1.2.2 BUILDING ENVELOPE (INSULATION, WALLS, ROOF)

Technology Description

National laboratory exhibits show the benefits of energy-efficient building envelope design (left). This home in Atlanta, Georgia, (right) will use 58% less energy for heating and 53% less energy for cooling than a home of comparable size without energy-efficient design.

The building envelope is the interface between the interior of a building and the outdoor environment. In most buildings, the envelope – along with the outdoor weather – is the primary determinant of the amount of energy used to heat, cool, and ventilate. A more energy-efficient envelope means lower energy use in a building and lower greenhouse gas emissions. The envelope concept can be extended to that of the "building fabric," which includes the interior partitions, ceilings, and floors. Interior elements and surfaces can be used to store, release, control, and distribute energy, thereby further increasing the overall efficiency of the buildings.

System Concepts

- Control of envelope characteristics provides control over the flow of heat, air, moisture, and light into the building. These flows and the interior energy and environmental loads determine the size and energy use of HVAC and distribution systems.
- Materials for exterior walls, roofs, foundations, windows, doors, interior partition walls, ceilings, and floors that can impact future energy use include insulation with innovative formula foams and vacuum panels; optical control coatings for windows and roofs; and thermal storage materials, including lightweight heat-storage systems.

Representative Technologies

- *Superinsulation*: Vacuum powder-filled, gas-filled, and vacuum fiber-filled panels; structurally reinforced beaded vacuum panels; and switchable evacuated panels with insulating values more than four times those of the best currently available materials should soon be available for niche markets. High-thermal-resistant foam insulations with acceptable ozone depletion and global warming characteristics should allow for continued use of this highly desirable thermal insulation.
- *Advanced window systems*: Krypton-filled, triple-glazed, low-E windows; electrochromic glazing; and hybrid electrochromic/photovoltaic films and coatings should provide improved lighting and thermal control of fenestration systems. Advanced techniques for integration, control, and distribution of daylight should significantly reduce the need for electric lighting in buildings. Self-drying wall and roof designs

should allow for improved insulation levels and increase the lifetimes for these components. More durable high-reflectance coatings should allow better control of solar heat on building surfaces.

- *Advanced thermal storage materials*: Dry phase-change materials and encapsulated materials should allow significant load distribution over the full diurnal cycle and significant load reduction when used with passive solar systems.

Technology Status/Applications

- Building insulations have progressed from the 2-4 hr ºF ft^2/Btu/in. fibrous materials available before 1970 to foams reaching 7 hr ºF ft^2/Btu/in. Superinsulations of more than 25 ºF ft^2/Btu/in. will be available for niche markets soon. Improvements in window performance have been even more spectacular. In the 1970s, window thermal resistance was 1 to 2 ºF ft^2/Btu. Now, new windows have thermal resistance of up to 6 ºF ft^2/Btu (whole window performance). Windows are now widely available with selective coatings that reduce infrared transmittance without reducing visible transmittance. In addition, variable-transmittance windows under development will allow optimal control to minimize heating, cooling, and lighting loads.

Current Research, Development, and Demonstration

RD&D Goals

- By 2008, demonstrate dynamic solar control windows (electrochromics) in commercial buildings; and, by 2010, demonstrate windows with R10 insulation performance for homes.
- By 2025, the program goal is to develop marketable and advanced energy systems capable of achieving "net-zero" energy use in new residential and commercial buildings.
- The long-term goal is to achieve a 30% decrease in the average envelope thermal load of existing residential buildings and a 66% decrease in the average thermal load of new buildings.

RD&D Challenges

- Foam insulations that retain high thermal resistance while using blowing agents with zero ozone depletion potential and negligible global warming effect.
- Self-drying wall and roof designs to avoid moisture problems such as materials degradation.
- Electrochromic window films and electrochromic/photovoltaic hybrid window films to control energy flows and generate electricity on site.
- Techniques to distribute and control daylight to reduce electrical energy use for artificial lighting.
- Advanced durable cost-effective superinsulations to reduce heating/cooling loads.
- Self-calibrating multifunction microsensors for monitoring building equipment performance and air-quality monitoring.
- Thermal storage materials: Typically, thermal storage in building components is achieved with heavyweight materials such as masonry. Advanced thermal-storage materials need to be lightweight to integrate with elements similar to drywall, floor, and ceiling panels.
- Scaling electrochromic window technology to commercial-scale window applications.

RD&D Activities

- Key agencies doing building envelope R&D are DOE, National Institute for Standards and Technology, several state agencies, and other institutions such as the Florida Solar Energy Center.

Recent Progress
• A DOE-sponsored RD&D partnership with the Polyisocyanurate Insulation Manufacturers Association, the National Roofing Contractors Association, the Society of the Plastics Industry, and Environmental Protection Agency (EPA) helped the industry find a replacement for chloroflurocarbons (CFCs) in polyisocyanurate foam insulation. This effort enabled the buildings industry to transition from CFC-11 to HCFC-141b by the deadline required by the Montreal protocol. • Spectrally selective window glazings – which reduce solar heat gain and lower cooling loads – and high-performance insulating materials for demanding thermal applications.
Commercialization and Deployment Activities
• A critical challenge is to ensure that new homes and buildings are constructed with good thermal envelopes and windows when the technologies are most cost effective to implement. • The market potential is significant for building owners taking some actions to improve building envelopes. Currently, 40% of residences are well insulated, 40% are adequately insulated, and 20% are poorly insulated. More than 40% of new window sales are of advanced types (low-E and gas-filled). In commercial buildings, more than 17% of all windows are advanced types. More than 70% of commercial buildings have roof insulation; somewhat fewer have insulated walls. • Building products are mostly commodity products. A number of companies produce them; and each has a diverse distribution system, including direct sales, contractors, retailers, and discount stores. • Another critical challenge is improving the efficiency of retrofits of existing buildings. Retrofitting is seldom cost-effective on a stand-alone basis. New materials and techniques are required. • Many advanced envelope products are cost-competitive now, and new technologies will become so on an ongoing basis. There will be modest cost reductions over time as manufacturers compete. **Market Context** • Building structures represent an annual market in the United States of more than $70B/year and involve thousands of large and small product manufacturers and a large, diverse distribution system that plays a crucial role in product marketing. Exporting is not an important factor in the sales of most building structure products.