U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

How-To Guide for Energy-Performance-Based Procurement

An Integrated Approach for Whole Building High Performance Specifications in Commercial Buildings

Through a series of new construction projects at the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) and ongoing collaborations between NREL and industry, the authors have found that high-performance, energy-efficient buildings can be procured within typical construction budgets.

Success stories include NREL's Research Support Facility (RSF), Energy Systems Integration Facility (ESIF), and Parking Structure; these buildings are all part of the recent NREL campus expansion in Golden, Colorado. Other projects that are working toward deep energy savings at typical construction costs include the Federal Center South for the Army Corps of Engineers in Seattle, Washington, and the SLAC National Accelerator Laboratory support building in Menlo Park, California. For these projects, an energy efficiency goal is a core requirement, defined at conception, included in the contract, and carried through design, construction, and operations.

A project energy efficiency goal is the foundation for the energy-performance-based procurement process described in this guide. The goal, though, is not sufficient for success. A project delivery approach that incentivizes an innovative design and construction team to meet the energy goal in design and operations is also critical. Using a well-planned energy-performance-based procurement process, which includes an energy goal and an appropriate project delivery approach, owners can be confident that their projects will have system-integrated, cost-effective efficiency strategies and renewable technologies that will perform as intended. Owner confidence in reduced operational costs and emissions is necessary if an energy efficiency focus is to prevail as a common project requirement; this guide aims to close the loop between industry expectations and results.

Specifically, this guide leverages NREL's recent campus expansion (which will be almost complete by the end of 2012) to provide best practices and lessons learned so other building owners can replicate these experiences to construct market-viable, world-class, energy-efficient buildings. The guide identifies and explains in detail the following five steps to Energy-Performance-Based Procurement:

1. Select the project delivery method.
2. Develop energy performance goals.
3. Include energy performance goals in the contract.
4. Manage design and construction to ensure energy goals are met.
5. Verify building performance.

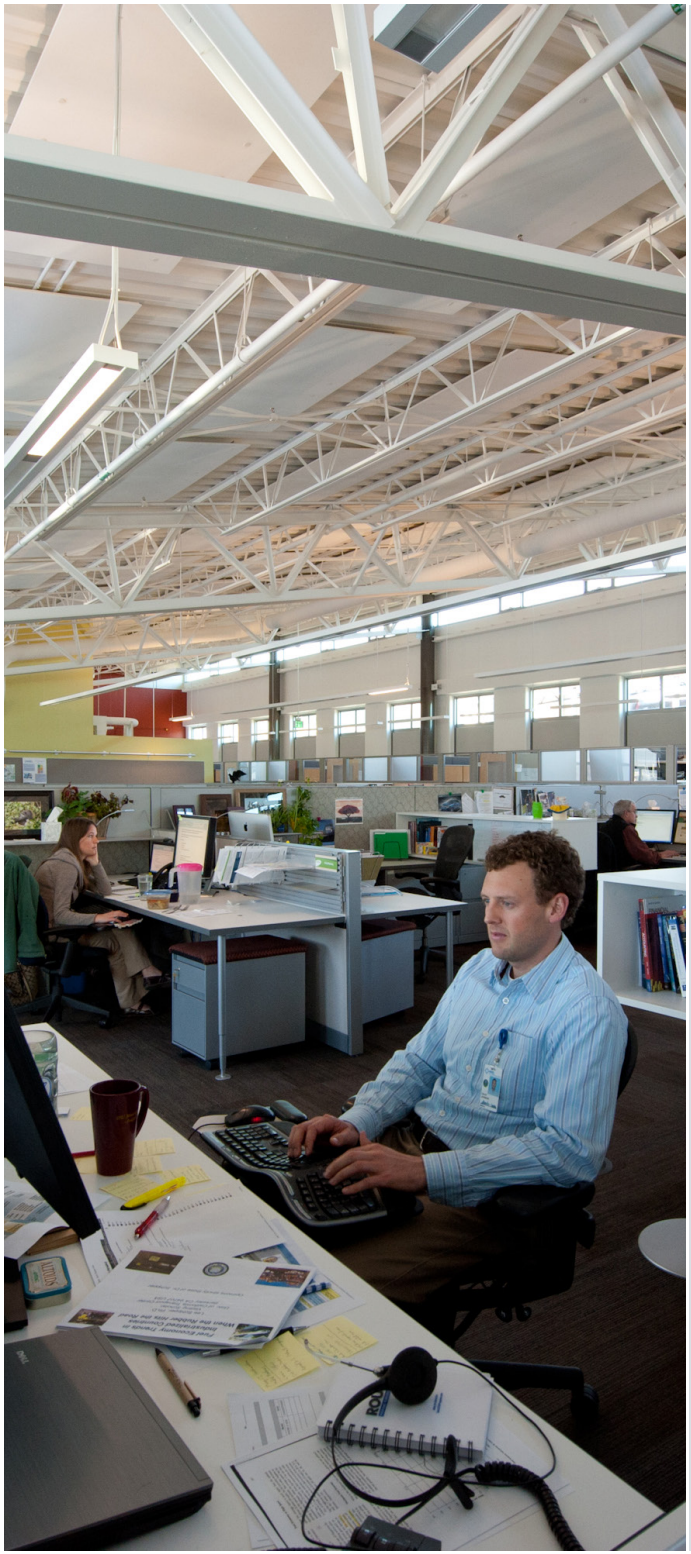
Although these high-level steps can apply to any project type, this guide focuses on high-performance, owner-occupied buildings that are either new construction or major retrofits; we have direct experience and proof of success in these areas. The variations in process details for other project types can be derived from these high-level principles.

The guide is intended for a broad audience of owner and design/construction team members. Each integrated project team member plays a role in achieving a high-performance building. That said, the how-to guidance is weighted toward the owner's perspective for a few reasons:.

- The authors have the most familiarity with this role.
- The success of a high-performance building is rooted in the owner's ability to set the tone for the project and carry the line throughout the building's life.
- Many resources are available to help the design and construction team members conceptualize, document, and cost estimate energy-efficient building designs. Example DOE resources that aid in the design process include the AEDGs and OpenStudio. (See "References" on page 48 for links and additional resources.)

This guide provides detailed information about integrating energy-performance-based requirements into integrated project delivery contracts. Basic guidance for related topics is also covered, but we assume the user has fundamental knowledge and experience with the following subjects:

- The design-build or other integrated delivery processes
- Energy efficiency terminology and design fundamentals
- Contracting and legal requirements
- Evaluating proposals and selecting bidders that provide the best value
- Oversight of the construction process
- Measurement and verification of energy use in commercial buildings.



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1.0 INTRODUCTION

It is rarely disputed that low-energy buildings are a good idea. Their advantages include:

- **They save owners and operators money.** Commercial building owners and tenants spend billions of dollars on energy every year, and reducing those expenses improves profitability.

- **Energy-efficient buildings are less subject to the risks associated with volatile energy prices.** Owners and operators of low-energy buildings can plan budgets with confidence, because energy accounts for a relatively small percentage of their operating expenses.

- **Improving energy efficiency shrinks a building's environmental footprint, because most energy use in buildings causes pollution and has other environmental impacts.** As markets begin to place a monetary value on avoiding pollutants, especially carbon dioxide and other greenhouse gases, the price of energy that produces pollutants is likely to rise. Higher energy prices will improve the already attractive economics of optimizing building energy efficiency. And increased building energy efficiency reduces U.S. dependence on foreign sources of energy, which improves national security and the balance of trade.

Many building professionals know how to build attractive, comfortable buildings that require little energy to operate. Further, many of the tools and strategies required to dramatically reduce energy consumption in buildings are mature, well-understood, and readily available.

Very few low-energy buildings have been built. Bridging the gap between the possible and the actual requires changes in the processes that owners, designers, and builders use to conceive and deliver buildings, and change can be difficult when there are real or perceived barriers (see Industry Barriers to High-Performance Buildings sidebar).

This effort is important, however, because today's buildings are large energy users and buildings have long lives. Commercial and residential buildings consume almost 40% of the primary energy and about 70% of the electricity in the United States. New buildings are built more quickly than old buildings are retired, so building energy use continues to increase. Electricity consump-

tion in the commercial building sector doubled between 1980 and 2000 and is expected to increase another 50% by 2025 (EIA, 2005).

In response to this need, the federal government is increasing the energy efficiency requirements for its building stock. In an October 5, 2009, Executive Order, President Obama instructed the federal government to "implement high performance sustainable Federal building design, construction, operation and management, maintenance, and deconstruction [by,]… beginning in 2020 and thereafter, ensuring that all new Federal buildings that enter the planning process are designed to achieve zero-net-energy by 2030" (Obama, 2009). Achieving these goals cost competitively will require new tools and strategies as well as refinements of design, construction, and operations and maintenance practices.

The NREL/DOE Research Support Facility (RSF), a large-scale net-zero energy office building, was one of the first projects to demonstrate how to meet this Executive Order using an energy-performance-based procurement process with contractual energy goals. From the beginning, the RSF presented a unique opportunity to demonstrate the state of the art in efficient, cost-effective, commercial office design and operation. The innovative procurement process that resulted in the RSF success demonstrates that significant gains in energy efficiency can be realized cost competitively in nonresidential buildings today with available technologies if careful attention is paid to delivery structure, energy goals, and integrated building design.

The results of new construction projects at DOE/NREL, including the RSF, and ongoing collaborations with industry provide application examples of the Energy-Performance-Based Procurement Process. The primary focus of the guide, though, is on the abstraction of these examples into best practices for realizing energy savings. It provides best practices to building owners' efficiency representatives, and informs executive management, contract development, and project management staff about how to develop energy use specifications in design-build contracts for high-performance new construction or deep renovation projects. There many possible variations to the recommendations provided in this guide, depending on the specific situation. As a result, we focus on the project types with which we have direct experience and that are likely to benefit the most from an energy performance based design-build process:

- **Owner-occupied buildings.** When the energy costs are incurred by the building owner, there is greater incentive to target high efficiency in the design stage and in practice. Owner-occupants have greater control over building operations, and can ensure that the intended savings are achieved. In an owner-tenant relationship, the tenant may not understand the nature of the efficiency measures and how to make the most of them. Similarly, the owner may not have the incentive to follow through with the necessary verification and ongoing commissioning steps. These hurdles can be overcome using creative leasing arrangements, but those strategies are outside the scope of this guide.
- **High-performance buildings.** When very high-performance (e.g. >50% savings beyond ASHRAE Standard 90.1-2010) or even net-zero energy buildings are targeted, innovative design and contracting practices are necessary to minimize cost, control risk, and ensure success. If saving energy is not a priority, common, straightforward project delivery methods may suffice. All architectural firms and construction companies are experienced with minimally code-compliant buildings, and such firms usually have sufficient capability with Leadership in Energy and Environmental Design (LEED)-certified buildings.
- **New construction or major renovation.** Integrated design is a prerequisite for achieving high-performance buildings, and is realistic only when the project involves new construction or major changes to the envelope and mechanical systems. Most common retrofit projects do not offer sufficient opportunities for fundamental design tradeoffs and passive energy efficiency measures, although all building improvement projects should consider system interactions.
- **Larger buildings or portfolios.** Much of the guidance requires energy modeling, innovative contract language, and other advanced project management techniques that may not be appropriate for small businesses with limited resources and relatively small utility bills. These initial investments can be easily recouped in larger projects, but may be too complex for small businesses. NREL is developing simplified approaches for smaller buildings that are more prescriptive and require less expertise.

Once an owner decides that a particular building will be high performance, a series of actions must be taken to ensure the building performs at a reasonable cost. These actions are front loaded, before the design process begins, and lay the groundwork for the energy-performance-based procurement process to play out with the integrated project team.

1. Select the project delivery method (predesign).
2. Develop energy performance goals (predesign).
3. Include energy performance goals in the contract (predesign).

4. Manage design and construction to ensure energy goals are met (design through construction).
5. Verify building performance (construction through occupancy).

A successful execution of this full process should result in a project that has integrated all necessary design efficiency strategies to meet the energy use requirements within the project budget. And, by following through with appropriate project and energy management principles, the predicted energy performance can be reached in actual operations.

How To Use this Guide

The energy-performance-based procurement process steps follow in time sequence with project planning through construction, as follows:

1. **Predesign.** Extends from project inception to the proposal phase, through contract award.
2. **Design.** Extends from schematic design, which follows after the proposal phase, through construction documents.
3. **Construction.** Overlaps with the design phase, extending until the building is turned over to the owner at project completion.
4. **Occupancy.** Extends from project completion to the building's end of life.

This guide reads as a project timeline (see Table 1). The sections are divided into the key steps needed to guarantee high performance, and are differentiated by the colors of the table rows. Each team member who plays a role in the Energy-Performance-Based Procurement Process is identified in the column headers. Each person or "role" has specific tasks that need to be performed at various steps. To find out which steps a person needs to perform, turn to the page given in the table for a task list. Not every project will identify team member roles as identified in this guide. The general responsibilities that differentiate each role are:

- **Owner/executive management.** Leaders in the owner organization who make decisions about the project delivery process type and structure. This role sets the overall tone for the project.
- **Owner representatives.** Guide the owner in developing contract language and review substantiation documents.
- **Owner/contracts.** Develops the contracting mechanisms that allow for collaboration, integration, and a focus on energy throughout the procurement process.
- **Owner/project manager.** Project leader who is involved from predesign through initial operations and sets the daily tone, requiring consideration of energy performance at each project decision point.
- **Energy modeler.** Takes the first step in the design process to determine if the energy goal is feasible and defines the building attributes that are necessary to achieve the goal.
- **Integrated project team (IPT).** An owner representative group that consists of building system specialists. The group participates in project meetings and reviews substantiation documents. In some cases, this group or person is the same as the owner representative.
- **General contractor.** Aside from traditional responsibilities, provides cost estimating early in the design and investigates approaches that decrease costs and improve energy performance throughout the process.
- **Architect.** Aside from traditional responsibilities, guides the design team, including engineers and other consultants, in an integrated delivery process.
- **Design engineer.** Aside from traditional responsibilities, investigates energy efficiency options and works with the energy modeler to assess these options in a whole-building energy model.
- **Commissioning agent.** Reviews all design documents for energy-related issues such as installation and operating efficacy. Verifies proper equipment installation and settings at the end of construction.
- **Owner/facility manager.** Maintains the building's high-performance operation from an equipment perspective.
- **Owner/energy champion**. Maintains the high performance operation of the building from an occupant and process perspective. Likely to be the same person as the Facility Manager.

In addition to the background information, specific steps, and task lists for each defined role, appendices contain the Request for Proposals (RFP), or contract, for three projects using the performance-based-procurement process.

Roles and Responsibilities (page number)

Procurement Step	Project Phase	Owner / Executive Management	Owners Representative	Owner / Contracts	Owner / Project Manager	Energy Modeler	Integrated Project Team	General Contractor	Architect	Design Engineer	Commissioning Agent	Owner / Facility Manager	Owner / Energy Champion
Select the project delivery method	Pre-design	p. 14	p. 16	p. 14		p.15							
Develop energy performance goals	Pre-design		p. 24			p. 25	p. 24						
Include energy performance goals in the contract	Pre-design		p. 27,28, 31	p. 32			p. 28,29	p. 32	p. 32	p. 32			
Manage the project to ensure energy performance specifications are met	Design through construction		p. 36, 41, 43	p. 43	p. 36, 43	p. 36	p. 36	p. 36, 41	p. 36, 41	p. 36, 41	p. 36	p. 36	
Verify building performance	Design through occupancy			p. 45	p. 45	p. 45					p.45	p. 45	p. 45

NREL Campus Expansion Background

The U.S. Department of Energy's (DOE) National Renewable Energy Laboratory's (NREL) goal is to expand its leadership as a state-of-the-art laboratory that supports innovative research, development, and commercialization of renewable energy and energy efficiency technologies that address the nation's energy and environmental needs. This growth has resulted in a significant increase in employees and facilities on its 327-acre main campus in Golden, Colorado.

To support this growth over the last five years, NREL Commercial Buildings researchers developed and demonstrated many of the new construction procurement and acquisition methods discussed in this guide. We have found that cost-effective and deep energy savings are possible when the design-build industry is better integrated. NREL facility growth was our opportunity to demonstrate these methods in real projects by incorporating energy performance specifications into the design-build RFPs and contracts. We developed and piloted this energy performance based design-build process with our first new construction project in 2008, the Research Support Facility (RSF). We have since replicated and evolved the process over four subsequent projects:

- Research Support Facility (RSFI). An 824-occupant, 220,000-ft2 office building with a data center
- Research Support Facility Expansion (RSFII). A 500-occupant, 150,000-ft2 office building and conference space expansion to the RSFI
- Energy Systems Integration Facility (ESIF). A 182,500-ft2 smart grid research laboratory with a supercomputer and 200 workstations
- Parking Structure and Site Entrance Building. A 5-deck, 1,800-car parking garage and a 1,500-ft2 campus access control building
- Staff Cafeteria (Café). A 12,000-ft2 commercial kitchen, servery, and 250-seat dining hall.

Each project incorporated world-class efficiency strategies using contractual energy use requirements in the design-build contracts, all on typical DOE construction budgets.

The growth of NREL's campus over the last five years posed challenges in the pursuit of DOE's energy and sustainability goals; however, these challenges enable NREL to demonstrate the procurement of world-class efficient and renewable applications. NREL is committed to demonstrating federal leadership in sustainability, working to continuously improve its performance, and leading by example. NREL's campus is a living laboratory that showcases new technologies, design practices, and operating behaviors. In all campus development, NREL looks for opportunities to integrate energy efficiency and renewable energy, high-performance buildings, and sustainable transportation options. A campus layout is shown below.

NREL Campus, 2012

RSFI is used as an example throughout the energy-performance-based procurement process sections. The other projects are discussed in terms of their performance goals and best practice highlights in the following sections.

STEP 1 SELECT THE PROJECT DELIVERY METHOD

Process Summary

- **Step 1: Select the Project Delivery Method**
  - Considerations when Selecting the Project Delivery Method
    - *Type of Construction Project*
    - *Type of Building*
    - *Type of Owner*
    - *Cost*
    - *Schedule*
    - *Risk*
    - *Efficiency Target*
  - Common Design and Construction Project Delivery Methods
    - *Design-Bid-Build*
    - *Construction Manager at Risk*
    - *Design-Build*
  - Define the Project Delivery Terms
  - Assemble an Integrated Project Team
    - *Assemble the Pre-Design Integrated Project Team*
    - *Assemble the Design and Construction Integrated Project Team*

+ Step 2: Develop Energy Performance Goals

+ Step 3: Include Energy Performance Goals in the Contract

+ Step 4: Manage the Project to Ensure Energy Goals are Met

+ Step 5: Verify Building Performance

Select the Project Delivery Method

The goal in applying a performance-based procurement process is to specify the performance requirements, including energy efficiency, rather than efficiency solutions. The process is most successful when the RFP allows for a well-integrated and motivated project team to deliver a world-class facility. When the RFP specifies a solution, such as allowable types of lighting, conceptual design drawings, floor plans, or architectural massing requirements, these key early design decisions are being made outside the competitive and integrated delivery process. This can result in poor energy decisions that limit the energy savings and cost effectiveness potential of a project even before the project team has been hired. This section gives considerations for owners when selecting a delivery process and describes which of the commonly used project delivery methods have synergy with the energy-performance-based procurement process.

Considerations When Selecting a Project Delivery Process

A number of factors enter into the choice of project delivery process and drive the optimal contracting mechanism and the viability of meeting ambitious energy performance targets. (See Sidebar, Select the Project Delivery Method.)

Type of Construction Project

New Building

All new buildings of relatively large size and complexity require both architectural and construction support. New buildings also offer the best opportunities for achieving high performance, because they pose fewer design constraints than do existing buildings. A blank slate is the ideal circumstance for leveraging creative and innovative design and construction techniques to construct a superior building with world-class energy efficiency.

Renovation/Addition

In general, the same considerations that apply when choosing a project delivery process for new buildings also apply for major renovations and building additions. The key is whether the changes are substantial enough that architectural services are required, and the contractor can be held accountable for overall building performance. Integrated design is essential for superior building performance, and when building systems are largely fixed (as in a typical retrofit), it is very difficult to achieve the necessary level of integration. In such cases, a more traditional approach such as energy performance contracting may be appropriate.

Type of Building

The size, complexity, and projected energy use of a building are important considerations when choosing a project delivery approach. Complex projects require substantial coordination among team members, so including energy performance as a key element will not add a significant burden. Smaller buildings such as those in strip malls, and low-EUI buildings such as warehouses, may not be ideal applications for some of the more advanced techniques discussed in this guide.

The same is true for cookie-cutter buildings where there is insufficient design flexibility to achieve truly high performance.

Type of Owner

All building owners (whether for-profit, nonprofit, or governmental) have the same basic requirements for a high-quality building that is cost efficient to build, comfortable and safe, and meets the functional needs of the organization. Certain owner types may, however, encounter institutional or legal barriers to innovative or alternative contracting approaches, including design-build contracts and performance-based requirements. Additional educational and administrative efforts may be necessary to overcome these barriers.

Cost

Project budgets are always important. When correctly implemented, the initial investment in high performance can be easily repaid through lower utility bills, reduced maintenance costs, enhanced worker productivity, and even higher sales for retail and service buildings. In fact, even the incremental first cost for high performance can be minimal if innovative and cooperative approaches to construction and building design are followed. When construction budgets are very small, a prescriptive path to high performance (such as the Advanced Energy Design Guides [AEDGs]) may be more appropriate to avoid energy modeling, large project teams, and other important features of larger projects.

Schedule

Schedule constraints may not allow for a clean step-by-step design and construction process. Instead, an integrated approach is often necessary, where the design is heavily influenced by constructability, and consequently, fewer change orders are needed.

Risk

The risk can be borne or shared by many parties involved in the project delivery process. When risk is transferred from the owner to a contractor, a price premium can be expected. But when all accountable parties clearly understand the requirements and are involved in the decision-making process, the overall project risk can be minimized.

Efficiency Target

If the goal is to build a code-minimum, or even a LEED-certified or ENERGY STAR® building, many project delivery approaches may work effectively. Very aggressive energy efficiency targets require extra attention to target setting and coordination of design and construction activities throughout the delivery process. World-class efficiency requires creativity and an integrated design philosophy that involves the full construction team as well as the building owner, occupants, and other stakeholders. Energy matters must be factored into every design decision, and flexibility must be maintained at every stage to exploit all opportunities. By fully defining the energy targets and providing the contractors with design flexibility and incentives to meet those targets, high-performance buildings can be achieved without significant additional cost or risk.

Common Design and Construction Project Delivery Methods

To better understand how to deliver cost-competitive, energy-efficient projects, we must first consider the available project acquisition and delivery methods.

Until the early 20th century, owners typically hired master builders to design, engineer, and construct buildings, a process similar to what we now call design-build. This delivery method has a venerable history. In ancient Mesopotamia, the Code of Hammurabi (1800 BC) required that master builders assume absolute responsibility for design and construction of their projects. In the succeeding millennia, the design-build paradigm was commonplace, accounting for projects ranging from cathedrals to bridges to cloisters to corporate headquarters (Design-Build Institute of America, 2009).

Over time, project schedules and budgets became more constrained and design and construction services became more specialized. Eventually, the dominance of the master builder gave way to a design-bid-build delivery system (Konchar, 1997). In 1985, only about 5% of all commercial work in the United States was done using design-build; about 90% used the design-bid-build method. In 2005, about 40% of commercial construction used design-build, and that percentage continues to grow (Design-Build Institute of America, 2009).

Design-Bid-Build

A design-bid-build scenario consists of the following steps:

1. A building owner enters into a contract with a designer to develop plans and specifications.
2. The owner and designer determine the project's scope, including the type of construction and the budget.

Industry Barriers to High Performance Buildings

Capital Cost and High Performance

First costs, or capital costs, for energy efficiency strategies in commercial buildings often form a significant barrier to realizing high-performance buildings with 50% or greater energy savings. Historically, the industry has been unable to achieve deep energy savings because it relies on energy cost savings and simple payback analysis alone to justify investments. A more comprehensive and integrated cost justification and capital cost control approach is needed. First cost barriers can be overcome by implementing innovative procurement and delivery strategies, integrated design principles and cost tradeoffs, life cycle cost justifications, and streamlined construction methods. It is now possible to build marketable, high-performance office buildings that achieve LEED Platinum status, save more than $1/ft2 annually in energy costs, and reach net-zero energy goals at competitive whole-building first costs, as illustrated by DOE/NREL's RSF. The RSF reached these goals while maintaining a firm-fixed price budget at competitive whole building capital construction costs (move-in ready) of $259/ft2.

The RSF project is not the first to claim that energy efficiency and green design do not require additional capital cost. An example near the RSF is the Aardex Signature Centre, a LEED Platinum built-to-suit office building. According to published claims by the developer and design team, the LEED Platinum and energy efficiency strategies had to pay for themselves within three years, or be considered on a "whole project" basis, considering all benefits and cost tradeoffs. A commonly cited example is the dedicated under floor air with chilled beam mechanical system, which included components that could be considered to be more efficient, but more expensive than a conventional system. However, those "additional" costs are offset by reductions in other building costs, such as the reduced building height of 10 in. per floor, resulting in less envelope, reduced ducting, and higher delivery air temperatures, so the overall project costs were similar to office buildings with conventional mechanical systems (Aardex, 2011). Ben Weeks, the Aardex principal in charge of the Signature Centre, has identified a key strategy for incorporating the best in energy efficiency and LEED:

> *A vertical integration of the development interests—design, construction, and ownership—will result in significant savings to a project—as much as 15% or more of overall costs. This allows implementation of the most beneficial strategies and features at a delivery price at or below market rates for conventional facilities. (Aardex, 2011)*

Two large sector-wide studies of LEED rating and capital costs have also concluded that there is no significant difference in average costs for green buildings compared to nongreen buildings. The Davis Langdon survey of capital costs (Davis Langdon, 2007) of institutional projects such as libraries and academic buildings documented a range of construction costs from $225/ft2 to more than $500/ft2—construction costs similar to our cursory survey of publically available project capital costs.

A more recent analysis was documented by Greg Kats (Kats, 2010). Based on a dataset of 170 projects, Kats documented that most green buildings have slightly higher costs than similar conventional buildings, but that some had no incremental costs. Kats proposed that the cost premiums for green buildings are more a function of the experience project teams have with cost-effective green design and construction rather than the LEED certification level. In fact, more than 80 of the projects in Kats' dataset reported 0%–2% green cost premium, with no correlation between the LEED level achieved and the cost premium.

> *For instance, many of the buildings in the data set with low (no more than 2%) or zero reported premiums are either Gold (29 buildings) or Platinum level (five buildings). Indeed, the data demonstrate that relatively green buildings can be built with virtually no cost premium, while some slightly green buildings can have a substantial cost premium. (Kats 2010, pp. 12–13)*

Our preliminary survey of construction costs and those available in industry show that energy-efficient and green buildings may cost more, but do not necessarily have to cost more. The procurement and acquisition best practices in this guide are presented to help owners and project teams realize high-performance green buildings that do not have to cost more.

Design Predictions and Actual Energy Performance

Another industry barrier to achieving high-performance commercial buildings, which operate from 50% savings to net-zero energy, is the disconnect between the energy performance design predictions and the realized energy use. A recent New Buildings Institute study (NBI 2009) documenting this industry barrier found that although some green buildings met their design site energy use intensity (EUI) predictions, many did not. In general, LEED modeling is not intended to be aligned with actual performance; rather, it is intended to be a tool for relative comparison to verify design energy savings over a fictitious baseline model. LEED models are typically not updated based on as-built conditions, so they miss many changes that occur between final design and occupancy. Key assumptions such as plug loads or the various types of occupancy patterns are typically not studied, resulting in less-than-realistic occupancy use patterns. And finally, when LEED projects are designed to a percent savings goal, it is not realistic to measure or operate a building against a percent savings prediction.

In a net-zero energy high-performance building project, relative savings energy modeling will not suffice. An estimate, or prediction, of actual energy use is needed to size onsite renewable energy systems to reach a net-zero position. Many key elements demonstrated in this guide also address this market barrier, from contractually requiring whole-building absolute (rather than relative) energy use to developing a detailed performance assurance plan with end use metering. Owners should expect high performance from their buildings, and this guide can help set up a procurement and acquisition process to help ensure high-performance facilities.

3. The designer estimates building costs based on experience and input from engineers and other consultants.
4. When the design is complete, the owner puts the job out for bid (often with the help of the designer). This process can take weeks—or even months—for a complex project.
5. During the bid phase, the owner receives and evaluates bids (again, often with the help of the designer) from the contractors who are competing for the job.
6. The owner enters into a contract with the successful bidder and warrants that the plans and specifications are complete and correct.
7. The contractor agrees to build the project according to the plans and specifications developed by the designer, and the parties agree on a price and schedule. The designer and contractor often have no contact or relationship with each other until after the contract is awarded, which limits the potential of integrated design concepts to provide the most cost-effective energy efficiency strategies. If the bids come in higher than the designer's estimates, the owner and designer must decide how to bring costs back within the budget.

This process takes time, and can result in the elimination of energy efficiency and other nonaesthetic building components and strategies that typically are not well integrated with the architecture or envelope, as these can be easily replaced with less efficient alternatives. Because the design and construction contracts are separate, this method offers some checks and balances for the owner (Molenaar, 2009); however, the owner pays a price in scheduling and fully integrated efficiency solutions. This method is also the most time-consuming of the three noted here and may result in adversarial relationships. The value engineering process, disputes, cost overruns, and construction delays can result in less-than-optimal performance, headaches (and often litigation), and can increase project costs.

Although the design-bid-build process typically provides the best price for the project, it limits the design team's creativity in developing the most cost-effective, integrated, and energy-efficient solution. It also often limits the design team's full integration with the builder, cost estimators, and subcontractors, resulting in a longer, more costly delivery process and lower value.

Construction Manager at Risk

An owner can retain a designer to furnish design services and a construction manager who guarantees the project meets cost and schedule requirements. In this delivery method, the owner authorizes the construction manager to handle many project details, but the owner is responsible for the design. The construction manager is involved from an early stage, and becomes a collaborative member of the project team (Molenaar, 2009). As such, he or she brings construction experience to bear during cost estimating, scheduling, and other preconstruction activities. However, the design and construction activities are not fully integrated.

Design-Build

In design-build, the building owner contracts with a single legal entity—the design-builder—to provide a completed building based on the owner's design criteria. Unlike design-bid-build and construction manager at risk, the design-builder controls the design and the construction processes. The owner develops a clear, comprehensive RFP that outlines the expectations, and the design-builder—like his or her master builder forebears—assumes complete responsibility for delivering the project as specified in the RFP, on time and on budget.

Prescriptive-Based

In prescriptive-based design-build, at least part—and sometimes most—of the design solution is included in the owner's RFP. Also called bridging, in this scenario the owner prescribes the solution in the RFP with plans and specifications. Because the owner developed the solution, the design-builder cannot be held accountable for the effectiveness of the design. As a practical matter, this approach may be very similar to design-bid-build.

Performance-Based

Performance-based targets allow for design flexibility and encourage innovative, cost-effective, and integrated design strategies. In performance-based design-build, the owner does not rely on plans and specifications to describe the project scope. Instead, the owner focuses on the problems and leaves the solutions to the design-builder. The intent is to give the design-build experts freedom to creatively meet the owner's objectives in a competitive forum. This delivery method allocates control and accountability differently in that the owner:

1. Sets a firm price for the project.
2. Establishes program and performance requirements.
3. Ranks these requirements in an RFP.
4. Invites design-builders to propose solutions that best achieve the priori-

tized requirements.

5. Selects a design-builder to complete the project for a fixed price, which includes the design-builder's specified scope of requirements proposed.

The successful design-builder designs, builds, and delivers a project that meets the contractually proposed requirements, within a proposed fixed schedule, and for the firm-fixed price (Design Sense Inc., 2008). Although the design-builder may have incentive to cut corners to increase the profit margin under a fixed price contract, the owner can reduce this risk by clearly specifying all minimum requirements and performance targets.

As a subset of the typical design-build process, performance-based design-build attempts to elevate design and performance requirements to be on par with budget and schedule. The object is to create an instrument that motivates marketplace providers to offer greater value for the owner's asset—value defined as performance over time acquired at a competitive cost. The following advantages of performance-based design-build make it the most appropriate project delivery mechanism for high-performance buildings:

- **Singular responsibility.** With design and construction in the hands of one entity, there is a single point of responsibility for coordination, quality, cost control, and schedule adherence. This avoids finger pointing between designers and builders for errors or shortcomings. It removes the owner from the role of referee and allows for productive time spent focusing on other project needs and timely decision making.
- **Quality.** The singular responsibilities inherent in the design-build process serve as motivation for high quality and proper performance of building systems, because accountability is clear and the design-builder has incentive to protect his or her reputation. Once the owner's requirements and expectations are documented (and agreed to by the design-build entity), the design-builder is contractually responsible to construct a facility that meets or exceeds those criteria.
- **Cost savings and value.** Design professionals and construction personnel work and communicate as a design-build team to efficiently, accurately, and creatively evaluate alternative materials, building systems, and construction methods. Value engineering and constructability reviews are used more effectively when the designers and builders work as one body during the design process.
- **Time savings.** Because design and construction can overlap, and because general contract bidding periods and redesign time are eliminated, total design and construction time can be significantly reduced. A contractor-driven schedule, IPT, and no project-driven change orders all contribute to reducing delivery time, saving significant capital costs.
- **Risk management.** After the project requirements are outlined in the RFP, the owner will receive design solutions and cost proposals representing the best thinking of several design-builders. These alternative designs enable the owner to weigh the risks and benefits of several competing proposals before committing to a design solution. Change orders caused by errors and omissions in the construction documents are eliminated because the design-builder—not the owner—is responsible to correct them. Risks are thus assigned to those best capitalized, staffed, and experienced to assume and manage them.
- **Innovation and commercialization.** Because prescriptive specifications are substituted with performance requirements, design-build teams are free to develop creative and innovative responses to stated problems.

Define the Project Delivery Terms

As described in the previous section, a design-build delivery method ensures, better than other established methods, a cost-effective, high-performance building. The delivery method must also consider the means for finding the highest value proposal, the approach for incentivizing value throughout design and construction, and the best guarantee of operational savings. The Design-Build Institute of America (DBIA) gives seven best practices that relate directly to ensuring value. DBIA offers in-depth training on the topics, which are described briefly (Leitner, Subcontract # AFJ-8-77550-01, 2008) and referenced throughout the energy-performance-based procurement process steps.

(Owner/Executive Management and Owner/Contracts)

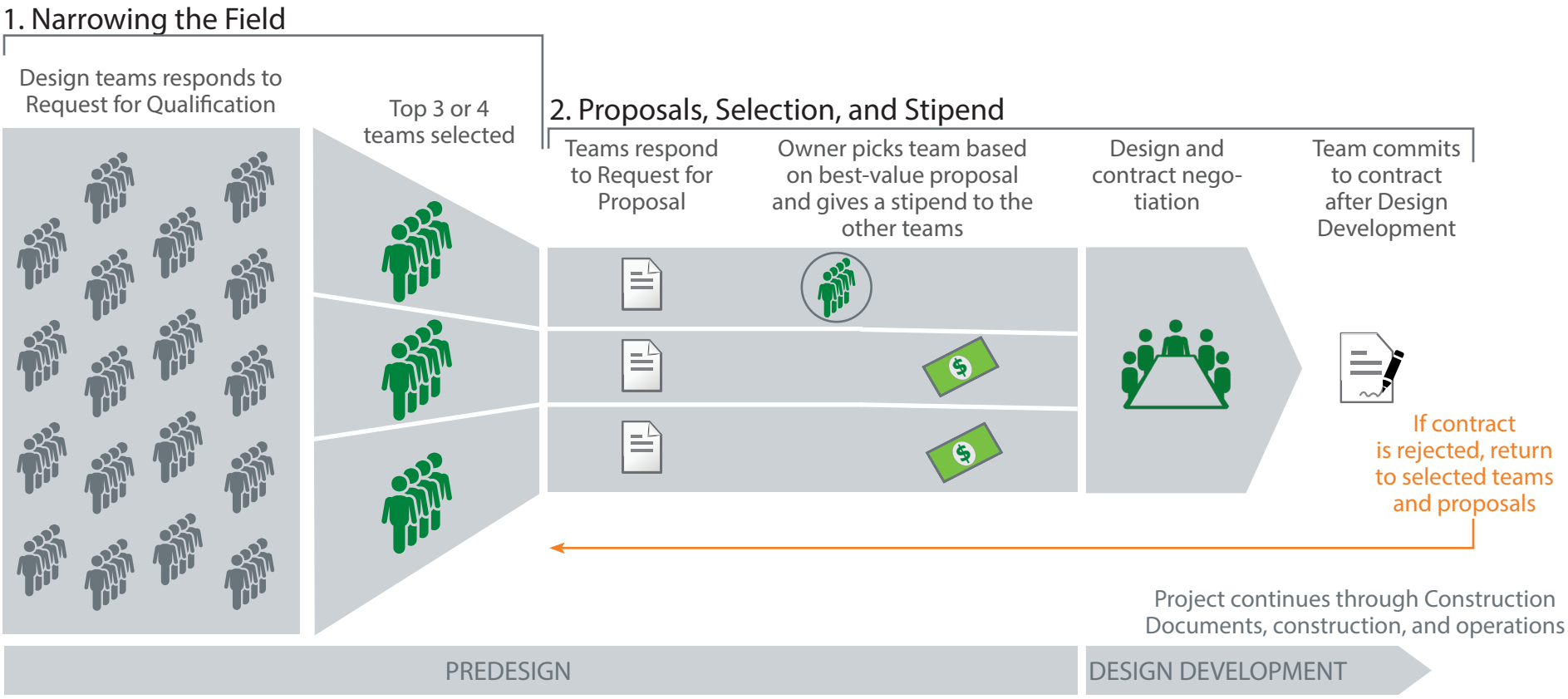
- **Best value procurement.** Present the scope in a ranked list so all offerers can give their perspectives on the items achievable within the fixed budget. (Or, weight energy-related items more than cost or other objectives in the proposal evaluation rubric. This topic is discussed in more detail in the "Set Energy Performance Goals" section.)
- **Two-phase solicitation.** Use an initial Request for Qualifications (RFQ) phase to compare resumes, experience, past performance, and safety records. Then provide the RFP to a short-listed set of offerers.
- **Short-list to no more than three qualified teams.** This gives offerers a one-in-three chance of winning, which can increase proposal quality, and gives reviewers time to discern the best-value team and risks

associated with moving forward if the proposals are not of the expected quality.

- **Interim interviews during competition.** Accept questions from offerers and provide answers to all teams to minimize RFP gaps and risks before proposal reviews.
- **Stipends to unsuccessful offerers.** Request conceptual designs as part of the proposal, the costs of which are offset by stipends. This approach gives the owner rights to use and share ideas from unsuccessful teams with the winning team.
- **Award fee program with incentives**. Motivate and modify subcontractor behavior with an ongoing performance evaluation program with a typical monetary value of 2%–3% of the total subcontract amount. This best practice ensures the owner has a voice during design and construction. (See Section 6.1.1.3 for more information on this DBIA best practice as applied to high-performance buildings.)
- **Performance specifications versus technical specifications.** The value of this approach was discussed in Section 2.2. In the Energy-Based-Procurement Process, the most important performance specification that will ultimately relate to technology specifications is the contractual energy goal, which is the thread connecting the remaining sections of this document.

These steps are described in the following diagram.

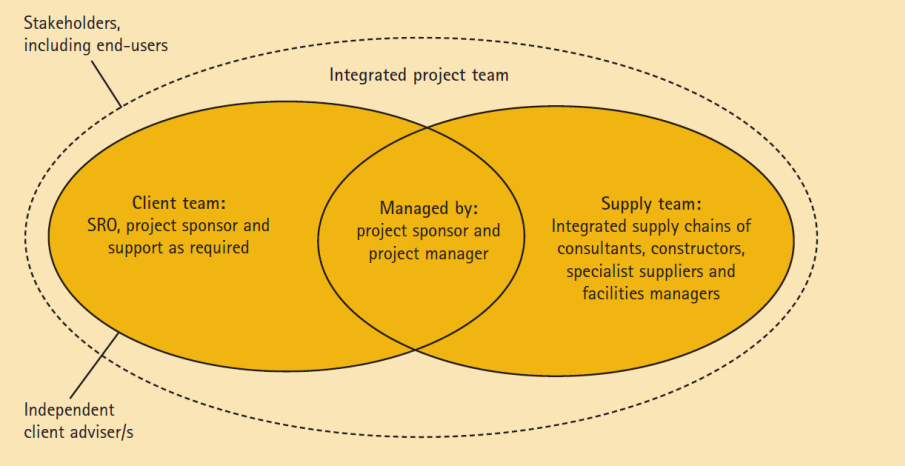
TWO STEP COMPETITIVE SELECTION



Assemble an Integrated Project Team

An IPT comprises architects, engineers, and builders, cost estimators, and key subcontractors. Its purpose is to ensure that the owner, designers, and contractors work together iteratively to improve quality and reduce costs. The means having all players participate in meetings and partnering sessions as soon as a contract is awarded so members become familiar and comfortable with each other long before construction begins. Because the general contractor and key subcontractors—typically the team members most familiar with cost and constructability issues—have input during the design process, this delivery method takes full advantage of the contractor's experience and knowledge.

A key member of the IPT is the project manager. He or she focuses on keeping the project moving—on time and on budget, integrates the needs of the various project teams, and helps them negotiate the inevitable obstacles that arise without losing sight of the overall project goals. The project manager does not necessarily make the decisions, but instead facilitates the decision-making process. The following image shows the IPT relationships.



(Credit: Office of Government Commerce: Procurement Guide 05, The integrated project team)

Assemble the Pre-Design IPT

Although performance-based design-build reduces the owner's financial risk, it places the responsibility for developing clear performance goals squarely on the owner. An early form of an IPT that includes just the stakeholders and independent client team can help the owner develop the key project requirements and energy goal, and ultimately draft the RFP and review the proposals.

The owner may choose to hire a design-build implementation services provider to help write the RFP. Because successful performance-based design-build procurements rely on clearly articulated performance goals, it is often prudent to hire an expert to develop this critical component. This owner representative has a large, early role to listen to—and clearly communicate—the owner's needs in a prioritized manner to the proposing IPTs.

(Owner/representatives)

- Identify building system and energy experts, either internal to the owner organization or third-party consultants who will not participate in the design competition and who can act as the predesign IPT.
- Request that the predesign IPT members read the section on setting energy performance goals so consideration is given to energy goals before the RFP is drafted.
- Help the owner, executive management, and other project team members to align their goals. Energy efficiency should be a top priority, but a few others, including budget, schedule, and safety, must also be considered. Help tease out the most important goals and ensure there are no obvious conflicts between top priorities.
- Document goals in a clearly formatted RFP. This will be discussed further in Section 4.

Assemble the Design and Construction IPT

With respect to the energy performance, all IPT members must participate in design review and substantiation. Detailed computer simulations help the team to assess whether the design, as it evolves, meets the owner's performance requirements and cost constraints. The performance must be maintained in construction, requiring all IPT members to understand the impact of their trade on the building's energy use.

If a design-build implementation services provider is hired, this person can also assist the project manager during the design and construction process by delivering key services such as:

- Design-build implementation
- Engineering support during design
- Engineering support during construction
- Third-party commissioning.

Select the Appropriate Project Delivery Method: RSF

During the initial acquisition planning process for the RSF in 2007, NREL decided that to deliver the RSF, with its challenging performance requirements, on time and on budget, a traditional design-bid-build procurement process would not suffice. The owner team thus opted for a performance-based design-build procurement process. The goal to achieve significant energy savings could not override a focus on cost effectiveness and ensuring DOE obtained the best value, as DOE provided a firm fixed price of ~$64 million to design and build the RSF. DOE budgeted the RSF's construction costs of 259/ft2 to be competitive with today's less energy-efficient institutional and commercial buildings (see Figure 3).

DOE typically uses a design-bid-build approach to project acquisition, selecting separate design and construction contractors. Although this process typically provides the best price for the project, it limits the design team's creativity in developing the most cost-effective integrated energy efficiency solution. Past NREL projects have shown that this process often limits the design team's full integration with the builder, cost estimators, and subcontractors, resulting in a longer, costlier delivery process with less value.

DOE and NREL selected a performance-based "Best Value Design-Build/ Fixed Price with Award Fee" delivery approach for the RSF and all future projects to:

- Encourage innovation on the parts of the design and build private sector.
- Reduce the owner's risk.
- Expedite construction and delivery.
- Control costs.
- Make optimal use of team members' expertise.
- Establish measurable success criteria.

To familiarize its staff with the finer points of the design-build process, DOE/NREL commissioned DBIA to conduct a week-long seminar on design-build best practices. NREL hosted a national design charrette to identify and fully define the project and its potential challenges. DOE/NREL implemented the DBIA best practice of hiring a design-build acquisition consultant to help shape the key performance objectives and performance substantiation criteria. In a process known as "3PQ Management" (DesignSense 2010), the team collaborated to:

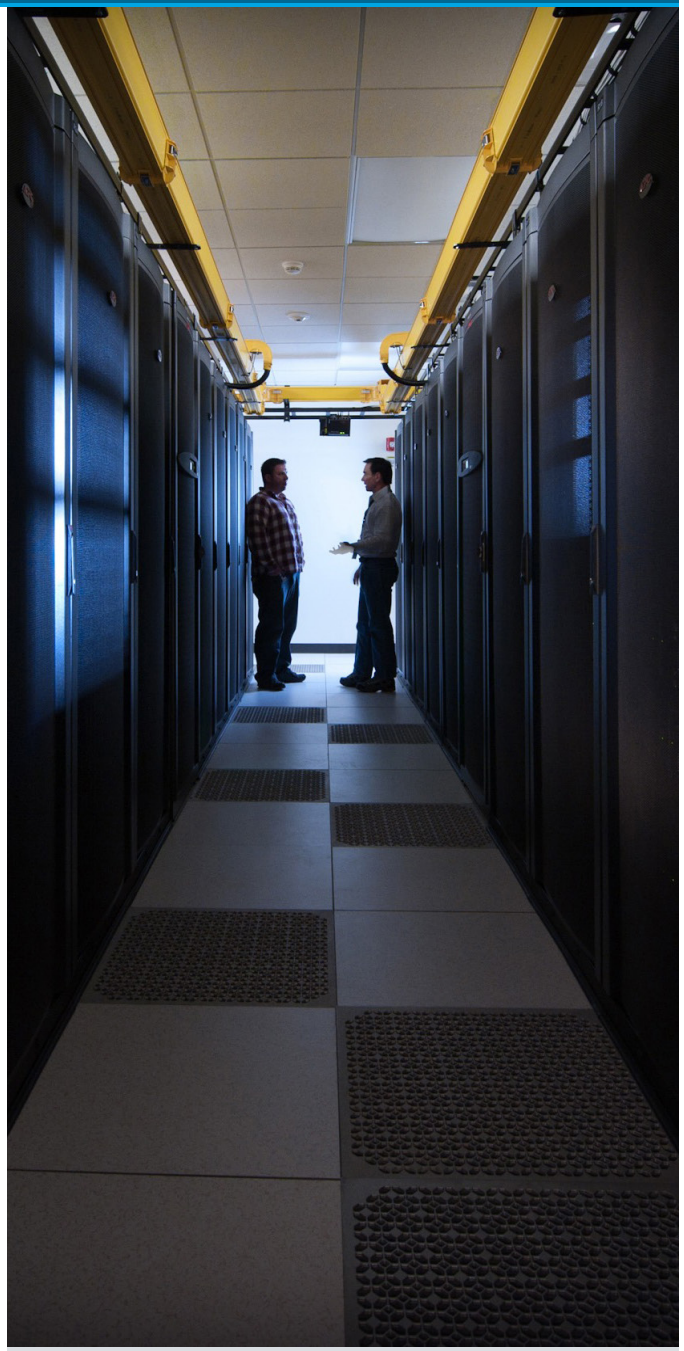
- Define the project goals, challenges, and constraints.
- Evaluate risks.
- Establish an acquisition strategy.
- Develop criteria for selecting the design-build team.
- Document the requirements with exacting measures to be used to substantiate overall project performance.

The RSFI is NREL's administrative support office building, and includes 824 workstations, numerous conference rooms, a data center, a lunchroom, a library, and an exercise room. It was completed in June 2010 and showcases numerous high-performance design features, passive energy strategies, and renewable energy technologies. With LEED Platinum certification, net-zero energy, and energy use of 35 kBtu/ft2/yr, it is a prototype for the future of large-scale, market-competitive net-zero energy buildings.

STEP 2 DEVELOP ENERGY PERFORMANCE GOALS

Process Summary

+ Step 1: Select the Project Delivery Method
– **Step 2: Develop Energy Performance Goals**
  - Specify Key Project Parameters and Drivers of Energy Use
  - Set Energy Performance Goals
    - *Energy Goal Options*
    - *Resources for Setting Energy Goals*
    - *Use Normalization Factors To Adjust Energy Goals*
    - *Subsystem-Level Targets*
+ Step 3: Include Energy Performance Goals in the Contract
+ Step 4: Manage the Project to Ensure Energy Goals are Met
+ Step 5: Verify Building Performance



In tandem with contract development, the Integrated Project Team or owner's representative will be defining project scope and priorities. In contrast to typical projects, a high performance project using the Performance-Based-Procurement Process needs to be thinking about the building needs, requirements, and specifications from an energy performance perspective. The following sections outline the considerations for the owner's project team.

Specify Key Project Parameters and Drivers of Energy Use

A first task of the predesign IPT is to define the project needs, often referred to as the basis of design or owner project requirements. In an energy-performance-based procurement process, energy-related features should be given careful consideration. The following project parameters have particularly strong impacts on energy use.

- **Building function.** Buildings are designed for the functions they will facilitate, and different building functions have different energy use characteristics. Retail buildings, for which merchandise display is a key function, typically have large lighting loads. Office buildings typically have high computing loads, and often require dedicated data centers. Some buildings may be considered as hybrids of other, single-function types (e.g., a hospital with medical offices). Functions such as electric vehicle charging stations and exterior lighting, which may be exterior to the building but still included in the immediate site, must be included.
- **Climate.** Envelope and ventilation loads, and the effectiveness of many efficiency strategies, vary with climate; for example, natural ventilation is most effective in mild climates. Energy performance of buildings with lower surface area-to-volume ratios or lower outdoor airflow requirements is less affected by climate.
- **Plug and process loads (PPLs)**. These vary with function and can have a substantial impact on whole-building energy use.
- **Hours of operation.** Operating requirements can differ between night and day. Cooling loads are larger during the day, whereas heating loads (in the absence of temperature setback) are larger during the night. For exterior spaces, lighting equipment is typically used only at night. Strategies that require solar energy or daylight are beneficial only during the day, and some strategies require spaces to be unoccupied when employed (e.g., night economizing to cool thermal mass). Accordingly, hours of operation can significantly affect how a building uses energy and which strategies can effectively reduce energy use.
- **Occupancy.** Occupancy dictates ventilation requirements. Occupants can also be a significant source of sensible and latent internal loads. Understanding occupancy densities and patterns is critical for system sizing and control schemes. Buildings with significant occupancy variations must have systems that are designed to operate efficiently over a wide range of loading conditions.
- **Service level.** Energy use is strongly tied to the service level for which the building is designed. Requirements for comfort and indoor air quality should be clearly defined. Certain space types may have unique conditioning requirements; for example, grocery sales areas are often maintained at a lower-than-normal dew point to reduce refrigerated case loads and prevent condensation.
- **Specialty space types.** Some buildings have specialty space types, such as data centers or laboratories, with unique loads. Characteristics of such space types are often project specific and can be difficult to define. Accordingly, specialty space types often require separate energy use analysis.

Once the key project parameters and drivers of energy use are determined, the predesign IPT can use these to determine the most appropriate energy performance goal and then to draft the RFP requirements.

Set Energy Performance Goals

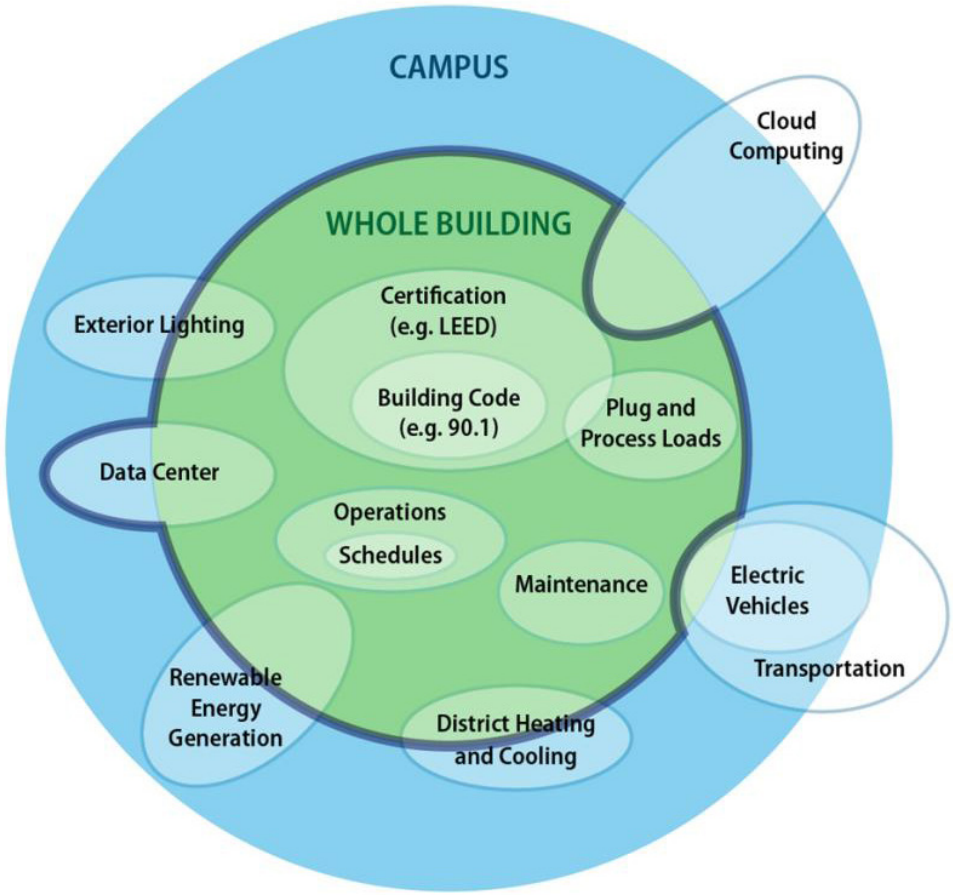
A performance-based RFP focuses on measurable performance outcomes rather than on prescriptive solutions to design problems. It describes in clear, measurable terms how the building will perform—what it will do rather than what it will be. This frees the owner to concentrate on functional expectations rather than on the details of how to meet those expectations and allows the design-builder to draw from all possible solutions rather than only those prescribed by the plans and specifications. The clearer and more measurable the performance criteria are, the more likely the project will successfully meet them.

A clearly defined energy performance goal brings focus to a project. When energy performance is defined in terms of a percent savings goal, significant analysis is typically required to translate that goal into a specific energy use target. Establishing a baseline requires assumptions that allow significant individual interpretation. Even with the best of intentions, generating a baseline that accurately represents the project can be time consuming; the subjective nature of this process (especially as it relates to defining quantities not governed by codes or standards, such as PPLs) can also easily be exploited to game rating or certification procedures. Whole-building absolute energy use targets provide clear energy performance goals that leave no room for interpretation.

A primary limitation of traditional goal setting, which typically measures performance against the requirements of a prevailing building code or recog-

nized national standard (such as ASHRAE Standard 90.1), is that such goals address only a subset of the energy-using building systems, typically neglecting PPLs and realistic operational schedules. Depending on the application, nonregulated loads such as PPLs can dominate energy use, and must be understood and controlled to meet energy performance goals (Brown et al. 2010). Specifying whole-building absolute energy use targets necessitates that all energy-using building systems are considered and reflected in energy performance goals.

Evaluating whole-building energy use will likely foster discussions that focus on often-overlooked energy use implications, and requires that the term whole-building be defined. Does the scope of the analysis encompass the entire site? If the site contains a charging station for electric vehicles, should the scope include transportation energy use? If the building is part of a larger campus, should associated district heating and cooling loads be attributed to the building? If the building houses a data center that serves multiple facilities, how should its energy use be assigned? The "Whole Building" figure illustrates the connectivity between a building, its governing building codes, and its surroundings, and demonstrates the complexity involved in defining whole-building.



We define whole-building as the building and its immediate site. We also define energy targets with respect to site energy, as opposed to alternative energy use metrics such as source energy or carbon emissions.

Determining a project's achievable energy performance requires a complete understanding of where and how the building will use energy, which is why the step of specifying key project parameters is an important starting place for the predesign IPT.

Energy Goal Options

To maximize energy performance, a project team should develop an aggressive, achievable whole-building energy goal that represents best-in-class energy use. In general, owners should consider using a combination of goal types to drive design-build teams to focus on efficiency and achieve general sustainability. The following goal options are given in order of most to least effective for reducing total annual energy use.

> *Best Practice: Include a Measurable Energy Goal in the RFP*
>
> *Teams must agree to a specific energy goal for high-performance buildings; all other best practices are predicated on this action. If the goal is presented as a priority, all team members will understand the energy goal and will consider their impacts on the goal when thinking through design options.*

Net-Zero Energy

A net-zero energy building has greatly reduced energy needs that have been achieved through efficiency gains, such that the balance of energy needs can be supplied with renewable technologies. Net-zero energy can apply to site energy use, source energy use, energy cost, and emissions (Torcellini 2006). The benefit of this approach is that the building will achieve zero annual energy use. A noted negative side is that the renewable energy can be used to mask poor efficiency decisions, but this does not need to be the case if energy efficiency is also set as a clear expectation in the documentation and an EUI target is used in combination with a net-zero energy goal. The cost of renewable energy compared to most efficiency strategies limits the need for the concern.

Energy Use Intensity

EUI is a building's energy consumption per unit area, most commonly given in kBtu/ft^2/yr and provides a clear, measurable target to the team. A potential risk of using EUI is that the goal might express the true potential for energy savings but the team has no incentive to exceed the goal. (Letting the design team set this goal during the design competition phase may prevent the owner from underestimating its potential. These best practices do not focus on this approach, as it has not been used on NREL projects.)

Specifying whole-building absolute EUI targets can help designers and owners ensure the desired level of performance for a project is achieved. Some benefits of whole-building absolute EUI targets are that they:

- Provide a directly measurable target that enables clear and straightforward determination of energy performance success.
- Compel design and construction teams to realize energy performance goals by explicitly including energy targets in contractual documents.
- Emphasize the importance of capturing whole-building energy use, as opposed to a subset of building energy uses required for compliance with building codes or certification programs.

Whenever possible, an EUI target should be used. This sets a hard boundary for net-zero energy design, gives a clear and measurable goal that will focus the design team during design development and into operations, and allows for simple comparison to the performance of other buildings.

Percent Savings

Typically, energy cost savings are compared using a well-documented baseline representing the code minimum form of the building design. A common example is a 50% energy cost reduction versus an ASHRAE 90.1 2010 baseline. This type of goal can be useful for incentivizing demand reduction. Although this goal is similar to a 25 kBtu/ft2/yr goal in likely design outcomes, a potential problem is that the baseline definition adds a layer of abstraction that can distract the design team from optimizing real energy savings and present a challenge during goal verification. Examples of standards that describe baseline buildings and savings calculation procedures are:

- ASHRAE 90.1—Code minimum with energy cost savings
- ASHRAE 189.1—Approximately 30% more aggressive than 90.1, with greenhouse gas and peak demand reduction calculation procedures
- Commercial Reference Buildings—Typical baseline buildings versus code baseline buildings. No calculation procedure is provided.

The percent savings goals are most commonly used within sustainability rating systems, and are useful for quickly comparing the impacts of various system types with associated cost information. Because creating the baseline is time consuming and the results are often misleading relative to actual energy savings, this goal type should be used in tandem with an absolute energy goal in an energy-performance-based procurement process.

Sustainability Rating

LEED is the most widely used sustainable rating system that encourages wise use of land, materials, water, and energy. It also promotes occupant comfort. The advantage of using a general goal such as LEED Platinum is that it broadens the team's focus to general sustainability issues. The disadvantage of using only this type of goal to promote energy use reduction is that the minimum required energy performance for program qualification does not typically imply world-class efficiency.

Resources for Setting Energy Goals

When specifying whole-building absolute energy targets for a project, it is wise to survey standards and best practices for the applicable building type. Case studies of projects demonstrating best-in-class efficiency provide insight into what can be achieved. A survey of the existing stock of a building type establishes typical energy use and provides context for best-in-class performance.

Best Practice: Use Multiple Resources To Develop the Energy Goal

Use a broad range of resources to ensure that energy targets are aggressive yet achievable. The ideal approach to setting whole-building absolute energy use targets uses all available data and takes advantage of the strengths of each data type.

Significant information is available to inform the specification of whole-building absolute energy use targets (50% AEDG series, Commercial Buildings Energy Consumption Survey (CBECS), High Performance Buildings Database, ENERGY STAR Target Finder, portfolio data, local building utility data, etc.); the challenge is filtering those data to extract the most applicable information. Defining key parameters and seeking out comparison data and target-setting recommendations according to compatibility with those parameter definitions can focus the target selection process and enable better-informed decision making.

For many projects, comparable industry best practice case studies will be available. For owners with large building portfolios that share a prototypical design, extensive measured data may be available for nearly identical projects. For projects that are more unusual, possibilities may include high-level comparison against a building type at the national or local level, piece-wise comparison of building sections designed for distinct functionality, and increased reliance on energy modeling to predict the energy use implications of project-specific parameter definitions.

High-Level Sector Data

Comparable industry best practice projects may not always be identifiable and portfolio-based comparisons may not be possible. In such cases, high-level sector data sources such as CBECS and ENERGY STAR Target Finder may be used to inform target setting. Such sources can provide a high-level look at energy use across a sector and for a certain location. Sector-average energy performance incorporates the performance of buildings of varying vintages and typically does not match performance characteristics of compliance with current codes and standards. Such high-level data are useful to establish context for project goals, but cannot typically be benchmarked against project-specific parameter definitions to the extent required to ensure whole-building absolute energy use targets are achieved.

Pros:

- Reference points for any project are readily available.
- Typical performance of buildings with similar functionality is indicated.

Cons:

- High-performance projects are not represented.
- Performance cannot be linked to specific strategies.

High-Performance Case Studies

Industry case studies demonstrating best practice may be excellent reference points for energy use target setting. Best practice performance should be identified and targeted any time it is cost effective or otherwise justifiable, such as for a corporate image boost.

Pros:

- Achievable, best-in-class performance is defined.
- Performance is linked to specific strategies.

Cons:

- Comparable case studies that align with the key parameter definitions of a project may not always be available.
- Case studies cannot be identified that achieve the level of performance desired by the design team.
- Case study budgets may not be provided, or may not align with a specific project.

Best Practice Guides

Best practice guides can provide a very solid basis for selecting energy targets. Few attempts have been made, however, to quantify the projected EUIs for commercial buildings that are constructed according to high-performance standards. The diversity of building types and the incompleteness of energy codes make it difficult to identify a meaningful set of EUIs for whole-building energy use in a variety of climates (see Figure 6).

DOE has partnered with professional societies (ASHRAE, the American Institute of Architects, U.S. Green Buildings Council, and the Illuminating Engineering Society) to develop a series of AEDGs that provide cost-effective, industry-vetted recommendations for achieving energy performance that goes well beyond the minimum requirements of commercial building codes. The K-12 School, Retail, and Large Hospital AEDGs provide guidance for specifying whole-building absolute energy use targets to achieve 50% savings beyond ASHRAE Standard 90.1-2004 (ASHRAE 2004); 50% AEDG energy use targets represent industry-vetted, economically replicable absolute reference points for industry best practice. Another resource for best practice is the High Performance Buildings Database.

The AEDG energy use targets are designed to simplify the process of setting whole-building absolute energy use targets. The AEDG energy use targets are whole-building, absolute targets that align with 50% savings beyond current commercial building code (ASHRAE Standard 90.1-2004). Specifying AEDG whole-building absolute energy use targets and following the prescriptive recommendations of the 50% AEDGs (which have been demonstrated to meet or exceed the AEDG energy use targets) represents a clear, easy-to-follow path to specifying and achieving whole-building energy use targets that reflect industry best practice in energy efficiency.

Because they embody the knowledge required to set practical, aggressive energy performance targets, specification of AEDG whole-building absolute energy targets can eliminate most analysis that may otherwise be required to

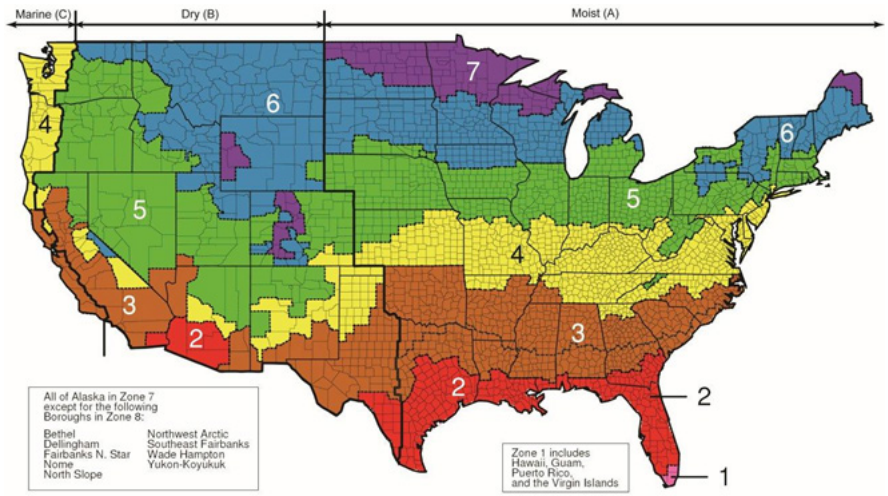
specify energy performance goals. In particular, the AEDG energy targets are defined in terms of absolute energy performance (in kBtu/ft2, rather than with respect to a theoretical baseline), so they can be specified without a baseline energy model. A design team can specify an absolute energy target based on the corresponding AEDG energy target and then focus analysis efforts toward achieving industry best practice energy performance rather than trying to define a reference point against which to measure performance.

Pros:

- EUIs available with correlating energy conservation measures.
- Limited need for modeling to deign to recommendations.

Cons:

- Limited resource set does not give results for all building or climate types.
- Limited number of buildings constructed using this approach.



U.S. Map Depicting the DOE Climate Zones (Credit: (DOE 2005))

Portfolio energy use data

An owner may have a portfolio of buildings that share a prototypical design; An owner may have a portfolio of buildings that share a prototypical design that varies somewhat by climate and functionality. In such cases, portfolio energy performance data are invaluable, as they provide options for selecting a reference point for energy use target setting. Such data enable an owner to determine typical performance and compare it to that for the most and least energy-efficient buildings in the portfolio. Poor performers represent straightforward opportunities for improvement; top performers represent possibilities with the current prototype design and reference points for efficiency improvements. These data can be used to validate or reject efficiency strategies, highlight opportunities for improvement, and illustrate a path of continuous improvement.

The greatest benefit of comparing buildings in a portfolio is that the resulting comparison projects have nearly identical parameter definitions. The biggest downside is that it tends to perpetuate the design status quo. The top-performing buildings may fall short of industry best practice in a number of respects; considering examples of best practice throughout the industry as a whole may shed light on design deficiencies and encourage forward thinking.

ENERGY STAR Portfolio Manager compares building energy use to CBECS data and assigns efficiency scores that define individual building energy performance with respect to the CBECS dataset. The score of the top-performing buildings establishes a context for portfolio performance and defines the gap between current design and industry best practice.

Pros:

- Similar buildings in a portfolio typically represent nearly identical comparison projects.
- Past renovation or new construction projects have been used to validate efficiency strategies.

Cons:

- Comparisons between buildings sharing a prototypical design tend to perpetuate the status quo in portfolio design.
- It is not an option for typical owners.

Whole-Building Energy Simulation

If a project cannot be accurately characterized using industry best practice case studies, portfolio data, or high-level sector data, annual whole-building energy simulations can be used to specify absolute whole-building energy use targets. A detailed whole-building energy model can accurately capture project-specific features and provide accurate energy use predictions that can be used to specify achievable, aggressive targets. The downside is that it is resource intensive and requires simulation expertise. Ideally, it should be

used to supplement best practice case studies or portfolio data and be used to explore the impact of project-specific parameters that are not sufficiently characterized by other sources.

Pros:

- Captures project-specific details in a way that other data sources cannot.
- Can be used to evaluate integrated design strategies.
- Can be used to evaluate strategies not represented by other data sources.

Cons:

- It is time and cost intensive.
- The quality of results depends on the modeler's knowledge and experience.

Use Normalization Factors To Adjust Energy Goals

Absolute energy goals are typically stated on a per area basis, most commonly as kBtu/ft2/yr. Normalizing energy use goals for area is helpful for building comparisons, but should not be stated without conditions that prevent energy use and area ballooning. Incentive factors should be defined in the RFP that encourage space efficiency and maintain the integrity of the energy goal as defined for a given building size and occupancy. Two examples are:

Best Practice: Use Normalization Factors To Develop the EUI Goal

Normalizing energy use goals for area is helpful for building comparisons, but should not be stated without conditions that prevent energy use and area ballooning. Incentive factors should be defined in the RFP that encourage space efficiency and maintain the integrity of the energy goal as defined for a given building size and occupancy.

- **Occupant density factor**. In building types such as offices, schools, and residences, the occupants are the primary drivers of energy use. The building typically needs a base energy level for continuous operation, but the occupants' needs and habits should be the main considerations for scaling the goal. The area per occupant can be determined for most space types, so an increase in EUI should be defined for increased occupant density. This can be given as a table or as an equation.
- **Space function factor**. In building types such as hospitals or parking structures, a given area per function is more important than the area per occupant when considering energy use. For example, a parking structure energy goal can be defined per parking space instead of per area to maximize the number of cars and to minimize the footprint.

Subsystem-Level Targets

Specialty space types may require separate analysis to determine subsystem targets. For example, a large, dedicated data center represents a specialty space type; data centers are typically thermally isolated and require dedicated heating, ventilation, and air-conditioning (HVAC) equipment and strategies. Accordingly, it may be useful to isolate the data center from the rest of the building and analyze it separately, seeking out case studies that highlight efficiency strategies that are specific to data centers. Wet and dry laboratories, commercial kitchens, surgery suites, and indoor swimming pools may also require this type of analysis.

Specialty space types may have unique energy performance metrics. For example, data center performance is measured with respect to power usage effectiveness (PUE), a ratio of total data center power consumption to computational power production.

Additional requirements such as heat recover can be added to the RFP to ensure a holistic view is considered while subsystem-level efficiency targets are being achieved.

(Owner representative and predesign IPT)

- Identify the key project parameters such as climate, function, building type, and operating hours, that impact energy use.
- Use a mix of resources such as high-level sector data, best practice guides, and portfolio data, if available, to bound the range of expected energy use and possibly define an aggressive energy goal.
- If the building is unusual enough in any defined project parameter, or you are trying to push the boundaries of case study energy efficiency, you should use energy modeling for guidance on an aggressive energy goal.
- Use the energy modeling results in IPT selection as a guide for which teams are on track with the most cost-effective approach for meeting the energy goal.

(Energy modeler)

- When required, a third-party energy modeler should be hired in project planning to run optimizations on the building footprint and systems, versus cost, to determine the highest level of energy efficiency possible.
- Pass the energy modeling results to the predesign IPT team in the form of a recommended EUI and system packages most likely to achieve the goal.

Energy Goal Definition: RSF

Include a Measurable Energy Goal in the RFP

- Goal types: Net-zero energy, an EUI, percent reduction, and rating system goals were all specified in the RSF I and RSFII contracts. The team focus for energy goal substantiation was primarily on the EUI.
- Energy-related RFP language:

  Mission Critical: LEED Platinum, ENERGY STAR First "Plus"

  Highly Desirable: 25 kBtu/ft^2/yr, building information modeling

  If Possible: Net-zero design approach, "most energy efficient building in the world," LEED Platinum Plus, ASHRAE 90.1 plus 50%, visual displays of energy efficiency, support personnel turnover (building handoff).

Use Multiple Resources To Develop the Energy Goal

High-level sector data, case study comparison, and whole-building energy modeling were used to develop the energy goal for the RSF. Because the building was a first of its kind in efficiency, careful consideration was required to make sure the goal was aggressive yet attainable.

Adjust Energy Goals Using Normalization Factors: RSF

NREL used the following occupant density table to scale the energy goal definition for the RSF.

EUI Based on Number of People and Floor Area (kBtu/ft^2)

Floor Area (ft^2)	EUI per Number of People* (kBtu/ft^2/yr)			
	650	700	750	800
200,000	27.50	29.62	31.73	33.85
220,000	25.00	26.92	28.85	30.77

*These EUI values do not include the 3.35 kBtu/ft^2/yr data center allowance.

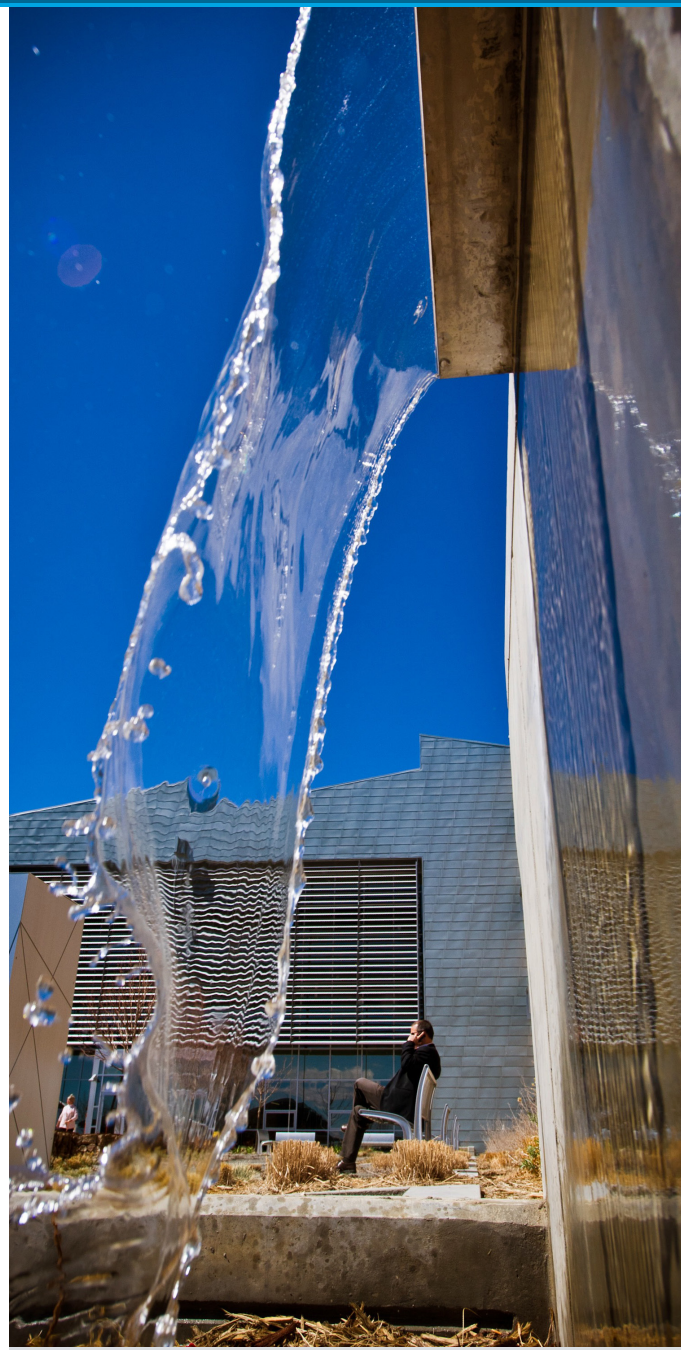
The RFP goal of 25 kBtu/ft^2/yr was developed using an assumption of 650 people in a 220,000 ft2 building. A normalization table was given with the intent of maintaining a constant energy impact of each employee in the building as was determined for the original goal.

The space density was increased due to the long wing design, which also helped daylighting and natural ventilation. Additional data center capacity allowance was also defined. The space density and data center capacity increases, resulted in a final EUI target of 35 kBtu/ft^2/yr.

STEP 3 INCLUDE ENERGY PERFORMANCE GOALS IN THE CONTRACT

Process Summary

+ Step 1: Select the Project Delivery Method
+ Step 2: Develop Energy Performance Goals
– **Step 3: Include Energy Performance Goals in the Contract**
  - Technology-Specific Efficiency Requirements
    - *Passive System Requirements*
    - *System Efficiencies*
    - *Managing Owner-Controlled Loads*
  - Use a Tiered Goal Structure to Prioritize Objectives
  - Establish Price Structure
+ Step 4: Manage the Project to Ensure Energy Goals are Met
+ Step 5: Verify Building Performance



Writing an RFP for a very low-energy building can be daunting for a building owner. Because making the RFP as clear and comprehensive as possible is key to the project's success, some experts suggest hiring an expert to help (Livingston, 2009) (Thompson, 2009).

RFPs must be carefully thought out, tested for achievability, and clearly written. Because RFPs for commercial buildings are typically hundreds of pages long, they must also be well-organized and easy to navigate.

Even seasoned construction professionals with design-build experience do not always use consistent terminology to describe procurement methods, pay methods, etc., which can lead to confusion. To increase the clarity of the RFP:

(Owner representative)

- Include definitions in the text or in a glossary to help avoid miscommunications.
- Describe performance objectives in clear, specific, measurable terms.

Performance expectations must include metrics to gauge success. Lessons learned from the exploratory exercises in Section 3, such as defining owner loads and running preliminary energy models, should be included. Although the energy goal could stand alone as the single energy performance requirement, additional guidance can be helpful as long as the language does not become prescriptive.

Technology-Specific Efficiency Requirements

It is possible that energy goal definitions in the RFP will drive world-class Energy goal definitions in the RFP may drive world-class design. These should thus be the featured energy language. Additional end-use or technology-specific goals can focus team attention on specific design challenges, encourage passive building design, and back up the team driver if the specific energy goal is off the mark.

> *Best Practice: Include Technology-Specific Efficiency Requirements in the RFP*
>
> *End-use or technology-specific goals can focus team attention on specific design challenges and comfort requirements, and encourage passive building design.*

Passive System Requirements

Include general system requirements such as daylighting and natural ventilation to influence concept design. Add specific performance language such as a daylight quantity-hour metrics to ensure attention to detail in the execution of the passive systems.

Daylighting

Natural light may offer health and productivity benefits, and the ability to reduce electric lighting use during the day is necessary to cost-effectively achieve aggressive energy goals.

Glare-free, useful daylighting can be difficult to achieve on an annual basis. To ensure occupant comfort and energy savings through this passive design strategy, include metrics in the RFP that address annual glare and daylight saturation. Example language includes:

- Prevent direct sun on work and vertical surfaces at specific times of the day.
- Minimize daylight saturation (illuminance over an area) in representative, best-case, sunny conditions.
- Minimize daylight saturation in representative, worst-case, cloudy conditions.

This example shows the important elements to be captured in the language: glare reduction and daylight saturation at typical and extreme daylight conditions. The latter is important because the design should perform well over a substantial time for electric lighting reduction for real energy savings. The exact language should be selected based on a review of daylighting metrics, as this is an evolving area of study. An annual simulation along with glare constraints is recommended.

Passive Solar Design

Passive solar designs improve occupant comfort and reduce maintenance, and can be a primary cost reduction strategy in a low-energy design. Simple elements such as fans and material placement can lead to reduced mechanical equipment sizing at almost no added cost. Depending on the level of specification warranted, the language can include specific prescriptive criteria:

- Window-to-wall ratio or solar heat gain coefficient maximums
- Building orientation parameters
- Hours of solar shading on specific façades or building elements.

Or, as recommended by this guide, the requirements can be performance based:

- Amount of heating purchased
- Solar savings fraction.

Natural Ventilation and Cooling

As with daylighting and passive solar design, natural ventilation can offer improved comfort. The occupant-based metric that should be included in the RFP is ASHRAE Standard 55. Prescriptive subsystem requirements include:

- Area required to benefit from natural ventilation
- Façade opening area required for natural ventilation.

In a completely performance-based approach, the RFP would recommend the use of passive strategies and establish comfort criteria around the systems. The risk is that system-specific metrics are not defined; energy-goal substantiation of the proposed design is not necessarily traceable to a subsystem use, making it more difficult to improve the energy performance of the design and substantiate performance during operations.

System Efficiencies

Treating the RFP as a layer of building code suggests that minimum efficiency should be provided, even if the most prominent language is centered on a measurable energy goal and passive design. Active-system language becomes particularly important in load-dominated buildings. General language such as "best in class" can be used if specific efficiencies are unknown or cannot be determined. Specific metrics, such as data center PUE, will bring design team attention to the RFP requirement and help ensure the desired level of performance.

Systems that should have minimum efficiency requirements—or at least a request for specification during energy-goal substantiation review—are:

- HVAC—ASHRAE Standards 90.1 and 55
  - o Space heating and cooling
  - o Ventilation
  - o Air distribution
- Water heating—ENERGY STAR or federal requirements
- Lighting—ASHRAE 90.1 lighting power densities and Illuminating Engineering Society of North America illuminance ranges
- Data centers—best-in-class PUE
- Motors—2007 Energy Independence and Security Act.

The references provided are examples of minimum standards. Consider increasing the RFP standards to a percentage above the minimum allowed to a level in line with other low-energy buildings or based on available utility rebates.

Additional system requirements (e.g., light-emitting diode [LED] only lighting) can be given but, again, prescriptive requirements can limit the design team's ability to find a holistic, creative solution at a reasonable cost.

(Owner representative and predesign IPT)

- Through early energy modeling efforts or case study researc, identify passive system types or active system efficiency requirements that are needed to achieve the goal.
- Define occupant comfort criteria around the passive systems identified.
- Include general comfort and application requirements for the identified passive systems. Do not specify how the systems must be applied, but leave the design team room to integrate the systems as most appropriate for the whole-building design.

Managing Owner-Controlled Loads (Power and Schedules)

Additional RFP language that is helpful for the owner and design team is a detailed list of all loads that the owner intends to include or allow. If the owner will specify the equipment, counts, efficiencies, and use profiles should be provided for the energy use calculations. If the design team will specify the equipment, types should be listed. Expected counts, efficiencies, and use profiles can be included as baseline information, but are not necessary, as teams should be encouraged to consider design approaches encouraging highest efficiency use.

> *Best Practice: Define Owner Loads*
>
> *If the owner will specify the equipment, counts, efficiencies, and use profiles should be provided for the energy use calculations.*

Process Equipment

List the equipment required to complete a specialized function such as cooking or surveillance. In addition to BP4, which encourages system level efficiency goals, the RFP (or an appendix) should include equipment-specific efficiencies for owner loads.

Office Equipment

Office equipment loads primarily consist of computers, printers, phones, and televisions. Create a list of all typically used loads in similar building types, taking care to think through all tasks, occupant types, and seasonal equip-

ment needs to capture potential use cases, which are also potential energy use reduction opportunities.

Other Plug Loads

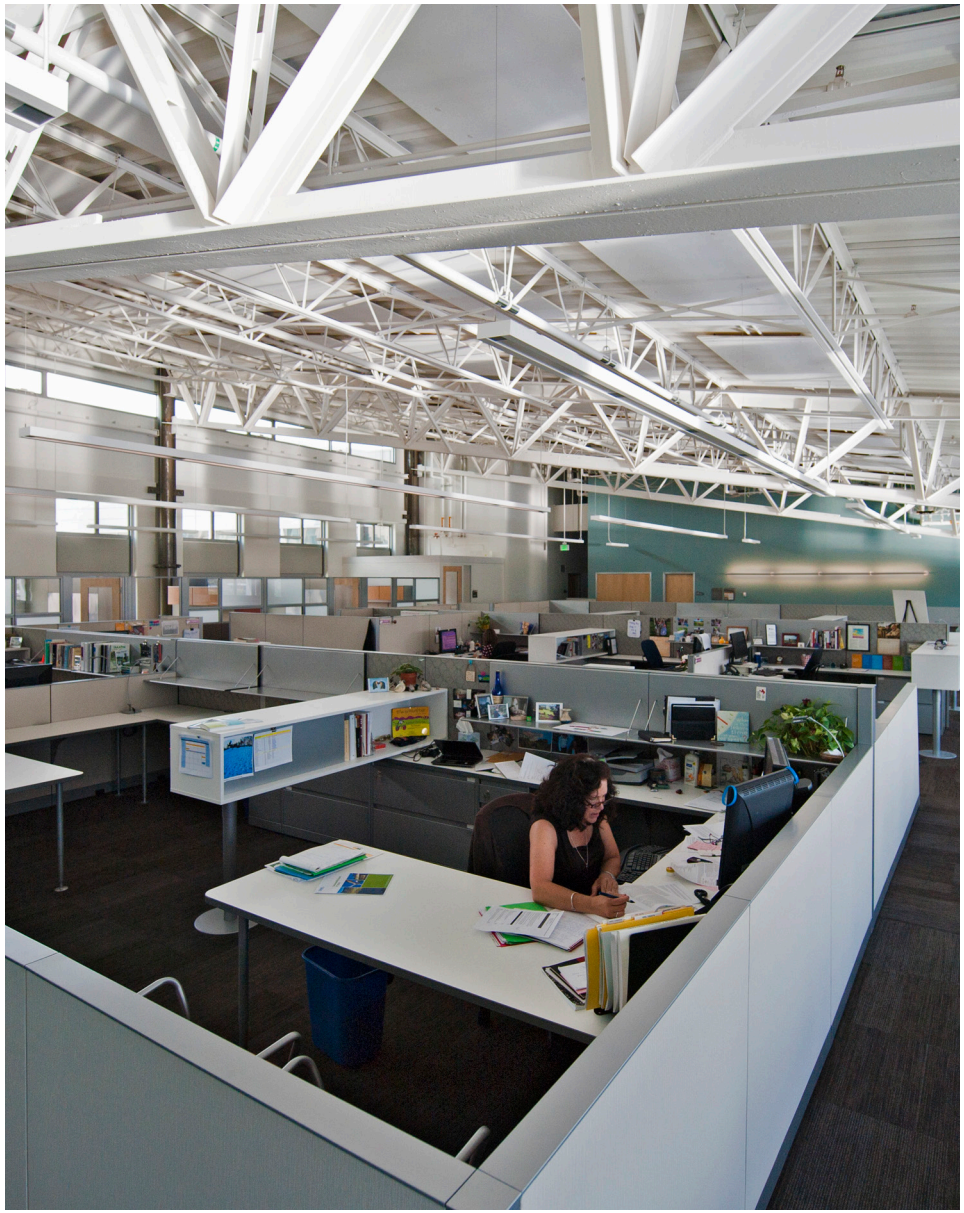
Example plug load reduction strategies included:

- Elevators
  - o Used energy-efficient elevators.
  - o Changed elevator lighting to energy-efficient fluorescent lighting.
  - o Turned off elevator lighting when the elevator is unoccupied.
- Break rooms
  - o Increased the number of people who use each break room from about 20 to 30.
  - o Eliminated the cooler on the drinking fountain.
- Task lights
  - o Shifted from 35-W fluorescent task lights to 15-W LED task lights.
- Phones
  - o Shifted from 1,000 standard phones to 1,000 voice-over Internet protocol (VoIP) phones that consume 4 W each.
- Copiers, printers, and fax machines
  - o Decreased the number of people who use individual copiers, printers, and fax machines.
  - o Increased the number of people who use each common, or group, copier, printer, and fax machine from 15 to 20.
  - o Increased the use of all-in-one machines.
- Computers
  - o Increased the number of laptops from 260 (33% of staff) to 720 (90% of staff).

If not already performed, the predesign IPT should assess plug loads and agree on the parameters that will ensure throughout operation.

(Predesign IPT, including owner facility manager and energy champion)

- Identify needed and allowed plug loads.
- Monitor existing building or portfolio plug loads if possible, to understand places for efficiency and needed equipment that might not have been accounted for without a review.
- Include the equipment specifications and schedules in the preliminary energy model, if one is created, and include all plug load assumptions for setting the energy goal in the RFP.



Include Technology-Specific Efficiency Requirements in the RFP: RSF

The energy goal was stringent enough to require daylighting in the RSF wings; however, the energy goal development team recognized the added value of explicitly providing a daylighting goal so the system would need to be individually substantiated and not lumped into a lighting simulation estimate. Specific language throughout the RFP related to the daylighting requirement includes:

- Interior lighting requirements list, "Daylighting: Provide ambient natural lighting in primary spaces that is of intensity adequate for essential tasks when measured on a typical overcast winter day in midafternoon (IESNA illuminance reference).
- LEED Platinum requirement, which indirectly required the use of a sunny, Equinox day at noon illuminance calculation to show that 75% of the work plane achieved at least 25 footcandles.

Although both requirements were useful in focusing the team on daylighting, the latter was more specific and therefore more effective as a dominant substantiation metric.

The building systems resulting from the energy goal and system-specific requirements were:

- Building orientation. The relatively narrow floor plate (60 ft wide) enables daylighting and natural ventilation for all occupants. Building orientation and geometry minimize east and west glazing. North and south glazing is optimally sized and shaded to provide daylighting and minimize unwanted heat losses and gains.
- Labyrinth thermal storage. A labyrinth of massive concrete structures is in the RSF crawlspace. The labyrinth stores thermal energy and provides additional capacity for passive heating.
- Transpired solar collectors. Outside ventilation air is passively preheated via a transpired solar collector (a technology developed by NREL) on the building's south-facing wall before delivery to the labyrinth and occupied space.
- Daylighting. All workstations are daylit. Daylight enters the upper parts of the south-facing windows and is reflected to the ceiling and deep into the space with light-reflecting devices.
- Triple-glazed, operable windows with individual sunshades. Aggressive window shading is designed to address various orientations and positions of glazed openings. Occupants can open some windows to bring in fresh air and cool the building naturally.
- Precast concrete insulated panels. A thermally massive exterior wall assembly using an insulated precast concrete panel system provides significant thermal mass to moderate the building's internal temperature.
- Radiant heating and cooling. Approximately 42 miles of radiant piping run through all floors, using water—instead of forced air—as the cooling and heating medium in most workspaces.
- Under floor ventilation. A demand-controlled dedicated outside air system provides fresh air from a raised floor when building windows are closed on the hottest and coolest days. Ventilation is distributed through an under floor air distribution system. Evaporative cooling and energy recovery systems further reduce outdoor air heating and cooling loads.
- Energy-efficient data center and workstations. A fully contained hot and cold aisle data center configuration allows for effective airside economizer cooling with evaporative boost and captures waste heat for use in the building. Plug loads are minimized with extensive use of laptops and high-efficiency office equipment.
- Onsite solar energy system. Approximately 1.6 MW of onsite photovoltaics (PV) will be installed and dedicated to the RSF. Rooftop PV power will be added through a Power Purchase Agreement (PPA), and PV power from adjacent parking areas will be purchased with 2009 American Recovery and Reinvestment Act funding.

Define Owner Loads: RSF

NREL conducted a survey of typical office loads and provided the following list to the design team.

- Plug loads:
  - Personal computers (desktop and laptop) and printers
  - Common office equipment (printer, copier, and fax machine)
  - Common break room plug-in equipment (refrigerator, coffee pot, microwave, vending machine, and drinking fountain)
  - Power of the data center per person
  - Personal miscellaneous loads (task lighting, cell phone chargers, radios, space heaters, personal fans, etc.)
- Process loads:
  - Data center cooling
  - Elevators
  - Miscellaneous HVAC equipment (actuators, low voltage transformers, energy management system, sensors)
  - Miscellaneous loads (step-down transformerssecurity cameras, smoke detectors, security card readers, occupancy sensors, lighting controls, thermostats, telephones, door locks, etc.)

The list serves as a starting point for design teams to think through the magnitude of owner loads and consider efficiency options.

Use a Tiered Goal Structure To Prioritize Project Objectives

At the beginning of the design process, design teams often spend significant time understanding specifically what the owner needs, and then developing owner buy-in to a design. Therefore, the more direction an owner can provide early on, the more early design time can be invested in optimizing and analyzing efficiency opportunities.

Best Practice: Use a Tiered Goal Structure To Prioritize Energy Goals With Nonenergy-Related Objectives in

All the owner's needs should be clearly identified and prioritized in the form of an objectives checklist. This allows the design-build team to focus the early design time on developing an integrated solution that meets all the performance objectives.

When the design-build team begins the design process, all the owner's needs should be clearly identified and prioritized in the form of an objectives checklist. This allows the design-build team to focus the early design time on developing an integrated solution that meets all the performance objectives. Objective categories with example, measurable goals include:

- Construction schedule—date of substantial completion
- Health and safety—zero safety incidents
- Functionality—minimum occupancy.

These goals need to be considered in tandem with the energy-related goals and ranked in a list that might have a few equally weighted items on each line.

Ranking a project's scope ensures the owner will receive proposed solutions that fit within the budget. The owner's needs will be ranked in at least three areas—mission critical (must be provided), highly desirable (should be provided), and if possible (optional). Performance-based design-build gives the design-builder control of the solution, and prioritizing the scope helps ensure budget compliance. As the design-builder considers various solutions to the RFP, focusing on high-priority requirements—even at the expense of low priority options—is an effective strategy for aligning the solution with the budget (Shelton D. , Senior Vice President, Design Sense Incorporated, 2010).

This tiered goal structure helps the team prioritize an owner's wish list of building features, functions, and design process outcomes. An example of the tier language used on NREL projects to classify the importance of goals such as energy, safety, and schedule follows.

- **Mission critical.** Required by the contract. Put at least one specific energy-related goal, such as net-zero energy, in this section.
- **Highly desirable.** Not required by the contract, but plays heavily into design-build team selection. If not mission critical, general sustainability goals or aggressive EUI targets can be included in this section.
- **If possible**. Not required by the contract, but can play into design-build team selection if a number of design competition submittals are similar. This is a good location for reach goals such as a highly aggressive EUI and percent savings.

Whether one or multiple goals are used, include at least one energy-related goal in the mission critical section and place this in an introductory page of the RFP. This emphasizes that energy performance expectations are equal to the other traditional pillars of budget, schedule, and scope.

Once the objectives are communicated, the owner needs to fully commit so the design-build process cost-effectively addresses the needs in an integrated manner. Any changes to the owner's objectives or needs after the design has begun slows the process, increases costs, and results in a suboptimal integrated design and delivery.

During the competitive design-build team selection process, teams should be selected based on their ability to incorporate and support as many prioritized objectives as possible within the overall fixed budget and schedule constraint.

(Owner representatives/predesign IPT)

- Assess the energy performance goals determined. For large projects, this is likely to include a specific EUI as recommended in this guide. All projects are also likely to have a percent energy savings goal if LEED certification is targeted. Additional system-specific energy goals or efficiencies should also be on the list, particularly if an energy optimization was performed early, giving clues to systems that are necessary for deep energy savings. Prioritize the goals, not from most aggressive to least, but from a standpoint of importance to the overall mission of the project and synergy with other project goals.
- Include the top priority energy goal in the "Mission Critical" requirements section in the introduction.

- Present the RFP to the downselected set of proposing teams.

(Architect, energy modeler, general contractor, design engineer)

- Review the RFP energy goals for budget and schedule feasibility.
- Assess the RFP requirements for consistency and clarity and create a list of questions for the owner to clarify ambiguities in the energy requirements or assumptions such as load types, schedules, and impact on other project requirements.

The interview process, which is held before the full proposal is developed, will align each proposing team and the owner's expectations. Clarifications that are needed after the interviews should be presented to all proposing teams.

Establish Price Structure

To encourage the innovative design and construction processes needed to achieve world-class performance at competitive first costs, the design-build team selection process should encourage and reward novel approaches. Including "if possible" stretch objectives in a competitive design competition for a firm-fixed price rewards innovative design, construction, and teaming concepts. The teams with the most innovative, integrated, and cost-effective solutions can provide the most performance objectives for a firm-fixed price, increasing their chances of winning. Limiting the design competition to three highly qualified teams and providing stipends to the losing teams to partially offset their participation costs ensures high-quality proposals.

(Owner/contracts)

- Provide a stipend to the non-winning teams.
- Guide the IPT in a best-value integrated project team selection process that will ensure the schedule, maximum scope, and most aggressive performance goals will be met within the budget.

Prioritizing Project Objectives Using a Tiered Goal Structure: RSF

The RSFI RFP included the following energy-specific performance objectives; those that relate to energy are italicized:

MISSION CRITICAL

- Attain safe work performance/safe design practices
- LEED Platinum
- ENERGY STAR First "Plus," unless other system outperforms

HIGHLY DESIRABLE

- Up to 800 Staff Capacity
- 25 kBtu/ft2/yr
- Architectural integrity
- Honor "future staff" needs
- Measurable ASHRAE 90.1-2004-50%
- Support culture and amenities
- Expandable building
- Ergonomics
- Flexible workspace
- Support future technologies
- Documentation to produce a "how-to" manual
- "PR" campaign implemented in real-time for benefit of DOE/NREL and design-build team
- Allow secure collaboration with outsiders
- Building information modeling
- Substantial completion by May 2010

IF POSSIBLE

- Net-zero design approach
- Most energy-efficient building in the world
- LEED Platinum Plus
- ASHRAE 90.1-2004-50% Plus
- Visual displays of current energy efficiency
- Support public tours and achieve national and global recognition and awards
- Support personnel turnover

STEP 4 MANAGE THE PROJECT TO ENSURE ENERGY GOALS ARE MET

Process Summary

+ Step 1: Select the Project Delivery Method
+ Step 2: Develop Energy Performance Goals
+ Step 3: Include Energy Performance Goals in the Contract
– **Step 4: Manage the Project to Ensure Energy Goals are Met**

Goal Substantiation

Calculation Methods
Goal Substantiation Timeline

Design Strategies

Consider Non-Energy Benefits of Efficiency Strategies
Allow for Cost Trade-offs Across Disciplines
Maximize Use of Modular and Repeatable Design Strategies
Emphasize Simple and Passive Design Strategies
Require Equipment with Best-in-Class Efficiency

Construction Strategies

Get the Details Right
Maximize use of Offsite Modular Construction and Assembly
Employ Continuous Value Engineering Throughout Construction
Integrate Experienced Subcontractors Early in the Design Process

Overall Project Management Strategies

Life Cycle Analysis
Managing Capital Costs
Leveraging Alternative Financing
Communication

+ Step 5: Verify Building Performance

Goal Substantiation

The energy performance goals are helpful to the decision making process only if substantiation results are available before—or in tandem with—key decision points. This can be ensured by including RFP language about calculation methods and the goal substantiation schedule.

Best Practice: Provide Calculation Methods for Substantiation

To prevent ambiguity in how the team is to substantiate that the energy goal is achieved, the RFP should include an appendix that lists all calculation methods to be used.

Calculation Methods

Many energy calculation and modeling approaches can be applied to any given design solution. To prevent ambiguity in how the team is to substantiate that the energy goal is achieved, the RFP should include an appendix that lists all calculation methods to be used. The required methods can be broad—such as calling out specific energy modeling software—or can focus on key parameters that will clarify energy goal definitions and influence high-level design decisions.

The design substantiation schedule and performance assurance plan must be included in the RFP so design teams understand the time commitment necessary to produce a high-performance building.

> *Best Practice: Develop a Process To Ensure Energy Performance*
>
> *The design substantiation schedule and performance assurance plan must be included in the RFP so design teams understand the time commitment necessary to produce a high-performance building.*

Having a computer model of the proposed building that meets performance expectations allows the team to run simulations during design development and construction to ensure performance expectations are met as the design evolves and construction proceeds. Energy models can be used to inform the design process and build confidence that the modeled performance is an accurate representation of how the completed building will perform (Pless S. , Senior Research Engineer, NREL, 2009). Models must also be updated to reflect construction changes or installation deficiencies.

The energy modeling schedule should coincide with design package completion for owner review. Owner comments on the design package can incorporate ideas on additional energy saving opportunities and questions about modeling assumptions with respect to the plans and specifications.

Modeling Software

The recommended or required software should complement the energy goal and subsystem metrics and efficiencies given in the RFP. For example, if daylighting is required and an annual saturation metric is defined, the required software should house this capability. Do not call out specific software unless there is information technology compatibility purposes to do so, such as future use of the model for predictive energy displays.

Site-to-Source Conversion Factors

Multipliers for converting site energy to source energy so renewable energy systems can be sized accordingly if the energy goal definitions require source net-zero energy.

Assumed conversion efficiencies for central plant

Energy loss factors to be used when calculating the effectiveness of plant or offsite energy resources.

Building Loads To Be Included in Energy Use Targets

Force teams to consider all building loads and identify possible efficiency strategies. Distribution transformers, light control parasitic loads, and elevator lights and fans should be incorporated into energy goals.

Operating conditions

Set the minimal level of services required for each space type. ASHRAE Standard 55 for thermal comfort, Standard 62 for ventilation rates, ASHRAE-recommended data center thermal conditions, and Illuminating Engineering Society-recommended illumination levels are good sources for setting minimum service levels.

Goal Substantiation Timeline

An energy performance goal must be considered during each stage of a project, starting with the proposal and continuing through commissioning to building occupancy and operation. All design and construction decisions should be considered for their energy performance implications. This section highlights the ways whole-building absolute energy use targets can be used to increase the probability of energy performance success at various stages.

> *Best Practice: Require Goal Substantiation Throughout the Design*

All design and construction decisions should be considered for their energy performance implications; an up-to-date energy model must be available for consideration at each decision point.

Team selection stage

Selecting a design-build team is critical to project success. If the owner or the owner's efficiency representatives can establish whole-building absolute energy use targets before the team is selected, team members are much more likely to be selected for their ability to reach the performance goal within the specified budget.

In a design-build scenario, including whole-building absolute energy use targets in the RFQ frees respondents from prescriptive design requirements and encourages innovative, cost-effective solutions. Willing and positive team participation to help meet energy performance requirements can be further encouraged via a voluntary incentive program that offers an award fee of 2%–3% of the total contract fee. This can be especially valuable during commissioning and warranty periods because it gives the design team a financial stake in identifying and addressing performance issues (Pless et al. 2011).

Using energy modeling to inform the team selection process can have significant benefits. Although approximate energy use goals based on case study research may be minimally sufficient to characterize the design problem at the team selection stage, energy modeling can be used to focus energy use goals by accounting for project-specific parameter definitions. Contractual inclusion of whole-building absolute energy use targets requires accurate energy use predictions that carefully consider all building energy uses. Greater confidence in predictions allows for more aggressive targets, and comprehensive whole-building energy modeling (energy simulation, thermal bridging calculations, daylighting modeling, natural ventilation modeling, thermal storage modeling, renewable generation calculations, specialty space type modeling, etc.) results in the most accurate predictions (Hirsch et al. 2011). Energy modeling can also be used to evaluate applicants' proposed design solutions. And because energy modeling is useful throughout the project, this capability should be an important applicant evaluation criterion.

Early Design Stage

Traditional goal-setting exercises tend to neglect energy uses not governed by the relevant building code or certification process. Because whole-building absolute energy use targets apply to all energy uses in a building, the process of specifying aggressive energy performance goals using these targets often identifies a wider range of energy use considerations.

The early design phase provides an opportunity to identify and understand efficiency opportunities for often-overlooked programmatic energy uses. Key examples include space planning, equipment organization, and operational schedules. For example, space layout considerations can affect design flexibility later. Designing an office space to prevent exposure to direct sunlight can alleviate elevated perimeter conditioning requirements and allow radiant cooling solutions to be considered.

It is important to understand the distribution of energy use types (loading type, operational schedule, etc.) throughout a building. Zoning spaces according to similarities in energy use type allows for the consolidation of HVAC equipment, reducing first costs and operation and maintenance costs. When considered during the early design stage, such issues can be resolved appropriately and cost effectively; as the design process progresses, potential solutions become less viable.

Energy modeling should be used in the early design stage to determine the extent to which whole-building absolute energy use targets need to inform the design of the building form (Hirsch et al. 2011). Architectural decisions can be made to ensure that building orientation, massing, and layout contribute to the achievement of energy goals, often at no additional fixed or life cycle cost. Many efficiency strategies, such as daylighting, thermal mass distribution, natural ventilation, and solar shading, require integration with the building envelope and structure. By using energy modeling to evaluate and incorporate these simple and passive strategies into the early design, a design team can significantly improve the probability that targets can be met within budget (Pless et al. 2012). Incorporating strategies that require integration with the building envelope and structure becomes progressively more difficult and expensive as a project progresses (Pless et al. 2011). During the early design stage, energy modeling can also be used to answer questions about efficiency strategies as they relate to energy use targets. Is daylighting necessary? What types of HVAC systems can I use to reach my goals?

Construction Stage

During construction, the impact of change orders on the overall energy budget should be carefully considered. Where they significantly impact energy use goals, they should be reevaluated.

Construction contractors are typically unaware of energy performance goals,

but whole-building absolute energy use targets can be written into contracts to provide contractors a financial incentive to help a project reach its energy performance goals.

As-Built Stage

Once design decisions are finalized and the building is constructed, all the necessary information is available to finalize end-use energy budgets. To be useful, these budgets must be realistic and take into account all operational details that affect energy use. Whole-building absolute energy use targets are a valuable reference during the specification of end-use energy budgets; the summation of these budgets should be no greater than the whole-building energy use target. An added benefit of this exercise is that the careful scrutiny required may highlight potential operational issues that would otherwise be overlooked (e.g., sequences of operation as they relate to system interactions).

As construction is completed, energy models should be updated to reflect any discrepancies between the final design and the constructed building. In particular, installed equipment power draws (including parasitic) should be measured and used to update energy model inputs (Hirsch et al. 2011). PPLs are notoriously difficult to predict and can have a significant impact on achieving an energy use target. Understanding installed loads and specifying energy model inputs accordingly can inform how associated control strategies may need to be updated to ensure that the PPL end-use energy budget will be met. As-built energy models should also reflect any differences between shop drawings and original plans, as well as the results of commissioning and testing and balancing. This final as-built energy model should be the final contractual requirement for the design-build team to substantiate it has met its contractual energy use requirements.

As-Operated Stage

Once the building is operational, end-use energy budgets can be used to inform the control sequence commissioning process and to fine-tune control schemes. The owner can compare actual end uses to energy budget allowances (using real-time, submetered data) to identify and reconcile discrepancies between design and operation: set points can be updated to match actual (as opposed to predicted) occupancy patterns; operation sequences can be modified to improve synergy between strategies such as economizing, natural ventilation, and supply air temperature control.

Energy models should be updated to reflect any changes made to control schemes or operational schedules during the control sequence commissioning process. Measured data should ultimately be used to evaluate success with respect to whole-building absolute energy use targets, but the final state of whole-building energy models should also be evaluated. Energy modeling results should be compared to measured whole-building and system-level (submetered) energy use data; discrepancies should be investigated and opportunities to improve modeling inputs should be identified. Lessons learned can inform future energy modeling efforts and improve the accuracy with which whole-building absolute energy use targets and end use energy budgets can be specified.

Comparing actual end use to energy budget allowances requires measurement and verification. Real-time, submetered data are required, and dashboards and displays designed to facilitate data analysis are strongly recommended.

(Owner/project manager, representatives, IPT, general contractor, architect, design engineer)

- Request, review, and act on energy modeling output with each major design milestone.
- When design alternatives arise to improve cost or schedule outlooks, consider the energy impacts of the decision and request further energy modeling as necessary for potentially large impacts on the energy predictions.

(Energy modeler)

- Develop a flexible model that can be perturbed for different design directions with reasonable effort. Design decisions should be evaluated using the energy model when possible.

(Commissioning agent)

- Review the energy model inputs to make sure the equipment specified can meet the sequence of operations.

(Owner/facility manager)

- Review energy model inputs to make sure the sequence of operations for equipment matches owner expectations.

Goal Substantiation: RSF

Provide Calculation Methods for Substantiation

The RFP requested a net-zero energy building, so the RFP appendix provided conversion factors for site-to-source energy so net-zero source energy status would be targeted. An additional calculation detail that could have caused ambiguity if not defined was the efficiencies of hot and cold water used from NREL's central plant. Clarity for these items, among others, was given in the RFP.

For the plug loads listed as owner loads, required peak hourly assumptions to be used in energy calculations were provided. The RFP included a description of assumptions used to arrive at the required loads and gave consent to decrease the loads in the calculation if further efficiency measured were applied in design.

Require Goal Substantiation Throughout Design

Substantiation timeline for the daylighting system, for example, was specifically called out in the RFP. The resulting process proved to be iterative and highly effective for optimizing the daylighting with respect to all other design decisions.

- Proposal. Information on overall building configuration that will permit daylighting to specified levels.
- Design development. Engineering calculations for representative spaces, predicting anticipated daylighting levels under specified conditions.
- Construction. Field test of lighting levels to verify compliance with performance requirements.

Application: Life Cycle Analysis

NREL used a preliminary design life cycle costing and optimization tool called OpenStudio to help set the RSF's energy savings targets. Building energy simulation and life cycle costing analysis is often used to evaluate "what-if" options in building design—a limited search for an optimal solution, or optimization. Computerized searching has the potential to automate the input and output, evaluate many options, and perform enough life cycle costing simulations to account for the complex interactions among combinations of strategies. The predesign RSF optimization analysis, based on a 30-year life cycle cost, suggests 40%–50% energy savings is theoretically the lowest life cycle cost. Based on this analysis, NREL selected the optimal life cycle cost solution of 50% savings and 25 kBtu/ft2 as project performance objectives.

Design Strategies

Consider Nonenergy Cost Benefits of Efficiency Strategies

Often, energy savings alone may not be sufficient to justify the most efficient strategy. In these cases, leveraging nonenergy benefits related the strategy can help to justify an energy efficiency design decision. For example, it is often difficult to justify the best-in-class traction elevators with regenerative drives for low- and medium-rise buildings with energy cost savings alone. However, high-efficiency traction elevators such as those installed in the RSF do not require a machine room, a deep elevator pit, or significant overhead accommodations. Therefore, they use less space and minimize the costly support spaces. The space and structure cost savings also help to offset additional costs. The regenerative drives can capture braking energy as electricity to power the building, rather than generating waste heat, which then has to be removed from the elevator control room with air conditioning. The regenerative drive may be a small cost addition, and capital cost increases can be absorbed by eliminating the need for control room air conditioning.

Purchasing laptops for all RSF staff was also justified in part by using benefits unrelated to their energy savings versus standard desktop computers. Even though laptops are significantly more efficient than desktops, the energy cost savings alone do not necessarily justify their higher costs. Laptops increase worker productivity by increasing office space flexibility, enabling work from home and travel mobility, and reducing redundant computing systems (having both a desktop and laptop). Mini-desktops are now also available that have the efficiency of a laptop without the cost or security concerns for workers who do not need to be mobile.

NREL replaced more than 300 individual printers with 18 single centralized high-speed multifunction printer/copier/scanner/fax machines with effective and robust standby modes. These are distributed throughout the RSF, and the cost was justified through the overall reduction in maintenance costs and unique toner support versus individual printers. Minimizing, centralizing, and standardizing the RSF's document services greatly increased the ease of implementing robust standby power configurations and significantly lowered service costs. Not only did NREL significantly reduce the total number of devices with unmanageable power settings, volatile organic compounds from the printer toners were isolated to a few copy rooms with dedicated exhaust, increasing the office space indoor air quality.

A final example was the move from drywall-enclosed offices and high cube

walls to a demountable and reconfigurable open office furniture system. The open office plan was a key daylighting and natural ventilation component, but the furniture systems are not necessarily cost justifiable with energy savings alone. The added flexibility from minimizing hard walled offices allows for significant cost savings during space reprogramming. The open office environment and narrow floor plan enable all occupants to work within 30 ft of windows with views to the outside. The open office plan also encourages and promotes an interactive and collaborative workplace environment.

Allow for Cost Tradeoffs Across Disciplines

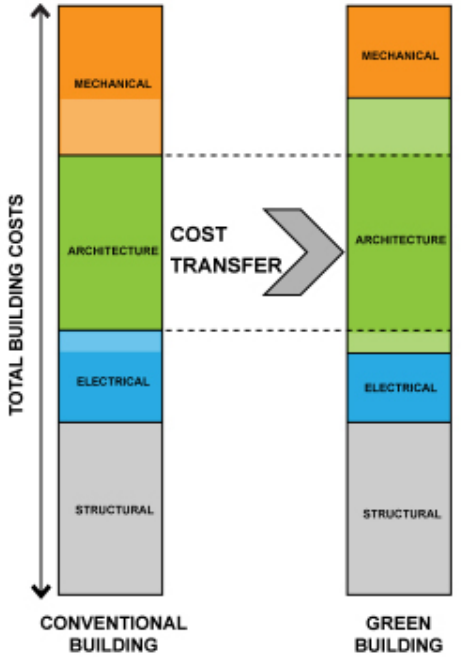
To ensure investments in architecture and building envelope measures are cost effective, the possible cost tradeoffs must be evaluated when right-sizing the corresponding smaller HVAC systems. Investments in shading, insulation, triple-pane windows, thermal mass, lower LPDs, and lower installed plug loads all result in smaller peak air-conditioning loads. First cost savings from installing a smaller cooling system to meet these reduced loads will help to offset any first costs associated with the load reduction strategies. Smaller outdoor air heating and cooling systems enabled by exhaust air energy recovery also help to pay for the energy recovery system. Investments in energy modeling, starting in the early design phases, are also required to optimize the architectural and mechanical efficiency strategies and maximize the benefits.

To ensure these types of cost tradeoffs are possible, the typical discipline-based construction budget allocations need to be reconsidered. Similarly, the traditional discipline-based fee percentages may unintentionally prevent the experts who are most capable of developing energy reduction strategies from applying their analytical technologies and abilities. Figure 8 shows that simple and passive efficiency investments in architecture and envelope can have corresponding mechanical and electrical system benefits so that the overall project costs are the same.

Maximize Use of Modular and Repeatable Design Strategies

Modular and repeatable design elements and space types reduce design and construction costs. Unique space types or design elements—such as curved wall sections—always add costs. Therefore, highly replicable building-block modules are often the most cost-effective design and construction strategies.

For the RSF, the primary office space block module is a 30-ft × 60-ft open office bay (see Figure 2). This bay design incorporates standard dimension



precast wall panels, a well-planned clear-span open and modular office space layout, standard south and north window details optimized for daylighting and views, a repeatable electric lighting layout, and a modular under floor air delivery system. This optimized open office bay was then replicated for each wing, reducing the overall design optimization time needed for the full facility. Integrating energy efficiency with modular construction techniques can save significant energy at similar overall project costs to a standard building.

For the RSF lighting system, the added costs of the selected premium efficiency lighting fixtures and controls were offset by reduced design and optimization time related to the modular and repeatable configuration and minimized unique fixtures in unique spaces. This results in a high-efficiency lighting system with similar total first costs to a standard office lighting system.

The panelized precast wall modules avoided the need for expensive interior design finishes. The precast wall panels were fabricated offsite with careful attention to interior concrete surface finishes. This allowed the exposed concrete to be painted white, maximizing the thermal benefit of exposed thermal

mass and reducing interior finishing costs. Similarly, the exposed ceiling deck with appropriate acoustical treatments was a cheaper solution than a suspended ceiling, and allowed for the radiant heating and cooling system to be integrated into the ceiling deck.

Any component that can be significantly replicated through repeatable design and manufacturing will be cheaper, through economies of scale, than a custom component. This best practice resulted in the largest savings in the south and north window system design in the RSF. The RSF has more than 200 south windows, all with the same overhang, window size, operable component, and daylighting redirection device. Similarly, more than 200 north windows are the same size with the same operable components. Standardizing these designs reduced the overall window costs, allowing for inclusion of additional energy efficiency elements such as overhangs, triple-pane glazing, and advanced thermally broken window frames.

Finally, increasing space efficiency through modular and open office space design strategies is a key cost control element for the RSF. Increasing space efficiency allows owners to include more of the building purpose in a smaller footprint, resulting in more project scope for lower first costs. For the RSF, the overall space efficiency results in 267 ft2 of building gross area per workstation. NREL's space efficiency in previous leased office space with typical enclosed offices and high cubicle walls was 350–400 ft2 per workstation. Because the RSF was designed around the furniture system, wasted space is minimized. The open office system allows for slightly smaller (72-ft2) cubicles, which feel much larger than enclosed cubicles. The program includes additional support spaces for 824 occupants, such as huddle rooms, a lunchroom and coffee bar, an abundance of conference rooms with capacity ranges of 8–100 occupants, a data center, an exercise room, and a library. In general, reinvesting space efficiency cost savings into efficiency strategies can result in high performance with similar overall first costs.

Emphasize Simple and Passive Efficiency Strategies

When long-term maintenance costs are incorporated into design decisions, simpler, longer lasting, and more passive systems are often considered advantageous. For the RSF, long-term operational costs helped to justify strategies such as exterior light-emitting diodes (LEDs). Although the lighting fixtures are more expensive, energy cost savings and longer lifetimes with lower relamping costs justify the first cost investment. Similarly, the extended lives of lamps in daylit spaces that are off all day help to justify the daylighting control system. The reduced maintenance costs from easily controllable hydronic radiant heating and cooling systems compared to an optimally and continuously tuned variable air volume system help to justify the hydronic piping in the ceiling slabs.

In general, simpler systems that require minimal attention during their operational lifetimes often have lower life cycle costs to ensure performance. Simple and passive strategies such as high thermal mass exposed concrete, good insulation, reduced lighting power density, rightsized HVAC systems, and overhangs have low to no operational maintenance costs and high assurance of actual performance. More complex efficiency strategies such as daylighting controls or carbon dioxide sensors require almost constant retro-commissioning and maintenance to ensure they are working as intended. These efficiency strategies can result in significant energy savings; however, the long-term maintenance, calibration, and operational costs must be considered to ensure a successful life cycle costing exercise.

Integrating energy efficiency strategies into the architecture and building envelope is key for any high-performance commercial building. Well-integrated strategies start with identifying single components that can perform multiple functions. For example, if the building orientation, massing, and layout can help to reduce energy use, these typically do not have additional costs. Passive strategies, such as daylighting, thermal mass, natural ventilation, and shading, integrate efficiency with the envelope and structure. They can also be effective, energy-saving architectural design decisions. The RSF design team looked to the pre-industrial age for guidance on how buildings were designed before the advent of air conditioning or electrical lighting. High mass stone and concrete buildings provided passive cooling with ample daylighting and natural ventilation. These simple, passive strategies were integrated into the RSF's envelope components through the use of a narrow floor plate with full access to daylighting, operable windows, insulated precast concrete panels with exposed interior thermal mass, solar shading, and optimal orientation. Continuous insulation in the concrete precast panels substantially reduce the thermal bridging, a common weak spot in commercial building insulation systems.

High-performance office buildings must include high-performance envelopes; window size, type, orientation, and shading are all key performance parameters. A key cost control and thermal performance control strategy for optimizing window parameters is window area. Reduced window area decreases overall envelope costs and improves thermal envelope performance. A purely theoretical optimal window area based on energy consumption would be a small amount of glass for daylighting purposes only. However, views would be significantly reduced, impacting the quality of the space.

Therefore, an optimal window area strategy that balances cost, thermal performance, daylighting, and views should be pursued. Such a strategy would first provide enough glass area for full, glare-free daylighting, and then identify key opportunities for view glazing without overglazing the envelope.

In general, well-integrated passive solutions are cheaper, simpler, and more reliable than technological solutions added after the architecture has been designed. Poorly integrated efficiency strategies require additional controls and moving components (all with additional costs) to reach aggressive energy goals.

Require Equipment With Best-in-Class Efficiency

In modern high-performance office buildings, PPLs are becoming the dominant end use. To reach aggressive energy savings levels, owners need to consider all possible PPL efficiency strategies. For the RSF, where PPLs represent half the building's energy consumption, the owner deployed a wide range of PPL efficiency strategies (see Lobato et al. 2011). PPL and data center energy savings of 49% are expected compared to business-as-usual practices in NREL's leased office space in 2007. One of the most cost-effective PPL control strategies has been to develop equipment procurement specifications that include best-in-class, energy-efficient office equipment. This procurement specification can be incorporated into the normal (and often very frequent) legacy equipment replacement cycle. For example, manufacturers of the following RSF equipment were identified as best in class, and were included in the normal equipment procurement:

- 48-W average hourly use refrigerator
- 18-W 22-in. LED liquid crystal display monitors
- 25-W laptops with docking stations
- 120-W 55-in. flat screen LED backlit displays
- Multifunction devices that print, copy, fax, and scan
- Blade servers in the datacenter.

The ENERGY STAR equipment database is a good starting point for identifying best-in-class equipment; however, best in class is often significantly more efficient than ENERGY STAR alternatives, often without added first costs. All the ENERGY STAR-enabled efficiency settings must be correctly configured to ensure all possible savings are realized.

Construction Strategies

Get the Details Right

The probability of success increases dramatically when the tradespeople on the job are invested in creating an energy-efficient building. Getting installation details right helps ensure that as-installed performance will match the energy models and the owner's performance goals. These details are verified through a substantiation process that should be part of the design-builder's agreement with the owner.

Maximize Use of Offsite Modular Construction and Assembly

For projects that have been designed to maximize the modularity of the key building blocks, the manufacturing and assembly processes for key building components may offer cost-saving opportunities. Key building components that are manufactured offsite in a quality-controlled assembly process typically cost less than onsite assembly. Moving as much of the building construction process offsite as possible minimizes site coordination details and safety concerns, allows for construction in a high-quality controlled environment, and results in faster installation—all saving total project costs. For the RSF, the offsite manufacturing of the precast wall panels resulted in a simplified construction process—the wall panels were hung on the steel structure, the panels joints were sealed, and then the interior concrete was painted—resulting in a high-quality, easily constructed finished wall system.

For the RSFII, further manufacturing advances allowed the precast wall panels to be glazed at the precasting manufacturing facility. The panels were then craned into place (see Figure 9). This approach decreased the combined cost of installation by reducing the site scheduling and coordination issues, freeing up project funds for triple glazing at the east and west balconies. This is also a safer and higher quality window installation than onsite alternatives.

Employ Continuous Value Engineering Throughout Construction

To reach a high level of energy efficiency and meet a firm-fixed price contract limit requires an early and evolving understanding of construction costs, energy performance, and construction scheduling. To develop an early and robust understanding of various project cost options, cost estimators must be integrated into the IPT. This results in a nearly continuous value engineering process throughout the design process. Early design decisions made without input from either constructability or energy experts often do not represent an optimal balance of schedule, scope, budget, and energy performance.

In the RSF, before the first design team project charrette, the energy modeling team was engaged to evaluate and recommend key conceptual design features, such as high mass concrete wall systems, radiant heating and cooling, building orientation, and a 60-ft cross section. With these key design considerations understood early in the process, the design development and value engineering of the RSF was able to integrate these critical energy features into the firm-fixed price contract and meet all required project objectives. As discussed in Best Practice #8 and Figure 5, the envelope design concepts evolved from a double skin façade to a transpired solar collector due to the effective value engineering process.

Integrate Experienced Key Subcontractors Early in the Design Process

To control the construction costs for novel or untested efficiency strategies, key mechanical and electrical subcontractors need to be included during the design process. This reduces excessive bids caused by design uncertainty from subcontractors who do not fully understand the design intent, and reduces the installation risk and added contingency carried by inexperienced subcontractors. Some of the most cost-effective and critical efficiency features were designed in conjunction with key subcontractors to ensure constructability. For the RSF, the design-build contractor developed a team with subcontractors and design partners. The team continuously evaluated bids from the subcontractor community to find the best value—the combination of complete scope, best experience, and past performance—compared to the lowest first costs.

For the RSF II, the design-build team leveraged the subcontracting team's experience, relationships, and investments to manage costs. The contractor's preconstruction team worked with all the primary subcontractors to negotiate commitments for cost reductions by leveraging the replication between RSFI and RSFII, the subcontractors' success at executing the first project, and the proven abilities in managing the overall work to support efficient construction. Every owner should consider leveraging this simple opportunity to get more for less—an expansion or additional building that follows while the construction team is already onsite can create important cost control leverage.

As stated in the sidebar, Industry Barriers to High-Performance Buildings, capital costs for energy efficiency form a significant barrier to widespread implementation. Design and construction IPT members can help to promote energy efficiency within typical project budgets by:

(Owner representatives)

- Consider the impact of system maintenance and occupant health and productivity for design alternatives of higher cost to justify a tradeoff in operating costs.
- Request best-in-class efficiency for all products as they are often cost competitive with traditional selections.

(General contractor)

- Keep all system and subcontract budgets open until construction to ensure cost tradeoffs can be made until the end of design.
- Consider alternative constructability paths for each system discussed and question the need for unique building elements and excess steps or materials.

(Architect and design engineer)

- Consider passive strategies that do not require advanced controls or supporting systems first.
- Design and engineer with an energy efficiency purpose.

The design and construction IPT has a critical role in energy performance assurance.

Overall Project Management Strategies

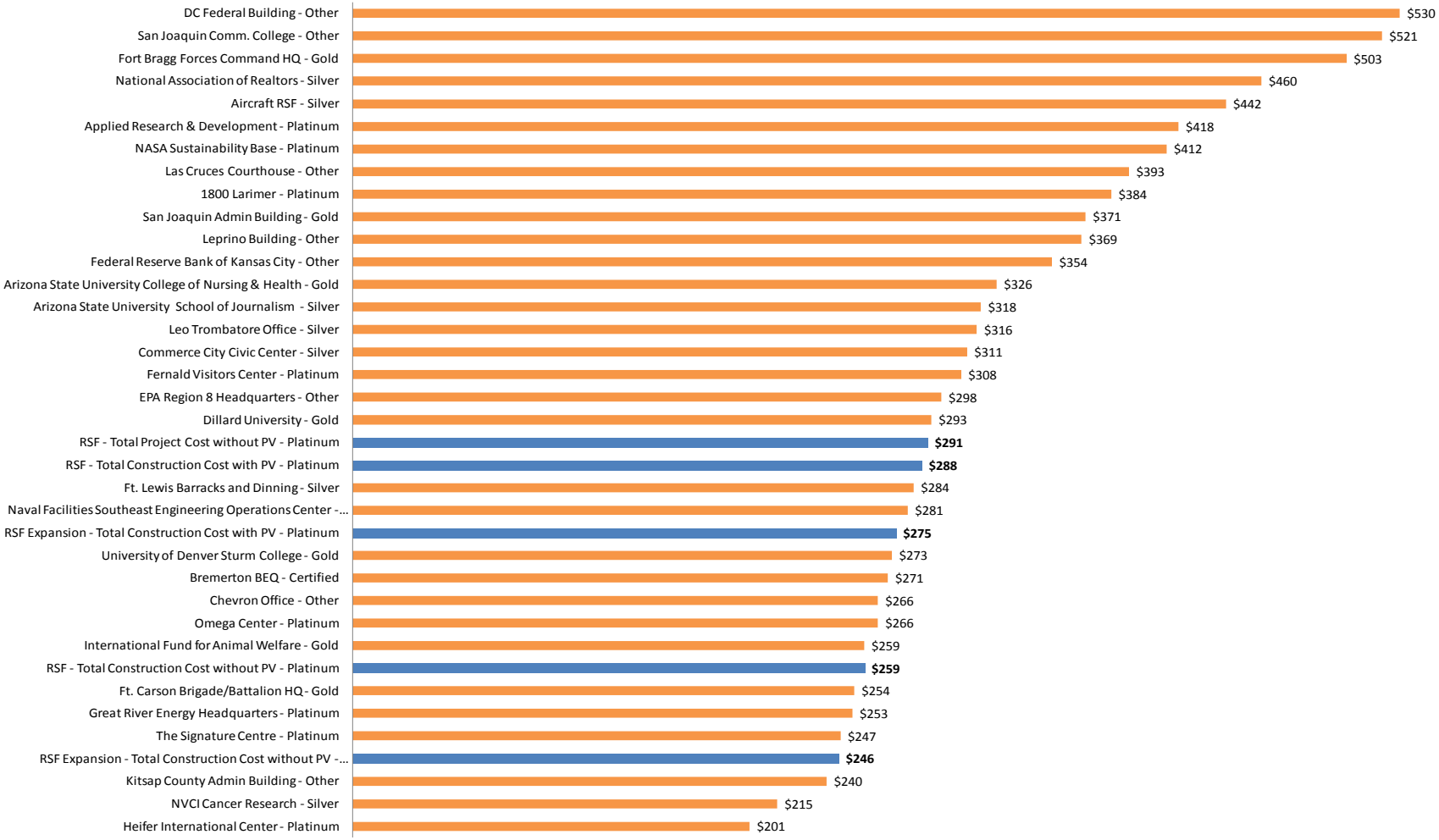
Several eneral project management techniques can contribute to the success of an energy performance-based design-build project.

Life Cycle Analysis

Life cycle costing has long been a key element of integrated design, and is becoming more commonplace in many commercial building projects. It compares first costs to long-term energy cost savings and maintenance, replacement, and operational costs over a given life cycle. For net-zero projects, the life cycle cost evaluation has an additional step. Investments in efficiency strategies must be compared to an investment into the equivalent renewable energy generation needed to offset the same amount of energy use (see sidebar, Life Cycle Analysis).

Managing Capital Costs

For very low-energy buildings to become common practice, the costs to design and build them must be comparable to similar buildings. The costs must also be easily understood by owners and building professionals. First costs, or capital costs, for energy efficiency strategies in office buildings often form a significant barrier to realizing high-performance buildings with 50% or greater energy savings. Historically, the industry has been unable to achieve deep energy savings because it relies on energy cost savings and simple payback analysis alone to justify investments. A more comprehensive and integrated cost justification and capital cost control approach is needed. By implementing innovative procurement and delivery strategies,



integrated design principles and cost tradeoffs, life cycle cost justifications, and streamlined construction methods, first cost barriers can be overcome. Marketable, high-performance office buildings that achieve LEED Platinum, save more than $1/ft2 annually in energy costs savings, and reach net-zero energy goals at competitive whole-building first costs are achievable.

Capital costs can be measured and evaluated for multiple purposes with multiple metrics. Often, when evaluating capital costs across multiple commercial buildings, it can be difficult to make quantitative comparisons between projects. Every project is different, with a highly variable program, project-specific constraints, local labor and construction costs, and site requirements. However, general cost comparison trends can be evaluated with certain capital cost metrics such as core and shell construction costs, total construction costs, and total project costs. To compare the RSF capital costs to other projects, we attempted to document total construction costs and total project costs for a range of recent projects. We used multiple sources, including the DBIA project database and other publically available capital cost sources, to document their total and capital costs. We focused on identifying comparable projects with either documented total project costs (which typically include all core and shell costs, finishes, furniture, and equipment, site costs, and soft design costs) or total construction costs (all core and shell costs, finishes, furniture and equipment, and site costs). Land costs are typically not included in capital cost metrics (see Figure …).

Leveraging Alternative Financing

For more expensive strategies such as onsite renewable generation, alternative financing models should be used when available. PPAs and performance contracting are common strategies for owners to incorporate onsite renewables without having to invest project capital. The PPA provider can take advantage of various tax deductions and credits, as well as local utility rebates, offering a competitive rate to the owner. This is especially useful for tax-exempt owners. Numerous demand-side rebate programs are also typically available from the local utility, which can help to defray the cost of efficiency investments.

Communication

A successful low-energy building requires more than top-notch technical, design, and construction talent. It also requires the personal commitment of everyone involved in the process and the outcome. As one participant puts it, “Individuals make this stuff happen—not companies” (Macey, 2009).

For building professionals who are new to performance-based design-build, adopting this delivery method requires changes in individual and organizational behavior. For some, these changes can be painful and difficult, but one design-build expert asserts that “people and organizations grow and evolve as a result of this process. It changes people for the better.” (Thompson, 2009)

Many project details are determined through negotiations between the owner, design-builder, and other team members, which makes the quality and frequency of communication critical. As members of the RSF design-build team noted, the three most important tools for success are “communication, communication, and communication” (Livingston, 2009) (Thompson, 2009).

Especially on a very low-energy project, good communication must extend to subcontractors and their employees. Weekly meetings between the subcontractors can help ensure an ongoing dialogue, and that design and construction problems are addressed promptly. Such meetings provide opportunities to communicate cultural values and the details required to successfully deliver a highly energy-efficient building.

In addition to the design and construction approaches discussed for managing capital costs in high-performance buildings, overarching project management steps should be taken on each project to ensure the best value.

(Owner/contracts and representative)

- Investigate alternative financing options for renewable energy systems.
- Investigate rebates available for energy efficiency strategies or results.

(Project manager)

- At each design decision, relate the impacts back to the big picture of owner energy efficiency priorities and request evaluations such as life cycle analyses or cost tradeoffs with other decisions.
- Maintain clear lines of communication with all design and construction IPT members so that no cost tradeoff or opportunity for energy or cost savings goes unnoticed.
- Reinforce the project mission often to emphasize the importance of all project pillars: budget, schedule, scope, and performance.

STEP 5 VERIFY BUILDING PERFORMANCE

Process Summary

+ Step 1: Select the Project Delivery Method
+ Step 2: Develop Energy Performance Goals
+ Step 3: Include Energy Performance Goals in the Contract
+ Step 4: Manage the Project to Ensure Energy Goals are Met
− **Step 5: Verify Building Performance**
  - Require Submetering
  - Check End Use Energy Budgets
  - Use Award Fees to Incentivize Buidling Performance

Building energy performance is rarely measured (using utility bills or installed metering); most commonly, an energy model representing the final low-energy design is used to determine percent savings over the baseline model. Energy modeling is extremely valuable for defining energy use targets, predicting building performance throughout the design and construction process, and setting end-use energy budgets, but the inherent differences between simulation and reality make it impossible for energy modeling results to fully represent the actual building. Thus, occupied building energy use must be measured to determine if energy performance goals have been met. Specification of whole-building absolute energy use performance targets shifts the focus of performance verification away from energy modeling and toward building measurement; whole-building absolute energy use can be measured with utility bills, allowing for simple and straightforward verification of energy performance goals. RFP language requiring energy goal substantiation should be followed by energy performance assurance expectations. The owner must be able to obtain feedback on the energy performance throughout the warranty phase and beyond, compare the results to model predictions, and leverage the design team to correct installation or control mistakes that inhibit energy performance.

Require Submetering

The granularity of a metering plan will vary depending on building type, but the RFP should require separate metering for at least end-use and whole-building energy consumption, water, and gas.

Check End Use Energy Budgets

Requiring the design team to provide end-use budgets determined through the energy goal substantiation process will give owners a point of reference for comparing end use metering data.

Use Award Fees to Incentivize Building Performance

An award fee can be a valuable tool for keeping the design-build team motivated and engaged throughout the process. An award fee pool can be established to give the design-builder the opportunity to receive additional compensation for superior performance in the following areas (Leitner, Subcontract # AFJ-8-77550-01, 2008):

- Safety
- Design effort and objectives
- Workmanship—quality of all work
- Responsiveness—willingness to engage in problem solving
- Cooperation
- Communication and professionalism
- Timeliness of completion.

The award fee incentive program allowed for award fees at the following evaluation stages:

- Completion of preliminary design
- Completion of design development
- Completion of construction documents
- Completion of construction
- Completion of closeout
- 12 months postoccupancy.

The program can also allow the design-builder to "roll over" any unearned award fee to the next stage if they meet certain requirements (Leitner, Subcontract # AFJ-8-77550-01, 2008). This incentivizes the design-builder to continuously improve.

Although a high-performance project is winding down after project completion, it requires larger activity than a typical project. Each design and construction IPT member is responsible to ensure energy performance as mandated by the contractual energy goals.

(Owner/project manager)

- Review cost tradeoffs for scope made during design and construction and prioritize additional scope according to the original owner priorities, including energy efficiency.

(Owner/contracts)

- Develop and enforce the incentive structure so a substantial portion of the mount is contingent on first-year energy performance.

(Energy modeler)

- Develop an as-built energy model that can be used for final substantiation of the energy goal in construction and then be calibrated in the measurement and verification process.

(Commissioning agent)

- Check all system sequences of operations and equipment installation and recommend improvements.

(Owner/facility manager)

- Communicate with building occupants about energy goals and requirements.
- Evaluate building conditions in a case-by-case, occupant-by-occupant process, and make building modifications over time that address energy and comfort targets.

(Owner/energy champion)

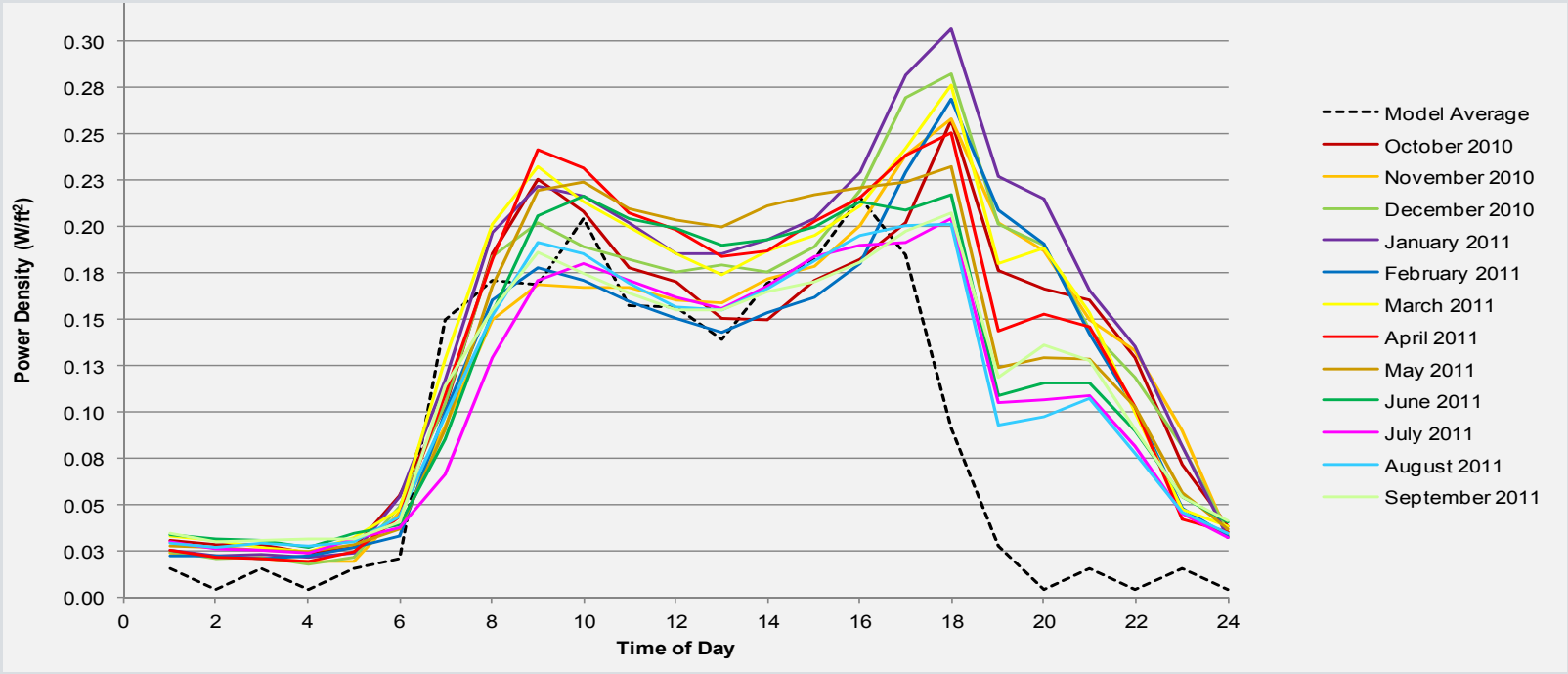
- Use energy displays or other forms of notification to communicate with occupants about building performance. Encourage energy-conscious behavior by adding various forms of feedback about energy performance, such as empathetic and competitive displays, and suggest actions that occupants can take to reduce energy and improve comfort.
- Work with executive and facility management to maintain the energy focus through the life of the building.

Develop a Process To Ensure Energy Performance: RSF

End use metering, enhanced commissioning, and M&V were all project requirements and have proven useful to the owner in addressing energy loads in operations.

For example, lighting energy use was shown to be higher than predicted in evening hours due to cleaning staff hours. Training was provided for the staff to use the egress lighting when possible or switch on entire zones as needed in attempt to realize predicted energy performance.

RSF1 Lighting Measured Use Comparison to Model Predictions:



ENERGY-PERFORMANCE-BASED PROCUREMENT REVIEW

For many building owners and professionals, performance-based design-build is a new and intimidating prospect. The construction industry is notoriously conservative, and it takes time and repeated exposure for building professionals to embrace new concepts and strategies.

Owners and designers typically develop detailed prescriptions that contractors follow. Convincing owners that they can get a better building in less time for a firm price by releasing control of the design and construction to a design-builder is usually a hard sell (Shelton D. , 2007). However, the industry is beginning to recognize the value in streamlining the delivery process with deeply integrated approaches—resulting in innovative and energy-efficient projects on typical construction budgets and schedules.

The need to reduce the environmental impact of buildings—particularly of energy use—is driving an industry-wide trend toward "greener" buildings. Although the idea of more energy-efficient, healthier buildings is emotionally and intuitively appealing, designing and constructing such a structure can be daunting. For example, writing an effective RFP for a large commercial building is overwhelming to most building owners.

NREL and DOE, owners of the RSF, had an advantage in that they have engineers and researchers on staff with the technical expertise and personal and professional commitment to write performance criteria that are likely to result in a positive outcome. The RSF RFP can serve as a guide for owners who are willing to take on the challenge, but some design-build veterans suggest hiring someone with experience writing successful design-build RFPs (Livingston, 2009) (Thompson, 2009), especially for the first few projects. Finding and vetting such a firm is getting easier (Design-Build Institute of America, 2009), but for most building owners, it is still a foray into unfamiliar territory.

Assembling a group of professionals with the right skill sets and temperaments to form a cohesive team is also a challenge. As one design-build veteran points out, "Design-builders are still learning how to integrate—how to work together optimally" (Thompson, 2009). To be successful, team members must develop trusting and collaborative relationships. To find the most innovative solutions, participants have to feel safe enough to make suggestions and mistakes.

This is not about warm fuzzies—organizations have to commit their best and brightest to the process (Macey, 2009). The design-build team is accountable for delivering the project on time and on budget, and there is no room for sloppy work or procedures. Each participant has to be a leader and a collaborator.

Performance-based design-build done right is difficult, but it will get easier as it becomes more common (Thompson, 2009) and building professionals become more comfortable with it. Its advantages as an effective delivery method for innovative buildings make the learning process worth the effort.

NREL has developed a new construction procurement and acquisition method that successfully integrates energy efficiency requirements into the design and operations. We developed and piloted the energy performance based design-build process with our first new construction project, the RSF, in 2008. We have since replicated and evolved the process to apply to an addition to the RSF, to the ESIF (a smart grid research laboratory), to our staff cafeteria, and to a 1,800-car parking structure and site entrance building. We have documented the best practices used to include energy performance requirements into design-build contracts, as well as best practices to ensure the operational energy performance meets the design requirements and found that:

- When energy efficiency is a core project requirement (as defined at the beginning of a project), innovative design-build teams can integrate the most cost-effective and high-performance efficiency strategies on typical construction budgets.
- Operational energy use can be aligned with design predictions.
- When the design-build contract includes measurable energy requirements and is set up to incentivize design-build teams to focus on achieving high performance in actual operations, owners can expect their facilities to perform at a high level.

As NREL new construction completes in 2012, we will look to deploy this robust how-to guide and training materials so other owners and their representatives can replicate our successes and learn from our experiences in attaining market-viable, world-class energy performance in the built environment.

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APPENDIX A BEST PRACTICE APPLICATION TO NREL CAMPUS PROJECTS

The Department of Energy's (DOE) National Renewable Energy Laboratory's (NREL) goal is to expand our leadership as a state-of-the-art laboratory that supports innovative research, development, and commercialization of renewable energy and energy efficiency technologies that address the nation's energy and environmental needs. As market demand for renewable energy and energy efficiency continues to expand, NREL responds. This growth has resulted in a significant increase in employees and facilities on our 327 main acre main campus in Golden, Colorado.

To support this growth over the last five years, NREL Commercial Buildings researchers have developed and demonstrated a new construction procurement and acquisition method that successfully integrates energy efficiency requirements into the design and operations. We have found that cost effective and deep energy savings are possible when the design/build industry is better integrated. NREL facility growth was our opportunity to demonstrate this concept in real projects by incorporating energy performance specifications into the design-build RFPs and contracts. We developed and piloted this energy performance based design-build process with our first new construction project in 2008. We have since replicated and evolved the process over the following projects:

Research Support Facility (RSF) – a 824 occupant, 220,000 ft2 office building with a datacenter

Research Support Facility Expansion (RSFII) – a 500 occupant, 150,000 ft2 office building and conference space expansion to RSF1

Energy Systems Integration Facility (ESIF) − a 182,500 ft2 smart grid research laboratory with a super computer and 200 workstations

Staff Cafeteria (CAFÉ) – a 12,000 ft2 commercial kitchen, servery, and 250 seat dining hall

Parking structure and site entrance building (SEB) – a 5 deck, 1,800 car parking garage and 1,500 ft2 campus access control building

Each project incorporated world class efficiency strategies using contractual energy use requirements in the design-build contracts, all on typical DOE construction budgets. Based on our experiences incorporating energy efficiency requirements into these NREL Campus projects, we have developed a set of best practices for other owners and owner's representatives looking to replicate this process:

Best Practice #1: Include a Measureable Energy Goal in the RFP

Best Practice #2: Develop the Energy Goal Using Multiple Resources

Best Practice #3: Develop the EUI Goal Using Normalization Factors

Best Practice #4: Include Technology-Specific Efficiency Requirements in the RFP

Best Practice #5: Define Owner Loads

Best Practice #6: Provide Calculation Methods for Substantiation

Best Practice #7: Require Goal Substantiation throughout Design

Best Practice #8: Develop a Process for Energy Performance Assurance

We have found that when energy efficiency is a core project requirement as defined at the beginning of a project, innovative design-build teams can integrate the most cost effective and high performance efficiency strategies on typical construction budgets. We have also found that it is possible to align operational energy use with design predictions. When the design-build contract includes measureable energy requirements and is set up to incentivize design-build teams to focus on achieving high performance in actual operations, owners can now expect their facilities to perform.

Research Support Facility I

In 2007 during the initial acquisition planning process for the RSF, it was decided that in order to deliver the RSF, with its challenging performance requirements, on time and on budget, a traditional design-bid-build procurement process would not suffice. Rather than designing the building and then putting it out to bid in the traditional way, the team opted for a performance-based design-build procurement process. The goal to achieve significant energy savings couldn't override a focus on cost effectiveness and ensuring DOE obtained the best value, as DOE provided a firm fixed price of ~$64 million to design and build the RSF. DOE budgeted the RSF's construction costs of 259/ft2 to be competitive with today's less energy efficient institutional and commercial buildings. To reach this level

of performance for the available budget, DOE and NREL felt that a different project delivery approach was required in selection of the project team and the design/construction process. Traditionally, DOE used a design-bid-build approach to project acquisition, selecting separate design and construction contractors. While this process typically provided the best price for the project, it limited the design team's creativity in developing the most cost effective integrated energy efficiency solution. In addition, as learned on past NREL projects, this design-bid-build process often limited the design team's full integration with the builder, cost estimators, and subcontractors, resulting in a longer, more costly delivery process with less value.

RSF I Rendering (RSF II, which is the third wing, is not shown), Credit: RNL

The RSFI is NREL's Administrative support office building, and includes 824 workstations, numerous conference rooms, NREL's datacenter, a lunch-room, a library, and an exercise room. It was completed in June of 2010. The RSF building showcases numerous high-performance design features, passive energy strategies, and renewable energy technologies. With LEED Platinum certification, net zero energy, and energy use of 35 kBtu/ft2/yr, it is a prototype for the future of large-scale, market competitive net-zero energy buildings.

The RSFI RFP included the following energy specific performance objectives; those that were provided in the design response are italicized:

MISSION CRITICAL

LEEDTM Platinum

ENERGY STAR First "Plus", unless other system outperforms

HIGHLY DESIRABLE

25 kBTU/sf/year (normalized to 35 kBTU/sf/year for space efficiency and external users of datacenter)

Measurable ASHRAE 90.1-2004-50%

IF POSSIBLE

Net Zero/Design approach

Most energy efficient building in the world

LEEDTM Platinum Plus

ASHRAE 90.1-2004-50% Plus

Visual displays of current energy efficiency

Application of Best Practices

BP1: Include a Measureable Energy Goal in the RFP

Goal types: Net-zero energy, an EUI, percent reduction, and rating system goals were all specified in the RSF I and II contracts. The team focus for energy goal substantiation was primarily on the EUI.

Energy Goal RFP Language (complete list of tiered goals given in Appendix E:

Mission Critical: LEED Platinum, Energy Star First "Plus"

Highly Desirable: 25 kBtu/ft2/yr, building information modeling

If Possible: Net-zero design approach, "most energy efficient building in the world", LEED Platinum Plus, ASHRAE 90.1 plus 50%, visual displays of energy efficiency, support personnel turnover (building handoff)

BP2: Develop the Energy Goal Using Multiple Resources

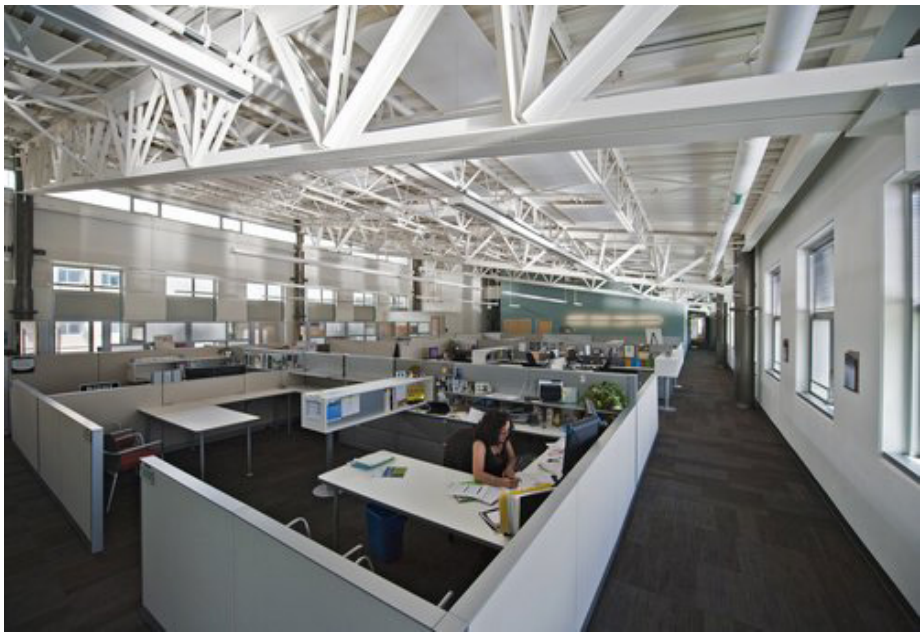
The energy goal for the RSF was developed using high level sector data, case study comparison, and whole building energy modeling. Since the building was a first of its kind in efficiency, a high level of consideration was required to make sure the goal was aggressive yet attainable.

BP3: Develop the EUI Goal Using Normalization Factors

The RFP goal of 25 kBtu/ft2/yr was developed using an assumption of 650 people in a 220,000 ft2 building. A normalization table was given, with the intent of maintaining a constant energy impact of each employee in the building as was determined for the original goal.

The space density was increased due to the long wing design, which also helped daylighting and natural ventilation as shown schematically in the

image below.



RSF1 and RSFII Daylighting

Additional data center capacity allowance was also defined. The space density and data center capacity increases, resulted in a final EUI target of 35 kBtu/ft2/yr.

BP4: Include Technology-Specific Requirements in the RFP

While the energy goal was stringent enough require the use of daylighting in the RSF wings, the energy goal development team recognized the added value of explicitly giving the team a daylighting goal to reach so that it the system would need to be individually substantiated and not lumped into a lighting simulation estimate. Specific language throughout the RFP related to the daylighting requirement includes:

Interior lighting requirements list, "Daylighting: Provide ambient natural lighting in primary spaces that is of intensity adequate for essential tasks when measured on a typical overcast winter day in midafternoon (IESNA illuminance reference).

LEED Platinum requirement, which indirectly required the use of a sunny, Equinox day at noon illuminance calculation to show that 75% of the work-plane achieved a minimum of 25 fc.

While both requirements were useful in focusing the team on daylighting, the latter requirement was more specific therefore more effective as a dominant substantiation metric.

BP5: Define Owner Loads

NREL conducted a survey of typical office loads and provided the following list to the design team.

Plug loads:

Personal computers (desktop and laptop)

Personal printers

Common office equipment (printer, copier and fax machine)

Personal task lighting

Common break room plug in equipment (refrigerator, coffee pot, microwave, vending machine and drinking fountain)

Power of the Data Center per person

Personal miscellaneous loads (cell phone chargers, radios, space heaters, personal fans, etc.)

Process loads:

Step-down transformers for 120 volts

Data center cooling

Elevators

Miscellaneous HVAC equipment (actuators, low voltage transformers, EMS, sensors)

Miscellaneous loads (security cameras, smoke detectors, security card readers, occupancy sensors, lighting controls, thermostats, telephones, door locks, etc.)

The list serves as a starting point for design teams to think through the magnitude of owner loads and consider efficiency options, as communicated in Appendix H.

BP6: Provide Calculation Methods for Substantiation

Since the RFP requested a net-zero energy building the RFP provided conversion factors for site to source energy so that net-zero source energy status would be targeted. An additional calculation detail that could have caused

ambiguity if not defined was the efficiencies of hot and cold water used from NREL's central plant. Clarity for these items, among others, was given in the RFP as shown in Appendix H.

For the plug loads listed as owner loads, required peak hourly assumptions to be used in energy calculations was provided as shown in Appendix H. The RFP included a description of assumptions used to arrive at the required loads and gave consent to decrease the load in the calculation if further efficiency measured were applied in design.

BP7: Require Goal Substantiation throughout Design

Substantiation timeline for the daylighting system, for example, was specifically called out in the RFP and the resulting process proved to be iterative and highly effective for optimizing the daylighting with respect to all other design decisions.

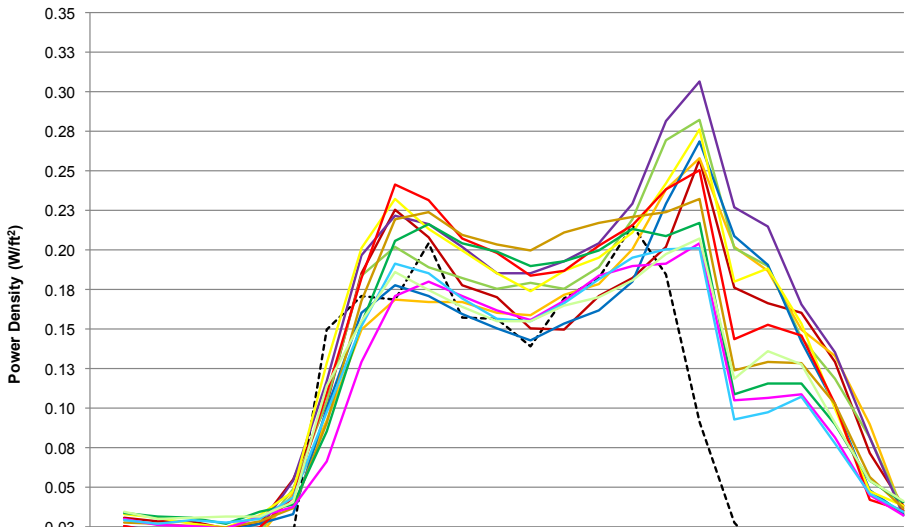
Proposal: Information on overall building configuration that will permit daylighting to levels specified.

Design Development: Engineering calculations for representative spaces, predicting anticipated daylighting levels under specified conditions.

Construction: Field test of lighting levels verifying compliance with performance requirements.

BP8: Develop a Process for Energy Performance Assurance

End use metering, enhanced commissioning, and M&V were all project requirements and have proven useful to the owner in addressing energy loads in operations. For example, lighting energy use was shown to be higher than predicted in evening hours due to cleaning staff hours. Training was provided for the staff to use the egress lighting when possible or switch on entire zones as needed in attempt to realize predicted energy performance.



RSF1 Lighting Measured Use Comparison to Model Predictions

Research Support Facility II

RSF I and RSFII Rendering, Credit: RNL

RSFII is an expansion onto RSFI, adding an additional 550 workstations and conference space. The RSFII was completed in November of 2011, with similar energy goals as RSF1. An additional 408 kW PV system is installed on the roof. With RSFI and RSFII combined, the total size is 360,000 ft2, houses approximately 1,324 NREL employees, uses 34.4kBtu/ft2 at 50% better than ASHRAE 90.1-2004, and costs a total of $91.4 million in construction costs. At $254/ft2 vs. the average cost of $335/ft2 for newly constructed commercial buildings designed to achieve LEED ratings in Colorado, it is a market competitive office building reaching net zero energy performance.

The RSFII RFP included the following energy specific performance objectives; those that were provided in the design response are italicized (the full list of prioritized objectives is shown in Appendix E):

MISSION CRITICAL

LEEDTM Platinum for the Facility

ENERGY STAR First “Plus”, unless other system outperforms

25kBTU/SF/Year (normalized to 33 kBTU/sf/year for space efficiency and external users of datacenter)

PV Installation, Building and Parking Lot

HIGHLY DESIRABLE

Measurable ASHRAE 90.1-50% plus

Net Zero/Design approach

Visual Displays of Current energy Efficiency

IF POSSIBLE

Most energy efficient building in the world

LEEDTM Platinum Plus

ASHRAE 90.1 plus 50%+

Energy Systems Integration Facility

ESIF Office Wing Rendering, Credit: SmithGroup

The Energy Systems Integration Facility (ESIF) on the campus of the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) in Golden, Colorado, will soon be the nation's first facility that can conduct integrated megawatt-scale research and development of the components and strategies needed in order to safely move clean energy technologies onto the electrical grid "in-flight" at the speed and scale required to meet national goals. Construction will be complete in the winter of 2012.

Research and development conducted in the ESIF will aim to overcome the challenges of integrating renewable energy into the electrical grid. These application and technology challenges span the entire electric power system — from generation to transmission, to distribution, and to end-use applications. Of particular focus are electric systems, buildings and facility systems, community power generation and microgrids, utility generation, thermal and hydrogen systems, energy efficient and advanced grid technologies, electricity system architectures, interoperability, and utility generation and grids that incorporate renewable energy (solar, wind, hydrogen, and advanced vehicles).

To support these areas of research, the 182,500 ft2 ESIF will house approximately 200 scientists and engineers and a wide range of fully equipped, state-of-the-art laboratories and out-door test areas. In addition to high-tech collaboration and visualization rooms, the ESIF will include a high-performance computing data center that will serve the breadth of NREL, expanding the laboratory's capabilities in modeling and simulation of renew-able energy technologies and their integration into the existing energy infrastructure.

The ESIF will not only meet the nation's crucial research objectives for integrating clean and sustainable energy technologies into the grid, but will do it in a way that is safe, efficient, and respectful to its surrounding environment. The ESIF will be built in accordance with the U.S. Green Buildings Council's standards and is expected, at minimum, to achieve LEED Gold Certification. The following energy efficiency strategies are included:

Reuse of data center and High Bay laboratory waste energy to maximize building/campus heating

Transfer of electrical energy from experiments between laboratories for simultaneous use/reuse

Underfloor air distribution for interior cooling and ventilation; outside air economizer

Active radiant beams provide for perimeter cooling and heating

Evaporative-based central cooling meets ASHRAE 55 thermal comfort range and all super-computer cooling

Natural ventilation mode with operable windows and ventilation shafts

Daylighting with high efficiency lighting (lights off 10 AM to 2 PM)

Energy Star rated equipment

ESIF East Facade Rendering, Credit: SmithGroup

The ESIF RFP included the following energy specific performance objectives; those that were provided in the design response are italicized (the full list of prioritized objectives is shown in Appendix E):

REQUIRED - Request for Proposal Submission

Achieve an annualized Power Use Effectiveness (PUE) of 1.06 or lower and an annualized Energy Use Effectiveness of 0.9 or lower for the HPCDC.

LEED™ Gold

REQUIRED – After Subcontract Award

Excess waste heat from the data center above that which is used to heat the facility is exported for use by the remainder of the campus.

GOALS

Achieve an average annualized EUE of 0.6 or less for the HPCDC

Achieve LEED™ Platinum for the entire facility.

Visual displays of current facility energy efficiency.

Most energy efficient data center in the country.

Additional RFP Energy Requirements include:

No mechanical cooling for the office areas or labs unless needed for process loads

No mechanical cooling for High Performance Computing Data Center

The office area should have a maximum annual energy usage of 25 KBTU/s.f./year, including plug loads

Excluding the energy consumption for the High Performance Computing Data Center, provide at least 30 percent less energy consumption than that of an equivalent minimally complying baseline building, demonstrated by comparing the actual Design Energy Cost to the Energy Cost Budget of a prototype building, both calculated in accordance with ASHRAE 90.1-2007.

Application of Best Practices

ESIF Office Wing in Construction

BP1: Include a Measureable Energy Goal in the RFP

Goal types: Data center efficiency targets and general efficiency and sustainability requirements were included in a prioritized goal structure.

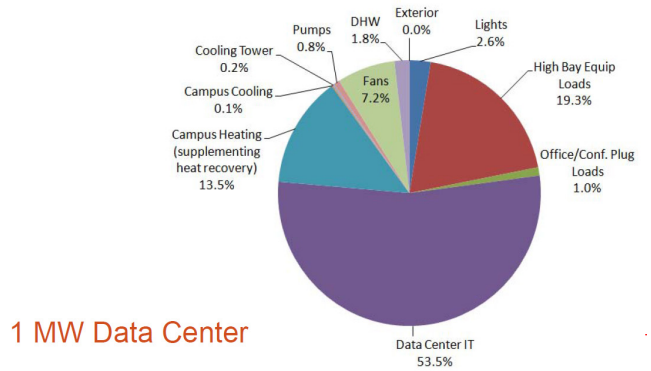
Energy Goal RFP Language:

Required: LEED Gold, Power Use Effectiveness (PUE) of 1.06 or lower and an annualized Energy Use Effectiveness (EUE) of 0.9 or lower for the data center, "Excess waste heat from the data center above that which is used to heat the facility is exported for use by the remainder of the campus", "Research equipment identified in the Program will be state-of-the art at the time of occupancy"

If Possible: EUE of 0.6 or less for the data center, LEED Platinum, "Most energy efficient data center in the country"

BP2: Develop the Energy Goal Using Multiple Resources

Much like the Café, the ESIF total building load will be dominant by the equipment serving the building's primary function. The following pie charts produced as part of an energy modeling substantiation report reinforce the value of focusing on equipment specific goals, such as data center EUE, versus whole building goals in equipment dominated buildings.

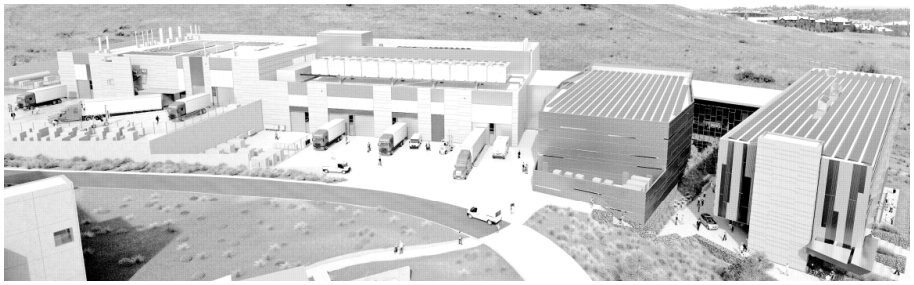


The EUE and PUE were developed using case studies, including the RSF data center.

BP4: Include Technology-Specific Requirements in the RFP

The RFP requirement of heat recovery from the data center and the daylighting saturation minimum indirectly imposed by the LEED Gold requirement were primary drivers for early massing decisions. The office (right side of following image) was aligned on an east-west axis mimicking the other newly constructed RSF office wings. The data center was centrally located

between the office and laboratory space for increased heat recovery efficiency to both occupied masses. The laboratory wing consists of high-bay spaces that can use translucent clerestory panels diffusing the low solar angles seen on east and west facades.



ESIF Rendering, Credit: SmithGroup

Additional RFP requirements on hydronic system purpose, heat recovery, and air distribution minimum specifications led to the following sample of design features:

Data Center:

Water side free cooling, cooling tower plant

Low approach cooling towers and HX

Low pressure-drop air delivery system

Low pressure-drop piping design

Labs:

Active chilled beams on perimeter

100% of heating from data center

BP5: Define Owner Loads

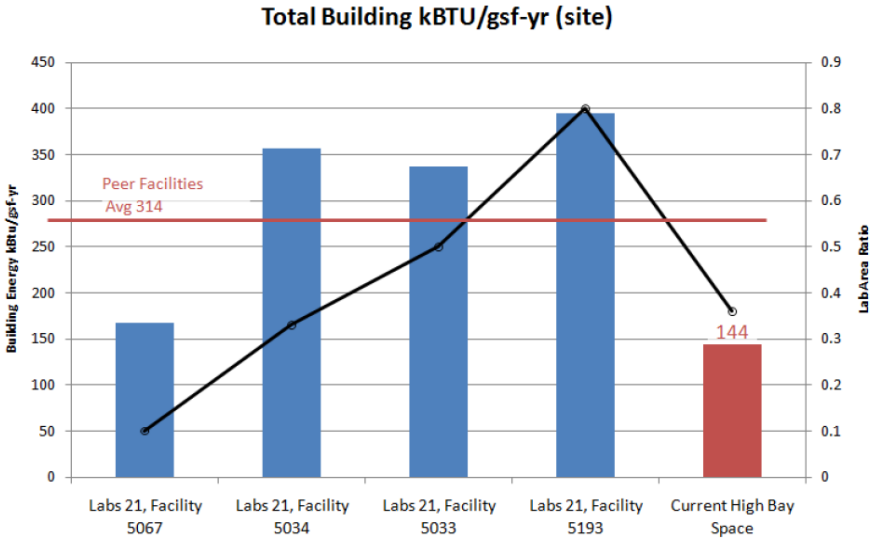
Next to the data center, laboratory equipment dominates the load profile of the building. Expected equipment was outlined in the RFP and was a point of continued reference and editing throughout the design-build process.

BP6: Provide Calculation Methods for Substantiation

The contract development process for the ESIF was able to use work already performed for the RSF. Exact language used for the RSF substantiation method was placed in the RFP of the ESIF as a reference for the office portion of the building, as shown in Appendix J.

BP7: Require Goal Substantiation throughout Design

In addition to the energy goals given as substantiation requirements, the EPA's Labs 21 criteria are referenced as minimum design standards. A mid-design comparison showed the ESIF lab space design achieving 144 kBtu/ft2/yr compared to an average of 314 kBtu/ft2/yr for similar Labs 21 facilities in cold, dry climates.



Source: Integral Group, Interim Energy Modeling Report

The goal was easily achieved by the massing applied by the design team and the equipment-specific strategies outlined in the RFP.

Parking Garage and Site Entrance Building

Figure 7 NREL Parking Garage

NREL's parking structure project is proving that large garages can be designed and built sustainably—at no additional cost. While meeting staff needs with up to 1800 parking spaces, this new structure features energy efficiency and renewable energy technologies and blend in with the natural landscape. At a construction cost of $14,172 per parking space, the high efficiency NREL garage is cost competitive with other comparable, but less efficient garages that typically cost $15,500 to $24,500 per parking space. The new parking garage was completed in the Spring of 2012 and provides centralized parking for employees who work at the South Table Mountain campus, many of whom used to park offsite and take shuttles to and from NREL. To encourage more sustainable forms of commuting, preferred parking is provided for carpool and vanpool vehicles, low-emission vehicles, and motorcycles and bicycles. In addition, pedestrian walkways connecting the parking structure to individual buildings encourage a "walkable" campus culture.

NREL's new parking structure is a showcase for energy efficiency and renewable energy technologies and water conservation. With energy use expected at less than 160 kBTUs per parking space per year at 90% more efficient than ASHRAE 90.1 standards, significant energy savings are possible even in parking garages. Key efficiency strategies include:

Reduced lighting loads to be achieved through:

Full Daylighting (enhanced by large light wells and an open central atrium)

Occupancy and daylighting sensors that automatically turn on lights when needed

Highly energy-efficient LED lighting with optimal layout to provide the lowest possible installed lighting power while maintaining safe and consistent lighting levels.

Controlled parking using digital signs to indicate available parking—and reduce driving and emissions

Reduced solar-gain and heat build-up in circulation area achieved with translucent skylights

Reduced energy usage achieved by limiting the garage to two elevators and encouraging employees to take the stairs. Regenerative traction elevators with LED lighting enabled by elevator occupancy save an estimated 75% in elevator energy use.

Natural ventilation achieved through sides that open to the elements, eliminating the need for a mechanical system

Electricity requirements will be offset by renewable energy power production of 1.13 MW from photovoltaic panels on the rooftop and floor level; excess power will help offset energy use in the nearby Research Support Facility.

Site Entrance Building Rendering, Credit: RNL

In addition to the parking garage to NREL's campus, numerous site access enhancements have been made to allow a smooth transportation system to and around the campus. As part of these campus transportation enhancements, NREL added a new south entrance and corresponding site access control building, or Site Entrance Building (SEB). While one of NREL's smallest buildings at 1,500 ft2, the SEB still includes the following NREL standard world class efficiency and sustainability strategies:

Fully daylit occupied spaces using lightshelves and dimming controls

High performance thermal envelope, including fiberglass window frames

Ground source water to water heat pumps with radiant cooling and heating

Underfloor ventilation air distribution system connected to energy recovery ventilators

8 kW roof mounted PV system to allow facility to meet net zero site goals

LEED Platinum

The Parking Garage and SEB RFP included the following energy specific performance objectives; those that were provided in the design response are italicized (the full list of prioritized objectives is shown in Appendix E):

MISSION CRITICAL

Site Entrance Building – Achieve LEED™ Gold

Parking Structure(s) - maximize LEED™ points

HIGHLY DESIRABLE

Achieve energy goals for parking structure(s) and site entrance building, including 9300 kWh annual energy goal for SEB, 175 kBtu/parking space/yr for garage

Maximize PV capacity capability

Site Entrance Building – Achieve LEED™ Platinum

Provide industry supported Electric Vehicle Supply Equipment (EVSE) for 2% of spaces immediately available on opening day

IF POSSIBLE

Provide infrastructure support to expand the industry supported Electric Vehicle Supply Equipment (EVSE) to accommodate up to 20% of the spaces without the need to upgrade or modify the electrical distribution system.

Parking management technology

Net Zero Energy for the Site Entrance Building

Application of Best Practices

BP1: Include a Measureable Energy Goal in the RFP

Goal types: Net-zero energy, an EUI, a total energy use goal, and rating system goals were specified in the RFP.

Energy Goal RFP Language:

Mission Critical: LEED Gold for SEB, Maximize LEED points for garage, minimize structure height, maximize PV capacity capability

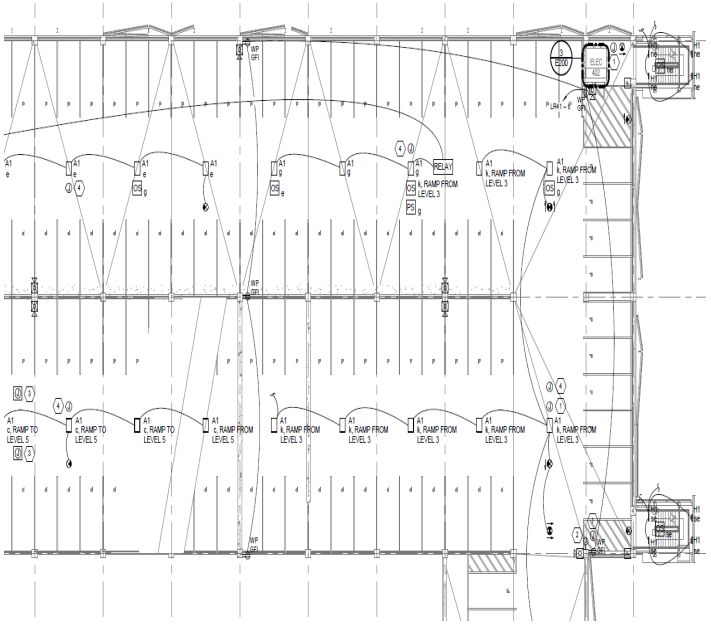
Highly Desirable: LEED Platinum for SEB, 9300 kWh annual energy goal for SEB, 175 kBtu/parking space/yr, 2% capacity for electric vehicle charging stations

If Possible: Net-zero energy for the SEB, parking management technology, 20% capacity for electric vehicle charging stations

BP2/BP6: Develop the Energy Goal Using Multiple Resources and Provide Calculation Methods for Substantiation

Defining the energy use goal for the garage required NREL to perform feasibility calculations since sector level and case study information is not readily available for high efficiency structures. The feasibility study included daylight modeling on basic structure forms to determine the extent of daylighting possible, occupancy profile logging to determine potential nighttime parking structure use, system-level case study comparisons, and a survey of top of the line equipment efficiencies. A summary of the energy goal development logic and resulting contract language for the garage is provided below.

The highly aggressive LPD and lighting use shown in the substantiation method was exceeded by the design team with the use of one LED fixture (A1) per bay as shown in the following reflected ceiling plan.



Parking Garage Lighting Details

The aggressive use profile was achieved through the use of daylight and occupancy sensors on all garage lighting fixtures.

BP3: Develop the EUI Goal Using Normalization Factors

The parking structure goal was defined per space rather than per area to maximize space density. The goal scaled well since the number of spaces required by the RFP was given in a tiered form, giving room for the team to work within the other requirements such as reduced garage height.

A unique energy goal definition for the Ingress/Egress project was the 9300 kWh energy use goal not normalized by area. Since the building was plug

load dominated by security equipment, NREL surveyed the existing entrance building and interviewed security about potential equipment additions. The comprehensive list in addition to assumed system components resulted in the total energy goal. Unforeseen equipment additions and size changes resulted in an extremely aggressive energy goal. NREL determined that the team was making the expected effort to reduce energy consumption therefore granted the team an adjustment on the energy goal. The used project goal was then officially changed in the contract to a slightly less aggressive 32 kBtu/ft2/yr. The team operated under the assumption that the primary goal was net-zero energy since it was identified as a building requirement in the team's RFP response.

BP4/BP5: Include Technology-Specific Requirements in the RFP and Define Owner Loads

As mentioned, the security equipment dominated the SEB, which was understood by the owner prior to RFP development. Much like the equipment list and substantiation load requirements given for the RSF in Appendix H, an initial equipment load matrix was provided to the team in the RFP and development of the matrix continued through design.

Daylighting and natural ventilation requirements for the garage drove the slightly elongated shape, bay width, and light well/dual wing design as shown at the top left side of the following aerial image.

Parking Garage Aerial during Construction

In addition to the almost negated need for lighting during the day, no natural ventilation is required due to the open sides.

BP/BP8: Require Goal Substantiation throughout Design and Develop a Process for Energy Performance Assurance

Energy calculations and daylight modeling were required and performed at each design phase. An example of design tuning based on modeling is the quantity and openness of the north façade panels to balance weather protection and daylighting.

Parking Garage North Façade Panels

Sub metering and commissioning was required for both the SEB and the garage. A contractual difference, possibly a key element of real performance, was an enhanced commissioning and M&V requirement. The garage will not receive enhanced commissioning or third-party M&V and so the difference in day one performance will be documented when data is available.

Cafeteria

Staff Cafe Rendering, Credit: RNL

At 12,000 square feet the Café is the first full-service dining facility to be built on the National Renewable Energy Laboratory's Golden, Colorado, campus. The Café will accommodate 240 guests at any given time, with the balcony and north terrace providing additional seating for 70+ individuals. Use of the dining facility will be staggered to accommodate all campus employees while promoting the efficient and economical use of the dining hall throughout the day. In addition, the facility will be in use as a multi-purpose space for evening and off-hour gatherings. The Café will be completed in the summer of 2012.

The facility efficiency features include full daylighting in the dining and servery, with some perimeter daylighting for kitchen staff. Optimal orientation of glazing to the south and north control unwanted summer sun, but allow for winter solar gains and diffuse daylighting year round. The foodservice design of the National Renewable Energy Laboratory Café includes commercial grade, heavy-duty cooking, storage, and preparation equipment with an acute focus on the lowest energy consumption available. The Café's foodservice design and construction model works to evaluate each piece of equipment to determine the most efficient product from both an energy use and operational standpoint. Where Energy Star equipment is the most efficient possible, it has been specified for the Café; however, where higher efficiency models are attainable, the team has worked to specify equipment that exceeds Energy Star performance. For example, the facility's dishwashers utilize half of the water that a standard Energy Star model consumes. The Café's exhaust hoods have high-efficiency filters, wall-style canopies and proximity hoods, with stainless steel end panels to reduce the CFM requirements. The variable volume exhaust system calculates the required exhaust CFM in real time to adjust the fan speed to meet the demand requirements while maximizing energy efficiency, all saving up to 75% of the energy use in a typical kitchen exhaust hood. Ware washing utilizes an Energy Star rated dishwasher equipped with dual-rinse technology – when in operation, the unit recycles the dirty rinse water to wash the next load. Refrigeration systems are removed from the general proximity to all coolers, freezers and ice machines, thereby reducing the heat generated in the kitchen and the demand on the HVAC cooling systems throughout the Café. The HVAC unit also features a direct/indirect evaporative cooling system which provides all kitchen and dining area cooling without the use of mechanical cooling equipment. Walk-in refrigerator/freezers include high density insulated panels, exceed the minimum R-rating for walk-ins and, in so doing, decrease heat loss into the floor and ambient spaces.

The Cafeteria RFP included the following energy specific performance objectives; those that were provided in the design response are italicized (the full list of prioritized objectives is shown in Appendix E):

MISSION CRITICAL

LEEDTM Gold

Maximize energy conservation in accordance with LEED credits.

Full Design of high efficiency café including, mechanical, electrical and kitchen equipment systems, flexible seating area(s), server areas, and elevator.

HIGHLY DESIRABLE

LEEDTM Platinum

50% decrease over ASHRAE 90.1 2007

Visual displays of current energy efficiency

IF POSSIBLE

LEEDTM Platinum 'Plus'

World class, most energy and resource efficient commercial kitchen and cafeteria in the world including grey water, composting, resource recovery, zero waste

Best in class energy efficiency kitchen equipment

Minimum 30% solar hot water fraction for kitchen hot water use

Maximize reuse of waste heat

Highest efficiency elevator

BP1: Include a Measureable Energy Goal in the RFP

Goal types: Text requiring high efficiency, world-class design, sustainability program goals, and percent reductions.

Energy Goal RFP Language:

Mission Critical: LEED Gold, "Maximize energy conservation in accordance with LEED credits", "Full design of high efficiency café including, mechanical, electrical and kitchen equipment systems, flexible seating area(s), server areas, and elevator"

Highly Desirable: LEED Platinum, 50% decrease over ASHRAE 90.1 2007

If Possible: LEED Platinum "Plus", "World class, most energy and resource efficient commercial kitchen and cafeteria in the world including grey water, composting, resource recovery, zero waste", "Best in class energy efficiency kitchen equipment", "Minimum 30% solar hot water fraction for kitchen hot water use", "Maximize reuse of waste heat", "Provide innovative waste water technologies", "Highest efficiency elevator"

BP2: Develop the Energy Goal Using Multiple Resources

The Café presented an energy goal definition challenge. Unlike the RSF, the café is unlike other building type on campus, does not have adequate sector or case study information, and is dominated by cooking schedules and food type preparation. The garage was also dominated by schedules, but those schedules could be determined from other campus information. Due to the lack of information to develop a building-wide goal, NREL used system and equipment efficiency definitions in the RFP. The 50% reduction over ASHRAE 90.1 goal was a stretch goal to place some incentive on building component efficiencies. As stated in the RFP energy appendix, "An absolute energy use requirement is more dependent of the cooking schedule than the efficiency of the systems. Instead of a whole building energy intensity goal, the intent of this list is to provide performance goals by subsystems."

BP4/BP5: Include Technology-Specific Requirements in the RFP and Define Owner Loads

The following list is a sample of what was provided to the owner in addition to an extensive survey of best in class kitchen equipment, a portion of which is shown in Appendix G. Italicized goals are those that have been met in the current design.

Best in class energy efficiency kitchen equipment- maximize high efficiency electric cooking equipment such as commercial induction cook tops

Best in class water efficiency kitchen equipment

All-VFD demand based exhaust hoods

Lowest possible cfm/linear foot of hood (close proximity hoods with side and back panels)

Integrated off-hours equipment controls to automatically schedule appropriate kitchen/support loads disconnects

Maximize solar hot water fraction for kitchen hot water use – 30% minimum required by EISA if life cycle cost effective, 50% solar fraction if possible (reasons for exclusion: cost)

Maximize waste heat from refrigeration equipment, including distributed refrigeration and ice machine equipment (reasons for exclusion: cost versus efficacy)

Maximize waste heat energy recovery from exhaust air

Maximize waste heat energy recovery from hot water drains (only true on some equipment scales, including dishwashing equipment)

All evaporative cooling, maximizing indirect evaporative cooling – no mechanical cooling for café and kitchen makeup

Hydronic heating (radiant, fin tube, etc.) (reasons for exclusion: cost and low heating demands)

Natural ventilation in the cafeteria

Achieve 25 fc in all cafeteria and servery spaces from daylighting from 9am-3pm with sunny skies. (i.e. lights to be off)

Maximize end use metering to fully understand how kitchen and cafeteria perform (BP8)

Maximize passive solar heating in café in winter

Minimize mechanical equipment exposed to exterior elements

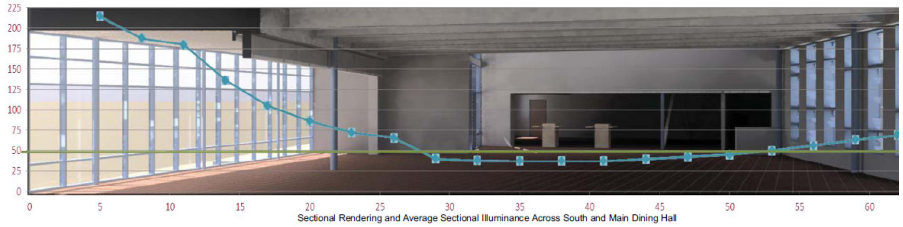
World class, most efficient commercial kitchen and cafeteria in the world that can attract commercial kitchen partners to demonstrate efficient equipment

Solar preheat of kitchen and cafeteria makeup air (reason for exclusion: Outdoor air load reductions from exhaust hood efficiency strategies)

PV ready roof and building design

BP7: Require Goal Substantiation throughout Design

Substantiation was performed for each component identified in the goals list. An example of system-specific substantiation is shown in the following annual average daylighting illuminance profile. The single-point-in-time goals equate to an approximate 50 fc annual average illuminance minimum requirement. Since this goal was not met with the north and south glazing alone, tubular daylighting devices were added to the core of the cafeteria to increase saturation.



Source: Daylighting Innovations, Construction Documents Substantiation Package

NREL Project Comparisons

In general, the NREL projects have succeeded in meeting all the energy specific RFP performance objectives. The Cafeteria is the only project that did not meet all the "Highly Desirable" or "If Possible" energy objectives, which was due to a poorly defined program and budget. This resulted in the project carrying too much scope during the design process, and when the project budget became defined, significant scope and efficiency strategies were removed from the project to meet the schedule requirements.

As shown in the table below, each project's key RFP energy goal is being met by the proposed design. Again, the Cafeteria is slightly below the minimal energy goal requirements due to the poorly defined scope and budget while maintaining an aggressive construction schedule.

NREL Project Requirements Compared to Design Predictions

	Energy Goal (Basis for Model Substantiation)	Predicted Energy Use 1	Reduction from Goal	Additional Energy Requirements
RSF I (office)	35 kBtu/ft2/yr	33 kBtu/ft2/yr 4	6%	Net-zero energy, source (combined boundary)
RSF II (office)	33 kBtu/ft2/yr	28 kBtu/ft2/yr	14%	
Garage	175 kBtu/parking space	158 kBtu/parking space	10%	
SEB (security building)	32 kBtu/ft2/yr	31 kBtu/ft2/yr	3%	Net-zero energy, source
Cafeterai	30% energy cost savings 2	26% energy cost savings	-13%	-
ESIF (office)	27 kBtu/ft2/yr	25 kBtu/ft2/yr	7%	7.5% renewable energy (LEED credit requirement)
ESIF (office and labs)	30% energy cost savings 2	36% energy cost savings	17%	
ESIF (data center)	1.06 PUE, 0.9 EUE	1.05 PUE, 0.5 EUE 3	-	No mechanical cooling

1 All are final, as-built energy predictions except for the ESIF and Café, which are mid-design energy predictions.

2 Based on an ASHRAE 90.1 2007 baseline. Café also has a highly desirable goal of 50% energy cost savings.

3 Day 1 estimate for a 1 MW data center load. Does not include 10 MW full build out.

4 Measured energy use for the RSF is on track with the predicted energy use. The other buildings are either under construction or have been operating for less than six months.

t2) On-site renewable energy sources: Desirable.

3) Improvement of efficiency through comprehensive building commissioning: Required.

4) Energy and water consumption measurement and verification systems: Required.

5) No use of CFC-based refrigerants: Required.

6) Use of HCFC's (or other EPA approved alternative) with as low an Ozone Depleting Potential (ODP) as possible: Required.

7) No use of Halon: Required.

e. Conservation of Materials and Resources:

1) Central location for collection and storage of recyclables: Required.

2) Recycling and/or salvaging of construction waste: Required.

3) Use of salvaged or refurbished materials: Required.

4) Use of materials containing recycled content: Required.

5) Use of local/regional materials: Desirable.

6) Use of rapidly renewable materials: Desirable.

7) Use of certified wood: Desirable.

f. Indoor Environmental Quality:

1) Smoking will be prohibited in the building.

2) Air isolation of janitor closets: Required

3) Minimum ventilation performance: Required.

4) Construction procedures that reduce impact on interior air quality during and after construction: Desirable.

5) Use of materials that are low-emitting, non-toxic, and chemically inert: Required.

6) Control of sources of indoor pollutants: Required.

7) Thermal comfort conditions: As specified.

8) Provision of daylighting: Required.

9) Provision of views to outdoors: Desirable.

g. Substantiation:

1) Proposal Stage: LEED™ Checklist annotated to show specific credits to be achieved with brief description of how they will be achieved.

2) Design Development and Construction Documents Stages:

a) LEED™ Checklist annotated to show specific credits status of design related to specific credits to be achieved.

b) Comprehensive checklist of certification documentation specified in LEED™ Reference Guide, annotated to show which forms of documentation have been submitted.

c) The documentation specified in LEED™ Reference Guide that is relevant to the degree of completion of the design; at subsequent design stages it will not be necessary to repeat submissions of the same documentation unless the design has changed.

3) At Completion: LEED™ Certification, by U.S. Green Buildings Council.

a) Design-Builder shall submit application and pay applicable fees and respond to all inquiries.

b) Design-Builder shall provide all certification documentation and install certification plaque.

c) Design-Builder shall provide Owner a complete duplicate of certification documentation.

h. Executive Order: Strengthening Federal Environmental, Energy, and Transportation Management.

1) Improve energy efficiency and reduce greenhouse gas emissions of the agency, through reduction of energy intensity by 3% annually through the end of fiscal year 2015, or 30% by the end of fiscal year 2015, relative to the baseline of the agency's energy use in 2003;

2) ensure that at least of the statutorily required renewable energy consumed by the agency in a fiscal year comes from renewable sources, and to the extent feasible, the agency implements renewable energy generation projects on agency property for agency use;

3) beginning in FY 2008, reduce water consumption intensity, relative to the baseline of the agency's water consumption in fiscal year 2007, through

life-cycle cost-effective measures by 2 percent annually through the end of fiscal year 2015 or 16 percent by the end of fiscal year 2015;

4) require in agency acquisitions of goods and services (i) use of sustainable environmental practices, including acquisition of biobased, environmentally preferable, energy-efficient, water-efficient, and recycled-content products, and (ii) use of paper of at least 30 percent post-consumer fiber content;

5) ensure that the agency (i) reduces the quantity of toxic and hazardous chemicals and materials acquired, used, or disposed of by the agency, (ii) increases diversion of solid waste as appropriate, and (iii) maintains cost-effective waste prevention and recycling programs in its facilities;

6) ensure that (i) new construction and major renovation of agency buildings comply with the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings set forth in the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (2006), and (ii) 15 percent of the existing Federal capital asset building inventory of the agency as of the end of fiscal year 2015 incorporates the sustainable practices in the Guiding Principles;

7) ensure that, if the agency operates a fleet of at least 20 motor vehicles, the agency, relative to agency baselines for fiscal year 2005, (i) reduces the fleet's total consumption of petroleum products by 2 percent annually through the end of fiscal year 2015, (ii) increases the total fuel consumption that is non-petroleum-based by 10 percent annually, and (iii) uses plug-in hybrid (PIH) vehicles when PIH vehicles are commercially available at a cost reasonably comparable, on the basis of life-cycle cost, to non-PIH vehicles; and

8) ensure that the agency (i) when acquiring an electronic product to meet its requirements, meets at least 95 percent of those requirements with an Electronic Product Environmental Assessment Tool (EPEAT)-registered electronic product, unless there is no EPEAT standard for such product, (ii) enables the ENERGY STAR feature on agency computers and monitors, (iii) establishes and implements policies to extend the useful life of agency electronic equipment, and (iv) uses environmentally sound practices with respect to disposition of agency electronic equipment that has reached the end of its useful life.

i. Substantiation:

1) Proposal Stage:

a) Checklist annotated to show specific techniques and systems to be utilized with brief description of how the objectives will be met.

b) Provide report indicating means of communication and reporting agency that establishes the methods to achieve the initiatives.

2) Design Development and Construction Documents Stages:

a) Identification of and implementation of tools to be utilized to monitor compliance with the Executive Order as well as the person responsible for proper documentation and certification.

3) At Completion:

a) Provide all required documentation and commissioning activities that ensured compliance with the initiatives stated in the Executive Order to the Owner.

5. In addition to the requirements of this section, comply with requirements of Project Information (Part 1-Procedures) and Design and Construction Procedures (Part 1-Procedures).

B. Amenity and Comfort:

1. Thermal Performance: Design and construct to provide comfortable interior environment in accordance with the code and the following:

a. Summer Interior Design Conditions:

1) Daytime Setpoint: 72 deg F (21 deg C), plus or minus 2 deg F (1 deg C) except as specified in the project program.

2) Night Setback: 78 deg F (25 deg C).

3) Interior Relative Humidity: 50 percent, maximum.

b. Winter Interior Design Conditions:

1) Daytime Setpoint: 70 deg F (20 deg C), plus or minus 2 deg F (1 deg C) except as specified in the project program.

2) Night Setback: 55 deg F (13 deg C)

3) Interior Relative Humidity: 10 percent, minimum.

c. Energy Design Wind Speed: 25 mph (40 km/h).

d. Typical operating conditions shall be in compliance with ASHRAE 55.

C. Health and Safety:

1. Fire Resistance: Provide appropriate Type construction in accordance with IBC International Building Code and Section Fire Protection.

2. Prevention of Accidental Injury: As required by code and as follows:

a. Safety Glazing: As defined by 16 CFR 1201; provide in locations required by code, glazed areas subject to human impact, glazed areas at grade, and doors.

b. Other requirements specified in other Sections and integration of elements of Safe Design.

3. Health Hazards:

a. Design to prevent growth of fungus, mold, and bacteria on surfaces and in concealed spaces.

b. Hazardous Construction Materials: Design and construct to comply with the requirements of the code.

1) Designs shall not make use of Polychlorinated biphenyls (PCB's).

c. Indoor Air Quality: Design and construct to comply with the code and the following:

1) Acceptable air quality as defined by ANSI/ASHRAE 62.1-2004.

2) Substantiation:

a) Design Development: Identification of methods to be used to comply with requirements; ventilation design calculations. Identification of unusual indoor contaminants or sources, and methods to mitigate their effects on occupants.

b) Commissioning: Field measured outside and supply air quantities for each space and its associated air handler.

4. Physical Security: In addition to any provisions that may be required by law or code, design and construct both exterior and interior spaces to incorporate accepted principles of crime prevention through environmental design (CPTED), using natural (as opposed to technological) methods of providing surveillance, access control, and territorial reinforcement wherever possible.

a. Definition of Elements at Ground Level: For purposes of physical security, any element within 20 feet (6 m) of the ground, grade, or adjacent paving.

b. Security Zones:

1) Public Access Zone: That area to which the public has free access, including public corridors, grounds, and parking lots.

2) Reception Zone: The area to which the general public has access but beyond which access is restricted at all times.

3) Operations Zone: The area to which only employees and visitors with a legitimate reason to be there have access.

4) Secure Zone: The area to which access is always controlled and which is monitored continuously.

5. Electrically-Operated Equipment and Appliances: UL listed for application or purpose to which they are put; suitable for wet locations listing for exterior use.

D. Structure:

1. Earthquake Loads: Accommodate loads as prescribed by code.

2. Wind Loads: South Table Mountain Site Per IBC (100 mph Fastest Mile; 120 mph-3 second gust).

E. Durability:

1. Expected Service Life Span: Expected functional service life of the built portions of this project is 50 years.

a. Service life spans of individual elements that differ from the overall project life span are defined in other Sections.

b. Additional requirements for elements not required to have life span equal to that of the project as a whole are specified below under "Operation and Maintenance."

c. Substantiation: Since actual service life cannot be proven, substantiation of actual service life is not required; however, the following are reasonable indicators of anticipatable service life:

1) Preliminary Design or Design Development: Service life expectancy analysis, for each element for which life span is specified; including:

a) Length of effective service life and aesthetic service life if specified, with action required at end; e.g. complete replacement, partial replacement, and refurbishment.

b) Basis of time estimates; e.g. proven-in-use application.

c) Basis of confidence in time estimates; e.g. similarity of present application to proven-in-use application.

d) Conditions under which estimate will be valid; e.g. expected uses, inspection frequency, maintenance frequency, etc.

2) Design Development: Replacement cost, in today's dollars, for each major element that has a service life expectancy less than that of the project;

include both material and labor cost, but not overhead or profit; base costs on installing in existing building, not as a new installation.

3) Design Development: Life cycle cost of project, over the specified project service life, excluding operating staff costs; include costs of:

a) Replacement of each element not expected to last the life of the project; identify the frequency of replacement.

b) Routine maintenance of operating equipment, including replacement of worn parts before failure; identify frequency of maintenance.

c) Calculate costs in today's dollars, disregarding the time value of money, inflation, taxes, and insurance.

2. Biological Factors:

a. Animals: Do not use materials that are attractive to or edible by animals or birds.

b. Insects: Do not use materials that are edible by insects, unless access by insects is prevented.

1) Wood: When wood is used, provide at least the protection recommended by AWPA as contained in AWPA U1-2007.

F. Operation and Maintenance:

1. Space Efficiency: Minimize floor area required while providing specified spaces and space relationships, plus circulation and services areas required for functions.

a. Substantiation: Areas and ratios measured and calculated in accordance with ANSI/BOMA Z65.1-1996.

1) Proposal: Calculation of Gross Building Area, Building Common Area and Floor Common Areas, and net area of each space.

2. Energy Efficiency: Minimize energy consumption while providing function, amenity, and comfort specified.

a. Provide energy efficient design using procedures and values specified in ASHRAE 90.1-2004.

1) Provide at least 50 percent less energy consumption than that of an equivalent minimally-complying baseline building, demonstrated by comparing the actual Design Energy Cost to the Energy Cost Budget of a prototype building, both calculated in accordance with ASHRAE 90.1.

2) Reference Project Goals (listed in Project Program) for required energy efficiency goals including the goal of using as little as "25 kBTU/sf/year" total energy consumption. Calculations shall be based on RSF Energy Target Definitions, dated 10/15/2007 (available from NREL).

b. Substantiation:

1) Proposal: Calculation demonstrating the "kBTU/sf/year" of the proposed design concept.

2) Proposal: Identification of method of calculation of energy efficiency to be employed.

3) Design Development: Detailed listing of design criteria and design analysis showing compliance, prepared by a licensed mechanical and electrical engineers.

4) Design Development: Projected energy consumption of all energy-consuming equipment and systems over the first year of operation; include analysis of probable change in annual energy consumption over time due to aging.

5) Construction Documents: Updated detailed listing of design criteria and design analysis showing compliance, prepared by a licensed mechanical and electrical engineers.

6) Construction Documents: Updated projected of energy consumption of all energy-consuming equipment and systems over the first year of operation; include analysis of probable change in annual consumption over time due to aging.

7) Commissioning: Actual measurements of energy consumption for all energy-consuming equipment and systems that demonstrate compliance with the design criteria and analysis.

8) Closeout: Recalculation using actual measurements of energy-consuming equipment and systems that demonstrate compliance with the design criteria and analysis.

3. Water Consumption: Minimize water consumption.

a. Substantiation:

1) Proposal: Estimated quantity of water that will be used in the first year of operation, divided into domestic water, HVAC water, and other water categories, with quantity of water recycled, if any; include basis of estimates.

2) Design Development: Quantity of water that will be used in the first year of operation, divided into domestic water, HVAC water, and other water

categories, with required storage capacity and quantity of water recycled, if any; include basis of calculations.

3) Construction Documents: Updated water consumption, based on actual equipment selections and sizes.

4. Ease of Operation: Provide facility, equipment, and systems that are easily operated by personnel with a reasonable level of training for similar activities.

a. Minimize the need for specialized training in operation of specific equipment or systems; identify all equipment and systems for which the manufacturer recommends or provides training programs.

b. Train Owner's personnel in operation of equipment and systems; see Part 1-Procedures (Design and Construction Procedures (Part 1-Procedures) for additional requirements.

c. Substantiation:

1) Proposal: Type of operating personnel and amount of training required; identification of each equipment item or system for which more than one day of training is required; identify source of data.

2) Design Development: Operating impact analysis, including identification of type and quantity of staff, tools, and supplies required; estimate of impact that aging materials will have on operating requirements; no cost calculations required; identify source of data.

5. Ease of Maintenance: Minimize the amount of maintenance required.

a. Substantiation:

1) Design Development: Maintenance cost for first year of operation, based on use of maintenance subcontracts; estimate of the impact that aging materials will have on maintenance costs; description of maintenance activities included in estimated cost.

2) Construction Documents: Updated maintenance cost for first year of operation, based on actual product selections.

6. Ease of Repair: Elements that do not meet the specified requirements for ease of repair may be used, provided they meet the specified requirements for ease of replacement of elements not required to have service life span equal to that specified for the project as a whole; the service life expectancy analysis and life cycle cost substantiation specified for service life are provided; and Owner' acceptance is granted.

7. Allowance for Changes in Occupancy and Arrangement:

a. Office Spaces: Design for churn of 15 to 30 percent, requiring periodic minor changes in location or layout of workplaces.

1) Size and Layout: So that relocation of individuals and small groups can be accomplished overnight with no disruption of work and no disruption of work of neighbors and no degradation of functionality or amenity.

2) Owner requires that operations staff be able to make such adjustments without technical help, with only a few days ordering/delivery time for new components.

3) Where fixed partitions are used to separate spaces, most components of relocated partitions need to be salvageable.

b. Substantiation:

1) Design Development: Incorporation of costs of anticipated changes into life cycle cost analysis.

ELEMENTS AND PRODUCTS

A. In addition to requirements specified in other Sections, provide products and elements that comply with the following.

1. Energy Conservation, Energy Efficient and ENERGY STAR Products shall apply to all NREL facilities. Refer to (http://www.eren.doe.gov/femp/procurement/begin.html).

B. Elements Made Up of More Than One Product:

1. Where an element is specified by performance criteria, use construction either proven-in-use or proven-by-mock-up, unless otherwise indicated.

a. Proven-In-Use: Proven to comply by having actually been built to the same or very similar design with the same materials as proposed and functioning as specified.

b. Proven-by-Mock-Up: Compliance reasonably predictable by having been tested in full-scale mock-up using the same materials and design as proposed and functioning as specified. Testing need not have been accomplished specifically for this project; when published listings of independent agencies include details of testing and results, citation of test by listing number is sufficient (submittal of all test details is not required).

c. The Design-Builder may choose whether to use elements proven-in-use or proven-by-mock-up, unless either option is indicated as specifically

required.

d. Where test methods accompany performance requirements, use those test methods to test the mock-up.

e. Exception: Where a design analysis is specified, or allowed by the Owner, substantiation of proven-in-use or proven-by-mock up construction is not required.

2. Where a type of product is specified, without performance criteria specifically applicable to the element, use the type of product specified.

3. Where more than one type of product is specified, without performance criteria specifically applicable to the element, use one of the types of products specified.

4. Where a type of product is specified, with applicable performance criteria, use either the type of product specified or another type of product that meets the performance criteria as proven-in-use or proven-by-mock-up.

5. Where more than one type of product is specified, with applicable performance criteria, use either one of the types of products specified or another type of product that meets the performance criteria as proven-in-use or proven-by-mock-up.

6. Where neither types of products nor performance criteria are specified, use products that will perform well within the specified life span of the building.

C. Products:

1. Where a product is specified only by a manufacturer name and model number/brand name, use only that model/brand product.

2. Where the properties of a product are specified by description and/or with performance criteria, use products that comply with the description and/or performance criteria.

3. Where manufacturers are listed for a particular product, use a product made by one of those manufacturers that also complies with other requirements.

SUBSTANTIATION

A. Definition: Substantiation is any form of evidence that is used to predict whether the design will comply with the requirements or to verify that the construction based on the design actually does comply. During Preliminary Design, Design Development, and Construction Documents, requirements to submit substantiation are primarily intended to forestall use of designs or constructions that will not comply. At any time before completion of construction, substantiation is presumed to be only a prediction and may subsequently be invalidated by actual results.

1. Regardless of whether substantiation is specified or not, the actual construction must comply with the specified requirements and may, at the Owner's discretion, be examined, inspected, or tested to determine compliance.

2. Substantiation submittals will not be approved, only accepted to the extent that they are part of documents required to be accepted in order to proceed to the next stage of design or construction. However, acceptance of substantiation will not constitute approval of deviations from the specified requirements unless those deviations are specifically identified as such on the submittal and accepted by the owner in writing.

3. The Owner accepts the responsibility to review substantiation submittals in a timely manner and to respond if they are unacceptable.

B. In addition to the requirements stated in other Sections, provide the following substantiation of compliance at each stage of the project:

1. If a substantiation requirement is specified without an indication of when it is to be submitted, submit or execute it before the end of Construction Documents.

2. See also the Subcontract and Appendices for submittal requirements.

C. Previous Construction: Where elements proven-in-use are used to comply with performance requirements:

1. In the Proposal, identify which elements will be accomplished using proven-in-use elements.

2. During Design Development, identify proven-in-use elements proposed for use, including building name, location, and date of construction, owner contact, and description of design and materials in sufficient detail to enable reproduction in this project.

D. Mock-Up Testing: Where elements proven-by-mock-up are used to comply with performance requirements:

1. In the Proposal, identify which elements will be accomplished using proven-by-mock-up elements.

2. During Design Development, identify proven-by-mock-up elements

proposed for use, with test report including date and location of test, name of testing agency, and description of test and mock-up.

3. Mock-up testing need not have been performed specifically for this project, provided the mock-up is substantially similar in design and construction to the element proposed.

E. Design Analyses (including Engineering Calculations):

1. Where a design analysis or calculation is specified without identifying a particular method, perform analysis in accordance with accepted engineering or scientific principles to show compliance with specified requirements, and submit report that includes analysis methods used and the name and qualifications of the designer.

2. Where engineering design is allowed to be completed after commencement of construction, substantiation may be in the form of shop drawings or other data.

3. Submit design analyses at the end of Design Development unless otherwise indicated.

4. Where design analysis is specified to be performed by licensed design professional, use a design professional licensed in Colorado.

F. Products:

1. Where actual brand name products are not identified by either the Owner or the Design-Builder, identify the products to be used.

2. In the Proposal:

a. Identify one or more product types for each system, assembly, or element.

b. For each product type, provide brief descriptive or performance specifications.

c. For major manufactured products that are commonly purchased by brand name, and any other products so indicated, identify at least one manufacturer that will be used.

3. During Preliminary Design or Design Development:

a. Where more than one product type is identified for a particular system, assembly, or element, identify exactly which type will be used.

b. For each product type, provide descriptive or performance specifications; early submittals may be brief specifications, but complete specifications are required prior to completion of construction documents.

c. For each product type, identify at least one manufacturer that will be used.

d. For major manufactured products that are commonly purchased by brand name, and any other products so indicated, provide manufacturer's product literature on at least one actual brand name product that meets the specifications, including performance data and sample warranty.

4. During Construction:

a. Identify actual brand name products used for every product, except commodity products specified by performance or description.

b. Where a product is specified by performance requirements with test methods, and if so specified, provide test reports showing compliance.

c. Provide manufacturer's product literature for each brand name product.

d. Provide the manufacturer's certification that the product used on the project complies with the subcontract documents.

5. Before End of Closeout:

a. Provide copies of all manufacturer warranties that extend for more than one year after completion.

END OF SECTION - FACILITY PERFORMANCE

SUBSTRUCTURE

PERFORMANCE

A. Basic Function:

1. Provide substructure as required to support the completed and occupied building safely and without uncontrolled subsidence, maintenance or other movement.

2. Substructure comprises the following elements:

a. Foundations: Structures responsible for transferring dead loads, live loads, and environmental loads of completed building to the earth in such a way that the building is supported evenly and without movement.

b. Basements: Space-enclosing elements below grade, including necessary excavation, structural walls and floor, and other elements of enclosure

such as waterproofing and thermal insulation.

3. Where substructure is integral with elements defined within another element group, meet requirements of both element groups.

4. In addition to the requirements of this section, comply with all applicable requirements of Facility Performance (Part 3-Performance Specifications).

B. Amenity and Comfort:

1. Thermal Performance: Provide thermal resistance as necessary to maintain interior comfort levels specified and in accordance with code and the following:

a. Energy Efficiency: As specified in Facility Performance (Part 3-Performance Specifications).

b. Average Thermal Transmittance: U-value of 0.15 IP (0.85 SI), maximum, for portions of substructure in contact with earth and enclosing conditioned space.

c. Condensation: None on interior surfaces under normal interior temperature and relative humidity conditions, during 98 percent of the days in the coldest 3 months of the year.

d. Substantiation:

1) Preliminary Design: Identification of major thermal resistant materials and systems.

2) Design Development: Detailed listing of design criteria and design analysis, prepared by licensed mechanical engineer.

3) Construction Documents: Product data on thermal materials and details of continuous thermal barrier.

2. Water Penetration: Prevent ground water penetration into the interior of the building, under any circumstances.

3. Water Accumulation: Prevent accumulation of water in open areas adjacent to substructure.

4. Acoustical Performance: Limit sound transmission through substructure as follows:

a. Ambient Sound Level: Maintain ambient sound levels in enclosed, occupied substructure spaces within noise criteria (NC) ranges specified in Interiors (Part 3-Performance Specifications) during normal hours of occupancy.

b. Vibration Control: Use substructure elements that will not resonate at frequencies that are characteristic of ambient underground sound and vibration sources at the project site.

C. Health and Safety:

1. Substance Exclusion: Prevent accumulation of harmful chemicals and gases such as radon and methane in spaces below substructure and subsequent penetration into occupied spaces.

2. Vermin Protection: Provide permanent protection against infestation of construction by ground dwelling termites and other vermin.

D. Structure:

1. Capacity: Provide loadbearing substructure members as required by code and designed to distribute dead loads, live loads, and environmental loads so that bearing capacity of soil is not exceeded.

a. Extend bearing portions of substructure to levels below frostline at project location; not less than 3 ft (0.9 m) below grade.

2. Dead Loads: Accommodate loads from weights of building materials, construction itself, and all fixed service equipment.

3. Live Loads: Accommodate loads from use and occupancy of the building, either uniformly distributed loads as prescribed by code or concentrated loads, whichever are more demanding structurally.

4. Environmental Loads: Accommodate loads from all environmental forces in accordance with code.

5. Substantiation:

a. Proposal: Identification of major structural materials and systems.

b. Preliminary Design: Soil investigation report, detailed listing of design criteria, and preliminary analysis, prepared by a licensed structural engineer.

c. Construction Documents: Detailed design analysis by licensed structural engineer.

E. Durability:

1. Corrosion Prevention: Provide supplementary protection for underground metal elements, sufficient to prevent corrosion completely for the

service life of the element without maintenance.

a. 3 inches (150 mm) of concrete cover is considered to be permanent protection.

F. Operation and Maintenance:

1. Provide substructure elements that will endure for the lifetime of the building with no maintenance.

PRODUCTS

A. Do not use any of the following:

1. Reinforced masonry.

2. Treated wood.

3. Foam plastic insulation below grade.

END OF SECTION - SUBSTRUCTURE

SHELL

PERFORMANCE

A. Basic Function:

1. Provide permanently enclosed spaces for all functional areas shown in the project program, unless otherwise indicated. Provide a physical enclosure that keeps out weather, unwelcome people, animals, and insects without requiring specific action by occupants, while providing convenient movement of occupants between inside and outside, desirable natural light, and views from inside to outside. Provide level floor areas, comfortable ceiling heights, and essentially vertical walls.

2. The elements forming usable enclosed space and separating that space from the external environment comprise the shell and consist of:

a. Superstructure: All elements forming floors and roofs above grade and within basements, and the elements required for their support, insulation, fireproofing, and firestopping.

b. Exterior Enclosure: All essentially vertical elements forming the separation between exterior and interior conditioned space, including exterior skin, components supporting weather barriers, and jointing and interfacing components; not including the interior skin unless an integral part of the enclosure.

INSERT POSITIVE DRAINAGE FOR ALL EXPOSED ELEMENTS.

c. Roofing: All elements forming weather and thermal barriers at horizontal and sloped roofs and decks, and roof fixtures.

3. Exterior Surfaces Exposed to View: Surfaces visible from street or ground level, plus surfaces visible from windows of same building and adjacent existing buildings.

4. Where shell elements also function as elements defined within another element group, meet requirements of both groups.

5. In addition to the requirements of this section, comply with all applicable requirements of Facility Performance (Part 3-Performance Specifications).

B. Amenity and Comfort:

1. Thermal Performance: Provide construction that will have thermal resistance as necessary to maintain interior comfort levels specified and in accordance with code and the following:

a. Energy Efficiency: As specified in Facility Performance (Part 3-Performance Specifications).

b. Condensation: None on interior surfaces under normal interior temperature and relative humidity conditions, during 98 percent of the days in the coldest 3 months of the year.

c. Components That Have Surfaces Facing Both Interior and Exterior Environment: Condensation Resistance Factor (CRF) as required to meet requirement above, when tested in accordance with AAMA 1503-1998.

d. Substantiation:

1) Preliminary Design: Identification of major thermal resistant materials and systems.

2) Design Development: Detailed listing of design criteria and design analysis, prepared by licensed mechanical engineer.

3) Construction Documents: Product data on thermal materials and details of continuous thermal barrier.

2. Air Infiltration: Maximum of 0.06 cfm (0.0003 cu m/s) per square foot (square meter) of exterior surface area, measured in accordance with ASTM E 283-2004 at differential pressure of 6.24 psf (298 Pa).

a. Use supplementary air barrier if necessary to maintain performance

over entire shell.

b. Use method of sealing joints between elements that will be effective given available construction practices.

3. Water Penetration: Design and select materials to prevent water penetration into the interior of the building, under conditions of rain driven by 50 mph (80 km/h) wind.

a. Substantiation:

1) Preliminary Design: Identification of major water resistant assemblies.

2) Design Development: Details of proven-in-use or proven-by-mock-up design.

4. Natural Light: Provide fenestration in shell as required to meet requirements for natural light as specified in Section C and in accordance with code.

5. Natural Ventilation: Design and construct shell to provide natural ventilation in accordance with code and the following:

a. Minimum Ventilation Opening Area: 8 percent of total floor area for each habitable room; not required for bathrooms, toilet compartments, closets, halls, or storage and utility spaces.

b. Ventilation Area: Minimum 10 percent of wall area for each floor equally distributed on all elevations.

c. Design ventilation to provide cross ventilation where possible.

d. Substantiation:

1) Proposal: Identification of spaces relying on natural ventilation with description of ventilation concept and required building elements.

2) Design Development: Drawings showing natural ventilation location, ventilation opening areas, and floor areas being served.

3) Construction Documents: Engineering design calculations and drawings prepared by licensed engineer.

6. Acoustical Performance: Design and construct the shell to limit sound transmission as follows:

a. Ambient Sound Level: Maintain ambient sound levels in perimeter spaces within Noise Criteria (NC) ranges specified in Section- Interiors during normal hours of occupancy.

b. Vibration Control: Use shell elements that will not resonate at frequencies that are characteristic of ambient exterior sound sources at the project site.

c. Substantiation:

1) Preliminary Design: Measurements of ambient site noise levels over full range of audible frequencies, identification of acoustic properties of major interior and exterior sound and vibration generators, and preliminary analysis prepared by an acoustical engineer.

2) Design Development: Acoustical analysis prepared by an acoustical engineer.

3) Construction Documents: Acoustical analysis prepared by an acoustical engineer.

7. Cleanliness of Exterior Surfaces: Design and select materials to:

a. Prevent attraction and adherence of dust and air-borne dirt and soot, and minimize appearance of settled dust and dirt.

b. Be washed reasonably clean by normal precipitation.

c. Prevent precipitation from washing settled dust and dirt over surfaces exposed to view.

8. Appearance: Design and select materials to provide exterior appearance with characteristics as follows:

a. Compatible with adjacent buildings on same campus.

b. Concealing equipment from view from campus buildings, and streets and parking areas.

c. Substantiation:

1) Proposal: Concept drawings of proposed solution indicating overall building configuration, massing, scale, materials, and relationship to surrounding buildings.

2) Preliminary Design: Drawings showing facade treatment for principal elevations identifying visible materials.

3) Design Development: Drawings and artist's rendering showing all building elements that are part of the shell with sizes and locations to scale.

4) Construction Documents: Details of building shell, annotated to show compliance with performance requirements.

C. Health and Safety:

1. Fire Resistance: Design and select materials to provide fire resistance in accordance with code.

a. For all elements required to have a fire resistive rating and which are not made of materials and systems specified as acceptable by the jurisdiction having the authority of code, use proven-by-mock-up construction.

b. For proven-by-mock-up construction, acceptable testing agencies are Underwriters Laboratories Inc. and Factory Mutual

c. Substantiation:

1) Design Development: Identification of assemblies required to have fire resistance rating and method to be used to achieve rating.

2) Construction Documents: Identifying numbers on the construction drawings.

2. Accidental Injury: Design and select materials to protect pedestrians and building occupants in accordance with code and the following:

a. Prevent ice and snow from falling off building elements onto pedestrians, building occupants, and vehicles.

b. Protect pedestrians, building occupants, and vehicles from objects accidentally dropped from elevated balconies, or plazas.

D. Structure:

1. Structural Performance: Design and select materials to support all loads without damage due to loads, in accordance with code.

a. Elements engineered by their manufacturer or fabricator, rather than by the engineer-of-record, are not acceptable for whole shell comprised of superstructure, exterior enclosure, and roofing.

b. Substantiation:

1) Proposal: Identification of major structural materials and systems.

2) Preliminary Design: Detailed listing of design criteria and preliminary analysis, prepared by a licensed structural engineer.

3) Construction Documents: Detailed design analysis by licensed structural engineer.

4) Construction: For structures engineered by their manufacturer or fabricator, detailed design analysis prepared by and shop drawings stamped by a licensed structural engineer, with approval of engineer-of-record recorded.

2. Construction Loads and Erection Stresses: Accommodate temporary construction loads and erection stresses during construction.

E. Durability:

1. Service Life Span: Same as building service life, except as follows:

a. Load-Bearing Structural Members: Minimum of 100 years.

1) No anticipated deterioration when protected as specified.

2) Protective Elements: Minimum 25 years.

b. Wall Primary Weather-Barrier Elements: Minimum 50 years functional and aesthetic service life, excluding joint sealers.

c. Transparent Elements (Glazing): Same as other wall primary weather-barrier elements, except accidental breakage is considered normal wear-and-tear.

d. Joint Sealers: Minimum 20 years before replacement.

e. Surfaces Exposed to View: Minimum 20 years aesthetic service life; in addition, deterioration includes color fading, crazing, and delamination of applied coatings.

f. Roof Covering Weather-Barriers: Minimum 20 years, fully functional.

g. Substantiation: As specified in Facility Performance (Part 3-Performance Specifications), including service life analysis and life cycle cost analysis.

2. Water Penetration: Design and select materials to prevent water penetration into the interior of shell assemblies, under conditions of rain driven by 50 mph (56 km/h) wind.

a. Exception: Controlled water penetration is allowed if materials will not be damaged by presence of water or freezing and thawing, if continuous drainage paths to the exterior are provided, and water passage to the building interior is prevented.

b. Substantiation: In addition to requirements specified for proven-in-use and proven-by-mock-up construction, drawings showing paths of water movement, with particular attention to changes in direction or orientation and joints between different assemblies.

3. Weather Resistance: Design and select materials to minimize deterioration due to precipitation, sunlight, ozone, normal temperature changes and atmospheric pollutants.

a. Deterioration includes corrosion, shrinking, cracking, spalling, delamination, abnormal oxidation, decay and rot.

b. Surfaces Exposed to View: Deterioration adversely affecting aesthetic life span includes color fading, crazing, and delamination of applied coatings.

1) Coated Finishes: Minimize use of materials with separate coated finishes.

2) Coating Performance: AAMA 2604-2005, minimum.

c. Joint Components and Penetration Seals: Capable of resisting expected thermal expansion and contraction; use overlapping joints that shed water wherever possible.

d. Transparent Elements (Glazing): No haze, loss of light transmission, or color change, during entire expected service life.

1) Test Criteria: Less than 1 percent change in haze, transmission, and color over 2 years exposure, when tested after natural exposure conditions or accelerated light and water conditions simulating natural exposure at project, in accordance with ASTM D 1003-2000; accelerated exposure documented with comparison to natural conditions.

e. Service Temperature: Low temperature equal to historically-recorded low; high temperature equal to that expected due to any combination of air temperature and heat gain from solar and other sources.

f. Freeze-Thaw Resistance: Adequate for climate of project.

g. Corrosion Resistance: In locations exposed to the outdoor air or in potential contact with moisture inside shell assemblies, use only corrosion-resistant metals as defined in this section.

h. Ozone Resistance: Do not use materials that are adversely affected by ozone.

i. Substantiation:

1) Design Development: Details of proven-in-use materials and test reports.

4. Impact Resistance: Design and select materials to resist damage due to impact in accordance with code and the following:

a. Minimize damage from windborne debris propelled at up to 35 mph (56 km/h).

b. Design and select materials to resist damage from hail of size up to 1/2 inch (12 mm).

c. Natural Hazards: Design to resist damage from perching, nesting, and feeding birds.

d. Substantiation:

1) Design Development: Identification of building elements required to resist impact damage, quantification of impact criteria, materials to be used, and methods of substantiation.

5. Moisture Vapor Transmission: Design to prevent deterioration of materials due to condensation of moisture vapor inside assemblies.

a. Use supplementary vapor retarder if necessary to meet requirements.

b. Use method of sealing joints between elements that will be effective given available construction practices.

c. Substantiation:

1) Design: Identification of building elements providing moisture barrier, materials to be used, and data showing performance.

2) Design Development: Proven-in-use or proven-by-mock-up data.

6. Wear Resistance: Design and select materials to provide resistance to normal wear-and-tear in accordance with code and the following:

a. Elements Within Reach of Pedestrians: Minimize degradation from rubbing and scratching caused by pedestrians.

F. Operation and Maintenance:

1. Ease of Maintenance and Alteration:

a. Provide floors elevated for access, with removable panels, at:

1) Main Server Room identified in the Project Program.

PRODUCTS

A. Corrosion-Resistant Metals:

1. Hot-dipped galvanized steel, with minimum zinc coating of 0.90 oz/sq ft (275 gm/sq m) total both sides.

2. Stainless steel, Type 304 or 316.

3. Cadmium-plated steel, with minimum coating of 12 micrometers.

4. Aluminum.

B. Coated Finishes:

1. Use one of the following:

a. Fluoropolymer coating (70 percent Kynar 500 (tm) or Hylar 5000(tm)), minimum two coats.

2. Do not use:

a. Paint or other field applied coatings.

C. Do not use:

1. Pre-engineered metal building.

2. Air-supported structure.

3. Different metals subject to galvanic action in direct contact with each other.

4. Aluminum in direct contact with concrete or cementitious materials.

5. Materials and products that require field finishing on surfaces exposed to the weather.

6. EIFS- Exterior Insulation Finishing System

END OF SECTION - SHELL

INTERIORS

PERFORMANCE

A. Basic Function:

1. Provide appropriately finished interiors for all spaces indicated in the program, equipped with interior fixtures as required to function properly for specific occupancies.

2. Interiors comprise the following assemblies:

a. Interior Construction: All elements necessary to subdivide and finish space enclosed within the shell, including applied interior surfaces of the exterior enclosure.

b. Interior Fixtures: All elements attached to interior construction that add functionality to enclosed spaces, except for elements classified as equipment or services fixtures.

3. Provide physical separation between spaces, constructed to achieve fire ratings required by code, appropriate security between adjacent spaces, and visual, acoustical, olfactory, and atmospheric isolation as necessary to maintain desirable conditions in each space.

4. Provide finishes for interior surfaces that are appropriate for the functions of each space.

5. Provide interior fixtures that are necessary for the proper functioning of each space.

6. Where interior elements also must function as elements defined within another element group, meet requirements of both element groups.

7. In addition to the requirements of this section, comply with all applicable requirements of Facility Performance (Part 3-Performance Specifications).

B. Amenity and Comfort:

1. Natural Ventilation: Design and construct interiors to permit air movement between exterior openings positioned to enhance thermal comfort of occupants in all major spaces.

a. Substantiation:

1) Proposal: Information on overall building configuration that will permit natural ventilation of all major spaces.

2) Design Development: Engineering calculations for representative spaces, predicting anticipated air movement under weather conditions typical for project site.

3) Construction: Field test of natural air movement, verifying compliance with predicted design performance.

2. Access: Provide access to all primary interior spaces from Circulation spaces (SC Spaces) (no access to any primary interior space exclusively through another primary interior space).

3. View: Provide views to the building exterior or interior atria (if provided) from most locations within primary interior spaces.

a. View spaces include the following types:

1) Customer Contact (SP1 Spaces).

2) Occupant Work (SP2 Spaces).

3) Assembly (SP5 Spaces).

4) Meeting and Instruction (SP6 Spaces).

5) Occupant Services (SR Spaces).

4. Natural Light:

a. Daylighting: Provide ambient natural lighting in primary spaces that is of intensity adequate for essential tasks when measured on a typical overcast winter day in midafternoon.

1) Spaces for daylighting include the following types:

a) Customer Contact (SP1 Spaces).

b) Occupant Work (SP2 Spaces).

c) Equipment Utilization (SP3 Spaces).

d) Assembly (SP5 Spaces).

e) Meeting and Instruction (SP6 Spaces).

f) Occupant Services (SR Spaces).

g) All other spaces to the maximum extent possible.

2) Light Levels: Provide minimum light levels not less than those recommended in IESNA Lighting Handbook, 2000, for the types of tasks to be anticipated in each category of space.

b. Natural Lighting: Ambient natural light is not required in the following types of secondary spaces; however, provide natural ambient light to the maximum extent possible and within reason for the following spaces:

1) Storage (SS Spaces).

2) Building Services (SU1 Spaces).

3) Utility Equipment (SU2 Spaces).

c. Visual Comfort: Provide ambient natural light in primary spaces that is free of excessive direct or reflected glare, as defined in IESNA RP-5, 1999, Recommended Practice of Daylighting.

d. Substantiation:

1) Proposal: Information on overall building configuration that will permit daylighting to levels specified.

2) Design Development: Engineering calculations for representative spaces, predicting anticipated daylighting levels under specified conditions.

3) Construction: Field test of lighting levels verifying compliance with performance requirements.

5. Acoustical Performance:

a. Background Noise: Provide interiors that maintain ambient sound levels in primary spaces within the following Noise Criteria (NC) ranges, as defined in ASHRAE HVAC Applications Handbook, 2003, when adjacent spaces are occupied and are being used normally:

1) Private Office: 20-30.

2) Conference Room: 25-30.

3) Semiprivate Office: 30-35.

4) Library: 30-35.

5) Large Open Office: 35-45.

b. Impact Insulation: Provide floor-ceiling construction, including floor structure, floor finish, and ceiling finish, to insulate primary spaces from undesirable impact noise when adjacent spaces are occupied and are being used normally.

c. Articulation Index: Provide articulation index (AI) of not less than 0.05 when measured in accordance with ASTM E 1130-2002.

1) Application: Open office areas where multiple work stations occur without intervening full-height partitions.

d. Substantiation:

1) Preliminary Design: Engineering calculations for representative spaces, predicting acoustical conditions.

2) Construction: Field test of acoustical conditions, verifying compliance with performance requirements.

6. Odor Control: Prevent unpleasant odors generated within a space from affecting occupants of adjacent spaces, by providing physical isolation of the spaces, separate ventilation, or a combination of isolation and ventilation.

a. Control odors from spaces of the following types:

1) Toilet rooms.

2) Trash collection.

3) Janitorial spaces

4) Occupant services

5) Kitchen areas

7. Appearance: Provide interiors that are pleasing in appearance and do not detract from the primary functions performed in each space.

8. Texture: Provide interior elements and surfaces that are textured appropriately for primary functions to be accommodated within each space.

C. Health and Safety:

1. Egress: Provide egress from all interior spaces in accordance with code.

2. Fire Resistance: Design and select materials to provide fire resistance in accordance with code.

a. Substantiation:

1) Design Development: Identification of assemblies required to have fire resistance rating and method to be used to achieve rating.

2) Construction Documents: Identifying numbers placed on the construction drawings.

D. Structure:

1. Structural Performance: Provide interior construction and fixtures to support without damage all loads required by code.

E. Durability:

1. Service Life Span: Same as building service life, except as follows:

a. Interior Doors and Other Operable Elements: Minimum 15 years functional and aesthetic service life.

b. Interior Ceiling Finishes: Minimum 15 years functional and aesthetic service life; including suspended ceilings.

c. Interior Wall and Floor Finishes: Minimum 10 years functional and aesthetic service life.

d. Other Interior Construction: Minimum 15 years functional and aesthetic service life.

e. Substantiation: As specified in Facility Performance (Part 3-Performance Specifications), including service life analysis and life cycle cost analysis.

2. Wear Resistance: Provide interior construction and fixtures that are suitable in durability for the degree and type of traffic to be anticipated in each space.

3. Corrosion Resistance: At toilet rooms and janitorial closets, provide interior construction materials and fixtures that are inherently resistant to corrosion and rot.

F. Operation and Maintenance:

1. Cleaning: Provide interior construction and fixtures that will not be damaged by ordinary cleaning and maintenance operations.

PRODUCTS

A. Do not use:

1. Exposed plastic surfaces.

2. Wood framing.

END OF SECTION - INTERIORS

APPENDIX C ENERGY USE INTENSITY TARGETS BY BUILDING TYPE AND REGION

High performance energy use intensity targets (kBtu/ft2/year)

	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7
Office/Professional	34	36	32	30	30	29	34	38	31	33	28	31	29	35
Education	75	27	31	20	22	27	26	17	19	22	19	22	24	27
Enclosed mall	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Food sales	0	112	0	119	94	99	113	0	0	102	110	106	0	101
Food services	482	298	0	317	334	304	305	0	401	316	293	306	198	292
Health Care (inpatient)	78	75	80	69	72	69	68	61	0	77	70	65	64	95
Health care (outpatient)	37	53	0	39	60	0	34	34	0	42	33	34	34	46
Laboratory	0	0	0	297	319	0	227	0	0	286	0	243	275	0
Lodging	36	31	0	30	26	0	29	30	29	28	27	27	28	28
Other	0	45	0	24	30	0	32	13	0	32	23	30	34	22
Public assembly	53	36	0	38	32	26	27	21	39	29	26	30	27	27
Public order and safety	0	39	0	36	51	0	38	0	0	49	59	44	61	0
Refrigerated warehouse	0	0	0	0	0	0	53	0	0	51	43	53	0	0
Religious worship	0	17	0	12	13	0	16	21	0	19	13	19	14	0
Retail (excluding mall)	23	33	39	26	26	25	28	25	0	29	30	31	33	35
Service	73	42	0	29	32	22	38	27	0	40	34	34	35	42
Skilled Nursing	0	94	0	85	77	0	95	0	0	93	69	75	74	0
Strip shopping mall	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vacant	0	6	28	13	10	8	16	17	6	7	8	14	0	28
Warehouse	14	13	0	15	15	12	17	22	14	19	22	21	18	21

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