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Shanti Pless and Paul Torcellini
National Renewable Energy Laboratory

David Shelton
DesignSense

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Shanti Pless
ASHRAE Member

Paul Torcellini, PhD, PE
ASHRAE Member

David Shelton, AIA
DBIA Member

ABSTRACT

This paper will review a novel procurement, acquisition, and contract process of a large-scale replicable net zero energy (ZEB) office building. The owners (who are also commercial building energy efficiency researchers) developed and implemented an energy performance based design-build process to procure a 220,000 ft^2 office building with contractual requirements to meet demand side energy and LEED goals. We will outline the key procurement steps needed to ensure achievement of our energy efficiency and ZEB goals using a replicable delivery process. The development of a clear and comprehensive Request for Proposal (RFP) that includes specific and measurable energy use intensity goals is critical to ensure energy goals are met in a cost effective manner. The RFP includes a contractual requirement to meet an absolute demand side energy use requirement of 25 kBtu/ft^2, with specific calculation methods on what loads are included, how to normalize the energy goal based on increased space efficiency and data center allocation, specific plug loads and schedules, and calculation details on how to account for energy used from the campus hot and chilled water supply. The RFP also provides for stretch goals, such as reaching net-zero energy. Additional advantages of integrating energy requirements into this procurement process include leveraging the voluntary incentive program, which is a financial incentive based on how well the owner feels the design-build team is meeting the RFP goals.

INTRODUCTION

The National Renewable Energy Laboratory's (NREL's) mission is to advance the U.S. Department of Energy's (DOE) and the nation's goals in the areas of energy security, environmental quality, and economic vitality. Today, buildings use roughly 39% of total U.S. energy consumption (22% residential, 18% non-residential), with energy consumption in this sector projected to grow by almost 30% in the next two decades. While energy efficiency and renewable energy integration in buildings are increasing over time, new buildings are being built and energy use in existing buildings is increasing at a high enough rate to outweigh the replacement of the building stock over time. In response to this need, the Federal government is beginning to increase the requirements for federal high performance buildings. 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 existing design, construction, operations, and maintenance practices. A new DOE-owned office building project that demonstrates a path to

Shanti Pless is a senior research engineer and **Paul Torcellini** is the group manager in the commercial building group at the National Renewable Energy Laboratory, Golden, CO. **David Shelton** is Senior Vice President for DesignSense Incorporated, Olathe, Kansas.

meeting the Federal high performance buildings executive order has been recently completed at NREL. The purpose of this paper is to delve into the details of how to implement energy use performance requirements as part of a performance based design-build process. We will document this process in a case study of the procurement, design, and construction process of DOE's recently completed Research Support Facility (RSF), a large-scale net-zero energy office building with contractually required energy performance goals. From the beginning, it was recognized that DOE's new RSF represented a unique opportunity to demonstrate the state of the art in terms of efficient, cost-effective, commercial office design and operation. The RSF and the innovative procurement process demonstrates that significant gains in energy efficiency can be realized in non-residential buildings today with existing technologies in a cost-competitive manner if careful attention is paid to project energy goals, building procurement, and integrative building design.

DESIGN AND CONSTRUCTION PROJECT DELIVERY METHODS

To understand the full potential of integrated design, we must first evaluate the various project acquisition and delivery methods to better understand how to deliver cost competitive energy efficient projects.

Design-Bid-Build

In a traditional design-bid-build scenario, the owner enters into a contract with a designer to develop plans and specifications for a building. The owner and designer determine the project's scope, including the type of construction and the budget. The designer estimates building costs based on past experience and input from engineers and other consultants. 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. During the bid phase, the owner receives and evaluates bids (again, often with the help of the designer) from a number of contractors competing for the job.

The owner then enters into a contract with the successful bidder and warrants that the plans and specifications for the building are complete and correct. 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 limited contact or relationship with each other until after the contract is awarded — limiting 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 non-aesthetic building components and strategies. Typical strategies eliminated are energy efficiency strategies that are not well integrated with the building 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 has the potential for adversarial relationships. The resulting value engineering process, disputes, cost overruns, and construction delays can cause less-than optimal performance, headaches (and often litigation), and increase project costs.

Construction Manager at Risk

An owner can also retain a designer to furnish design services and a construction manager to build the project who guarantees the cost and schedule. In this construction manager at risk delivery method, the owner authorizes the construction manager to handle many of the project details, but the owner is responsible for the design. The construction manager is involved from an early stage of the process, 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.

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, in design-build, the design-builder controls both the design and the construction process. The owner develops a clear, comprehensive request for proposals (RFP) that outlines the expectations for the project, and the design-builder—like their master builder forebears—assumes complete responsibility for delivering the project as specified in the RFP, on time and on budget. 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 it.

Performance-Based Design-Build

In performance-based design-build, the owner does not rely on plans and specifications to describe the scope of the project. Instead, the owner focuses on the problem(s) to be solved, and leaves the solutions to the design-builder to work out. This delivery method allocates control and accountability differently - in that the owner sets a firm price for the project, establishes program and performance requirements, prioritizes these requirements in a request for proposals (RFP), and then invites design-builders to propose solutions that best achieve the prioritized requirements. The owner then 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 is responsible and accountable for designing, building, and delivering the project which meets the contractually proposed requirements, within a proposed fixed schedule, and for the firm-fixed price (Design Sense Inc., 2008).

RESEARCH SUPPORT FACILITY PROJECT OVERVIEW

The research, development, demonstration, and deployment of cost effective and energy efficient technologies and design processes are part of DOE's and NREL's mission. As such, DOE/NREL felt a sense of urgency about maximizing the energy efficiency of the buildings on the NREL campus. At the beginning of 2007, DOE invested the funding needed to design and build the RSF. The vision was for the RSF to be a showcase of sustainable high-performance design to demonstrate the integration of high performance building design and practices in a replicable manner, showcase technology advances, and capture the public's imagination for renewable and energy efficient technologies. The final design for the RSF uses a wide variety of well integrated off-the-shelf energy efficiency measures to reduce demand-side energy use by 50% compared with ASHRAE Standard 90.1-2004. Combined with photovoltaics mounted on the roof and parking lot, the RSF is designed to offset all its energy use with on-site renewables. The 220,000-ft^2 Class A office building is designed to house 822 employees on NREL's Golden, Colorado, campus. NREL is currently leasing office space in a nearby office complex, and the RSF is enabling many staff to move to a central location on campus while saving significant leasing costs. A review of the RSF energy efficiency strategies is available at www.nrel.gov/rsf and Pless (2010).

While the RSF incorporates a range of readily available energy efficiency strategies combined in innovative ways, the DOE/NREL team's real breakthrough was rethinking the procurement process. It was decided early in the procurement process 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/ft^2 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.

DEVELOPING AN ENERGY PERFORMANCE BASED DESIGN-BUILD PROCESS

DOE and NREL selected a performance-based "Best Value Design-Build/Fixed Price with Award Fee" delivery approach in order to:

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

To familiarize DOE/NREL staff with the finer points of the design-build process, DOE/NREL commissioned the Design-Build Institute of America (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. In addition, 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, and document prioritized requirements with exacting measures to be used to substantiate overall project performance.

Project Objectives

Instead of specifying technical standards such as building size, configuration, conceptual drawings, and other attributes, DOE and NREL used the RFP to specify prioritized key performance parameters as "Mission Critical", "Highly Desirable", and "If Possible". Competing design-build teams were, in part, judged based on their ability to incorporate and support as many of the prioritized objectives as possible within the overall fixed budget and schedule constraint. These objectives included:

1. Mission Critical
    a. Attain Safe Work Performance and Safe Design Practices
    b. LEED Platinum Designation
    c. Energy Star Appliances, unless other system outperforms
2. Highly Desirable
    a. 800 Staff Capacity (later adjusted to 822)
    b. 25 $kBtu/ft^2$ including NREL's datacenter
    c. Architectural Integrity
    d. Honor "Future" staff needs
    e. Measurable 50% plus energy savings versus ASHRAE 90.1-2004
    f. Support culture and amenities
    g. Expandable building
    h. Ergonomics
    i. Flexible workspace
    j. Support future technologies
    k. Documentation to produce a 'How to' manual
    l. "PR" campaign implemented in real time for benefit of DOE/NREL and DB
    m. Allow secure collaboration with outsiders
    n. Building information modeling
    o. Substantial completion by June 2010

3. If Possible
    a. Net-zero design approach
    b. Most energy efficient building in the world
    c. LEED Platinum Plus
    d. Exceed 50% savings over ASHRAE baseline
    e. Visual displays of current energy efficiency
    f. Support public tours
    g. Achieve national and global recognition and awards
    h. Support personnel turnover

The 508 page RFP also included calculation and substantiation specifics for each of these performance requirements. The specific energy performance requirements, such as the absolute energy use intensity (EUI) objective of 25 kBtu/ft^2 site energy consumption and net-zero energy balance, required detailed calculations procedures to provide clarity in meeting our requirements. Performance requirements such as exceeding 90.1-2004 or achieving LEED Platinum already incorporate substantial calculation and substantiation requirements, but do not specifically result in meeting DOE and NREL's high expectations. The design-build team was asked to commit to providing each of these performance objectives at the Final Completion stage of the project.

Hiring the Right Team

From their DBIA training, DOE/NREL knew that choosing the right design-build team would be essential to the success of the RSF project. They advertised a national request for qualifications (RFQ), and identified ten qualified firms from among the respondents. They then shortlisted three highly qualified teams and invited them to respond to the RFP. The RFP required that each response include a management plan and conceptual design that demonstrated which of the prioritized "RFP Requirements" would be achieved, and how each would be achieved. This work involved a substantial investment of time and resources for the respondents, so to ensure a robust competition, DOE/NREL paid the unsuccessful firms a stipend of $200,000 (DesignSense, 2010).

At the end of this intense competition, DOE/NREL selected the Haselden Construction/RNL design-build team. DOE/NREL's focus on performance goals rather than technical specifications gave the Haselden/RNL design-build team the flexibility to develop a solution that would achieve all of DOE/NREL's "mission critical," "highly desirable," and "if possible" project objectives at a competitive cost. The competitive proposal process identified the design-build team that developed design concepts such as PV procured with a power purchase agreement, innovative daylighting strategies, and design-build team structures and analysis strategies that would allow for further innovation of integrated solutions. With the design team selected, Haselden/RNL, NREL, and DOE worked closely through an integrated design approach to fully understand and define every aspect of the project and to prepare the preliminary design. The most challenging performance objectives were the net-zero energy and the 25 kBtu/ft^2 EUI goals. Therefore, unlike traditional design where architecture defines form and impacts function, the RSF design was driven by its energy performance requirements. The Haselden/RNL team used extensive energy modeling to establish basic building architecture and structure, determining that two long and relatively narrow structures consisting of repetitive 30' by 60' modules maximized daylighting. Once the basic form was decided, the interior design team designed the workspace to take full advantage of the abundant daylighting and to facilitate the employee interactions critical to efficient and effective operations. Mechanical, electrical, and plumbing systems were designed to accommodate the energy efficient design and occupancy needs. This process – energy, form, interior, mechanical— is a change from the traditional approach to design. Energy modeling was continuously performed to evaluate the impact of design changes on project energy performance. By incorporating energy performance requirements into the RFP, the design-build team was forced to use integrated design strategies. To meet the contractual energy goals, the design-build team had to take advantage of the fact those changes and improvements in the design process are relatively easy to make at the beginning of the design process, but get progressively more difficult and expensive as the project progresses.

To incentivize the design-build team to perform superior work on the RSF, DOE/NREL also developed a "voluntary" award fee program to modify the design-builder's behavior. This incentive, typically 2%-3% of the contract value, is based on a DBIA best practice to ensure the design-builder continues to work with the owner in meeting (and exceeding) their expectations. This program proved to be invaluable for keeping the design-build team motivated and engaged throughout the process, resulting in superior performance throughout the process.

Energy Performance Objectives Calculation Details

A well developed absolute energy use (demand side EUI or net-zero energy use) calculation procedure in the RFP is necessary to ensure the design-build team focuses on developing the design strategies needed to meet your energy goals rather than trying to take advantage of calculation uncertainties or relying on overly optimistic assumptions. For the RSF, the 25 kBtu/ft^2 EUI goal and included the following calculation details in the RFP:

- **Set EUI goal based on expected space density.** Based on standard GSA space density for a 220,000 ft^2 office building, we expected 650 occupants. The 25 kBtu/ft^2 was normalized for this standard space occupancy. By normalizing the EUI goal by space density, this did not penalize the design-build team for increasing the number of occupants through increasing space efficiency. Through integrated office furniture planning, the space efficiency was increased to allow for 822 occupants in a 222,000 ft^2 building. This resulted in a normalized EUI goal of 32 kBtu/ft^2.
- **Demand side goal only.** On-site renewables such as PV or solar-hot water are not included in meeting the EUI goal. Hot water delivered from NREL's wood chip boiler does not count in meeting the EUI goal. This ensures the design includes adequate thermal envelope design and does not rely on NREL's central plant efficiencies to meet the EUI goals.
- **Include all expected loads in the building**. This includes NREL's datacenter, prorated for the occupants in the buildings at 65W/occupant. To encourage the design/build team to take advantage of the full datacenter waste heat load, the EUI goal also incorporated a credit of 3 kBtu/ft^2 to account for datacenter loads for NREL employees that are not RSF occupants but use the datacenter. This resulted in a final normalized EUI goal of 35 kBtu/ft^2. The RFP also directed the team to include all plug and process loads, including distribution transformers, all workstation loads, elevators, control systems loads, etc. District heating and cooling energy inputs were also included as part of the whole building EUI requirement. The RFP specified the expected level of many of these loads based on an owner-commissioned survey of plug and process loads expected in the RSF.
- **Provide typical operational schedules plug load profiles**. The RFP allowed and encouraged the design-build team to identify design strategies to help reduce unoccupied loads as well as identify more efficient equipment for NREL/DOE to procure.
- **Provide typical operational schedules for indoor air quality**. The RFP specified indoor air parameters such as temperature and humidity set points that had to be in compliance with ASHRAE 55, as well as outdoor air requirements in compliance with ASHRAE 62.1-2004.
- **Specify unknown model inputs to ensure good design.** To account for the unquantified efficiency of delivered hot water and chilled water from NREL's central plant, the RFP specified a fixed delivered hot water efficiency of 90% and a chilled water system efficiency based on a COP of 3.0. The chilled water efficiency is based on code-minimum air-cooled chillers and the hot water is based in a high efficiency natural gas boiler. The central plant energy use is included in the overall demand side EUI requirements.
- **Require design-build team to substantiate all other unspecified model inputs.** For all other model inputs, the design-build team must substantiate (prove to NREL/DOE) the model inputs.

For the net-zero energy calculations, the RFP references net-zero energy classifications and definition publications to ensure a clear communication system is used that is based on an appropriate calculation framework (Pless, 2010; Crawley 2009; Torcellini, 2006). Starting with a clear net-zero energy framework allowed the design-build team to focus on developing innovative solutions rather than investing critical design time in investigating the various net-zero energy definitions.

CONCLUSION AND LESSONS LEARNED

The benefits of design-build delivery have been apparent for some time. As documented by Konchar in 1997, a Penn State researcher compared the design-build and design-bid-build project delivery methods (Konchar, 1997). He found that design-build projects cost an average of 6% less, were an average of 12% faster to build, and were an average of 33% faster to deliver (i.e. from conception through completion). Especially for an innovative building, design-build delivery coupled with clear and prioritized energy performance requirements (performance-based design-build) appears to be a successful combination. And establishing prioritized performance goals from the beginning greatly increase the probability that the completed building will meet the project's critical goals. As the RSF process demonstrates, when the owner's RFP requests a net-zero energy building, and the criteria for selection clearly reflect that goal, all the players will focus on that outcome and evaluate management, design, construction, commissioning, and operational strategies based on how they affect that outcome.

Based on the RSF team's experience, incorporating absolute EUI performance requirements into a performance-based design-build procurement process appears to be an effective strategy for achieving aggressive energy performance goals on a firm fixed price. In this delivery method, the owner establishes performance goals for the building (energy use, percent savings, LEED rating, etc.), and the design-builder is contractually bound to meet those goals—within the budget and on schedule. By hiring a design-build team and contractually obligating them to satisfy measurable energy use requirements, NREL encouraged (and forced) the formation of an integrated design process comprising architects, engineers, and builders (which included cost estimators and key subcontractors). This arrangement resulted in an iterative pattern between the architects, engineers, and builders aided with detailed computer simulations needed to assess whether the building design, as it evolved, would meet the performance requirements of the owner. An added advantage is that 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.

In addition, the arrangement put the onus on the owner to clearly define the scope and goals of the project in the RFP, and allow the creativity of the design-build team to find market-viable solutions to meet those goals. Having specific demand side whole-building energy use requirements necessitated that energy modeling and trade off cost optimizations is included in the design process from the very beginning. The firm fixed budget for all work (conceptual design, preliminary design, final design, and construction) of $64 million required that cost modeling be given as much emphasis as the energy modeling to ensure the design build team could meet the energy use requirements in the most cost effective and integrated manner as possible. Based on our experiences developing and implementing this energy performance design build process for the RSF, we offer the following best practices for owners of future projects looking to implement a similar energy performance design build procurement process:

- Set measurable energy use requirements in the RFP and Design Builder contracts. A performance-based RFP focuses on measurable performance criteria rather than prescriptive solutions to design problems. It describes how the building will perform, in clear, measurable terms—what the building will do rather than what it will be. This frees the owner to concentrate on the functional expectations of the building rather than worrying about 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 more clear and measurable the performance criteria are, the more likely the project will successfully meet them.

- Require whole building energy model based substantiation of energy performance throughout the delivery process, including requiring the design-builder to deliver a project that meets the energy goals based on a Final Completion As-Built energy model. Plan on extensive Monitoring and Verification to measure

- Once the energy use requirement is set and agreed upon for all parties, do not change it. During the design process, hard decisions have to be made to meet your energy goals- changing the energy goal has to be harder than making the hard design decisions. Let the design-build team develop an integrated solution to best meet your performance requirements. Anytime the owner specifies details of the design, they risk decreasing the integration of the final design resulting in higher costs and sub-optimal performance.

- Provide calculation procedures for including unknown or external loads such as datacenters, plug loads, and central plant efficiencies. Include all planned loads in the whole building EUI goals, including datacenters, cafeterias, elevators, all plug loads, distribution transformers, building control systems, and energy inputs for district hot water, etc. Benchmark your current operations and provide this baseline to your design-building team. Encourage your design-build team to help you identify and design for (and account for in the energy model) more efficient operation opportunities.

- Provide normalization methods of energy use to encourage space efficiency in design.

- Spend the necessary planning time upfront to develop the problem statement. The RFP must be carefully thought out, tested for achievability, and clearly written. Because RFPs for commercial buildings are typically hundreds of pages long, it must also be well-organized and easy to navigate. If needed, retain an RFP criteria consultant to help write your energy performance specifications and procure your design-build team. Because making the RFP as clear and comprehensive as possible is key to the project's success, include performance objectives in clear, specific, and measurable terms. Toward that end, performance expectations must include metrics to gauge success.

- Use a voluntary incentive program to ensure design-build team is a willing and positive participant in helping you meet their energy performance requirements. Plan on measuring the energy performance through an extensive measurement and verification program, and reward your team and be willing to pay for "Superior" performance.

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