Henry L. Green

High-Performance Buildings

The built environment forms a backbone that is critical to maintaining and enhancing economic growth, competitiveness, productivity, and quality of life. The construction industry in the United States contributes more than one trillion dollars to the yearly gross domestic product , but based on government statistics like those shown in Figure 1, it continues to stagnate or even lose productivity, unlike most other large-scale U.S. businesses.

The construction industry is characterized by a large number of small clients, vendors, designers and contractors who are often not in a position to provide leadership in adopting new technology and practice. Other industry segments, with different structures, have seen more rapid change and significant increases in the productivity of both design and construction. For example, in the process and power industry, the capital cost per kilowatt hour of output from a power plant has declined steadily over the past decade.

The construction industry as a whole, and the government agencies that work with it, have not invested significantly in research and development , and have not adequately demonstrated the technologies that do exist. Often, new methods are tried out only on individual projects, and the result is slow adoption of new technology in the marketplace. Where new technology is developed, it is most often pursued to fill an identified market niche rather than being an industry-wide innovation.

In looking for the reasons for this low rate of productivity, performance, and adoption of technology, it is important to consider the role of codes and standards in building design and construction in maintaining the status quo. As currently structured, the industry is primarily driven by codes and standards that establish minimum requirements; these, in turn, are based largely on typical industry performance levels. Therefore, standards typically only prescribe minimum performance requirements that can be met by most of the design, construction, and manufacturing community. An owner or builder who wants to do better than the min-

Henry L. Green is President of the National Institute of Building Sciences. Before coming to the Institute in 2008, Mr. Green was Director of the Bureau of Construction Codes for the State of Michigan. He is also a Past President of the International Code Council, developer of the International Building Code. The National Institute of Building Sciences is a private, nonprofit organization established by Congress as a single authoritative national source to make findings and advise both the public and private sectors on the use of building science and technology to achieve national goals and benefits.

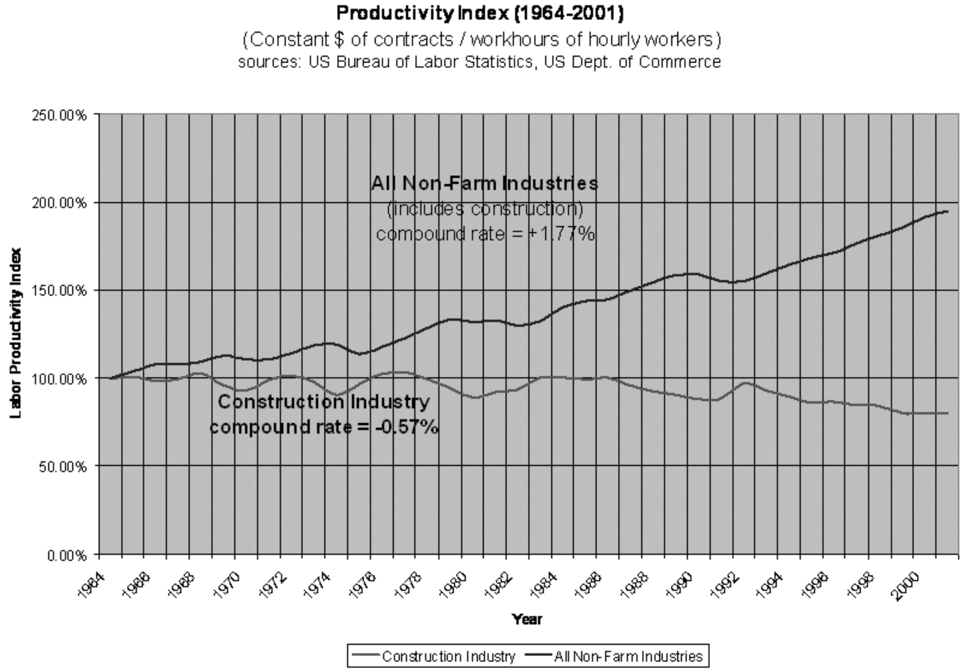

Figure 1. Productivity Index, 1964-2001.

imum will find little in the existing codes and standards to ensure that a building will, in fact, provide higher levels of performance.

Moreover, the nation's building community uses thousands of standards produced by hundreds of standards development organizations. While a few large organizations write multiple standards, most groups write only a handful. Standards do provide a degree of uniformity in a complex and sometimes fragmented industry. When master or guide specifications for a building refer to standards, they impact the entire design of the building, including the levels of quality and performance for selecting and procuring building materials, products, and systems under contractual agreements. When standards are adopted into building codes, they set the requirements for verifying that materials, products, and systems meet a jurisdiction's minimum levels of performance for the safety, health, and welfare of the occupants.

There are only a limited number of standards that significantly exceed the minimum requirements. If a single building's attributes like energy efficiency or safety are maximized without paying attention to other important attributes, the other attributes can end up being sub-optimal. Thus, new requirements are needed to optimize each attribute within the context of overall building performance. A suite of new high-performance standards would enable designers, developers and owners to produce buildings that focus on enhanced performance rather than minimum requirements. Not only will high-performance buildings use much less energy; they also have the potential to improve the health, comfort, and productivity of their occupants. The United States needs to develop an overall strategy to achieve high-performance infrastructure; that strategy must integrate and optimize all the major high-performance attributes including resilience, energy efficiency, sustainability, safety, security, durability, productivity, functionality, and operational maximization.

Owners in both the public and private sectors who seek a higher level of overall performance have not had access to criteria upon which they could base design solutions that will create and maintain greater performance. Perhaps more importantly, they have typically had no compelling reason to request designs or features that exceeded the minimum performance levels found in most U.S. codes and standards.

But high-performance standards open the door to enhanced value. That value may derive from reduced energy and operating costs, lowered maintenance costs, improved functionality and productivity, maximized protection and security, enhanced environmental conditions, sustainability, building durability, or capacity to continue operating after a catastrophic event. Whatever its source, that value has the potential to offer building owners dramatically greater returns on their investments. If high-performance standards permit the designers, builders, and operators of buildings to better understand the cost/benefit implications of design decisions, they can lead to owners deciding to make optional improvements to the building's performance, well above the requirements set by minimum codes and standards.

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It is clear, based on past programs to advance building design, that only a systems approach will achieve those goals in the future. Whether we are changing only one component or rehabilitating the whole system, effective approaches require advice from experienced practitioners of all types. And the value of our actions will be determined by the total performance that results. For all these reasons, the United States needs new metrics and benchmarks, as well as a new set of verification and validation standards, to ensure that we reach our overall performance goals.

At least seven key components of high-performance value must be considered while buildings are being designed and constructed:

1. Design should consider a building from cradle to grave and look for ways to reuse the existing parts in the next-generation systems.
2. Design should stress for durability.

3. Design should aim for energy efficiency and efficient use of materials.
4. Design should make buildings efficient enough to justify the economic use of renewable resources.
5. Better tools and standards for validating and evaluating performance must be developed.
6. Commissioning must be used as a part of the design and construction process: from design intent, through the construction period, and including some post-occupancy tests.
7. Predicted performance must be verified against actual data.

One of the most important attributes of a high-performance building is its inherent durability, i.e., its long-term performance. By appreciably extending the service life of buildings, owners can reduce life-cycle costs and achieve major savings from less frequent retrofits and replacements. A second critical consideration is the incorporation of appropriate passive energy efficiency and sustainability measures that lead to savings from smaller and less-expensive equipment and less fuel use.

The concept of high-performance buildings comes at a time when the design and construction community is being pulled in many directions and needs a framework for balancing competing interests. Several developments confirm that this is the right time to begin a paradigm shift in the production of the built environment: the increasing popularity of sustainable or "green" buildings, the need to address post-9/11 safety and security concerns, the new contractual and delivery methods available to builders, and the market mechanisms driving institutional investors to seek out energy and other efficiencies in their asset portfolios.

The emergence of the need for high-performance buildings provides a valuable opportunity to look deeply at some fundamental possibilities in terms of organization, procurement, research, and technology. We cannot afford to waste the current positive attention surrounding the links between the built environment and energy awareness, energy efficiency, sustainability, asset management, and technological feasibility.

The Energy Independence and Security Act (EISA) of 2007 established a new and aggressive plan for achieving energy independence in the nation's building stock by the year 2030. The act requires that federal buildings (both new buildings and renovations) reduce their consumption of energy from fossil fuels on the order of 55 percent by the year 2010 and 100 percent by 2030. The Act also requires that sustainable design principles be applied to the design and construction of federal buildings. Importantly, the Act defines high-performance buildings as those that integrate and optimize on a life-cycle basis all major high-performance attributes, including energy conservation, the environment, safety, security, durability, accessibility, costs and benefits, productivity, sustainability, functionality, and operational considerations.

We have little choice but to make the EISA timetable. The demand for natural resources is fast exceeding supply on this planet. Environmental preservation and economic, social, and technological development must be seen as interdependent and complementary concepts, where economic competitiveness and ecological sustainability are complementary aspects of the common goal of improving the quality of life.

In many ways sustainability is at the forefront of the environmental movement: taking a holistic-systems approach to defining preferred performance; pushing the science of life-cycle assessment; asking the tough questions about environmental impacts; balancing environmental, economic, and social considerations; and, most importantly, responding to demand by providing and communicating the keys to responsible design. Environmental performance indicators cover the areas of siting/smart growth, energy, atmosphere, water efficiency, public health and well-being, environmentally responsible materials, and social responsibility. Better energy efficiency and decreased aggregate energy usage lie at the heart of sustainable buildings when compared with similarly benchmarked systems, because they can help reduce the use of fossil fuels.

Building functionality means how well a building can meet the needs and services of its users. Maintainability is its capacity to be serviced easily in terms of the functional requirements. Functionality establishes a building's basic characteristic or mission, and maintainability indicates its capacity to maintain that function over time. Today our society's focus is on environmental sustainability. But if we design highly sustainable buildings with poor functionality, that retards productivity, what have we really accomplished? Despite our many standards and protocols for maintainability, relatively little is in place on functionality. A family of useful functionality standards is emerging; though they are not yet widely used, a few federal agencies and large corporations have made a start.

Because so many of the nation's buildings suffer significantly from deferred maintenance, much of the building stock is functionally obsolete if not structurally deficient. We are not going to reach the EISA goals by improving these buildings with the best of existing technology. From a standpoint of design and engineering, transforming this building stock to high-performance buildings will require an unprecedented research effort that will allow us to insert in these buildings a whole new array of advanced materials and intelligent systems.

The deteriorated state of the nation's built environment has led the research community to look at using alternative materials that cost and weigh less, perform better, are more durable, and require less maintenance. Over the past decade, the industry and research institutions have developed a large variety of these new advanced materials and intelligent systems for buildings and for other purposes. This is an important step in the right direction and a foundation for further improvements. We will have to systematically take advantage of these new technologies, and their successors from future research, by moving aggressively to high-performance codes and standards and to accelerated research if we are to succeed in addressing the problem of deteriorating, obsolescent, unsustainable, and vulnerable buildings. A high-performance built environment must be our goal.