




An Energy-Performance-Based Design-Build Process: Strategies for Procuring High-Performance Buildings on Typical Construction Budgets

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An Energy-Performance-Based Design-Build Process: Strategies for Procuring High-Performance Buildings on Typical Construction Budgets

Jennifer Scheib, Shanti Pless and Paul Torcellini, National Renewable Energy Laboratory

ABSTRACT

The National Renewable Energy Laboratory (NREL) experienced a significant increase in employees and facilities on its 327-acre main campus in Golden, Colorado, over the past 5 years. To support this growth, we developed and demonstrated an acquisition method that successfully integrates energy-efficiency requirements into the design-build contracts for new buildings and piloted this process with our large office building, the Research Support Facility (RSF). The process has been replicated and refined in several additional new construction projects including an office building expansion, a smart grid research laboratory with a supercomputer, a parking structure, a site security building, and a cafeteria. Each project incorporated unique and measureable energy performance requirements in the design-build contracts, resulting in the use of aggressive efficiency strategies with typical construction budgets.

We found that, when measureable energy efficiency is a core requirement defined at the beginning of a project, owners can expect facility energy performance to meet design expectations. NREL staff successfully completed the new construction projects and documented recommended practices (RPs) in training materials and a how-to guide so that other owners can learn from our experience and replicate market viable, world-class energy performance in the built environment without increasing first costs. This paper summarizes the RPs and gives context within the NREL projects.

Introduction

A primary goal of the Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) is to lead innovative research and deployment of renewable energy and energy efficiency technologies that address the nation's energy and environmental needs. Due to energy cost increases, energy security concerns, and environmental impacts from energy systems, the market demand for renewable energy and energy efficiency has expanded. NREL's growth has paralleled this increased demand and resulted in a significant increase in employees and facilities on its 327-acre main campus in Golden, Colorado. From 2010-2011, NREL staff levels increased 20% and campus square footage expanded 48%. This pace of campus construction continued through 2013 with the addition of six new structures totaling a construction cost of nearly $400 million.

To support both NREL's growth and DOE's energy and sustainability goals, NREL Commercial Building researchers worked with the capital construction team to develop and demonstrate a construction acquisition method that integrates measureable energy-performance requirements into the project requests for proposals (RFP) and contracts. This process is founded in the idea that cost-effective and deep energy savings are possible when design and construction are well integrated within the constraints of a budget. NREL facility growth provided an opportunity to demonstrate this concept in real projects. We developed and piloted this energy-performance-based design-build process with the first major construction project in the campus build out, and then replicated and evolved the process with five other buildings. The following is a list of the projects that are referenced in a photo of the campus in Figure 1:

- (1) Research Support Facility (RSF I) – a 824-occupant, 220,000 ft^2 office building with a data center, completed in June of 2010
- (2) Research Support Facility Expansion (RSF II) – a 500-occupant, 138,000 ft^2 office building and conference space expansion to RSF I, completed in November of 2011
- (3) Parking structure and (4) site entrance building (SEB) – a five-deck, 1,800-car parking garage and 1,500 ft^2 campus access control building, both completed in February of 2012
- (5) Staff cafeteria – a 12,000 ft^2 commercial kitchen, servery, and 250-seat dining hall, completed in July of 2012
- (6) Energy Systems Integration Facility (ESIF) − a 182,500 ft^2 smart grid research laboratory with a supercomputer and 200 workstations, completed in January of 2013.

Figure 1. Aerial Picture of the NREL campus taken in May, 2013. *Source*: images.nrel.gov #25812.

Each project features world-class efficiency strategies, performs as expected, and was constructed within typical DOE project budgets.

The goal of this paper is two-fold: to summarize how NREL incorporated energy-performance requirements into the building acquisition process; and to inform owners and owner's representatives of the state of replication and provide resources for improving the operational energy performance of future commercial buildings. Toward this end, this paper is divided into three sections: 1) Definition of an energy-performance-based design-build process using a set of RPs; (2) Examples of how NREL construction projects used the RPs; (3) Outreach and deployment efforts that have sparked replication of the process on a broader scale. The paper concludes with links to the training and how-to materials created for use by owners and design teams interested in replicating the process.

An Energy-Performance-Based Design-Build Process, Defined

NREL's recently constructed buildings incorporate a range of readily available energy efficiency strategies combined in innovative ways. While this should not be overlooked as a key aspect of success, the innovation started with rethinking the acquisition process. Traditionally, NREL had used a design-bid-build method with informal energy-related goals. The designs were highly energy efficient for the time but the process relied on extensive design standards and lacked integration of design with the actual construction and building operation. As an owner, NREL had to heavily participate to keep design standards on the cutting edge of technology and stay within the budget.

In 2007, during the initial acquisition planning for the RSF I, the team opted for a "Best Value Design-Build/Fixed Price with Award Fee" acquisition approach (DBIA 2013). This approach is intended to encourage innovation of the design and construction team, reduce owner's risk, increase the speed of construction and delivery, control costs, and establish measurable success criteria (Pless 2011). For NREL, the success criteria became, among other things, measureable energy use intensity (EUI) and cost control. NREL set an aggressive EUI of 25 kBtu/ft^2/yr and DOE provided a fixed price of approximately $64 million. Based on the final size of the project, the construction cost was $259/$ft^2$. This is at the low end of the same type of buildings built in the same time period (Pless 2012).

All NREL new construction projects now use an energy-performance-based design-build process. Instead of specifying technical standards such as building size, configuration, conceptual drawings, and other attributes, NREL uses the RFP to prioritize key performance parameters as "Mission Critical," "Highly Desirable," and "If Possible," with energy criteria throughout. Competing design-build teams are judged, in part, based on their ability to incorporate and support as many of the objectives as possible within the overall fixed budget and schedule constraints. All recent NREL projects have proved the feasibility of procuring low-energy buildings on typical construction budgets.

The guidance presented here serves as a cornerstone for achieving real energy savings. The RPs are written for new construction, design-build projects; however, variations of the RPs could be used for retrofits and for projects with other contract structures that encourage an integrated project delivery approach where all team members are responsible for the energy goal from day one into warranty. Following are descriptions of RPs for an energy-performance-based design-build process.

RP #1: Include a Measureable Energy Goal in the RFP and Contract

Energy requirements should be included in prominent parts of the RFP (and later in the contract) and reinforced throughout the document. In the RFP, the owner states the mission of the building and defines the focus of the design team for the project. The RFP should outline a specific, aggressive, and measureable target. This goal should be presented in context with other project requirements.

Energy Goal Options

The following options for energy goals are presented in order of most to least effective for reducing total annual energy use.

- Whole-building EUI target: A building's energy use per unit area, most commonly given in kBtu/ft2/yr.
- Net zero energy building: A building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies.
- Percent savings relative to a baseline: Typically, energy cost savings compared to a well-documented baseline representing the code minimum form of the building design.
- Sustainability rating system requirement: An example is Leadership in Energy and Environmental Design (LEED), which encourages wise use of land, materials, water, and energy, while promoting occupant comfort.

In general, owners should consider using a combination of goal types to drive design-build teams to focus on efficiency while achieving general sustainability. Whenever possible, an EUI target should be used. This encourages reducing energy demand before supplying renewable energy, sets a hard boundary for net zero energy design, gives a clear and measureable goal that will focus the design team during design development and into operations, and allows for simple comparison to the performance of other buildings.

Tiered Goal Structure

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

- Mission Critical: Minimum required for the project. Typically, very few items fit into this category.
- Highly Desirable: Not required by the project to proceed, but plays heavily into design-build team selection. If not Mission Critical, general sustainability goals or aggressive EUI targets can be located in this section of the RFP.
- 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 stretch goals such as a highly aggressive EUI and percent savings goals.

The key is to rank the importance of the energy efficiency goals in the context of other competing project goals within these categories. As previously mentioned, teams are partially evaluated on the depth in which they can achieve the priorities. Then, the team that wins the competitive procurement process is bound contractually to meeting the items to which they committed. Multiple energy goals should be used throughout the list to maximize the value to the owner and to test the depth that energy efficiency can be achieved within the fixed budget.

RP #2: Develop the Energy Goal Using Multiple Resources

Once the goal type and structure is defined, the owner team must select the value for specific energy use or percent reduction goals. In this task, use a broad range of resources to ensure that it is aggressive yet achievable. The ideal approach to setting whole-building absolute energy use targets makes use of all available data, taking advantage of the strengths of each data type. Examples of data types are:

- High-level sector data: Examples include Commercial Buildings Energy Consumption Survey and ENERGY STAR® Target Finder.
- High performance case studies: Examples include the High Performance Buildings Database (DOE 2013), ASHRAE High Performance Buildings magazine, Advanced Energy Design Guides case studies (Leach et al 2012), and New Buildings Institute reports (NBI 2014).
- Portfolio energy use data: An example is a retailer with a number of stores that share the same prototypical design.
- Whole-building energy simulation: Examples of energy simulation programs include EnergyPlus, eQUEST, and DOE-2.

If goals are properly selected and tiered in the RFP document, the actual number of the goal is less important as the market will determine competitively the level of efficiency that can be achieved for the provided fixed price.

RP #3: Develop the EUI Goal Using Normalization Factors

Normalizing energy use goals to floor area is helpful for building comparisons but unintended consequences could happen when put into a competitive environment. For example, the EUI of a building will decrease if fewer people are in the building and space efficiency can be compromised. In this example, incentive factors can be defined that encourage space efficiency while maintaining the integrity of the energy goal as defined for a given building size and occupancy. For example, NREL used the following two factors in the office building energy goal definitions:

- Occupant density factor: For office spaces, define an increase in EUI for increased occupant density. This can be given as a table or as an equation.
- Parking space density factor: For parking garages, define the energy goal per parking space instead of per area to maximize the number of cars in the structure and/or minimize the footprint of the structure.

Additional normalization factors can be created and defined depending on building unknowns such as data center capacity or other housed services.

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

Additional end use or technology-specific goals can add value by focusing team attention to specific design challenges and encouraging passive building design. Some examples of technology-specific requirement to include in the RFP are:

- Passive system requirements: Include general system requirements such as daylighting or 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.
- System efficiencies: 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 power usage effectiveness (PUE), will bring design team attention to the RFP requirement and ensure the desired level of performance.

It is important to note that language should be performance based and not solutions (prescriptive) based. Focus on performance and not on a specific solution. Design teams, along with their contractor, are being paid to generate creative solutions—owners need to provide the boundaries and let them do the job they are being paid to do.

RP #5: Define Owner Specified Energy Loads

Additional RFP language that is helpful to include for both the owner and design team is a detailed list of all loads that the owner intends to include or allow in the building. Expected counts, efficiencies, and use profiles can be included as baseline information but teams should be encouraged to consider design approaches encouraging highest efficiency use. Examples of owner loads are:

- Miscellaneous loads: This load type primarily consists of plug loads such as computers, printers, phones, and video displays. Create a list of all typically used loads in similar building types, taking care to think through all tasks, occupant types, and season equipment needs to capture potential use cases, which are also potential energy use reduction opportunities (NREL 2011).
- Process equipment: List the equipment required to complete a specialized function such as cooking or surveillance.

In addition to RP #4, which encourages system level efficiency goals, the RFP should include specific equipment-specific efficiencies for owner loads.

RP #6: Provide Calculation Methods for Substantiation

There are many energy calculation/modeling approaches for 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. Ideally, the required calculation methods should focus on key parameters that will clarify energy goal definitions and influence high-level design decisions. Examples of specific calculation methods to include are:

- Net zero energy site-to-source factors: Multipliers for converting site energy to source energy so that renewable energy systems can be sized accordingly if the energy goal definitions require source net zero energy.
- Central plant and conversion efficiencies: Energy loss factors to be used when calculating the effectiveness of plant or off-site energy resources.
- ALL building loads in energy use requirements: Teams to consider all building loads, and therefore, identify possible efficiency strategies, including distribution transformers, light control parasitic loads, elevator lights and fans, etc.
- Definition of minimal thermal comfort, lighting levels, and ventilation rates: Sets the minimal level of services required for each space type.

RP #7: Require Goal Substantiation Throughout Design

The energy goal and supplemental calculation information/methods are only helpful to the decision making process if substantiation results are available prior to or in tandem with key decision points. Including a substantiation schedule in the RFP will ensure a tandem schedule.

- Energy modeling schedule: This schedule should coincide with design package completion for owner review. Comments on the design package provided by the owner can incorporate ideas on additional energy saving opportunities and questions about modeling assumptions with respect to the plans and specifications. For energy goals, the energy model should match the as-built condition of the building at time of turnover.

- Model results for commissioning: If possible, a final, updated design model should be provided prior to commissioning so that end use system profiles and sequence of operations can be used as an extension of typical functional testing checklists.

RP #8: Develop a Process for Performance Assurance in Operations

RFP language requiring energy goal substantiation should be followed by energy performance assurance expectations so that energy performance is not realized in actual operations. The owner must be able to get 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 are inhibiting maximum energy performance. Specific considerations to include in the RFP are:

- Submetering requirements: 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.
- End use budgets: The design team should provide owners with end use budgets that are determined through the energy goal substantiation process in order to supply a point of reference for comparing end use metering data.
- Real performance incentives: An award fee can be structured so that a large portion of the money can be withheld until predicted energy performance is realized within a defined error range. This delayed incentive can help smooth the transition process of the building from the intimate knowledge of the design team to new owner operation.

It is important to include the design substantiation schedule and performance assurance plan in the RFP so that design teams understand the time commitment necessary to produce a high performance building. While RFP requirements cannot guarantee a world-class energy design, these RPs are a comprehensive list of actions that has proven to be effective for the NREL facilities.

An Energy-Performance-Based Design-Build Process at NREL

This section describes the representative NREL campus projects in terms of their use of the RPs. Each project used the entire RP set in some form; highlights are given.

Measured energy performance results from April 22, 2013 through April 22, 2014 are presented in comparison to each project's highest priority measureable energy goal The results show that, as a whole, the NREL new construction is meeting the energy allowance. Energy use is approximately 5% more than the sum of the model predictions, which is primarily due to a cooler winter and warmer summer than the model weather file used for all projects (TMY3), as well as a few instances of higher than expected miscellaneous electric loads. A detailed assessment of measured performance will be the topic of another report. Overall, though, the interim results support the efficacy of the energy-performance-based acquisition approach.

Research Support Facility I and II

The RSF I (the two wings shown in Figure 2) and the RSF II expansion (a third wing) is NREL's 360,000 ft^2 administrative support office building, and includes 1,375 workstations, numerous conference rooms, NREL's high efficiency corporate data center, a lunchroom, a library, and an exercise room. The RSF I and II showcase numerous high-performance design features and passive energy strategies such as optimal east-west building elongation, daylighting, static solar shading, transpired solar collectors, a crawl space for thermal storage, radiant heating and cooling, underfloor ventilation-air distribution, and approximately 1.5 MW of PV on the office wing roofs and on the adjacent parking lot canopy (NREL 2014b).

Figure 2. East perspective image of the RSF I wings. *Source*: images.nrel.gov # 19548.

The acquisition process used for the RSF I was the seed for the rest of the campus. The energy goal was developed in preplanning and included in the tiered, best-value RFP with the help of a design-build acquisition consultant (DesignSense 2010). The goal-type diversification, goal status in the RFP structure, and normalization approach was replicated for the other campus construction. The following are snapshots of the first three RPs in application.

RP #1 (Include a measureable energy goal in the RFP and contract)

- RSF I and II 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:
  - Mission Critical: LEED Platinum
  - Highly Desirable: 25 kBtu/ft^2/yr, normalized, as discussed in this section
  - If Possible: Net zero energy design approach

RP #2 (Develop the energy goal using multiple resources)

The EUI goal for the RSF I was developed using high-level sector data, case study comparison, and whole-building energy modeling. An EnergyPlus-based optimization engine, now incorporated into OpenStudio, was used to find a low energy use range when footprint and window-to-wall area ratio were varied (DOE 2014). 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. The following NREL campus buildings either reused this goal with some tweaking or used simple spreadsheet estimates to set a new goal.

RP #3 (Develop the energy goal using normalization factors)

An RFP goal of 25 kBtu/ft^2/yr was developed using an assumption of 650 people in a 220,000 ft^2 building for RSF I and 450 people in a 150,000 ft^2 building for RSF II. These values are based on government office building space utilization standards. A normalization table was given in the RFP with the intent of maintaining a constant energy impact of each employee in the building as was determined for the original goal. The occupant density was increased in coordination with the elongated wings, open floor plan, and compact furniture systems. An additional data center capacity allowance of 65 watts per person (for people using the data center, but not an RSF I or II occupant) was also defined. The space density and data center capacity increased the energy goals as shown in Table 1. The lesson regarding additional data center load accounting is, at a campus scale shared loads should be clearly normalized and allocated to each building when possible.

Table 1. RSF I and II Normalized Energy Goals for Occupant Density and Data Center Load

	kBtu/ft^2/yr			
Project name	RFP goal	Occupant density	External data center users	Contract goal
RSF I	25	+7	+3	35
RSF II	25	+8	0	33
Weighted average	25	--	--	34

Energy Systems Integration Facility

The ESIF has three distinct functions: office, laboratory, and supercomputer. It houses approximately 200 scientists and engineers and a wide range of fully equipped, state-of-the-art laboratories and outdoor test areas. Key energy efficiency strategies that apply to all spaces are reuse of supercomputer waste energy for office and laboratory space heating, evaporative cooling, outside air economizing, daylighting, and high-efficacy fluorescent lighting. Additional strategies used selectively throughout the building include underfloor air distribution, radiant beams for perimeter cooling and heating, natural ventilation with operable windows and ventilation shafts, and ENERGY STAR-rated equipment.

Figure 3. Southeast perspective image of the ESIF. *Source*: images.nrel.gov # 25820.

The full data center build out will equal 10 MW, making this a primary focus of the energy reduction effort. While an EUI requirement was used for the office area, mimicking that of the RSF I and II, the energy use effectiveness goal and heat recovery requirement for the data center were the most prominent RFP energy language.

RP #4 (Include technology-specific efficiency requirements in the contract)

The specific language listed as "required" early in the RFP are:

- Achieve an annualized PUE of 1.06 or lower for the supercomputer. (An annual Energy Use Effectiveness of 0.9 or lower was also included in the RFP to place emphasis on energy recovery from the supercomputer to other parts of the building in addition to the general space efficiency encouraged by PUE.)
- 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.

The RFP requirement of heat recovery from the data center was the primary driver for early massing decisions. The office (left side of Figure 3) was aligned on an east-west axis. 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. 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 heat exchanger; low pressure-drop air delivery system; low pressure-drop piping design
- Labs: Active chilled beams on perimeter; 100% of heating from data center

Cafeteria

The 12,000-ft^2 cafeteria was designed to accommodate 240 guests inside and 70 additional outside. Its efficiency features include 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. A direct/indirect evaporative cooling system provides kitchen and dining area cooling without the use of mechanical cooling equipment.

CAFETERIA
EUI goal: 30% energy cost savings versus Standard 90.1-2007, which is 190 kBtu/ft^2/yr

EUI prediction: 144 kBtu/ft^2/yr

Actual performance: 143 kBtu/ft^2/yr

Figure 4. East perspective image of the cafeteria. *Source*: images.nrel.gov # 21698.

Like the ESIF, the energy use of the cafeteria is driven by equipment. In these instances, the most important set of RPs are to clearly set expectations for equipment and define the loads or equipment that will be needed so that all design team members are clear as to which equipment needs to be "best-in-class" and included in energy calculations.

RP #5 (Define owner-specified energy 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.

- Best-in-class energy efficiency kitchen equipment such as commercial induction cook tops
- Best-in-class water efficiency kitchen equipment
- Variable frequency drive 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 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)
- World-class, most efficient commercial kitchen and cafeteria in the world that can attract commercial kitchen partners to demonstrate efficient equipment.

This language helped drive the design team to select ENERGY STAR equipment and higher efficiency models when attainable. For example, the facility's dishwashers use half the water of a standard ENERGY STAR model. The cafeteria's exhaust hoods have high-efficiency filters, wall-style canopies and proximity hoods, with stainless steel end panels to reduce the airflow requirements, and variable volume exhaust, all saving up to 75% of the energy use in a typical kitchen exhaust hood. Additionally, dual-rinse ware washing technology (the unit recycles the dirty rinse water to wash the next load) were specified and condensers were 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.

Site Entrance Building

While one of NREL's smallest buildings at 1,500 ft^2, the LEED Platinum SEB includes an array of world-class efficiency and sustainability strategies. The occupied space is fully daylit using light redirecting devices and dimming controls. The high thermal performance envelope includes fiberglass window frames. A radiant heating and cooling system is supplied by ground source water-to-water heat pumps. The underfloor ventilation-air distribution system is connected to energy recovery ventilators. These demand-side efficiency strategies are matched with an 8 kW roof-mounted PV system to allow the SEB to meet a net-zero energy goal.

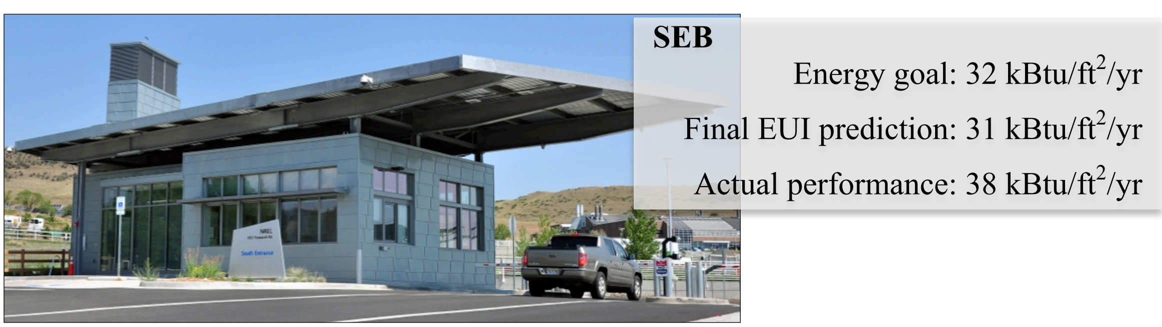

Figure 5. Southeast perspective image of the SEB. *Source*: images.nrel.gov # 22680

Of the NREL campus construction, the energy-performance-based acquisition process for the SEB most closely parallels that developed for the RSF I and II. An EUI was developed, required, and became the focal point of substantiation discussion throughout the project.

RP #6 (Provide calculation methods for substantiation)

Since the RFP requested a net zero source energy definition be used, which accounts for the value of the type of energy supplied to the building, the RFP appendix provided conversion factors for site-to-source energy so that this potentially variable factor was clear to all parties early in design. 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. The plug load calculations required peak hourly assumptions. The RFP included a description of assumptions used to arrive at the required plug loads and gave consent to decrease the load in the calculation if further efficiency measures were applied in design. A snapshot of the direction given in the RFP is as follows:

"[32 kBtu/ft^2/yr[1]] Annual Goal. This goal is intended to serve as a mechanism to create a building that uses less than this energy intensity annually within its own footprint. The goal is a demand-side goal to be achieved through energy efficiency strategies. Supply-side renewable generation options such as PV, biomass, wind, or renewable energy credits do not count toward the goal. The intent is to use the goal as a tool to develop a comprehensive program of efficiency measures and building operational strategies and policies to reduce energy use in the building as the first priority, rather than encouraging the use of supply side renewable options coupled with a less efficient building where all energy efficiency options have not been first fully exploited.

- The whole-building energy use will be measured at the building footprint. It includes all loads in the building for lighting, HVAC, plug loads, and other miscellaneous equipment connected through the building, such as transformers and control systems. It also includes any façade lighting.
- All losses from transformers and inverters are considered part of this energy calculation.
- Under this definition, PV on or through the building will be considered a supply side technology, and not count toward the goal.
- Transpired collectors, Trombe walls, solar hot water, and other such technologies are considered demand side technologies (e.g., if additional heat was produced using these systems and supplied to another building, that energy could be counted in the supply-side part of the net zero energy calculation).
- Plug loads will be included in the demand side calculation. Equipment included in the annual energy goal derivation:
  - One Dell Latitude E6400 Laptop, and docking station per occupant
  - Two Dell 24" G2410h LCD Monitors per occupant
  - One all-in-one copier/printer/fax machine
  - One LED task light per occupant
  - One VOIP phone per occupant

[1] A planning-phase goal of 9300 kWh was modified early in the project to an area-normalized goal of 32 kBtu/ft^2/yr due to the changing floor area in design and the uncertainty of a number of security-related miscellaneous electric loads.

- One refrigerator
- One coffee pot/maker
- One microwave
- One visitor badge printer
- One visitor badge camera, scanner and signature pad.” (DOE 2014)

While the calculation appendix and plug load list was critical to set the stage for the design process and for demonstrating that the building could meet the energy goal, it did not prevent the later addition of loads that are causing the EUI to exceed the energy goal and prediction. The lessons to be learned are that the energy goal helps us understand what loads above and beyond expectation are being added to the building and that, while an energy-performance-based acquisition process is the cornerstone for expected results, it is not sufficient. The building energy use must be tracked and corrective action taken when the goal is not met, as described by RP #8.

Parking Structure

NREL’s parking structure project proves that large garages can be designed and built with world-class energy efficiency at no additional cost. While meeting current and future staff needs with 1,800 parking spaces, the structure features energy efficiency and renewable energy technologies such as daylighting, natural ventilation, an 80% reduction in lighting power density versus code, and a PV array to make the RSF complex (RSF I, RSF II, and garage) net zero energy (NREL 2013). At a construction cost of $14,172 per parking space, the high efficiency garage is cost competitive with other comparable, but less efficient garages.

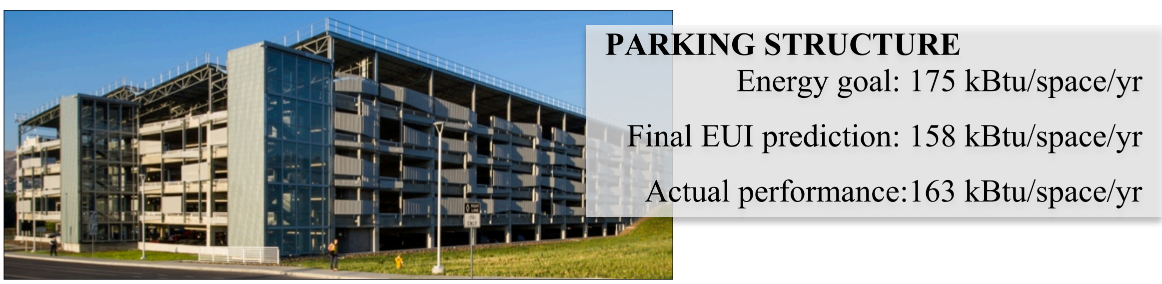

Figure 6. Northeast perspective image of the parking structure. *Source*: images.nrel.gov # 22471.

RP #7 (Require goal substantiation throughout design)

In a unique request for the design team, the parking garage RFP required the use of energy performance calculations throughout design. Typically, garage design focuses on the electric lighting and ventilation systems, but this aggressive goal, which was normalized per parking space, drove the design team to focus on passive technologies first, maximizing daylighting and eliminating all mechanical ventilation requirements through passive natural ventilation. The following shows examples from the parking garage RFP for requiring substantiation for meeting daylighting efficiency requirements at all stages through the design.

- 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.*"*
- Substantiation:
  - "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 Documents: Details of lighting control mechanisms
  - Construction: Field test of lighting levels verifying compliance with performance requirements." (DOE 2014)

RP #8 (Develop a process for performance assurance in operations)

The parking structure, like the other new NREL buildings, used a variety of approaches to performance assurance in operations. The basic RFP requirements for every project were enhanced commissioning and end use metering. Data visualization was not emphasized in any of the RFPs, although the RSF complex (RSF I, RSF II, and parking structure) does feature dashboards that show instantaneous power and interval analysis results for energy use. The visualizations have proven useful as an energy performance assurance tool 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.

While the performance assurance process has worked at NREL as a shared responsibility among researchers and site operations staff, we recommend that future projects write a formal energy performance assurance role into the RFP. The role would be responsible for overseeing the best practices presented in this paper as well as tracking energy goals in operations and taking action on discrepancies.

In general, the NREL projects have succeeded in meeting all the energy-specific RFP performance objectives in design, and all of the design predictions in operations; however, two lessons learned warrant identification. The cafeteria did not meet all the "Highly Desirable" or "If Possible" energy objectives in design, which was due to a poorly defined program and budget. The lesson learned here is that specific, measurable energy goals must be set in the contract along with a firm, fixed budget. The SEB is operating at a higher energy use than the prediction. The lesson learned is that high-load density buildings present the biggest challenge to setting an energy goal prior to design. Despite the challenge and required rigor in planning an energy goal for a high-load building, an energy goal would be used again in such a scenario because of its usefulness in calibrating expectations among the team members.

An Energy-Performance-Based Design-Build Process, Deployed

Once the energy-performance-based design-build process had proven successful for the RSF I and II construction, DOE provided funds to NREL to create training materials for a new construction, design-build suited audience. Additionally, organizations such as NASA asked NREL to hold workshops to transfer the RPs and lessons from the integrated project team to their key construction and operations team members. Over the past 5 years, these outreach efforts have allowed the transfer of information to deployment partners who are now realizing aggressive energy savings in operations. Table 2 lists replication efforts completed or underway. NREL was involved in the formulation of the acquisition process for these projects. Project outcome is not meant to be attributed to NREL; rather, this list shows the replication of project type using an energy-performance-based acquisition process of some form.

Table 2. Sample of Industry Replication of the Energy Performance Based Acquisition Process

Project Name	Description
Federal Center South for the Army Corps of Engineers	200,000 ft^2 General Services Administration office building in Seattle, WA EUI goal: 27.6 $kBtu/ft^2/yr$ including renewables
Fort Carson New Command Air Battalion	$700 million of new construction including barracks Minimum EUI goal: 44 $kBtu/ft^2/yr$ with option to exceed; Net zero energy
SLAC National Accelerator Laboratory	60,000 ft^2 visitor center and office space Tiered EUI goals: 40, 35, and 31 $kBtu/ft^2/yr$
University of California, San Francisco	Academic office building Tiered EUI goals: 33 and 20 $kBtu/ft^2/yr$

The how-to guidance, annotated RFPs, case studies, and training materials developed in support of the replication effort can be accessed via a guided website and are applicable to a variety of owner, design, and construction team members (DOE 2014). The primary deployment effort to date, which reaches a much broader audience than NREL can alone, is the development of a Design-Build Institute of America online course (DBIA 2013).

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. NREL and DOE, owners of the new NREL campus buildings, 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 training materials developed as a result of the NREL campus experience can serve as a guide for owners and their representatives to replicate our successes and learn from our experiences in attaining market-viable, world-class energy performance in the built environment.

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