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TRENDS IN ENERGY

Industrialized Housing: Exploring the Potential for Energy Efficiency

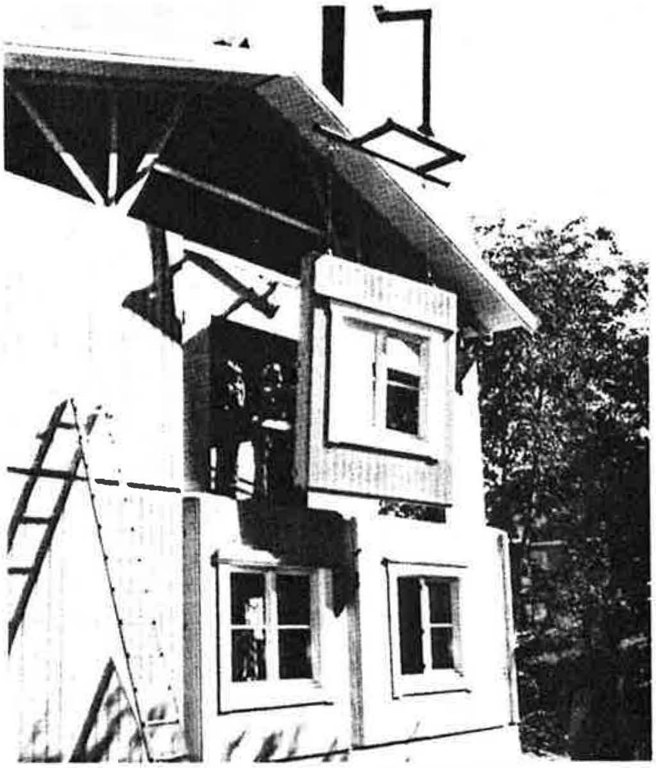
Industrialized, or factory-assembled, home building has been growing in fits and starts since the early 1960s. The Energy Efficient Industrialized Housing Research Program, conducted by the University of Oregon and the Florida Solar Energy Center, recently calculated that "over 90% of all housing production is industrialized to a degree." Given this statistic, it is important to ensure that energy-efficient processes and materials are used in factories as much as in on-site construction. Bringing energy-efficient design into the factory is one relatively easy way to upgrade the efficiency of new homes. However, the multitude of building codes, the differences in climate, and the variety of methods and materials used in production all play a part in determining the energy-saving potential of these types of homes.

The industrialized housing research, sponsored by the U.S. Department of Energy, surveyed all four types of industrialized housing: panelized homes, including domes, precuts, and log homes; modular homes; HUD-code homes (mobile homes); and production homes, those built by large-scale building firms that incorporate industrialized processes on-site.

Panelized

The energy-saving potential of panelized homes in the United States depends on the design of the individual panel, the level of insulation, and on correct installation of the panels to avoid later infiltration problems, according to the DOE research summary report written by G.Z. Brown and Subrato Chandra.[1] Other research, reported by Steve Andrews in *Foam-Core Panels & Building Systems,*[2] found that foam-core panels have proven energy savings and are less problematic in installation. "Annual heating requirements of a 1,176 ft^2 Pennsylvania home required only one-fourth the energy costs (of) comparably sized new homes," Andrews writes.

Panel factories in Sweden are highly automated, producing connected walls and floors, which allows insulation



Swedish Council for Building Research

and sheathing to be installed at the same time, say Subrato and Brown. U.S. factories produce the panels separately, so the focus is on making these individual units more energy-efficient. For example, the American Plywood Association stresses that when using extruded polystyrene cores with waferboard as a facer, a solvent-based adhesive should be applied. The amount of pressure, curing time, and ambient temperature are all important factors in ensuring that panels will perform to their potential. Proper installation of the panels to join them well is essential to avoid excessive air infiltration, which can be very costly in the northern United States where panelized homes are most common.

Modular

Modular homes are assembled as whole buildings, are typically rectangular in plan, and have all plumbing and electrical equipment installed before they leave the factory. The "modules" of the homes are stacked like boxes by a crane. With this technique, it is important that the exterior envelope of the building be well-sealed, the DOE study found.

One program designed to improve the efficiency of modular homes, the Hayward Avenue Project in Baltimore, Md., used local funds to construct extra-efficient modular homes to be sold to low-income families. Typically, in low-cost factory-built homes, minimum levels of insulation are installed, and often only in the walls and floor. But the City of Baltimore's Energy-Efficient Housing Demonstration Program provided extra funding for upgrades to be performed on the homes. Wall insulation was increased between studs using R-13 fiber-glass batts, and rigid R-4 foam over the plywood sheathing. Band-joist insulation was installed where the upper and lower boxes connect: R-30 on the top of the lower box and R-13

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installed in the bottom of the upper box. The basement floor was insulated with R-11 insulation. Mechanical chaseways (a closed-off column housing the trunkline of the furnace) between the basement and the attic were sealed airtight at bottom and top. Water heaters had R-12 insulation jackets installed. Kitchen range hood fans were ducted directly to the exterior. Attic hatches were modified to be more airtight, and a blower door test was conducted to see if further air sealing was necessary.

David Wentling, energy inspector of the project, says the first two homes, tested after the upgrades, showed great improvements in airtightness compared to other modular homes he's inspected. Wentling says the biggest problem he's seen with modular homes is the lack of gasketing, which would enable the boxes to fit tightly into place. "I've seen ¼ to ½" gaps between plate and platform when they put the modules together. The manufacturers walk through later and just stuff strips of fiber-glass in there." The gaps not only cause infiltration, but they also leave room for fire to spread rapidly to the second floor. "Homes in Scandinavia," Wentling continued, "All have their own version of gasketing, and I think it's a trend that has not yet caught on in the manufacture of modular homes."

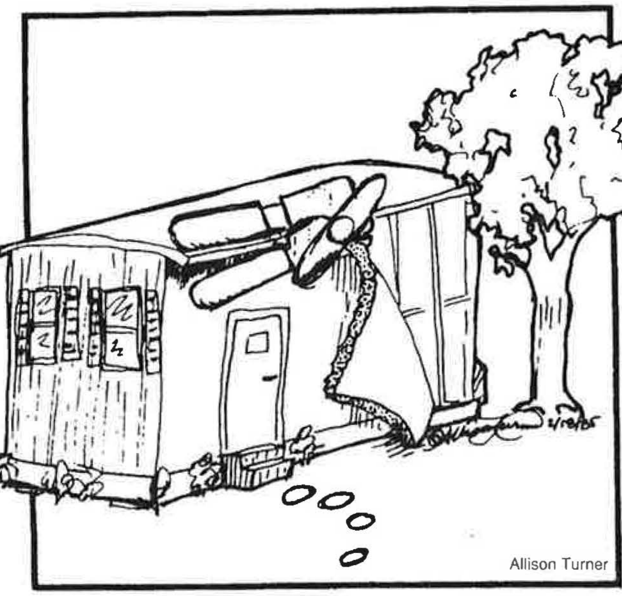
David Wentling

Here the modules in the Hayward Avenue Demonstration Project are being set into place by a crane.

Mobile Homes

More common for low-income housing are Housing and Urban Development (HUD)-code mobile homes, which are manufactured in an assembly-line process and sold as single units or double-wides. Designed to be transported on highways on their own built-in chassis, they are long and narrow and have higher surface area-to-volume ratios than other homes, increasing their heat loss. Compared to the other two types of industrialized homes, HUD code homes require the most need for upgraded energy efficiency in the United States, the DOE study states.

"Part of the reason," confirms Michael Lubliner of the Washington State Energy Office, "is that the controlling codes are federal, whereas modular and panelized codes are local and state and therefore much more strict as far as energy-efficiency is concerned." Bonneville Power Administration (BPA) funded a project implemented by state energy offices in Oregon, Washington, Idaho, and Montana, the Residential Construction Demonstration



Allison Turner

Project, which worked with the states' mobile home manufacturers to upgrade the energy efficiency of mobile homes. The upgrades followed the specifications of the Super Good Cents program, a utility program for new construction in the Northwest. In the floor, R-7 insulation was raised to R-30. R-11 wall insulation was raised to R-19, and ceiling insulation was raised from R-14 to R-30. U-values of the windows were reduced from 0.75 to 0.45 using interior storm windows, or double-glazed vinyl windows. Although monitored results of the study won't be released until later this summer, Lubliner says the modelling indicates an estimated savings of up to 50%. Typical current practice mobile homes in warm region of Washington use 8.4 kWh per ft^2 per year compared to the Super Good Cents rating of 3.8 kWh per ft^2 per year. In Spokane, which is a little colder, a typical current practice home is using 11.3 kWh per ft^2 per year in comparison to the 6.2 kWh Super Good Cents rating for that area.

Working with manufacturers to upgrade the quality of new mobile homes is one way to increase their energy efficiency. But there are still many existing HUD-code homes in the United States that need retrofits. (See "CMFERT: Training and Testing of Mobile Home Retrofits," *HE*, Jan/Feb '90, p. 13.)

Myths, not Energy-Efficiency, from Japan

Contrary to popular belief, industrialized housing in Japan is not the model of energy efficiency, the study found. The mainstream modular and panelized homes in Japan are steel-framed and have minimal insulation. But Japan is currently beginning to build homes more energy-efficient, using 2x4 construction borrowed from the United States and Canada. They are also producing wood modules that are smaller than the ones currently on the market in Japan. This experimentation suggests that they will come up with industrialization techniques that will probably be marketed as housing in North America.

In Sweden, the efficiency of factory-built homes is very high. They are well-insulated, well-constructed, and use thermal breaks in the wall system. Rubber gaskets are installed around all wall openings and between floor-wall-roof systems.

[T]his technique along with the use of heat exchangers make [S]wedish technology a model for the world.

"The next step for us will be the designing of the 21st [C]entury House," says G.Z. Brown. The house will be the [p]rototype of efficiency combining new materials, subsystems, [a]nd types of design. "Since we're looking far into the future, [w]e're redefining the whole concept of what a house is."

Meanwhile, energy officials throughout the country are [b]eginning to work more closely with manufacturers to [i]ncorporate proven energy-saving techniques into factory [p]rocesses.

—John Lancaster

[R]eferences

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2. Steve Andrews, "Foam-Core Panels & Building Systems: Principles and Practice Plus Product Directory," 1988, Cutter Information Corp., Arlington, MA.
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[A]cknowledgements

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New and Improved Weatherization: The Minnesota Example

The Low-Income Weatherization Assistance Program in [M]innesota is on its way to a major renovation, as findings [f]rom the M200 Enhanced Low-Income Weatherization [D]emonstration Project are adapted for implementation by [s]ubgrantees across the state. The M200 Project, intended to [c]ombine the most cost-effective techniques for insulation [a]nd air sealing with heating system measures and enhanced [c]lient education, was tested in 200 low-income single-family [h]omes during the summer of 1988 (See *HE*, Jan/Feb '90, [p].15) and the final report was just released.[1] The project is [b]ased on the recognition that residential energy use is [g]overned by a complex interaction of the building's ther[m]al envelope, mechanical systems, and resident lifestyle. [T]herefore, M200 was designed to provide cost-effective energy [s]avings, maintain healthy interior environments, and aid [r]esidents in learning ways to manage their energy use and [c]omfort. Key to the approach is decentralized decision-making, [w]hich gives workers the tools and responsibility for diagnosing [t]he needs of each house, prescribing the necessary interven[t]ions, and ensuring job quality.

The Existing Weatherization Program

Minnesota's existing weatherization protocol focuses [o]n six major steps: (1) general heat waste (primarily air [s]ealing and water heater blankets); (2) replacement of oil [b]urners with flame-retention head burners if the steady-state efficiency is less than 75%; (3) attic insulation; (4) wall insulation (using a two-hole, gravity-blow method); (5) foundation insulation; and (6) replacement of doors and windows. About half of Minnesota's agencies use blower doors as part of the weatherization process, and a few check heating systems for safety problems like backdrafting. In 1986, a statewide evaluation of the weatherization program, using PRISM analysis of utility bills (see p. 27), found net savings in single-family detached housing of 11%, and a simple payback time of 25 years (based on total program costs of $1,450 per house, including materials, labor, overhead, and administration).

Components of M200

Measures. The M200 Project changed the weatherization process and personnel roles for nine local agencies throughout the state. The new protocol includes: a visit by two energy auditors to inspect the heating system, educate the client, and collect information the crew will need (i.e., amount of insulation required, dimensions of windows needing repair); a visit by the heating contractor (if efficiency or safety improvements are called for); and finally, the visit by the weatherization crew. The crew then: (1) installs high-density wall insulation; (2) seals major air leaks and bypasses (but no caulking or weatherstripping at this point); (3) installs attic insulation; (4) repairs or replaces windows; (5) seals leaks in supply and return ducts; (6) installs a water-heater jacket and low-flow showerheads; (7) does secondary air-sealing (guided by periodic blower door checks, until cost-effectiveness or tightness limits are reached); (8) performs pressure balancing tests; (9) installs supply duct insulation (if easily done and ducts pass through spaces where temperatures drop below 55°); (10) installs rim joist and foundation insulation, if economical; and (11) tests for backdrafting. The energy auditors make specifications for insulation and window repairs, while the crew determines the needed air-sealing work.

Client Education. Client education is conducted primarily by one of the energy auditors, and is reinforced by the crew. The client accompanies the auditor during the inspection of the house, taking notes and even using the blower door. Then, the auditor and client fill out a "Client Plan of Action" (CPA). In the CPA, the auditor agrees to provide certain weatherization measures for the client's home, while the client must write down two to four steps that his or her family will take to save energy. The purpose of the CPA is two-fold: it empowers clients by making them partners in the energy-saving process, and it requires clients to make a public commitment to specific energy-saving actions. Post-weatherization questionnaires revealed that education did have a significant impact on energy behavior, including reduced thermostat settings, lowered hot water temperatures, and decreased humidifier use.

Training for New Roles. All crew involved in the pilot M200 (close to 100 people) underwent extensive training, including a week-long classroom session. Three days were devoted to the building envelope and mechanical systems and two days to client education. To give agency personnel a thorough understanding of why changes were being made and to foster their sense of partnership in the project, they were introduced to the philosophy of the project and its attitudes toward weatherization. The project organizers felt