RESEARCH&DESIGN

The Quarterly of the AIA Research Corporation
Summer, 1980 Volume III, Number 1

Energy Conscious Redesign

Saving energy in a redesigned environment

COMMENTARY

The energy and architectural challenge to the building design professions in the '80s is clear: Redesign the existing stock of 78 million housing units and 35 billion square feet of commercial floor space to improved standards of thermal integrity.

This challenge is as enormous as the numbers imply.

Our existing stock of housing consumes over 16 quadrillion (16×10^{15}) BTUs of energy a year. This is equivalent to 585 million metric tons of coal or 400 metric tons of crude oil. Commercial buildings consume another 10 quadrillion BTUs annually. Thus, our current building stock accounts for over a third of the total annual U.S. energy budget.

For the remainder of this century, total U.S. energy consumption will in large measure be determined by what we do with this existing stock of buildings. New construction will be considerably more energy efficient due to rising energy costs, regulations, and market demand; in that respect, our future is known. Now we must decide what to do about existing buildings.

What is the nature of energy consumption in buildings? What is the opportunity for reducing that consumption? Energy use in residential buildings is dominated by space heating, which accounts for almost half of the 16 quads. Domestic water heating accounts for 2.25 quads; refrigeration, for 1.5 quads, and space cooling, for 1.1 quads. Space heating also dominates commercial energy consumption, accounting for 4.56 quads; lighting follows closely, accounting for 2.23 quads, with space cooling accounting for 2.2 quads. These numbers do not reflect the fuel source from which the consumed energy is derived. For residential buildings, energy consumption is presently divided equally between fuel (gas and oil) and electricity. In commercial buildings, electricity consumption is several quads larger than fuel consumption.

With the cost of energy so closely tied to fuel type and end-use application efficiency, it is a matter of national policy (and concern to designers) to reduce consumption of costly energy—importing oil to New England for electrical power production, for example—and to increase energy use efficiency by matching end-use application to fuel type—residential space heating with gas or solar energy.

Recent projections of energy consumption in the building sector show that by the year 2000, consumption can be *below* current levels. We can be using *less* energy to heat, cool, light, and power our existing and new building stock in the year 2000 than we use today. This can be achieved without a radical change in lifestyle and without a radical change in building design and construction practice. The key to achieving this goal is a drastic reduction in energy use in existing buildings. This is where the building design professions must look for new business, and where they must make their contribution to meeting U.S. energy goals.

This issue of *Research & Design* is the kick-off of the challenge of the '80s. It presents the challenge clearly as one of design—in fact, of redesign. One does not achieve the levels of energy savings required simply by slapping gadgets onto and into buildings. Rather, as with all design problems, one must begin at the beginning. Original architectural programs must be revisited, and questions must be asked. Has the building changed functions, operating schedules, or physical configuration? Is the present energy budget of the building divided? How much goes to heating, to cooling, to lighting? What energy sources provided by the building or the site can be captured, cost-effectively, to meet energy needs? Is there waste heat available? Can daylighting be used? What about passive heating and cooling, or active water heating? The list goes on and on.

We must recognize, for better or worse, the heritage of our existing buildings, and reclaim them as enhanced places for human activity. As building designers we have no choice: This is our job, and this is our moral and ethical responsibility to the American people.

michael j. holtz

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2 Notebook
The first of the nation's local climatological summaries are out, and the proceedings from a state-of-the-art conference on energy conscious retrofitting soon will be.

4 Energy Conscious Redesign
Existing buildings, commercial and residential alike, are being converted to new uses and new lives across the country. The reconstruction business is booming, and for more than a few architects, that's an opportunity to turn conversion into energy conservation, often with a passive solar twist.

8 Uncommon Sense
Some recent energy conscious redesigns.

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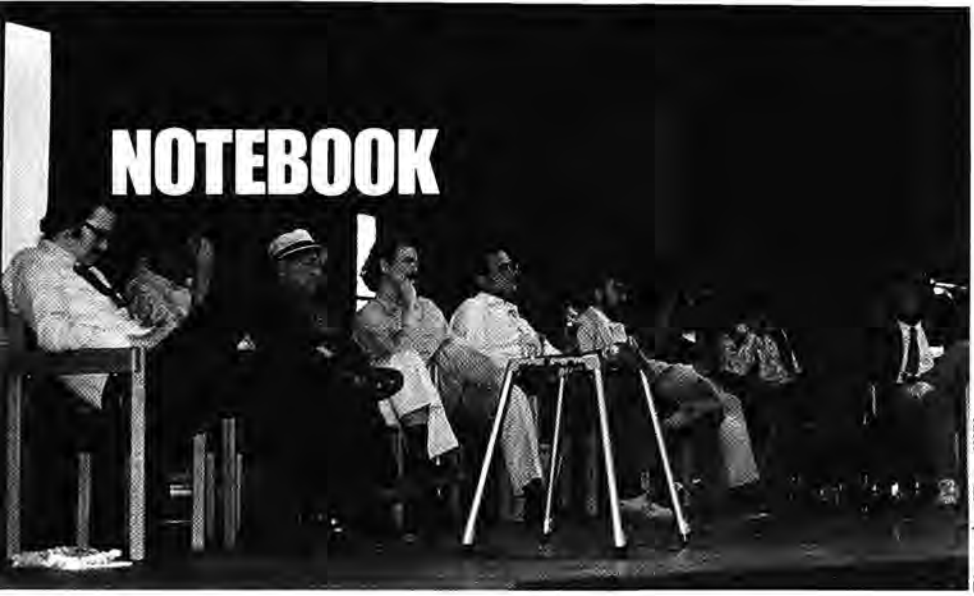


Photo by Tom Wilson

Proceedings out by October for Princeton's June conference on energy conscious retrofitting

"Insolation vs. insulation" was the debate topic for this panel discussion during June's Energy Conscious Retrofitting conference at Princeton. Participating, from left above, were TEA's Dan Scully, Zomeworks designer Steve Baer, engineer Fred Dubin, architect Doug Kelbaugh, Princeton Center researcher Robert Socolow, Drew Gillett of the Northeast Solar Energy Center, researcher Dan Lewis, Joe Kohler of TEA, and discussion moderator Don Prowler of South Street Design.

If you're interested in the subject of this issue of *Research & Design*—the energy-conscious redesign of existing buildings—then one of the best ways to spend $10 this fall will likely be to buy a copy of the proceedings from the field's most recent state-of-the-art conference.

"Opening and Closing the Envelope: Energy Retrofit Conference" was the way the gathering was billed. Sponsored by the Mid-Atlantic Solar Energy Association (MASEA) in cooperation with the Princeton Center for Energy and Environmental Studies, it was held on the campus of Princeton University in Princeton, N.J. for three days last June.

Princeton—the town, the university, and the Center—has become a locus of solar and energy-conscious research and design activity. Largely organized by the local design contingent, the conference brought redesign specialists in from as near as New York City (55 miles) and as far as the West Coast.

The first day of the session was devoted to "closing the envelope"—retrofitting to negate thermal loss. The morning was political in emphasis; speakers included representatives of the U.S. Department of Energy's now burgeoning Residential Conservation Services program, the alternative-oriented Center for Renewable Resources, Pennsylvania Power & Light, and the Tennessee Valley Authority. The entire afternoon was devoted to the Center for Energy and Environmental Studies' remarkable research into thermal loss at the Twin Rivers townhouse development not far from Princeton. Among the fascinating papers presented by researchers from the Center were "Beyond Twin Rivers: Energy Analysis and the 'House Doctor'," "Performance Indices for Energy Use in Houses," and "Economics of Retrofitting Houses: Analytical Methods and Results." For more on the Center's research—which shows that furnace energy consumption can be cut up to 75 per cent in townhouses like those in Twin Rivers—see the main article beginning on page 5 of this issue.

The second day focused on "opening the envelope" with integrated solariums, attached solar greenhouses, and the like. Among the speakers: designer Travis Price on a full-block energy-conscious retrofit underway in Pittsburgh; architect Don Prowler on his Philadelphia office retrofit; architect Dan Scully on his solar redesign of an East River fireboat house; Stuart White on industrial loft conversion in Manhattan; Zomeworks principal Steve Baer on "recent ideas and work;" West Coast retrofitter Kit Mann on recent Northern California projects; well-known greenhouse designer Bill Yanda on solar greenhouses, and energy-conscious engineer Fred Dubin on "procedures for retrofitting non-residential buildings."

Both of the first two days were well attended by builders, architects, engineers, but the third day's open session for area homeowners interested in energy-conscious renovation was packed. Presentations by some of the nation's leading energy retrofitters and redesigners touched on every aspect of residential retrofitting.

According to MASEA's Tom Wilson, who's organizing the conference proceedings, transcripts of all the presentations made in June will appear in the proceedings. So will illustrations and photographs. The whole thing should be ready by the Fifth National Passive Design Conference, scheduled for mid-October in Amherst, Mass., says a hopeful Wilson.

If you can't make it to Amherst to pick up your copy of the proceedings, copies will be available from October on for $10, from MASEA, 2233 Gray's Ferry Avenue, Philadelphia, Pa. 19146.

TVA publishes climate summaries for nine cities in its area, as NOAA gets nationwide recommendations

In February, 1979, more than 50 architects, engineers, homebuilders, and climatologists met at the AIA Research Corporation in

Washington, D.C. for the first federally-sponsored conference to be held on climate and architecture in nearly 30 years (see *Research & Design,* Vol. II, No. 2).Now the products of that conference are beginning to come available to practicing architects.

The key goal of the conference was to produce a prototype "local climatological summary," a tool that would give designers all the pertinent climate data for a specific locality, better enabling comprehensive climate- and energy-conscious design.

The information that went into development of that prototype came from dozens of sources. The last significant national work on climate and architecture—the joint AIA/House Beautiful studies and reports of the early 1950s—provided much of the basic input. Though climate-conscious design waned in the '50s and '60s, the sciences of meteorology and climatology advanced substantially, providing more sophisticated indices of wind, temperature, humidity, and, correspondingly, human comfort. In the late '70s, the surge of energy-related design research produced such valuable tools as "solar mountain" matrices of solar radiation and mean daily temperature, computer-generated by the University of New Mexico's Ray Bahm, and a variety of sun-angle siting calculation procedures developed by The Architects Taos and others.

Both the office of the state architect in California and designers at the Tennessee Valley Authority, late in the '70s, produced preliminary climatological summaries for projects in their respective areas. Their summaries became models for the prototype summary to be developed at the climate and architecture conference in Washington.

Now, TVA's Architectural Design Branch has become the first group to actually publish a set of climate summaries. Nine booklets, averaging 26 pages apiece, document climatic conditions in nine metropolitan areas within TVA's operating purview. Summaries are complete and available for Jackson, Miss.; Huntsville, Ala.; Paducah, Ky.; Asheville, N.C.; Knoxville, Nashville, Chattanooga, and Memphis, Tenn., and the Tri-Cities area between Kingsport and Johnson City, Tenn., and Bristol, on the Tennessee-Virginia border.

Each of the TVA summaries offers a wide range of climatic data for its area. Nashville's, for example, begins with basic data on temperature means and extremes, degree days, seasonal solar radiation, earth and ground water temperatures, and design temperatures for sizing mechanical systems. A map locates the city within the region, pinpoints the local weather stations from which the climatic data was obtained, and identifies the geographic influences that shape Nashville's climate. A brief narrative describes hurricane, flood, earthquake, and tornado potentialities. Six pages of easily-read charts offer detailed, monthly graphs on temperature, degree days, relative humidity, clear and cloudy days, hours of sunshine, precipitation (in days and amounts), and wind speed and direction. Another eight pages of graphs and meteorological maps summarize the typical warm and cold front "events" that make up Nashville's winter and summer weather cycles.

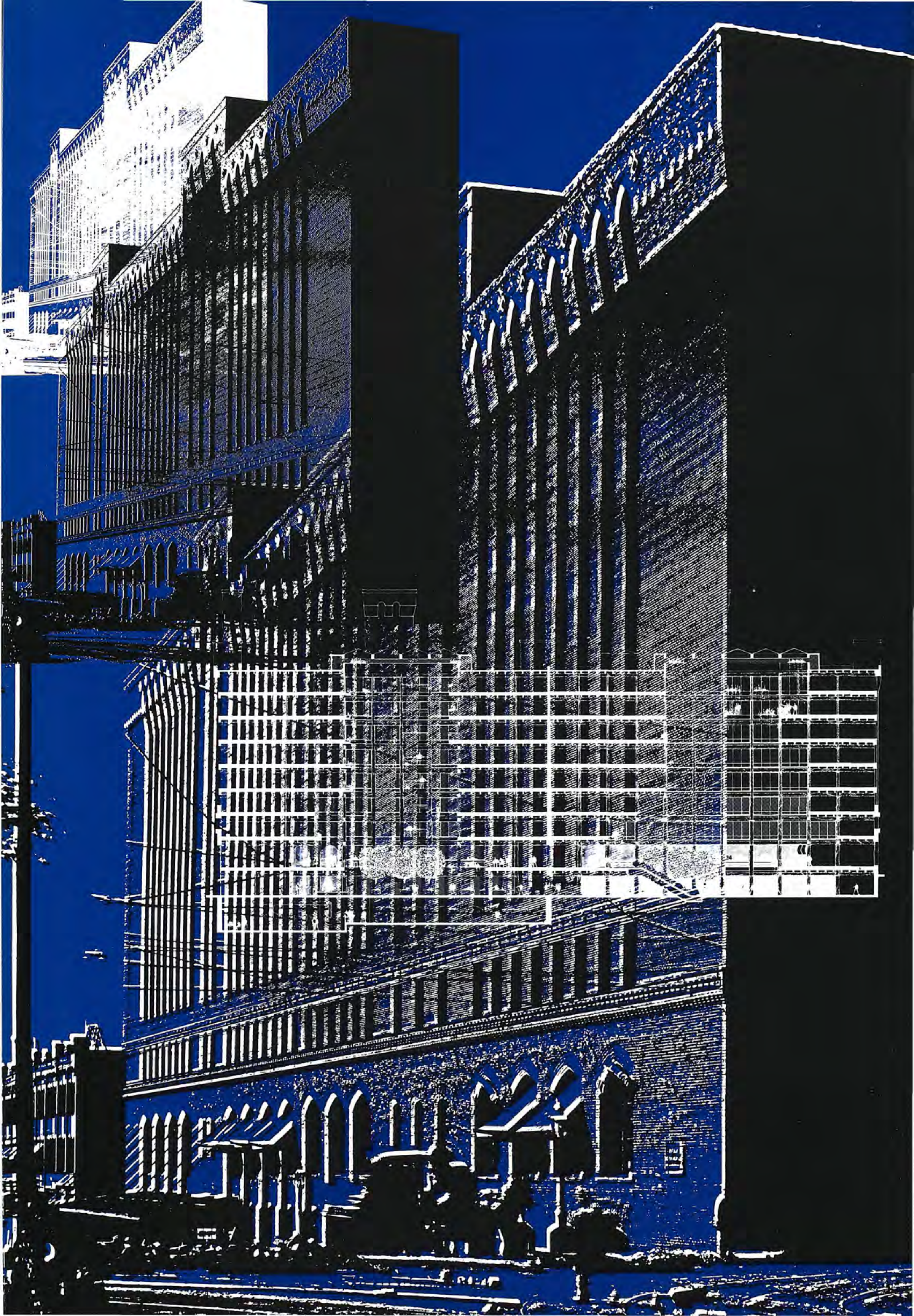
TVA's summaries are a precursor of the nationwide summary program that could soon come, via the National Oceanic and Atmospheric Administration (NOAA), out of last year's climate and architecture conference.

NOAA will receive this fall the final prototype summary recommended by participants at the conference, which was sponsored by NOAA and the U.S. Department of Energy. The recommended prototype looks much like TVA's summaries. Under present plans, NOAA will then begin the time-consuming process of producing local climatological summaries for those areas around the nation for which detailed climatic data exists. With over 130 major weather stations in existence—and hundreds of smaller stations run by the U.S. Air Force and other groups—the summaries should eventually cover most of a very large and climatologically-varied country.

For building designers outside TVA's area, there will be a wait for such developments. But designers interested in TVA's nine cities can order the summaries, free of charge, by writing to TVA Citizen Action Lines, 400 Summit Avenue, Knoxville, Tenn. 37902, or by calling 800/362-9250 from within Tennessee and 800/251-9242 outside the Volunteer State.

Correction

In the last issue of *Research & Design* (Vol. II, No. 4), we incorrectly identified Professor Ralph L. Knowles as the "UCLA-based designer, researcher, author, educator . . . responsible for much of the leading solar architectural research of the past ten years." Professor Knowles is based at the University of Southern California (USC), not at the University of California at Los Angeles. We regret the error, and happily reaffirm that the remainder of the original sentence is accurate.



Energy Conscious Redesign

The reconstruction business is booming. So is the business of redesigning existing buildings to save energy.

Call it redesign, retrofitting, renovation, rehabilitation, renewal, recycling, remodeling, restoration, preservation, conservation, revitalization, reuse—by any name, and with or without energy as a consideration, the reconstruction and reuse of America's building stock has grown to become a very important part of the design and construction industry. *With* energy as a consideration, it's become one of the hottest fields in research and design today.

Reconstruction alone is big business. It's common knowledge that 80 per cent of the buildings that will be in use 30 years from now are already in use today. Less widely known is the fact, according to the Bureau of Building Marketing Research, that last year alone more than $40 billion was spent nationally on the renovation of existing buildings—$29.7 billion of that on nonresidential buildings. Reconstruction activity increased by 31 per cent, on a par with the increase in new construction. Among architects, the increase in renovation was 11 per cent; in new construction, only 3 per cent. Nonresidential reconstruction expenditures have nearly doubled in the past five years, soaring from $19.4 billion in 1975 to an estimated $35.6 billion in 1980. And in another five years, such reconstruction is expected to amount to half of all the building activity in the nation.

The reasons are numerous for this movement to existing buildings. One is a renewed interest in city living (and, to an extent, city business) across the nation. A turn in the tide that, during the '50s and '60s, saw radical changes in urban population patterns and a mass middle class exodus from city to suburb, now sees decaying city centers left behind in that exodus being reinhabited, renovated, "gentrified." Building quality is another element in this movement. Buildings simply cannot be built the way they used to be, at least not for equivalent sums of money.

And it is money, of course, that is the underlying factor in the reconstruction boom. Homebuyers often get more room and better construction in an older home, whether it's out in the country or in a resurgent city neighborhood. Buyers of commercial buildings can get more space for substantially less investment than builders of new commercial buildings—frequently at savings sufficient to cover major retrofitting and still yield a bargain.

Older buildings are deemed unfit for modern use because they are either functionally, physically, or economically obsolete, says a recent issue of *Building Design & Construction* devoted to the reconstruction boom. But renovation can often overcome any one of those problems. In Pittsburgh, a downtown warehouse failing functionally because of limited truck access has been converted into Fort Pitt Commons, a successful office building. Small rooms and awkward interior spaces were bringing low Casa Marina, a once grand Key West hotel; an interior renovation doubled room sizes and propelled the hotel into the black. And in New York, the 77-story landmark Chrysler Building was a failing, half-occupied anachronism before redesign turned it into a once-again desirable address that rents office space for twice what its owners hoped it would.

The historic preservation movement can't be discounted as a progenitor of the reconstruction boom. The

Butler Square, Minneapolis, Minnesota
by Miller Hansen Westerbrook Bell Architects

Chrysler Building's landmark status—attained against its owners' will—is what finally assured its renovation. Legislation backed by this increasingly powerful movement has put tax-related teeth into landmark designation, encouraging building owners to restore what might otherwise be demolished. From New York's Grand Central Station to Seattle's Grand Central Arcade, preservationists have proven reconstruction more socially and financially attractive than new construction, and where it's most important—with some of the nation's finest older architecture.

The energy consideration in this reconstruction boom is fairly new. In fact, *Building Design & Construction's* issue devoted to the boom didn't mention energy. But energy—or the lack of it—has shaped the nation's buildings from time immemorial. From the solar-oriented puebloes of native Americans to the half-buried sodbuster homes of the Midwest, from New England's saltboxes to Charleston's breezy piazzas, much of America's architectural evolution documents a struggle to defeat the less pleasant aspects of climate and environment *without* energy as an ally. In this century, the development of sophisticated systems for heating, cooling, and lighting and the existence of cheap, plentiful energy to power them has allowed designers to be far less conscious of that struggle—and architecture has probably advanced farther and faster without the hindrance.

But with the onset of the energy crisis, designers have gradually become more aware of their forebears' struggles, and their solutions. Actual research and documentation in the field has finally begun. That research is showing that the nation's older buildings are frequently its most energy-efficient, and that the energy-conscious retrofitting of our existing buildings can create a tremendous new "source" of energy, through conservation.

In 1977, Syska & Hennessy and the Tishman Research Corporation completed a U.S. Department of Energy-funded study of energy performance in high-rise New York City office buildings. Their results confirmed that buildings designed and built before World War II were performing at significantly higher levels of energy efficiency than more recent buildings. In fact, buildings built before 1900 averaged 95,000 BTUs per sf per year for all utilities over five years, while offices built from 1941-62 averaged 126,000 BTUs per sf per year, and buildings built from 1962-70 averaged 115,000 BTUs per sf per year. Not surprisingly, energy efficiency seems to have declined in direct relation to the development of central heating and airconditioning systems.

The S&H/Tishman study and others have shown that the declining energy performance of modern buildings is a function of energy wasted through excessive and inadequate glazing, inadequacies in the building envelope, and overillumination. *Energy Future*, the report issued last year by the Harvard Business School, called the conservation of this waste the nation's most potent source of energy for the near future. DOE Deputy Secretary John Sawhill went even further in an address to the Smithsonian Institution last May. Sawhill cited studies by the National Academy of Sciences and others to say that "we can save at least 25 per cent of the energy we would normally expect to use in buildings over the next ten years. Residential and commercial buildings consume approximately 38 per cent of the energy we expend, and an estimated 41 per cent of this energy—or the equivalent of 5.7 million barrels of oil per day—is wasted." Sawhill went to quote estimates that widespread retrofitting to make buildings more efficient "could save eight quadrillion BTUs of energy annually by 1990—the equivalent of discovering two new oil fields the size of Alaska's North Slope."

Sawhill also touched on a newer and likely far more persuasive argument that is the focus of more recent research: the energy investment embodied in buildings already built, wasted when existing buildings are torn down, doubly wasted when a new building goes up on the same site.

"An existing building represents a certain repository of value," Sawhill told his audience. "It took energy, materials, and manpower to put it up. Take the example of a five-ton steel girder delivered to a construction site. The energy invested in processing and fabricating the girder is 257 million BTUs; transporting it to the construction site and installing it might require 13 million BTUs. By leaving it in place (instead of tearing down the building) the contractor would obviate the consumption of a total of 270 million BTUs . . And save the price of the girder."

Photos courtesy of the National Trust for Historic Preservation

Study results released this spring by the federal Advisory Council on Historic Preservation go beyond Sawhill's girder analogy to say that the rehabilitation of existing buildings can be accomplished using less than half the energy involved in new construction. The study, *Assessing the Energy Conservation Benefits of Historic Preservation*, was conducted by researchers Booz, Allen & Hamilton Inc. It was aimed at identifying the total energy cost of demolishing a building and replacing it, and looked at *embodied* energy (the amount of energy required to process building materials, transport them to the site, and put them in place); *operational* energy (the amount needed for heating, cooling, water, lighting, ventilation, and other systems), and *demolition* energy (the energy involved in razing an existing building and hauling away its materials).

One of the project's case studies focused on the newly renovated Grand Central Arcade—formerly the Grand Central Hotel—in Seattle's Pioneer Square. "Rehabilitating the old Grand Central Hotel required only one-fifth of the energy that would have been needed to build a comparable new facility," reported an architect on the research team. "The rehabilitated Arcade uses only 5 per cent more energy than a comparable new structure would use, and it will provide a net energy investment advantage over an equivalent new structure for the next two centuries."

A second case study focused on an old carriage house in Washington, D.C., converted into a three-unit apartment building. Said the same architect: "The insides were entirely ripped out and only the exterior shell was left intact. Even so, the rehabilitation materials and construction activities required less than half as much energy as an equivalent new building would have required."

New York architect and researcher Richard Stein has gone even further in his research into the energy embodied in the existing built environment. His firm has been exploring the energy investment in the "infrastructure"—the sewer, water, communication, and transportation systems that serve a city—which must grow as new and larger buildings increase the density of the city. "The energy investment in the infrastructure is huge," Stein has said, "and vital to energy considerations. If the density of New York City's CBD increases beyond the capacity of the infrastructure, then existing systems won't meet needs." The expansion of such systems, of course, bears as great an energy cost as new construction does.

All of these energy considerations in the argument for reconstruction—which wouldn't seem to need arguing anymore—are recent developments, products of the boom in architectural energy research that started in the late '70s. As a percentage of all reconstruction projects underway today, the number of projects that involve energy conscious redesign isn't great. But then not all retrofitting projects involve reconstruction.

Since the onset of the energy crisis in 1973-74 and the wave of federal energy legislation that followed, the government has created, and since sizeably increased, its programs encouraging energy conservation in commercial and residential buildings. DOE's Residential Conservation Service (RCS) is the program of the moment. Since commercial and industrial energy conservation is most often a matter of systems rather than buildings, the RCS program is aimed where architectural issues come to the

(Continued on page 16)

Uncommon Sense

A look at 8 recent redesign projects, including two commercial buildings, that blend renovation and conservation

A greenhouse that heats itself, and more

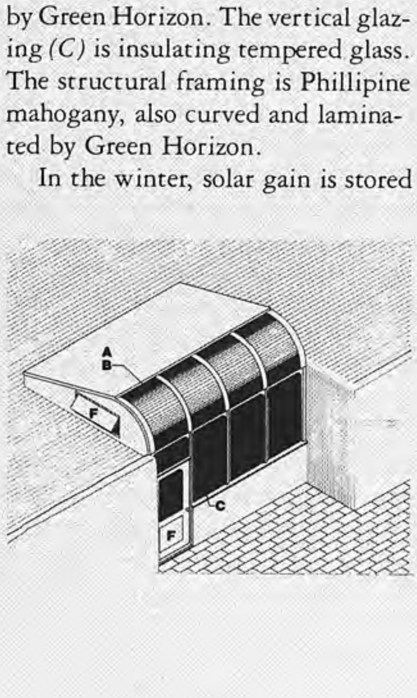
Santa Fe designer and builder Valerie Walsh runs Green Horizon, a firm specializing in solar greenhouse additions and doing rather well, especially since a recent cover story in Solar Age.

Green Horizon designers Noel and Jody Norskog are responsible for this 12-by-13-foot greenhouse addition enclosing the small courtyard of an adobe home in Santa Fe. The keys to its thermal efficiency are the unexposed east and west walls and the generous amount of insulated (R-27) roof area *(A in the sketch below)*. This strategy reduces heat loss on winter nights and minimizes exposure to the summer sun. According to Walsh, the greenhouse maintained 48°F temperatures inside when the exterior temperature on a December night dropped to 6°F.

The greenhouse's south wall is its solar collector. The overhead glazing *(B)* is a double-walled acrylic curved by Green Horizon. The vertical glazing *(C)* is insulating tempered glass. The structural framing is Phillipine mahogany, also curved and laminated by Green Horizon.

In the winter, solar gain is stored in the three massive adobe walls and flagstone floor of the greenhouse. The interior adobe walls of the main house also store heat, and the heat gained in the greenhouse circulates into the main house through three openings—French doors into the den and a glass door and window into the kitchen. All can be closed off in the summertime.

For summer cooling, air is circulated from the exterior door *(F)* and exhausted through two automatic upper vents *(F)* activated by heat motors. A deciduous tree directly in front of the south glazing provides shade all summer, then conveniently sheds is leaves to allow winter solar penetration.



A passive solar addition for Marin

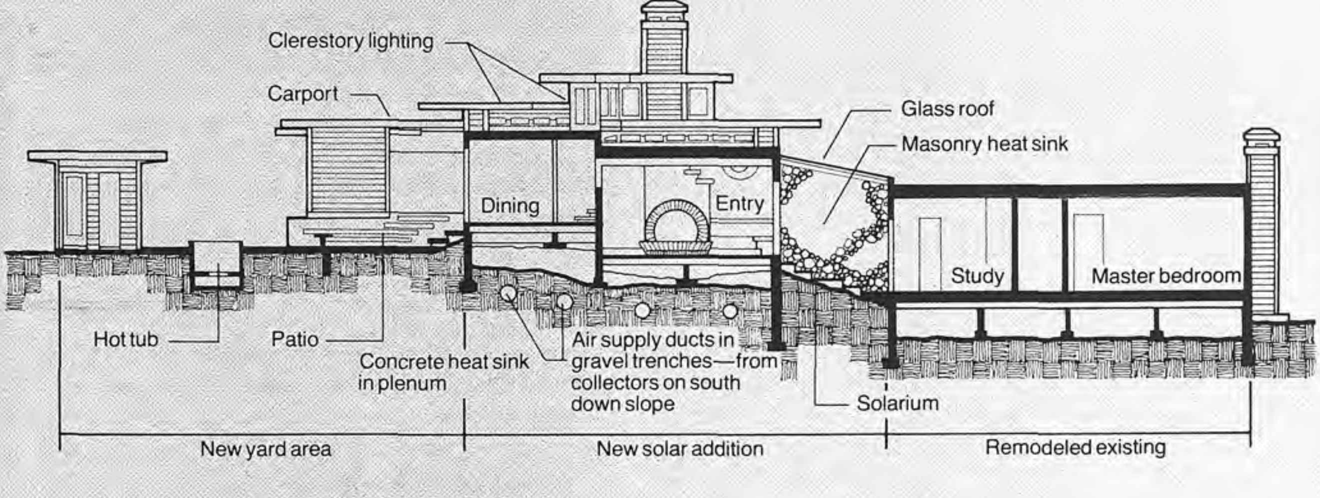
Mill Valley, Calif. architect M. Dean Jones' addition for the Mitchell's Mill Valley residence more than doubled the size of the house. The existing 600-sf flat-roofed home on a south-sloping site was joined by 888-sf of entry, living room, dining room, kitchen, and a greenhouse-solarium (160-sf) that acts as a passive solar collector.

The renovation's most ingenious passive device is a below-floor plenum warmed daily by insolation entering through two large glass areas under the two windows on the addition's south wall *(above, left)*. The glass areas are protected at night by insulated panels, covered with siding, which fold down in the daytime. Heat trapped in the plenum warms the floor above for radiant floor heating in the house.

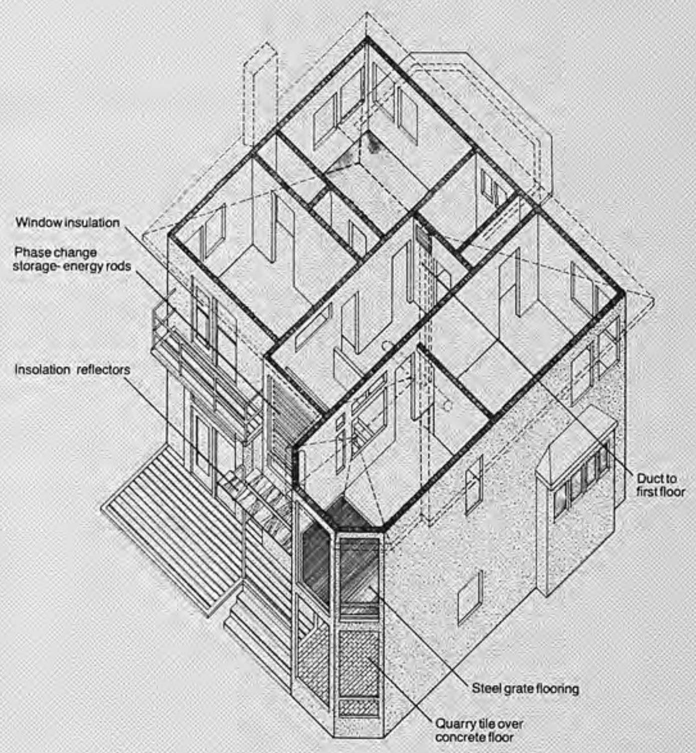
Nine yards of stone in trenches under the plenum are installed to accommodate more warm air supplied through air ducts by down-slope collectors. Domestic hot water is preheated in copper supply lines running through one of the trenches beneath the plenum.

Jones says that winter sunlight bearing on the greenhouse (which connects Jones' addition to the original house) keeps interior living spaces at a comfortable temperature. A central masonry fireplace with built-in convective vents can supply additional heat during Mill Valley's relatively mild winters. The fireplace and its masonry hearth also reradiate solar heat absorbed when sunlight enters through a rolling "barn window" in the living room.

Essential to the residence is a patio and hot-tub located off the addition, with spacious views of the rolling Marin hills, Sausalito, and San Francisco. Jones designed the hot-tub to accommodate fin-tube convective solar collectors as well.



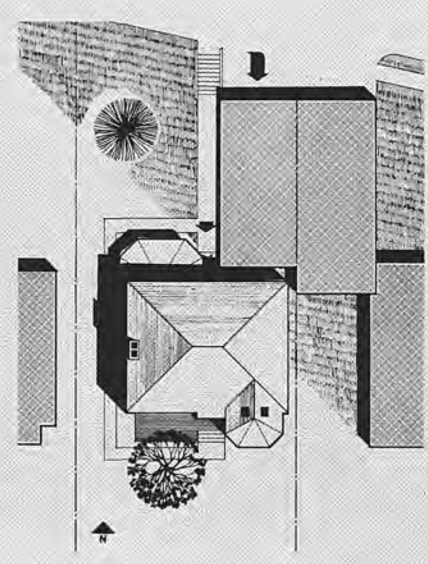
In Minneapolis, a new south face, with solarium



When Minneapolis architect Peter Pfister of the Architectural Alliance bought his 1,980-sf, essentially uninsulated 1920 wood frame house in 1978, he decided to add several energy conservation features before renovating for passive solar purposes.

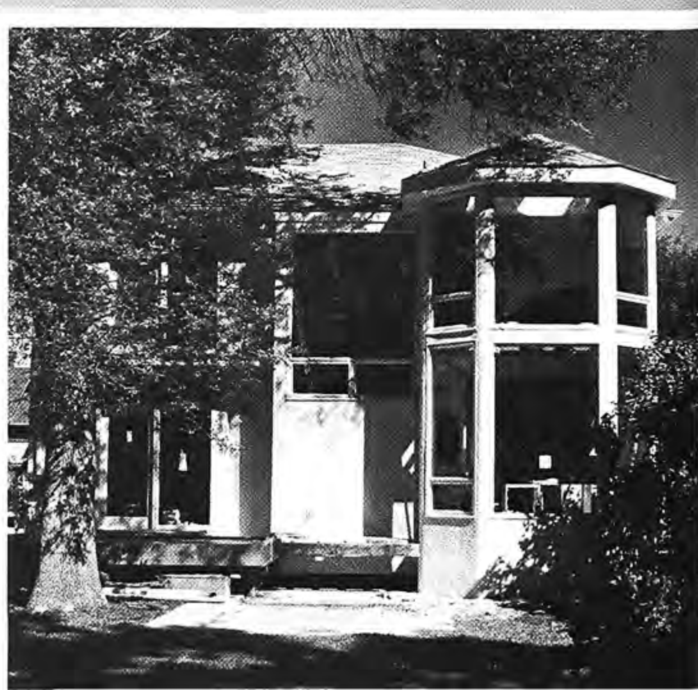
Pfister had polystyrene beads blown into wall cavities (increasing insulation value to R-15), painted interior surfaces with vapor barrier paint, increased attic insulation from two to 12 inches of fiberglass batts (R-40), caulked, weatherstripped, and applied moveable insulation to several windows. Then Pfister began his renovation of the home's south, backyard wall *(below)*.

With an original "sunroom" ironically placed on the home's northeast corner, and with minimal glazing to the south, Pfister's solar objectives were to increase the south glazing, increase thermal mass inside the house, and improve access and the view to the backyard from the home's living spaces.



His retrofit added two primary solar gain areas to the house. A 9-by-12-foot, two-story solarium was added to the southeast corner, extending the kitchen/breakfast area on the first floor and creating a sunroom on the second floor. And, at the center of the south wall, a large window the height of the center stairway landing area was installed and equipped with phase-change thermal storage "energy rods." The rods, three and a half inches in diameter and six feet long, provide a total of 95,000 BTUs of latent heat storage and 14,000 BTUs of sensible heat storage. External reflectors below the window increase the amount of sunlight striking the rods. Motorized rolldown insulating curtains protect both the landing window and the solarium glazing from summer insolation and winter night heat loss.

Pfister's unique distribution system for heat gained on the south involves a metal grate as the sunroom floor above the kitchen, through which heat rises freely to the upstairs spaces, and open "cutouts" in the upstairs walls, which encourage convective airflow. Small fans also send warm, stratified air from the ceiling of the stairway to the north side of the living and dining spaces, and return cool air from the living room floor to the stairway thermal storage area.



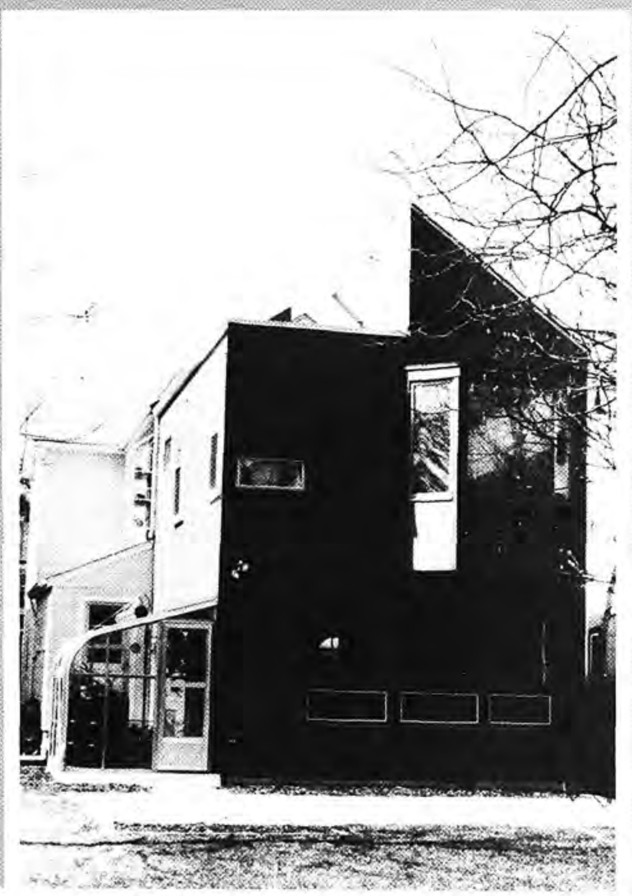
In Princeton, passive heat for a Victorian

Ann and Craig Battle of Princeton, N.J., asked local designer Doug Kelbaugh of Kelbaugh & Lee Architects to increase (by 50 per cent) the size of their century-old Victorian house and ease their heating burden at the same time. Hemmed in on a narrow lot, the house could only be expanded into a spacious backyard to the east, but its south wall lined up within 15° of true south. So Kelbaugh designed a contemporary extension to the east, giving the Battles a passively-warmed, two-story addition with a family room and small greenhouse downstairs, master bedroom and bath above.

A clerestory roof aperture is the addition's primary passive device. Kelbaugh carried the existing roofline across the addition on the north side, but cut it away to create a sawtooth clerestory on the south. Winter sunlight enters the master bedroom through the clerestory— reflective surfaces both above and below the glazing increase the effective insolation— and strikes the bedroom's chocolate brown north masonry wall, which provides radiant evening heat.

Downstairs in the addition, both a small solar greenhouse and an additional window face south. Occupying the greenhouse and doubling as plant shelves are three water-filled 55-gallon drums for heat storage. These, together with the space's tile-covered concrete floor, warm the adjacent family room during the day. At night, a curtain separates family room and greenhouse, with the stored heat enough to protect greenhouse plants from freezing outdoor temperatures. Sunlight penetrating through the greenhouse into the family room, as well as through the additional south window, warms that room's tile floor for radiant evening heating.

Windows in the 720-sf addition are covered with insulating drapes or shades at night, to prevent heat loss. Electric fans located in the clerestory and family room ceilings can pull excess heat in the addition through ducts to the original house. And to improve the entire structure's thermal performance, Kelbaugh installed storm windows, increased insulation, and added south windows to the Battles' original house.



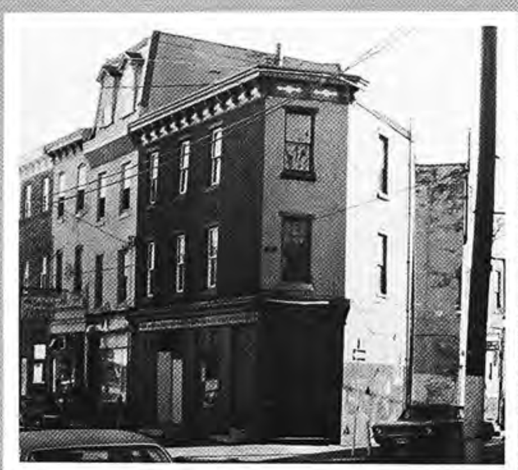
Commercial redesigns: A Philadelphia office . . .

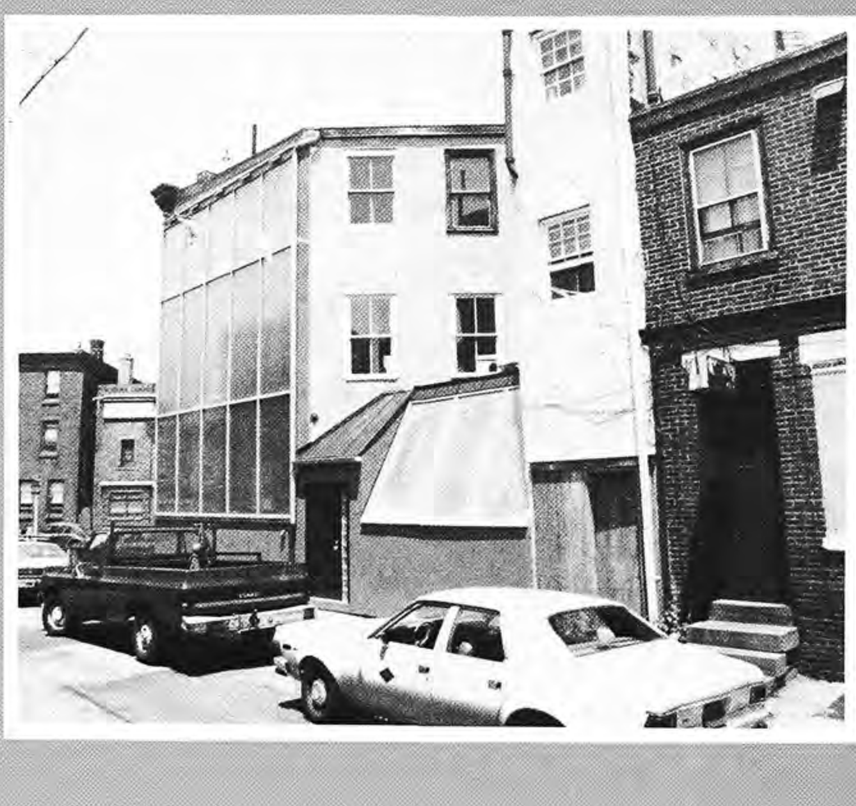
Philadelphia's Donald Prowler and South Street Design are responsible for the energy conscious renovation of the building that houses their own architectural office on the second floor, a loft on the third, and the headquarters of the Mid-Atlantic Solar Energy Association (MASEA) on the first.

Sited on a corner lot with one wall facing almost due south, South Street Design's building posed an interesting challenge for a small commercial retrofit. The firm decided to make a stagnating Trombe wall out of the brick south facade. After painting the brick black and replacing three double-hung windows with fixed glazing, contractors covered nearly the whole wall with twin-walled acrylic two inches from the brick. With no convective circulation between the Trombe airspace and the building's interior—hence the term "stagnating"—only radiant warmth from the brick wall heats the interior spaces. This kind of Trombe wall is less efficient, but according to South Street principal Prowler it often suits a retrofit best, since no holes need to be punched through an existing brick wall, and since the solid brick barrier between interior spaces and the acrylic plastic of the Trombe wall provides a simple solution to the fire code.

Also facing south on the building is a greenhouse addition linked to the first floor (increasing 600-sf of space to nearly 800) and venting warm air to the second.

Only four 55-gallon water drums occupy the space, providing thermal mass; the area isn't actually used as office space. But its construction converted a small vacant notch behind the building into a plant- and light-filled heat source that offers significant visual relief to MASEA's



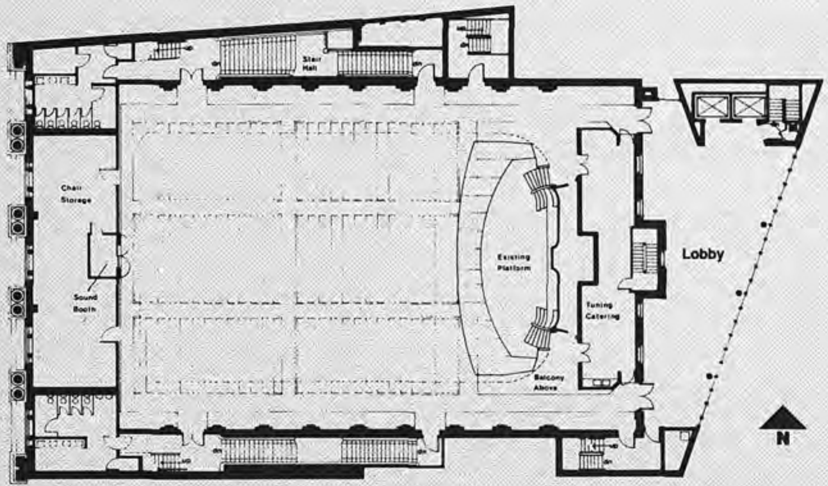


first floor occupants.

Exterior surfaces not covered with glazing are insulated with glued-on foam insulation and a concrete-and fiberglass based finish ("commercially available in 22 colors," Prowler notes).

The South Street renovation was completed in mid-March of last year, and didn't require auxiliary heating for the remainder of a mild Philadelphia winter. Prowler feels some auxiliary heating will be necessary over the course of a full winter. But it's hard to predict how much, he says, since most of the available hand-calculation procedures assume a residential setting without evening and weekend setbacks.

. . . And a historic auditorium in Mass.



Historic Mechanics Hall in Worcester, Mass., renovated by Anderson Notter Finegold in 1978, has won acclaim and an AIA Honor Award more for the quality of the design firm's historic preservation and adaptation effort than for energy considerations. But despite the limited thermal impact of the building's new, fully-glazed three-story rear lobby, the renovation of Mechanics Hall is important for the links it boldly suggests between historic preservation and energy conscious retrofitting on the commercial scale.

Due to new parking and traffic patterns in Worcester, the new rear entrance to the historic auditorium *(right)* is at least equal in importance to the old front doors *(below)*. The new space serves as major entrance, theater lobby, and, in the daytime, as meeting and exhibition space.

The lobby's three-story glazing, following the property line, is canted east-southeast, as near to true south as the situation would permit. The space acts as a solar greenhouse when morning sunlight bears on the non-thermal glazing, with the masonry of the building's original brick rear facade acting as thermal storage mass. On sunny days, the insolation is sufficient to render the mechanical heating system installed for the lobby unnecessary.

Photos by Steve Rosenthal

Studies are now underway to consider a recirculation system that will bring the lobby's passively heated air to other parts of the building. Anderson Notter Finegold is also reportedly exploring the passive solar and conservation potential of renovating urban, multifamily, masonry row housing—a project that, as Progressive Architecture recently noted, could have important implications for commercial adaptation and reuse functions in the existing masonry buildings common to America's cities and towns.

Photo by Randolph Langenbach

Two restored barns, one with a greenhouse . . .

One of two recent barn renovation projects for Princeton's Harrison Fraker Architects—this one involving the conversion of more than 6,000-sf of rude stalls and lofts into comfortable living space—presented a unique set of solar design problems.

Fraker and firm divided the large barn into five separately manageable heating/living zones: a living suite and greenhouse on the lowest level, a three-story space upstairs *(below)* called "the Great Hall of the People" by the owners, two small studies stacked above each other, two extra bedrooms similarly arranged, and a separate apartment located above the garage. Each zone is independently heated, with temperatures allowed to swing according to use patterns.

The lower level living suite comprises master bedroom, living room, kitchen, and dining room. Completely buried on the north side (where a constantly cool subterranean room serves as the kitchen's cold storage), the suite opens on the south to a full-length greenhouse—the family's plant room, day-sitting room, and primary solar heat source. Sunlight entering the greenhouse strikes a row of cabinet-enclosed 55-gallon water drums (which vent warm air to the space with a thermostatically-controlled fan) as well as the masonry floor and rear wall of the greenhouse itself. An insulating curtain drawn against the glazing keeps the greenhouse warm well into winter evenings. At night, doors between suite and greenhouse are closed and the interior spaces are warmed by the radiant masonry wall (with a woodstove for backup).

Upstairs, the dramatic, three-story hall—a difficult space to heat—is glazed on the south and west walls. Solar gain is stored in a large

interior masonry chimney servicing both the hall's high-efficiency fireplace and the woodstove downstairs. Translucent blue multilayer insulating shades cut solar gain in the summer and heat loss on winter nights. These strategies are generally adequate to ensure comfort in the large space, used mostly for entertaining and used seldom during the winter months.

Used far more regularly are two studies stacked above one another and in full view of the large hall, though thermally separated by sliding glass doors. South glazing in each study is backed with water-filled columns *(above)* that absorb heat by day and reradiate it by night, when insulating curtains slow heat loss to the outside.

Two stacked bedrooms at the northeast corner of the home are infrequently used. Warmed with electric baseboard heat when necessary, they are the only non-solar spaces in the building. The garage—a former bullpen—and the two-room apartment above it are warmed, like the studies, indirectly with water-stored solar gain.

. . . And one that solves its orientation

An energy-conscious renovation of the Porters' barn in Mendham, N.J., presented Princeton architect Harrison Fraker and firm with a difficult solar orientation problem. Like a great many barns, this one was built into a hill, exposing two full stories to the north and only one, the upper level, to the south. Bringing sunlight into the spaces on the lower level was the design challenge.

Fraker's first step was to put the home's major living spaces—family, dining, and living rooms, master bedroom, and kitchen—on the upper floor, where maximum winter insolation enters through the glazed south wall. Ten-foot-tall fiberglass water tubes immediately behind the glazing *(above, right)* gain warmth from the sunlight, reradiating it to the inside at night.

To create an indirect gain system for the lower level, Fraker centered a greenhouse extension on the south wall *(right)* and cut a floor opening behind it to allow solar penetration downstairs *(above)*. Another wall of water tubes, a floor below and a hall's width away from the greenhouse, collects heat by day and delivers it convectively by night, through sliding windows, to a pair of bedrooms behind the wall. A stairwell at the southeast corner of the home is used in the same fashion, with sunlight entering through large south windows, striking a water wall, and heating a third downstairs bedroom.

Sliding glass doors between the greenhouse and the main structure are left open during winter days for convective heating of the living

spaces and better transmission of sunlight to the downstairs water tubes. A row of 55-gallon water drums front the greenhouse. They receive both direct and reflected insolation, and provide enough thermal storage to protect plants through the night. When the sun sets, an insulating curtain covers the greenhouse glazing, and insulating shades protect other windows against heat loss.

In summer, the greenhouse's insulating shade is replaced by a canvas sunshade, drawn throughout the day. The Porter's home is cooled by both natural and induced ventilation. Doors and windows are opened, and vents high in the greenhouse exhaust hot air as cooler air is drawn in through windows on the north wall. Skylights above the airy 6,000-sf home's double-story spaces also serve to vent hot air, encouraging convective cooling.

(Continued from page 7)
fore—homes. Encouraging weatherstripping, caulking, insulation, and other small-scale conservation steps that homeowners can take, the RCS program takes its content from one of the most fascinating architectural research projects in recent history.

In 1972, a group of researchers from Princeton University's Center for Energy and Environmental Studies began, with National Science Foundation funding, a five-year study of energy use in a new development of "nominally identical" townhouses (purchase price: \$20,000) in Twin Rivers, N.J., whose construction probably represented as closely as is possible the standard practices of the industry. With one townhouse rented as an uninhabited laboratory, the researchers monitored energy performance there and in several inhabited townhouses. What began as performance monitoring—with thermostats set back and "thermistors" installed to record room temperatures—eventually developed into a complex program of research involving "thermographic" readings for cold spots in walls, attics, and ceilings, and thorough examinations of doors, windows, cracks, vents, insulation, and all of the architectural elements that affect a building's energy performance. What emerged was a complete and unprecedented understanding of energy performance on the residential scale, as designed and constructed by the standards of the day.

The results of the study were a testimony to energy waste, and they encouraged the researchers to explore ways of reducing the amount of energy wasted at Twin Rivers. With new DOE funding, the researchers employed caulking and weather stripping. They applied greater insulation where thermographic readings indicated cold spots (often where one might least expect). And they used several tools as exotic as the "blower-door" (a door-mounted fan used to pressurize interior spaces and thereby reveal thermal leaks in the envelope) to find and stem energy waste.

Their results from this second phase, published in a valuable book called *Saving Energy in the Home* (Ballinger Publishing Co., Cambridge, Mass.) recently dominated the first and third days of a three-day conference on energy-conscious retrofitting held this summer at Princeton (see Notebook). The domination was understandable: the researchers claimed that it is entirely possible to reduce by 75 per cent the energy consumed by the furnace in "quite ordinary, reasonably well-built townhouses in Twin Rivers, N.J." Indeed, one member of the research team said it is quite possible to reduce energy use further by sealing the home even more tightly, but that radon and interior pollution might become problems if the home is made too tight.

The Princeton conference reflected the state of the art in energy conscious architectural redesign today. Like the art itself, the conference was divided into two parts. The first day focused entirely on "closing the envelope"—sealing a building against the leaks and inefficiency that, by the Princeton researchers' estimates, may account for 75 per cent of all energy used. Many of the architects in the conference's audience of 400 spent the day listening not to "redesign" ideas, but to proposals that architects conduct energy audits aimed at finding and identifying sources of thermal loss. The Princeton researchers also made a presentation on an audit-followup program they are recommending called, not inappropriately, "House Doctor." The program would link a building energy audit with immediate followup steps to improve energy performance—steps as simple as setting back hot-water thermostats and making immediate insulation recommendations.

The conference's second day was devoted exclusively to redesign, to "opening the envelope." Princeton architect Doug Kelbaugh (whose solar work was recently highlighted in *Newsweek*, and whose energy conscious renovation of the Battle residence appears here on page 13) opened and moderated the day's remarks. Among the speakers: designer/researcher Travis Price, who is overseeing an ambitious, DOE-supported renovation and revitalization effort aimed at cutting energy use by 40 per cent in an entire city block in the Manchester neighborhood of Pittsburgh; Philadelphia architect Don Prowler, whose commercial retrofit (page 12) houses both his own design firm and the offices of the Mid-Atlantic Solar Energy Association; designer Dan Scully, of New Hampshire's Total Environmental Action, whose retrofit of an East River fireboat house in Manhattan will soon become an energy-efficient energy museum for the children of New York; New Hampshire architect Stuart White, who talked about the barriers to large scale, energy conscious commercial renovation, but showed slides of New York's skyline from the south and pointed to the hundreds of multi-story, south-facing warehouse facades that could be thermally glazed for passive solar energy efficiency.

Several designers presented recent, energy conscious renovation projects, most of them residences, some of which appear in this issue. The techniques—ranging from active, rooftop collector systems for domestic hot water, to solariums integral to existing buildings, to greenhouses barely attached to the living structure—were diverse. But the preponderance of residential projects and the relative sparsity of commercial retrofits was both obvious and honest, reflecting the state of the energy conscious redesign art. Energy-conscious architectural renovations at residential scale have been proven costworthy and effective. The same can't be said of commercial scale—although SOM's renovation of Chicago's Monadnock Building, Anderson Notter Finegold's award-winning Mechanics Hall in Worcester, Mass. (featured here on page 14), and Architectural Heritage-Baltimore's Baltimore City Hall renovation provide notable exceptions that suggest as much as they achieve.

That the same *will* be said, not far in the future, is assured. The revitalization and reuse of America's existing buildings is already in fashion, and the pressures of the economy will continue to apply in that direction. The same pressures will make energy consciousness—still looked at askance by payback-conscious commercial building owners—more attractive with every energy price hike. And the architectural challenges that arise when energy and redesign come together—already responded to with particular skill in the projects featured on the following pages—will make for some of the most interesting architecture to come in the last 20 years of the century.

—Kevin W. Green

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