# Cost Control Best Practices for Net Zero Energy Building Projects

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# Cost Control Best Practices for Net Zero Energy Building Projects

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### Abstract

For net zero energy (NZE) buildings to become the norm in commercial construction, it will be necessary to design and construct these buildings cost effectively. While industry leaders have developed workflows (for procurement, design, and construction) to achieve cost-effective NZE buildings for certain cases, the expertise embodied in those workflows has limited penetration within the commercial building sector. Documenting cost control best practices of industry leaders in NZE and packaging those strategies for adoption by the commercial building sector will help make the business case for NZE. Furthermore, it will promote market uptake of the innovative technologies and design approaches needed to achieve NZE.

This paper summarizes successful cost control strategies for NZE procurement, design, and construction that key industry users (such as building owners, architects, and designers) can incorporate into their everyday workflows. It will also evaluate the current state of NZE economics and propose a path forward for greater market penetration of NZE buildings. By demonstrating how to combine NZE technologies and design approaches into an overall efficiency package that can be implemented at minimal (zero, in certain cases) incremental capital cost, the domain of NZE design and construction can be expanded from a niche market to the commercial construction mainstream.

**Keywords:** cost control, energy efficiency, high performance, net zero energy, renewable energy

## 1. Introduction

As the momentum behind net zero energy (NZE) builds and more commercial projects are demonstrating that NZE is an achievable goal, there is a growing need to identify approaches that will enable broad replication. Design teams and building owners commonly cite the incremental first costs of energy-efficiency strategies as a significant barrier to realizing high performance in commercial construction projects [1]. The prevailing perception is that NZE is cost prohibitive and suitable only for showcase projects with atypical, large budgets; however, there is mounting evidence that NZE can, in many cases, be achieved with typical budgets. While it is true that high-efficiency components typically cost more than standard-efficiency equivalents, innovative design and construction teams have developed a variety of strategies to offset the cost of implementing the best-in-class efficiency required to achieve NZE.

This paper explores the current economic reality of NZE as a performance goal and summarizes a set of successful strategies for NZE procurement, design, and construction that key industry users (such as building owners, architects, and designers) can incorporate into their everyday workflows to make NZE achievable with a typical construction budget. It also promotes the value of documenting the successes of industry innovators, and proposes a path forward for developing NZE cost control best practice guidance for the mainstream commercial buildings sector.

## 2. The current state of NZE economics

In the past few years, innovators in the commercial construction sector have progressed in leaps and bounds in improving the economic viability of high-performance buildings. While improvements in energy efficiency and renewable generation technologies have contributed to this progress, a significant shift in how high performance is approached has also played a critical role. Historically, project teams have relied on simple payback analysis to justify energy-efficiency strategies somewhat independently of other design decisions. Recently, project teams have begun to employ more comprehensive and integrated approaches to cost justification and capital cost control that leverage innovative strategies in procurement, integrated design, streamlined construction, and operational accountability. The impact of these improvements is evident in the growing number of construction projects that have been able to achieve NZE within the constraints of typical project budgets.

In 2006, NREL compiled a case study report on six high-performance commercial buildings and found that integrated design and early prioritization of energy performance goals could be used to cost effectively achieve significant energy savings (25% to 70% better than required by ASHRAE 90.1-2001) [2][3]. In the same year, Griffith et al. built upon these findings, using a large-scale simulation analysis to estimate that, given realistic assumptions about the area available for photovoltaic (PV) generation (50% of the total building roof area), the commercial sector could achieve NZE if average building energy consumption were reduced by 59% compared to the minimum requirements of ASHRAE 90.1-2004 [4][5]. Additionally, the vast majority of commercial buildings could achieve NZE at energy savings of 70% or less (including warehouses, office buildings, education facilities, retail stores, and outpatient healthcare facilities). For buildings with high energy use intensity (e.g., large hospitals) or little area available for PV (e.g., urban, high-rise office buildings), alternative paths to achieving NZE that leverage offsite renewable generation are available [6][7].

More recent data indicate that cost-effective NZE design and construction is currently a reality for certain combinations of building type and climate zone. NREL's Research Support Facility (RSF) illustrates that it is now possible to achieve LEED Platinum certification and NZE in a cold-arid climate (Golden, Colorado) with a large office building that is first cost competitive [1]. The first phase of the RSF, a 20,400 $m^2$ headquarters and administrative office building with a corporate-scale data center, was able to achieve its ambitious performance goals at a move-in ready cost of $2,790/$m^2$, which falls comfortably within the range of market-acceptable capital costs. This project was then expanded to a total of 33,400 $m^2$; aggregate costs for the second phase of construction were reduced by $150/$m^2$, while energy performance was improved by 11%.

In a 2012 study, the New Buildings Institute (NBI) found that NZE design and construction had been achieved at incremental costs of 0%-10% in comparison to standard practices [8]. NBI found that NZE buildings had been constructed in most U.S. climate zones. Most buildings in the study had floor spaces under 1,900 $m^2$, with the exception of an elementary school and the RSF. NBI also found that most NZE buildings had been constructed using technologies that were readily available, though there was a significant need for practical guidance to help designers, developers, and owners understand the value of NZE and the resources available to help them get there. In a 2014 update to this study, NBI found that NZE has expanded from the domain of a few small demonstration projects by universities or nonprofits to an increasingly mainstream presence that spans a variety of building types and sizes [9]. NBI documented that the number of buildings that have achieved or are targeting NZE have more than doubled in the past two years and that high-performance buildings, including NZE buildings, are approaching costs comparable to industry average. Evaluation of recent NZE construction projects (both new construction and comprehensive retrofits) points towards clear trends in design, construction, and operation approaches that include: (1) passive energy-efficiency strategies that leverage the capabilities of the building envelope; (2) innovative HVAC strategies that decouple ventilation from space conditioning and reduce fan energy; (3) increased and ongoing attention to tuning controls in response to performance monitoring and building feedback; and (4) realization that occupant interaction with the building is critical to achieving NZE in operation. These findings are consistent with the earlier analysis of Griffith et al [4].

In September of 2013, the National Association of State Energy Officials (NASEO) and NBI sponsored the "Getting to Zero National Forum" as part of NASEO's 2013 Annual Meeting [10], where the cost of NZE building design and construction was a key topic of discussion. A focal point of the cost control discussion was the value of integrated design in allowing for crucial design tradeoffs that can keep the cost of NZE buildings within typical project budgets. This meeting indicated that: (1) there is a growing consensus throughout the commercial construction sector that certain types of NZE buildings can be scalable and cost effective; and (2) successful practices are emerging with respect to the design and construction that are making this possible.

In "The World's Greenest Buildings," author Jerry Yudelson asserts that pursuing "green" certification has become business as usual, due in part to the fact that building developers, managers, and owners, both public and private, have embraced intangible benefits of high-performance buildings, including: enhanced marketability; higher tenant, manager, and owner productivity and morale; and improved public relations through demonstration of commitment to sustainability and environmental stewardship [11]. He stresses that making a business case for high-performance buildings is essential for obtaining buy-in from project decision makers, and that highlighting the long-term economic benefits of sustained utility cost savings, higher rent and increased occupancy, and greater availability of equity funding, can go a long way to making the case. Yudelson also notes that the additional cost of renewable generation required to make the leap from high-performance to NZE can be justified by considering the capital cost reduction that can be achieved through an integrated design strategy that leverages best-in-class efficiency to reduce overall system and envelope costs.

Depending on the project, sufficient capital may or may not be available to purchase the renewable generation required to move building performance from cost-effective, best-in-class energy efficiency to NZE. The cost of integrating renewable generation systems into the building design is usually not the issue (particularly for PV); it is the cost of the systems themselves that is likely to exceed financial thresholds. For cases in which sufficient capital is not available for investment in renewables, third-party financing may be leveraged to secure the renewable generation needed to achieve NZE. And, while securing capital to purchase renewables may require an increase in capital budget, a growing number of projects have been able to justify that incremental investment because of the organizational image boost that NZE provides.

For the first phase of RSF construction, the design-build team leveraged a third-party power purchase agreement to secure the PV generation required to achieve NZE without exceeding the project budget (and without increasing the utility rate at which NREL purchases "green" power). Applying lessons learned from the first phase, the design team was able to significantly reduce the overall cost of the second phase. Those savings, in part, enabled NREL to purchase, rather than finance, the PV required for the second phase.

## 3. Successful strategies for NZE cost control

Through its campus improvement efforts, NREL has identified key strategies for controlling capital costs in high-performance office buildings. By applying those strategies, NREL has demonstrated that NZE can be achieved in large commercial office buildings at market-competitive first costs. To promote large-scale replication of its campus construction successes, NREL has disseminated its lessons learned in NZE cost control in the form of successful practices that procurement, design, and construction teams can implement to achieve energy goals on competitive budgets [1][12]. These practices, while informed primarily by the procurement, design, and construction of the RSF, can be applied to a wide range of building types. To that end, the 50% Advanced Energy Design Guides (AEDGs) for K-12 schools, large hospitals, and medium to big box retail buildings have incorporated subsets of these practices [13][14][15].

The following subsections provide a high-level summary of the successful strategies that NREL has compiled through its campus improvement efforts and ongoing discussions with industry cost control experts.

### 3.1. Acquisition and delivery strategies

Thoughtful execution of the acquisition and delivery process for a design and construction project is critical to ensuring that desired building performance is achieved. For the RSF, NREL implemented a performance-based design-build procurement process to most effectively balance performance, value, and cost savings. Traditionally, the U.S. Department of Energy (DOE) construction projects (NREL's buildings are owned by DOE) follow a design-bid-build approach to acquisition that results in the selection of separate design and construction contractors. A design-bid-build approach can weaken integration between the project team members. Architects may be reluctant to push the limits of efficiency without certainty that the project contractor will implement solutions according to a preliminary budget estimate based on quality historical cost data. When presented with "innovative" designs, contractors may bid more conservatively due to lack of confidence in efficiency strategies that may not fully account for construction considerations.

Competitive procurement of an integrated project team (design team, contractor, and trade partners) equipped to achieve fixed, measureable energy performance targets is the key to cost-effective acquisition and delivery. Incorporating measureable performance goals into the project request for proposals (RFP) clearly establishes energy efficiency expectations and provides the owner or developer with a fixed metric for evaluating energy performance success. For the RSF, energy performance was substantiated at construction completion using an energy model. When combined with an aggressive, measureable performance target, a market-competitive, fixed, firm price compels potential project teams to identify innovative, cost-effective design and construction solutions.

As improved building design reduces energy consumption, plug and process loads are becoming dominant end uses in many building types. For the RSF, plug and process loads make up half of the building's energy consumption. NREL has found that developing equipment procurement specifications that require best-in-class equipment efficiencies and incorporating those specifications into the project RFP is a highly effective approach to plug and process load control. Note that this approach applies both to plug and process loads considered integral to the building (potentially including elevators, security systems, kitchen equipment, and workstation task lights) and to those assigned to occupants (such as personal computers and multifunction printing equipment). In a design-build scenario, building-integral plug and process loads are normally the responsibility of the design-build team, whereas occupant plug and process loads are specified by the building owner. To ensure that plug load mitigation is sufficient to enable whole-building energy performance targets to be met, the owner must work together with the design-build team to ensure that all plug and process loads are fully considered. While the design-build contractor is responsible for meeting the overall energy performance goal, the owner or occupant is responsible for meeting established occupant-provided plug load profiles. These plug load profiles serve as the communication bridge between the owner's needs and the project team's design.

### 3.2. Design strategies

In most cases, high-efficiency building components are more expensive than standard-efficiency equivalents. However, not all efficiency strategies require additional capital investment. In particular, innovative design teams can integrate simple, passive energy-efficiency strategies into the building architecture and envelope at no additional cost. Building orientation, massing, and layout can be designed to reduce building thermal loads without increasing material or construction costs. Other passive strategies, including daylight redirection, thermal massing, natural ventilation, and solar shading, can be integrated with the building structure to create architectural designs that also save energy. The RSF's south-facing daylight redirection strategy demonstrates the value of leveraging building architecture to implement cost-effective, passive efficiency strategies. Rather than employing adjustable blinds or automatic roller shades to control solar glare, the RSF design uses passive, fixed light-redirecting devices that maximize daylight penetration and completely eliminate solar glare without requiring occupant interaction or adjustment. Well-integrated solutions can often eliminate the need for additional controls and mechanical components that increase first cost and require long-term maintenance. In the case of the RSF, application of simple, passive, well-integrated efficiency solutions such as the daylight redirection strategy enabled mechanical systems to be substantially downsized.

It is common for design teams to justify the cost of efficiency strategies using energy cost-saving predictions. However, energy savings alone may not be sufficient to justify the cost of many effective efficiency strategies. For projects in which performance-based procurement establishes clear energy performance and capital budget requirements from the outset, the cost of efficiency drives the need for innovation in design. In such cases, project teams can leverage the principles of integrated design to ensure that energy performance goals are met without using too much of the project budget. Effective project teams use analysis to identify holistic solutions that balance energy efficiency, cost, and architectural detail. The owner sets the tone of the project with the RFP; the contractor and design team develop integrated solutions that address the requirements of the RFP as a total building package, rather than as individual components.

This integrated approach to cost justification that considers cost tradeoffs across building systems can be effective in securing the necessary first cost budget for efficiency strategies. Energy modeling plays a key role in this approach, enabling design teams to accurately predict the relationship between building loads and the appropriate capacity of HVAC components. In the recently constructed, LEED Platinum, NZE headquarters building for the Packard Foundation in Los Altos, California, the design team was able to avoid the cost of a $150,000 perimeter heating system and more than $300,000 in additional PV by investing $75,000 in triple-pane glazing to reduce perimeter thermal gains and losses [16].

Innovative design can generate uncertainty among decision makers. Regardless of how cost effective and energy efficient a design, the project team may have difficulty convincing decision makers to approve strategies outside of their comfort zone. To increase daylight penetration and enhance natural ventilation, the RSF design team proposed an open office layout that diverged significantly from NREL standard practice in space planning and office allocation. Before approving the layout, NREL wanted to fully understand its impacts, not only on budget and energy performance, but also on the productivity and satisfaction of building occupants. "Soft" benefits (such as favorable life cycle cost projection or contribution to the building mission) can be valuable in securing decision maker buy-in. By convincing NREL decision makers that the open office layout would improve productivity by promoting collaboration and increase occupant satisfaction through enhanced connection to the outdoors, the design team was able to obtain approval for their cost-effective, innovative, but also relatively unproven design approach.

Glazing constructions are expensive and poorly insulating compared to other exterior envelope constructions. On the other hand, glazing provides connection to the exterior environment, facilitates daylighting and natural ventilation, and contributes significantly to the overall quality of the interior environment. An ideal approach is to first specify dedicated daylighting glass as required to meet daylighting goals (totaling only 11% window-to-wall ratio for the RSF), and then to identify key opportunities for view glazing that improve interior environmental quality while minimizing thermal gains. East- and west-facing glazing should also be limited to the extent possible.

Modular and repeatable design strategies can be used to reduce overall design and construction costs. Design elements that can be replicated reduce costs through economies of scale. The best example of this strategy in the RSF is the south- and north-facing window system design. More than 200 south-facing windows in the RSF are the same size, have the same operable component, are shaded with the same overhang, and are fitted with the same daylight-redirection device. Likewise, more than 200 north-facing windows are the same size and have the same operable components. This standardization significantly reduced the overall cost of building glazing systems, enabling significant glazing-efficiency improvements (overhangs for solar shading, triple-pane glazing, and thermally broken window frames) to be incorporated into the budget.

### 3.3. Construction strategies

Construction strategies, while often overlooked, also play a key role in overall project cost control. It is important to integrate contractors and trade partners into the overall decision-making process from an early stage to ensure that construction considerations are properly weighed during design. Ensuring that designers and contractors are on the same page and fully understand the energy and cost implications of their decisions will pay dividends down the road by streamlining the construction process.

Integrating key trade partners into the design process at an early stage can help control the construction costs for uncommon or untested efficiency strategies (such as natural ventilation, radiant heating, and daylighting). When faced with implementing strategies via a nonintegrated approach, trade partners are forced to account for uncertainty in their bids. When trade partners are brought into the design process early on, it ensures that they fully understand the design intent and can collaborate to devise and implement construction cost control approaches that will maximize building system performance while minimizing installed cost. By leveraging subcontractor familiarity with building components and applying lessons learned from the first phase of RSF construction, total project construction costs of the second phase were reduced by $150/m$^2$ while energy performance was improved by 11%.

In a typical construction process, value engineering is employed during construction to counteract budget creep by eliminating design features (including efficiency strategies) considered to be nonessential. This often prevents performance goals from being achieved and reduces the overall value of the project. Using an integrated approach that makes cost estimators key members of the project team from the outset promotes accountability for the budgetary impact of each design decision. Through this "continuous value engineering" process, budgetary constraints are considered holistically, and each design and construction decision is made with clear understanding of the economic and energy implications. All decisions made through this process are considered essential, and any future decisions are carefully evaluated to ensure compatibility with essential functionality. If the energy goal is part of the construction contract, critical energy-saving features are less likely to be eliminated due to budget creep.

In the same way that modular design elements can be utilized to reduce design costs, offsite, modular construction and building component assembly techniques can be utilized to reduce construction costs. Offsite construction allows components to be manufactured or assembled in a controlled environment, improving construction safety as well as quality control. Additionally, offsite construction simplifies the onsite construction process and can significantly reduce the length of the construction schedule. This strategy was used extensively during RSF construction. Precast insulated exterior wall panels were fully assembled offsite. Once exterior wall panels reached the RSF construction site, exterior concrete surfaces had been finished. This resulted in a significantly simplified onsite construction process for the first phase of the project: (1) panels were hung on the steel structure; (2) panel joints were sealed; (3) windows were installed and sealed; and finally, (4) interior concrete surfaces were painted. The result was better quality control with respect to exterior wall air leakage and a shorter construction schedule. During the second phase of the project, the onsite construction process was further simplified by installing and sealing the windows during offsite assembly. This refinement contributed to the cost savings that enabled the PV for the second phase to be purchased outright, rather than financed by a third party.

## 4. Conclusion: increasing the market penetration of NZE

For NZE buildings to become the norm in commercial construction, it will be necessary to demonstrate to the mainstream commercial buildings sector that they can be designed and constructed cost effectively. The successful practices that NREL has compiled and disseminated through its campus improvement efforts provide a necessary foundation. In order to develop NZE cost control best practices that can be applied at scale across the commercial buildings sector, this foundational work needs to be expanded to reflect the approaches of other innovators in NZE procurement, design, and construction who have implemented cost control strategies to address a wide range of programmatic and budgetary constraints.

To market this guidance to potential adopters, it is essential to document the successes of industry innovators. While the RSF and similar projects demonstrate that NZE can be achieved within typical programmatic and budgetary constraints in certain cases, documenting a wider range of cost control strategy implementation is needed to inspire confidence in its broad feasibility. While each project has a unique set of cost drivers, clear documentation and measurement of individual project successes is critical. A common criticism of case studies is that they lack the transparency required to inspire replication. Likewise, creative accounting can make strategies look more effective than they are and lack of quantifiable detail makes it difficult to assess the effect of project-specific parameters.

It will be critical to engage key industry practitioners (primarily designers and contractors) who have demonstrated cost-effective NZE building design and construction to validate and build upon NREL's foundational work by documenting the successful implementation of NZE cost control strategies throughout the commercial buildings sector. This approach will shed light on the procurement, design, and construction strategies that allow many NZE buildings to achieve aggressive performance goals at first costs comparable to the industry average. These strategies will help audiences better understand what separates the NZE buildings with higher incremental costs from those with zero incremental cost. Clear documentation of successful implementation of these strategies will inspire confidence in potential adopters.

To ensure that the resulting best practice guidance is appropriately market facing, it is important to collect feedback from deployment partners about the types of information resources and dissemination methods most helpful to increasing deployment of NZE buildings. Recruited deployment partners may include one or more of the following types of organizations: (1) building owner organizations actively planning high-performance construction projects constrained by typical construction budgets; (2) outreach organizations that engage owners at the project-specific level and are able to give feedback regarding what NZE cost control best practice content or format would change industry practices; and (3) educational organization or professional societies engaged in existing industry-wide outreach or educational efforts that could be informed by NZE cost control best practices.

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