A 20-YEAR INDUSTRY PLAN FOR COMMERCIAL BUILDINGS

HIGH-PERFORMANCE COMMERCIAL BUILDINGS

A TECHNOLOGY ROADMAP

Developed by:
REPRESENTATIVES OF THE COMMERCIAL BUILDING INDUSTRY

Facilitated by:
OFFICE OF BUILDING TECHNOLOGY, STATE AND COMMUNITY PROGRAMS
ENERGY EFFICIENCY AND RENEWABLE ENERGY • U.S. DEPARTMENT OF ENERGY
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Challenges for Tomorrow's Commercial Buildings

Thanks to a steady stream of innovations during the 20th century, commercial buildings have become increasingly comfortable and productive places. We often take these marvels of architecture and engineering for granted, as if they were inevitable fixtures of the landscape. Yet there are many reasons to reconsider this landscape. Will our current approaches to commercial buildings fit the changing nature of U.S. businesses and their workforces? And how can we enjoy the benefits of flexible, functional workplaces while also better protecting the natural environment?

This technology roadmap describes the vision and strategies for addressing these challenges developed by representatives of the buildings industry. Collaborative research, development, and deployment of new technologies, coupled with an integrated "whole-buildings" approach, can shape future generations of commercial environments that are highly resource-efficient and that enhance human creativity, productivity, and quality of life in ways we can only begin to envision.

A NEW INITIATIVE

The U.S. Department of Energy's Office of Building Technology, State and Community Programs (BTS) is facilitating industry-led initiatives to develop a series of technology roadmaps. The roadmaps identify key goals and strategies for different areas of the building industry. *High-Performance Commercial Buildings: A Technology Roadmap* identifies a plan for integrating research, development, and deployment for the next generation of commercial buildings in the U.S.

This roadmap initiative is a fundamental component of the BTS strategic plan and will help to align government resources with the high-priority needs identified by industry. The roadmap will guide cooperation among public and private researchers, developers, architects, the many and varied participants in the commercial building industry, and other State and Federal offices to help this industry achieve its long-term vision.

EXECUTIVE SUMMARY

WHAT IS THE "WHOLE BUILDINGS" APPROACH?

Today's commercial buildings employ complex and diverse technologies in their construction, operation, and maintenance. Building materials, components, and subsystems traditionally have been designed and implemented based on standardized criteria that are largely independent of one another. For example, water-heating loads are considered to be solely a function of building use and are calculated independently of a building's plumbing design. Potential interactions between the two functions — for example, heat recovery from outgoing wastewater for pre-heating the incoming supply — are usually ignored.

Through a *whole-buildings approach* — sometimes referred to as "systems engineering" — all of the building components and subsystems are considered together, along with their potential interactions and impact on occupants, to achieve synergies. The fundamental goal is to optimize the building's performance — in terms of comfort, functionality, energy efficiency, resource efficiency, economic return, and life-cycle value. The whole-buildings approach crosses disciplines — requiring the integration of planning, siting, design, equipment and material selection, financing, construction, commissioning, and long-term operation and maintenance. Implementing a whole-buildings approach has been shown to enhance air quality, lighting, and other key aspects of the building indoor environment. The natural environment benefits as well — through energy and waste reduction and more effective land use.

RETHINKING OUR COMMERCIAL LANDSCAPE

Throughout much of human history, work and living spaces coexisted. Farmers lived on their land, merchants above their shops, craftspeople next to their forges and looms. The industrial revolution changed all that, as work became concentrated in factories and offices, at first in the vicinity of the labor force, and later, miles away along the trolley line or highway.

The separation between commercial and residential spheres grew ever sharper during the 20th century. Modern office buildings became possible with the advent of fluorescent lighting and air conditioning, epitomized, at mid-century, by the sealed, self-contained International Style glass box. Today, our daily routines often take us from one specialized, comfort-controlled commercial facility to another — to work, learn, shop, and play — then home to distinctly residential communities.

VISION

By the year 2020 —

- Successful public/private partnerships will deliver highly adaptable, sustainable, cost-effective commercial buildings.
- Advances in building design and operation will provide simple solutions to address the complex interactions of systems and equipment.
- America's commercial buildings will be valued by occupants, owners, builders, and communities as healthy, productive, and desirable places to learn, work, and play.

STRATEGIES

- **Performance metrics.** Establish key definitions and metrics for high-performance commercial buildings.
- **Technology development.** Develop systems integration, monitoring, and other technologies that enable commercial buildings to optimally achieve targeted performance levels over their life cycles.
- **Process change.** Create models of collaborative commercial whole-buildings design and development, and establish the tools and professional education programs needed to support these processes.
- **Market transformation.** Stimulate market demand for high-performance commercial buildings by demonstrating and communicating compelling economic advantages.

Yet in the past few decades, some have begun to question how well commercial building technologies and practices serve emerging needs. Can we afford the environmental consequences of carrying the 20th century model into the future, or can we create commercial spaces that produce less waste, consume less energy, reduce reliance on cars, and minimize land use? Will specialized commercial facilities remain the norm, or will mixed-use buildings and communities better suit the way we live and work today? How must commercial buildings evolve to enhance human health and productivity, and to support the increasingly mobile, digital, and team-based nature of today's businesses?

Developers of this technology roadmap document put these and many other questions on the table over the past two years. They also evaluated the promise of new technologies and practices in the design, planning, siting, construction, and operation of commercial buildings and environments.

MEETING NEW DEMANDS

Their conclusion? That commercial buildings can be dramatically reshaped in the coming decades by combining the results of sound, but separate, research in such fields as energy-efficient building shells, equipment, lighting, daylighting, windows, passive and active solar, photovoltaic, fuel cells, advanced sensors and controls, and combined heating, cooling, and power. Such technologies — together with a ***whole-buildings*** approach that optimizes interactions among building systems and components — will enable commercial buildings to respond effectively to the changing needs of today's businesses, while also helping to meet our national goals of environmental protection and sustainable development.

Specifically, participants crafted their vision for the year 2020 (see sidebar), identified barriers to be addressed, and defined strategies that will help make their vision a reality. Each strategy, as well as associated activities and milestones, is discussed in detail in this document.

BOLD STEPS

New technologies will be essential in realizing the vision for high-performance commercial buildings. At the component level, increased private and public investment is needed in research and development of energy-efficient building materials and equipment, advanced sensors and controls, on-site power generation, and other enabling technologies.

However, pathways for component technologies are the subject of other technology roadmapping efforts being facilitated by DOE and are not described in this document. Instead, the roadmap focuses on four strategic challenges:

- How the benefits of high-performance buildings can be accurately defined and measured and conveyed to the buildings industry.
- How the best existing technologies, as well as future technologies, can be integrated more effectively within a whole-buildings (systems) context.
- How cross-discipline collaboration can become the norm in the siting, design, construction, commissioning and start-up, and operation and maintenance of commercial buildings — a prerequisite to a whole-buildings approach.
- How market demand for high-performance commercial buildings can be stimulated.

INTRODUCTION

"With this roadmap, which represents the work of the finest industry thinkers and practitioners, commercial buildings can be transformed into attractive, affordable, productive workplaces. We are proud to help turn visions of high-performing buildings into reality."

— Mark Ginsberg
Deputy Assistant Secretary
Building Technology, State and Community Programs
U.S. Department of Energy

FOUNDATION FOR PARTNERSHIPS

What demands must commercial buildings meet in the future? What are our "ideals" for future commercial buildings, and how do we get there? How can we speed technology development and deployment in commercial buildings in the next decades? These questions have been at the heart of this technology roadmap process, spearheaded by representatives from many sectors of the commercial building industry.

The Federal government has participated alongside industry in this process. As the largest owner and operator of commercial facilities in the Nation, the government has a strong interest in accelerating research, development, and deployment (RD&D) of innovative building technologies. Facilitation of roadmap meetings and documentation has been performed by the Department of Energy's Office of Building Technology, State and Community Programs (BTS), which manages the largest buildings RD&D program in the Federal government.

In a series of four workshops, participants — including architects, engineers, lighting and other designers, equipment manufacturers, researchers, building owners and developers, facility managers, building trades representatives, utility and energy service company representatives, and financiers — discussed the current state of the industry, significant trends and opportunities, and ways to align public and private RD&D with real-world needs. They also identified areas of market transformation and education where industry participants could cooperate and where the Federal government could play an expanded role. In all, more than 250 individuals from 150 different organizations participated in the workshops and the roadmap development.

JOINING FORCES

By defining the industry's long-term vision and strategies, the technology roadmap can help focus both public and private RD&D investments on the industry's highest priorities. It can also ensure more effective partnerships between industry and government, ascertaining that Federal programs enhance, but do not duplicate, industry efforts, and accelerating the transfer of research results from Federal laboratories to the private sector.

In joining forces to implement this technology roadmap, leaders in the industry will lay the foundation for commercial buildings that are increasingly healthy, comfortable, durable, flexible, secure, energy- and resource-efficient, cost-effective, and attractive to owners, occupants, and communities.

STEPS IN THE ROADMAP DEVELOPMENT PROCESS

EXECUTIVE FORUM

When and where:	July 27, 1998, Cooper Hewitt National Design Museum, New York, New York
Who participated:	36 representatives of the building industry, building-related associations, and interested parties from government and academia
Challenge:	To develop a vision statement and strategic goals for commercial buildings in the year 2020
Results:	Participants defined the history of a whole-buildings approach, explored the current commercial buildings marketplace, and developed a vision statement and strategic goals.

BUILDING DELIVERY WORKSHOP

When and where:	October 22-23, 1998, Cosmos Club, Washington, DC
Who participated:	66 designers, developers, and representatives from the building trades, as well as equipment and component manufacturers
Challenge:	To examine the forces driving or impeding whole-buildings approaches to design, siting, construction, and commissioning
Results:	Participants developed the information contained in the Trends and Barriers sections of this roadmap and explored strategic issues.

BUILDING OPERATION WORKSHOP

When and where:	January 11-12, 1999, The Presidio, San Francisco, California
Who participated:	76 representatives of the building industry, related associations, government, and academia
Challenge:	To define the principal gaps and needs in technology and processes related to the commissioning, operation, and maintenance of commercial buildings of the future
Results:	Participants created detailed action plans to meet identified strategic needs, such as performance targets and first/next steps.

BUILDING TECHNOLOGY WORKSHOP

When and where:	April 27, 1999, Morrison-Clark Inn, Washington, DC
Who participated:	9 futurists and visionaries
Challenge:	To develop a vision of the technology of the built environment in 2050
Results:	Participants brainstormed vision of high-performance commercial building technologies 50 years into the future.

FINAL WORKSHOP

When and where:	October 25-26, 1999, Washington Plaza Hotel, Washington, DC
Who participated:	79 representatives of the building industry, related associations, government, and academia, many of whom attended previous roadmap workshops
Challenge:	To develop a prioritized list of activities for joint industry-government work to further the whole-buildings approach within the commercial building sector
Results:	Participants prioritized activities and identified key steps to successful implementation of the strategies defined in this roadmap.

TRENDS AND VISION

THE ENERGY DIMENSION

Today, the 4.6 million commercial buildings in the United States account for approximately one-sixth of total national energy consumption, or 16 quadrillion BTU[1] and 32 percent of total national electricity consumption. Consumption of electricity in the commercial buildings sector has doubled in the last 18 years, and can be expected to increase by another 25 percent by 2030 if current growth rates continue.

Making commercial buildings more energy- and resource-efficient represents an enormous opportunity to save money and reduce pollution in every community across the country. Indeed, with annual energy expenditures in the commercial buildings sector of $100 billion, an efficiency improvement of *30 percent* would yield $30 billion per year in bottom-line savings. Benefits to the environment would also be substantial, including reduced emissions of sulfur dioxide, nitrogen oxides, and carbon dioxide from fossil-fueled power generation.

Such a 30 percent improvement in energy efficiency can be realistically achieved in the coming decades by applying *existing technologies*. Even more dramatic improvements — ranging from *50 to 80 percent* — could be achieved with aggressive implementation of this technology roadmap, including a long-term approach to research and development. Ultimately, the appropriate use of combined heating, cooling, and power systems, optimized building controls, solar and other forms of renewable energy, and energy-efficient building shells and equipment can produce commercial buildings that become net electricity *generators* rather than consumers.

THE SHAPE OF COMMERCIAL BUILDINGS IN 2020

Major social, economic, technological, and environmental trends are changing the way we work, learn, and play. These changes, in turn, will create new demands on commercial buildings of the future. Here are some of the most evident trends and their possible implications in the coming decades.

Knowledge-based work. With the ongoing growth of the information-based economy, people will be increasingly engaged in highly visual and analytical work. Commercial buildings will be expected to provide reliable, continual, and instantaneous connectivity to information and electronic communications resources. Information technologies will no longer be captive in desktop computers, but will be distributed within the commercial environment, integrated into everything from furniture to windows. Demand will grow for personalized control of lighting, temperature, ventilation, and other aspects of the interior environment to enhance the productivity of knowledge workers.

Collaborative, reconfigurable workplaces. Advanced communications and computing technologies will enable coworkers to collaborate ever more effectively from remote locations, decreasing the need to spend the workweek in shared physical spaces. When colleagues do work together, they will more often require flexible and reconfigurable space, to accommodate team-based activities and frequent organizational and operational shifts. Education will also become more reliant on electronic technologies and team-based activities, redefining the requirements for future schools, libraries, and other learning facilities.

An aging, shifting population base. The mean age of the U.S. population continues to trend upward, increasing the need for ease of access and mobility within commercial facilities. Population will continue to increase in our deserts and on our seacoasts, two fragile ecosystems, requiring increased attention to resource efficiency, energy efficiency, and sustainable practices in commercial buildings.

Urban rebirth. Another trend having an effect on commercial building is the rebirth of urban centers and the corresponding need to reconfigure existing buildings for new uses. To stem over-development in suburban areas, increasing numbers of communities will enact zoning and create incentives to encourage the movement of businesses and residences back into the city.

[1] Source: Energy Information Administration estimates.

Construction labor shortages. Demographic and economic shifts will continue to reduce the pool of skilled construction workers, necessitating less labor-intensive building methods and technologies in the future.

Environmental and health issues. Increasing public concern about environmental issues, coupled with the potential for more stringent environmental regulation, will drive market demand for commercial buildings that minimize resource use and waste in their construction and operation. Demand for healthier and more comfortable indoor environments will also grow as environmental awareness encompasses indoor as well as outdoor areas.

Energy issues. Greater cost-competitiveness of photovoltaics, fuel cells, and combined heat and power — coupled with the purchasing flexibility created by utility restructuring — will make on-site power generation an increasingly viable option for commercial buildings. Shrinking capacity margins in baseload power generation, and resulting concerns about the reliability of power, will further fuel this trend. Demand will also grow for energy-efficient buildings, particularly in areas with relatively high power costs or reliability concerns. Any future controls on carbon dioxide emissions will accelerate the demand for "green" power, renewable energy, and energy efficiency.

Insurance and liability issues. Insurers will exert pressure on the commercial building industry to increase the safety and longevity of buildings. Insurance will be increasingly expensive or unavailable for buildings constructed "in harm's way," e.g., in flood plains or seismic hot spots. Insurers will increase their involvement in building code development and enforcement. Both builders and building component manufacturers will be subject to higher liabilities for failures. Lawsuits related to indoor air quality and other health issues will become more prevalent.

CREATING THE VISION

Against this backdrop of key trends, developers of the high-performance commercial buildings technology roadmap defined their vision for the future:

By the year 2020 —

Successful public/private partnerships will deliver highly adaptable, sustainable, cost-effective commercial buildings.

Advances in building design and operation will provide simple solutions to address the complex interactions of systems and equipment.

America's commercial buildings will be valued by occupants, owners, builders, and communities as healthy, productive, and desirable places to learn, work, and play.

The Intelligent Workplace at Carnegie Mellon University, Pittsburgh, Pennsylvania
Photo: Alan Steel

" 'Smart materials' that can respond to external conditions by changing their color, shape, stiffness, or permeability to air or liquids could become the stuff of the future cities whose buildings are more comfortable and better able to field sudden violent challenges from earthquakes or terrorist bombs. Smart materials also could lead to cities whose infrastructure can sense — and even automatically compensate for — the wounds of corrosion, metal fatigue, age,and other slings and arrows of urban decay."

— Ivan Amato
Stuff, The Materials the World Is Made Of

LOOKING FORWARD

How might these "healthy, productive, and desirable" commercial buildings look and perform? Tomorrow's high-performance commercial buildings are likely to:

Incorporate smart, responsive technologies. Commercial buildings will become almost "alive," using "smart" materials and systems that sense internal and external environments, anticipate changes, and respond dynamically. Through wireless sensors and controls, energy-using components will monitor when and how much they are needed and will adjust their operation accordingly. Individualized control of lighting, ventilation, and thermal conditioning will become possible, and "user profiles" that specify personal environmental preferences will follow an individual through a building (or group of buildings). Uniform protocols will allow control devices to talk to each other and communicate externally. Buildings will aggregate performance information, self-diagnose and correct problems, and alert users to causes of substandard operation.

Reflect sound environmental practices. Tomorrow's commercial buildings will be highly resource-efficient and will make use of environmentally sustainable (low embodied energy) materials. They will also operate efficiently, using 30 to 80 percent less energy than 20th century buildings. Some will even be net electricity exporters, generating their own power through such on-site technologies as fuel cells and photovoltaics, and supplying excess power back to the grid. Sunlight will be used increasingly to produce electricity as well as for daylighting. Passive solar construction and natural ventilation will be regularly incorporated. Buildings will be designed for much greater flexibility and adaptability to reuse, resulting in longer life. Components and materials will also be designed for complete recyclability at the end of their lifetimes.

Be an integral part of sustainable community development. Commercial buildings will become more closely integrated with the surrounding environment. Building philosophy will shift from design of single, stand-alone buildings to campuses or even communities. Resource management will be optimized across the entire community — through strategies such as distributed power generation. More building space will perform double duty as both commercial and residential space. Fewer but better

buildings will be constructed as a consequence. Communities will benefit from better land and resource use, better quality of life, and lower investments in highways and transit, and will structure tax and zoning policies to encourage whole-building development.

Be recognized for their bottom-line benefits to businesses and developers. By enhancing occupant productivity, health, and safety — and reducing life-cycle energy and operating costs — high-performance commercial buildings will make measurable contributions to the bottom line of tenant businesses. Financiers and insurers will acknowledge high-performance buildings through favorable lending and underwriting practices, and will also market high-performance building modifications as an option to their customers. Developers will realize better asset value as a result of the strong market appeal, adaptability, and long life of high-performance commercial buildings.

Be designed for simplicity and safety. Future buildings will be ever simpler to construct and operate. Design and building techniques will enhance construction safety, reduce development and construction time, and cut labor intensity. Building controls and subsystems will be intuitive and elegant, requiring minimal technical expertise to operate and maintain.

4 Times Square, New York City
Photo: Andrew Gordon,
Fox & Fowle Architects

A MODEL IN MANHATTAN

Project: 4 Times Square

Developer: Durst Organization

Project Architect:
Fox & Fowle Architects, P.C.

Construction Manager:
Tishman Construction Corporation

Project Engineer:
Cosentini Associates

4 Times Square, at the intersection of Broadway and 42nd Street, is the first Manhattan office tower to incorporate "green" standards — energy-efficient design, indoor ecology, sustainable materials, and on-site power generation. Highlights of this 1.6 million-square-foot, 48-story building include:

- The ability to generate some of its electricity with on-site fuel cells — large, natural gas "batteries" that create power through a chemical reaction. They run cleanly and quietly 24 hours a day. No combustion is involved and waste products are hot water and CO_2.
- The use of building-integrated photovoltaic (PV) panels on limited areas of the facade. Peak output is about 15kW, enough electricity to run five suburban homes.
- The use of DOE-2, state-of-the-art software for analyzing a building's energy use. It can accurately model and compare potential energy savings from a variety of technical options.
- A ventilation system that provides tenants with 50 percent more fresh air than required by code.

Use of whole-building standards has reduced energy costs at 4 Times Square by an estimated $500,000 annually compared to expected costs in a traditionally constructed building, resulting in a payback period of five years or less.

BARRIERS

RELATED TECHNOLOGY PATHWAYS

Component-level technologies — such as lighting, windows, building envelopes, and heating, ventilation, and air conditioning systems — are the subject of other technology roadmap efforts under way by industry experts, with the facilitation of DOE's Office of Building Technology, State and Community Programs. As these roadmap activities progress, and particularly throughout the implementation phases to come, *High-Performance Commercial Buildings: A Technology Roadmap* will evolve as well, to reflect improvements in capabilities and costs at the component level.

Similarly, improved technologies for on-site power generation — including photovoltaics and fuel cells — will benefit high-performance commercial buildings. While mapping the RD&D pathways of these technologies is beyond the scope of this technology roadmap, it is expected that advances in component technologies will be closely monitored and exploited by high-performance building advocates.

NEED FOR INNOVATION

By 2020, high-performance commercial buildings can be making substantial contributions to sustainable community development and environmental protection, and also returning healthy bottom-line benefits to tenant businesses in the form of energy savings, operational savings, and productivity improvements. What will it take to get there?

Overcoming technology barriers will certainly be vital. Achieving the integrated, "smart" buildings of the future, together with higher levels of energy- and resource-efficiency, will require continued research and development, with a focus on **system integration and monitoring**, as well as component optimization.

Although technology challenges are significant, they are dwarfed by the need for:

- **Clear performance metrics** that make a compelling economic case for and help define high-performance commercial buildings,
- **Changing the process** by which building planning, design, construction, and operation and maintenance are conducted — enabling a collaborative whole-buildings approach, and
- **Market transformation**, to overcome the current lack of demand for high-performance commercial buildings.

The developers of this technology roadmap emphasize the need for increased investment by both the private and public sectors to address fundamental barriers in all four areas: **performance metrics, technology development, process change**, and **market transformation**. Challenges in each area are discussed below.

NEED FOR CLEAR PERFORMANCE METRICS

A compelling case for high-performance commercial buildings must be proven. The whole-buildings approach seeks to achieve low total costs over the life of the building, by minimizing energy and resource consumption, simplifying operational and maintenance requirements, and extending building life. However, the "first costs" for a whole-buildings development can often be higher than for traditional approaches. For example, the whole-buildings approach may entail higher capital expenditures for sophisticated lighting and windows, nontraditional construction to maximize daylighting, and investments in on-site power generation equipment. It may also require additional upfront investments by the owners, developers, designers, contractors, and other key parties.

Justifying higher initial costs in order to realize lower life-cycle costs is a difficult sell in the commercial development world, where the driving force is to keep first costs as low as possible. Life-cycle operational costs and performance issues — such as the quality of the indoor air or functionality of lighting — are seldom on the table at contract-signing time. Developers and builders generally have no stake in the long-term operating costs or performance of the building, and are rewarded based on their ability to control first costs. The ultimate building occupants typically have little voice in design and construction decisions, and are seldom able to quantify how the benefits of lower operational costs or improved building performance might justify a higher initial investment.

Measurable, defensible, and reproducible financial returns will be needed to create markets for commercial whole buildings. What are the broad-based, life-cycle benefits — in energy and resource use, operational cost savings, asset value, productivity of tenant businesses, and sustainable community development? And what returns will developers and communities realize by investing in high-performance buildings? Anecdotal evidence, while valuable, is not sufficient to spark widespread adoption of whole-buildings approaches, particularly given the large investments and risks involved in a typical commercial building. Determining which performance metrics are of greatest value, and their most reliable means of measurement and reporting, are core challenges.

TECHNOLOGY CHALLENGES

Research, development, and deployment efforts will be essential in realizing the vision for high-performance commercial buildings. Improvements are required in building components and equipment, as well as in how these elements are integrated within a whole-building, and even whole-community, systems context.

Systems integration challenges — rather than component-level technologies — are the focus of this technology roadmap. (Key components and subsystems are the subject of other DOE-facilitated technology roadmap efforts, as described in "Related Technology Pathways.")

Despite tremendous advances in computing and control technologies, most buildings are still relatively "dumb" in their operation. For example, even though heat generated by lighting and office equipment is integrally related to building heating and cooling loads, these building functions are generally operated independently and are often at odds. Interior offices are cut off from natural light. Ventilation systems are out of sync with the configuration of offices and hallways. Buildings respond reactively to external conditions rather than proactively anticipating them, and inefficiencies abound. The results are utility bills higher than necessary and tenant dissatisfaction.

The commercial buildings vision calls for new technologies to overcome the inefficiencies. In particular, it foresees **whole-building design tools** and **smart, integrated building controls** that enable optimized interactions among such subsystems as heating, lighting and daylighting, ventilation, and the building envelope. Whole buildings will be designed for optimal utility, environmental performance, and life-cycle value, and will essentially control themselves to maintain targeted performance. Critical barriers that must be addressed include lack of standard protocols for interoperability, difficulty and expense in retrofitting existing buildings, and restrictive building codes. In addition, advances will be needed in the performance and cost of sensors and wireless control technologies.

BARRIERS

Commercial buildings are those designed, built, and operated for any use other than residential, including everything from schools to hospitals, offices to grocery stores. These buildings can be dedicated to a single, homogeneous use such as a corporate headquarters, or they can be a complex combination of rooms for public interaction, space for commercial activity, classrooms, workspaces, cooking and dining facilities, and even living quarters, such as those found in dormitories.

REQUIREMENTS FOR PROCESS CHANGES

Developing a high-performance commercial building is a team effort, requiring close collaboration among building owners, architects, engineers, financiers, managers and operators, building trades representatives, contractors, and other key players. The starting point: to reach agreement on the system requirements — i.e., the performance (economics, energy, productivity, resource, recyclability) targets to be set for the building. Collaboration is needed throughout the siting, design, construction, and commissioning process to make the holistic evaluations and tradeoffs leading to optimal solutions. In the years to follow, ongoing collaboration is also needed to monitor building performance and evaluate lessons learned.

This kind of integrated building design and construction process departs radically from the approach used today, in which each discipline in the fragmented development process performs its work largely in isolation from the others and often with very different driving goals. Its widespread adoption will require new channels, tools, and methodologies for collaborative communication, problem solving, and decision making across these disciplines. Restructuring compensation and incentives may also be necessary — for example, basing a portion of fees, commissions, and rental incomes on how successfully the building achieves targeted performance requirements. Liability issues — such as those associated with making performance information public and tracking responsibility for design changes — must be addressed as well.

Owens Corning Headquarters, Toledo, Ohio
Photo: Timothy Hurfley

MARKET-TRANSFORMATION CHALLENGES

Stimulating market demand for high-performance commercial buildings hinges on demonstrating a compelling economic case, as described under “Need for Clear Performance Metrics.” In addition, several critical barriers must be overcome:

Fragmentation within the commercial buildings "industry." A defining characteristic of the U.S. building sector is its fragmentation. Hundreds of thousands of companies of all sizes design, build, finance, equip, own, or manage commercial buildings. Collaboration and communication among these companies is minimal, even in the context of a joint building project. People designing buildings typically do not own them, and the people providing financing are not those who will inhabit them. Carpenters work independently of plumbers, who in turn work separately from electricians, who wire components already installed by the heating, ventilation, and air conditioning contractors. Component manufacturers generally sell through representatives and have no direct connection to designers, developers, and owners or users.

The high degree of industry fragmentation greatly complicates the process of implementing and marketing commercial whole-building concepts, since no single company or professional association influences the full range of disciplines and functions involved. It also limits private-sector research, development, and deployment of new technologies. Individual companies are seldom large enough to risk sizeable investments on their own or to capitalize on any resulting innovations, and mechanisms for joint investments by the diverse industry parties are virtually nonexistent.

Financing barriers and tax disincentives. Commercial building is by nature speculative and uncertain. Financing tends to reward conservative practices and impede innovation. When tax incentives and special financing options are offered, they are usually for individual components (such as HVAC systems) rather than for whole-building design approaches. As a result, developers and designers first pursue options for which incentives are offered, and design strategies for whole-buildings may be suboptimal or neglected altogether. In addition, the current tax code actually discourages saving energy: energy costs are deductible against income — thus saving energy may actually increase a building owner’s income tax liability.

Lack of holistic regional planning. Commercial building locations are still determined based on an underlying assumption of cheap transportation and continued road building. As a result, many communities are marked by a sharp distinction between where people work and where they live. Given the long lifetime of such infrastructure, regions can be locked into inefficient patterns for decades. In contrast, a commercial whole-buildings approach to urban planning and site development might engage regional decision-makers in evaluating the cost savings and environmental benefits of building fewer roads and reducing commuter traffic, and might weigh these factors in a total cost/benefit evaluation. Effective models of holistic regional planning will be required, together with metrics that demonstrate the financial returns to communities.

“The High-Performance Commercial Buildings *roadmap initiative represents a unique and important opportunity for whole-building integration and optimization of the many factors that impact how our buildings consume energy, impact the environment, and affect our lives as building occupants.”*

— Steven Winter, FAIA
Chairman, U.S. Green Building Council

STRATEGIES

Commercial buildings and their corresponding energy and resource use cast long shadows into the future. One indication: in 1995 more than a third of existing commercial building floor space had been built prior to 1960.[2] Efforts to promote high-performance commercial buildings practices must take existing buildings into account, as well as new construction.

[2] Source: Energy Information Administration, Commercial Buildings Energy Consumption Survey.

TAKING BOLD STEPS

Four interrelated strategies will be key to advancing the high-performance commercial buildings vision. Each strategy must address the unique requirements of rehabilitation projects, as well as of new construction.

- **Performance metrics.** *Strategy: Establish core definitions and metrics for high-performance commercial buildings.*
- **Technology development.** *Strategy: Develop systems integration, monitoring, and other technologies that enable commercial buildings to optimally achieve targeted performance levels over their life-cycles.*
- **Process change.** *Strategy: Create models of collaborative commercial whole-buildings design and development, and establish the tools and professional education programs needed to support these processes.*
- **Market transformation.** *Strategy: Stimulate market demand for high-performance commercial buildings by demonstrating and communicating compelling economic advantages.*

Ongoing cooperative efforts by both private and public sectors will be essential in implementing these strategies. New alliances must be formed among such diverse groups as building owners (BOMA), facility managers (IFMA plus Federal, e.g., Department of Defense, General Services Administration, Department of Energy), architects (AIA), engineers (ASHRAE), realtors (NAR), insurance industry representatives, bankers, appraisers, union representatives, property developers (ULI), community planners, academics, and researchers, plus policymakers at the regional, State, and Federal levels.

The Federal government has key roles in cost-shared research, development, and deployment projects; standards-setting that supports high-performance buildings; sponsorship of demonstration projects at government-owned facilities (e.g., through the General Services Administration); and ongoing implementation of the technology roadmap (e.g., convening, facilitating, documenting, and disseminating information).

Thoreau Center for Sustainability, San Francisco
Photo: Courtesy of the Thoreau Center

PERFORMANCE METRICS

STRATEGY—Establish core definitions and metrics for high-performance commercial buildings.

Activity

Define *what* to measure — i.e., determine the central characteristics of high-performance commercial buildings. As part of this effort, conduct market research to determine what characteristics would be most highly valued by different categories of customers.

Define *how* to measure — i.e., determine methods for measuring performance of commercial whole buildings over time (building performance indices), and for collecting representative data on a valid scale.

- Develop national protocol(s) for organizing, storing, and retrieving this information. Draw on methods already being used in the marketplace, for instance the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System, DOE's International Performance Measurement and Verification Protocol (IPMVP), and industry standards such as ASHRAE's Standards 55, 62.1, and 90.1, and Guidelines 10, 14, and 18.

Determine how to apply the metrics to enable key audiences to evaluate costs and benefits of high-performance building investments (including opportunities to improve the performance of existing buildings, as well as to optimize projected life-cycle value of new buildings).

- Establish methods for evaluating total life-cycle costs and benefits for owners (e.g., asset value); occupants (e.g., productivity gains, lower insurance and workers comp, energy and O&M cost savings); and communities (e.g., enhanced land use, regional development, environmental protection).

TECHNOLOGY DEVELOPMENT

STRATEGY—Develop systems integration and monitoring technologies that enable whole buildings to achieve optimal, targeted performance over their life cycles.

Activity

Develop verifiable design and performance analysis models and tools that enable component and system optimization (e.g., automated decision-support tools).

Develop methods to improve interoperability among architectural, mechanical, electrical, plumbing, and other key building subsystems, working with standards organizations.

Develop cost-effective, reliable monitoring and control technologies (e.g., indoor air quality sensors, wireless sensors and controls) to ensure that performance targets are met throughout building life.

- Promote "plug-and-play" simplicity and integration for monitoring and control technologies.
- Gauge the cost-effectiveness of sensor systems and increase the reliability of volumetric airflow sensors, self-diagnosing sensors, and self-calibrating sensors.
- Apply sensors technology to building cleaning and maintenance.

PROCESS CHANGE

STRATEGY—Create models of collaborative high-performance commercial building design and development, and establish the tools and professional education programs needed to support these processes.

Activity

Develop, pilot, and document new models of collaborative whole-building design and development, and create implementation guidelines for applying such processes.

- Evaluate existing models and tools for collaborative design, such as charrettes, retreats, and web-based processes.
- Research the current dynamics of commercial building financing, permitting, design, contracting, and procurement processes, and identify key barriers that must be addressed in whole-building models.
- Develop models of high-performance commercial building design, construction, and operation processes that extend beyond the boundary of the building (e.g., approaches to clustered development such as eco-industrial parks).

Create tools (e.g., software, communications) to support integrated decision-making in commercial building design, construction, operation, and renovation.

Establish educational programs for professionals who are key to implementing and supporting commercial whole-buildings approaches.

- Establish whole-building curricula as an integral part of formal education and continuing education for architects, designers, and engineers.
- Establish a new architectural specialty — the building producer — that focuses on the collaborative process facilitation and systems integration requirements of whole-building development.
- Develop educational initiatives for contractors and unions on commercial whole-building processes, including apprenticeships and professional development programs.

MILESTONES (Examples)

YEAR 2	YEAR 3
Pilot projects to model and document whole-building development processes are initiated. Foundation dedicated to sustainable whole-building development is established. Banks offer high-performance commercial mortgages. Change is made in tax laws to revise depreciation schedules. Harvard Business Review (HBR) article is published on topic. Whole-building processes are featured at a professional association national conference.	At least one integrated tool for collaborative design is developed (year 3). Five cities or government agencies adopt whole-building protocols.

MARKET TRANSFORMATION

STRATEGY—Stimulate market demand for high-performance commercial buildings by demonstrating and communicating compelling economic advantages.

Activity

Demonstrate and document the economic case for high-performance commercial buildings through pilots and case studies.

Define and promote tax and financing incentives that would support commercial whole-building approaches.

- Pursue tax incentives (e.g., revised depreciation schedule), financial market discounts, favorable insurance policies, Federal subsidies for research, and required changes in building codes and standards.

Develop and implement a strategic communications and marketing plan addressing all key audiences (e.g., architects, engineers, builders, facility managers, building trade unions, financiers, insurers, policymakers, community planners, researchers, environmental groups, general public).

- Communicate successes and best practices (e.g., through general and business media, trade media, industry events, and professional development programs).
- Sponsor competitions and conferences; work with organizations such as the Urban Land Institute (ULI), Building Owners and Managers Association (BOMA), International Facilities Management Association (IFMA), and professional societies to develop awards programs to showcase new best practices.

Develop and promote a "brand name" and identity for high-performance buildings (e.g., a simple, well-communicated program similar to the ENERGY STAR model).

YEAR 5	YEAR 10	YEAR 20
First high-performance building REIT (Real Estate Investment Trusts) is formed. GSA and other Federal agencies adopt whole-buildings approach as standard practice for new construction and retrofit projects. First draft of building performance indices is available for public use.	25% of new buildings and major rehabilitation projects employ whole-building design.	70% of new buildings and major rehabilitation projects employ whole-building design.

NEXT STEPS

A VIEW OF A POSSIBLE FUTURE

Commercial buildings in 2020 will feature:

- Organic, dynamic envelopes (like human skin)
- Microscale thermal conditioning sources, individually controlled
- Dynamic, personalized ventilation (decoupled from conditioning)
- Organic composite materials
- "Plug-and-play" components and systems
- Waste source materials
- Solid-state sources for lighting, coupled with dynamic levels and daylighting
- Distributed energy resources at the site level (photovoltaic, fuel cells, combined cooling, heating, and power)
- Water resources, biological treatment integrated with technological, zero discharge
- Digital wireless microsensors, personalized building controls, and metering
- Product as service: lease rather than purchase

Buildings will be considered as part of a larger "whole community" (where the best building may be no building). The focus of building finance will become long-term, taking into account life-cycle benefits (versus today's 3-year horizon).

High-Performance Commercial Buildings: A Technology Roadmap outlines an ambitious vision for the buildings industry. It serves as a resource for both the public and private sectors and offers a framework for greater collaboration across the industry in creating new market opportunities for high-performance commercial buildings. The roadmap also provides guidance for the Department of Energy and other agencies in planning future activities, particularly in forming research and development partnerships with industry.

The technology roadmap intentionally excludes detailed implementation approaches. These will be jointly developed between government and industry as the roadmap's strategies are analyzed and enriched. One early implementation step will be to investigate existing efforts already under way and determine how these might be leveraged to further the commercial buildings vision and avoid duplication of effort.

Feedback on the technology roadmap is welcome. In particular, DOE and other sponsoring organizations welcome input on which of the identified activities most directly relate to your organization's goals and needs, and whether your organization would want to be an active participant in implementing these activities. To become involved, contact one of the co-sponsoring organizations, or

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commercial_roadmap

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A NOTE FROM…

Drury Crawley, Team Leader
High-Performance Commercial Buildings: A Technology Roadmap

As team leader of the roadmap development process for DOE's Office of Building Technology, State and Community Programs (BTS), I wish to thank the hundreds of organizations and individuals that contributed to this significant effort. In particular, I want to acknowledge the crucial guidance of the Commercial Roadmap advisory group: **Bill Browning**, Rocky Mountain Institute; **Jim Cole**, California Institute for Energy Efficiency; **Rick Fedrizzi**, Carrier Corporation; **Jim Hill**, National Institute of Standards and Technology; **Steve Kendall**, Housing Futures Institute, Ball State University; **Gail Lindsey**, Design Harmony; **Tom Phoenix**, Moser Mayer Phoenix Associates; and **Jim Yi**, Johnson Controls.

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Throughout the development of the roadmap, the participants have been an extraordinarily inspired, energetic, and expert group. We look forward to working with them and many others in realizing their vision for high-performance commercial buildings.

The organizations that participated in developing this roadmap include:

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CH2M Hill
City and County of San Francisco
City of Oakland
City of Seattle
Con Edison Solutions
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(continued on next page)

COMMERCIAL BUILDINGS ROADMAP WEB SITE

For up-to-date information on implementation, refer to the High-Performance Commercial Buildings Roadmap Web site at www.eren.doe.gov/buildings/commercial_roadmap

(continued)

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York International Corporation

JUST AHEAD

BETTER BUILDINGS

HIGH-PERFORMANCE COMMERCIAL BUILDINGS

A TECHNOLOGY ROADMAP

Tomorrow's commercial buildings will be healthier, more productive, and more desirable places to learn, work, and play.

Find out how the "whole buildings" approach will make it possible.

For more information, contact:

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Call the Energy Efficiency and
Renewable Energy Clearinghouse at:
1-800-DOE-3732

Or visit the Commercial Buildings Roadmap Web site at:
www.eren.doe.gov/buildings/commercial_roadmap

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