING

Performance modeling during Conceptual Design should focus on loads modeling, to inform the architecture and to help develop system concepts. Building and plant-level loads should be segregated for deeper insight into opportunities to improve performance. Important considerations:

- The contribution from facade architecture to peak loads will become obvious by identifying the potential hot and cold zones.
- At the zone level, load problems are typically associated with windows, so it is important to understand issues related to windows early enough to influence the facade design.

Cooling and heating loads (for peak hour and/or peak day) should be associated with the break out of specific loads, either imposed by the building (envelope and internal heat gains); or by mechanical systems (ventilation, fan heat, reheat). Questions at this stage to consider:

- What program aspects are likely to have the greatest impact upon energy costs?
- What is an appropriate energy use target?
- What are the top three energy end uses?
- What is an appropriate peak load target?
- How much of the peak heating or cooling load is contributed by each of the following: heat transfer through the envelope, direct solar gain, internal heat gains, ventilation, and other system imposed loads (reheat or fan heat)? Insights from load disaggregation are particularly useful to help fine tune the architectural design and make decisions about systems concepts to be analyzed.
- What are the impacts of design criteria choices on peak loads (first cost) and annual energy use?
- What passive strategies make the most sense for the project?
- What is the magnitude of the potential annual energy savings:
  - In units of energy?
  - In annual cost saving?
  - In \$/SF-year?
  - On a life-cycle basis?

## PERFORMANCE MODELING

It is important to continue to track both disaggregated loads and disaggregated energy use. A small load, relative to peak heating or cooling, such as a server room that may use energy 24/7, may turn out to be a major energy use on an annual basis. An understanding of peak loads is critical for sizing equipment and capital budgeting, but may be much less significant for a final energy budget.

# SCHEMATIC DESIGN



## CLIMATE

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### CLIMATE

Revisit climate integrated design issues and questions first addressed during the conceptual design phase and update assumptions and conclusions as needed.



## USE

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### USE

Revisit integrated design issues relating to occupancy, use, and scheduling and the questions first addressed during Conceptual Design as well as conclusions of energy programming efforts. Update assumptions as needed.

Begin to consider the potential impacts of schedule changes on overall energy use and on specific loads, e.g., daily operating schedules on lighting energy use, the alignment of seasonal operating schedules with peak cooling loads; and how the scheduling of cleaning crews can impact lighting energy use.



## DESIGN

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### DESIGN

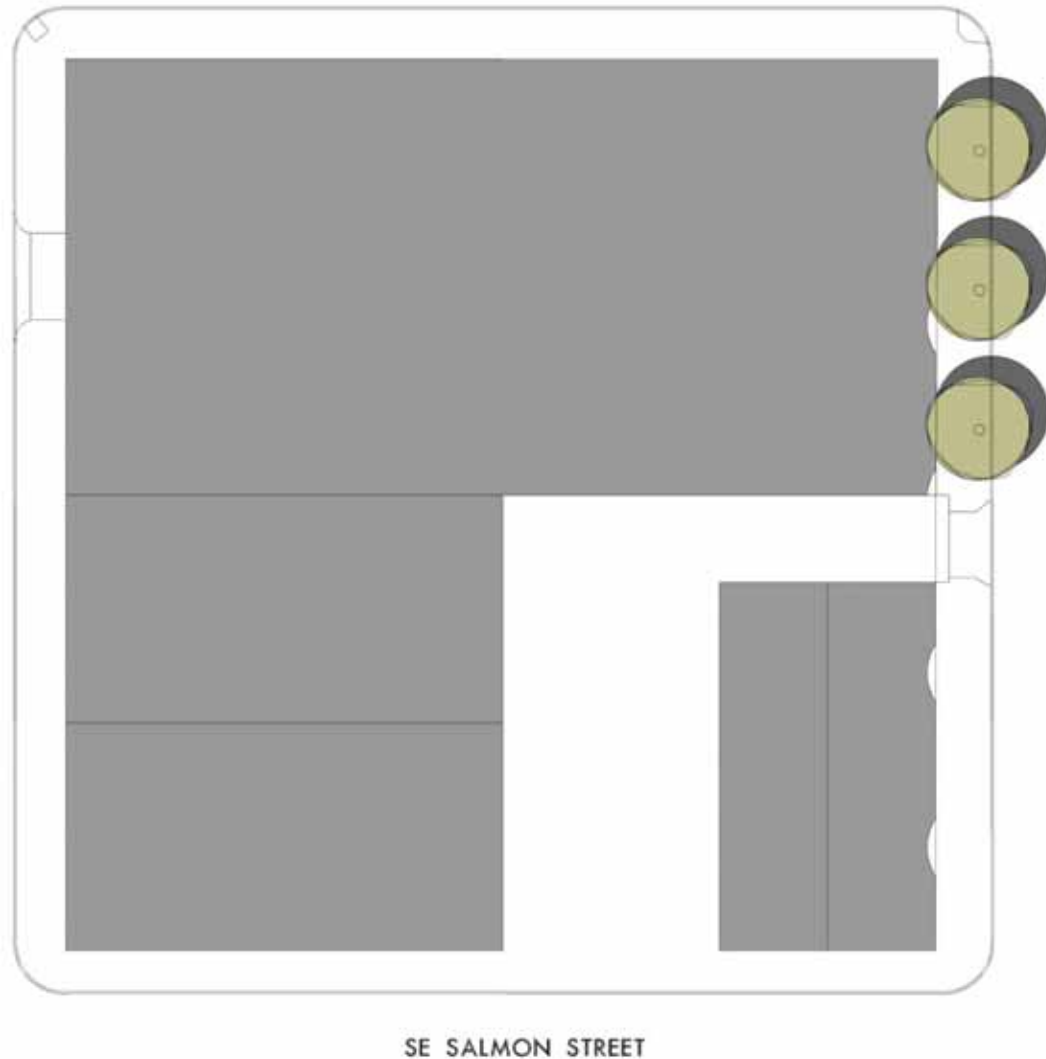
#### Form and Orientation

Optimize the form and orientation of the building in order to take advantage of passive heating and/or cooling opportunities and natural ventilation. Design questions to consider:

- What is the proposed window-to-wall ratio and can it (should it) be adjusted?
- Where should windows be located? Where should they be concentrated or eliminated?
- What are the top lighting and/or side lighting daylighting opportunities for the optimized design?
- What exterior shading options are likely to provide the best control of direct solar gain on different building facades? Analysis of geometry and dimensions associated with exterior shading options can be done with heliodon studies using physical model or with software (Ecotect, Sketch-up, etc.).

## FORM AND ORIENTATION SKETCH

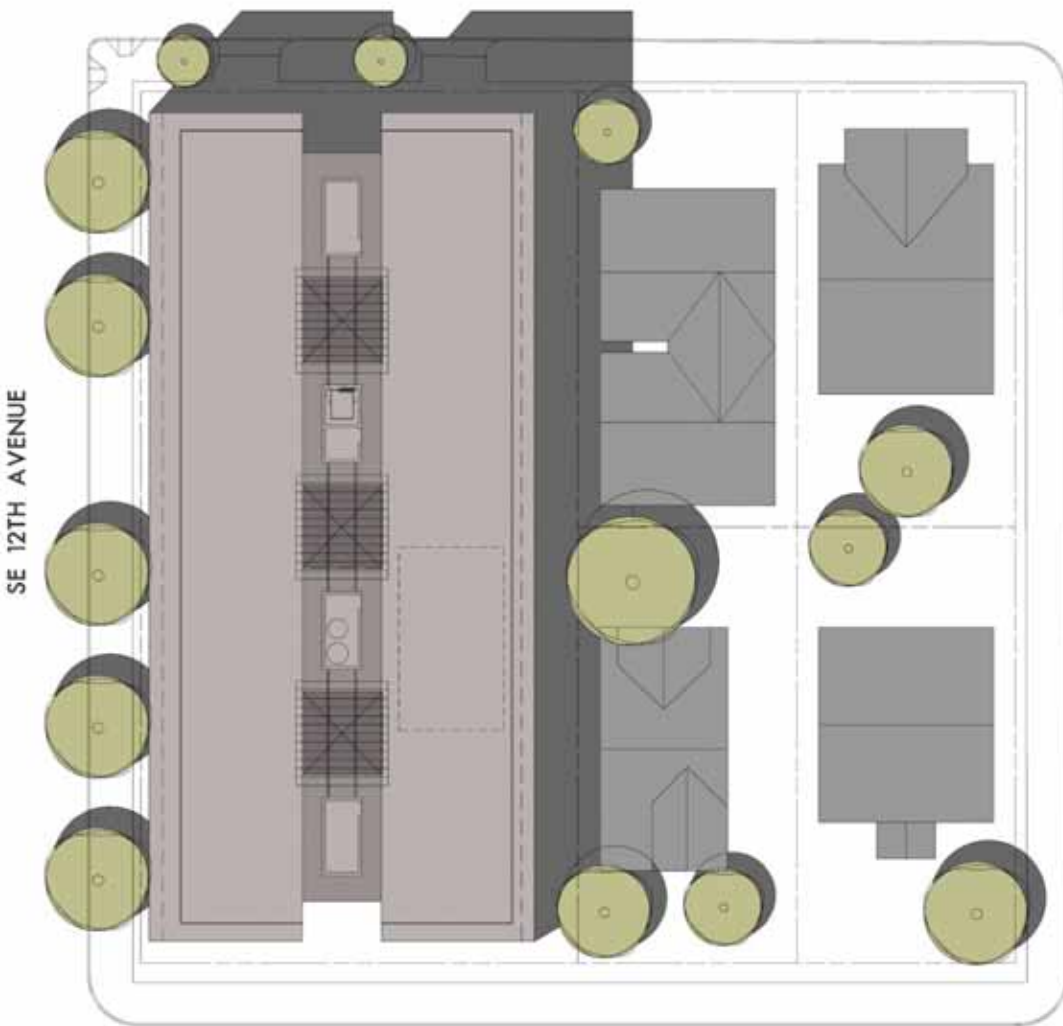
*Graphic provided courtesy of the University of Oregon's Energy Studies in Buildings Laboratory.*



### Envelope

Consider the various energy and daylighting implications of the roof form at this point in the design.

- How much insulation should be in the roof? Is there a preferred roof color?
- How much insulation should be in the walls? How much thermal mass?
- What type of glazing is optimal? Does glazing selection depend on orientation?



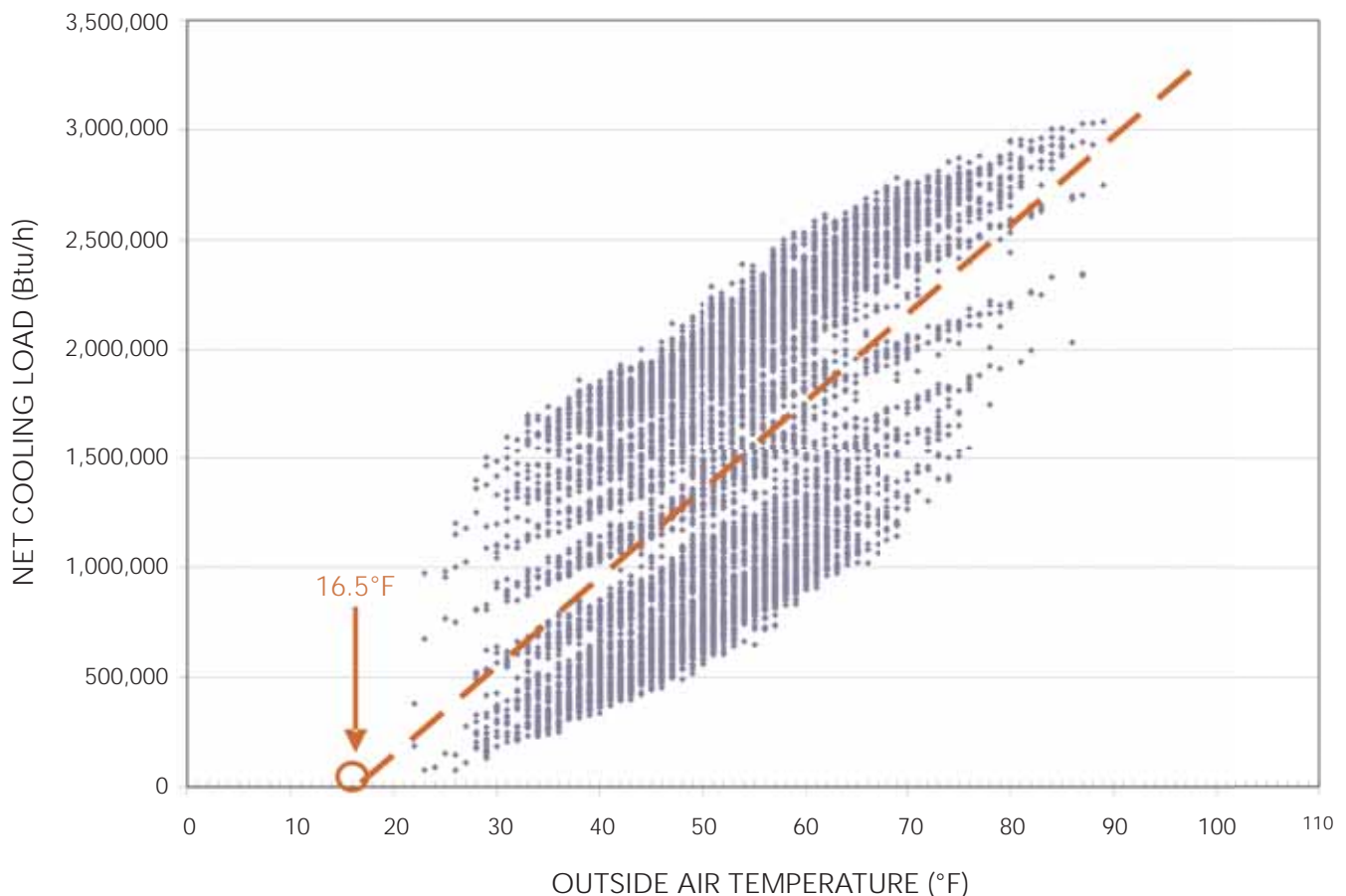
## Thermal Loads

- What will be the project's peak cooling and heating loads: in absolute units (Btu/hr or tons of cooling) and in indexed units (SF/ton or Btu/hr-SF) to compare anticipated project loads with indexed loads typical for similar projects?
- What are the diurnal, weekly, and annual distributions of peak thermal loads?
- What are the disaggregated peak loads, e.g., the distinct envelope loads on roof, walls, fenestration; internal gains from occupants, lighting, equipment, etc.

- Does the design engineer agree with these load projections? If not, what are the disagreements?
- Review the project's peak cooling loads to illustrate how HVAC system concepts align with peak cooling load ranges and the potential opportunities and benefits from strategies such as night ventilation of mass, displacement ventilation, radiant cooling, VAV, etc.
- Can zone loads be met with passive comfort systems? With alternative active systems, such as modular HVAC systems carefully sized to zonal requirements?
- Where are the "hot spots" in the perimeter? In the core? What load reduction strategies make sense to improve "hot spot" performance?
- What is the balance point temperature (envelope loads versus internal loads)?

## BALANCE POINT TEMPERATURE

Graphic provided courtesy of Solarc Architecture and Engineering, Inc.



- o Balance point temperature is a relatively simple metric with profound systems implications. It is useful to assess opportunities such as (1) heat recovery and (2) elimination of simultaneous heating and cooling.
- o Balance point is also a very significant energy metric for internally-load driven occupancies such as hospitals. It demonstrates how we can effectively design systems, recognizing that the problem at the building level is always about removing heat, while the issue at the zone level is about moving heat from one area to another without using systems that add more heat while consuming more energy.

## Electrical Demand

- What is the anticipated peak electrical demand, both in absolute terms (kW) and indexed units (watts/SF)? When does the peak electrical demand occur daily, weekly, and annually?
- How much electricity can be generated with roof-mounted photovoltaics?



## SYSTEMS

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## SYSTEMS

- What are the requirements for humidification/dehumidification?
- Is it feasible to develop ground-coupled heat pumping: appropriate loads, geology, hydrogeology, drilling difficulties?
- What other renewable energy strategies are applicable?
- What are the 1st and 2nd law considerations?
- Where can mechanical areas be located to reduce distribution pressure drop?
- What system options and alternative design solutions should be considered?

## Passive and Hybrid Systems

- What passive system concepts are appropriate?
- Can passive strategies eliminate the need for certain active systems, e.g., the integration of shading/fenestration systems in order to reduce heat gain, lower cooling loads and eliminate the need for air conditioning?

- What is the potential solar fraction for solar potable water heating systems?
- How much thermal energy can solar systems contribute toward meeting the space heating load?
- Should the building include passive solar heating elements?
- What hybrid (integrated active/passive solutions) should be considered?
- What are the optimum locations for fresh air inlets and exhaust vents?

### Efficient Thermal Distribution Systems

- Which working fluid (air or water) will be more efficient? Why?
- What performance gains might be achieved by separating the ventilation system from thermal distribution?
- What will be the effect of thermal storage on increasing the capacity of the distribution system? What are the meaningful diurnal, weekly, and seasonal storage dynamics?
- What are the potential benefits from different ventilation system configurations, e.g., floor-based vs. ceiling-based?

## PERFORMANCE MODELING

The project team should review energy model results in relation to the project goals. Answer the following “big picture” questions to inform potential integrated design strategies:

- What are the emergent and meaningful synergies between climate, use, loads, and systems?
- Based upon the current version of the energy model and considering life cycle costs, what is the overall integrated design strategy that attempts to balance energy supply and demand towards net zero conditions?
- Will prescriptive approaches allow the project to comply with the applicable energy code, or will more complex, time-consuming, and expensive approaches be required?
- Can the design direction be modified to make code compliance less burdensome?
- What are the initial energy efficiency strategies and how are they expected to perform from an energy and loads perspective?

- What are some strategies that can be employed by the project architect to address architecture-imposed heating and cooling loads?
- What are some of the strategies that can be employed by the mechanical engineer to address system-imposed peak loads (fan heat, pump heat, reheat, duct/piping losses, ventilation)?
- What are some of the trade-off opportunities for construction costs?

Ideally, at this early stage of design, project managers should consider integrated design issues and the questions listed above via multiple schemes and parametric modeling runs. Compare the preliminary results of the energy model based upon the initial integrated design strategy with the baseline building/code minimum model. In addition to analysis using the simulation model, daylighting analysis using physical models or software should begin supporting the integrated design process. Electric lighting design support should also begin at this time. How can the results of performance modeling be packaged into the overall schematic design document set? This might be an excellent place for performance diagramming to be employed, e.g., daylight concepts, air flow paths, etc.



# DESIGN DEVELOPMENT



## CLIMATE

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### CLIMATE

Revisit climate integrated design issues and the questions first addressed during the conceptual design and schematic design phases, and update assumptions and conclusions as needed.



## USE

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### USE

Revisit occupancy, use and scheduling integrated design issues and the questions first addressed during conceptual design and schematic design phases, and update assumptions and conclusions as needed.



## DESIGN

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### DESIGN

Use the energy model and project cost estimates to optimize envelope U-values, R-values, and glazing characteristics and to demonstrate the effectiveness of integrated design strategies at reducing heating, cooling, ventilation, and lighting loads.

Compare revised performance modeling results—load assumptions and system sizing—with the system sizes defined by the HVAC designer. Once input details have been defined and developed by the HVAC designer, this comparison can be very productive and provide great design integration insight.



## SYSTEMS

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### SYSTEMS

#### Integrated Daylighting/Electric Lighting Solutions

- Develop and share lighting layouts and luminaire/light source selections. Preliminary plans are more useful than specifications.
- Consider the various reasons to choose between automated and manual lighting controls.
- Consider side lighting and top lighting daylighting strategies.
- Develop strategies to control direct solar penetration and glare from fenestration.

- Specify high efficacy lighting and efficient ballasts.
- Develop strategies to control glare from luminaires.
- Specify lighting controls to match building scheduling and to sense occupancy within each zone. Ensure that the sequence of operation properly integrates the performance of daylight controls and occupancy sensors.
- Specify lighting controls to optimize energy savings from daylighting.

### HVAC: Passive and Hybrid Systems

- What passive strategies and system concepts continue to offer the greatest potential to eliminate the need for active systems?
- What are the supplemental active systems that will support the passive concepts, i.e., exhaust fans to supplement night ventilation?
- What hybrid (integrated active/passive solutions) continue to make sense?

### Active Mechanical Systems

During Design Development, consider the following mechanical system design issues:

- Heat and ventilation air recovery systems.
- Heat pumping should increasingly factor into heat generation and heat rejection discussions. Energy and loads modeling can be particularly valuable to design teams considering ground-coupled heat pumping. If earth-coupled heat exchangers are proposed for the project, proper sizing requires prediction of annual heat additions and heat extractions—information easily pulled from annual energy models but not so easily extracted from conventional loads calculations (used for HVAC equipment sizing).
- What can be learned from the performance modeling results about over-sized systems and components that are chosen based upon peak load conditions but perform inefficiently under other operational conditions?

- First, ensure that air and water distribution systems have been designed for efficiency. Then optimize fan and/or pump sizing and evaluate all potential applications for variable frequency drives.
- How much of the load and energy use is imposed by inefficient system concepts such as simultaneous heating and cooling (reheat)?
- What strategies can be employed to minimize the contribution of fan heat to cooling loads?
- For ducted cool air systems, what will be the effects of various minimum VAV box damper positions on energy use, cooling and heating loads, and reheat?

## Mechanical and Lighting System Controls

- Ensure that the controls sequence of operations has been developed and is consistent with modeled assumptions. Many design teams wait until the last minute to complete work on the controls sequence of operations, but this work should be completed during design development, with a communication strategy formulated to track any modifications to these critical assumptions.

The modeling runs prepared at the end of Schematic Design should be used to generate a set of performance questions to inform the Design Development phase. The performance modeler should be fully engaged with both the continued brainstorming and the overall design approach to achieve project performance goals—just updating an energy model (as performance targets are repeatedly missed) is not sufficient. Constantly relate performance modeling analysis to life cycle cost considerations to support design choices.

During Design Development, there is a set of additional activities where the energy engineer/performance modeler should actively help integrate the contributions of the various designers whose work affects the energy use of the building. Interaction with the design team should begin to include performance modeling tasks that supplement the energy simulation model and support designers' focus on meeting project energy targets. These modeling techniques include, but are not limited to:

## PERFORMANCE MODELING

## PERFORMANCE MODELING

- CFD modeling for air flow (as needed) or other air flow modeling techniques;
- Pipe and/or duct sizing and optimization tools such as Flo-Series or T-duct.

The energy simulation model can be used to size mechanical equipment. However, if the mechanical design and energy engineering are separate functions, with two distinct tools being used for system design and sizing, both the energy simulation and the sizing tool MUST use the same assumptions. Calculation results should be compared and any differences in the results should be analyzed.

At the end of Design Development and the start of Construction Documents, revise the energy model to:

- Reflect any changes to fenestration, glazing specifications, and shading strategies.
- Assess system design and provide comments about how proposed systems and potential alternates will affect energy performance.
- Review proposed sequences of operation for various systems, align with modeled assumptions, and comment on the potential effects of chilled water and heating water setpoints on building energy use, as well as the effect of supply air temperature reset on energy use, cooling and heating loads, and reheat (as applicable).

Prepare a summary report to provide the client and project team with a comprehensive review of the energy model results in relation to the project's sustainability goals. Work closely with the commissioning agent during this review. This report may also be used as the deliverable that begins to define the involvement of "external" energy efficiency participants: utilities, governmental programs, USGBC, etc. The summary report at the end of Design Development can provide the detailed energy analysis to support decisions and actions by these participants.

# CONSTRUCTION DOCUMENTS, ADMINISTRATION, CLOSE OUT



CLIMATE

USE

DESIGN

SYSTEMS

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## CLIMATE, USE, DESIGN

Most of the design decisions informed by the integrated design process will have been made by this point in the project schedule. However, in this stage of the process, an energy engineer plays a critically important role by informing the review process commonly known as “value engineering”. The energy engineer should be empowered to protect building performance using all the analysis completed to date.

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## SYSTEMS

Ensure that all necessary sensors and measurement devices have been incorporated into the system design.

### Assess Energy Impact of Proposed Changes and Substitutions

Determine the need for additional modeling runs to assess the potential energy use impact of proposed substitutions and changes.

### Final Energy Model

- Final review and coordination of performance modeling consistency with controls should include both HVAC and lighting.
- Additional specific “commissioning related” consistency checks should also include:
  - Assumptions about air infiltration rates
  - Assumptions about hours of system operation
  - Assumptions about space temperature setpoints

## PERFORMANCE MODELING

## PERFORMANCE MODELING

- Identify and document the performance parameters and input assumptions that could greatly affect the modeled building energy use. If the actual parameters turn out to be different from assumptions made during design phase performance modeling, building energy use could be greatly affected.
- Ensure the final sequence(s) of operation remain consistent with modeled control strategies.
- Complete the final energy model, using as-builts for design performance documentation, code submission, utility program submittals, and LEED documentation.
- Prepare a final summary report of expected building performance, as designed.
- Provide the client with both electronic and printed copies of the energy model. (While final energy/loads models have been used primarily to support utility/government incentive programs, building owners and operators can also use them for monitoring and verification purposes.)

# ACKNOWLEDGEMENTS

This material on energy engineering and performance modeling evolved from a request by NBBJ's Margaret Montgomery to the Northwest Energy Efficiency Alliance's (NEEA) BetterBricks initiative, for a document that NBBJ might use to consistently define their work with energy modelers to help increase the energy performance of the firm's projects. The earliest drafts were reviewed by NBBJ architects, who were testing some of our concepts as we rolled them out.

The authors are indebted to G.Z. "Charlie" Brown of the University of Oregon School of Architecture and his insights into integrated design processes that have the potential to significantly increase energy performance. The integrated design framework used to organize this material—searching for synthesis from an exploration of Climate, Use, Building and Site Design, and Systems—is drawn from his work. We have both had the opportunity to work closely with Charlie and to learn from him.

The Harvard University Office for Sustainability Green Building Resource graciously agreed to let us draw upon its Energy Modeling: Ideal Process. For those looking for a simpler definition of energy modeling scope, without wanting to consider broader aspects of energy engineering and performance modeling, go to <http://green.harvard.edu/theresource/new-construction/building-modeling/methodology/>.

Dr. Ery Djunaedy, Research Scientist at the Integrated Design Lab, Boise and Dr. Khee Poh Lam, a professor in the Carnegie Mellon School of Architecture, experienced performance modelers and educators who have worked to improve the performance of many buildings around the world and to teach simulation skills to others, provided useful edits and suggestions. We thank them both.

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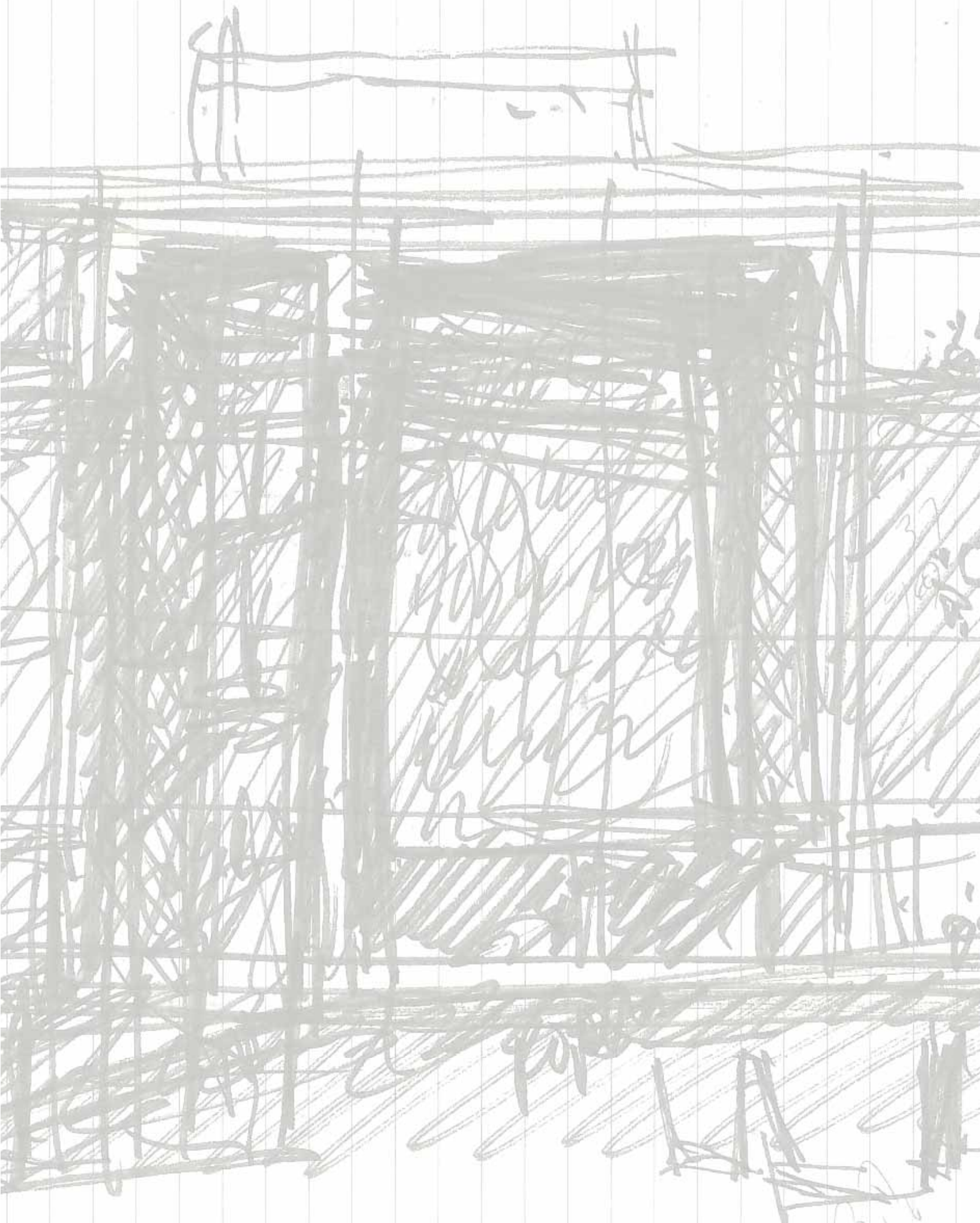
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Michael is a principal in SOLARC Architecture and Engineering, Inc., a firm dedicated to energy efficiency in the built environment. Over the past 25 years, he has managed and conducted energy analysis, design, and construction projects on well over 30,000,000 square feet of residential, commercial, and industrial space. His focus over the last five years has been to communicate with owners, architects, and project stakeholders about how to cost-effectively achieve efficiency and sustainability in new construction projects. His personal commitment to resource efficiency is evident throughout his professional activities as an engineer and educator.

### About NEEA's BetterBricks

BetterBricks is the commercial building initiative of the Northwest Energy Efficiency Alliance, which is supported by local electric utilities. Through the BetterBricks initiative, NEEA advocates for changes to energy-related business practices in buildings. In this era of heightened appreciation for the impact climate change is having on our environment and our economy, energy efficiency is a crucial component in addressing these issues. On [www.BetterBricks.com](http://www.BetterBricks.com), find information, tools, training and resources to help buildings make a difference to the bottom line and the environment.





# BETTERBRICKS

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