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Improving Sustainability of Buildings Through a Performance-Based Design Approach

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Improving Sustainability of Buildings Through a Performance-Based Design Approach

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Introduction

The design of most buildings is typically driven by the need to meet a set of minimum criteria, including budget constraints, time scheduling, functionality requirements, safety regulations, and energy codes. This process typically produces buildings that just meet these minimum criteria. To achieve better than average or exceptional performance, the design team, which includes the building owner, needs to work together in a focused effort. Performance goals provide direction to these efforts. The earlier in the design process the goal setting begins, the easier it is to implement and the better the results.

This paper describes a performance-based design process and the benefits of this approach. Examples from six buildings are used to show how specific design goals influenced the final building. The High Performance Buildings Initiative (HPBi) at the National Renewable Energy Laboratory (NREL) has monitored each of the example buildings extensively.

Performance-Based Design

In the traditional building design process, the building owner and architect create the building program. This document contains the functional, economic, and time requirements of the building that forms the basis for developing the building design. Typically, there are no performance goals established for the building. The architect designs the building to satisfy the program requirements, and then the project engineers design the electrical and mechanical systems. The architect and engineers may try to design efficient systems, but with no performance goals to direct the design and little interaction, the results are usually mediocre.

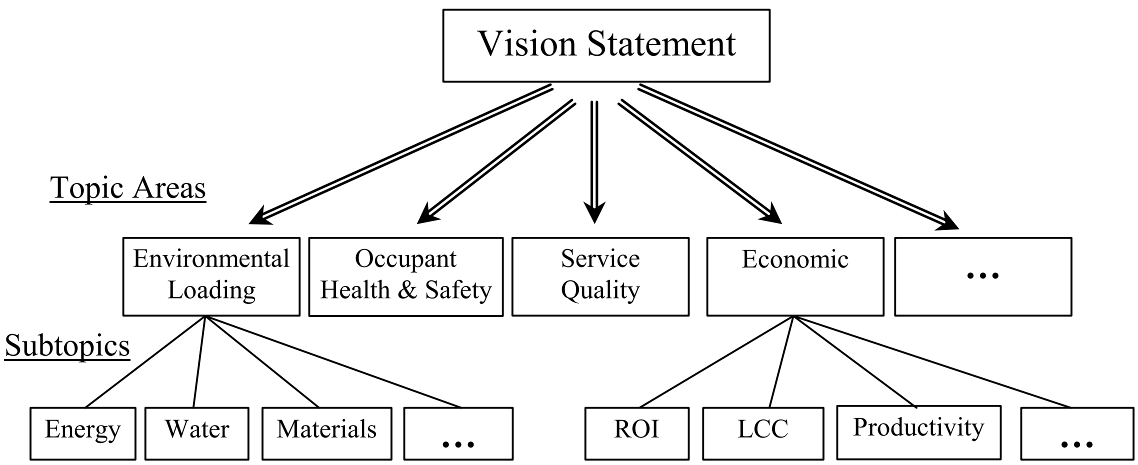
In a performance-based design approach, performance goals are developed during the initial stages of the design. The design team should buy into the goals, and it is most effective when the design team is involved in establishing the goals. The Integrated Design Process Guideline provides examples of how goals can be integrated into the design process (IEA 2003).

A schematic of the process is shown in Figure 1. The process starts with a vision statement, such as:

> *This project will design, construct, and operate a building that provides a healthy and productive work environment and minimizes the use of nonrenewable material and energy resources in a cost-effective manner.*

The vision statement should be used throughout the life of the building to help guide key decisions concerning material selection, building design, and system operation and maintenance. The vision statement is a broad declaration about the final building performance, which should be broken down into topic areas that can be implemented by the design team and later used to assess performance by the building operators. For example, the above vision statement can be divided into the following areas: *environmental loading, economic, service quality,* and *occupant health and safety*. Each of the topic areas should be further divided into more specific subtopics. Examples of topic and subtopic areas are shown in Figure 1. The Whole-Building Design Guide (NIBS 2004) provides another example of dividing building performance into eight "objective areas" with further division into subtopic areas.

In general, it is difficult to aggregate subtopic areas with a single value. For example, water and energy use cannot be aggregated into a single value. Sometimes, indirect comparisons can be made, such as comparing the costs of water and energy. Financial metrics are often used to aggregate topics and subtopics. LEED uses weighting factors to combine the subtopic areas into a single performance indicator (USGBC 2004). Other tools, such as GBTool and MCDM-23 rely on user selected weighing criteria to combine subtopic metrics into aggregate performance indicators (iiSBE 2000, IEA 2002).



Energy Subtopic
Objective: Minimize source energy consumption for building operations.
Goal: Reduce annual source energy consumption by 70% compared to an energy code compliant building using ASHRAE 90.1 and a typical weather year.
Performannce Metrcs: Net Source Energy Use Intensity, Percent Savings Compared to ASHRAE 90.1-2001 Benchmark.

Materials Subtopic
Objective: Minimize construction and demolition waste going to landfill disposal.
Goal: Recycle and /or salvage at least 50% by weight of construction, demolition, and land clearing waste (USGBC 2004).
Performannce Metrcs: Percent construction material waste sent to recycling, percent of demolition material recovered for reuse or recycling.

Figure 1 Schematic of the Performance-Based Design Process

The next step in the performance-based design approach is to define objectives for each subtopic area. The objectives are general statements about the desired outcome. Specific goals are then developed from the objective statements. Developing goals is an iterative process during the conceptual design phase. Setting realistic goals involves engineering and economic analysis to determine what is possible and how much it will cost.

Goals are most effective if they are clearly stated and understood by the design team, construction personnel, and building occupants. In addition, progress toward the goals should be measurable. Goals that are not clear and measurable are open to interpretation, which limits their effectiveness. Measuring success requires baselines or benchmarks and performance metrics to quantify the progress. Well-defined performance metrics allow the design team to easily evaluate their success in achieving the goals throughout the design and operation of the building (Hitchcock 2003).

Once the goals are established, the design team can work on identifying the obstacles in reaching the goals and finding design solutions to overcome the obstacles. This process can be in the form of computer simulations, consulting with technical experts, communication with product manufacturers, or research into similar projects.

The performance-based design approach defined in this paper can be summarized in the following six steps:

1. Develop a vision statement for the building project to act as a guide for the design, construction, and operation of the building.
2. Divide the vision statement into topic and subtopic areas to address specific details.
3. Define objectives of the building project for each of the subtopic areas.
4. Establish clear and measurable goals (may be an iterative process).
5. Define performance metrics to measure the progress toward achieving the goals.
6. Develop and carry out a plan for monitoring the building performance throughout the design and operation of the building.

The final step requires the most effort and is often not carried out completely; however, it is the most important. If the performance is not verified, there is no way of knowing if the goals are satisfied, and more importantly, there is no way knowing how the building is performing. The monitoring plan should specify responsible parties and reporting requirements.

The basic tenant behind this design process is that "you get what you ask for." When there is a clear vision of the desired outcome, which is broken down into objectives and goals, there is a greater chance for producing a high-performance building.

Examples of How Goals Drive the Design

NREL has monitored the performance of several high-performance buildings. One of the important lessons NREL staff learned from these projects is how the performance is driven by the design goals. The environmental performance goals and measured building performance of six projects are summarized in Table 1. The six buildings included the BigHorn Home Improvement Center, Silverthorne, Colorado; the Pennsylvania DEP Cambria Office Building, Ebensburg, Pennsylvania; the Chesapeake Bay Foundation (CBF) Merrill Center, Annapolis, Maryland; the Oberlin College Lewis Center, Oberlin, Ohio; the National Renewable Energy Laboratory Thermal Test Facility (TTF), Golden, Colorado; and the Visitor Center at Zion National Park, Springdale, Utah (Torcellini et al. 2004; DOE 2004).

Table 1 Performance Goals and Measured Performance

Building	Performance Goals	Performance Category				
		Net Energy Cost	Net Energy Use	Water Use	Materia Selec tion	Site Impact
BigHorn	60% energy cost saving reduce site impact	●	●	○	○	◒
Cambria	LEED Gold, 66% energy cost saving, 33% water saving, material selection, low site impact	◒	◒	◒	●	●
CBF	LEED Platinum, 50% energy cost saving, low water consumption, material selection, low site impact	○	◒	●	●	●
Oberlin	Net zero energy building	◒	●	◒	◒	◒
TTF	70% energy saving	●	●	○	○	○
Zion	70% energy saving	●	●	○	○	◒

● High Performance (50% or greater savings) ◒ Better Performance (20% to 49% savings) ○ Standard Performance (0% to 19% savings)

Note that all of the buildings had aggressive energy savings goals. Three of the buildings achieved greater than 50% energy cost savings, the Oberlin and Cambria buildings have just under 50% energy cost savings. Only the CBF building has energy performance much lower than expected. All of the buildings, except for the TTF, include on-site energy generation with photovoltaic (PV) systems. The Cambria and CBF buildings had aggressive water use reduction goals that strongly influenced the design process. In addition, Cambria and CBF had aggressive goals for material selection, which guided the selection of materials considered sustainable within the LEED framework.

In general, each of the buildings performs very well in the areas that had clear goals set from the beginning of the design process. The performance in the other sustainability areas is slightly better than standard practice. These projects show that defining specific goals help the design team produce better results.

Setting and following design goals does not guarantee that the goals will be satisfied in actual operations of the building. It is important to continue to track and verify the performance. Commissioning a new building is essential, but it only ensures that the building systems operate as specified. Continual monitoring of the performance using key performance metrics is important to ensure that the goals of the design are met under normal operating conditions. In all of the buildings in Table 1, adjustments were made to the operating buildings to better align the performance with the design goals.

Conclusion

Building performance typically follows the design goals established early in the design process; in other words, you get what you ask for. The projects presented in this paper illustrate this point. When specific and measurable goals are set, the resulting performance is better than if no goals or vague goals are set. Goals help the design team focus their efforts on specific aspects of the design to improve the performance. Performance goals should be set for each performance subtopic area and should follow from a vision statement for the building project. The more specific the goals, the more effective and measurable they become. Another important aspect of setting goals, is determining the best performance metrics to measure the success of the project at meeting the goals. Achieving and maintaining a high-performance building requires a consistent effort, which is absent in most buildings. Continually tracking building performance is expensive and requires a motivated staff. However, advances in metering technology, computerized communications, and automated controls are reducing the costs of monitoring building performance. Additional research is needed to further reduce costs, better optimize control strategies, and improve reliability to realize the full energy savings potential of high-performance buildings.

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The design of most buildings is typically driven by budget, time, safety, and energy codes, producing buildings that just meet these minimum criteria. To achieve better or even exceptional energy performance in buildings, the design team needs to work with the building owner and others involved in the building process toward a focused energy performance goal. This paper describes the performance-based design process for buildings and benefits of this approach.

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