GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: June 16, 1980

Project Title: Georgia Builders Energy Manual 1980

Project No: A-2657

Project Director: W. B. Himes

Sponsor: Georgia Office of Energy Resources; Atlanta, Ga.

Agreement Period: From 5/1/80 Until 7/31/80

Type Agreement: Unnumbered contract dated 5/1/80 (Subcontract under DOE Grant DE-FG44-77CS60212)

Amount: $10,717

Reports Required: Monthly Progress Reports; draft manuscript; final manuscript

Sponsor Contact Person (s):

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<th>Contractual Matters</th>
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<td>Mr. Ed Bistany</td>
<td>(thru OCA)</td>
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<tr>
<td>Office of Planning and Budget</td>
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<td>Georgia Office of Energy Resources</td>
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<tr>
<td>270 Washington St.</td>
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<tr>
<td>Atlanta, Georgia 30332</td>
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<tr>
<td>Phone: 656-5176</td>
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Defense Priority Rating: none

Assigned to: TAL/ECD (School/Laboratory)

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SPONSORED PROJECT TERMINATION

Date: 5/4/81

Project Title: Georgia Builders Energy Manual 1980

Project No: A-2657

Project Director: W. B. Himes

Sponsor: Georgia Office of Energy Resources; Atlanta, Georgia

Effective Termination Date: 7/31/81

Clearance of Accounting Charges: 7/31/80

Grant/Contract Closeout Actions Remaining:

- Final Invoice
- Final Fiscal Report
- Final Report of Inventions
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G-7A
June 18, 1980

Mr. Ed Bistany
Georgia Office of Energy Resources
270 Washington Street, S.W.
Room 615
Atlanta, Georgia 30334

Re: Progress Summary for EES/GIT Research Project A-2657
for Period May 1, 1980 through June 15, 1980

Dear Mr. Bistany:

This report covers work accomplished during the first half of Project A-2657, "Building and Marketing the Energy Conserving Home in Georgia 1980."

During the first week of the project a budget, schedule, and plan were developed. As of this date the project is on schedule and expenses to date are within the budgeted amount.

A copy of the project plan has been marked to indicate our current position. Also included is a revised copy of the outline for the new manual.

As indicated on the enclosed plan, several areas are complete or in progress. A thorough review of the old manual has been completed. Material requiring changes was identified and 90% of these changes are complete for the first draft.

Several areas of the manual will remain essentially unchanged. The decision was made to have the typing done on a word processor. Typing has begun and the first draft will be complete by Monday, June 23.

Additional information has been developed concerning the design and installation of systems to use wood for space heat. Efficiencies for fireplaces and various types of wood stoves are discussed and installation details are explained to allow the builder to safely provide for wood heat systems.

Jim Clark is expanding the material on passive and active solar systems. He has accumulated manufacturers literature, met with contractors and researched current literature for information that will be useful to the home builder.
During the remainder of the project final artwork will be developed. A meeting with OER to discuss the first draft will be scheduled and necessary revisions to the manual will be made.

In summary, work is progressing on schedule, within budget, and without any unforeseen problems.

Sincerely,

William B. Himes
Project Director

WBH/kw
Building and Marketing the Energy Conserving Home in Georgia 1980

I. Format

A. Cover
1. Change date to 1980
2. Print in sepia brown

B. Title Page
1. Change names
2. Third Printing, August 1980

C. Table of Contents
1. Include Subheadings and Page numbers

D. Type Style
1. Type text space and a half
2. Type set Chapter Headings if budget allows
3. Redraw existing art work to match stove book
4. Maximum number of pages 100

II. Text

A. Introduction
1. Explain the manual
2. Discuss OER

B. Chapter 1 -- Energy Outlook
1. Update all cost figures
2. Redraw graph on page 2

C. Chapter 2 -- Construction Techniques
1. Arkansas Plan, 2" x 6" Framing System
2. Wall Sheathing with Insulating Rigid Foams for 2" x 4" Framing
3. Thermal Door Systems
4. Window Design
5. Window Heat Loss and Heat Gain
   a. Winter heat loss
   b. Summer heat gain
6. Combination Storm Doors for Retrofit
7. Construction Details

D. Chapter 3 -- HVAC
1. Heating and Cooling Load Estimation
2. Selecting HVAC Equipment
D. Chapter 3 -- HVAC (continued)

3. Types of Equipment
4. Sizing Heat Pumps
5. Sizing Air Conditioners
6. Sizing Heating Equipment
7. Zone Control, Separate Systems
8. Sizing Ductwork
9. Duct Design / Installation
10. Controls
11. Ventilation
12. Combustion Air

E. Chapter 4 -- The Economics of Insulation and Energy Conserving Equipment

1. Economic Analysis of insulation and building systems
2. Energy Conserving Equipment
   a. Add heat pump water heaters

F. Chapter 5 -- Std. Const. vs Energy Conserving Const.

1. Standard Construction HVAC
2. Energy Conserving Construction HVAC
3. House Plan Details
4. Design Heating and Cooling Loads
5. Installed HVAC Equipment
6. Annual Heating and Cooling Cost Comparison
7. Extra Cost
8. HVAC Savings
9. Summary and Payback

G. Chapter 6 -- Installing a Wood Heat System

1. Introduction to Wood
2. Wood Equipment Efficiencies
   a. Different types
   b. Sizing
3. Installation
   a. Placement
   b. Clearances
      i. Unshielded
      ii. Shielded
   c. Heat Shields
      i. Floors
      ii. Walls
      iii. Ceilings
      iv. Sizing
   d. Ventilation and Flues
4. Educating the new Owners
H. Chapter 7 -- Building the Solar Energy System
   1. Solar Water Heaters
      a. Introduction
      b. Design & Sizing Systems
      c. Economics
         i. Cost
         ii. Benefit
         iii. Payback
   2. Passive Solar Design
      a. Summer Design and Site Orientation
      b. Winter Design and Site Orientation
         i. Design Consideration
            (a) Glass
            (b) Storage Mass
            (c) Ventilation
            (d) Cost
            (e) Payback

I. Chapter 8 -- Georgia Energy Code
   2. Common Questions and Answers

J. Chapter 9 -- Insulation and Infiltration
   1. Thermal Insulation
      a. R Factors
      b. Cost
   2. Vapor Barriers
   3. Infiltration
      a. Caulking
      b. Sealers
      c. Foam

K. Chapter 10 -- Marketing The Energy Conserving Home
   1. Introduction
   2. Energy Costs
   3. Cost / Benefit Analysis
   4. Energy Conserving Home Marketing Approach
      a. Subcontractor
      b. Inspectors
      c. Appraiser
      d. Lenders
      e. Real Estate Agents
      f. Home Buyer
         i. Costs
         ii. Benefits
         iii. Explanation of Features
L. Chapter 11 -- Summary

M. Appendices

a. Seasonal Heating Costs
b. Heating and Cooling Cost Multipliers for other Cities
c. Cost Data for Energy Conserving House Plans
d. Glossary
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<td>5/3</td>
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<tr>
<td>Review manual &amp; outline necessary changes</td>
<td>5/10</td>
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<tr>
<td>Pre-project meeting with OER</td>
<td>5/17/24</td>
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<td>Contact GHBA for input into changes</td>
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<td>Develop outline for new manual</td>
<td>6/7</td>
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<td>Begin typing unchanged sections</td>
<td>6/14</td>
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<td>Develop data for additions</td>
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<td>7/26</td>
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**LEGEND**

- The black bars represent the tasks and their duration.
- The dates on the left side correspond to the completion of the respective tasks.
CONVENTIONAL FRAMING

2"x4" STUDS - 16" O.C.
INTERIOR FINISH

PACK SPACE BETWEEN BLOCKING OF CORNER POST W/ INSULATION

VAPOR BARRIER TO WARM SIDE ONLY

3/12" FULL THICK BATT INSULATION R-13

RIGID FOAM SHEATHING

EXTERIOR CORNER & WALL FRAMING

NOTE:
ATTIC VENTILATION REQUIREMENTS DESIGNED FOR COOLING SEASON. THIS WILL BE ADEQUATE TO PREVENT CONDENSATION DURING HEATING SEASON. 1.5 TO 2.0 CFM PER SQ.FT. OF ATTIC FLOOR AREA.

DO NOT RESTRICT AIR FLOW

3" CONT. SOFFIT VENT

ATTIC VENTILATION

INTERSECTION OF INTERIOR WALL

WIRING RACEWAY
4" CONC. SLAB OVER VAPOR BARRIER

1/2" SHEATHING

2"x3" or 4" STUDS - 24" O.C.

1"x6" OR METAL BACK-UP CLIP

2"x6" STUDS - 24" O.C.

HEADER DETAIL
(MAXIMUM SPAN - 4'-0"

1/2" SHEATHING

2"x6" STUDS - 24" O.C.

1"x6" OR METAL BACK-UP CLIP

NOTE:
ATTIC VENTILATION REQUIREMENTS DESIGNED FOR COOLING SEASON. THIS WILL BE ADEQUATE TO PREVENT CONDENSATION DURING HEATING SEASON. 1.5 TO 2.0 CFM PER SQ.FT. OF ATTIC FLOOR AREA.

DO NOT RESTRICT AIR FLOW
BUILDING AND MARKETING THE ENERGY CONSERVING HOME

Produced by Georgia Institute of Technology, Engineering Experiment Station

Sponsored by the Georgia Office of Energy Resources
With Assistance from The Home Builders Association of Georgia
For additional information or copies of this document, please contact:

Georgia Office of Energy Resources
270 Washington Street, S.W.
Room 615
Atlanta, Georgia  30334
(404) 656-5176
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The residential builder in 1980 is faced with rising material and labor costs, a fluctuating and high interest rate market, and potential consumers who are increasingly concerned with the high energy costs usually associated with home ownership. The 1980 edition of "Building and Marketing the Energy Conserving Home in Georgia" addresses how today's builders can effectively incorporate energy conservation techniques in residential construction without an unrealistic increase in overall consumer costs. The publication focuses on three areas:

1. Energy costs and economic analyses of standard housing versus energy efficient housing in terms of HVAC systems, construction techniques, and insulation.

2. State of the art developments in energy efficiency equipment including set-back thermostats, pilotless ignition systems, woodstoves, and passive solar heating.

3. Marketing and appraising the energy efficient house as viewed by FHA/VA, FHLMC, FmHA, and conventional savings and loan institutions.

This publication was produced by the Technology Transfer Branch of the Georgia Tech Engineering Experiment Station (GT/EES) under contract to the Georgia Office of Energy Resources. The Georgia Office of Energy Resources is the state's primary energy agency and is charged with encouraging energy conservation and the use of renewable energy resources. Georgia Tech EES Technology Transfer Branch is a group whose function is to assimilate information regarding new developments in areas such as energy conservation and effectively communicate that data to the public in both a written and oral format.
Energy conservation was not a prime concern in home design until world events of the past decade disrupted the flow of foreign oil to Americans. Boasts about rising utility bills as a status symbol quickly gave way to groaning complaints when energy costs became a major portion of the family budget. As shown in Figure 1.1, the cost of living index has doubled since 1970 while fuel costs have more than tripled. That is an average yearly increase of 12% for residential electricity and 14% for natural gas.

A number of research teams across the United States have recently investigated energy consumption patterns for the future. They concluded that we do not need to lower our standard of living to cope with energy constraints of the future; we need to take steps now that will avoid wasting the energy available. Opportunities are many in the residential sector. Houses built today will be standing 50 years or more, saving or wasting energy for that lifetime. More insulation, lower infiltration, better glazing and doors, high efficiency mechanical systems, and proper site orientation and shading can all be easily incorporated during the construction phase.

Fortunately for homebuilders, these simple structural and design changes can cut home energy use in half, yet increase cost of the home a mere 3%. And surveys have shown that today's home buyers are willing to pay for energy conserving features when it means lower utility bills.

So the wise homebuilder will develop an energy awareness, incorporate this awareness into his building and marketing strategies, and know that he has contributed in the fight against rising fuel costs. The discriminating home buyer will recognize these extra efforts and reward the homebuilder with an enthusiastic response to a sensible, energy-conserving home.
NATURAL GAS

UNIT PRICE INCREASES FOR GEORGIA

1970-1980

PERCENT INCREASE

ELECTRICITY 200%
NATURAL GAS 260%
COST OF LIVING 200%

$14.40

$3.60

COST OF LIVING

ELECTRICITY

NATURAL GAS


Figure 1.1

SOURCE: GEORGIA POWER COMPANY
CHAPTER 2

DETAILS OF NEW CONSTRUCTION TECHNIQUES

As both builders and architects have become more aware of the economic advantages of energy efficient housing design and construction, the market has seen the advent of new construction techniques geared specifically to these needs. The goal in developing these construction techniques is to minimize conduction heat loss and gain while keeping material and labor costs to a minimum. Houses built in this manner can still retain the conventional look, but at the same time, have a number of energy saving features. The basic plan is the Arkansas Framing System Plan, which includes high efficiency wall sheathing and the design and installation of thermal door and window systems.

ARKANSAS PLAN 2" X 6" FRAMING SYSTEM

Responding to the need for affordable energy conserving housing, an air conditioning engineer, a power company employee, and, years later, a construction analyst created the "Arkansas Plan." This construction method greatly conserves energy and is finding increasing acceptance by home builders. The original test houses using this construction method were built in Little Rock, Arkansas. Careful analysis of utility bills from these houses showed a dramatic 73.6% savings in energy use for heating and cooling.

The Arkansas Plan produces a conventional looking house, but uses a different framing system that allows more use of insulation. Walls are constructed of 2 x 6 studs on 24" centers, rather than 2 x 4 studs on 16" centers, thus cutting down on framing lumber and allowing the use of R-19 fiberglass wall insulation. Figure 2.1, "Exterior Corner and Wall Framing," shows the details. Note the position of the vapor barrier and use of a 1 x 6 or plaster back-up clips at the exterior corner to eliminate excess framing. The diagram on "Intersection of Interior Wall" shows the same use of a 1 x 6 or metal back-up clips to eliminate framing and allow the use of more insulation and less wood in the exterior walls. The "Slab Floor" diagram shows rigid foam perimeter insulation and location of a wiring raceway that keeps wires out of the main wall cavity, allowing it to be completely filled with insulation. The "Header Detail" shows an open header filled with insulation and strengthened with plywood
ENERGY CONSERVATION THRU INSULATION

TWO WAYS TO UPGRADE INSULATION (CHECK ONE □)

1. THE ARKANSAS PLAN
2. CONVENTIONAL FRAMING

NOTE: THESE METHODS APPLY TO BRICK VENEER AND/OR FRAME CONSTRUCTION

IN ENERGY EFFICIENT HOUSING, SPECIAL EMPHASIS SHOULD BE PLACED ON
MINIMUM INFILTRATION AROUND WINDOWS, DOORS, ELECTRICAL BOXES, PIPES,
AND CANTILEVERED AREAS. GLASS AREAS SHOULD BE LIMITED AND DOUBLE
GLAZING OR STORM SASH ARE OF GREAT VALUE. ADEQUATE ATTIC VENTILATION
SHOULD BE PROVIDED.

THE DEGREE OF ENERGY EFFICIENCY IS DEPENDENT ON BOTH QUALITY OF
WORKMANSHIP AND QUANTITY OF INSULATION.

NEW (R-VALUE) INSULATION STANDARDS

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</table>

*RECOMMENDED BY OWENS-CORNING

NOTE: WITH FOIL FACED FOAM SHEATHING, USE 6 MIL. POLYETHYLENE VAPOR BARRIER INSIDE.
sheathing. Finally, the "Walls Section" shows an overall view of this framing system, including under-floor insulation and a truss roof that allows installation of extra insulation.

There is less lumber used in this type of construction. Builders who are familiar with the Arkansas system claim that less labor is involved and there is little if any extra cost over standard construction. The extra cost for insulation is offset by lower costs for smaller heating and cooling equipment.

More information on this construction technique is contained in a booklet from Owens/Corning Fiberglas, "Energy-Saving Homes, The Arkansas Story."

WALL SHEATHING WITH INSULATING RIGID FOAMS FOR 2" X 4" FRAMING

There are two basic types of wall sheathing—structural and non-structural. High density fiberboard, plywood, and "Thermoply" are considered structural sheathing. Cross-bracing is not required at the corners of the house with these materials if they are tested and approved for this use.

Rigid foams ("Thermax," "High R," "Styrofoam," Beadboard) and low density fiberboard are non-structural. They offer much higher insulating values (2 to 8 times better than structural sheathing), but must be used with cross-braces on corners of exterior walls.

Structural sheathing is applied with common nails or roofing nails. It must be cut with hand or power saws. Standard sizes are 4' x 8' or 4' x 9' sheets.

Rigid foam sheathing requires roofing nails or other nails with large diameter heads. It can be cut or scored and broken with a razor knife. Standard sizes are 4' x 8', 4' x 9', and 2' x 4' sheets. Some brands have a tongue-and-groove edge; others have a flat edge.

Extra care should be taken when installing rigid foam sheathing to avoid breakage. Any holes in the sheathing should be repaired before the siding is applied. Repairs are made by replacing the damaged section or taping it back in place.

Rigid foam sheathing that has a foil face requires installation of a polyethylene vapor barrier between the drywall and wall studs. This prevents moisture from building up in the wall cavity, which can lead to dry rot and peeling of exterior paint. "Thermax," "High R," and "Climate Guard," require a 6-mil poly vapor barrier. Most other foam sheathing that has a foil face backed with cardboard requires a 4-mil poly vapor barrier. Dow "Styrofoam" and white beadboard require only the Kraft paper vapor-barrier on the fiberglass batts.
THERMAL DOOR AND WINDOW DESIGNS

Thermal Door Systems. Standard pre-hung exterior doors are made of solid wood or a solid core with veneer finish. A new type of door, called a "steel-faced foam core door" or "an insulating door" is rapidly replacing the standard exterior door. These insulated doors have about five times more resistance to heat flow and near zero infiltration (air leakage) rates. However, special attention must be paid when installing these doors.

First, READ THE INSTRUCTIONS. Most manufacturers tape an instruction sheet to the door. Each maker has slightly different installation instructions; be sure to read them carefully.

All steel-faced doors must be shimmed to a proper height so that they will clear the finished floor surface. Standard doors made of wood can be planed if they are too long and scrape on the floor or bind on the rug. You cannot plane a steel-faced door, so allowance must be made during installation so that the door will clear any conceivable floor finish from plush wall-to-wall carpet to hardwood floors.

The threshold of these doors are adjustable in height to position the threshold snugly against the weatherstrip at the bottom of the door. One common adjustment system is large exposed screws that, when turned, raise and lower the threshold; another uses sliding wedges to change the threshold height. There are other systems on the market; again, check the manufacturer's instructions.

The doors usually are pre-drilled for the entry lock. Many home buyers want the extra protection of a deadbolt lock. If this is the case, the door should be ordered pre-drilled for both entry lock and the deadbolt lock to save mistakes and time in the field.

Many manufacturers include two extra long screws with the installation instructions. If these are provided, they should be used to replace screws in the top hinge. Their extra length allows them to penetrate the rough framing behind the finish door frame. This helps strengthen the door system and better supports the heavier weight of the insulated door.

Combination Storm Doors for Retrofit. Storm doors are not a good choice for new construction. The metal-clad foam core door costs the same as a standard door plus storm door and the metal-clad door is superior in insulating capability. Storm doors are more useful for retrofit of existing houses. Most better models offer a screen for summer use, with a vertically sliding glass window. Less costly types require removal of the glass and replacement with the screened insert. Payback periods and installation are the same as with storm windows.
**Window Design.** The window is both hero and villain in energy conservation. Windows admit natural sunlight, fresh air, and ventilation. They also lose heat during the winter and gain heat during the summer. Obviously, a compromise is needed. Proper window design incorporates the following rules:

- Minimize the amount of glass area, keeping it just above the minimum code requirements.
- Eliminate or minimize use of glass on the west side to reduce solar heat gain during the summer.
- Minimize use of glass on the north side.
- Maximize use of glass on the south side, and use a properly designed overhang to shade the glass during the summer and allow the sun to enter during the winter.
- Use high quality windows with low air infiltration rates; install storm windows or double glazing.

Large expanses of glass are a thing of the past, unless specially designed on a passive solar collector system on the south side of a house. This type of design must provide for thermal mass such as a concrete slab floor to store and release the heat and prevent overheating. A single pane window will lose about 20 times more heat per square foot than a well-insulated wall. It can be said that people who live in glass houses—shouldn't. The cost of heating and cooling them will become prohibitive in the future.

**Window Heat Loss and Gain.** U-values are commonly used to express overall conduction heat loss for windows. A single pane window has a U-value of 1.13; add a storm window, and the U-value drops to 0.64, a 44% lower heat loss. Double glazing has a U-value of 0.71, or a 38% lower heat loss than single pane, and triple glazing has a U-value of 0.42, 63% lower heat loss than single pane. The R-value of single pane, double pane, single pane plus storm window, and triple glazing are 0.88, 1.41, 1.56, 2.38, respectively. Triple glazing is not economical in Georgia at this time, but may prove feasible in the future, especially on all-electric homes.

Solar heat gain is a large portion of the air conditioning load. It is worth comparing the heat gain of various window configurations, using a single pane east or west facing window as the basis. (See Table 2.1.)
Some conclusions may be drawn from the above:

- Unshaded east or west glass produces the highest air conditioning load; west glass is the worst orientation, as the solar gain through the window occurs at the hottest time of the day. White, opaque window shades reflect some sunlight, cutting the heat gain significantly.

- Exterior shading (shade screen, awnings, porches, trees) is the most effective way to control the solar heat gain that causes high air conditioning loads. Placing the garage or carport on the west side of the house and eliminating the glass on this side is an effective way to prevent the problem before the house is built.

CONSTRUCTION DETAILS

Figure 2.2 is W. D. Farmer's guide to energy conserving construction. It covers many of the details listed above and proper installation of new insulation systems.
**Energy Conservation Thru Insulation**

**Specifications for Energy Efficient Housing**: (Applies to brick veneer and/or frame)

**Foundation**:
1. With unexcavated areas, use R-Insulation between floor joist and 4 mill polyethylene vapor barrier on grade.
2. With slab floor foundation or basement slab above grade, use 1½" rigid urethane perimeter insulation.
3. Apply fiberglass sill sealers or bead of caulk.

**Framing**:
1. Use 4 mill polyethylene vapor barrier on warm side of walls, and full thick batt insulation between 2½" exterior stud walls or Kraft-faced insulation between studs. Use 1" thick polystyrene foam sheathing.
2. Chink and caulk around all windows, exterior doors, pipes, electrical outlets, and cantilevered overhangs. Cover these areas with vapor barrier.
3. Restrict glass area on north and west sides of house as much as possible. Windows to be insulating glass and/or storm sash.
4. Use metal clad, foam core exterior doors with magnetic weatherstripping.
5. For amount of recommended insulation, see chart, page 1 of 1, this sheet.
6. Use continuous ridge and soffit vents and/or thermostatically controlled power ventilator for attic ventilation.

Note: Some of the specifications on this sheet may show greater requirements than the construction prints. In that case, the information on this sheet should take precedence.
CHAPTER 3

HEATING, VENTILATING AND COOLING SYSTEMS

It has been estimated that almost 70% of a typical utility bill is spent on heating and air-conditioning the house. Of major importance to the builder and HVAC (Heating, Ventilating and Air Conditioning) contractor is selection and installation of properly-sized equipment for an individual house. Calculation of the heating/cooling load for a particular house will determine the type and size of equipment to be selected. Once installed, the builder must also address the problems of duct design and insulation, zone control, and ventilation to insure the most efficient system for his house.

HEATING AND COOLING LOAD ESTIMATION

Probably the most important task in assuring high energy efficiency with heating and air conditioning installations is an ACCURATE calculation of the structure’s heating and cooling loads. In the past, most installers sized heating and air conditioning equipment by rough block load estimates (for example, 600 square ft per ton). With the current trend toward well-insulated homes and homes constructed with careful attention toward reducing air leakage, rough estimates must be avoided. Inaccurate estimates of heating and cooling loads almost always lead to the selection of oversized heating and air conditioning equipment, and oversized equipment is one of the major factors in energy inefficiency.

Even when going through the calculation of the heating and cooling loads, careful attention should be given to exercising maximum accuracy. The use of rough estimates for such things as infiltration and ventilation rates or structural areas, will always lead to an inaccurate heating and cooling load calculation. Quality installation necessitates obtaining accurate information as to structural characteristics and insulation thicknesses and then proceeding with an accurate calculation.

Within the industry, there are two accepted reference methods used in calculating heating and cooling loads. These are:

- American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Handbook of Fundamentals.
- National Environmental Systems Contractors Association—Manual J.

In the past, the ASHRAE Handbook has been primarily utilized in the calculation of heating and cooling loads for larger systems—commercial, institutional, and industrial applications. For residential applications, the Manual J has been the most
used. Due to the more energy efficient building techniques that are currently being used, both of these methods should be utilized as needed. Also, because it is difficult for these reference methods to stay current with the latest energy conservation building techniques, these methods should be modified where a more energy conserving building technique is being employed. Manual J recently added an "Addenda to Table 2, Manual J, 4th Edition" that covers many new insulation systems.

In calculating the cooling load, very accurate data should be used for such things as the solar load and the internal heat load. With the well-insulated home, these loads amount to a large percentage of the total load. Therefore, a rough estimate of the number of people, cooking appliances, and square feet of window area for solar load can make a very big difference in the total calculation.

Another area to give careful attention to in the calculation is the heat loss or heat gain from the ducts. It has been common practice to estimate the duct loss at 10% of the total building load. With the more energy efficient homes, better duct installations are used that will result in less heat loss or gain.

SELECTING AND SIZING HVAC EQUIPMENT

Selection. For maximum efficiency, the heating and cooling equipment must be selected to match as nearly as possible the heating and cooling load calculation. Do not mistrust your calculation and install oversized equipment. Do not allow others to convince you to install oversized equipment. Oversized equipment can only result in a waste of energy and too much capital cost for the equipment.

There is a general opinion from the contractors who are accustomed to installing equipment in houses with normal insulation that the small units will not be satisfactory in energy conserving houses because of such a small volume of air distributed within the structure. Standards adhered to in the past have dictated or suggested a certain air movement for comfort within a building. When calculations for the better insulated homes indicate a unit one-half the size commonly installed, they raise questions about the possible discomfort and stuffiness with such little amount of air distribution.

For this reason, heating contractors often calculated a 1-1/2 ton cooling load only to mistrust their calculation and put in a 3 ton air conditioner because of the CFM (cubic feet per minute) concern. This should be avoided. Experience with well-insulated homes where small tonnage has been installed shows that comfort conditions are maintained with the smaller CFM's. Remember that air movement and concepts like "CFM per square foot" were created for warm air systems. Older systems that
heated houses with steam or hydronic radiators had no CFM passing from room to room. Air circulated at much lower velocities in each room by natural convection. Only enough CFM is needed to properly unload the installed tonnage of the air conditioning system, and to maintain a proper temperature rise from return to supply air for the heating system. Ducts and registers must be downsized to maintain proper velocities into the room for good air distribution.

Types. There have been many discussions as to which types of heating and air conditioning equipment are more efficient. At present utility rates, natural gas heating with electric air conditioning is the lowest cost. Where natural gas is not available, the utility costs for heat pump systems are very competitive with propane gas or oil heating and electric air conditioning. Gas absorption air conditioning with natural gas is competitive with other systems as to fuel cost, but capital investment is so much higher compared to the other systems that it is seldom used. When considering electric units, the heat pump is recommended because of its higher efficiency as compared to resistance heating.

Heat Pumps. Heat pumps should be sized for the cooling capacity. Efforts should be made to select equipment with cooling capacity as nearly equal as possible to the cooling load calculation. A slight oversize, perhaps 10%, may be necessary to match particular models of equipment. Equipment that is slightly undersized will operate more efficiently and will provide satisfactory performance if the heat gain calculation has been made with accuracy. Do not undersize by more than 10% however.

It is recommended that auxiliary resistance heater capacity be installed to meet 100% of the heat loss of the structure. These heaters should be wired in incremental stages--approximately 5 KW per stage is the normal practice. Careful attention should be given to controlling the heaters so they are only energized at the lowest possible outdoor temperature. Remember that a heat pump with only the compressor supplying the heat is a very efficient unit, operating at a coefficient of performance (COP) of near 2.5 or above at 40°F outdoor temperature. Resistance heaters on the other hand have a COP of 1.0. Therefore, when the resistance heaters are allowed to be energized at temperatures where the heat pump cannot handle the heat load or in too many stages, the overall COP of the heat pump drops. This causes the unit to be less efficient and more costly to operate.

A performance curve should be superimposed on the heat loss curve of the structure. This type of diagram is shown in Figure 3.1. This will show at what temperatures resistance heating is needed to supply booster heat to handle the heating
Figure 3.1

HEAT PUMP AUXILIARY HEAT CONTROL

HEATING CAPACITY AND HEATING LOAD (1000 BTUH)

OUTDOOR TEMPERATURE (°F)

HEAT PUMP CAPACITY
W/12 KW SUPP. HTG.

3RD. STAGE HTG (4KW)

2ND. STAGE HTG (4 KW)

1ST. STAGE HTG. (4 KW)

BALANCE POINT

2 1/2 TON HT. PUMP CAPACITY

HOUSE HEATING LOAD
Load. Let's assume that the compressor can handle the structure heat load down to 40°F outdoor temperature. The first stage of the resistance heaters should be controlled to operate at this 40°F outdoor temperature. This is usually accomplished by using an indoor thermostat with two steps of heating. The number one step controls the heat pump compressor. The second step controls the first stage of auxiliary resistance heating. It is recommended that this first stage also be controlled through an outdoor thermostat set at this 40°F setting. The other resistance heater stages are controlled through outdoor thermostats at appropriate settings along with the second stage of the indoor heating thermostat.

A switch should be installed on or near the indoor thermostat to bypass the outdoor thermostats. This allows resistance heaters to be utilized for heating the structure if the compressor is inoperative. It will also allow quick heat recovery within the structure when desired.

Air Conditioners. Again, air conditioners should be sized so that the capacity is sufficient for the heat gain calculation or cooling load. Oversizing of air conditioning should be avoided. Oversizing an air conditioning system can lead to call-backs. Short cycling due to over-capacity will cause discomfort and lead to high humidity in the house. Longer cycle times are needed for dehumidification to take place, and the evaporator coil may become blocked with ice under severe conditions. Finally, oversized units will cause high utility bills because of their less efficient operation.

High SEER (Seasonal Energy Efficiency Ratio) split systems are available and should be used. An SEER of 9.0 or above is generally considered to be an energy conserving air conditioner. Some manufacturers have SEER ratings of 10.0 or more.

Heating Equipment. As with the air conditioning sizing, heating equipment should be sized to meet the heating load calculation. Oversizing again should be avoided. Many zones can be utilized with electric resistance baseboard heating.

All furnace systems and hot water heaters that burn gas or oil must be adjusted to the correct air/fuel ratio. This is done with a CO₂ test kit. Improper adjustment will cause soot deposits or excess air consumption, which will lower the efficiency of the system and increase the operating costs.

DUCT WORK

Sizing Ductwork. The branch runs should be sized for the heating loads, because people are more sensitive to the heating comfort than they are to comfort during the cooling season. Volume dampers should be used in all branch runs. A volume control
damper should be used in any main ducts that have a splitter (for example, a main duct separating for the upstairs versus the downstairs area). All too frequently installers rely on registers for controlling the volume in balancing the system. This will result in air noise and improper balancing on the system. The volume dampers are very inexpensive and will result in a good quality installation.

Duct Design/Installation. The duct design and installation are very important as to the efficiency of a heating and air conditioning system. Major areas of waste include:

- Improper insulation.
- Unbalanced system that results in overheating or overcooling certain areas to maintain comfort conditions in others.
- Inadequate provisions for balancing the system due to changing conditions or changing living habits.
- Leaking ducts and ducts that are too small resulting in inadequate air distribution and inefficiency of the system.

Careful attention should be given to sealing all duct work and eliminating any leaks. This is extremely important where there is extensive duct run in unheated areas.

Where ducts are run in unheated areas, both the supply and return ducts should be insulated with two inches of glass fiber insulation. The insulation should have a vapor barrier to the outside (for example, foil-back insulation). The joints and seams should be carefully taped to insure a continuous vapor barrier. Improperly insulated duct and an improper vapor barrier will result in condensation soaking the insulation, sharply decreasing its insulating value.

ZONE CONTROL, SEPARATE SYSTEMS

In two-story homes and split level homes, it is very difficult to obtain good air distribution in both summer and winter for even-comfort temperature conditions. Separate units are recommended for the upstairs and downstairs. This will provide zone temperature control and result in higher efficiency. Separate zones may also be justified where different activities within these zones will result in air conditioning loads at different times of the day or where different temperature settings may be desirable. Higher settings can be maintained in some areas of little activity, and more comfortable temperature settings can be maintained in other areas. An example is a zone for the living and dining area and a second zone for the sleeping areas. Separate systems can usually be justified in houses exceeding 2,000 square feet for reasons of economy and control.
Controls. Controls usually consist of indoor thermostats, outdoor thermostats, time switches, and other related components. The indoor thermostat should be located near the center of the zone to sense the most representative air temperature in that zone. Careful attention should be given to locating this item away from direct sunlight, heat-producing appliances, and areas behind doors. This control should be located near a main return.

Setback thermostats are gaining in popularity and are a very effective way of reducing energy costs. Experience has shown that these units will pay for themselves in a short time—usually less than two years. This type control utilizes a time switch with day and night thermostat settings. At a preset time at night, the thermostat automatically switches to the night setting. During the heating season, for example, the day setting may be 70°F. At bedtime, the thermostat automatically sets back to a night setting of 62°F, and resets to the day setting around 6:00 a.m. the next morning. This technique will yield a substantial energy savings over the year.

Ventilation. With the more energy efficient homes that have better insulation and are constructed to reduce air infiltration to a minimum, some attention should be given to ventilation of the home. The normal ventilation equipment within the home consists of bathroom ventilating fans, range hood ventilating fans, and exhaust outlets for furnace, dryer, or other combustion appliances. This air is normally made up by infiltration. However, with the tighter construction, this could cause a problem when exhausting air from the home. One arrangement that might be considered is a fresh air supply duct for the home with a relief damper operated by a pressure differential device. This device would automatically supply make-up air to the home when pressure differentials indicate the need for this air. This would cause ventilation fans to operate properly, but would not introduce excessive outside air causing an energy waste. The old method of running an outside air inlet duct into the air return system without automatic control of a damper should not be used.

Combustion Air. Ducting combustion air from outside the house to a furnace room in the conditioned space is important. The tighter a house is built, the more difficult it is for a gas, propane, or oil furnace or hot water heater to obtain enough air to burn the fuel. It would be better when possible to locate the furnace in the crawlspace or cold storage area rather than the conditioned space to avoid this problem. In severe cases the operation of kitchen, bath, and clothes dryer fans can pull stack gases back into the house if the furnace room does not have an outside air duct.
For safety and energy conservation, the interior furnace room should have an unvented door and two air inlets—one near the ceiling and the other near the floor. The size of the openings needed varies with the furnace input rating, whether it is equipped with a draft hood, and where the combustion air is taken in. Check with your local code official for the proper size. NFPA (National Fire Protection Association) Booklet No. 54, pages 23-26, contains diagrams of typical installations. The air inlets must be separated by at least 3-1/2 feet, measured vertically, with the top inlet above the draft board.
The most important areas that the builder must address in order to maximize the energy efficiency of his construction are those of thermal insulation and infiltration and vapor barriers. Energy conservation in the shell of the building starts with thermal insulation to retard the flow of heat, the application of vapor barriers to preserve the structure and insulation of the house, and infiltration barriers to decrease air leakage.

THERMAL INSULATION

Thermal insulation is used to retard the flow of heat. Houses lose and gain heat three ways: conduction, convection, and radiation. Common insulating materials reduce heat flow by conduction; they have little effect on radiant and convective heat transfer.

There are two benefits of adding thermal insulation:

1. Money and energy are saved. Less heat is lost in the winter, and less air conditioning is needed in summer.

2. More comfort is provided. Walls, ceilings, and floors will be closer to the temperature of the air in the room, rather than to the conditions outside.

As fuel costs rise, the economic thickness of insulation increases. The economic thickness is the amount of insulation which yields the lowest total cost per year for utility bills plus mortgage payments for the cost of the insulation. In essence, the owner of a building wants to pay the lowest "comfort cost" per year, which will be the sum of the utility cost and the yearly mortgage bill for insulation. There is not one "optimum R-factor." The economic thickness of insulation varies with energy, insulation, and installation costs. The cost per R-factor per square foot for widely used insulating materials is given in Table 4.1.

General Notes on Insulation. There are three basic types of insulation commonly used in new construction. Fiberglass is the best all around insulation for most purposes. While it is fire resistant, it should be noted that the vapor barrier is not. Rigid foams are now in use, primarily for wall sheathing. They are more expensive than fiberglass per R-value, but they are used for purposes for which fiberglass is not
TABLE 4.1

<table>
<thead>
<tr>
<th>Cost Comparison (for materials only) (not including installation)</th>
<th>Approximate cost, Cents per sq. ft. per R value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. &quot;Thermax&quot; or &quot;High R&quot;</td>
<td>5.9</td>
</tr>
<tr>
<td>2. &quot;Styrofoam&quot;</td>
<td>5.5</td>
</tr>
<tr>
<td>3. &quot;Supersheath&quot;</td>
<td>6.1</td>
</tr>
<tr>
<td>4. White bead board</td>
<td>3.2</td>
</tr>
<tr>
<td>5. Urea formaldehyde foam</td>
<td>5.0</td>
</tr>
<tr>
<td>6. Glass fiber - batts or blankets</td>
<td>1.4</td>
</tr>
<tr>
<td>7. Glass fiber - blown or poured</td>
<td>1.1</td>
</tr>
<tr>
<td>8. Cellulose</td>
<td>1.1</td>
</tr>
<tr>
<td>9. Fiberboard sheathing</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Note: Table 4.1 is a cost comparison for cost of insulating materials. These prices vary with time, locality, and thickness of material and are only an approximate guide. Rigid foam prices are based on 3/4" thick sheets and batts and loose fill on 3-1/2" thickness. These prices are for Atlanta, June 1980.

The polystyrene and urethane foams are the most flammable and must be covered with sheetrock to meet building codes. The polyisocyanurate types are the most fire resistant, but require poly vapor barriers. Rock wool is a good material for attic insulation. Cellulose insulation is also good for attics, and some insulation installers can spray it into the wall cavity with a binder to keep it in place. Fire resistance of this material is dependent on chemical treatment. Effective July 6, 1979, (FR, Vol. 44, No. 131, pp. 39938-40002), the Consumer Products Safety Commission promulgated new testing procedures to assure more fire resistance and quality control. Copies of these regulations may be obtained from the U.S. Government Printing Office.

The new test for fire resistance is an amended version of HHI-515D, a General Services Administration specification. The cellulose is rated on a pass/fail basis in two categories and must pass them both. The Consumer Products Safety Commission is involved in setting up and amending these safety and reliability guidelines. It is recommended that this material be kept 3" away from heat sources such as recessed spotlights.

Urea formaldehyde "wet foam" insulation has made little penetration into the new home market. The product is relatively new and is currently being investigated to determine whether there are potential hazards associated with its use. The possible
shrinkage of the material, formaldehyde odor, and high price are its drawbacks. Installed cost is about 4 times as much as R-11 fiberglass.

Foam core insulated doors are made with a variety of core materials. The door leading to the garage must be fire-rated; these are available from most of the insulated door manufacturers.

R-Value and Cost of Typical Materials

R-value represents the resistance of the insulation to heat flow: the higher the R-value, the better the insulating capability of the material. Tests to determine R-value are developed by the Federal Trade Commission. Table 4.2 gives R-values for commonly used insulating materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>R Value per 1&quot; Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. &quot;Thermax&quot; or &quot;High-R&quot; or &quot;Climate Guard&quot;</td>
<td>8.0</td>
</tr>
<tr>
<td>2. &quot;Styrofoam&quot;</td>
<td>5.41</td>
</tr>
<tr>
<td>3. White bead board, &quot;Supersheath&quot; &quot;Super-R Plus&quot;</td>
<td>4.25</td>
</tr>
<tr>
<td>4. Urea formaldehyde wet foam</td>
<td>4.2</td>
</tr>
<tr>
<td>5. Cellulose - blown</td>
<td>3.7</td>
</tr>
<tr>
<td>6. Rock wool, glass fiber - batts or blankets</td>
<td>3.2</td>
</tr>
<tr>
<td>7. Perlite and vermiculite</td>
<td>2.6</td>
</tr>
<tr>
<td>8. Fiberboard sheathing</td>
<td>2.6</td>
</tr>
<tr>
<td>9. Rock wool - blown or poured</td>
<td>2.5</td>
</tr>
<tr>
<td>10. Glass fiber - blown or poured</td>
<td>2.2</td>
</tr>
<tr>
<td>11. Pine</td>
<td>1.3</td>
</tr>
<tr>
<td>12. Gypsum board (drywall)</td>
<td>0.9</td>
</tr>
<tr>
<td>13. Common brick</td>
<td>0.2</td>
</tr>
<tr>
<td>14. Concrete</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Note: You are trying to buy resistance to heat flow, not thickness of material. The material which is lowest in cost per R-value is always the best buy if the installation cost is the same for both materials.
VAPOR BARRIERS

Vapor barriers reduce the rate of flow of water vapor. They are used on walls, floors, and ceilings of residential construction to prevent water vapor from entering the insulation in large enough quantities to cause condensation. When water vapor touches a cold surface below the dewpoint temperature of air, the water vapor condenses to liquid water and wets the insulation. This causes a loss of insulating capability and possible rotting of the wood and peeling of exterior paint. Vapor barriers are especially important in kitchen and bathroom areas where high concentrations of water vapor exist. Extra care should be taken in these areas to provide a continuous and undamaged vapor barrier. Vapor barriers are also installed on top of the earth in the crawlspace of a house to keep the crawlspace and flooring dry.

Finally, vapor barriers help produce a better living environment in the house by keeping it drier in the summer and maintaining higher humidities during the winter. From the builder's standpoint, installing the minimum amount and type of vapor barrier is best because it keeps costs down. Do not use a more expensive vapor barrier system than the wall sheathing requires.

Types and Installation of Vapor Barriers. There are three common types of vapor barriers used in residential construction: asphalt coatings, metallic foils, or plastic films. The most common is asphalt-coated back-up paper found on batt and blanket fiberglass. This material offers adequate protection for all installations except when used with foil-faced, rigid foam wall sheathing. The paper (sometimes called asphalt impregnated Kraft paper, or just Kraft paper) is also used to staple the insulation to the framing. Care should be taken to repair tears in this material; use duct tape for this purpose.

The second type is foil-backed gypsum board or drywall. This is frequently used for ceilings where blown insulation, which has no vapor barrier of its own, is to be installed. This vapor barrier offers adequate protection except with some foil-faced wall sheathings such as "Thermax" and "High R."

Polyethylene plastic film is the third vapor barrier in widespread use. It offers superior protection to asphalt paper or foil-backed sheetrock. A 6 mil thickness is adequate protection for all types of insulation. The 4 mil thick film is adequate for all rigid foam sheathing with or without foil facings, except for "Thermax" and "High R" which require the 6 mil thickness. Four mil polyethylene film is also used to cover damp earth in the crawlspace of the house to keep the crawlspace and flooring dry.

The asphalted paper vapor barriers are stapled to the face of the wall or ceiling framing members. They can be side stapled to the wall studs, but face stapling is
preferred. For crawlspace installation, the vapor barrier is faced up to the floor and the fiberglass insulation is kept in place by spring wires or chicken wire. The asphalted paper always faces the heated side, that is, up against the drywall of walls or ceilings, and against the subfloor. If the drywall ceiling is already in place, batts or blankets of insulation are placed between ceiling joints, again with the asphalted ("Kraft paper") side facing down against the dry-wall or gypsum board.

Foil-backed drywall has a thin aluminum foil vapor barrier on the side that faces the wall stud. The drywall is installed normally. The insulation used with this system needs no additional vapor barrier.

Polyethylene film is installed after wall insulation is in place and before or after ceiling insulation is installed. Sheets of this plastic film are stapled in place. After stapling, holes are cut out for windows and doors. The material is stapled to the wall studs and ceiling joists on the inside of the framing and then the drywall is installed over it.

All vapor barriers are installed facing the living area. Never reverse the vapor barrier and place it on the outside of the wall or on top of the ceiling joists. Always face the vapor barrier up, facing the subfloor in crawlspace or basement installation. If excess moisture exists in the crawlspace, cover the damp earth with 4 mil polyethylene; do not turn the vapor barrier face down on fiberglass insulation installed under the floor in an attempt to cure this problem.

**INfiltrATION**

Cost. Energy conserving construction means tight construction. More insulation and better equipment can help, but the house must be tightly constructed in order for insulation to do its job effectively.

Infiltration costs money. On the average, total infiltration in residential construction is one air change per hour. Under these conditions, all the air in the house leaves and is replaced by outside air at ambient temperature each hour. This causes higher heating and cooling bills, higher humidity during the summer, and drier air during the winter. Infiltration may be up to 40% of the heating and cooling load of a well-insulated house.

Where does all this air leak into and out of the house? Table 4.3 shows test results on a 1780 square foot house. Table 4.4 shows the cost of infiltration.
### TABLE 4.3
**SOURCES OF INFILTRATION**

<table>
<thead>
<tr>
<th>Infiltration Area</th>
<th>Percent</th>
<th>Air Changes per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Soleplate</td>
<td>25%</td>
<td>0.25</td>
</tr>
<tr>
<td>2. Wall outlets</td>
<td>20%</td>
<td>0.20</td>
</tr>
<tr>
<td>3. Duct System</td>
<td>14%</td>
<td>0.14</td>
</tr>
<tr>
<td>4. Windows</td>
<td>12%</td>
<td>0.12</td>
</tr>
<tr>
<td>5. Range Vent</td>
<td>5%</td>
<td>0.05</td>
</tr>
<tr>
<td>6. Fireplace</td>
<td>5%</td>
<td>0.05</td>
</tr>
<tr>
<td>7. Exterior Doors</td>
<td>5%</td>
<td>0.05</td>
</tr>
<tr>
<td>8. Recessed Spotlight</td>
<td>5%</td>
<td>0.05</td>
</tr>
<tr>
<td>9. Dryer Vent</td>
<td>3%</td>
<td>0.03</td>
</tr>
<tr>
<td>10. Sliding Glass Door</td>
<td>2%</td>
<td>0.02</td>
</tr>
<tr>
<td>11. Bath Vent</td>
<td>1%</td>
<td>0.01</td>
</tr>
<tr>
<td>12. Other</td>
<td>3%</td>
<td>0.03</td>
</tr>
</tbody>
</table>

* Based on 1 air change per hour under average conditions.

### TABLE 4.4
**ANNUAL COST PER 1,000 SQUARE FEET FOR 1 AIR CHANGE PER HOUR**

<table>
<thead>
<tr>
<th></th>
<th>Gas + A/C</th>
<th>All Electric</th>
<th>Heat Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>$40</td>
<td>$88</td>
<td>$39</td>
</tr>
<tr>
<td>Cooling</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>$59</td>
<td>$107</td>
<td>$58</td>
</tr>
</tbody>
</table>

* See Appendix I for utility costs

With these figures for the Atlanta area, the sole plate which "leaks" 0.25 air changes per hour would cost $14.75, $26.75 and $14.50 per year for gas and A/C, all electric, and heat pump systems respectively.

The area of largest loss is a surprise; not the windows and doors, but the soleplate leads the list.

1. The solution is simple--apply a bead of caulk between the soleplate and flooring or slab during installation. An alternate is to caulk the interior crack between the soleplate and flooring after it is secured. Urethane wet foams can be used for the application.

2. The second largest area is the electrical outlets on exterior walls. Caulk the wire and pipe holes where they penetrate the upper and lower wall plates, and pack the wall insulation behind the outlet box.
3. The duct system leaks can be reduced by taping the seams before applying duct insulation. Tape is still needed to contain the air in the duct; the insulation is not designed to do this.

4. Window infiltration was primarily leakage around the frame. The shim space between the rough opening and frame should be packed with insulation and covered with a vapor barrier. It can also be filled with urethane foam.

5. The range vent should have a back draft damper. The area around the vent duct should be sealed where it penetrates the wall or ceiling.

6. The fireplace damper is one leakage point. Glass doors in front of the fireplace and exterior combustion air ducts can cut this loss.

7. Standard exterior doors can be replaced with foam core doors with superior weatherstripping.

8. Recessed spotlights should be avoided.

9. The dryer vent should have a back draft damper. Joints should be sealed with tape.

10. Sliding glass doors should be avoided; foam core doors, especially French doors of this type, will let in the view with lower heat loss.

11. The bath vent should have a back draft damper; seal the space between the sheetrock and the fan shroud.

Sealing the Sill Plate. Sill plate infiltration was not included in the above tests, but can cause higher heating and cooling bills in houses which have a finished basement. A house built over a crawl space which contains no fuel-fired appliances (furnace or hot water using gas or fuel oil) should also be sealed. If it contains fuel-burning appliances, a sealer is not necessary or desirable. Sealing is accomplished by running a bead of caulk down the center of the foundation before the sill plate is bolted down. Another product used for this purpose is "sill sealer" which is fiberglass material 1" thick and 4" wide. It is unrolled along the top of the foundation before the sill plate is bolted down, in effect, becoming a gasket between the sill plate and foundation. New polyurethane foams are available which can seal this crack after the sill plate is placed. The foam is applied as a bead on the inside of the sill plate. It comes in pressurized aerosol cans and has much the same consistency as shaving cream before it dries. This system cannot be used where the dried foam will be subjected to sunlight, as the ultra-violet portion of sunlight will cause the foam to disintegrate in a matter of months.

Caulking and Sealers for Infiltration Control. Caulking is used to seal around openings (doors, windows, etc.) to keep air and water from passing through cracks in
the house. Since it is used on the exterior of the house, it is exposed to the weather and sunlight. Poor quality caulk will weather, harden, and fall out of these cracks in a short time. It pays to use higher grade, longer lasting caulks on the exterior of the house. Remember the relation of caulking, cracks, and air infiltration—these cracks will add about $20 per year to the heating and cooling bills of the average all electric house, and about $10 per year for a natural gas/electric house. Since caulking is always applied to a new house, the only extra cost involved in sealing these cracks is the extra cost of a better caulk. The ideal caulk would be easy to apply, have good adhesion, and stay flexible indefinitely.

Some of the common types of caulking currently used by homebuilders are:

**Oil Base**

Oil base caulking is the oldest and usually the cheapest caulking available. In general oil base caulks have the shortest life. (There are exceptions, however; see Consumer Reports, May 1976, p. 291, for brand name comparisons). Oil base caulks are more than adequate for interior caulking jobs. Many oil base caulks are difficult to tool smoothly.

**Acrylic Latex and Latex**

These two caulking materials offer better resistance to aging than most oil base caulks at slightly higher cost; they also are easy to tool smoothly after application.

**Butyl Rubber**

Butyl rubber also offers better resistance to aging than most oil base caulks at moderately higher cost. Most are difficult to tool smoothly.

**Polyurethane, Polysulfide and Silicone Rubber**

The polyurethane, polysulfide, and silicone rubber caulks offer better resistance to aging than most oil base caulks, at a much higher cost (several times the cost of oil base caulk). Some types are difficult to tool smoothly, and most silicone rubber products cannot be painted. Other than these two problems, silicone rubber caulks are excellent, except for their high price.

**Fillers**

Large, deep cracks must be filled to within 1/2" of the surface in order to retain caulk and cut waste. Fill the crack with oakum, wood, cotton, glass wool, or other inert material before applying caulk.
Interior Wet Foam Sealants

A relatively new product is on the market which is used to seal the wall cavity from the inside. These are polyurethane base wet foams that come in a can. "Monofoam" and "Polycel One" and "Insta foam" are three of the brands currently available. While a standard tube of caulking compound will produce a 1/4" bead 25' long, a small aerosol can of foam (selling for about $8 a can) will produce about 25 times as much bead at an obvious cost savings. This material cannot be used on the exterior of a house, as sunlight degrades it. It is a logical choice for sealing around the sole plate, door and window frames, and piping and wiring holes which are protected from sunlight. Very large cracks can be filled with fiberglass or other insulating materials at a lower cost, and topped if necessary, with wet foam sealant.

Summary

A good oil base caulk or latex or acrylic caulk is the most economical choice. Price is not always a good guide to performance. Check test data for better brands. Synthetic rubber caulks may give superior results, but have high cost and are difficult to tool.
CHAPTER 5

ECONOMIC ANALYSIS
OF INSULATION, BUILDING SYSTEMS, AND EQUIPMENT

The first question people ask when confronted with the option of purchasing an energy efficient house is, "How much extra will it cost me"? The purpose of this chapter is to quantify the cost factors involved in energy conserving construction and the associated payback periods. The energy situation is one that faces every American every day. It is cheaper to pay for an energy efficient house through mortgage payments than to pay ever increasing utility costs.

INSULATION AND BUILDING SYSTEMS

The payback periods shown in Table 5.1 are found by dividing the extra installed cost of an item by the first year savings. This does not take into account rising fuel cost, inflation, or interest rates. However, it is the most foolproof and uncomplicated way of judging the relative merits of energy conserving items.

Due to rising fuel costs, the payback periods will undoubtedly be shorter. In addition, the lower first cost of the smaller heating and air conditioning system will also produce a faster payback.

All calculations are based on standard construction at prevailing energy costs for Atlanta. Table 5.2 lists the energy conserving option followed by the item it is compared to. Values listed are from the Atlanta Gas Light Company and the Georgia Power Company. Figures not available from these sources were calculated using "Manual 3" and published test data.

Cathedral Ceilings. The payback period of 45 and 14 years for two of the ceiling systems listed are the same for all three heating and cooling systems. The R-value is essentially the same, yielding the same heating bill. Only the air conditioning load changes due to extra ventilation.

The first option with a 45-year payback is for R-19, 6" fiberglass sandwiched between roof deck and drywall ceiling on 2 x 6 rafters with no ventilation. The energy conserving option uses 2 x 6 rafters with 3-1/2", R-13 fiberglass, plus 1" rigid foam under the drywall and ridge and soffit vents.

The second option is R-19 fiberglass sandwiched between roof deck and ceiling on 2 x 6 rafters. The energy conserving option is R-19 fiberglass with 2 x 8 rafters and ventilated air space over the fiberglass with ridge and soffit vents.
### TABLE 5.1
ENERGY CONSERVING EQUIPMENT

<table>
<thead>
<tr>
<th>Item</th>
<th>Extra Installed Cost</th>
<th>Payback Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Saving Shower Head</td>
<td>$10</td>
<td>1</td>
</tr>
<tr>
<td>Water Saving Aerators</td>
<td>$3</td>
<td>1</td>
</tr>
<tr>
<td>Low Flush Toilet</td>
<td>None</td>
<td>Save $30/year</td>
</tr>
<tr>
<td>Pilotless Ignition on Furnace</td>
<td>$100</td>
<td>4</td>
</tr>
<tr>
<td>Pilotless Ignition on Range</td>
<td>$90</td>
<td>10</td>
</tr>
<tr>
<td>Water Pipe Insulation</td>
<td>$10</td>
<td>5</td>
</tr>
<tr>
<td>Set-Back Thermostat</td>
<td>$80</td>
<td>2</td>
</tr>
<tr>
<td>Humidifier</td>
<td>$100</td>
<td>See Note 7</td>
</tr>
<tr>
<td>Attic Power Roof Vent</td>
<td>$75</td>
<td>See Note 8</td>
</tr>
<tr>
<td>Ridge and Soffit Vents</td>
<td>$100</td>
<td>10</td>
</tr>
<tr>
<td>Heat Reclaimer for Air Conditioner</td>
<td>$600</td>
<td>See Note 10</td>
</tr>
<tr>
<td>Fluorescent Light</td>
<td>$15</td>
<td>2</td>
</tr>
<tr>
<td>Automatic Vent Damper</td>
<td>$100</td>
<td>3</td>
</tr>
<tr>
<td>Whole House Fan</td>
<td>$400</td>
<td>See Note 13</td>
</tr>
<tr>
<td>Heat Pump Water Heater</td>
<td>$700</td>
<td>4</td>
</tr>
</tbody>
</table>

If the ceiling has room for more than 6" batts (while maintaining the ventilation space) the additional fiberglass would be the most economical improvement. The air space is desirable and may be necessary to pass code. The scissors truss is an expensive but good solution in some cases.

It is painfully obvious from the long payback period that cathedral ceilings are a difficult problem. Substitution of rigid foam is a high cost solution. Perhaps the best solution is to limit them to smaller rooms or eliminate them altogether.

**Walls.** The savings shown for the R-13 + 3/4" rigid foam construction contains a factor for reduced infiltration. The calculation assumes the foam sheathing reduces infiltration by 0.2 air changes per hour, yielding twice the savings normally attributed to the additional R-value.
Notes on Table 5.1, Energy Conserving Equipment:

1. **Water Saving Shower Head**: Cuts flow rate to 3 gpm; 50% reduction in water needs for showering.

2. **Water Saving Aerators**: Cuts water flow on sinks to 2 gpm.

3. **Low Flush Toilet**: Cuts water use per flush from 5 to 7 gallons to 3 to 3-1/2 gallons. Cuts water bill by 15%.

4. **Pilotless Ignition on Range**: Reduction in a gas bill, $9 per year. This item is usually available only on better quality models.

5. **Water Pipe Insulation**: Insulating the first 1 or 2 feet of the hot and cold water lines and safety valve vent pipe from the hot water heater can cut these standby losses by 50%.

6. **Set-back Thermostat**: Reduction in heating bills with 5° night set-back, 11%. Not advisable for heat pump operation.

7. **Humidifier**: Humidifiers can raise comfort levels in a house. However, they do little to save energy, and may even cause higher heating bills. While a 1° to 2° decreased thermostat setting is possible because of higher humidity, yielding fuel savings, 1,000 BTUs are needed to evaporate each pound of water added to the house. It costs 36¢ to $1.25 per day to supply this needed heat if a 13 gpd humidifier is running at full capacity.

In a tightly constructed house with low infiltration rates, the water vapor supplied by cooking, washing, and breathing should be enough to keep humidity at a comfortable level without a humidifier.

8. **Attic Power Roof Vent**: Extra cost over roof louvers, $75. Payback period with R-19 or better insulation, fan power consumption may meet or exceed air conditioning savings, fan may never pay for itself. Reduction in ceiling air conditioning load, 25%. Seasonal power consumption, $14.

While attic ventilation in excess of minimum property standards will cut the air conditioning load, the effect is small with large amounts of attic insulation. The continuous ridge and soffit vent is preferred to the power roof vent because of no maintenance, noise, or power consumption.

9. **Ridge and Soffit Vents**: Reduction in ceiling air conditioning load, 25%.

10. **Heat Reclaimer for Air Conditioner**: These units are composed of a heat exchanger and water pump. They extract heat from the air conditioner and reject it to a pre-heating storage tank for domestic hot water use. They provide hot water at a 5% to 10% reduced cost for air conditioning. Problems have been experienced with heat exchanger fouling where drinking water has a high mineral content. Best used where more than 6 months of air conditioning is needed or on all-electric houses. Approximate payback: 6 years all-electric, 15 years with gas/electric.

11. **Fluorescent Light**: These produce about 4 times the light per watt of an incandescent bulb. Lower air conditioning costs, and less frequent and therefore lower replacement costs. Best used in bath and kitchen.

12. **Automatic Vent Damper**: This device is an automatic damper that closes off the vent to the gas furnace when the furnace burner is not operating. This prevents warm air from escaping up the chimney. Savings depend on the installation, with furnaces located in heated spaces having faster paybacks. Expected savings 10% to 20%.

13. **Whole House Fan**: A fan of sufficient size to provide a complete air change in 1 to 1½ minutes is recommended in warmer climates such as Georgia. Savings will depend on how much each homeowner is willing to reduce the amount of time his air conditioning operates. A 50% reduction in A/C cost results in a 3 to 5 year payback.

14. **Heat Pump Water Heater**: These devices heat water for approximately one-half the cost of conventional electric water heaters. This can provide a savings of $150-$200 per year for a family of four.
<table>
<thead>
<tr>
<th>Application</th>
<th>Items Compared</th>
<th>Gas Heat &amp; Electric AC</th>
<th>Total Electric</th>
<th>Heat Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceilings</td>
<td>R-30 batt vs. R-11 batt</td>
<td>16</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>R-26 blown vs. R-19 blown</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Cathedral Ceiling</td>
<td>R-13 + 1&quot; foam vented vs R19 unvented</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>R-19, 2 x 8, vented vs. R-19, 2 x 6, unvented</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Walls</td>
<td>R-13 + 3/4&quot; foam vs. R-11</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>R-13 vs. R-11</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Floors</td>
<td>Over Basement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R-11 vs. R-0</td>
<td>7</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Over Crawlspace</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R-11 vs. R-0</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Windows</td>
<td>Storm vs. No Storm</td>
<td>12</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Doors</td>
<td>Insulated vs. Wood</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
CHAPTER 6

STANDARD VS. ENERGY CONSERVING CONSTRUCTION
FOR THREE HOUSE PLANS

CONSTRUCTION DETAILS

Three house plans were selected for thermal and economic analysis. The plans were donated by W. D. Farmer, a residential designer in Atlanta. The house size covers the normal range, 1200 to 2200 square feet. Each house has a different heating and air conditioning system. Heating and cooling loads and annual costs are calculated for the three plans using standard and energy conserving construction. The extra cost for the energy conserving features is used in the economic analysis.

The house plans are shown in Figure 6.1. The 1200 plan (1200 square feet) is a one story slab-on-grade design. The 1600 plan is one story with a crawl space. The 2200 plan is two stories with a full basement. The heating and air conditioning systems are as follows:

- **1200**: Electric furnace, mechanical air conditioning
- **1600**: Gas furnace, mechanical air conditioning
- **2200**: Heat pump, two systems (zoned)

The standard plan has insulation and equipment found in the majority of present construction. Most of the items meet or exceed minimum property standards.

The energy conserving plan uses added insulation, better infiltration barriers, and glazing to cut heating and cooling loads. The package was assembled with readily available components at a modest extra cost with short payback periods.

The economic analysis, material cost, utility cost, and thermal design are indicative of construction in the Atlanta area. The annual cost for heating and cooling can be approximated for other cities by use of the data found in Appendix II.

Table 6.1 is a summary of the alternate house systems.
HOUSE PLANS USED IN ENERGY AND ECONOMIC COMPARISON

PLAN NO. 1200
- HOUSE: 1190 SQ. FT.
- SINGLE CAR PORT & STORAGE: 294 SQ. FT.
- DOUBLE CAR PORT & STORAGE: 490 SQ. FT.
- STOOP: 25 SQ. FT.
- TERRACE: 140 SQ. FT.
- Alternate adding basement stairs

PLAN NO. 1600
- HOUSE: 1190 SQ. FT.
- GARAGE: 473 SQ. FT.
- DECK: 11112 SQ. FT.

PLAN NO. 2200
- FIRST FLOOR: 1105 SQ. FT.
- SECOND FLOOR: 1105 SQ. FT.
- TOTAL: 2210 SQ. FT.
- BASEMENT: 1105 SQ. FT.
- STOOPS: 95 SQ. FT.
TABLE 6.1
CONSTRUCTION DETAILS
IN STANDARD AND ENERGY CONSERVING HOUSE PLANS

<table>
<thead>
<tr>
<th>Component</th>
<th>Standard</th>
<th>Energy Conserving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>R-19</td>
<td>R-26</td>
</tr>
<tr>
<td>Walls</td>
<td>R-11</td>
<td>R-13 + R-4 (Rigid Foam)</td>
</tr>
<tr>
<td>Floors (1200)</td>
<td>None</td>
<td>1&quot; Rigid Foam</td>
</tr>
<tr>
<td>Floors (1600)</td>
<td>None</td>
<td>R-11</td>
</tr>
<tr>
<td>Windows</td>
<td>Single Pane</td>
<td>W/Storm Windows</td>
</tr>
<tr>
<td>Doors</td>
<td>Weatherstripped</td>
<td>Insulated Doors</td>
</tr>
<tr>
<td>Ducts</td>
<td>2&quot; Duct Insulation</td>
<td>2&quot; Duct Insulation</td>
</tr>
<tr>
<td>A/C (1200, 1600)</td>
<td>SEER 7.0</td>
<td>SEER 9.0</td>
</tr>
<tr>
<td>Heat Pump (2200)</td>
<td>Two Systems</td>
<td>Two Systems</td>
</tr>
<tr>
<td>Other Features:</td>
<td>Standard Thermostat</td>
<td>Set-Back Thermostat</td>
</tr>
<tr>
<td></td>
<td>Dark Roof</td>
<td>Light-colored Roof</td>
</tr>
<tr>
<td></td>
<td>Roof Louvers</td>
<td>Ridge and Soffit Vents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sill Sealer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extra Caulking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Wet Foam)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tight Construction</td>
</tr>
</tbody>
</table>

In the energy conserving version, the ceiling insulation is raised to R-26. The calculations are based on blown fiberglass. The walls have R-13 batts plus 3/4" styrofoam (R-4 wall sheathing) rather than fiberboard sheathing. This was chosen because sheathing thicker than 3/4" requires extension of door and window trim. Storm windows are added to all standard window units. Foam core insulated doors replace standard exterior doors, including french doors. Both plans use 2" duct insulation in attic and basement areas. High efficiency air conditioners (SEER 9.0) are used, and a split system heat pump on the 2200 plan. There is little variation in heat pump efficiency for a given manufacturer at present, so no allowance is made for this. Other items in the energy package are a set-back type thermostat, light-colored roof, ridge and soffit vents, extra caulking (using wet foam applied by a subcontractor), and tight construction.
Table 6.2 and Table 6.3 compare the heating and cooling loads and installed equipment size for the alternate plans.

**TABLE 6.2**

<table>
<thead>
<tr>
<th>HOUSE PLAN</th>
<th>HEATING</th>
<th>COOLING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard</td>
<td>Energy Conserving</td>
</tr>
<tr>
<td>1200 sq.ft.</td>
<td>32,200</td>
<td>15,900</td>
</tr>
<tr>
<td>1600 sq.ft.</td>
<td>48,400</td>
<td>21,300</td>
</tr>
<tr>
<td>2200 sq.ft.</td>
<td>42,400</td>
<td>23,600</td>
</tr>
</tbody>
</table>

Average Percent Reduction: 50.3% 35.4%

*Design load in Btuh does not include duct loss, latent heat load and equipment efficiency.

**TABLE 6.3**

<table>
<thead>
<tr>
<th>HOUSE PLAN</th>
<th>HEATING</th>
<th>COOLING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard</td>
<td>Energy Conserving</td>
</tr>
<tr>
<td>1200 sq.ft.</td>
<td>16 KW</td>
<td>11 KW</td>
</tr>
<tr>
<td>1600 sq.ft.</td>
<td>80M Btuh</td>
<td>40M Btuh</td>
</tr>
<tr>
<td>2200 sq.ft.</td>
<td>3-1/2 Ton</td>
<td>2-1/2 Ton</td>
</tr>
</tbody>
</table>

The savings are dramatic, the heating load cut in half, cooling load by one third. Equipment size drops correspondingly, using the nearest equipment size which will handle the load. On the 2200 plan, only a 2 ton system is needed for the total load, but the first floor has a higher load and requires a 1-1/2 ton heat pump.
Equipment sizing is important. The following is a quote from Ralph J. Johnson, President of the NAHB Research Foundation:

"Do not let an overly conservative manufacturer, HVAC contractor, architect or engineer convince you to use oversized heating or cooling equipment. THIS IS THE CARDINAL ENERGY SIN. An oversized heating or cooling unit costs more to purchase, costs more to operate, wastes more energy and produces less comfort."

Heating equipment is available in smaller sizes. Several manufacturers offer one-ton heat pumps, others have 40,000 Btuh input furnaces that can handle several tons of air conditioning.

Finally, in Table 6.4 we have estimates of annual heating and cooling costs for the standard and energy conserving plans.

<table>
<thead>
<tr>
<th>HOUSE PLAN</th>
<th>HEATING</th>
<th>COOLING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard</td>
<td>Energy Conserving</td>
</tr>
<tr>
<td>1200 sq.ft.</td>
<td>$528</td>
<td>$163</td>
</tr>
<tr>
<td>1600 sq.ft.</td>
<td>$360</td>
<td>$122</td>
</tr>
<tr>
<td>2200 sq.ft.</td>
<td>$313</td>
<td>$157</td>
</tr>
</tbody>
</table>

We see some surprising savings. Annual heating and cooling cost for the 1200 plan drops from $688 to $238, down 65%; the 1600 plan drops from $680 to $243, down 64%; and the 2200 plan goes from $645 annual cost to $382 down 40%.
Are these savings possible? Yes, houses built under the Arkansas Plan with roughly similar thermal characteristics showed 73.6% savings over Minimum Property Standards construction in actual use. But remember, these savings are possible only when houses are built to the specification used in the energy conserving plan. Insulation that is missing or improperly installed can't reduce heat loss. Sole plate caulking can't cut infiltration if it's missing. Attention to detail is the mainstay of tight construction.

Now that we have seen the savings, what about the extra cost?

Total extra cost to the home builder is listed in Table 6.5. An item by item breakdown is found in Appendix III.

<table>
<thead>
<tr>
<th>House Plan</th>
<th>Total Dollars</th>
<th>Dollars per square foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200 sq.ft.</td>
<td>$1,231</td>
<td>$1.03</td>
</tr>
<tr>
<td>1600 sq.ft.</td>
<td>$1,778</td>
<td>$1.11</td>
</tr>
<tr>
<td>2200 sq.ft.</td>
<td>$1,740</td>
<td>$0.79</td>
</tr>
</tbody>
</table>

Total cost includes ceiling, wall and floor insulation, storm windows, insulated doors, higher efficiency air conditioners, set-back thermostat, ridge and soffit vents, sill sealer, and caulking for piping and wiring holes. The reduction in operating costs takes these items into account.

The reduction in heating and cooling loads brings with it a need for smaller heating and cooling equipment. Table 6.6 shows the comparative installed HVAC equipment cost.
TABLE 6.6
HVAC EQUIPMENT COST

<table>
<thead>
<tr>
<th>House Plan</th>
<th>Standard</th>
<th>Energy Conserving Plan</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200 sq.ft.</td>
<td>$1895</td>
<td>$1665</td>
<td>$230</td>
</tr>
<tr>
<td>1600 sq.ft.</td>
<td>$2530</td>
<td>$1975</td>
<td>$555</td>
</tr>
<tr>
<td>2200 sq.ft.</td>
<td>$4555</td>
<td>$3865</td>
<td>$690</td>
</tr>
</tbody>
</table>

The savings on installed equipment cost for the 1200, 1600, and 2200 plans are 12%, 22%, and 15%, respectively. These reductions are primarily from reduced tonnage on the air conditioner and heat pump. Smaller savings are from reduced duct and flue size and associated insulation costs. It is obvious that cutting a load in half cannot cut the installed cost in half.

The extra cost of installing a higher efficiency air conditioner (SEER 9.0 instead of 7.0) and the set-back thermostats is included in Table 6.5 entitled "Extra Cost for Energy Conserving Construction." These additions would bring the HVAC cost closer to that of standard construction. Equipment savings are realized only when the HVAC contractor PROPERLY SIZES the equipment. Using the same rule of thumb just won't do. Installing the "normal" air conditioner tonnage in a house with a glass wall on the west side will find the system short on capacity. In the same way, installing the "normal" tonnage on a house without windows on the west side, with tight construction, will find the unit oversized. The same is true of heating systems. A new "rule of thumb" will generate itself with experience on energy conserving homes.

Table 6.7 shows the cost of the energy conserving features and the HVAC equipment savings. Two figures are included for dollars per square foot. The first is the cost to the builder. The second includes overhead and profit, and is the cost to the home buyer.

The extra cost per square foot of house is less than 3% of the selling price of the house. The payback period of the energy package is 3 to 5 years. These are numbers that any builder and buyer can live with.
### TABLE 6.7

PAYBACK PERIOD FOR ENERGY CONSERVING HOUSE PLANS

<table>
<thead>
<tr>
<th>House Plan</th>
<th>Extra Cost of Material</th>
<th>Equipment Savings</th>
<th>Net Extra Cost*</th>
<th>Cost to Builder $ Per Sq. Foot</th>
<th>Cost to Homebuyer $ Per Sq. Foot**</th>
<th>Annual Savings***</th>
<th>Payback Period Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>$1231</td>
<td>$230</td>
<td>$1001</td>
<td>$.83</td>
<td>$1.08</td>
<td>$450</td>
<td>3</td>
</tr>
<tr>
<td>1600</td>
<td>$1778</td>
<td>$555</td>
<td>$1223</td>
<td>$.76</td>
<td>$.99</td>
<td>$437</td>
<td>4</td>
</tr>
<tr>
<td>2200</td>
<td>$1740</td>
<td>$690</td>
<td>$1050</td>
<td>$.48</td>
<td>$.62</td>
<td>$261</td>
<td>5</td>
</tr>
</tbody>
</table>

* Extra material cost minus equipment savings.

** Builder cost plus 30%.

*** Estimated annual utility savings.
CHAPTER 7

FIREPLACES AND WOODSTOVES IN RESIDENTIAL CONSTRUCTION

Wood is a relatively cheap, renewable fuel which is available today. The fireplace is a familiar extra in many homes being built presently. In the future, more people may choose a woodstove. Why? It's a matter of efficiency. While a fireplace is romantic and pleasant, it is very inefficient. Many homeowners want to reduce their fuel bills by burning wood, but find little savings possible in using a fireplace.

Because of consumer demand, few builders to date have begun new residential woodstove installation on a regular basis, but they are becoming attractive alternatives to conventional heating methods and the inefficient fireplace. With the advent of aesthetically pleasing stoves and heat shields, more people are seriously considering them as a supplement to their primary home heat source. The homebuilder who is considering woodstove installation in his design and construction must address four major areas in making this decision:

1. The marketing concept must be evaluated in terms of sales potential, cost, and market area strategies.
2. The type, size, efficiency, design features and chimney must be properly selected.
3. Installation requirements, including floor and wall clearances, as well as heat shields, chimney, and stovepipe must be determined.
4. The homeowner should be informed of the maintenance and safety requirements of woodstoves.

MARKETING

The concept of marketing woodstoves must be evaluated in terms of sales potential, area strategies and cost. The potential for the sale of woodstoves has never been better in light of escalating home heating fuel costs. Although the market is better in rural areas where lower priced fuels may not be available and fire wood is inexpensive, many inner city and suburban homeowners are becoming more receptive to the idea of woodstove installation. The advent of more aesthetically pleasing heat shields and stove designs has prompted many potential fireplace owners to consider a woodstove. Some North Georgia builders are designing their houses around a woodstove and are no longer using the inefficient fireplace. Once installed, the builder can enhance his sales opportunities by: (1) pointing out the fact that the house
was designed around the stove and thus looks better than a fireplace would, (2) overall utility bills will be less than with conventional space heating and (3) the installed cost of a woodstove is roughly one-half as much as an equivalent fireplace system, with at least twice the efficiency.

**STOVE SELECTION**

Stove selection is a function of many factors including type, shape, size, efficiency and chimney style.

**Type.** There are three basic types of woodburning stoves--open, box, and airtight. Open stoves are for watching the fire; box stoves are for occasional heating of small areas. However, to effectively supplement a regular heating system and decrease an annual fuel bill, airtight stoves are the best choice. (Note that some open stoves are convertible to airtight with closely-fitted doors.) Air leaks are almost always detrimental to combustion because they occur at the wrong place and the wrong time, cutting down the ability to control the heat output. The only practical test is a visual inspection. Look for cracks around joints of the various fixed parts of the stove.

**Shape.** Open stoves, also known as Franklins, attempt to combine the efficiency of an enclosed firebox with the romance of dancing flames. Open stoves are much more efficient than regular fireplaces, but not as efficient as airtight stoves. They require frequent stoking to obtain a steady heating rate and cannot keep a fire overnight. A tightly constructed house can cause an open stove to smoke by restricting its air supply. A good rule of thumb for this is to only use direct vented stoves in those houses which have 1/2 air changes per hour or less. This is mainly a safety consideration. Most open stoves are for people who want to keep warm while watching the fire. Note: Some open stoves are convertible to airtight with closely-fitted doors.

Box stoves may be square, round, oval or pot-bellied. Unlike Franklins they don't have doors for viewing the fire. Box stoves are also very drafty, so control of the fire is limited to size and frequency of refueling. Box stoves are for occasional use with constant attention.

Size and shape can vary, but airtight means no air can get into the combustion area except where it's designed to get in—at the air inlet dampers. This makes them more efficient and more controllable than open stoves or box stoves. Airtights are for heating large areas over long periods of time with minimum supervision.
**Size.** The stove should be sized to supply the heat needed—no more, no less. Average values for heat output of typical stoves are:

- Small box: 20,000 Btu/hr
- Large box or open: 30,000 Btu/hr
- Small airtight: 40,000 Btu/hr
- Large airtight: 60,000 Btu/hr

But how much heat is needed? This requires a heat loss calculation taking into account outdoor temperature, building construction, floor plan, and the indoor temperature considered to be comfortable.

Measure the firebox and compare heat needs with the heat output curve shown in Figure 7.1. Choose stove accordingly. All heat calculations should be evaluated in terms of the available manufacturer's literature in order to insure the correct size stove is chosen.
**Efficiency.** Table 7.1 is a list of approximate efficiencies for various woodburning equipment.

**TABLE 7.1**  
WOOD APPLIANCE EFFICIENCIES

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Approximate Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fireplace</td>
<td>10%</td>
</tr>
<tr>
<td>Circulating Fireplace</td>
<td>25%</td>
</tr>
<tr>
<td>Woodstove</td>
<td>40%</td>
</tr>
<tr>
<td>Airtight Woodstove</td>
<td>60%</td>
</tr>
<tr>
<td>Central Wood Furnace</td>
<td>65%</td>
</tr>
</tbody>
</table>

These figures on efficiency show how superior a woodstove is to a fireplace. An airtight woodstove requires only $1/6$ as much wood as a fireplace to do the same heating job. A circulating fireplace which has a steel liner and circulates warm air to the room is one improvement over the standard masonry type. The addition of glass doors and use of exterior combustion air, as well as electric fans, also improve fireplace efficiency. All fireplaces should have a tight fitting damper to control the fire and prevent air infiltration when not in use.

Unbiased efficiency ratings are becoming more readily available to the public. Jay Shelton discusses stove design and efficiency in his *Woodburner's Encyclopedia* and his newest publication, *Wood Heat Safety*.

**Chimney.** The chimney is a critical part of the woodstove heating system. It not only carries smoke out of the house, but also pulls in the air needed for good combustion. Whether to use a masonry or prefabricated metal chimney is a matter of choice and design. Size and correct installation are more important. Unless the manufacturer specifies otherwise, use a chimney diameter equal to that of the flue pipe collar on the stove. An oversized chimney can cause excessive water and creosote condensation. A chimney that meets fire and building codes will ensure a stove system that heats the home rather than burning it down. Exact specifications for chimney design and installation may be found in the NFPA 89M and NFPA 211 bulletins, as well as the National Building Code.
INSTALLATION CRITERIA

**Stove Placement – Where and Why.** The stove should be located in a frequently used area such as the living room, family room, or den. The homeowner can stay warm and comfortable for most daily activities and still keep the bedrooms cooler for sleeping. Choose a room at least 12 times the size of the stove.

The best place for a stove is in the center of the room where it can radiate heat in all directions. The worst place to put a stove is in a closet or alcove. Practically speaking, stoves are usually placed in the middle of an outside wall. This makes venting the stove much easier. But it requires proper clearance between the stove system surfaces and their surroundings to keep the home fire-safe.

**Some Materials Burn, Some Don’t.** A woodstove gives off radiant and convective heat. If a combustible material is too close to the stove, it will become hot and catch on fire. For example: wood studs, even though covered by noncombustible sheetrock, can burn at abnormally low temperatures if exposed to constant heat from a woodstove. Clearances are specified by safety codes to prevent overheating of combustible materials by keeping them at a distance. Shielding combustibles from the heat reduces the required clearances. Following these recommendations closely will ensure a safe installation in the home.

A wall or ceiling is considered to be noncombustible if it is made entirely of masonry (brick, concrete, concrete block, plaster on brick, stone) or other noncombustible materials such as sheetmetal. Combustible walls are those that contain wood framing, such as plaster and sheetrock walls on wood lath or wood studs. Nearly every wall and ceiling in residential buildings contain wood.

With regard to insulated brickwork walls, it is recommended that the contractor install ventilated brickwork in its place. This is because: (1) the required insulation is difficult to obtain for residential construction and (2) 4" brick with 2" insulation is still not sufficient to keep the wood studs from becoming hot. **Always assume combustion is possible, and maintain the proper clearances.**

A floor is considered noncombustible if it is concrete, slab on grade design or solid concrete that has steel or concrete, BUT NOT WOOD, supports. A standard masonry hearth is noncombustible if there are no wood forms left in place below it and if stove placement will allow at least 18" of hearth in front of the loading door.

All wood floors, carpets, and synthetic flooring materials are considered combustible and must be protected in an approved manner. Remember, once the homeowner takes possession, combustible materials such as furniture, draperies, and magazines may be in close proximity to the stove unless its placement is properly determined.
Clearances – A Must for Safety.
The following information is based on NFPA Booklet 89M. If the clearances differ from manufacturer’s instructions, use the larger clearance.

Unshielded Walls and Ceilings. All stoves require 36" clearance on top and on all sides (Figure 7.2).

The stovepipe must have 18" clearance to combustible walls and ceilings, measured at right angles to the pipe.

No clearance is needed for stoves or pipes to noncombustible walls. However, it is good practice to allow 6" or more for good air circulation and dissipation of heat.

Unshielded Floors. All stoves must have legs at least 4" high to allow air circulation underneath no matter what floor they are mounted on.

The only base a stove can be installed on without special shielding is a noncombustible floor or hearth. According to the National Building Code, it should extend at least 18" in front of the loading door to prevent damage from sparks, embers, ash or radiant heat. It should also extend 6" or more on the three remaining sides.

Reduced Clearances with Heat Shields. Woodstoves may be placed closer to a combustible material that is shielded in an approved manner.

The most common method of heat shielding is 28 gage or thicker sheetmetal (galvanized steel, aluminum, copper). Presently, there are new, decorative heat shields available in ceramic tile, stone, stucco, or brick. All of these materials must be spaced one inch out from the wall or ceiling. That is, they must be anchored to the combustible surface so that a 1" air space exists between the sheetmetal, brick, etc. and the combustible material. This allows air to flow freely, removing heat by convection and ensuring a low enough temperature to avoid catching the wall on fire.

Sheetmetal or any type of shield nailed to the wall without this airspace offers no protection and cannot be considered a heat shield. The same applies to brick stacked or mortared against a combustible wall and to "Z-brick" or other veneer brick and stone coverings. If these materials are mounted on sheetmetal and if the 1" minimum spacing to the wall is maintained, then they can be considered as acceptable heat shields.
### TABLE 7.3

**MINIMUM HEAT SHIELD WIDTHS FOR STOVEPIPES**

<table>
<thead>
<tr>
<th>Type of Protection</th>
<th>Distance of Pipe to Heat Shield</th>
<th>6&quot; Single Wall Pipe</th>
<th>8&quot; Single Wall Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 gage sheetmetal spaced out 1&quot;</td>
<td>9&quot;</td>
<td>35&quot;</td>
<td>37&quot;</td>
</tr>
</tbody>
</table>

Assembling the Stovepipe. The chimney connector or vent connector is commonly known as the "stovepipe." This single wall metal pipe is NOT a chimney; it connects the stove to the chimney. Blue or black steel stovepipe is the most common material and usually costs the least. Thickness of the stovepipe for a given diameter is as follows:

- 4" diameter: 26 gage, 0.019 in
- 6" diameter: 24 gage, 0.024 in
- 8" diameter: 24 gage, 0.024 in
- 10" diameter: 22 gage, 0.030 in

The pipe should be the same diameter as the pipe outlet on the stove. The stovepipe should be as short as possible for safety reasons, but installations with five feet or so of pipe are acceptable. The extra length raises the efficiency of the woodstove by reclaiming some heat from the stack gases before they enter the chimney.

**Remember:** A connector serving another appliance must not be connected to a chimney flue serving a fireplace.
## Insulation Required for Residential Construction

<table>
<thead>
<tr>
<th></th>
<th>Georgia Code</th>
<th>FHA** HUD</th>
<th>Farmers+ Home Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>R-19</td>
<td>R-19</td>
<td>R-26</td>
</tr>
<tr>
<td>Cathedral Ceiling</td>
<td>R-10</td>
<td>R-19</td>
<td>---</td>
</tr>
<tr>
<td>Walls</td>
<td>R-11</td>
<td>R-11</td>
<td>R-16</td>
</tr>
<tr>
<td></td>
<td>R-19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floors over Crawlspace</td>
<td>R-6, R-4 or R-4</td>
<td>R-7</td>
<td>R-16</td>
</tr>
<tr>
<td>Slab-on-grade</td>
<td>R-4, R-6 if heated</td>
<td>R-2.5, R-4.4 if heated</td>
<td>1&quot; thick, 24&quot; wide perimeter insulation</td>
</tr>
<tr>
<td>Windows</td>
<td>---</td>
<td>---</td>
<td>Storm or Double Pane</td>
</tr>
<tr>
<td>Doors</td>
<td>Weatherstripped</td>
<td>Solid Core, Weatherstripped</td>
<td>Insulated Door or Storm Door</td>
</tr>
</tbody>
</table>

* The Georgia Code allows R-11 wall insulation with single pane glass up to 15% (based on wall area). R-19 insulation is required with more than 20% single pane glass, based on wall area. North Georgia is considered to be north of Macon.

** FHA-HUD specifications prohibit more than 15% glazing, based on exterior wall area. The Home Builders Association of Georgia has adopted this as a minimum standard, along with their seven year maximum payback rule for energy packages. North Georgia is considered to be north of Macon.

+ Farmers Home Administration will loan on the construction of cathedral ceilings, sliding glass doors, and fireplaces only if they can be justified under their program. They permit the construction of a flue for a woodburning stove if conditions warrant it. A poly vapor barrier is required for the walls. The R-16 figure for walls in north Georgia includes insulation and sheathing. North Georgia is considered to be north of Macon.

Note:
The dividing line for north and south Georgia differs for these three codes, check with your local representative to be sure of requirements in your area.
**Walls**

- **1/2" Gypsum Wallboard**
- **R-11 Insulation**
- **Vapor Barrier**
- **2x4 Studs**
- **Wood Siding or Brick Veneer**

**Options:**

- **1/2" Gypsum Wallboard**
- **Vapor Barrier**
- **R-8 Rigid Insulation**
- **Lightweight 2-Core 8" Concrete Block**

**Conditions:**

- If under 20% glass in walls
- If over 20% glass in walls

---

**Ceiling/roof**

- **Ventilation**
- **Clg. Joist**
- **Insulation**
- **Vapor Barrier**
- **Rafters**

**Options:**

- **R-19 Insulation**
- **Clg. Joists or Rafters**
- **Built-up Roof Sheathing**
- **Vapor Barrier**
- **Ceiling Finish (See Schedule)**

**Additional Details:**

- **Cathedral Type Ceiling**
- **Built-up Roof**
- **R-10 Rigid Insulation**
- **Wood or Plywood Sheathing**
- **Vapor Barrier**
- **2x4 Studs**
- **Wood Siding or Brick Veneer**

**Remarks:**

- **Lightweight 2-Core 8" Concrete Block**
- **R-8 Rigid Insulation**
- **R-8 Rigid Insulation**
- **R-8 Rigid Insulation**
* If floor is over a heated basement, no insulation is required.

R-11 is sufficient in all cases except for a few areas in extreme North Georgia.

In South Georgia (i.e., Savannah and Albany) no floor insulation is needed if carpet and pad are installed. R-4 is sufficient where there is no carpet and pad.

** R-5 may be used instead of R-8 for areas south of Marietta and Gainesville.

If insulating glass or storm windows are installed, R-11 alone is sufficient for wood stud construction, and R-8 alone is sufficient for concrete block construction up to 25% glass in walls.
**COMPARISON OF ENERGY CODES FOR SOUTH GEORGIA**

<table>
<thead>
<tr>
<th></th>
<th>Georgia Code</th>
<th>FHA** HUD</th>
<th>Farmers+ Home Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>R-19</td>
<td>R-19</td>
<td>R-30</td>
</tr>
<tr>
<td>Cathedral Ceiling</td>
<td>R-10</td>
<td>R-19</td>
<td>---</td>
</tr>
<tr>
<td>Walls</td>
<td>R-11</td>
<td>R-11</td>
<td>R-16</td>
</tr>
<tr>
<td></td>
<td>R-19*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floors over Crawlspace</td>
<td>Carpet and Pad, or R-4</td>
<td>None Required</td>
<td>R-11</td>
</tr>
<tr>
<td>Slab-on-grade</td>
<td>R-0, R-4,</td>
<td>None Required</td>
<td>None Required</td>
</tr>
<tr>
<td>Windows</td>
<td>---</td>
<td>---</td>
<td>Storm or Double Pane</td>
</tr>
<tr>
<td>Doors</td>
<td>Weatherstripped</td>
<td>Solid Core, Weatherstripped</td>
<td>Solid core, weatherstripped or hollow core with storm</td>
</tr>
</tbody>
</table>

*The Georgia Code allows R-11 wall insulation with single pane glass up to 15% (based on wall area). R-19 insulation is required with more than 20% single pane glass, based on wall area. South Georgia is considered to be Macon and all cities to the south, including Savannah and Albany.*

**FHA-HUD specifications prohibit more than 15% glazing, based on exterior wall area. The Home Builders Association of Georgia has adopted this as a minimum standard, along with their seven year maximum payback rule for energy packages. South Georgia is considered to be Macon and southward. Effective May 16, 1979 are HUD Revisions for single family dwellings 4900.1, available from your local HUD office.*

+Farmers Home Administration will loan on the construction of cathedral ceilings, sliding glass doors, and fireplaces only if they can be justified under their program. They permit the construction of a flue for a woodburning stove if conditions warrant it. A poly vapor barrier is required for the walls. The R-11 figure for walls in south Georgia includes insulation and sheathing. South Georgia is considered to be Macon and southward.

**Note:**
The dividing line for north and south Georgia differs for these three codes; check with your local representative to be sure of requirements in your area.
Materials for heat shields can be obtained locally at building supply and sheetmetal shops. Prefabricated heat shields are available through stove and fireplace dealers. These come in a variety of finishes and sizes. They usually incorporate a metal shield with an insulated liner on the back. While these panels are the most expensive, their insulation will help reflect more heat to the room. Several other types of protection may be used; NFPA Booklet 89M covers the lesser used materials. A complete list of manufacturers and materials (classified by regional supplier) may be obtained from the Wood Energy Institute. Magazines such as the "Wood Energy Digest" may be consulted on a regular basis for new material design specifications and availability.

Shielded Walls and Ceilings. Table 7.2 shows clearances using heat shields on walls and ceilings. These clearances are also depicted in Figure 7.3.

Shielded Floors. All combustible floors must be protected. A floor shield must be made of 24 gage or thicker sheetmetal or a prefabricated stoveboard or hearth shield.

Brick, slate, or patio stone may be used but must be installed on top of a sheetmetal base. The base should extend 18" in front of the loading door to prevent damage to the floor from sparks, embers, ash, or radiant heat. The base should extend 6" or more on the three remaining sides.

TABLE 7.2
CLEARANCES TO WALLS AND CEILINGS WITH HEAT SHIELDS

<table>
<thead>
<tr>
<th>Type of Heat Shield Protection</th>
<th>Stove</th>
<th>Stovepipe</th>
<th>Stove Top</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 gage sheetmetal spaced out 1&quot;</td>
<td>12&quot;</td>
<td>9&quot;</td>
<td>18&quot;</td>
</tr>
</tbody>
</table>

Notes:
1. These clearances are from the side of the stove or stovepipe to a parallel combustible surface.
2. Loading doors require at least 24" clearance even with heat shields or noncombustible surfaces to allow room for loading the stove.
3. There must be at least 36" clearance from the top of the stove to any unprotected combustible surface.
4. Use these clearances or those contained in the manufacturer's instructions, whichever is greater.
Maintaining 18" of noncombustible base in front of the loading door is a common sense way to keep ashes and embers off the combustible floor.

**Sizing Heat Shields.** The sheetmetal spaced out from the wall should extend 34" past the edge of the stove in height and width for stoves. These are minimum dimensions when the stoves are placed as close as the code will allow. If the stove is placed farther from the wall, the width and height of the shield can be found by measuring from the side and top edge of the stove to the wall at a minimum of 36".

The heat shield must be centered behind or above the pipe to protect the wall or ceiling. Table 7.3 shows minimum heat shield widths for installation behind stove-pipes.

Figure 7.3 shows the overall relationships discussed above. The larger the distance between the stove or pipe and the wall, the smaller the heat shield needs to be. For further information, contact your local building code inspector.
Through the Wall with Thimbles. A metal or ceramic thimble is used when passing through noncombustible walls. It should be permanently cemented into the chimney and extend through the chimney wall to the inner face or liner, but not beyond. A short section of stovepipe, crimped on both ends, is pushed into the thimble and secured with furnace cement or stove putty. The stovepipe should extend as far as possible into the thimble, but not stick out into the chimney. A masonry thimble (Figure 7.4) used to pass through the chimney will cost more, but last longer.

A stovepipe may never pass through a ceiling, closet, or concealed area; for these arrangements a Class "A" chimney (explained below) is required. Once the stovepipe connects to the chimney, it must remain a chimney from that point on. No further use of stovepipe is allowed. From a stovepipe to an exterior wall, use a Class "A" wall pass-through adapter. This item is both cost effective and safe.

If you must vent through an interior or exterior wall that is combustible, either convert from stovepipe to Class "A" metal chimney or use a ventilated thimble (Figure 7.5). This is a metal flange that allows air circulation to prevent heat buildup. The thimble must be at least 12" larger than the stovepipe, or 18" for a 6" pipe and 20" for an 8" pipe. A non-ventilated thimble may be used with a fire clay or metal thimble surrounded by brickwork at least 8" wide on all sides (Figure 7.6).

Chimneys. Chimneys used with woodstoves must meet Class "A" standards. A Class "A" masonry chimney must be 4" brick with a tile liner or 8" of brick. Double-wall insulated pipe or triple-wall pipe, both with stainless steel liners, also meet Class
requirements. These are sometimes referred to as "prefabricated chimneys" or "UL tested all-fuel chimneys." The metal chimneys are usually cheaper than their masonry counterparts, however the bricks will last longer and be more aesthetically pleasing to the homeowner.

When the stovepipe extends to the ceiling, a support package and stovepipe adapter are installed at the ceiling, and one or more sections of metal chimney are added to the rise above the roof. Usually a 2" clearance is required between the metal chimney and wood framing in the ceiling and roof (Figure 7.7).

In rooms with cathedral ceilings, the roof and ceilings are combined, and a special adjustable collar is needed to support the weight of the chimney on the rafters (Figure 7.8).

The third common type of installation is a through-the-wall arrangement. This requires a support kit composed of an insulated tee with clean-out plug and a wall bracket. At the roof line an adjustable flashing and storm collar are used to keep rain out (Figure 7.9).

![Diagram of chimney installations](image-url)
Whether metal fabricated or masonry, it is recommended that the builder size the chimney for 8" pipe, since most stoves use 6" or 8" pipe. This gives the homeowner more versatility if he is able to choose the stove for the house. It should be kept in mind that any stove where the fire can be viewed will require an 8" pipe.

Chimney height is critical to creating proper draft and preventing down-drafts during windy weather. The code requires 3 feet minimum height, plus at least 2 feet more than any part of the roof within 10 feet measured horizontally. Table 7.4 shows the height above the roof required for various roof slopes.

The chimney height over the roof given in Table 7.4 is for chimneys 10 feet or more from the roof ridge. If the ridge is closer, the proper heights can be calculated by the following formula:

$$(\text{Roof Slope} \times \text{Distance to Ridge}) + 2'0" = \text{Required Chimney Height}$$

For example, a chimney on a 5/12 sloped roof, located 6 feet from the ridge requires:

$$((5/12 \times 6') + 2'0" = 4'6" \text{ height over roof})$$

A brace may be needed for heights exceeding 4 feet. Finally, a chimney cap is added to keep out rain and help prevent downdrafts (Figure 7.10).

**TABLE 7.4**

**MINIMUM CHIMNEY HEIGHTS**

**METAL AND MASONRY CHIMNEYS**

<table>
<thead>
<tr>
<th>Roof Slope*</th>
<th>Height above Roof for Ridge 10 feet or More from Chimney</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/12</td>
<td>3'0&quot;</td>
</tr>
<tr>
<td>2/12</td>
<td>3'8&quot;</td>
</tr>
<tr>
<td>3/12</td>
<td>4'6&quot;</td>
</tr>
<tr>
<td>4/12</td>
<td>5'4&quot;</td>
</tr>
<tr>
<td>5/12</td>
<td>6'2&quot;</td>
</tr>
<tr>
<td>6/12</td>
<td>7'0&quot;</td>
</tr>
<tr>
<td>7/12</td>
<td>7'10&quot;</td>
</tr>
<tr>
<td>8/12</td>
<td>8'0&quot;</td>
</tr>
<tr>
<td>10/12</td>
<td>10'4&quot;</td>
</tr>
<tr>
<td>12/12</td>
<td>12'0&quot;</td>
</tr>
</tbody>
</table>

* Roof slopes are given in feet of rise per 12 feet of run. A 6/12 slope rises 6 feet per 12 feet of horizontal run.
Remember, stovepipes and metal chimneys are not the same. Single wall stovepipes may NOT pass through a ceiling or attic. They only connect the stove to the masonry or Class "A" metal chimney.

The rule of thumb with regard to "smokestacks" is to avoid them all together. Inherent problems necessitate that one always check local building codes and use Class "A" construction wherever possible.

In designing and locating the installation, keep in mind that the most trouble-free system will have few, if any, horizontal stovepipes and elbows. A vertical chimney and stovepipe gives the best possible draft and allows creosote and soot to fall back into the stove to be burned. Cleaning a vertical system will be extremely easy for the homeowner. It generally is lowest in cost because elbows and tees are more expensive than straight stovepipe and chimney. Long runs of horizontal stovepipe inevitably fill up with soot, ash, and creosote and should be avoided.

Figure 7.10
SAFETY AND MAINTENANCE

The builder/installer of woodstoves should be aware of inherent safety hazards and the maintenance associated with them, and be prepared to educate the homeowner should the need arise. The most important areas that should be addressed are:

Safety:

1. Lighting and rekindling the fire
2. Proper draft and flue damper operation
3. Proper fuels (dry wood, etc.)
4. Fire prevention equipment (smoke alarms, fire extinguishers, etc.)
5. Hazards of stove smoking
6. Chimney fires

In any case, the builder should be as well informed about woodstoves as he is about any other facet of his buildings.

Maintenance:

1. Remove creosote deposits on a regular basis.
2. Clean the chimney, pipe, and stove.
3. Conduct a smoke test after cleaning to determine any system leaks.

An excellent source of information for woodstove safety and maintenance may be found in the publication, "Safe and Warm Wood Heat," by Georgia Tech and the Tennessee Valley Authority, available from the Georgia Office of Energy Resources. Your local Georgia Forestry Commission office also has free information on woodstoves.
CHAPTER 8

BUILDING THE SOLAR ENERGY SYSTEM

The material presented here will familiarize the homebuilder with the different types of solar energy systems available today. It is not a detailed design manual, but should provide the builder enough information to select a well designed solar energy system and know when it is properly installed.

Solar energy has been used for centuries to heat living quarters, warm bath water, and cook meals. There is even evidence of an ancient city using concentrated sunlight to set fire to attacking ships.

For most of this century, however, there has been a cheap and abundant supply of fossil fuels available in the United States, and solar energy has been considered more a novelty than a practical consideration. With the rapidly rising cost of conventional energy during the past decade, greater attention has been placed on the oldest source of "free" energy.

In the residential market, there are four basic areas in which solar energy is currently being used extensively:

1. Passive design features for space heating,
2. Domestic hot water heaters,
3. Swimming pool heaters, and
4. Active systems for space heating.

There are a number of other solar energy applications adaptable to residential installation including air conditioning, photovoltaic power, and solar stoves. However, these concepts have not been developed yet to the point that they are attractive to the American home buyer.

Three factors will be the primary considerations in a home buyer's interest in solar energy systems: aesthetics, economics, and individual attraction or distaste for the idea of using solar energy. These factors will be discussed later in this chapter, but first we must consider what is involved in each type of solar energy application.

PASSIVE SOLAR ENERGY DESIGN

Passive solar systems use the building as the collector and storage system. The word "passive" means that few if any fans or pumps are used; heat moves on its own by conduction, convection, and radiation.
There are two distinct areas of passive design that home builders should understand:

1. Summer design consists of proper orientation of the house on the lot, and shading of windows to decrease solar heat gain, thereby reducing air conditioning costs.

2. Winter design attempts to let in the sun and store the heat gained from the sunlight, while minimizing heat loss.

Note that passive solar energy systems do not require different construction methods than used in conventional home building. The only difference between a conventional home and a passive home is the orientation on the site and the location of the glass and mass in the house.

Summer Design and Site Orientation. The roof ridge on a house with a standard gable roof should run east and west. The roof eave on the south side should extend 18" to 24" past the south wall of the house. On two-story houses, a setback (cantilevered design) at the second floor can shade the lower story. This eave will shade the south windows during midday in the summer, and yet allows sunlight to penetrate during the winter.

Windows on the west side of the house let in large amounts of heat during the late afternoon. The solar load developed by an unshaded single pane window facing west is about one ton per 100 square feet of glass (using Manual J figures). In contrast, a shaded, double pane window develops a one ton air conditioning load per 420 square feet of glass.

The best method of cutting this load is to eliminate or limit the west facing glass by placing the garage on the west side of the house. Other methods are shade screen, large pine or hardwood trees, or awnings. Figure 8.1 shows these relationships.

The windows which face east generate nearly the same air conditioning load and should be shaded. The east windows generate their peak load in the morning when it is cool and shading them is less critical than shading west windows. As noted in Chapter 2, even white, opaque roller shades can help, although outdoor shading is far superior to inside shading. Adding a roller shade to a double pane window facing east or west decreases the air conditioning load 20%.

North windows let in diffused light during most of the year. In midsummer, a few hours of direct sunlight may pass through them, but the air conditioning load developed is small.

Porches can help shade the glass on the house. A short porch is all that is necessary on the south side. A porch on the east or west side must be quite wide (6' to
Figure 8.1
in order to effectively shade the wall and glass. In addition, positioning a screened-in porch used for eating on the west side is not recommended. The summer sun will heat the porch and its occupants when they are most likely to use it, at dinner time. The east or south side would be cooler at this time of day.

Winter Design for Solar Heating. In all of Georgia, a double pane glass window which faces south will gain more solar heat during an average winter than it will lose. This simple fact opens the way for partial heating of homes with simple, passive solar energy.

As with many things that appear simple, there are complex factors that must be accounted for before we can make use of solar heat.

1. **Storage.** The solar radiation which enters south facing windows is converted to heat when it strikes the wall, floors, and furniture in a room. Enough mass must be built-in to soak this heat up and release it at night.

2. **Infiltration.** If windows are poorly installed or of poor quality, air leakage will cancel out any solar gains.

3. **Added air conditioning load.** Even if the south facing glass is properly shaded, it will add to the air conditioning load by conduction heat gain, increasing summer air conditioning bills, even though it decreases winter heating bills.

These are the three main problems involved in passive heating design. The following information will give the builder a basic understanding of the solutions, and a basis for working with your designer or architect on these problems.

**Design Considerations.** The site should have a relatively unobstructed horizon to the south. Tall pine trees, or a hill to the south will reduce the number of hours of sunlight available. Five hours of sunlight on December 21st should be considered a minimum figure for a site. Hardwood trees to the south pose no problem if they lose their leaves early in the winter.

The house must include enough mass to prevent overheating and to save the heat for nighttime use. A rule of thumb is to have at least 1 cubic foot (150 lbs.) of concrete or 4 gallons of water in the rooms on the south side per square foot of glass. The mass should be directly exposed to the sun; if not, 4 times the mass is required. The concrete can be the floor slab, with beefed up perimeter insulation. The floor should not be carpeted; a quarry tile or cracked tile finish is best. The usual thickness of concrete required is 4" to 8", depending on the amount of glass. Mass can be built into the north wall of the room using concrete blocks filled with sand, brick veneer, or an extra layer of sheetrock.
Water storage may be added later but it is more difficult to work with aesthetically. Water usually is stored in fiberglass tubes or reconditioned water drums. It can be concealed from view, but should be able to absorb direct sunlight. Low mass elements in the room should be light-colored to diffuse and reflect light; high mass elements should be dark, but need not be black. There should be about 3 square feet of exposed surface of the mass per square foot of glass.

The amount of glass in the south wall should never exceed 25% of the conditioned floor area in the rooms to be heated. The expected savings of a passive solar energy system as a function of south facing glass are shown in Table 8.1. Note that these figures apply to a well-built energy conserving house, and not to standard construction.

<table>
<thead>
<tr>
<th>Glass Portion of South Wall (%)</th>
<th>Expected Savings (%) Without Night Insulation</th>
<th>Expected Savings (%) With R-9 Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>22</td>
<td>34</td>
</tr>
<tr>
<td>17</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

Insulation can be placed over the glass at night to reduce night time heat losses. As Table 8.1 shows, R-9 night insulation increases the expected savings by about 50%.

Much of the glass should be fixed to eliminate infiltration, and the shim space between the rough opening and the window trim should be sealed and insulated.

Daily temperature swings in the solar heated portion of the house will probably be 15° to 20°F. Overheating of the space, with loss of efficiency and decreased savings and comfort must be avoided. Enough mass must be provided for each square foot of window, and the amount of glazing should not exceed the 25% rule stated above. Attempts to provide more than 50% of heating with this passive system will increase the odds that overheating will occur.

The net heat gain for a properly designed passive system in Atlanta will be about 80,000 Btu per square foot of double pane glass per winter. At current fuel prices found in Appendix I, it will save $.48, $.52, $1.11, $1.03 per square foot of glass for natural gas, heat pump, fuel oil, and electric furnace heating systems. Using Manual J
data, this glass, if properly shaded to eliminate solar gain during the summer, will add 20¢ per square foot per summer to the air conditioning bill. The heating savings versus air conditioning cost produce two concepts:

1. North Georgia, where heating needs predominate and little air conditioning is needed for a well-shaded house, is a prime candidate for this system.

2. The inclusion of interior or exterior insulating shutter systems on the south wall may be needed to shed the summer solar load in south Georgia and will also help cut night losses during the winter.

The economics of this system are highly dependent on efficient design and cost control by the builder. Using insulating glass made in standard sizes for sliding glass doors can keep the extra cost of the south wall to $3 per square foot of glass. The extra cost for a tile floor over carpet and pad cost would be about $3 per square foot of glass. Payback periods for a house with an electric furnace would be 7 years, for natural gas, 25 years, including the added cost of air conditioning. These payback periods can be improved considerably by using Kalwall or Filon fiberglass panels instead of glass. The owner of the house may also feel that the tile floor is desirable esthetically, outside of its solar function, in which case its cost may not be a factor. Finally, a house in the northern part of the state with higher heating and lower air conditioning costs would show a faster payback period.

SOLAR HOT WATER HEATERS

For residential hot water heating, flat plate solar collectors are typically used. These collectors can supply heat at temperatures up to 180°F.

A typical flat plate collector consists of a black absorber surface inside an insulated box with one or more glass or plastic covers over it. The black absorber surface is usually made from a metal such as copper, aluminum or steel and painted with a high temperature resistant flat black paint or coated with a selective surface such as black chrome. Radiation from the sun strikes the absorber surface which raises its temperature (just like a metal roof that gets hot on a sunny day). The clear cover provides a "greenhouse effect" by trapping the sun's energy inside the collector. For this part of the country a single cover (glazing) is usually sufficient. The heat collected by the absorber surface is transferred to air, water or another heat transfer fluid which flows across the absorber surface or through tubes connected to it. Figure 8.2 shows the construction of two flat plate collectors, one for heating air and the other for heating a liquid such as water.
Domestic Hot Water Systems. Five basic types of domestic hot water systems are available; however, many variations of these systems exist. The five types of systems include the thermosyphon system, the antifreeze system, the drain back system, the drain down system and the air system.

1. Thermosyphon Systems. The thermosyphon system (sometimes called a passive system) consists of one or more solar collectors connected in parallel, a water storage tank, a check valve (to prevent reverse thermosyphoning at night) and piping and insulation. A schematic of this system is shown in Figure 8.3. This is known as a passive system because a pump is unnecessary. Instead natural convection causes the water to flow. On a sunny day, the flowrate through a thermosyphon system is about 1 gallon per hour per square foot of collector.

Advantage:
- No pumps or controllers are required. Typically thermosyphon systems have no power requirements.

Disadvantages:
- No freeze protection unless it is installed in a conditioned space (like a greenhouse) or a controller (which requires power) and valves are installed to drain the collector during freezing weather.
- The storage tank must be mounted above the collectors. If the collectors are mounted on the roof (which is usually done) then the tank would also have to be mounted on the roof and this may be prohibitive due to structural or architectural constraints.
Thermosyphon systems are the most widely used solar hot water system in parts of the country where freezing is not a problem.

2. Antifreeze Systems. The antifreeze system consists of one or more collectors connected in parallel, a hot water storage tank, a pump, an on-off differential controller, a heat exchanger, an expansion tank, a check valve, piping and insulation. A schematic of this system is shown in Figure 8.4. In this system an antifreeze fluid, such as a glycol-water solution is heated by circulating it through the collector loop. The heated antifreeze flows through the heat exchanger which heats the potable water in the storage tank.

Advantage:
- Collector does not have to be drained during freezing weather.

Disadvantages:
- Glycol is corrosive to the system and corrosion inhibitors must be added. Glycol leaks can also damage a roof.
- Building codes may require the use of doublewalled heat exchangers which are more expensive.
- Antifreeze fluids have lower heat capacity than water which means they must be circulated at higher flowrates to collect the same amount of heat. This increases the power required for pumping.
3. Drain Back Systems. The drain back system consists of basically the same components as the antifreeze system except that additional valves are needed for the drain back mode, and an additional water storage tank and a pump are required for the collector loop. A schematic of the system is shown in Figure 8.5. In this system, water is heated by circulating it through the collector. The heated water is held in the storage tank and the potable water is heated by circulating it through a heat exchanger located in the storage tank. The hot potable water is then stored in another hot water storage tank. When the weather approaches freezing, the water in the collector and the piping is drained into the collector loop storage tank.

Advantages:

- Can use treated water in the collector loop which reduces scaling and fouling of collector and piping.

- Water has a higher heat capacity than antifreeze, which means lower flowrates can be used. This means less pumping power is needed.

- Leaks are of lesser consequence than with antifreeze systems.
Disadvantages:

- Extra valves and controls are needed for the drain back function and can malfunction allowing water to freeze in the collector and damage it.

- A potential corrosion and rust environment exists when the water is drained from the collector and outside air enters in. Therefore collector and piping materials must be corrosion and rust resistant. This is not a problem when copper is used.

4. **Drain Down Systems.** The drain down system is basically the same as the drain back system except no heat exchanger and extra storage tank are needed. In this system, the potable water is heated directly by circulating it through the collector. Freeze protection is similar to the drain back system except that the water usually flows into a drain instead of a holding tank. A schematic of this system is shown in Figure 8.6.

Advantages:

- Less complex and costly than the antifreeze or drain back system.

- Consequences of leakage are less severe than with the antifreeze system.
Disadvantages:

- Possibility of scaling and fouling of the collector and the piping, because untreated water flows through the collector.

- Extra valves and controls needed for the drain down function can malfunction allowing water to freeze in the collector and damage it.

- A potential corrosion and rust environment exists when water is drained from the collectors and outside air enters in. Therefore, collector and piping materials must be corrosion and rust resistant.

5. **Air Systems.** The air system consists of one or more collectors, a hot water storage tank, an air-to-water heat exchanger, a fan, a pump, a controller, piping and insulation. A schematic is shown in Figure 8.7. This system is basically the same as the antifreeze system with air used in the collector loop instead of a glycol-water solution. Air systems are typically used for both space heating and water heating.

Advantages:

- Freezing is not a problem.

- Corrosion and rust are not a problem with dry air.
Leaks are a smaller problem; they do decrease the efficiency of the collector.

Expansion tanks are not required.

Disadvantages:

- Air is a poor heat transfer medium and has a low heat capacity. Therefore, more collector area is required, and more transfer medium (i.e., air) must be circulated than in a liquid system.

- Air-to-water heat exchangers are more expensive than water-to-water (liquid-to-liquid) heat exchangers.

- Larger ducts are needed for an air system than are needed for a water system.

- An air filter is required to keep dust off the absorber surface.

Design Considerations in Glycol Systems. The two types of glycol solutions most frequently used in antifreeze systems are ethylene glycol and propylene glycol. Both solutions have similar physical properties. The difference is that ethylene glycol is toxic and propylene glycol is nontoxic and somewhat more expensive than ethylene.
glycol. These glycols are usually diluted with water to a concentration that prevents freezing of the solution at the lowest expected temperature in the area.

Use of a glycol solution requires particular attention to materials selection and the following points should be considered.

- Glycols are corrosive to aluminum. Corrosion inhibitors must be used in all glycol solutions. Inhibitors using chromium compounds must not be used since this can damage pump impeller shaft packing.

- Galvanized piping and fittings must not be used with glycol solutions due to the reaction of corrosion inhibitors with the zinc coating to form a sludge.

- High temperatures can break down glycols resulting in increased acidity (causing corrosion) and sludge (causing fouling). Glycol solutions should be kept from reaching temperatures above 250°F which should not be a problem with flat plate collectors under normal operating temperatures.

- A pH reading on glycol solutions every year is recommended.

**Design Considerations in Drain Back and Drain Down Systems.** In designing a drain down or drain back system, several points must be considered.

- The collectors, piping, connections and manifolds must be installed so that they are completely drainable.

- Piping should have a minimum downstream slope of 1/8-in. per foot.

- Pipe spans must not sag under their own filled weight. Also they must be kept from being bent by construction workers who may walk or step on them causing localized bends that may trap water.

- Failure in drain down systems usually results from improper valve operation. Air vents may freeze or become plugged with ice and then not operate on a drain down command. To avoid freezing air vents, they should be insulated and heat tracing used. Heat tracing should be highly localized and thermostatically controlled to reduce parasitic power losses.

- Controlled valves must be designed to fail in a drain down position (normally open) upon power failure.

**Orientation of Collectors.** To get the best annual performance from a flat plate solar water heater, the collectors should face south plus or minus 20° and slope at an angle equal to the latitude. In Georgia, collectors should be sloped at about 35° from the horizontal.

Also, collectors should be located so they are not shaded by trees or other buildings especially in the winter when the sun is low in the sky.
Sizing the Hot Water System. The first step in selecting the number of collectors is to determine the average daily hot water load for the house. On the average, a person uses 15 to 20 gallons of hot water per day. Table 8.2 can be used as a guide for selecting the number of collectors in Georgia. The following assumptions have been used in making this table.

- An average hot water load of 20 gallons per day per person
- The collectors face true south and are sloped at an angle equal to the latitude.
- The area for each collector is 20 square feet.

To size a hot water system to supply 100% of the annual hot water load is presently uneconomical. Therefore, this table gives the number of collectors to provide 60% to 80% of the annual hot water load.

**TABLE 8.2**

<table>
<thead>
<tr>
<th>Persons</th>
<th>Daily Hot Water Usage (Gallons)</th>
<th>Number of Collectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>2 or 3</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>3</td>
</tr>
</tbody>
</table>

Other Considerations in a Solar Hot Water System

- To prevent rupturing the collectors and storage tanks, pressure relief valves must be installed in the collector array and the storage tanks.
- Check valves should be installed on the supply side of the pump to prevent reverse thermosyphoning at night. Some pumps have built in check valves.
- Expansion tanks should be installed on the supply side of the pump to allow for fluid volume changes while keeping system operating pressure within acceptable limits.
- Air vents should be installed in the collector loop to aid in filling and draining the system.
A tempering valve (or mixing valve) should be installed on the hot water line going into the house. This valve prevents scalding water from entering the house by mixing cold water with it.

**Solar Energy Economics.** The basic trade-off when the economics of a solar energy system is considered will be the balance between a relatively high cost of initial construction and the savings in fuel throughout the life of the dwelling. An additional factor is the protection provided against shortages of conventional fuels. While this is an important issue, particularly in some parts of the country, it is very difficult to measure its value in monetary terms. (How much would you be willing to pay for heating fuel on a winter day when there is none available?)

When estimating the savings obtained from a solar energy system, it is important to recognize that the cost of energy is escalating rapidly. From January 1979 to January 1980, the energy component of the consumer price index increased by more than 40%.

Thus, the dollar savings will increase as time passes. This means that a solar energy system that would not pay for itself at today's cost of natural gas or electricity, may actually offer quite a savings over its life. Many consumers however are much more interested in near-term savings.

While each system must be analyzed on its own merits, some generalizations may be made. At the present time, swimming pool heating and domestic water heating are attractive applications of solar energy if the alternative is electric resistance heating. If natural gas is available, its current price is still low enough to discourage solar installations. However, the price of natural gas has been inflating much more rapidly than that of electricity. Without a crystal ball, it is very difficult to determine just when the price of natural gas will climb high enough to make solar energy a viable alternative for near-term savings.

Space heating with active solar energy systems is very expensive, and this option will probably not be economically attractive for some time. Passive space heating measures, on the other hand, are generally much less expensive to install, but it can be difficult to measure accurately the savings they provide.

Various incentives are being offered by the federal government to encourage installation of solar energy systems. An income tax credit for the homeowner of 40% of the first $10,000 spent on a solar energy system and its installation reduces the actual amount of taxes owed. Also, the State offers a refund of sales tax paid for solar equipment, and a constitutional amendment allows counties and cities to exempt the value of the solar system from the assessed value of the property.
Recently, Congress established a Solar Energy and Energy Conservation Bank which will be set up in the Department of Housing and Urban Development (HUD) to provide subsidized loans to persons who make energy conservation improvements or install solar applications in residential or commercial buildings.

The new bank will have the same corporate powers as the Government National Mortgage Association. It will make payments to local financial institutions willing to provide below market rate loans or a principal reduction on loans to borrowers for solar and conservation improvements.

Builders will be eligible for up to 40% subsidies for solar projects with a maximum subsidy of $5000 for a single family unit. If the owner obtains the subsidy rather than the builder, the percentage is dependent on family income and may be as high as 60% for lower income owners.

Under the combined influence of escalating cost of conventional fuels, increased tax credits of solar installations, and low interest loans for the Solar Bank, it may be expected that the demand for solar energy systems will continue to rise.

Further Information on Solar Energy Systems. Further information on active solar design practices can be found in the "Active Solar Energy System Design Practice Manual" prepared for the Department of Energy. To get a copy send a postcard to:

Design Manual
Technical Information Center
Department of Energy
P.O. Box 62
Oak Ridge, Tenn. 37830

For a copy of "Passive Solar Energy for Builders" contact:

Southern Solar Energy Center
61 Perimeter Park
Atlanta, Georgia 30341

The federal government has an agency to provide general information on solar energy. If you want to be on their mailing list or if you have any questions, you can write to them at:

National Solar Heating and Cooling Information Center
P.O. Box 1607
Rockville, Md. 10850

Also you can call them toll free at 1-800-523-2929.
STATE OF GEORGIA REQUIREMENTS

The "Georgia State Energy Code for Buildings" sets minimum standards for energy conservation in single and multi-family residential housing. This is a minimum code, and most builders already meet or exceed its standards. This code went into effect on July 16, 1978, and all present and future construction is governed by it. Presently there are proposed revisions in committee which would convert the insulation requirements from R-values to U-values. A copy of these revisions, as well as a copy of the code, are available from the Georgia Department of Community Affairs, Mr. Leslie Zsuffa, 32 Peachtree Street, N.W., Atlanta, Georgia 30303 (404)656-2259. The cost of the code is $6, plus $1.50 for the "Applications Manual."

The Home Builders Association of Georgia has taken a neutral stand on the code. The major provisions of the Code are equal to or less stringent than the FHA standards that H.B.A.G. has adopted as a minimum standard.

For residential construction the Code calls for minimum insulation in walls, ceilings, floors, and around slab-on-grade, as well as tight-fitting windows and doors, weatherstripping, and caulking of cracks where air infiltration might occur.

The Code allows the builder three methods of compliance:

1. Acceptable practice
2. Component performance
3. Alternative design

The acceptable practice method is the simplest to use and involves very few numerical calculations. The two-page chart in the center of this manual shows typical constructions and the corresponding insulation that would satisfy the Code requirements. This quick reference chart is the centerfold of this book and may be removed for easy use. The pull-out also contains a comparison of the Georgia Code with FHA-HUD and Farmers Home Administration requirements.
The component performance method allows more flexibility in the design of the house. If more glass is desired or less insulation is desired for the walls or floor or ceiling than is shown in the centerfold, insulation can be added in places to maintain the same overall heat loss. The procedure to be followed in this case can be found in Chapter V of the Code.

The alternate design method gives maximum flexibility in the design of a house. It allows for innovative features such as passive or active solar systems to be used in minimizing the energy requirements of the structure. The procedure for this method is found in Chapter IV of the Code.

The following is a fact sheet with the most frequently asked questions and answers.

Q - How was the code developed?
A - The State Building Administrative Board selected a special energy advisory committee, which included representatives from the board's State Code Advisory Committees on Heating and Air Conditioning, Plumbing, Building, and Electrical. Seven public hearings were held for comments.

Q - Does the code apply statewide?

Q - Does the code apply to all buildings?
A - The thermal standards in the code apply to all new and renovated buildings, except certain exempt ones, and the lighting standards apply to all buildings used by the public which excludes residential buildings.

Q - Who is responsible for enforcement of this code developed by the State Building Administrative Board?
A - The act specifically provides that enforcement shall be solely the province of local governing authorities, except in regard to buildings owned by the state.

Q - What about old buildings?
A - Existing buildings are not covered by the code, except when undergoing renovation.

Q - What does the code require?
The provisions of the code cover:

(1) The design and construction of the exterior envelope (in terms of adequate insulation and low air leakage), and

(2) The selection of efficient heating, ventilating, and air conditioning equipment, service water heating and usage, and electrical distribution and the selection of lighting for all buildings except residential.

What are the requirements for residences other than insulation?

The requirements include:

(1) Perimeter slab insulation (amount determined by location).

(2) Shower restricters with a total flow of 3 gallons per minute.

(3) Gas-fired heating equipment (includes hot water heaters) to have a combustion efficiency of 75% or better.

(4) Manual or automatic thermostats for heating and cooling to have a 55° to 85° setting range with a maximum setting of 75° F for heating and a minimum setting of 70° F for cooling.

(5) Air leakage will be controlled by requiring tight-fitting windows.

(6) Return air ducts in unconditioned spaces shall be fully insulated according to location of residence.

(7) All exterior joints are to be caulked, gasketed, weatherstripped, or otherwise sealed to reduce air leakage and heat loss.

Does the code require maximum insulation in attics?

No. In residential construction, R-19 insulation will be sufficient according to the code. However, if one wants a large picture window, the code permits it if more insulation, R-22 or R-30, is used in the attic to compensate for the greater heat loss through the larger window.

Does this mean increased residential construction costs?

No. Generally, the code may increase the cost of the exterior walls, floors, and roof due to more insulation. However, this increase is offset by the savings in smaller but adequate heating, ventilating, and air conditioning systems. Furthermore, the code-built residence should save at least 5% per year in energy.

What are the possible consequences if we fail to build by an energy conservation code?

The U.S. Department of Energy is formulating national building energy performance standards for new residential and commercial buildings. After these standards are promulgated in 1981, all federal financial assistance for new construction, including mortgage guarantees, may be terminated in areas which have not adopted equally stringent thermal standards. Building by the Georgia State Energy Code for buildings may avoid federal preemption.
The November 28, 1979, Federal Register contains the proposed DOE guidelines for the Building Energy Performance Standards for new buildings, designated as BEPS. This rule, when adopted, will cover both commercial and residential buildings. The standards are applied during the design of a building and regulate its design energy conservation potential. They do not regulate the operation, maintenance, or energy consumption of the building once built. The standards do not specify the methods, materials, or processes used to meet the energy goals. As such, they can accommodate changes in design and technology over time. Copies of the rule may be obtained for 75¢ per copy from the U.S. Government Printing Office. Currently, the effective date of BEPS is not certain, but when it does become effective, Congress may act to terminate all federal financial assistance for new construction in areas not enforcing BEPS or an equally strict code.
TODAY’S HOMEBUYER

The contemporary homeowner and homebuyer are well aware of the high costs of their energy. They are also aware that utility bills will continue to be an increasing percentage of their monthly expenses. Homeowners are now looking beyond the initial cost for their homes and making critical evaluations of what it will cost to operate their homes five, ten, and fifteen years from now. A conservative estimate would be that, on the average, a typical Georgian is reminded 15 times per week, via mass media, signs, or at work, that some of our current fuels are in short supply, that energy costs are going up, and that energy conservation should be practiced at home or on the job.

Today's homebuyer is ready for the energy conserving home, and current sales of energy conserving homes support this statement. Many builders throughout the Southeast are altering their designs and building techniques to build only energy conserving homes. In the words of one southern builder:

I took a hard look at the new design ideas and then sent my people back to the drawing boards to redesign all of the houses we had planned at the time. Actually, making the design changes doesn't take a great deal of doing; and in the average home, the cost differential will only be about $1,700. But when the savings are measured for the buyer, month after month, year after year, why this looks like the only logical thing to do.

In a survey, Professional Builder reported that 89.3% of actual buyers were willing to spend $600 or more at the time of construction in order to cut their heating and cooling bills by $100 per year. Another example of how well sales of energy conserving homes are going is that the largest home builder in the state of Virginia builds and markets only energy conserving homes.

The demand exists for energy conserving homes, and the progressive builder with insight into the changing home market will recognize this fact and gear up to supply them.

THE EFFECT OF ENERGY COSTS ON THE HOMEBUYER

Notwithstanding the energy awareness of today's average person, the prospective homebuyer needs to have certain facts emphasized. For an average house with gas heat and electric air conditioning, utility bills equal 12% of the mortgage payment.
For all electric homes, this figure is 21%. Table 10.1 illustrates representative cost figures for the Atlanta area.

### Table 10.1

<table>
<thead>
<tr>
<th>Sq. Ft. of House</th>
<th>Gas Heat, Elec., A/C</th>
<th>All Electric w/Baseboard Ht.</th>
<th>Monthly Mortgage Payment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>$58</td>
<td>$101</td>
<td>$492</td>
</tr>
<tr>
<td>1600</td>
<td>$82</td>
<td>$136</td>
<td>$657</td>
</tr>
<tr>
<td>2200</td>
<td>$102</td>
<td>$184</td>
<td>$903</td>
</tr>
</tbody>
</table>

Percent of Mortgage Payment: 12% (1200 sq. ft.), 21% (1600 sq. ft.), 21% (2200 sq. ft.)

*30 year mortgage, 12% interest, $42 per sq. foot of conditioned space, 95% financing, principal and interest only.

Heating and air conditioning constitute the major portion of the energy bill for the average home, with a substantial part of the remainder being made up by domestic hot water. Figure 10.1 illustrates results of a study performed to determine electrical energy usage patterns for typical new, single-family home construction by Gulf Power Company. It shows the predominance of heating and cooling as items making up the total energy bill.

![Figure 10.1. Annual Energy Consumption in New Single Family Residences](image-url)

WATER HEATING 3000 KWH

HEATING AND AIR CONDITIONING 13000 KWH

SMALL APPLIANCES AND LIGHTING USE 9000 KWH

12% 52% 36%

Figure 10.1. Annual Energy Consumption in New Single Family Residences
Since many new homes are constructed without adequate energy conservation features, much of the heat in winter, and cool air in summer, leaks or is directed out of the house, increasing the homeowner's costs with no net effect on comfort.

The figures given above have additional significance when it is considered that:

- Energy costs will continue to go up,
- Mortgage payments to an existing loan are constant over the loan life,
- Money that is spent on a mortgage is an investment in one's home, while money spent on utilities yields no tangible, future return.

A further illustration to sharpen the prospective home buyer's interest appears in Figure 10.2. The graph shows a projection of the change in utility bills versus mortgage payments, with time, assuming a 15% per year increase in energy costs. The graph shows rapid growth of utility bills, with the all electric house utility bill and mortgage payment becoming equal after 11 years; for natural gas heat, the figure is 15 years. In addition, the peak month utility bill will surpass the mortgage payment much sooner. This event has already occurred for many homeowners with all electric homes during recent winters; what is worse, cost increases will more likely be higher than the 15% used in the graph.

By advising prospective home buyers of these facts and offering the energy saving home as the solution, the builder, developer, and real estate agent will be satisfying market demands, selling homes faster, and making more money on slightly higher priced homes, while giving the homeowner the assurance of lowered energy use and costs.

COST/BENEFIT ANALYSIS

From a cost/benefit standpoint, the analysis in Table 10.2 would seem appropriate for today's home buyer.

<table>
<thead>
<tr>
<th>Interest Rate</th>
<th>Extra Mortgage Payment Per Month</th>
<th>Avg. Monthly Utility Savings</th>
<th>Net Cash in Hand Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>12%</td>
<td>$10.29</td>
<td>$43.70</td>
<td>$26.30</td>
</tr>
</tbody>
</table>

TABLE 10.2
MONTHLY CASH FLOW BASED ON 1,000 SQ. FT. OF HOUSE
MONTHLY CASH FLOW - MORTGAGE PAYMENTS
AND ENERGY COSTS FOR
TYPICAL 1600 SQ. FT. HOME IN ATLANTA

$600

$400

$200

PRESENT

$657 CONSTANT MORTGAGE PAYMENT-12% INTEREST

TOTAL ELECTRIC

GAS HEAT/ELECTRIC A/C

NOTE: ASSUMES A 15% PER YEAR INCREASE IN UTILITY RATES
It should be re-emphasized that the extra mortgage payment of $10.29 per month is "saved" also. The buyer is building equity in the house with it, and will recoup the money upon sale of the house. Savings may be greater outside the Atlanta area where this energy cost data was derived.

Lenders will be pleased to note that there is a simple basis for this method of economic analysis: any energy conserving item which saves as much per month as it costs in mortgage payment ($10.29 per month, per $1,000 first cost to the home buyer) has a simple payback period of 8.1 years. Also, for the homeowner, if the savings as a result of energy conserving features shown above were invested at 7% interest, the savings over the 30 year mortgage would be in excess of $37,000.

THE ENERGY CONSERVING HOME MARKETING PACKAGE

Two important principles apply here:

- A package of energy conserving features is more desirable than one or two energy extras.
- The marketing of the energy saving home requires the coordination and expertise of all of the people involved in the new home industry: builders, subcontractors, appraisers, lenders, real estate agents, and home buyers.

It is important to use a package of energy conserving features and, where possible to standardize this package for a particular area. The use of a standardized package has the advantages of:

- Tightening up the house equally in all its weak areas, producing the greatest amount of comfort and savings.
- Making the job of communication between builder and subcontractors, inspectors, appraisers, lenders, sales agents, and home buyers easier.
- Using available, tested materials thereby making it simpler to pass building codes and increasing consumer recognition.

Individuals outside the home building industry are often amazed at the complexity of the scheduling and coordination required to build and sell a house. This same scheduling and coordination are required to build and market the energy conserving home. The wise builder will make sure that the following people are completely aware of the energy saving plans and materials he has built into his homes:
... Subcontractor...

The HVAC contractors, insulators, and framing crews are at the heart of producing a tightly constructed, energy conserving home. They must be fully aware of new techniques and their part in the construction of the energy saving home.

... Inspectors...

By building a standard energy efficient package into homes and informing the building inspector of the details of this package, the task of satisfying the building code will be simplified.

... Appraisers...

Appraisers must be aware of all the energy saving features in a new home. Figure 10.3 is a sample "FHA Description of Materials Form" with energy extras noted for the energy conserving house plans, to illustrate the degree of detail which should be used. Figure 10.4 is the most recent "Federal National Mortgage Association Residential Appraisal Report" form (FNMA Form 1004 and FHLMC Form 70, Revised 7/79). It is a form widely used in appraisal and lending circles, makes special emphasis of energy efficient items in the valuation process. Today, appraisers are giving energy saving features their due in terms of market value, but they can only include these features in their appraisal if they are aware of them.

... Lenders...

Lenders are committed to a policy of fostering energy conservation in the construction of new homes. One of the considerations used in evaluating the allowable debt-to-income ratio for prospective buyers is whether the home has energy conserving features that would reduce the buyer's anticipated utility bills and hence, permit the lender to allow a slightly higher debt ratio. Real estate agents and home buyers in particular should be aware of this consideration. But, once again, the lender must know the extent and type of energy saving features. Another advantage to a builder of using a standardized package is that, by reputation, appraisers and lenders will come to expect or look for energy saving features from a particular builder.
5. Exterior Walls:

Additional information: Sole plate - latex caulking to flooring

6. Floor Framing:

- Joists: wood, grade, and species ___________; other ___________; bridging ___________; anchors ___________. Concrete slab: □ basement floor; □ first floor; □ ground supported; □ self-supporting; mix ___________; thickness ___________; reinforcing ___________; insulation ___________; membrane ___________; Fill under slab: material ___________; thickness ___________. Additional information:

12. Roofing:

Additional information: light in color

15. Decorating: (Paint, wallpaper, etc.)

Additional information: Wire and pipe holes latex caulked

17. Windows:

- Weatherstripping: type ___________; material ___________; Storm sash, number X

18. Entrances and Exterior Detail:

Main entrance door: material See Below; width ___________; thickness ___________. Frame: material ___________; thickness ___________.

Head flashing ___________; Weatherstripping: type Mag. and compression

Additional information: Steel faced foam core insulated doors

22. Plumbing:

<table>
<thead>
<tr>
<th>Fixture</th>
<th>Number</th>
<th>Location</th>
<th>Make</th>
<th>Mix's Fixture Identification No.</th>
<th>Size</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water closet</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>3 1/2 Gal. Water Saving</td>
<td></td>
</tr>
<tr>
<td>Bathtub</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shower over tub</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>3 GPM Water Saving</td>
<td></td>
</tr>
<tr>
<td>Stall shower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laundry trays</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerators</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2 GPM Water Saving</td>
<td></td>
</tr>
<tr>
<td>Water pipes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pipe Insulation at Hot Water Heater</td>
<td></td>
</tr>
</tbody>
</table>

23. Heating:

- Warm air: □ Gravity; □ Forced. Type of system Gas Furnace
- Duct material: supply ___________; return ___________; Insulation ___________; thickness ___________; □ Outside air intake.
- Furnace: make and model ___________; Input ___________; Btu.; output ___________; Btu.
- Additional information: Duct joints taped, pilotless ignition on furnace
- Other heating, ventilating, or cooling equipment: continuous ridge and soffit vent, EER 9.0 air conditioner, air conditioner heat reclamer, solar etc.

25. Lighting Fixtures:

Non-typical installation: Number and location of Fluorescent light fixture.

26. Insulation:

- Location | Thickness | Material, Type, and Method of Installation | Vapor Barrier |
- Roof      | R-26      | Fiberglass, 8 1/4"                         | Kraft Face    |
- Wall      | R-17      | R-13 Fiberglass batt + R-4 rigid foam wall sheathing | Kraft Face    |
- Floor     | R-11      | Fiberglass batt                            | Kraft Face    |
-     or     | R-4       | One inch - Beadboard perimeter insulation, 24"  |

Special Equipment:

- Pilotless ignition on range (make and model #)

Also prepare a separate sheet entitled "Addendum to 2005", note section numbers which contain energy conserving items, explain their function if necessary. Make a note on page one of 2005; "To the attention of the appraiser, see Addendum to 2005 on energy conserving items".
### RESIDENTIAL APPRAISAL REPORT

#### Borrower
- Property Address
- City:
- State:
- Zip Code:

#### Location
- Market Area:
- City:
- County:
- State:
- Zip Code:

#### Growth Rate
- Fully Developed:
- Over 5%:
- 25% to 75%:
- Under 25%:

#### Property Values
- Increasing:
- Stable:
- Declining:

#### Present Land Use
- % 1 Family:
- % 2-4 Family:
- % Apts.:
- % Condo:
- % Commercial:

#### Marketing Time
- Under 3 Mos.:
- 4-6 Mos.:
- Over 6 Mos.:

#### Present Land Use
- % Industrial:
- % Vacant:

#### Change in Present Land Use
- % Not Likely:
- % Likely (*):

#### Predominant Occupancy
-Owner:
- Tenant:

#### Single Family Price Range
- $ to $:

#### Single Family Age
- yrs to yrs:

#### Zoning classification
- Present improvements:
- Public:
- Other (describe):

#### Topo
- Street Access:
- Surface:
- Shape:

#### Drainage
- Storm Sewer:
- Curb/Gutter:

#### Comments
- Favorable or unfavorable, including any apparent adverse easements, encroachments, or other adverse conditions:

### SITE

#### Dimensions
- Sq. Ft. or Acres:

#### Zoning
- Highest and best use:
- Existing:
- Proposed:
- Undeveloped:

#### Roof Material
- Manufactured Housing:

#### Foundation Walls
- % Basement:
- % Floor Drain:

#### Gutters & Downspouts
- % Sump Pump:
- % Concrete Floor:

#### Exterior Walls
- % Finished:
- % Storm Sash:
- % Screen:

#### Insulation
- % Ceiling:
- % Roof:
- % Walls:

#### Rooms
- Type:
- Design:
- Lower Level:
- 2nd Level:

#### Basements
- % Finished:
- % Floor Area:

#### Bathrooms
- % Total Baths:

#### Kitchens
- % Total Kitchens:

#### Heating Type
- Central:
- Other:

#### Air Conditioning
- On:
- Off:

#### Attic
- % Storage
- % Garage

#### Public Parks
- % Open Space:

#### Street Access
- % Sidewalk:

#### Other
- % Storm Sewer:
- % Curb/Gutter:

#### Comments
- Favorable or unfavorable, including any apparent adverse easements, encroachments, or other adverse conditions:

### IMPROVEMENTS

#### Quality of Construction (Materials & Finish)
- % Good:
- % Fair:
- % Poor:

#### Condition of Improvements
- % Excellent:
- % Adequate:
- % Inadequate:

#### Plumbing
- % Adequate:
- % Inadequate:

#### Electrical
- % Adequate:
- % Inadequate:

#### Kitchen CABINETS
- % Adequate:
- % Inadequate:

#### Storage
- % Adequate:
- % Inadequate:

#### Location
- % Good:
- % Fair:
- % Poor:

#### Overall Livability
- % Good:
- % Fair:
- % Poor:

#### Appeal and Marketability
- % Good:
- % Fair:
- % Poor:

#### Yrs. Est. Remaining Economic Life
- % Good:
- % Fair:
- % Poor:

#### Figure 10.4
85
Real estate agents, by and large, recognize the desire by the home buying market to purchase energy conserving homes. The time spent in informing sales people of the nature and significance of energy conserving features will be returned many times over by faster sales at slightly higher prices.

The home buyer, in many ways, is the most easily convinced of the value of the energy conserving home. No one wants to buy an energy hog. But the buyer must know what will be gained by paying the slightly higher price for an energy conserving home:

- Lower utility bills
- Improved monthly cash flow
- Energy and dollar savings
- Quality, tight construction
- Greater comfort
- Higher resale value
- A hedge against increasing utility costs

The buyer shall be informed of the specific energy saving features in the home so that he or she will understand their value. Some ways of providing this information are:

- **Home Energy Profile Card.** Shown in Figure 10.5, this may be filled out when the house nears completion and hung in a conspicuous place where it can be viewed by the appraiser, buyer, or salesman. Copies are available from the Home Builders Association of Georgia.

- **Public Utilities Advertising.** Certifications, promotions and other advertising campaigns are sponsored by the local utility companies to promote residential energy conservation. Contact your local utilities for more information.

- **Energy Tags.** It is becoming increasingly popular to tag energy savings features in model homes or in all homes. This applies to doors, walls, insulation and major appliances.

- **Brochures.** Prepare a descriptive brochure or use existing available brochures to promote the benefits of energy saving features for prospective buyers.

- **Promotions to Encourage Energy Conservation.** For example, one developer in the Southeast offers to pay the lowest monthly utility bill of the energy saving homeowners in his development. This approach stimulates interest in energy conservation by homeowners while giving the developer effective, low cost publicity.
HOME ENERGY PROFILE

THIS HOME CONTAINS THE FOLLOWING ENERGY CONSERVATION FEATURES:

<table>
<thead>
<tr>
<th>BATT OR BLOWN INSULATION</th>
<th>FOAM INSULATION</th>
<th>TOTAL INSUL. 'R' FACTORS</th>
<th>AIR INFILTRATION BARRIER</th>
<th>ROOF</th>
<th>WINDOWS AND DOORS</th>
<th>HEATING AND COOLING SYSTEM</th>
<th>FIREPLACE</th>
<th>APPLIANCES &amp; FIXTURES</th>
<th>OTHER ENERGY SAVERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ INCHES — CEILING</td>
<td>□ INCHES LOC. AND TYPE</td>
<td>□ INCHES LOC. AND TYPE</td>
<td>□ SILL SEALER</td>
<td></td>
<td>□ STORM SASH</td>
<td>□ INSULATED DUCTS</td>
<td>□ GLASS DOORS</td>
<td>□ FLUORESCENT LIGHTS</td>
<td>□ OVERHANGS FOR SHADE — SOUTH SIDE</td>
</tr>
<tr>
<td>□ INCHES — WALLS</td>
<td>□ WIRING HOLES CAULKED</td>
<td>□ WIRING HOLES CAULKED</td>
<td>□ WIRING HOLES CAULKED</td>
<td></td>
<td>□ DOUBLE Pane</td>
<td>□ TAPED DUCT JOINTS</td>
<td>□ EXTERIOR COMBUSTION AIR</td>
<td>□ PILOTLESS IGNITION ON STOVE</td>
<td>□ GARAGE ON WEST SIDE FOR SHADE</td>
</tr>
<tr>
<td>□ INCHES — FLOORS</td>
<td>□ PIPE HOLES CAULKED</td>
<td>□ PIPE HOLES CAULKED</td>
<td>□ PIPE HOLES CAULKED</td>
<td></td>
<td>□ FOAM CORE STEEL DOORS</td>
<td>□ HEAT PUMP: _______ TONS</td>
<td>□ CIRCULATING FIREPLACE</td>
<td>□ EXTRA INSUL. ON ELEC. WATER HEATER</td>
<td>□ PORCH — EAST, WEST, OR SOUTH SIDE</td>
</tr>
<tr>
<td></td>
<td>□ POLY VAPOR BARRIER</td>
<td>□ ATTIC STAIR SEALLED &amp; INSULATED</td>
<td>□ ATTIC STAIR IN UNCONDITIONED SPACE</td>
<td></td>
<td></td>
<td>□ HIGH EFF. A/C _______ EER (MIN. 9.0)</td>
<td>□ TIGHT-FITTING DAMPER</td>
<td>□ WATER-SAVING SHOWER HEAD</td>
<td>□ □ □</td>
</tr>
<tr>
<td></td>
<td>□ ATTIC STAIR SEALLED &amp; INSULATED</td>
<td></td>
<td>□ ATTIC STAIR IN UNCONDITIONED SPACE</td>
<td></td>
<td></td>
<td>□ SET BACK TYPE THERMOSTAT</td>
<td></td>
<td>□ LOW-FLUSH TOILET</td>
<td>□ □ □</td>
</tr>
<tr>
<td></td>
<td>□ ROOF LIGHT COLORED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>□ ELECTRONIC IGNITION ON FURNACE</td>
<td></td>
<td></td>
<td>□ □</td>
</tr>
<tr>
<td></td>
<td>□ RAVE HOLES &amp; SOFFIT VENTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>□ TIMER SWITCH ON EXHAUST FAN</td>
<td>□ □</td>
<td></td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>□ WIND POWERED TURBINE VENT</td>
<td></td>
<td></td>
<td></td>
<td>□ SOLAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BUILDER: ___________________________  DATE: ____________

Figure 10.5

87
**Name of Corporation**
Refrigerator-Freezer
Model(s): AH503, AH504, AH507
Type of Defrost: Full Automatic

**ENERGYGUIDE**

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour.

**Model with lowest energy cost**

$68

**Model with highest energy cost**

$132

*This Model*

Estimated yearly energy cost

Your cost will vary depending on your local energy rate and how you use the product. The estimates are based on a national average electric rate of 4.97¢ per kilowatt hour.

How much will this model cost you to run yearly?

<table>
<thead>
<tr>
<th>Yearly cost</th>
<th>Estimated yearly cost shown below</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per kilowatt hour</td>
<td>$44</td>
</tr>
<tr>
<td>2¢</td>
<td>$44</td>
</tr>
<tr>
<td>4¢</td>
<td>$88</td>
</tr>
<tr>
<td>6¢</td>
<td>$132</td>
</tr>
<tr>
<td>8¢</td>
<td>$176</td>
</tr>
<tr>
<td>10¢</td>
<td>$220</td>
</tr>
<tr>
<td>12¢</td>
<td>$264</td>
</tr>
</tbody>
</table>

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area.

*Important: Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302).*

---

**FTC Energy Guide Labels.** Available not only for the new homebuyer but also for all consumers, effective March 25, 1980, are the Federal Trade Commission Energy Guide appliance labels. The FTC is requiring energy guide labels to be placed on the following appliances: refrigerator-freezers, freezers, room air conditioners, furnaces, dishwashers, washing machines, and water heaters. The labels are a comparative guide which rate the appliance against other models in a particular class in terms of annual energy cost and energy efficiency. An example of the label is shown in Figure 10.6.

In conclusion, the energy saving home has advantages that make it more desirable to home buyers than the conventional home. Through effective coordination, construction, and marketing of these homes, the forward-thinking builder and home buyer are setting the trend for today's market.
CHAPTER 11

SUMMARY

The energy conserving home can be built now, for little extra cost and with available materials. For about 3% extra cost to the homebuyer, the heating and cooling utility bills can be cut in half. The "package" approach is best, not just adding a feature here and there.

The following energy dos and don'ts will be useful reminders when designing the energy conserving house.

DO
- Consider site orientation and shading
- Use a package approach
- Use natural attic ventilation
- Install fluorescent lights
- Use a cashflow sales approach
- Use tested materials and products
- Minimize window area
- Check subcontractors' work
- Duct exterior combustion air to furnace
- Choose compact house designs

DON'T
- Allow oversizing of equipment
- Install needless appliances and equipment
- Make inflated claims
- Outprice yourself from the market
APPENDIX I

SEASONAL HEATING COSTS

Figure A1.1 shows the dramatic effect that the R-value and its reciprocal, U-value, have on heat loss.

Even small improvements in the R-value at low R's produce large savings, as in the case of adding storm windows on insulating an uninsulated attic or heating ducts. Adding more insulation to an already insulated area, such as going from R-19 to R-26 attic insulation, yields smaller savings. The law of diminishing returns works against us at higher R-values.

This graph may be used for the Atlanta area at present utility rates. Table A1.1 gives the data used in its preparation.

TABLE A1.1

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>36¢/therm</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>96¢/gallon</td>
</tr>
<tr>
<td>Electricity</td>
<td>4.4¢/KW-hr (heating)</td>
</tr>
<tr>
<td></td>
<td>5.2¢/KW-hr (cooling)</td>
</tr>
<tr>
<td>LP Gas</td>
<td>66¢/gallon</td>
</tr>
<tr>
<td>Annual average degree days:</td>
<td>2,961</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heating Unit</th>
<th>Seasonal Performance Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas or LP Gas Furnace</td>
<td>0.60</td>
</tr>
<tr>
<td>Oil Burner</td>
<td>0.50</td>
</tr>
<tr>
<td>Electric Baseboard Heat</td>
<td>1.00</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>2.00</td>
</tr>
</tbody>
</table>

*From: "NAHB Thermal Performance Guidelines For One and Two Family Dwellings"

The R-value in Figure A1.1 is the overall R of the insulation plus sheetrock, sheathing, and air film. A tabulation of equivalent R and U values is found on the graph to aid in converting the two units. To calculate seasonal heating costs for other
HEATING COST PER SEASON vs. R-VALUE & U-VALUE
(FOR ATLANTA)

Figure A1.1
locations, multiply the Atlanta seasonal cost by local fuel cost and heating cost multiplier found in Appendix II, and divide by the Atlanta fuel cost.

This graph can be used to check the payback period for adding insulation. First find the difference in annual heating cost for standard and extra insulation thickness. This is the annual savings. Next divide the extra installed cost per square foot by the annual savings. The result is the payback period in years.

Heating cost can also be found using a calculator and the following equations:

- Electric Resistance: $ \text{per season per sq. foot} = 0.915 \div R$
- Oil Burner: $ \text{per season per sq. foot} = 0.975 \div R$
- Electric Heat Pumps: $ \text{per season per sq. foot} = 0.458 \div R$
- Natural Gas: $ \text{per season per sq. foot} = 0.426 \div R$

The above equations can be used with U-value rather than R-value. Simply multiply by U rather than dividing by R.

It should be noted that the graph is for heating only. A similar graph for air conditioning cannot be constructed due to the large and variable heat gain from windows.
APPENDIX II

HEATING AND COOLING COST MULTIPLIERS FOR OTHER CITIES

Data for annual cost and savings on the 1200, 1600, and 2200 house plans can be estimated for cities throughout Georgia by use of the multiplication factors in Table A2.1.

TABLE A2.1

HEATING AND COOLING COST MULTIPLIERS

<table>
<thead>
<tr>
<th>City</th>
<th>Heating Cost Multiplier</th>
<th>Cooling Cost Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albany</td>
<td>.61</td>
<td>1.62</td>
</tr>
<tr>
<td>Athens</td>
<td>.96</td>
<td>1.08</td>
</tr>
<tr>
<td>Atlanta</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Augusta</td>
<td>.82</td>
<td>1.26</td>
</tr>
<tr>
<td>Columbus</td>
<td>.77</td>
<td>1.35</td>
</tr>
<tr>
<td>Dalton</td>
<td>1.08</td>
<td>.98</td>
</tr>
<tr>
<td>Macon</td>
<td>.72</td>
<td>1.44</td>
</tr>
<tr>
<td>Rome</td>
<td>1.08</td>
<td>1.02</td>
</tr>
<tr>
<td>Savannah</td>
<td>.63</td>
<td>1.46</td>
</tr>
</tbody>
</table>

These multipliers are based on 30 year average heating and cooling degree data from the National Weather Service.

The following example shows how to estimate annual cost and savings for the city of Augusta for house plan 1200. Cost data is taken from Table 6.4 entitled "Annual Heating and Cooling Cost and Consumption."
For Augusta use .82 heating cost multiplier, 1.26 cooling multiplier.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Energy Conserving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating $528 \times .82 = $433$</td>
<td>$163 \times .82 = $134$</td>
</tr>
<tr>
<td>Cooling $160 \times 1.26 = $202$</td>
<td>$75 \times 1.26 = $95$</td>
</tr>
<tr>
<td>Total, Heating and Cooling Cost $$635$</td>
<td>$$229$</td>
</tr>
</tbody>
</table>

The total heating and cooling costs of $\$635$ for the standard plan and $\$229$ for the energy conserving plan are approximate values for Augusta. An exact estimate would also need to consider design temperature ratios.

Cost of fuel may vary from Atlanta. See Appendix I for Atlanta fuel cost; multiply by local fuel cost divided by Atlanta fuel cost.

Cost for fuel oil and propane are not included in the comparative house plans. Use the factors in Table A2.2.

**TABLE A2.2**

ADJUSTMENT FACTORS FOR FUEL OIL AND PROPANE

<table>
<thead>
<tr>
<th>Cost/Gal</th>
<th>Fuel Oil</th>
<th>LP Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>$.60</td>
<td>1.93</td>
<td>2.38</td>
</tr>
<tr>
<td>$.70</td>
<td>2.25</td>
<td>2.78</td>
</tr>
<tr>
<td>$.80</td>
<td>2.57</td>
<td>3.17</td>
</tr>
<tr>
<td>$.90</td>
<td>2.90</td>
<td>3.57</td>
</tr>
<tr>
<td>$1.00</td>
<td>3.22</td>
<td>3.97</td>
</tr>
<tr>
<td>$1.10</td>
<td>3.53</td>
<td>4.38</td>
</tr>
<tr>
<td>$1.20</td>
<td>3.85</td>
<td>4.78</td>
</tr>
</tbody>
</table>

Multiply the heating cost data for natural gas by the above factors to find fuel oil or LP gas cost after using heating cost multiplier.
# APPENDIX III

## COST DATA FOR ENERGY CONSERVING HOUSE PLANS

<table>
<thead>
<tr>
<th>Item</th>
<th>1200 Plan</th>
<th>1600 Plan</th>
<th>2200 Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm Windows</td>
<td>$300</td>
<td>$360</td>
<td>$630</td>
</tr>
<tr>
<td>Floor Insulation</td>
<td>44</td>
<td>311</td>
<td>223</td>
</tr>
<tr>
<td>Attic Insulation</td>
<td>72</td>
<td>97</td>
<td>68</td>
</tr>
<tr>
<td>Wall Sheathing-Foam</td>
<td>138</td>
<td>153</td>
<td>255</td>
</tr>
<tr>
<td>Wall Insulation-Fiberglass</td>
<td>28</td>
<td>31</td>
<td>51</td>
</tr>
<tr>
<td>Insulated Doors-Regular</td>
<td>115</td>
<td>80</td>
<td>81</td>
</tr>
<tr>
<td>Insulated Doors-French</td>
<td>—</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Ridge and Soffit Vents</td>
<td>100</td>
<td>126</td>
<td>72</td>
</tr>
<tr>
<td>Sill Sealer</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Caulk Pipe, Wireholes, and Soleplate</td>
<td>144</td>
<td>192</td>
<td>264</td>
</tr>
<tr>
<td>Set-Back Thermostat</td>
<td>80</td>
<td>80</td>
<td>--</td>
</tr>
<tr>
<td>SEER 9.0 A/C</td>
<td>200</td>
<td>250</td>
<td>--</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1231</strong></td>
<td><strong>$1778</strong></td>
<td><strong>$1740</strong></td>
</tr>
</tbody>
</table>
APPENDIX IV

DEFINITION OF KEY TERMS

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Humidity</td>
<td>The weight of water vapor per unit volume, pounds per cubic foot or grams per cubic centimeter.</td>
</tr>
<tr>
<td>Absorbent</td>
<td>The less volatile of the two working fluids used in an absorption cooling device.</td>
</tr>
<tr>
<td>Absorber</td>
<td>The surface in a collector that absorbs solar radiation and converts it to heat energy; generally, matte black surfaces are good absorbers and emitters of thermal radiation while white and metallic surfaces are not. (See Selective Surface.)</td>
</tr>
<tr>
<td>Absorptance</td>
<td>The ratio of energy absorbed by a surface to the energy striking it.</td>
</tr>
<tr>
<td>Active System</td>
<td>A solar heating or cooling system that requires external mechanical power to move the collected heat.</td>
</tr>
<tr>
<td>A/C Tons</td>
<td>A 1-ton air conditioner has 12,000 Btuh of cooling capacity.</td>
</tr>
<tr>
<td>Air Conditioning Load</td>
<td>The rate of heat transfer through a structure. Heat gain of windows, doors, walls, ceiling, floor, and infiltration are added together to determine the heat gain of a structure.</td>
</tr>
<tr>
<td>Airtight Stove</td>
<td>A stove wherein all the air which enters it goes through the inlet air dampers, thus providing an increased efficiency.</td>
</tr>
<tr>
<td>Air-Type Collector</td>
<td>A collector that uses air as the heat transfer fluid.</td>
</tr>
<tr>
<td>Altitude</td>
<td>The angular distance from the horizon to the sun.</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>The temperature of the air surrounding an object.</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>Abbreviation for the American Society of Heating, Refrigerating and Air-Conditioning Engineers.</td>
</tr>
<tr>
<td>Auxiliary Heat</td>
<td>The extra heat provided by a conventional heating system for periods of cloudiness or intense cold when a solar heating system cannot provide enough.</td>
</tr>
<tr>
<td>Azimuth</td>
<td>The angular distance between true south and the point on the horizon directly below the sun.</td>
</tr>
<tr>
<td>Bioconversion</td>
<td>Conversion by bacteria of agricultural or municipal wastes to fuel.</td>
</tr>
<tr>
<td>Btu (British Thermal Unit)</td>
<td>A unit of heat to express the amount of heat. The amount of heat required to raise the temperature of one pound of water 1°F. One kilowatt of electricity converted to heat in a resistor produces 3,413 Btus per hour.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Btu (Btu per Hour)</td>
<td>A rate of heat transfer. A structure loses heat at the rate of so many Btuh. Heating equipment must produce heat at an equal or greater Btuh rate to maintain temperature in the structure.</td>
</tr>
<tr>
<td>Calorie</td>
<td>The quantity of heat needed to raise the temperature of one gram of water on degree Celsius.</td>
</tr>
<tr>
<td>CFM</td>
<td>Cubic feet per minute, units for airflow.</td>
</tr>
<tr>
<td>Chimney</td>
<td>Provides combustion air to the stove and carries smoke out of the house.</td>
</tr>
<tr>
<td>Circulating Stove</td>
<td>A stove with an outer jacket, beyond the main structure, with openings at the bottom and top so that air can circulate.</td>
</tr>
<tr>
<td>Coefficient of Heat Transmission</td>
<td>The rate of heat loss in Btu per hour through a square foot of wall or other building surface when the difference between indoor and outdoor air temperatures is 1°F.</td>
</tr>
<tr>
<td>Collector</td>
<td>A device that collects solar radiation and converts it to heat.</td>
</tr>
<tr>
<td>Collector Efficiency</td>
<td>The ratio of usable heat energy extracted from a collector to the solar energy striking the cover.</td>
</tr>
<tr>
<td>Collector Tilt</td>
<td>The angle between the horizontal plane and the solar collector plane.</td>
</tr>
<tr>
<td>Concentrating Collector</td>
<td>A device which concentrates the sun’s rays on an absorber surface which is significantly smaller than the overall collector area. (See Heliostat.)</td>
</tr>
<tr>
<td>Conduction</td>
<td>The flow of heat due to temperature variations within a material.</td>
</tr>
<tr>
<td>Conductivity</td>
<td>A measure of the ability of a material to permit conduction heat flow through it.</td>
</tr>
<tr>
<td>Convection</td>
<td>The motion of bulk matter such as gas or liquid by which heat may be transported. (See Gravity Convection.)</td>
</tr>
<tr>
<td>COP (Coefficient of Performance)</td>
<td>A ratio calculated by dividing the total heating capacity provided by the refrigeration system including circulating fan heat, but excluding supplementary resistance heat (Btuh) by the total electrical input (watts) times 3,413 (a ratio calculated for both cooling and heating capacities by dividing capacity in watts by power input in watts).</td>
</tr>
<tr>
<td>Cover Plate</td>
<td>A sheet of glass or transparent plastic placed above the absorber in a plat-plate collector. (See Absorber and Collector.)</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Creosote</td>
<td>Chimney deposits originating as condensed organic vapors or condensed tar fog.</td>
</tr>
<tr>
<td>Degree-Day</td>
<td>A unit that represents a $1^\circ F$ deviation from some fixed reference point (usually $65^\circ F$) in the mean daily outdoor temperature.</td>
</tr>
<tr>
<td>Degree of Saturation</td>
<td>The ratio of the weight of water vapor associated with a pound of dry air to the weight of water vapor associated with a pound of dry air saturated at the same temperature.</td>
</tr>
<tr>
<td>Design Heating Load</td>
<td>The total heat loss from a house under the most severe winter conditions likely to occur; a concept used in the design of building and their heating systems.</td>
</tr>
<tr>
<td>Design Temperature</td>
<td>A temperature close to the lowest expected for a location; used to determine the design heating load.</td>
</tr>
<tr>
<td>Dew Point Temperature</td>
<td>The temperature at which the condensation of water vapor in a space begins for a given state of humidity and pressure as the temperature of the vapor is reduced. The temperature corresponding to saturation (100% relative humidity) for a given absolute humidity at constant pressure.</td>
</tr>
<tr>
<td>Diffuse Radiation</td>
<td>Indirect sunlight that is scattered from air molecules, dust and water vapor.</td>
</tr>
<tr>
<td>Direct Radiation</td>
<td>Solar radiation that comes straight from the sun, casting shadows on a clear day.</td>
</tr>
<tr>
<td>Double-Glazed</td>
<td>Covered by two panes of glass or other transparent material.</td>
</tr>
<tr>
<td>Emittance</td>
<td>A measure of the propensity of a material to radiate energy to its surroundings.</td>
</tr>
<tr>
<td>GPM</td>
<td>Gallons per minute, units for fluid flow.</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilating, and Air Conditioning</td>
</tr>
<tr>
<td>Heat Shield</td>
<td>Ceramic or metallic material used to reduce the required clearances between the stove and a combustible material.</td>
</tr>
<tr>
<td>Heat Storage</td>
<td>A device or medium that absorbs collected solar heat and stores it for use during periods of inclement or cold weather.</td>
</tr>
<tr>
<td>Heat Storage Capacity</td>
<td>The ability of a material to store heat.</td>
</tr>
<tr>
<td>Heating Load</td>
<td>The rate of heat transfer from a structure. Heat loss of windows, doors, walls, ceiling, floor, and infiltration are added together to determine the heat loss of a structure.</td>
</tr>
<tr>
<td>Heliostat</td>
<td>A mirror used to reflect the sun's rays into an absorbing device. (See Concentrating Collector.)</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Humidity</td>
<td>Water vapor in the air.</td>
</tr>
<tr>
<td>Humidity Ratio</td>
<td>In a mixture of water vapor and air, the weight of water vapor per pound of dry air. Also called specific humidity.</td>
</tr>
<tr>
<td>Hybrid Solar Energy System</td>
<td>A system that uses both active and passive methods in its operation. (See Active System and Passive System.)</td>
</tr>
<tr>
<td>Infiltration</td>
<td>The uncontrolled movement of outdoor air into the interior of a building through leaks, cracks, windows, and doors.</td>
</tr>
<tr>
<td>Infrared Radiation</td>
<td>Electromagnetic radiation from the sun that has wavelengths slightly longer than visible light.</td>
</tr>
<tr>
<td>Insolation</td>
<td>The total amount of solar radiation—direct, diffused, and reflected—striking a surface exposed to the sky.</td>
</tr>
<tr>
<td>Insulation</td>
<td>A material with high resistance (R-value) to heat flow.</td>
</tr>
<tr>
<td>Kilowatt (KW)</td>
<td>A measure of power equal to 1,000 watts, approximately 1-1/3 horsepower, usually applied to electricity.</td>
</tr>
<tr>
<td>Kilowatt Hour (kwh)</td>
<td>The amount of energy equivalent to one kilowatt of power being used for one hour; 3,413 Btus.</td>
</tr>
<tr>
<td>Latent Heat</td>
<td>A term used to express the energy involved in a change of state.</td>
</tr>
<tr>
<td>Liquid-Type Collector</td>
<td>A collector using a liquid as the heat transfer fluid. (See Collector.)</td>
</tr>
<tr>
<td>Natural Convection</td>
<td>See Gravity Convection.</td>
</tr>
<tr>
<td>Nocturnal Cooling</td>
<td>The cooling of a building or heat storage device by the radiation of heat to the night sky.</td>
</tr>
<tr>
<td>Passive System</td>
<td>An assembly of natural and architectural components which converts solar energy into usable or storable thermal energy (heat) without mechanical power.</td>
</tr>
<tr>
<td>Percent Possible Sunshine</td>
<td>The percentage of daytime hours during which there is enough direct solar radiation to cast a shadow. (See Direct Radiation.)</td>
</tr>
<tr>
<td>Photovoltaic Cells</td>
<td>Semiconductor (solid-state) devices that convert solar energy directly into electricity without any moving parts.</td>
</tr>
<tr>
<td>Psychrometer</td>
<td>An instrument for measuring solar radiation. (See solar Radiation.)</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Radiant Stove</td>
<td>A stove without the outer jacket which gives off its heat as infrared radiation.</td>
</tr>
<tr>
<td>Radiation</td>
<td>The flow of energy across open space via electromagnetic waves such as visible light.</td>
</tr>
<tr>
<td>R-Value</td>
<td>Thermal resistance to heat flow of material of specified thickness. The U-value factor for a building section equals one divided by the sum of resistances of materials used in the construction of a square foot of the building section.</td>
</tr>
<tr>
<td>Reflected Radiation</td>
<td>Sunlight that is reflected from surrounding trees, terrain or buildings.</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>A liquid or gas such as Freon that is used in cooling devices to absorb heat from surrounding air or liquids.</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>The ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature.</td>
</tr>
<tr>
<td>Reradiation</td>
<td>Radiation resulting from the emission of previously absorbed radiation.</td>
</tr>
<tr>
<td>Resistance (R-Value)</td>
<td>The tendency of a material to retard the flow of heat.</td>
</tr>
<tr>
<td>Retrofitting</td>
<td>The addition of a solar heating or cooling system to an existing building.</td>
</tr>
<tr>
<td>Risers</td>
<td>The flow channels or pipes that distribute the heat transfer liquid from the headers across the face of an absorber plate. (See Header.)</td>
</tr>
<tr>
<td>Saturated Air</td>
<td>A mixture of dry air and saturated water vapor, all at the same dry-bulb temperature.</td>
</tr>
<tr>
<td>Seasonal Efficiency</td>
<td>The ratio, over an entire heating season, of solar energy collected and used to the solar energy striking the collector.</td>
</tr>
<tr>
<td>SEER</td>
<td>A ratio of appliance efficiency calculated by dividing the cooling capacity in Btuh by the power input in watts at any given set of rating conditions, expressed in Btuh per watt. The higher the SEER the better the efficiency. An air-conditioning system with an SEER of 9 uses one third less energy than a system with an SEER of 6.</td>
</tr>
<tr>
<td>Selective Surface</td>
<td>A surface that absorbs radiation of one wavelength (for example, sunlight) but emits little radiation of another wavelength (for example, infrared); used as coating for absorber plates.</td>
</tr>
<tr>
<td>Sensible Heat</td>
<td>A term used in heating and cooling to indicate any portion of heat which changes only the temperature of the substance involved.</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
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<tr>
<td><strong>Shading Coefficient</strong></td>
<td>The ratio of the solar heat gain through a specific glazing system to the total solar heat gain through a single layer of clear double-strength glass.</td>
</tr>
<tr>
<td><strong>Solar Cells</strong></td>
<td>See Photovoltaic Cells.</td>
</tr>
<tr>
<td><strong>Solar Constant</strong></td>
<td>The average intensity of solar radiation reaching the earth outside the atmosphere; amounting to two langleyes or 1.94 gram-calories per square centimeter, equal to 442.4 Btuh/ft², or 1,395 watts/m².</td>
</tr>
<tr>
<td><strong>Solar House</strong></td>
<td>A dwelling that obtains a large part, but not necessarily all, of its heat from the sun.</td>
</tr>
<tr>
<td><strong>Solar Rights (Sun Rights) or Solar Access</strong></td>
<td>A legal issue concerning the right of access to sunlight.</td>
</tr>
<tr>
<td><strong>Solar Radiation (Solar Energy)</strong></td>
<td>Electromagnetic radiation emitted by the sun.</td>
</tr>
<tr>
<td><strong>Specific Heat</strong></td>
<td>The quantity of heat, in Btu, needed to raise the temperature of one pound of material 1°F.</td>
</tr>
<tr>
<td><strong>Stovepipe</strong></td>
<td>The portion of a stove's venting system between the stove and the chimney.</td>
</tr>
<tr>
<td><strong>Sun Path Diagram</strong></td>
<td>A circular projection of the sky vault, similar to a map, that can be used to determine solar positions and to calculate shading.</td>
</tr>
<tr>
<td><strong>TD (Temperature Difference)</strong></td>
<td>The difference between indoor and outdoor design temperature expressed in degrees Fahrenheit.</td>
</tr>
<tr>
<td><strong>Therm</strong></td>
<td>A quantity of heat. One therm is 100,000 Btus.</td>
</tr>
<tr>
<td><strong>Thermal Mass or Thermal Inertia</strong></td>
<td>The tendency of a building material (brick, concrete, or adobe) to remain at the same temperature or to fluctuate only very slowly. Thermal Mass also refers to the overall heat storage capacity of a building.</td>
</tr>
<tr>
<td><strong>Thermal Radiation</strong></td>
<td>Electromagnetic radiation emitted by a warm body. (See Infrared Radiation.)</td>
</tr>
<tr>
<td><strong>Thermosyphoning</strong></td>
<td>The process that makes water circulate automatically between a warm collector and a cooler storage tank above it. (See Gravity convection.)</td>
</tr>
<tr>
<td><strong>Thimble</strong></td>
<td>Device installed in combustible walls through which the stovepipe passes, intending to help protect the walls from igniting due to stovepipe heat.</td>
</tr>
<tr>
<td><strong>Tilt Angle</strong></td>
<td>The angle that a flat collector surface forms with the horizontal plane. (See Collector Tilt.)</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>-------------------------------</td>
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<tr>
<td>Trickle-Type Collector</td>
<td>A collector in which the heat transfer liquid flows slowly past the absorber and is heated. (See Collector.)</td>
</tr>
<tr>
<td>Tube-in-Plate Absorber</td>
<td>A metal absorber plate in which the heat transfer fluid flows through passages formed in the plate itself.</td>
</tr>
<tr>
<td>Tube-Type Collector</td>
<td>A collector in which the heat transfer liquid flows through metal tubes that are fastened to the absorber plate by solder, clamps, or other means. (See Collector.)</td>
</tr>
<tr>
<td>U-value</td>
<td>Thermal transmittance. Heat loss through one square foot of building section with a temperature difference of 1°F.</td>
</tr>
<tr>
<td>Ultraviolet Radiation</td>
<td>Electromagnetic radiation with wavelengths slightly shorter than visible light.</td>
</tr>
<tr>
<td>Unglazed Collector</td>
<td>A collector without a cover plate.</td>
</tr>
<tr>
<td>Vapor Barrier</td>
<td>A material which resists the flow of water vapor.</td>
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</tbody>
</table>