1.2 BUILDINGS

1.2.1 BUILDING EQUIPMENT, APPLIANCES, AND LIGHTING

Technology Description

A school in North Carolina features daylighting, state-of-the-art lighting controls, and an energy management system, allowing individual teachers to select optimum lighting levels for each room.

Energy use in buildings depends on equipment to transform fuel or electricity into end-use services such as delivered heat or cooling, light, fresh air, vertical transport, cleaning of clothes or dishes, and information processing. (The effects of passive and related systems are discussed in other profiles.) There are energy-saving opportunities within individual pieces of equipment – as well as at the system level – through proper sizing, reduced distribution and standby losses, heat recovery and storage, and optimal control. Another promising opportunity lies in multifunction devices ranging from heat pumps, which provide both refrigeration and hot water, to an office appliance that serves as a networked printer, copier, scanner, and paperless fax machine.

System Concepts

- Major categories of end-use equipment include heating, cooling, and hot water; ventilation and thermal distribution; lighting; home appliances; miscellaneous (process equipment and consumer products); and on-site energy and power.
- Key components vary by type of equipment, but some crosscutting opportunities for efficiency include improved materials, efficient low-emissions combustion and heat transfer, advanced refrigerants and cycles, electrodeless and solid-state lighting, smart sensors and controls, improved small-power supplies, variable-capacity systems, reduction of thermal and electrical standby losses, cogeneration based on modular fuel cells and microturbines, and utilization of waste heat from fuel cells and microturbines.

Representative Technologies

- Residential gas-fired absorption heat pumps, centrifugal chillers, desiccant preconditioners for treating ventilation air, heat-pump water heaters, proton exchange membrane fuel cells, heat pump water heaters, solid-state lighting, and lighting controls.
- Specialized HVAC (heating, ventilating, and air-conditioning) systems for research laboratories, server/data systems, and other buildings housing high technology processes.

Technology Status/Applications

- Technology improvements during the past 20 years – through quality engineering, new materials, and better controls – have improved efficiencies in lighting and equipment by 15% to 75%, depending on the type of equipment. Efficiencies of compact fluorescent lamps are 70% better than incandescent lamps; refrigerator energy use has been reduced by more than three-quarters during the past 20 years; H-axis clothes washers are 50% more efficient than current minimum standards. Electronic equipment has achieved order-of-magnitude efficiency gains, at the microchip level, every two to three years.

Current Research, Development, and Demonstration

RD&D Goals

- By 2025, research, develop, and demonstrate marketable and advanced energy systems required to achieve "net-zero" energy use in new residential and commercial buildings through a 70% reduction in building energy use – via high-performance lighting, HVAC, and appliances – with the balance of energy needs met by renewable energy sources.
- By 2010, heat pumps for residential and small commercial applications are 40% more efficient than condensing gas furnaces.
- By 2010, reduced standby losses, improved heat pump water heating, and application of heat-recovery techniques reduce energy use for domestic water heating by 60% over electric storage water heaters.
- By 2020, photovoltaics offer cost-competitive alternatives to grid electricity, enabling the construction of net-zero energy homes/buildings, when combined with ~70% whole building load reductions.
- By 2020, alternative refrigeration equipment with low greenhouse warming potential (e.g., Stirling cycle, Brayton cycle, acoustic, magnetic, thermal electric) will be commercially introduced.
- By 2008, develop a portfolio of distributed generation technologies (including microturbines) that show an average 25% increase in efficiency (compared to 2000 baseline) with NO_x emissions less than 0.15 lb/MWh.
- By 2013, develop solid-state lighting for general illumination applications with luminous efficacy of 90 lumens per watt by 2008, and 160 LPW by 2013.
- By 2030, all aspects of the building envelope, equipment, and appliances will be integrated and combined with on-site microcogeneration and zero-emission technologies.
- The basic RD&D needed ranges from materials science to solid-state electronics, and from a better understanding of combustion fundamentals to advances in control theory. Research is also needed on behavioral and ergonomic dimensions of the user-machine relationship.

RD&D Activities

- Most Federal R&D on building equipment is performed by DOE.
- International funding is less relevant than state activities such as currently ongoing in California, New York, and other states. This research is synergistic with and complements the DOE research.

Recent Progress

- Recent DOE-sponsored R&D, often with industry participation, includes an improved air-conditioning cycle to reduce oversizing and improve efficiency; a replacement for inefficient, high-temperature halogen up-lights (torchieres), which use only 25% of the power, last longer, and eliminate potential fire hazards; ozone-safe refrigerants, where supported R&D was directed toward lubrication materials problems associated with novel refrigerants and ground-source heat pumps.

Commercialization and Deployment Activities

- Building equipment, appliances, and lighting systems currently on the market vary from 20% to 100% efficient (heat pumps can exceed this level by using "free" energy drawn from the environment). This efficiency range is narrower where cost-effective appliance standards have previously eliminated the least-efficient models.
- The stock and energy intensity of homes are growing faster than the building stock itself, as manufacturers introduce – and consumers and businesses eagerly accept – new types of equipment, more sophisticated and automated technologies, and increased levels of end-use services.
- The rapid turnover and growth of many types of building equipment – especially electronics for computing,

control, communications, and entertainment – represent important opportunities to rapidly introduce new, efficient technologies and quickly propagate them throughout the stock.

- The market success of most new equipment and appliance technologies is virtually ensured if the efficiency improvement has a three-year payback or better and amenities are maintained; technologies with payback of four to eight-plus years also can succeed in the market, provided that they offer other customer-valued features (e.g., reliability, longer life, improved comfort or convenience, quiet operation, smaller size, lower pollution levels).
- Applications extend to every segment of the residential and nonresidential sectors. Major government, institutional, and corporate buyers represent a special target group for voluntary early deployment of the best new technologies.

Market Context

- Building equipment and appliances represent an annual market in the United States, alone, of more than $200B, involving thousands of large and small companies. Certain technologies, such as office and home electronics, compete in global markets with little or no change in performance specifications.