Developing a Roadmap to the 21st Century for Commercial Buildings

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ABSTRACT

The U.S. Department of Energy (DOE) has been working with the buildings industry to develop a "technology roadmap" for Commercial Buildings. This roadmap is a plan for research, development and deployment activities relating to commercial buildings for the private and public sectors over the next 20 years. DOE has been working with various parts of the buildings industry on four roadmaps: Commercial Buildings, Lighting, Windows, and Building Envelope. DOE plans to begin developing other roadmaps in 2001.

Four major strategies are emerging from the Commercial Building Roadmap: Process Change, Market Transformation, Performance Metrics, and Technology Development. This paper describes the progress to date on the Commercial Building Roadmap, outlines the major activities proposed, and presents progress towards implementation.

Introduction

In 1998, the U.S. Department of Energy's Office of Building Technology, State and Community Programs (BTS) began a process that involves the buildings industry in developing a "technology roadmap" for Commercial Buildings. A technology roadmap is a plan for research, development and deployment activities for both the private and public sectors over the next 20 years. DOE is facilitating the effort, not leading it. DOE has begun working with the buildings industry to develop roadmaps in four areas: Commercial Buildings, Lighting, Windows, and Envelope. DOE plans to work with the buildings industry on other roadmaps in 2001. This paper describes the progress to date on the Commercial Building Roadmap.

What is a Technology Roadmap?

A Technology Roadmap is a plan for industry (in this case, the commercial buildings industry) that outlines technological or market goals, milestones, and how the relevant players—both public and private—fit into it. Essentially the roadmap is a "big picture" of where the industry sees itself going over the next few decades. Roadmaps generally contain the following elements:

- Trends and drivers: factors that shape the industry environment, both internal and external;
- Performance targets: technical or market-based industry goals;

- Technology barriers: obstacles to technology deployment (technical, financial, regulatory, information-based, or otherwise);
- Research, development, and deployment needs: technical and other activities required to move the industry from its current state to its performance targets; and
- Potential government role: areas where government can make an effective contribution.

A roadmap is a work plan for moving the building industry from the current situation to the place industry desires to be in the future. In this regard, industry input is critical in producing the technology roadmap. Ultimately, industry must carry out the activities identified in the roadmap.

What Are Commercial "Whole" Buildings?

Commercial buildings include everything from schools to hospitals, office buildings to grocery stores. They can be a single use such as an office building, or complex combinations of offices, cooking and dining facilities, and even living space as with hospitals. Essentially, they are buildings that are designed, built, and operated for any use other than residences or industrial processes.

As the uses for buildings and demands on them have multiplied, they have evolved into increasingly complex aggregations of diverse technologies (ranging across construction materials and practices, building equipment, and maintenance and operation). These technologies have generally 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 the building's plumbing design. Potential interactions between the two, e.g., heat recovery from outgoing wastewater for preheating the incoming supply, are thus generally missed.

The "Whole Building" concept is a departure from the standard way that buildings have been designed and constructed over the last century. Through a whole building (or "systems engineering") approach, all of the building components and subsystems are considered together along with their potential interactions. The goal of this approach is to capitalize on potential opportunities while mitigating or eliminating negative interactions among subsystems. The treatment of the building as a set of interrelated systems offers much potential in the way of energy and resource efficiency and is a key component in the developing field of sustainable construction.

Why Create A Road Map for Commercial Buildings?

Commercial buildings in the United States are responsible for roughly one-sixth of all the energy used by the nation, along with the environmental consequences of that energy use. A large opportunity exists to improve the resource efficiency of commercial buildings through a whole buildings approach, both in their construction and operation, while simultaneously enhancing the indoor environment and improving worker well being. The current roadmapping activities are intended to greatly accelerate the implementation of this approach in the commercial buildings sector.

The Federal Role

The buildings industry is different from other industries (e.g., automotive) in that it consists of many hundreds of thousands of companies that design, build, finance, and manufacture products for the buildings market. These firms range from small businesses of just a few employees to major corporations with large market shares. These companies and individuals typically do not coordinate their efforts and in fact may never even communicate given their disparate roles during the life of a building. It is rare indeed when the building designer, builder, owner, operator, and occupant are all members of the same firm or when they are all involved throughout the entire construction and delivery process.

The fragmented nature of the buildings industry means that much needed research and development cannot be performed by the private sector, nor can the improvements developed by one small company disseminate through and change the industry for anything short of a miraculous improvement. These are areas where the Federal role is most effective: supporting or encouraging R&D that would not be performed in the government's absence, and promoting the adoption of successful technologies through education and training efforts and other deployment activities.

The Federal Government is facilitating the production of this Commercial Buildings Roadmap—bringing various industry groups together, with the intent of encouraging the development and use of a whole buildings approach in the commercial buildings sector. Despite the benefits to both the industry and the nation of such an approach, it would be slow to develop, if ever, in the absence of such a facilitator. The road map developed as a result of this exercise will articulate future roles of both the Federal Government and the private sector in attaining the vision described in the industry vision statement.

Commercial Building Situation Analysis: Where We Are Today

Building Market

There are over 4.6 million commercial buildings in the U.S. as of 1995, according to Energy Information Administration estimates (EIA 1997). Together, these buildings total over 58.8 billion square feet of floor space. Of this floor space, more than half was built before 1970. Less than 10% of the building stock has been built since 1990.

Four building activity types—mercantile and service, office, warehouse and storage, and education—account for 67% of the total floor area (see Figure 1). Mercantile and service was the largest category with 22%, office space next largest at 18%, followed by Warehouse and Storage facilities (14%) and Educational buildings (13%). The remaining third of floor space is shared among a variety of uses.

On a floor-area basis, over 80% of commercial buildings are owner-occupied. This includes government-owned buildings, which account for over one-fifth of commercial floor space. Local governments dominate the government ownership category (13%), with the remaining floor space about evenly split between the Federal (3%) and state governments (4%).

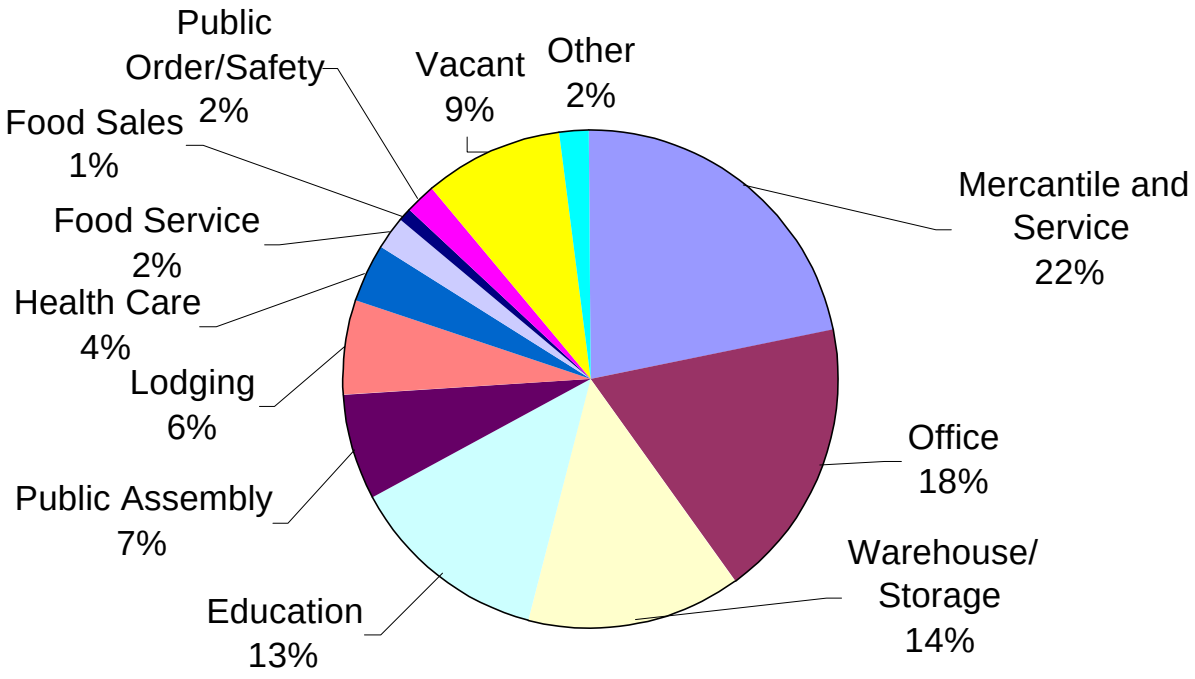

Figure 1. Percentage Floor Space by Principal Commercial Building Type, 1995

On a total floor area basis, buildings less than 10,000 ft^2 account for 21% of the total, those between 10,000 and 50,000 ft^2 account for 30%, those between 50,000 and 100,000 ft^2 are 12%, and those greater than 100,000 ft^2 are 36%. Less than 10% of all floor space is in buildings of one-half million ft^2 or more in size. Of the total number of commercial buildings in the U.S., more than half are 5,000 ft^2 in area.

New commercial building construction was valued at almost $170 billion in 1996 (US Department of Commerce 1996). Almost another $100 billion was spent on renovations and repairs (USDOC 1998). According to a sample of over 400 respondents that had recently renovated commercial buildings, nearly 95% of these renovation/improvement projects involved energy conservation measures, and most (70%) projects included measures to resolve indoor air quality projects (Buildings 1996).

Energy Use

Energy is used to provide a wide variety of services in buildings including occupant comfort (temperature and humidity control), lighting, water heating, and power to drive appliances and other miscellaneous electrical devices. The US consumed almost 93 quadrillion BTUs (Quads) of energy in 1996. Of this total, commercial buildings accounted for over 11 Quads. This is roughly equivalent to the amount of gasoline consumed annually by the nation's cars.

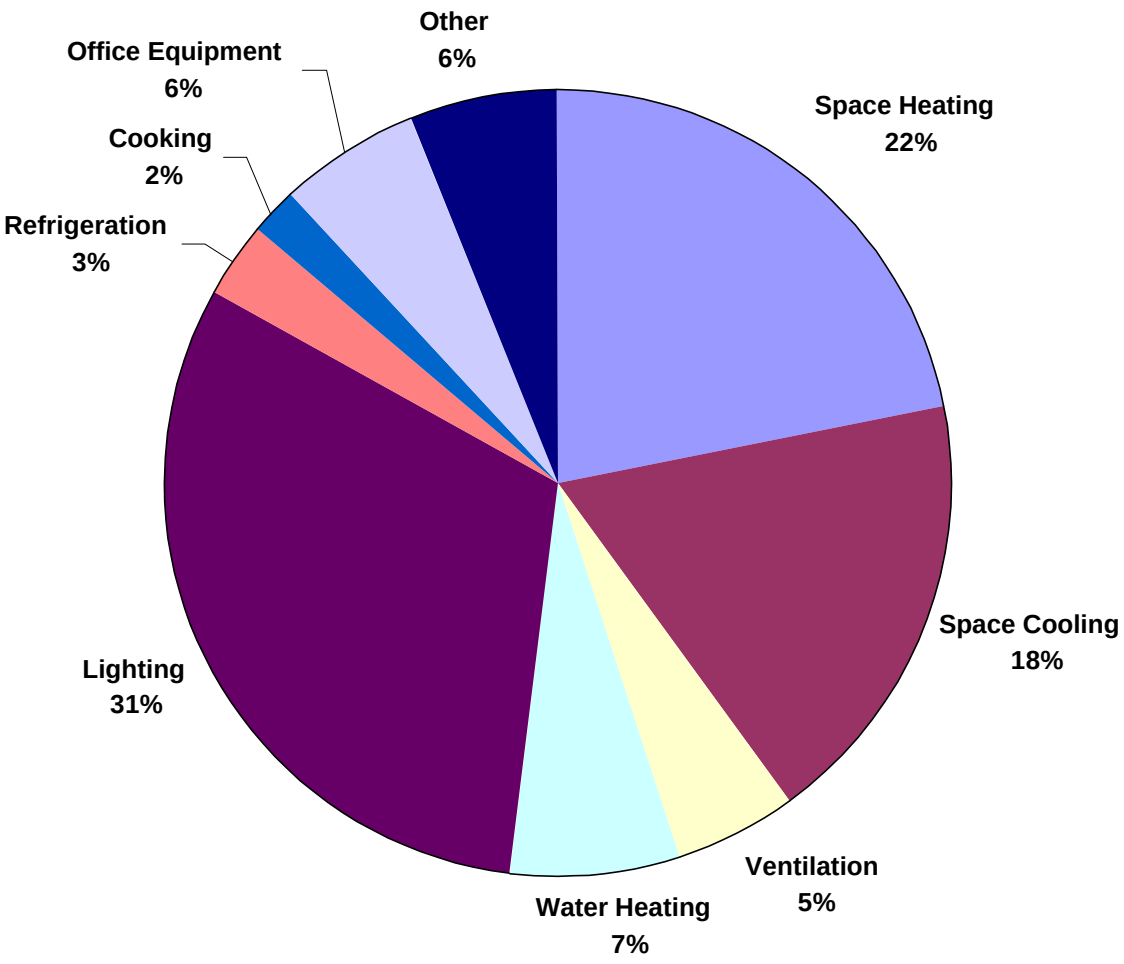

Figure 2. Commercial Building Energy End-Uses, 1995

The energy total includes not only energy consumed directly on-site, but also the coal, gas and nuclear fuel consumed at the power plant to produce electric and district heat services. Together these are called primary or sometimes source energy.

When considering total source energy consumption, space conditioning (heating, cooling, and ventilation) represents that largest use of energy in commercial buildings and is nearly half of total use (see Figure 2). At 30% of the total, lighting is another large use representing. Computers and other miscellaneous office equipment are a growing source of energy usage in commercial buildings.

The annual energy bill in commercial buildings was almost $70 billion in 1995. Three-quarters of this cost was for electricity alone. However, on a square foot basis, energy costs were only $1.19/ft^2. The highest costs of energy were in food sales ($4.11/ft^2), while office space was near the average at $1.51/ft^2.

Despite these relatively low costs, energy services are closely tied to occupant safety and comfort. Lighting, temperature, and air quality are relate to energy. Further, improvement to energy efficiency nearly always can have positive impacts for occupant comfort as well as contribute to the bottom line.

Roadmap Process

The DOE is facilitating development of the industry-led roadmap for commercial buildings using a three-step process:

- Visioning: 'where should we (commercial buildings industry) go?
- Roadmap: 'what needs to be done?
- Implementation: 'what should be done and who should be involved?

Progress on the first two steps is described below.

Vision: Where We Hope to be in 2020

A draft vision statement was developed at an Executive Forum of industry leaders in July 1998. This Executive Forum included developers, contractors, owners, architects, engineers, visionaries, other design professionals, building operators and managers, manufacturers, finance, utilities, and researchers. According to the draft vision statement, by the year 2020:

- Successful public/private partnerships will deliver highly adaptable, sustainable, and cost-effective commercial buildings.
- Advances in building design and operation will provide simple solutions for 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

Industry representatives gathered in October 1998 and January 1999 to identify strategic needs and develop detailed action plans for achieving the 2020 vision[1]. They identified four strategies for implementing the commercial building roadmap:

Process Change. The overall building process needs to be revolutionized to eliminate fragmentation and minimize inefficiencies and lost opportunities. An example of change needed is early and continued collaboration between the various players, i.e., building owners and architects, financiers and operators, unions, etc. Each construction effort should start with a definition of the project and establish and communicate goals from the outset of design, with each party contributing their perspective to the discussion. Such high levels of collaboration should continue throughout the construction process and even beyond to gather feedback on successes and lessons learned. This kind of cooperative, integrated building construction process constitutes a fundamental change from the more isolated, parallel building activity approach that exists at present. Key steps in this area include:

- Developing a quality assurance program for building performance that is adopted by 70% of buildings constructed in the year 2020.

[1] These two workshops focused on Building Delivery and Building Operation respectively. Two subsequent workshops were held in April 1999 to brainstorm future technologies needed to achieve the vision and in October 1999 to further develop the RD&D activities in the Roadmap.

- Creating a receptive audience for the adoption of a Commercial Whole Building approach. The goal is to have this approach used for 70% of new buildings and 45% of existing buildings by 2020.
- Establishing incentives to drive early collaboration in the design, siting, construction, commissioning, and operation and maintenance of commercial buildings.

Market Transformation. The sheer size of the built environment limits the relative impact of new ideas or technologies despite their merits on an individual basis, until their implementation has crossed a sufficient market threshold. A recognized market for new technologies leads manufacturers or other market participants to create products to address that market, in turn spawning competitive innovations and resulting new markets. However, sometimes incentives or assistance of various types are needed to encourage initial progress in particular areas or to overcome consumer caution related to state of the art innovations. Targeted deployment activities to do this can be crucial in the initial stages of a new innovation like the whole building approach. Key steps in this area include:

- Proving the concept of a commercial whole building approach through case studies and a database of stellar buildings and examples of good performance and operations, including studies of productivity and user impacts.
- Developing an overall marketing plan for commercial whole buildings.
- Transforming the market for Commercial Whole Buildings by conducting market testing and analysis to decide on the best approach to providing quality whole buildings and promoting creative finance contracting and procurement approaches.
- Developing "brand name" and identify for sustainable whole buildings. Benefits accruing to a branded product would include preferential treatment for land use, tax incentives, and variances.
- Disseminating information about the value of a whole building approach to influence and change the specifications/guidelines and building standards (best practices) operations and maintenance.

Performance Metrics. Anecdotal evidence can provide valuable information for individuals considering alternative investments such as use of a whole building approach, but is generally insufficient to justify such alternatives on a widespread basis. Measurable, defensible and reproducible results are needed, particularly given the large investment decisions involved with a typical commercial building. Not all of the metrics that might be relevant for these purposes are as straightforward to measure as, for example, the flow of fresh ventilation air in the building and the cost of providing that flow. Such ventilation air may help to keep employees more alert and thus improve their productivity, which, given their associated cost, provides a value far outstripping the cost of the additional ventilation capacity. Determining which metrics are of the greatest value and their most reliable means of measurement and reporting are areas requiring significant effort in the near future. Such metrics will be a necessary contributor to widespread implementation of the commercial whole building approach. The desired outcome of this area is a Building Performance Index (BPI). Steps in developing this index include:

- Defining user needs and requirements. User needs would form one axis of a matrix that defines all relevant items to be measured by the BPI.

- Developing a BPI to decide what building characteristics should be measured and how best to measure them. These characteristics would form the second axis in the BPI matrix.
- Combining the items being measured into useful indices and defining a standard reporting format of some simple measures.
- Defining a strategy for using the index.

The life-cycle ramifications of building decisions should also be considered from the outset. Buildings should be designed using computer tools that calculate energy and environmental performance in real time as a result of the building's design, construction, and operation, and will show the full environmental impact and occupant/owner benefits of choices made. These impacts will be documented and recorded from the first day of operation, and returned as feedback to the original designers on the relative successes/liabilities of their design decisions. Key steps toward encouraging life-cycle benefits assessments include:

- Educating and motivating building decision-makers to consider the long-term consequences of building construction, operation and maintenance.
- Developing quality life-cycle decision-making tools to support a whole-building approach.

Technology Development. Products and processes must be developed in order to achieve commercial whole building goals for 2020, including:

- Systems integration and performance optimization products for flexible and integrated systems. These systems should be flexible, fast, quiet, and seamlessly integrated with the building (e.g. wireless control).
- Technologies to assist in a whole building approach to the design, construction, and operation of commercial buildings. In addition to developing these technologies, operators must be trained to use them.
- Technologies and intelligent systems that essentially allow a building to run itself. These technologies would include the development of low-cost solid-state wireless monitoring/communications for building performance throughout the building and a "self-learning" building management system with active operator guidance and training feedback. This would allow for real-time monitoring and control of energy, IAQ, comfort and pollutants.

How the Buildings Industry Can Use the Roadmap

In order for this vision to become a reality, substantial changes will have to take place in both the way commercial buildings are built and operated as well as the market for these buildings. First, there must be a team approach to the way buildings are conceived, built, and operated. No longer can architects, developers, builders, and operators work in isolation, nor can their efforts be considered as separate and distinct stages. Changes in specification from original designs must give full consideration to overall cost and impact on building construction and operation. All parties must work together to achieve a level of building performance that meets the design when the building is commissioned and handed over to the

new owners. Building operators need to be fully trained to understand how to operate and maintain the building correctly. This functionality must endure throughout the building's life cycle, surviving changes that might include ownership and building use.

Because the roadmap is the building industry's plan for RD&D, it identifies the critical opportunities, collaboration required, and specific activities needed to move the industry ahead—to meet its vision. It also provides the beginnings of an industry-wide agreement on what is important and what we should be doing.

Next Steps

The development and implementation of the roadmaps is a continuous process. DOE is actively pursuing industry involvement in developing and performing the activities identified in the roadmap as well as advice, guidance, and review of results. During 2000, we integrated the results of the four workshops and other activities into a draft roadmap for review by the more than 250 people and 150 organizations involved in the process to date. The roadmap was published and BTS began realigning its commercial building RD&D activities to those identified in the roadmap. BTS continues to form partnerships to ensure that the ambitious goals of the roadmap are met. Thus the roadmap is just the first step of a journey for the buildings industry—public and private sectors—can begin working together to implement the vision and start the work.

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Web Resources

Information on the Commercial Building and other roadmaps facilitated by the US Department of Energy are available on the web:

http://www.eren.doe.gov/buildings/technology_roadmaps/

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Altieri Sebor Weiber Engineers
American Express Company
American Gas Cooling Center
American Institute of Architects
American Iron and Steel Institute
American Society of Heating Refrigerating and Air-conditioning Engineers
Antares Group
Armstrong World Industries
Arthur D Little
Ball State University
Barry Donaldson & Associates
Bevilacqua-Knight
British Columbia Buildings Corp
Bromley Companies
Buildings in Use
Burt Hill Kosar Rittelmann Associates
California Energy Commission
California Institute for Energy Efficiency
Carnegie Mellon University
Carrier Corporation
CEDRL
Center to Protect Workers' Rights
The Chattanooga Institute
CH2M Hill
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City of Oakland
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Con Edison Solutions
Constructive Technologies Group
Cornell University
Design Harmony
Don Prowler & Associates
Durst Organization
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Eley Associates
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Georgia Institute of Technology
Geothermal Heat Pump Consortium
Halton Group
Haworth
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Herman Miller
Heschong Mahone Group
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IBACOS
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Interface Research Corporation
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John A. Clark Company
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Marinsoft
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Susan Maxman, Architects
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Owens Corning
Pacific Contracting
Pacific Energy Center
Pacific Gas and Electric Company
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Passive Solar Industries Council
Portland Energy Conservation
Price Waterhouse
Prime Group Realty Trust
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Rocky Mountain Institute
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