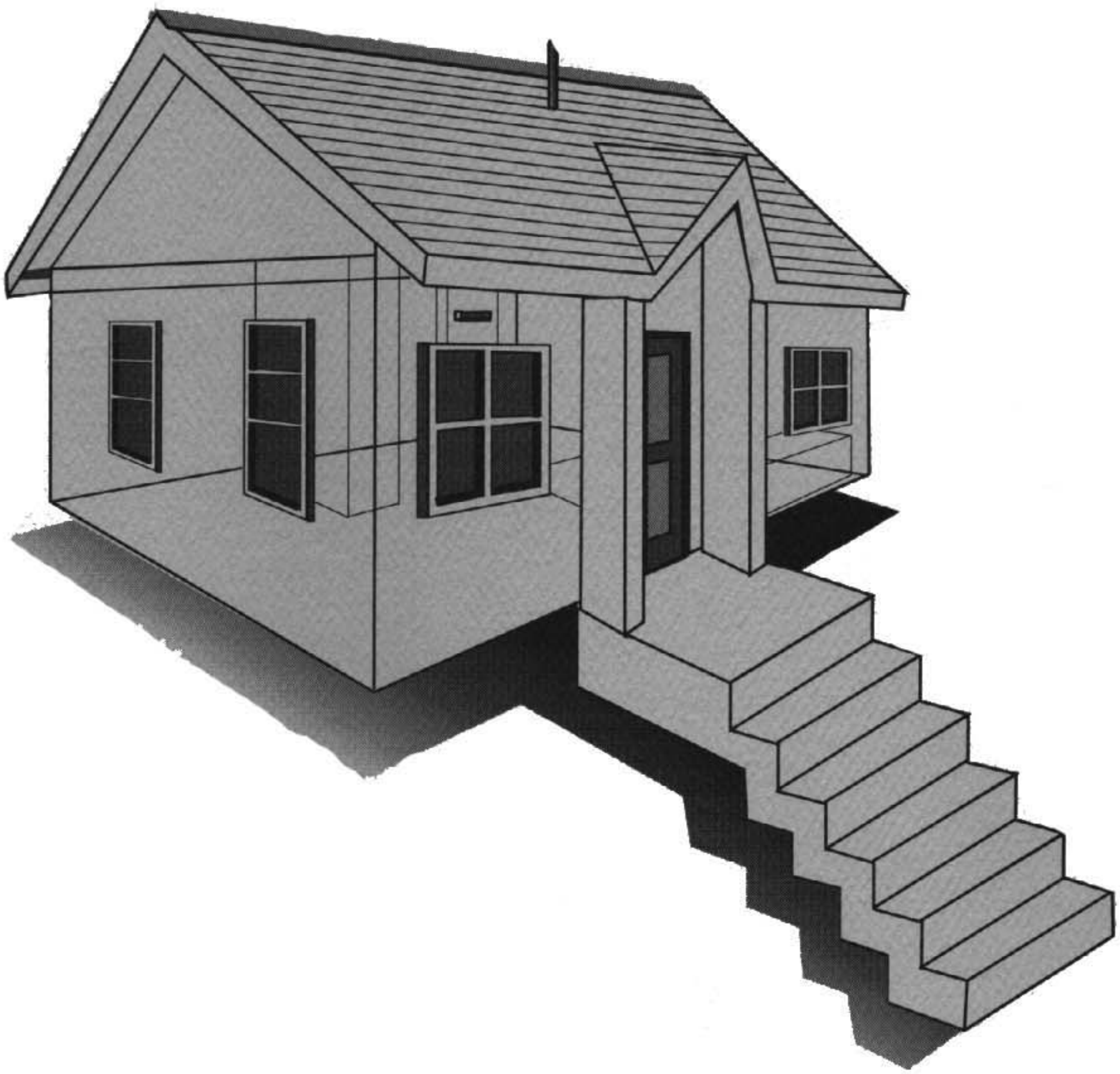
Sensible Living for the 90's

A Portfolio of Case Studies from RCDP Cycle I



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Sensible Living for the 90's:
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August 1990

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Ken Eklund
Idaho Department of Water Resources

Prepared for Bonnevile Power Administration, Office of Energy Resources, Division of Resource Management, Residential Programs Branch, Residential Technology Section.

SENSIBLE LIVING FOR THE 90s

A Portfolio of Case Studies: Energy-efficient Homes in the Pacific Northwest

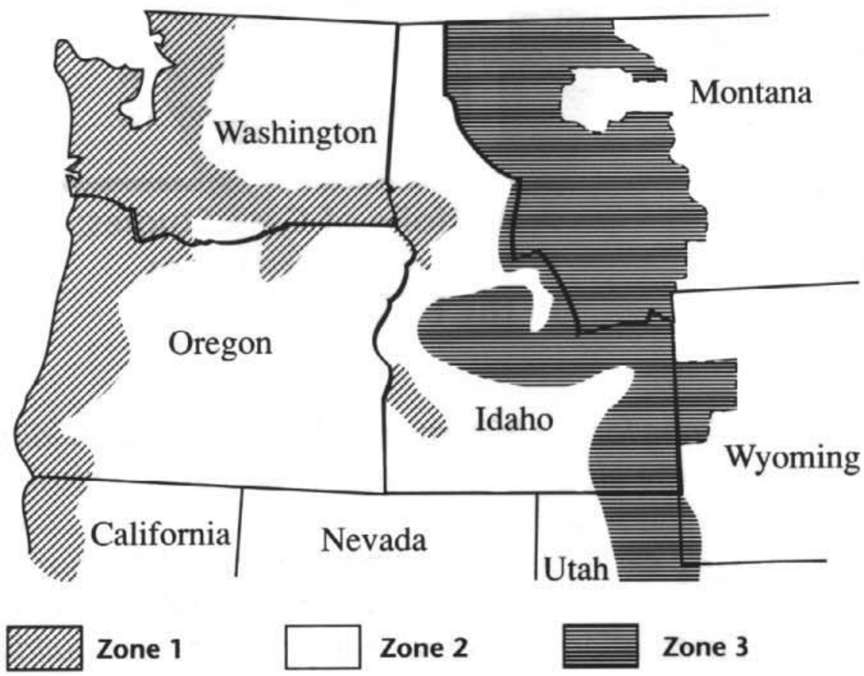
"Sensible Living for the 90s" means designing and building homes that are energy efficient, comfortable and economical.

Following are examples of sensible homes. All the homes shown are electrically heated. They were constructed to meet or exceed Model Conservation Standards—energy efficient building standards developed by the Northwest Power Planning Council for new electrically heated commercial and residential buildings. These standards don't specify how a home must be built, but instead set levels for the efficient use of electricity in the home. The unique designs of these homes prove that energy-efficient homes can look good, too.

A profile is given for each home. Comments from energy specialists and, in most cases, the owners are included. Information is provided on the features of the homes and how well they work. A glossary of technical terms is listed in the back of the book.

Climate Zones

BPA Service Area



The Bonneville Power Administration (BPA) was created in 1937 to market and transmit power from Bonneville Dam. Today, BPA sells power from 30 Federal dams. BPA supplies about half the electricity used in the Pacific Northwest.

An Act of Congress created the Northwest Power Planning Council in 1980. Since its inception, the Council has attempted to meet two challenges: 1) to plan the effective and efficient use of all electricity generated by publicly owned dams in the Pacific Northwest; and 2) to assure wise power plant investments. The MCS are a result of that planning. These standards are now used by the Council as guidelines in the construction of homes and commercial buildings to ensure efficient use of electricity.

BPA carries out the Power Council's plan and works to implement the MCS in the Northwest Region. When the MCS were adopted by the Council as guidelines, the region was unfamiliar with the idea of energy-efficient construction. Gradually, this is changing as more and more people realize the benefits of energy-efficient housing.

Such change is instigated by BPA's field demonstration programs—its Residential Standards Demonstration Program (RSDP) and the Residential Construction Demonstration Project (RCDP). Super Good Cents and the Northwest Energy Code programs then serve to popularize these proven technologies.

Test results consistently show that homes built to the MCS use about 50 percent less energy for space heating than homes built by "conventional practice." These energy savings are cost-effective and important to homeowners, as well as to all who live in the Northwest. The MCS are speedily being adopted across the Northwest. Consequently, during the first decade after regionwide acceptance we will eliminate the need for building between one and three coal-fired plants through conservation alone.

Efficient use of electricity is a key factor in the region's power supply, one which we all play a part in. For example, if people buy energy-efficient homes, they are using power wisely and responsibly. If not, they are hastening the day when building expensive new power plants is necessary. Such plants use costly fuels and affect our environment. The costs incurred are passed on to consumers through rate increases.

The MCS require homes to meet a certain level of thermal performance depending on the climate zone in which they are located. These standards provide several construction menus for each climate zone, giving builders various courses by which to achieve these levels of performance.

Table 1 delineates climate zones according to average heating degree days. Climate zones may vary widely within a geographic area because of altitude differences and localized climate conditions.

TABLE 1. Climate Zones by Annual Heating Degree Days*

ZONE 1	LESS THAN 6,000
ZONE 2	6,000 TO 8,000
ZONE 3	GREATER THAN 8,000

***Note: Areas near the transition point are sometimes administratively determined to be in the next highest climate zone, because of the cost effectiveness of the higher MCS in that area. For example, Missoula, Montana at 7,839 degree days is classified as Zone 3.**

For standards required at the time these case study homes were built, see Table 2. A list of component values (i.e., R-values, U-values and area percentages for various measures) for conventional practice in each climate zone is also included in Table 2 for comparison purposes.

House designs may also comply with the MCS if calculations show a heat loss rate or predicted performance that is equal to or better than a comparable design. This "performance standard" allows a wide range of design flexibility. The calculations may be done by hand or with a time-saving computer program.

Annual Heating Costs

at 5¢ per KWH for a 2,000 sq. ft. House

RCDP Average
$310

Conventional Practice
Average (RSDP Control Home)
$770

TABLE 2. Component Values during the Study Period

COMPONENT	MCS			CONVENTIONAL PRACTICE		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Ceiling, attic &	38	38	38	30	38	38
vaulted	38	38	38	30	38	38
Wall (above grade)	19adv	25	30	11	11	19
Wall (below grade)						
if interior insulation	11	19	19	11	11	11
if exterior insulation	10	12	15	N/A	N/A	N/A
Floor over crawlspace						
or unheated basement	30	30	30	19perim	11	11
Slab on grade perimeter	15	15	15	N/A	N/A	N/A
Doors (maximum U-value)	0.2	0.2	0.2	0.46	0.46	0.46
Windows						
maximum tested U-value	0.4	0.4	0.4	0.67	0.67	0.56
glazing area limit (percent of floor area)	12%	12%	12%	typically 10 to 12%		
Air leakage control	all penetrations sealed and continuous air/vapor barrier			some penetrations sealed		
Heat recovery ventilation systems	Yes	Yes	Yes	No	No	No

NOTES:

* These are MCS specifications for 1984. Current specifications are different.
* The specifications given for conventional practice are for a hypothetical 2,000 square foot house with zone electric heat which would use at least 7.74 KWH/(FT2/YR) at representative locations in each of the 3 climate zones. Energy calculations were done with SUNDAY 2.0. computer energy use simulation program developed by Ecotope, Inc.
* Conventional practice in many parts of the region has improved significantly since1984 when the RSDP control sample was monitored, and in 1986 the State of Washington adopted a statewide energy code which mandated an upgrade for all residential and commercial buildings.

Residential Standards Demonstration Program (RSDP)

As an effort to demonstrate and refine the MCS, BPA initiated the Residential Standards Demonstration Program (RSDP) in 1984. Four hundred twenty-three MCS homes were constructed within the region's three climate zones.

Monitoring established the average energy use for each of these homes. In addition to this, each participating builder tracked the costs of additional and upgraded products necessary for the construction of the MCS home(s). A comparable number of homes built to "conventional practice" were monitored in the same way.

Blower Door test

Residential Construction Demonstration Program (RCDP)

The Residential Construction Demonstration Project (RCDP) was started by BPA in 1986. RCDP is implemented by the state energy offices in Idaho, Montana, Oregon and Washington and funded by BPA. The purpose of the RCDP is to serve as the MCS laboratory. The program tests innovative materials, systems and construction techniques useful in building energy-efficient housing and monitors their effectiveness. The goal is to produce cost-effective reliable and marketable housing in the Pacific Northwest. RCDP is an ongoing project. These case studies are taken from the first cycle of RCDP research.

Many of the lessons learned through RCDP are incorporated into the technical specifications for the Super Good Cents Program and the Northwest Energy Code. The Super Good Cents Program is offered by many electric utilities in the region to promote building to MCS .

The Northwest Energy Code is a MCS building code for electrically heated buildings, now adopted by many jurisdictions in Washington and Idaho. BPA funds both of these programs to implement the MCS.

Stack Effect Measurement

Early in 1986, builders from around the region were selected to participate in the first cycle of the RCDP. To be selected, a builder was required to verify that he/she was a licensed contractor engaged in the home building industry and had completed training in MCS construction techniques.

These builders agreed to build a home (or homes) to the MCS before the next heating season. They also agreed to gather cost information and provide that information to the state energy offices. Cash incentives were given to the builders to offset the additional costs involved with building MCS homes and collecting information.

The MCS homes are designed to reduce air leakage. Windows and doors are rated for low air infiltration; seams and penetration points are caulked.

Many homes in the project were designed to exceed the MCS. All of the homes in this portfolio have one or more of the following innovations:

- high R-value walls
- Advanced Drywall Approach for air sealing
- Heat recovery ventilation options, such as: air-to-air heat exchangers with duct heat - ers, air-to-air heat exchangers integrated with furnaces, and exhaust-air heat pumps that capture waste heat for the domestic hot water.

Northwest Residential Infiltration Survey (NORIS)

In 1987, BPA began to investigate ventilation rates in homes not built to MCS. This study, called the Northwest Residential Infiltration Survey (NORIS), provided measurements of the average air leakage characteristics for new, single-family homes in the BPA service area. The NORIS results are used in these case studies for comparing the RCDP leakage area to conventional practice.

Data

There were 165 homes built in the RCDP, Cycle I. Data have been collected on 158 of these homes. (Eight of the homeowners did not sign monitoring agreements.)

The homes all had separate power consumption meters specific to space heating and water heating. Sensors were used to record the inside and outside temperatures. The efficiencies of the heat-recovery ventilation systems were also monitored.

Occupants recorded meter readings for space, water and total electricity usage on postcards and sent them to the Washington State Energy Office each week. Occupants received payments to keep these records and to refrain from burning wood, since many of the homes had fireplaces or wood stoves.

A fan-pressurization test, called a "blower-door" test, was performed to determine the amount of air leakage present and to find those leaks. "Tracer gas" tests were used to determine long-term ventilation rates. These tests also check the effectiveness of the mechanical ventilation system.

The following pages discuss the results of the data analysis. That analysis is compared with the performance of homes constructed to conventional practice. The results of this analysis are focused under the following headings:

- Space Heating
- Average Energy Use
- Air Leakage Area
- Operation of Heat Recovery Ventilators

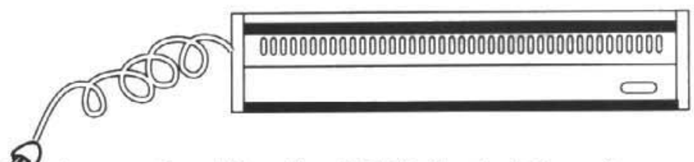
Fact sheets follow the overview of the data analysis. these case studies portray thirteen Northwest homes included in RCDP Cycle I. The fact sheets contain graphs and charts showing the results for each home.

Space Heating

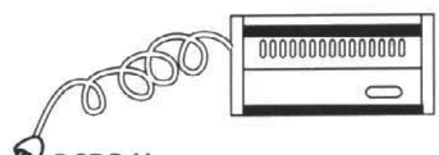
The total space heat used within one year was measured in kilowatt hours. In comparing houses of different sizes, the total number of kilowatt hours was divided by square feet of heated floor space. This computation gave the number of kilowatt hours per square foot for the test year (KWH/(ft^2 x yr).

The average of all RSDP conventional practice houses equals 7.74 KWH/(ft^2 x yr)*; the average of all RCDP houses equals 3.09 KWH/(ft^2 x yr).

Average space heat/ (Square foot of floor space x yr.)



Conventional Practice (RSDP Control Home)
7.74 KWH/(ft^2x yr)



RCDP Home
3.09 KWH/(ft^2x yr)

Following is a breakdown of the average energy consumption for the RCDP houses in KWH/(ft^2 x yr.):

Idaho	3.04
Montana	3.22
Oregon	2.30
Washington	3.21
Wyoming	3.94

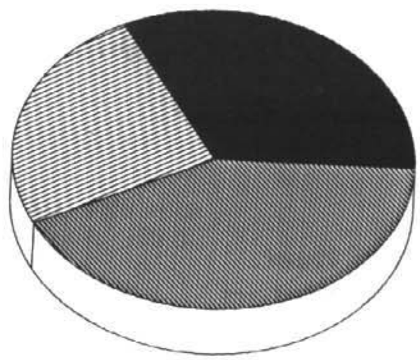
***In those jurisdictions which have adopted energy codes, the standard construction practice should be more energy efficient than the RSDP average conventional practice. For example, the MCS space heat use is about 30% lower than the 1986 Washington State Energy Code and 50% below the RSDP conventional practice average.**

Average Energy End Use

Energy use in a home is called "end use." Because an energy-efficient home uses less space heat, this use drops in relationship to energy used for heating water and operating appliances. The pie charts compare the RCDP average end use percentages to conventional practice. The size difference between the charts is proportional t the difference in total energy use.

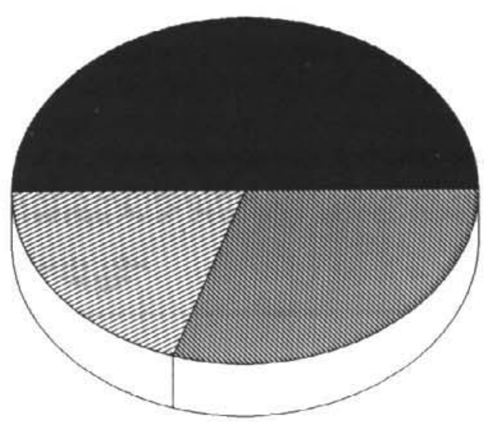
RCDP average end uses

- 33 percent space heating (6,210 KWH)
- 25 percent water heating (4,600 KWH)
- 42 percent appliances/lighting (7,700 KWH)



Conventional practice average end uses

- 50 percent space heating (12,420 KWH - RSDP control average)
- 20 percent water heating (4,600 KWH - estimated)
- 30 percent appliances/lighting (7,700 KWH - estimated)



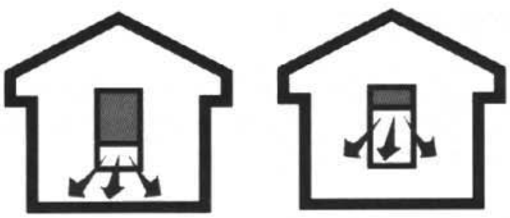
Air-leakage Area

Blower-door tests measure the effective air-leakage area in each house. The illustration below visually compares the leakage areas of RCDP and conventional practice homes as measured by the Northwest Regional Infiltration Survey.

The RCDP average leakage area is nearly 50 percent less than the leakage area found in a house built by conventional practice. Comparisons between the air-tightness of houses are made by dividing the total leakage area (measured in square inches) by the number of square feet of heated floor space in the house. This figure is then multiplied by 100. Another comparison is between air changes per hour (ACH). Both leakage area and ACH are discussed in the Glossary.

Average air leakage area

(in^2/floor area) x 100



RCDP
2.85 in^2
.153 ACH

Conventional Practice
6.78 in^2
.45 ACH

Operation of Heat Recovery Ventilators

All the homes presented in these case studies have heat recovery ventilation systems. This is an MCS option, as the MCS ventilation requirement can, now, be met through non-heat recovery systems. Heat recovery ventilators offer positive ventilation in addition to recovering some of the heat from the outgoing exhaust air.

Measurements were taken of the heat reclaimed from exhausted air and returned to the house in fresh air. (See "air-to-air heat exchanger" in the glossary.) Measurements were also taken of the average number of hours the system was on each day. The averages for all the RCDP houses were as follows:

average hours of operation each day = 8.9
average heat recovery effectiveness = 49 percent

Fact Sheets

The following fact sheets illustrate the construction and performance of RCDP homes and, at the ssame time indicate varied aspects:

- the component R-values and construction descriptions for walls, ceilings and floors;
- the window and door types with U-values;
- the climate zone and heating degree days for each house location;
- effective solar glazing as a percent of total glass area.

Graphs are provided to show the energy use, house tightness and ventilation system efficiency of each home on the facing page. Sample Graphs 1 through 5, and their explanations, tell how the graphs accompanying the homes in the Portfolio are to be interpreted.

Graph 1. is a line graph showing space heat. The pointer ("house value") locates the consumption of the home in kilowatt hours per square foot for one year (KWH/FT2 x YR). The left end of the line is the RCDP homes' "lowest use," and the right end is the RSDP conventional-practice average use. The RCDP average use is shown between lowest and highest use. (See "KWH" and "KWH/(FT2 xYR)" in the glossary.)

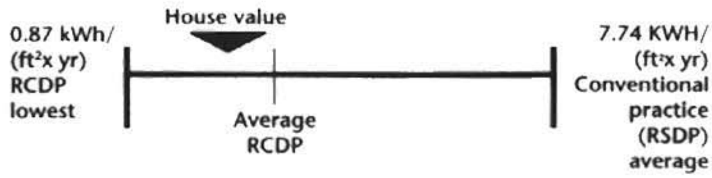
Graph 2. is a pie chart showing the average breakdown of thetotal energy and corresponding number of average kilowatt hours used by all RCDP homes. Individual profiles of each house contain a chart like this showing the energy end.

Graph 3. is a line graph showing house tightness in square inches of leakage area per 100 square feet of heated floor space. The pointer locates the leakage area of this home. The left end of the line indicates the leakage area of the tightest house in RCDP. The right end shows the conventional practice average. The RCDP average is indicated between the two. (See "leakage area" and "air changes per hour" in the glossary.)

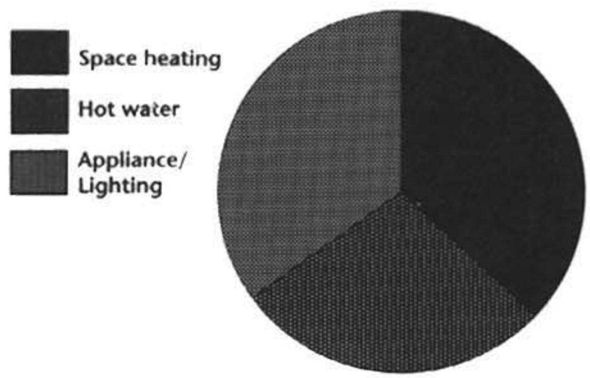
Graph 4. is a line graph showing the average hours per day the ventilation system operated. The pointer locates the average hours for the home. The left end of the line is the RCDP lowest average time, while the right end is the RCDP highest average time. The RCDP average is also shown. Conventional practice is not shown, because these houses do not typically have heat recovery ventilation systems. (See "air-to-air heat exchanger" and "heat recovery ventilation" in the glossary.)

Graph 5. is a line graph showing the average percent of heat recovered from vented air by the heat recovery ventilation system. The pointer locates the percentage recovery for the home. The left end of the line shows the lowest percentage recovery of the RCDP homes, while the right end shows the highest percent recovery. The RCDP average is indicated at a point between the ends. Conventional practice homes do not have heat recovery ventilation and are not shown.

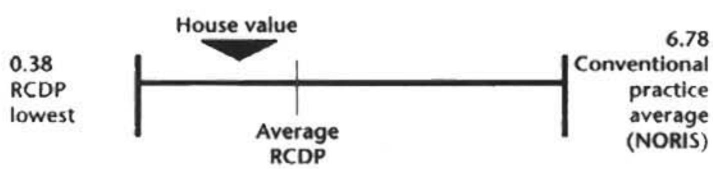
Graph 1. Space heat energy performance



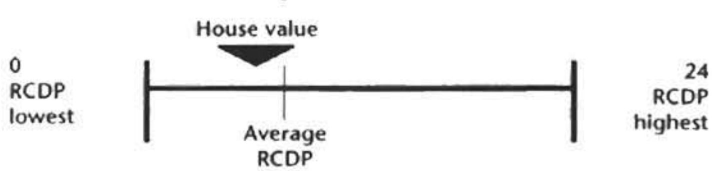
Graph 2. Breakdown of energy use



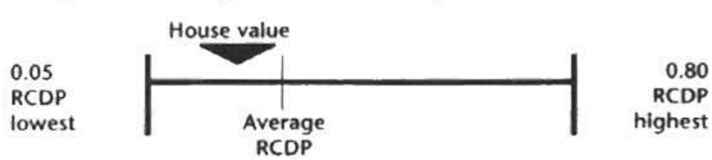
Graph 3. Air leakage area
(in²/total ft²) x 100



Graph 4. Average hours per day of AAHX operation



Graph 5. Average heat recovery effectiveness

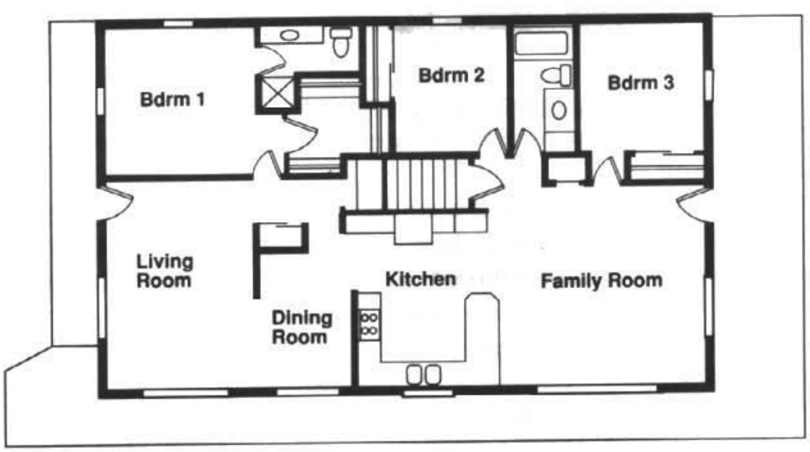


This house is in a country setting outside of Bonners Ferry. It has clear southern exposure, and a simple, spacious feeling. Of the Idaho RCDP houses presented in this portfolio, this house used the lowest amount of heat per square foot. Yet, the house stands in the coldest Idaho climate and was kept at the second highest average temperature setting during the demonstration. This is not a surprise, because the house has the highest R-value ceilings and walls and the lowest air leakage rate among the Idaho, RCDP homes.

The owner, who designed the initial floor plans, said, "If there is any sun at all, the house is 70° F. in the winter without any added heat. On the coldest winter days you can walk barefoot comfortably."

The house is heated throughout the year entirely by internal heat gains (people, lights and appliances) and solar gains, except during four months: December, January, February and March. The cost of electric heat during this short heating season is about $30 per month, computed at 4 1/2 cents per kilowatt hour. Fabric curtains and good insulation keep the house cool in the summer.

OWNER: Anonymous
DESIGNER/BUILDER:
Kurt Wedel, B.F. Builders
Bonners Ferry, Idaho
LOCATION: Bonners Ferry
CLIMATE: 7,072 degree days
Climate Zone 2
BUILDING DATA:
Ceilings: R-60 advanced frame 2x4 truss
Walls: R-33, 2x6 frame with R-19 fiberglass batts plus 2" polyisocyanurate foam board sheathing
Floors: R-30 over unheated basement
Windows: U-0.38 1/2" double, Low-E, wood frame
Doors: Insulated metal with thermal break
Ventilation:
Air-to-air heat exchanger
Heat system: Electric baseboards
Air barrier: Advanced Drywall Approach
SQUARE FOOTAGE: 1,664
EFFECTIVE SOLAR/ TOTAL GLAZING: 77 percent
SPECIAL FEATURES:
Advanced Drywall Approach
Air-to-air heat exchanger
High-R walls and ceilings
Insulated fabric window shades



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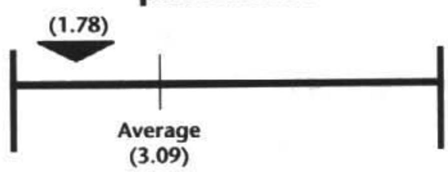
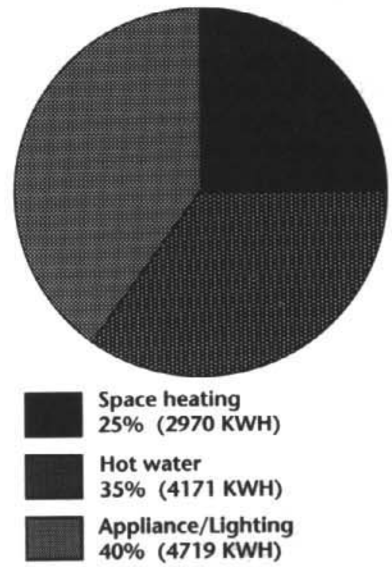
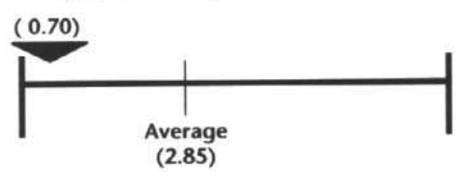


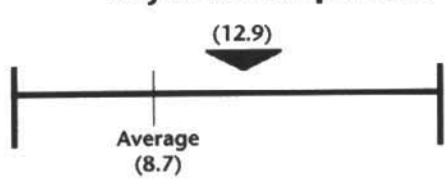
Graph 2. Breakdown of energy use



Graph 3. Air leakage area (in²/total ft²)



Graph 4. Average hours per day of AAHX operation



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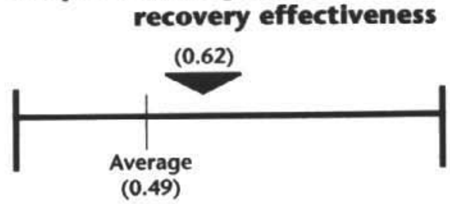


This home sits on a hill near Coeur d'Alene with a rural valley spread below it to the south. Its north side nestles into a sheltering stand of evergreen trees. The house has three stories, including a well-insulated basement, and is heated with electric baseboards at a cost of just under 11 cents per square foot per year. (These costs are figured at 1989 rates.)

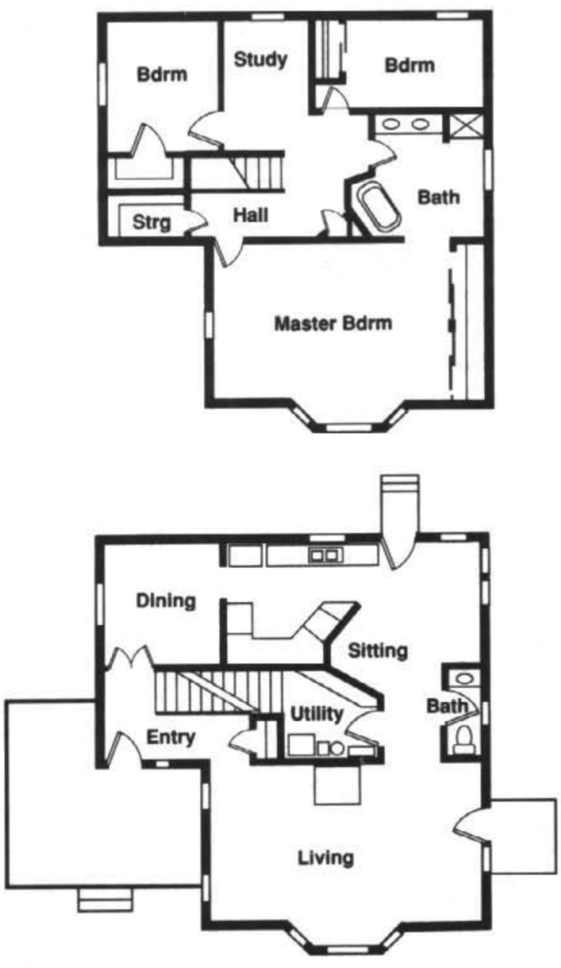
Mrs. Gaffney said, "We wanted the looks of an older home, with modern energy efficiency. The home is comfortable in the winter and stays cool in the summer-- not at all like the older home we used to live in."

Gary Gaffney finds no drafts in the home, saying, "Temperatures remain even throughout the rooms." He attributes this to the good air seal. The Gaffneys find the air-to-air heat exchanger "works ok" They keep the system on low; it is quiet and no drafts from the blowers are felt. The house has no moisture problems.

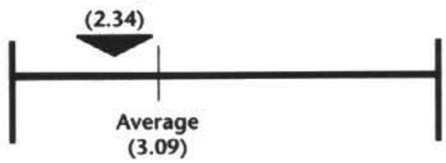
Prior to the winter of 1988-89, the Gaffneys used baseboard heating and had a $42 heat bill in the coldest month. In the fall of 1988 they installed a small wood stove and heated with about 1 1/2 cords of wood, using no electricity.

The designer, who also framed the house, said the exterior wall studs were notched at the bottom, rather than drilled for electrical wiring. This process alleviates compressing the insulation. Another special feature is found in the exterior of the basement wall, which is insulated with fiberglass board. This material drains water away from the basement wall when installed properly.

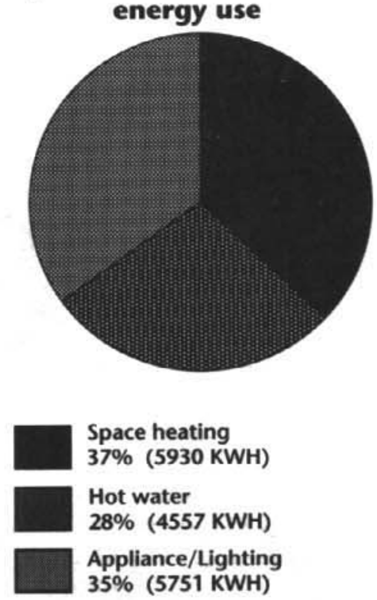
OWNER:
Gary and Meredith Gaffney
DESIGNER:
Tom Stone, Coeur d'Alene, Idaho
BUILDER:
Art Elliot, Shelter Associates
Coeur d'Alene, Idaho
LOCATION:
Coeur d'Alene
CLIMATE: 6,461 degree days
Climate Zone 2
BUILDING DATA:
Ceilings: R-49 advance-frame truss
Walls: Below grade: R-19 exterior fiberglass
Above grade: R-27, advance frame 2x6 + 1" polyisocyanurate rigid foam sheathing
Floors: R-30 over crawlspace
Basement slab floor perimeter at garage R-10, 2" extruded polystyrene foam
Windows: U-0.33 1/2" double, Low-E, wood frame
Doors: Insulated metal with thermal break
Ventilation: Air-to-air heat exchanger
Heat system: Electric baseboards
Air barrier: Advanced Drywall Approach
SQUARE FOOTAGE: 2,530
EFFECTIVE SOLAR/ TOTAL GLAZING: 62 percent
SPECIAL FEATURES:
Advanced Drywall Approach
Air-to-air heat exchanger



Graph 1. Space heat energy performance

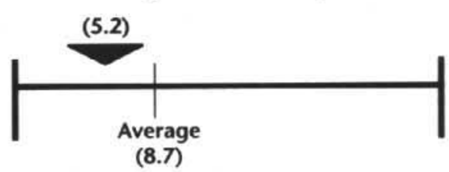


Graph 2. Breakdown of energy use

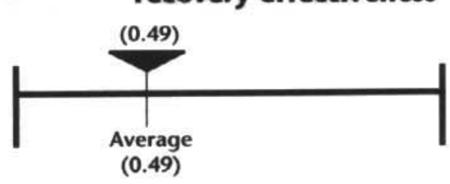


Graph 3. Air leakage area (in^2/total ft^2) x 100

Graph 4. Average hours per day of AAHX operation



Graph 5. Average heat recovery effectiveness



This is the first home Benner, an architect, has designed for his own family. His objective was to create a functional design, one that would withstand the assault of two children and yet offer amenities appropriate to country elegance.

The quarry tile floors in the family and living rooms help store passive solar heat and provide a pleasing effect with low maintenance.

The house is in a semi-rural setting and designed to evoke the image of a farmhouse. The Benner family completes the picture with their cats, dogs, horses, pole fence and barn. A mud room/vestibule between the garage and house is used for removal and storage of boots and coats, but also offers protection from cold, gusty winds blowing directly into the house.

Benner said they are very happy in their new home, and that he knows the energy features are worth any additional expense. The energy savings are not the only benefit considered here, as the added comfort of the home is considerable -- especially when it is compared with the 70-year-old house they lived in prior to building this home.

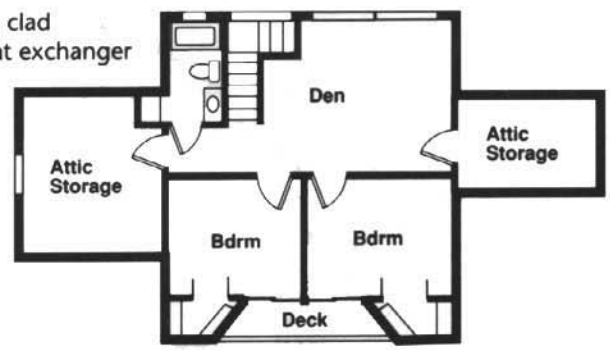
OWNER: Eileen and Steve Benner
DESIGNER:
Steven D. Benner, Architect
BUILDER:
Gordon Jensen Caldwell, Idaho
LOCATION: Boise
CLIMATE: 5,802 degree days
Climate Zone 1
BUILDING DATA:
Ceilings: R-49 with raised heel trusses
Walls: R-30, 2x6 advance frame, R-19 fiberglass batt plus 1.5" polyisocyanurate sheathing
Floors: Slab on grade: R-10 continuous rigid foam
Floor over crawlspace: R-30
Windows: U-0.44, 1/2" double, Low-E, TIM frame
Doors: Insulated fiberglass clad
Ventilation: Air-to-air heat exchanger with duct heater

Heat system: Fan-forced wall heaters
Air barrier: Advanced Drywall Approach

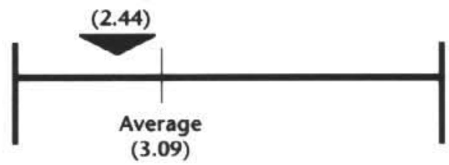
SQUARE FOOTAGE:

Upper	950
Main level	1,400
Total	2,350

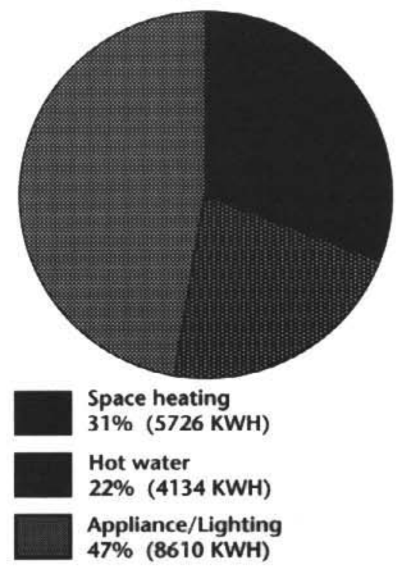
EFFECTIVE SOLAR/TOTAL GLAZING:
72 percent
SPECIAL FEATURES:
Passive solar orientation and glass
Thermal mass tile floor
Fireplace with outside combustion air
Advanced Drywall Approach
Air-to-air heat exchanger



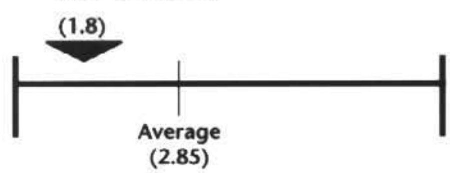
Graph 1. Space heat energy performance



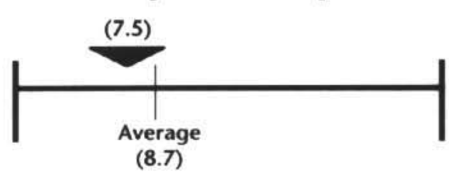
Graph 2. Breakdown of energy use



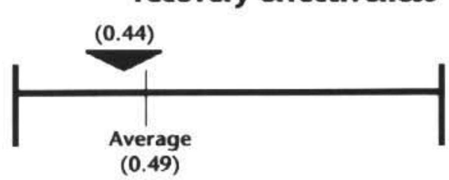
Graph 3. Air leakage area (in^2/total ft^2)



Graph 4. Average hours per day of AAHX operation



Graph 5. Average heat recovery effectiveness



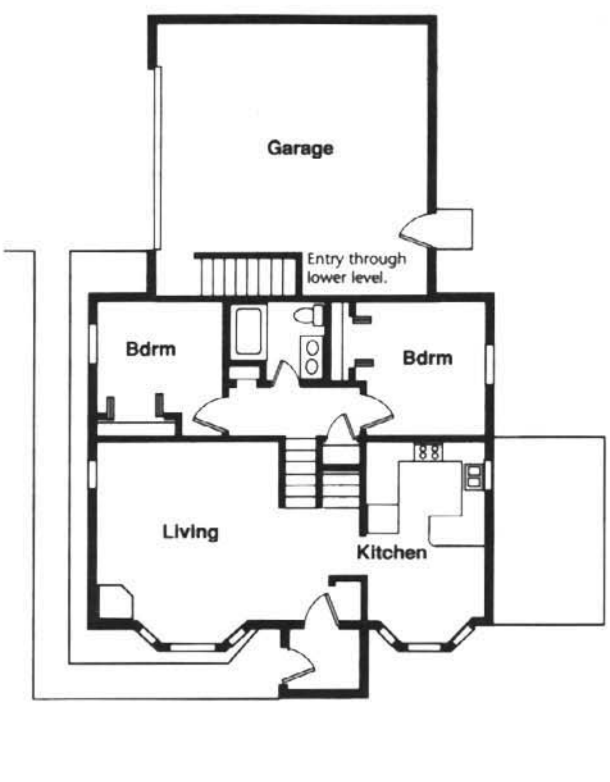
This house, located in an established residential neighborhood, is a key example that energy efficiency does not determine the design or positioning of a house. This house blends in beautifully with the older homes in the area, while making the most of a corner lot with west and north exposures. A large part of the glass faces west, yet is shaded against summer overheating by new and existing deciduous trees.

The owner states that the house was built on a modest budget saying, "Given this constraint, it's incredible." They praise the quality of the house and its snug construction.

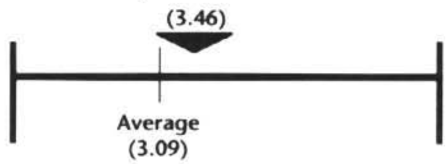
There are, however, some things the Dloughys would do differently a second time around. Experience shows that warm air collects in the vaulted ceilings. Placement of a ceiling fan would mix the air to a more comfortable temperature. The-air-to-air heat exchanger does perform a mixing function, yet the relatively cool air from the supply vents is delivered in locations that cause the occupants to feel chilly.

A duct heater, in line with the supply air from the heat exchanger, could warm this air up to a more comfortable temperature. This innovation was not used for this house, but may serve in other homes to provide a more comfortable environment.

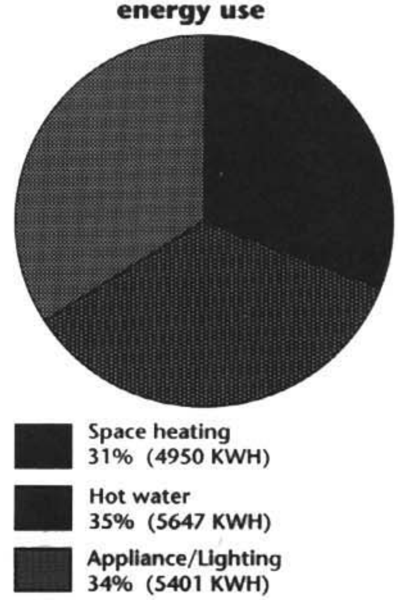
OWNER:
Darrel and Debbie Dloughy
DESIGNER: Tom Stone
Coeur D'Alene, Idaho
BUILDER:
Kim Riley Construction
Hayden, Idaho
LOCATION: Coeur d'Alene
CLIMATE: 6,461 degree days
Climate Zone 2
BUILDING DATA:
Ceilings: R-38 advance-frame truss
Walls: Below grade: R-34, R-19 fiberglass batt plus 3" extruded polystyrene
Above grade: R-29, 2x6 BIB + 1" polyisocyanurate sheathing
Floors: Slab edge: R-5 1" extruded polystyrene
Windows: U-0.38, 1/2" double, Low-E, wood frame U-0.39, 1/2" triple, TIM frame
Doors: Insulated metal with thermal break
Ventilation: Air-to-air heat exchanger
Heat system: Electric baseboards
Air barrier: Advanced Drywall Approach
SQUARE FOOTAGE: 1,430
EFFECTIVE SOLAR/TOTAL GLAZING: 64 percent
SPECIAL FEATURES:
Advanced Drywall Approach
Air-to-air heat exchanger



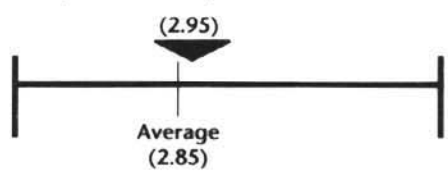
Graph 1. Space heat energy performance



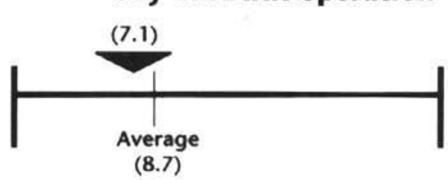
Graph 2. Breakdown of energy use



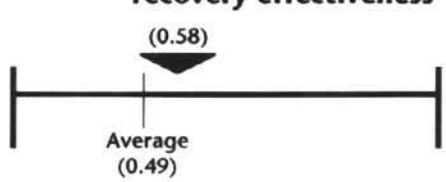
Graph 3. Air leakage area (in²/total ft²)



Graph 4. Average hours per day of AAHX operation



Graph 5. Average heat recovery effectiveness



This house has nearly 3,000 square feet and uses as much heat as would be produced by four hand-held hair dryers operating an average of ten minutes per hour during a long heating season. The Nelsons use electric baseboards to supply heat not contributed by the sun, appliances and other internal gains. They find that the whole house is much cleaner than their previous home, which had a wood stove.

Kay Nelson said, "I only need to do a little dusting about every three months."[1] David Nelson added, "We're glad to be off wood."[2]

This house can be called super-insulated, having the highest insulation values of all the houses among the case studies. It was one of the best performers in RCDP, with a heating energy consumption of only 1.49 kilowatt hours per square foot during the study year; that comes to slightly less than one-half of the RCDP average. The home is superbly designed for a cold climate.

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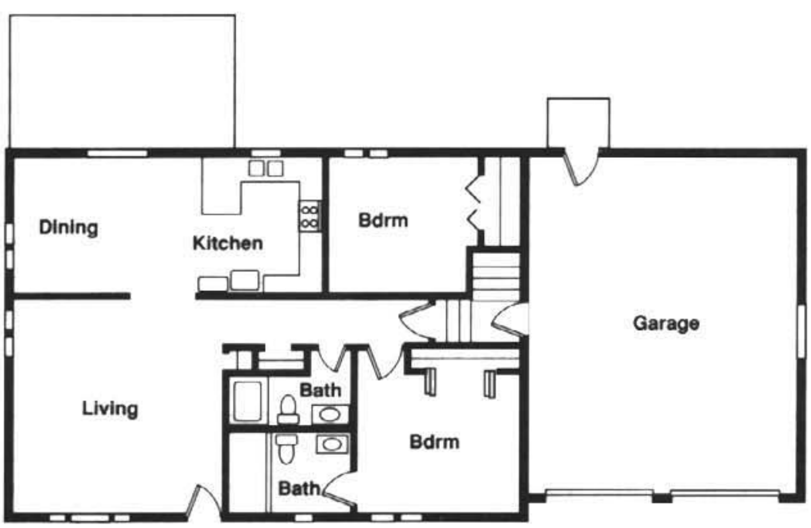
[1]Montana Department of Natural Resources & Conservation, Warm Places, (Helena, Montana, 1988, pp. 199.

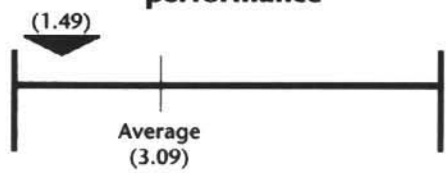
[2]Warm Places, pp. 199.

OWNER: David and Kay Nelson
DESIGNER: Owners
BUILDER: Roger Fangsrud
Missoula, Montana
LOCATION: Turah
CLIMATE: 7,839 degree days
Climate Zone 3

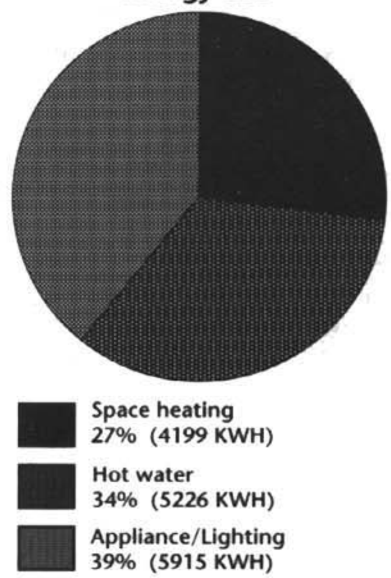
BUILDING DATA:
Ceilings: R-60 advanced frame 2x4 truss, 21" blown in fiberglass
Walls:
Above grade: R-45 double wall; BIB in 2x6 advance frame outer wall, plus fiberglass batts between wall frames and in 2x4 inner wall
Below grade: R-16, 1" polyisocyanurate foam plus fiberglass batts in 2x4 frame wall
Floors: Concrete slab: R-15 perimeter (2' width of 3" Extruded polystyrene) plus R-7.5 under the rest of floor (1.5" foam)
Windows: U-0.38, 1/2" double, Low-E, wood frame; U-0.31, 1/2" triple, wood frame
Doors: Insulated metal with thermal break
Ventilation: Air-to-air heat exchanger
Heat system: Electric baseboards
Air barrier: Advanced Drywall Approach
SQUARE FOOTAGE: 2,816
EFFECTIVE SOLAR/TOTAL GLAZING: 65%
SPECIAL FEATURES: High R-value wall and ceilings
Advanced Drywall Approach
Air-to-air heat exchanger



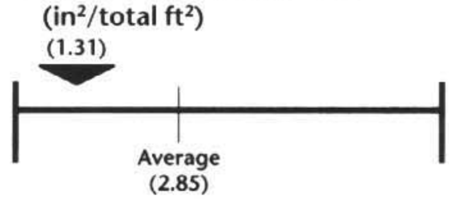
Graph 1. Space heat energy performance



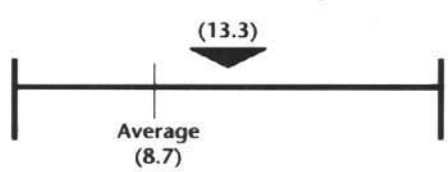
Graph 2. Breakdown of energy use



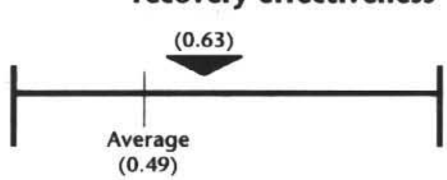
Graph 3. Air leakage area (in²/total ft²)



Graph 4. Average hours per day of AAHX operation



Graph 5. Average heat recovery effectiveness



This house is located a half-mile from the Gallatin River where osprey and deer are seen frequently. It is a raised, ranch-style house with a clear, southern exposure.

South-facing glass heats the main floor during most days. The electrical space heat was only 2.49 kilowatt hours per square foot for the monitoring year, or about 12 cents per square foot at 1989 rates. During this time period the owners kept the upstairs warmer than usual to accommodate a new baby.

Alvin Vander Vos said, "Any house of comparable size in this area costs at least one-third more to heat than this one."

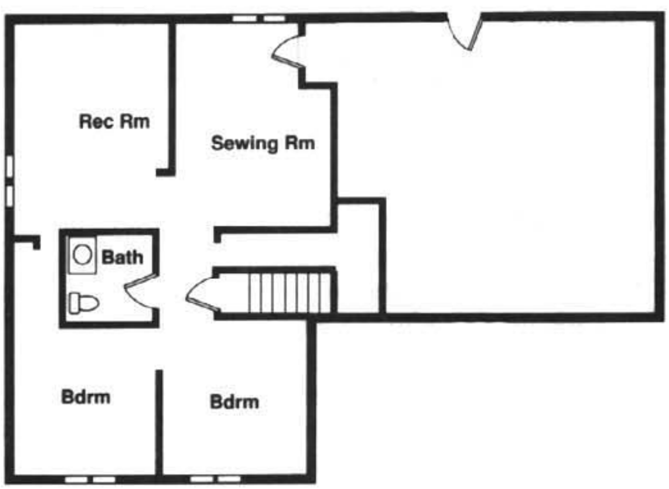
The Vander Voses did not plan to have an energy-efficient home, but their builder, Ron Schmit, was already participating in the RCDP Program. He offered to build the MCS home for the same price as the standard 2x6 frame model they thought they wanted.

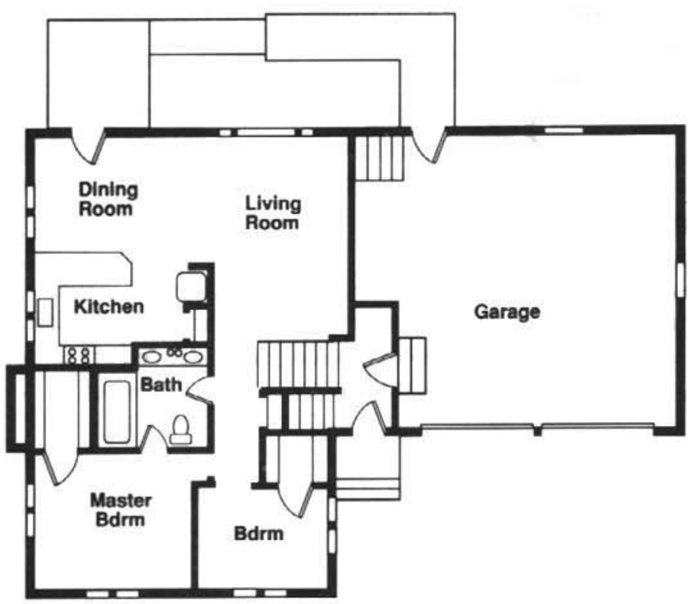
This is a very tight house with .64 square inches of leakage area per 100 square feet of floor space. (The RCDP average was 2.85.) Ventilation is performed by an exhaust-air heat pump, which extracts heat from the outgoing air and transfers it to the domestic hot water tank. The installed system cost $2,900. A water softener was installed to protect this investment from mineral deposits.

The system operated an average of 20.3 hours per day with performance that the Vander Voses see as quite satisfactory. The system is operated manually, as the dehumidistat control "never worked." They had to turn the system off during "a 40-below-zero cold spell" because of an ice build-up on the heat exchanger. Although the exhaust air heat pump can be switched to operate as an air conditioner, the Vander Voses found it did not cool effectively during the summer months.

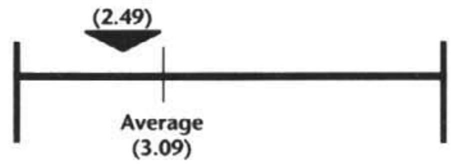
Unlike many Montana home owners, the Vander Voses do not have a wood stove. Alvin Vander Vos comments that wood is "a lot of trouble," and believes it would take many years to recover the cost of a stove, due to their present low heating bills.

OWNER:
Alvin and Rita Vander Vos
DESIGNER: Floor plan: owners
Energy design: Ron Schmit
BUILDER:
Ron Schmit, Schmit Construction
Belgrade, Montana
LOCATION: Belgrade
CLIMATE: 8,686 degree days
Climate Zone 3
BUILDING DATA:
Ceilings: R-38 standard truss
Walls:
Below grade: R-19 interior
Above grade: double 2x4 stud wall, R-31 blown-in batt
Windows: U-0.39, 1/4" triple, wood frame
Doors: Insulated metal with thermal break
Ventilation: Exhaust-air heat pump
Heat system: Electric baseboards
Air barrier: Advanced Drywall Approach
SQUARE FOOTAGE: 2,283
EFFECTIVE SOLAR/TOTAL GLAZING: 69%
SPECIAL FEATURES:
Advanced Drywall Approach
Exhaust-air heat pump
High R-value walls

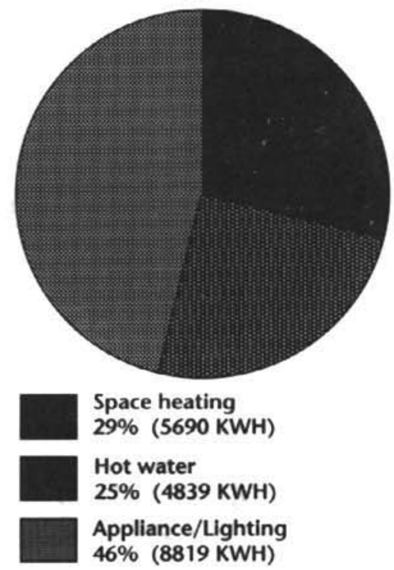




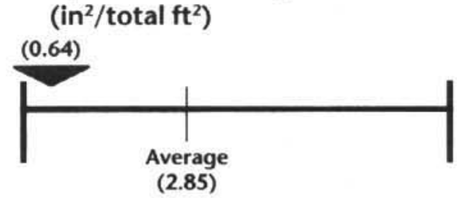
Graph 1. Space heat energy performance



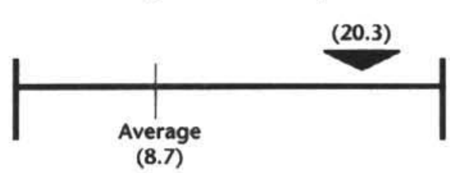
Graph 2. Breakdown of energy use



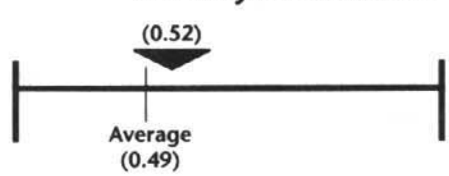
Graph 3. Air leakage area (in^2/total ft^2)



Graph 4. Average hours per day of AAHX operation



Graph 5. Average heat recovery effectiveness



Energy efficiency and a restricted budget are not mutually exclusive. This owner needed an affordable house with an economical heating system.

In Warm Places,[1] Krause is quoted, saying, "Single income and low-income families shouldn't give up on owning a home. They can afford to build and maintain their homes through low-income funding and by designing them to meet Montana's Super Good Cents program."

This home has 862 square feet and is the smallest in the RCDP group. Small houses tend to use more heat than larger homes built to the same standards, because they have larger surface-to-volume ratios. During the 12 months the house was monitored, it used 4,666 kilowatt hours of electricity for heating, which computes to about $200 at 4 1/2 cents per kilowatt hour. Even though this comes to a relatively high energy consumption—5.41 kilowatt hours per square foot of floor space—the cost for heating is still extremely low.

This house is tight with an air leakage area of only 1.56 square inches per 100 square feet. The air-to-air heat exchanger ventilation system was operated almost all the time, during the monitoring.

Krause said, "I used to smoke a lot and I found out how tight this house was when I shut off the ventilator one night. The next morning the air in the living room was full of my stale cigarette smoke and it looked like a fire was smoldering in there."

Half the windows face south with clear solar access. The owner reports significant solar heat contribution saying, "When the sun is out, even though it's only 20° outside, I don't have to turn on my heat until seven or eight at night."

"Why anyone, low income or not, would want to build anything but an energy-efficient house is beyond me," she said. "The comfort and money saved are unbelievable."

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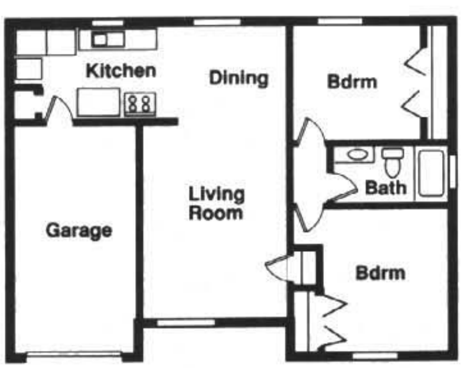
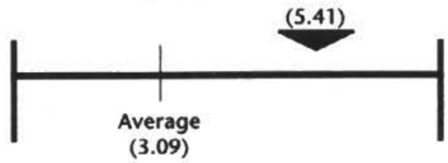
[1] Montana Department of Natural Resources & Conservation, Warm Places, (Helena, Montana, 1988, pp. 115.

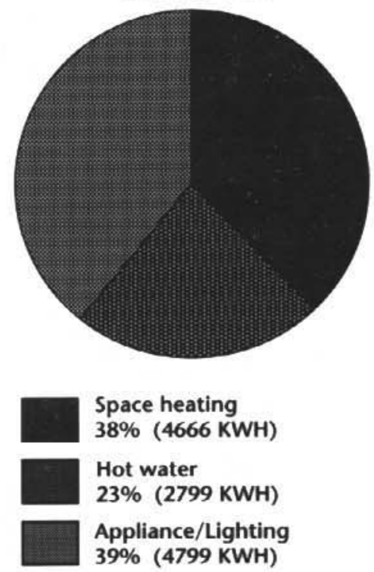
OWNER: Cynthia Krause
DESIGNER: David Lilyquist
Hamilton, Montana
BUILDER: Campbell Massey
Corvallis, Montana
LOCATION: Hamilton
CLIMATE: 7,253 degree days
Climate Zone 3
BUILDING DATA:
Ceilings: R-60 advance frame 2x4 truss
Walls: R-22 advance frame 2x6 with BIB
Floors: R-30 over crawl space
Windows: U-0.40, 1/2" double, thermally-improved metal with storm window
Doors: Insulated metal with thermal break
Ventilation:
Air-to-air heat exchanger
Heat system:
Electric baseboards
Air barrier:
Advanced Drywall Approach
SQUARE FOOTAGE: 862
TOTAL GLAZING: 66%
SPECIAL FEATURES:
Advanced Drywall Approach
Air-to-air heat exchanger



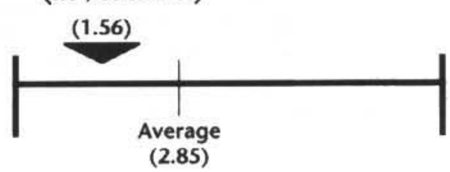
Graph 1. Space heat energy performance



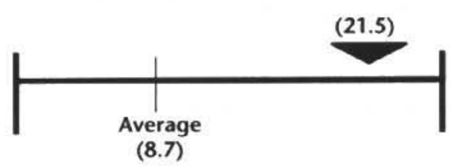
Graph 2. Breakdown of energy use



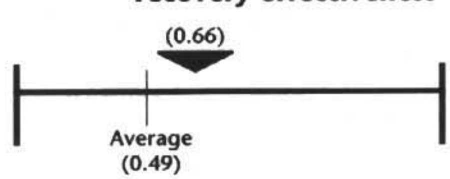
Graph 3. Air leakage area (in²/total ft²)



Graph 4. Average hours per day of AAHX operation



Graph 5. Average heat recovery effectiveness



[redacted]

This attractive split-level home, located in a hillside subdivision, demonstrates that energy efficiency is not a visible feature, but can be part of any style home.

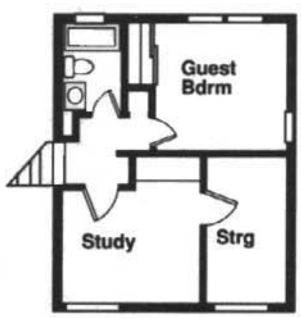
The owner said, "I've been here three-and-a-half years and wouldn't change a thing."

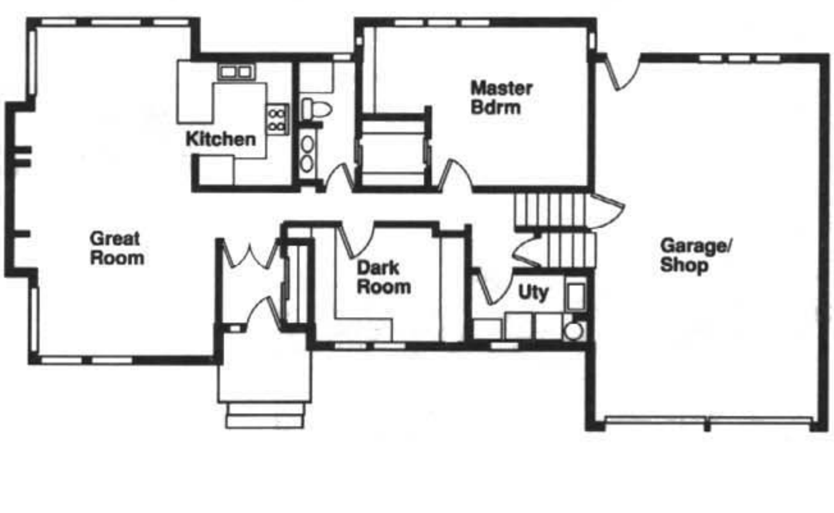
The thermostat remains at 68°F year-around. The heat pump heats the house with some assistance from the sun. The owner notes that in the winter the family opens the draperies in the morning and finds the heat pump does not come on for several hours.

The air-to-air heat-exchanger ventilation system is quiet, and operates only occasionally. This system is controlled by a dehumidistat, which turns it on only when the humidity level rises due to long showers or cooking. The system comes on for a short time and exhausts the moisture. The owners are finding no moisture or stale air problems.

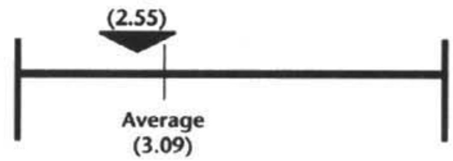
Because of the efficiency of the envelope and the heat pump, the space heat performance of this home is low—yet, not as low as the .87 Kilowatt hours per square foot reported in the monitoring results. The process of monitoring buildings is complex; sometimes mistakes are made. In this case, the space heat meter apparently measured only the fan and compressor energy for the heat pump—not the backup electric resistance element.

DESIGNER/BUILDER:
Larry Medinger
Medinger Construction Company
Ashland, Oregon
LOCATION: Ashland
CLIMATE: 5,143 degree days
Climate Zone 1
BUILDING DATA:
Ceilings: R-40 advanced-frame, raised-heel truss; R-40 vaulted ceiling
Walls: R-25 advanced frame, 2x6 plus 1 inch poly isocyanurate foam board
Floors: R-30 over crawlspace
Windows: U-0.49, 1/2" double, thermally improved with storm
Doors: Two insulated metal with thermal break , one wood solid core
Ventilation:
Air-to-air heat exchanger
Heat system:
Electric air-source heat pump
Air barrier:
Advanced Drywall Approach
SQUARE FOOTAGE: 1,888
EFFECTIVE SOLAR/ TOTAL GLAZING: 75%
SPECIAL FEATURES:
Advanced Drywall Approach
High R walls
Air-to-air heat exchanger

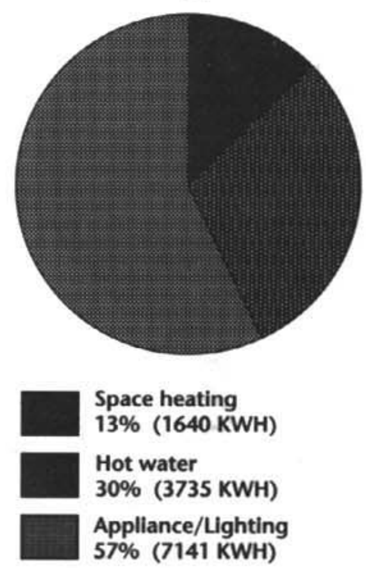




Graph 1. Space heat energy performance

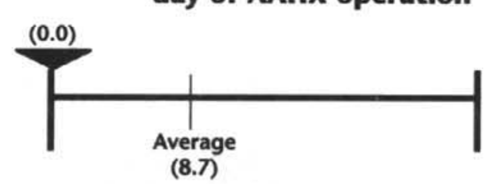


Graph 2. Breakdown of energy use

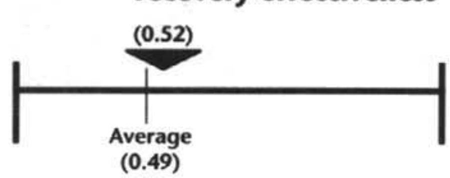


Graph 3. Air leakage area (in^2/total ft^2)

Graph 4. Average hours per day of AAHX operation

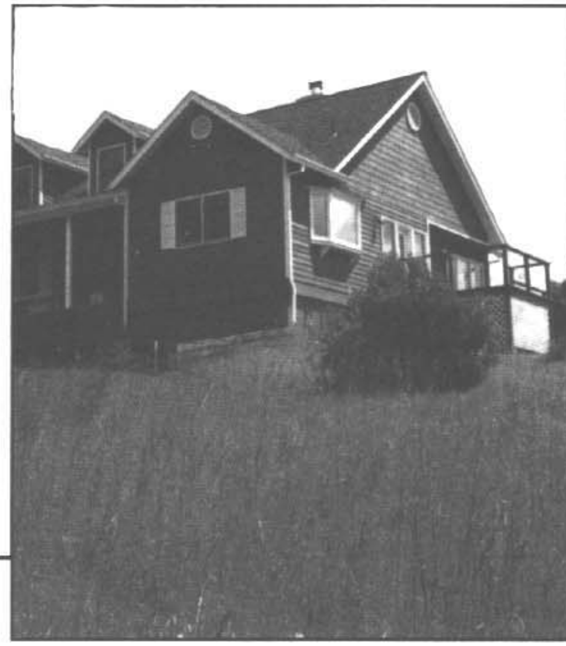


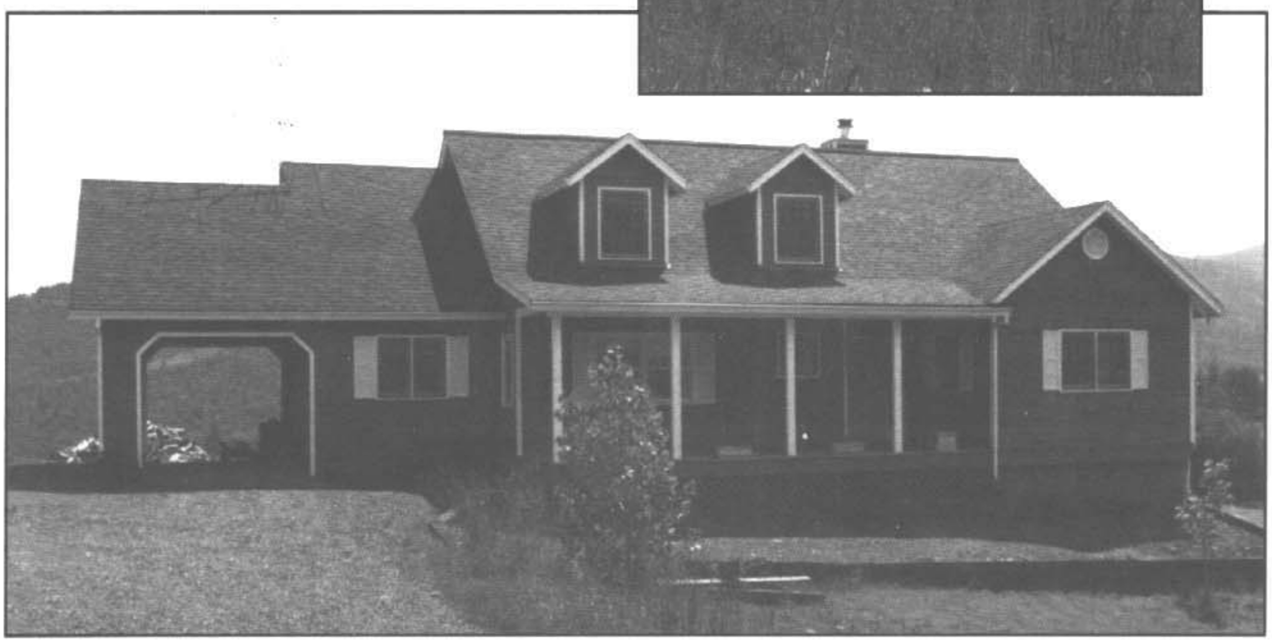
Graph 5. Average heat recovery effectiveness

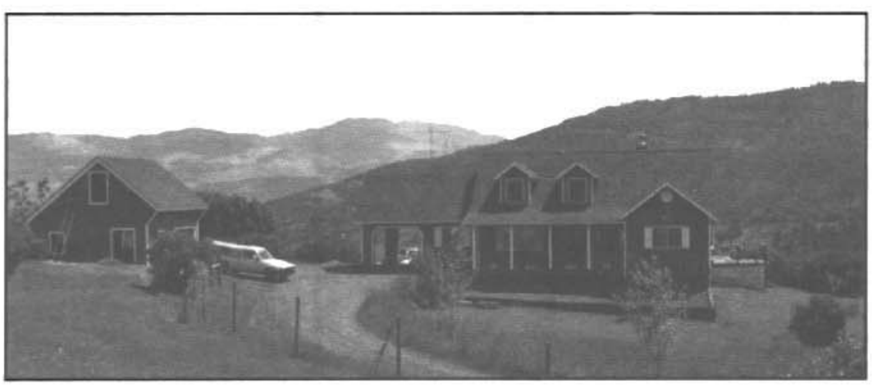


This home, located in a rural setting, has the benefit of excellent solar exposure. Most of its windows face either south or east and contribute as heat sources.

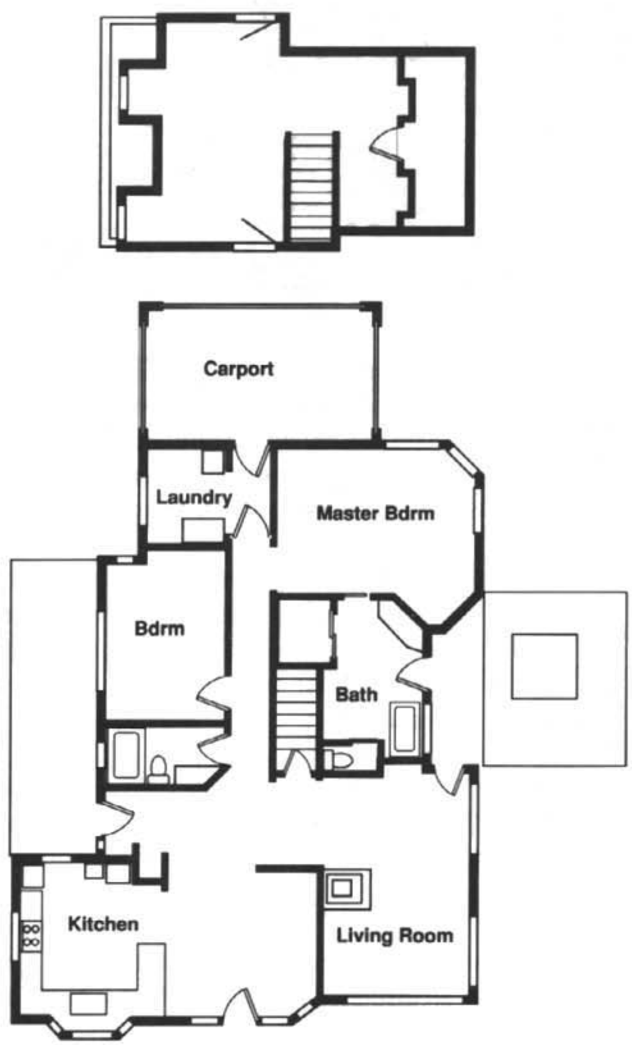
Comparing photographs of this home with those of other RCDP homes by Mr. Medinger show us that energy-efficient construction practices do not restrict the architectural style.



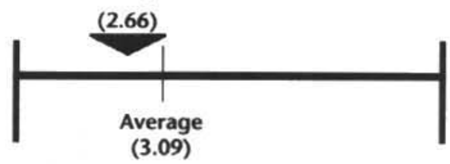




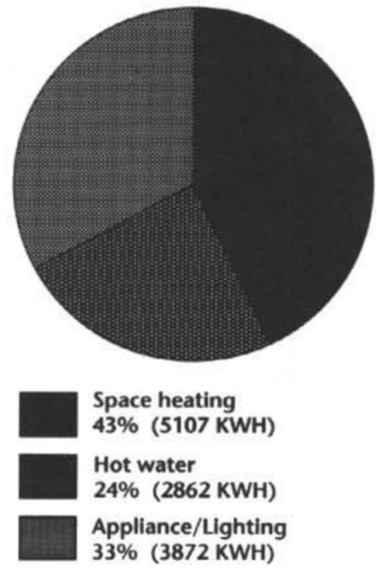
OWNER: Anonymous
DESIGNER/BUILDER:
Larry Medinger
Medinger Construction Company
Ashland, Oregon
LOCATION: Talent, Oregon
CLIMATE: 5,143 degree days
Climate Zone 1
BUILDING DATA:
Ceilings: R-49 advance frame truss
Walls: R-19 advanced frame
Floors: R-30 floor over crawl space
Windows: U.38 1/2" double, Low-E, wood frame
Doors: Insulated metal with thermal break
Ventilation:
Air-to-air heat exchanger
Heat system: Electric furnace integrated with AAHX
Air barrier:
Advanced Drywall Approach
SQUARE FOOTAGE: 1,923
EFFECTIVE SOLAR/ TOTAL GLAZING: 66%
SPECIAL FEATURES:
Advanced Drywall Approach
Air-to-air heat exchanger



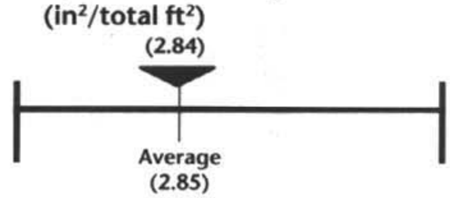
Graph 1. Space heat energy performance



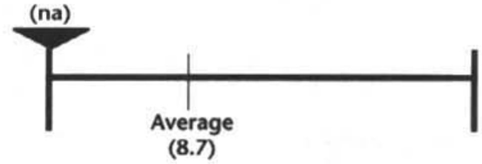
Graph 2. Breakdown of energy use



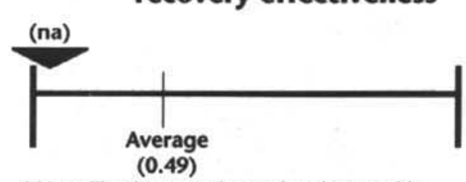
Graph 3. Air leakage area (in^2/total ft^2)



Graph 4. Average hours per day of AAHX operation*



Graph 5. Average heat recovery effectiveness*



* Note: The date recorder produced no useable information about the heat recovery system.

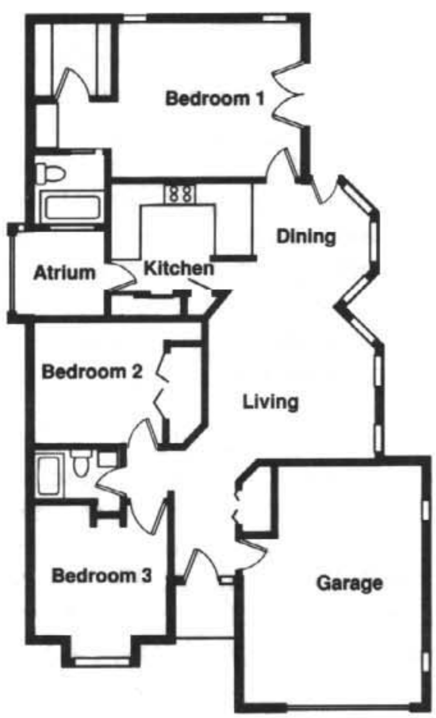
This home is located in an energy-efficient subdivision. All the homes in this development meet or exceed the Model Conservation Standards. The developer's goal is to provide a reasonably priced, energy-efficient alternative to homes built to conventional practice.

During the winter the home is now heated with a woodstove; rarely does the owner turn on the electric baseboard heaters. The window area is not large in relation to floor area. Still, most of the window area serves as effective solar glazing.

"The sun helps during winter months," the owner said. "It comes right into the dining room and is very comfortable—even when it is freezing outside!"

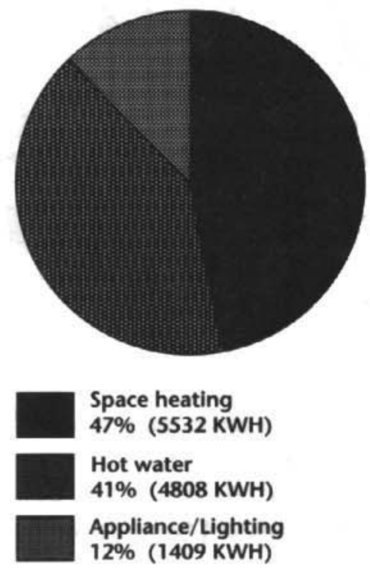
The air-to-air heat exchanger ventilation system provides fresh air during the winter. This system is located in an insulated enclosure which is easily accessible from the garage, and the owner says it is "very quiet." Natural ventilation and energy-efficient insulation keep the house cool in the warmer months.

OWNER: Anonymous
DESIGNER/BUILDER:
Larry Medinger
Medinger Construction Company
Ashland, Oregon
LOCATION: Ashland
CLIMATE: 5,143+ degree days
Climate Zone 1
BUILDING DATA:
Ceilings: R-38 advance-frame raised-heel truss
Walls: R-19 advance-frame 2x6
Floors: R-30 over crawl space
Windows: U-0.49, 1/2" double, wood frame
Doors: Insulated metal with thermal break
Ventilation:
Air-to-air heat exchanger
Heat system:
Electric baseboards
Air barrier:
Advanced Drywall Approach
SQUARE FOOTAGE: 1,280
EFFECTIVE SOLAR/ TOTAL GLAZING: 82%
SPECIAL FEATURES:
Advanced Drywall Approach
Air-to-air heat exchanger

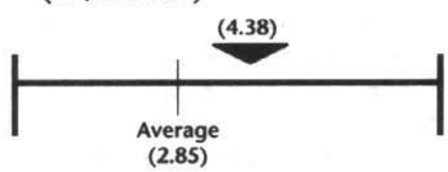


Graph 1. Space heat energy performance

Graph 2. Breakdown of energy use

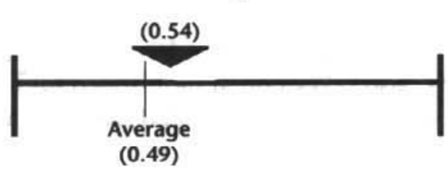


Graph 3. Air leakage area (in²/total ft²)



Graph 4. Average hours per day of AAHX operation

Graph 5. Average heat recovery effectiveness



The Langes designed this home before they heard of the RCDP Program. After learning of the program, however, they changed their original design to accommodate the energy-efficient features, which they now cherish.

"We designed it," Jack Lange said, "and we will probably live here forever. We like the Low-E glass that we used for windows—no moisture problems. We have two kids, yet our monthly electric bill in the winter is $100. Only about one-quarter of that is for space heat."

The Langes believe that fresh air and ventilation control are the main benefits of the air-to-air heat exchanger. The house air is never stale, and there are no humidity problems, even though the house is as tight as the RCDP average.

The system supplies fresh air at five locations and takes exhaust air from the kitchen, two bathrooms, the laundry room and crawl space. The system is controlled by bathroom fan switches, a manual switch and a dehumidistat.

When a bathroom fan comes on, the heat exchanger also comes on at high speed for a short period of time. The system is operated manually at low speed about 50 percent of the time during the winter. The dehumidistat turns the system on high speed only when the humidity in the house rises above the desired level.

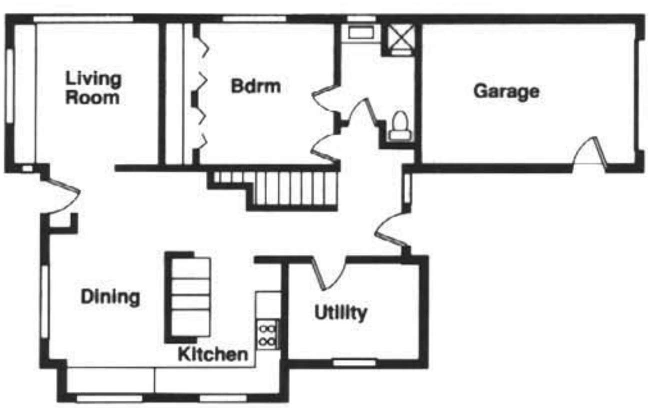
This heat recovery system had a 2 kilowatt duct heater to boost the temperature of the incoming fresh air. The Langes found, however, that the duct heater was too small to have much impact on the whole house. So they reinstalled the duct heater to serve the living room and dining area where it does a good job of heating this smaller space.

The Langes note the house sometimes gets too warm in late summer because of solar gains. The house has a large percentage of glass facing south and the two-foot overhang is not enough to shade a full height window during August and September, though it works perfectly on June 21, the longest day in the year. As the days get shorter, the angle of the sun is lower, allowing for deeper penetration into the home.

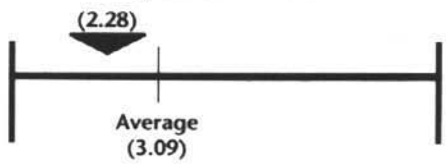
Overheating demonstrates the need for house designs to balance solar gains with thermal mass, and to provide window shading at the right time of year. One of the most effective remedies is to prevent the sunlight from entering the house with shade plants or curtains.

OWNER: Jack and Mary Lange
DESIGNER: Owners
BUILDER: Rene Fabricant
Sequim, Washington
LOCATION: Sequim
CLIMATE: 5,580 degree days Climate Zone 1

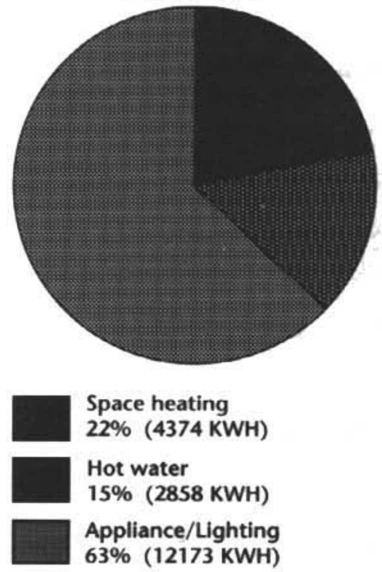
BUILDING DATA:
Ceilings: Frame construction: R-38 vaulted
Walls: South side: R-23, 2x6 advance with R-19 fiberglass batt + 1" exterior extruded polystyrene foam board
Other sides: R-24, 2x6, R-19 + 1.5 interior polystyrene beadboard
Floors: R-11 over crawlspace plus R-19 perimeter
Windows: U-0.38, 1/2" double , Low-E, wood frame; U-0.49, 1/2" double , wood frame
Doors: Insulated metal with thermal break
Ventilation:
Air-to-air heat exchanger
Heat system: Electric baseboards and duct heater
Air barrier: 6 mil polyethylene U.V. inhibited plastic with caulked seams
SQUARE FOOTAGE: 1,921
EFFECTIVE SOLAR/
TOTAL GLAZING: 77%
SPECIAL FEATURES:
Air-to-air heat exchanger with duct heater



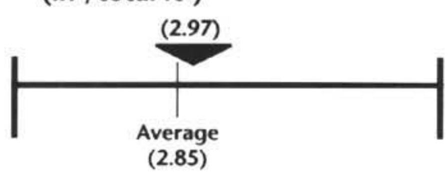
Graph 1. Space heat energy performance



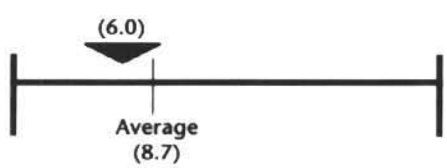
Graph 2. Breakdown of energy use



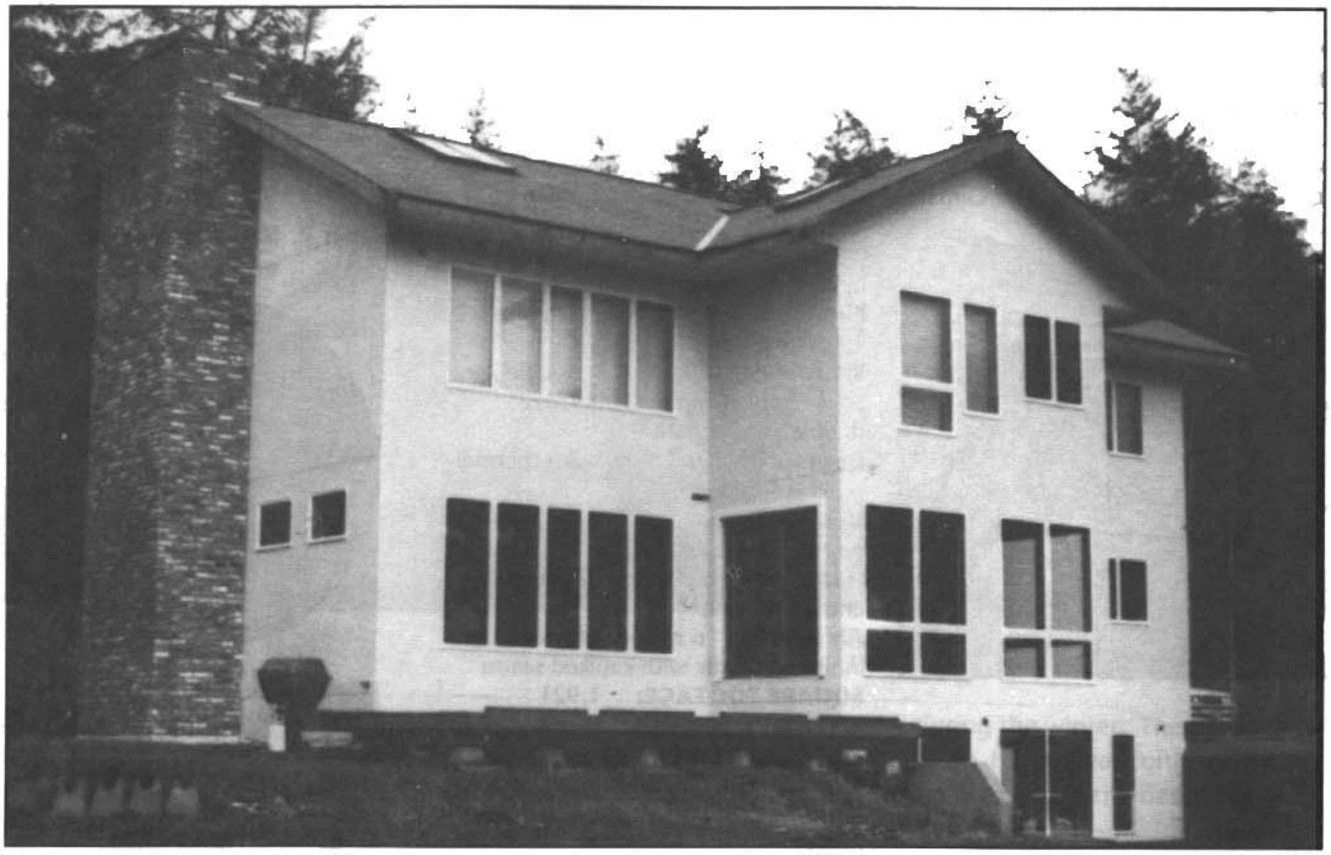
Graph 3. Air leakage area (in²/total ft²)



Graph 4. Average hours per day of AAHX operation



Graph 5. Average heat recovery effectiveness



Mike and Betsy Quinn, owners, say the advantages of this house are "very low heating bills and additional comfort."

"The windows are warm," said Mike Quinn, "and the temperature is even throughout the house."

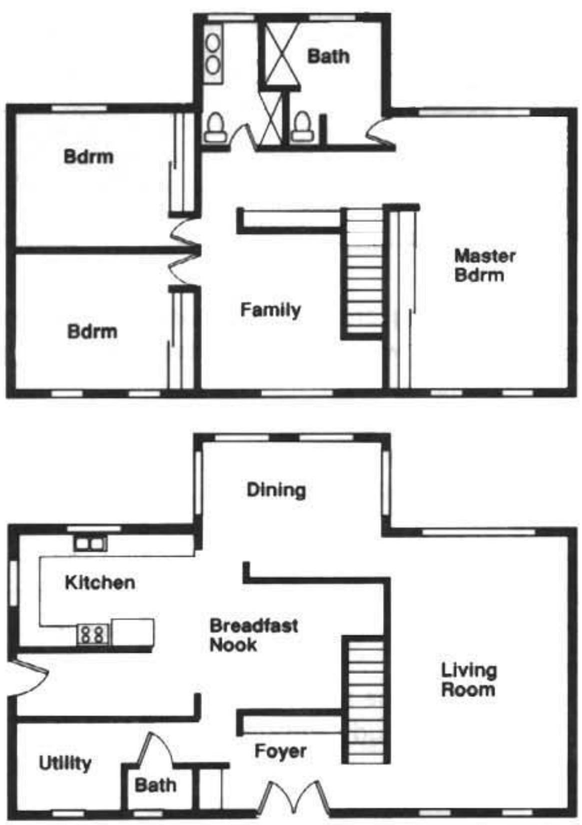
This house has a large glass area compared to its floor area and almost 80 percent of that glass is effective solar glazing. The south-facing windows are almost equally distributed among the three stories. The second story and daylight basement windows are not shaded. All this solar gain maintains a morning temperature of 65°F in winter without any supplemental heat.

During warmer months, the solar gains create a potential cooling problem. This is especially true because the home is light frame construction which does not have sufficient "thermal mass" to balance the gains. However, the home is located on a knoll.

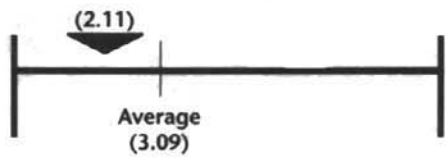
Quinn said, "A good breeze cools the house down and keeps it comfortable."

"I won't build any homes—unless they are energy-efficient," said Quinn, who now builds homes for a living.

OWNER: Mike and Betsy Quinn
DESIGNER:
Mike and Betsy Quinn
Quinn Craft Construction
Oak Harbor, Washington
BUILDER: John Dentel
LOCATION: Oak Harbor
CLIMATE: 5,609 degree days
Climate Zone 1
BUILDING DATA:
Frame construction, 2-story
Ceilings: R-49 advanced frame truss and scissor truss allow full insulation depth
Walls: R-27, 2x6, standard frame with BIB plus 1" interior, rigid, polystyrene foam sheathing
Floors: R-30 over crawlspace
Windows: U-0.27, double glazed, Low-E, wood frame with storm
Skylights: Double glaze, 1/2" Low-E, wood frame
Doors: Wood solid core
Ventilation:
Exhaust-air heat pump
Heat system:
Fan forced wall heaters
Air barrier: Advanced Drywall Approach and taped insulation board
SQUARE FOOTAGE: 2,480
EFFECTIVE SOLAR/TOTAL GLAZING: 78%
SPECIAL FEATURES: Exhaust-air heat pump converts waste heat in exhaust air into usable, water heat



Graph 1. Space heat energy performance



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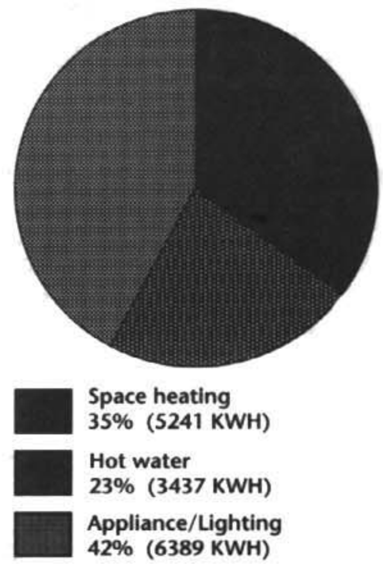
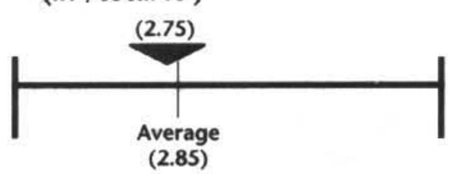
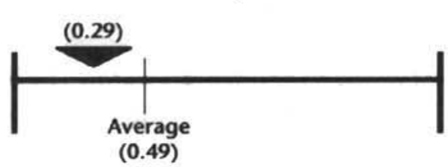


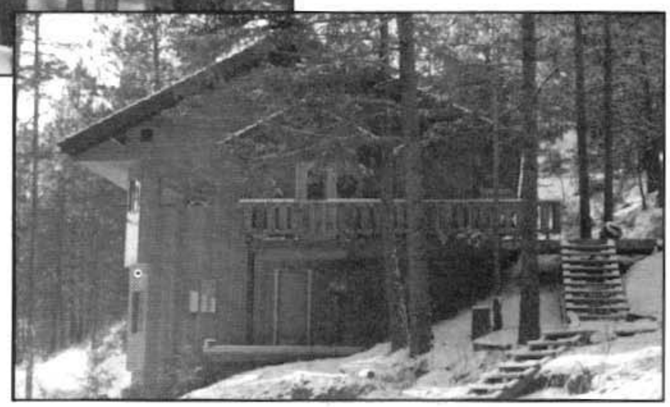
Graph 3. Air leakage area (in^2/total ft^2)



Graph 4. Average hours per day of AAHX operation

Graph 5. Average heat recovery effectiveness





This house is located in a narrow canyon above Leavenworth, Washington, on the east side of the Cascade Mountains.

The benefits of this house are best described by owner Karen Splittgerber who said, "I love this home. It's warm, the windows are never foggy and my entire electric bill for the two, coldest winter months was $61.00—and this included lights and hot water. The house is comfortable in both the winter and the summer. That is important to us—that it will remain cool in the summer."

"During winters, the heat is even throughout the house. You can sit in the dining room, next to the wall of windows and still feel warm. The house is so quiet we can't even hear the neighbor's dog barking next door!"

The electric heaters are usually on two hours in the morning and one hour in the evening during the winter, with outside low temperatures typically 0°F.

"Everything about this house is geared toward heating efficiency," Splittgerber said. "But there are just as many cooling benefits."

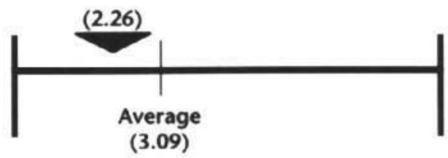
This house has no air conditioning and the south-facing windows are not curtained. A 2.5 foot overhang shades the south-facing glass on the main level.

During the summer of 1988, the owner conducted a private study and monitored the indoor and outdoor temperatures with simple thermometers, marking minimum and maximum temperatures. The inside thermometer is located at the top of the stairs on the upper level, where the hottest air tends to collect. The temperature at this location never exceeded 70°, although outside temperatures climbed to over 100°F.

OWNER: Karen Splittgerber
DESIGNER/BUILDER:
Jeff Splittgerber,
Eagle Creek Services
LOCATION: Leavenworth
CLIMATE: 7,500 degree days
Climate Zone 2
BUILDING DATA:
Frame construction, 1 story with daylight basement
Ceilings: R-50 advanced truss system
Walls: Below Grade: R-22 interior fiberglass batts
Above grade: R-33, 2x8 advance frame with BIB plus 1.5" interior foam sheathing; and R-38, double stud 2x4 with fiberglass batts
Floors: Concrete slab R-12 continuous R-30 over crawlspace

Windows: U-0.38, 1/2" double, wood frame, Low-E
Doors: Insulated fiberglass with thermal break
Ventilation:
Air-to-air heat exchanger
Heat system: Wall heaters with fans
Air barrier: Advanced Drywall Approach and taped insulation board
SQUARE FOOTAGE:
Main level 1,470
Basement 432
Total 1,902
EFFECTIVE SOLAR/TOTAL GLAZING: 73%
SPECIAL FEATURES:
Passive solar orientation
Advanced Drywall Approach
Air-to-air heat exchanger

Graph 1. Space heat energy performance



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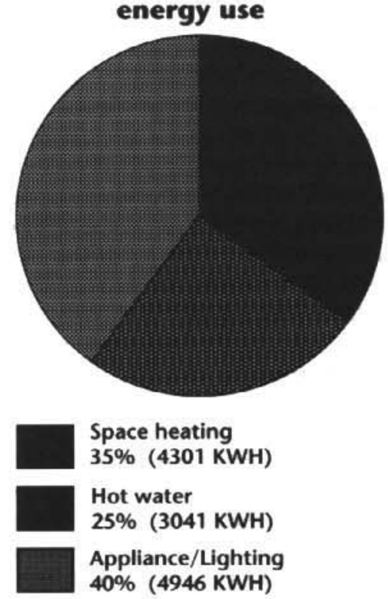

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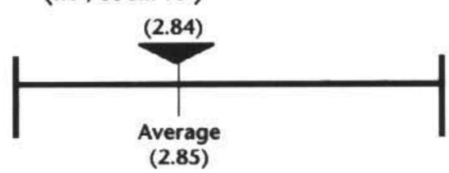

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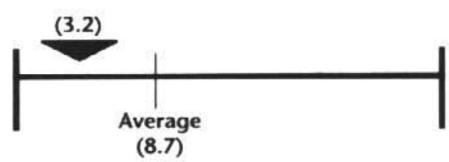
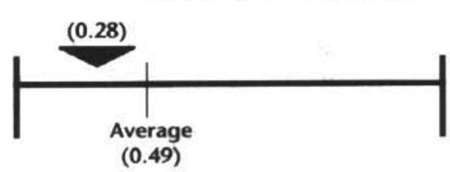


Graph 5. Average heat recovery effectiveness



Advanced Drywall Approach (ADA): A continuous air leakage barrier, formed by drywall, sealed to the wall and ceiling framing. A vapor barrier is supplied by vapor retardant paint, foil-faced drywall, or other equivalent product with a rating of 1 perm or less. Houses built with ADA have average air exchange rates of .2 per hour, while those built to conventional practice have rates of 0.4 to 0.5 per hour.

Advanced framing: Construction methods that reduce the amount of wood used in framing and allow for more insulation. Specifically, wood has an R-value of 1 per inch, and forms a thermal bridge, or heat conduit, to the outside surface. Advanced framing significantly reduces the area of this thermal bridge. Optimum Value Engineering is another phrase used to describe this framing method.

Air change per hour (ACH): That part of the total volume of air inside the house which is replaced by outside air in one hour. For example, if the house has a volume of 10,000 cubic feet and an ACH rate of .5, 5,000 cubic feet of heated air will be lost in one hour. This is due to natural air leakage when wind or cold air from the outside forces its way in through uncaulked gaps in the house envelope. Ventilation can also be artificially induced by mechanical systems. Air leakage is sometimes expressed in terms of "leakage area" (term defined in a separate glossary entry.)

Air space: Refers to the distance between panes of glass in a double- or triple-glazed window, skylight or glass door. The best distance is between 1/2" to 1". For example, the U-value of a 1/2" double-glazed window with a thermally improved metal (TIM) frame is 0.56. The same window, yet with a 1/4" air space, has a U-value of 0.67. This represents a 20% greater rate of heat loss.

Air-to-air heat exchanger (AAHX): A ventilation system which recovers heat from warm, exhaust air and transfers this heat to the cold, incoming air. Blowers force both outgoing, stale air and incoming fresh air through a heat exchanger, which moves heat from the exhaust to the incoming airstream. The systems may also include an electric duct heater to supply supplemental heat. Correct installation and balancing are critical to proper and efficient function.

Blower door test: A test for air leakage that uses a variable-speed fan mounted in a doorway to pressurize or depressurize a house. The pressure difference between the inside and the outside air at various fan-induced pressures is measured with metering equipment. This method determines the natural ACH rate. Air leaks are located with a smoke- or powder-gun while the house is pressurized.

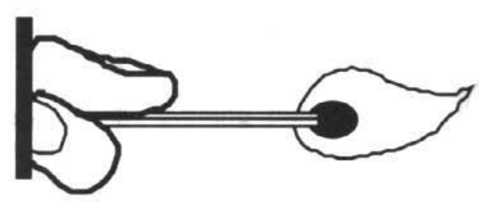
Blown in blankets (BIB): A fiberglass insulation that is mixed with an adhesive and blown into wall cavities, having a slightly higher R-value than standard fiberglass batts or blankets. BIB fibers are a randomly packed substance, providing greater density and a more complete barrier to air motion in the wall. Cellulose fiber is also applied with a similar technique called "sprayed in cellulose."

BTU (British thermal unit): A unit of heat measurement that represents the amount of heat energy needed to raise the temperature of one pound of water by 1° F. This is about the amount of heat given off by a wooden match.

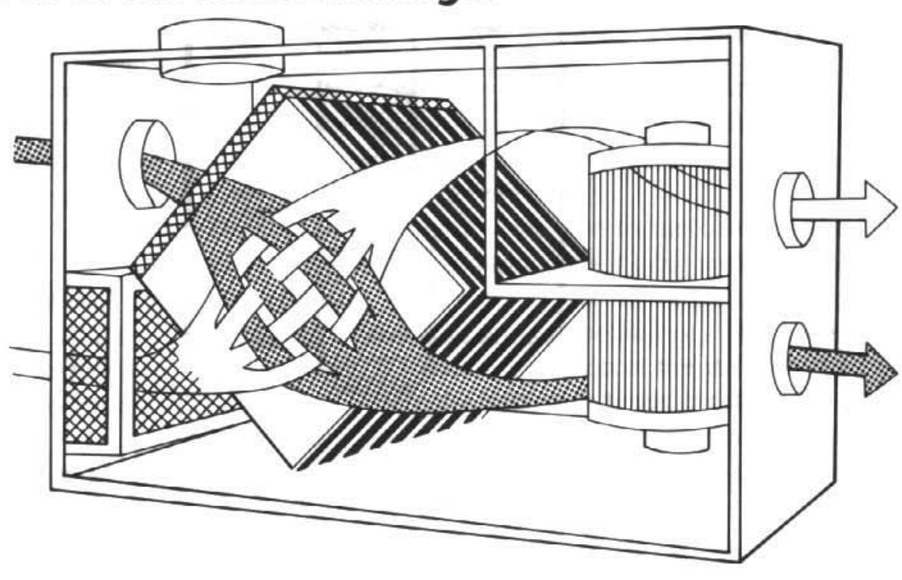
Climate zone: The climate zone for a location is determined by adding all the degree days in that area for an average year. A very cold climate can have 10,000 or more degree days per year. Conversely, a mild climate may have less than half this number.

Conventional practice: Conventional building practice refers to the way buildings are constructed in the absence of a higher set of standards. Conventional practice varies between locations, changes with time and is influenced by local building codes and HUD Minimum Property Standards.

Degree days (heating): One degree of difference between the inside and outside temperatures that lasts for 24 hours. To determine the number of heating degree days in a 24-hour period, the average daily, outside temperature is subtracted from the average daily, inside temperature. For example, if the 24-hour average daily, outside temperature is 30° F. and the average daily, inside temperature is 70° F., there are 40 degree days in this day.



Air-to-Air Heat Exchanger



Dehumidistat: An instrument for regulating or maintaining the degree of moisture in the air. When the humidity level rises above a preset limit, the dehumidistat turns on the ventilation system; when the humidity falls, the dehumidistat turns the system off. Many widely-available dehumidistats are imprecise and unreliable. An alternative control is an automatic timer switch.

Effective solar glazing: Glass which faces south or another direction that is equivalent, in terms of solar gain, to south-facing glass. Every direction receives sunlight, contributing to space heat. In cloudy climates, the diffused light comes from all directions. For this reason, a north-facing window in Seattle will have greater effective solar area than a north-facing window in Boise.

Energy end use: Energy is used to perform specific tasks, such as heating water and cooking. These are called energy end uses. For example, the total electricity used by the houses in this portfolio is sub-metered to measure how much is used for space heat and how much for hot water.

Exhaust-air heat pump: A refrigeration cycle is used in this device to pump heat from the exhaust air. This process heats water for domestic use or space heating. Because the heat pump recovers about 3 units of heat for every 1 unit of electricity needed to run the pump, water heating costs are cut. In hot weather, the air stream can be reversed allowing the heat pump to cool the incoming supply air. The resulting cooling effect is about the same as a small air conditioner could produce.

Extruded polystyrene rigid foam board: A plastic insulation that has a R-value of 5 per inch. This material, used to insulate exterior foundation walls, is resistant to moisture penetration. Compression strength is another favorable characteristic, allowing this product to be used as an insulator under concrete slabs. When used above ground, protection from sunlight and physical damage is important, as is sealing against ants and other insects.

Heat recovery ventilation (HRV): All ventilation systems remove interior air, called exhaust, and bring in fresh air from outside, which is called the "supply" or "make-up" air." Heat recovery ventilators capture some of the heat in the exhaust air for reuse. Air-to-air heat exchangers use the heat to warm the supply air. Exhaust air heat pumps direct the recovered heat into the hot water tank.

House envelope: The set of surfaces (floors, walls and ceilings) which contain the heated space. The energy efficiency of the envelope is defined by insulation values and the continuity of the infiltration/vapor barrier.

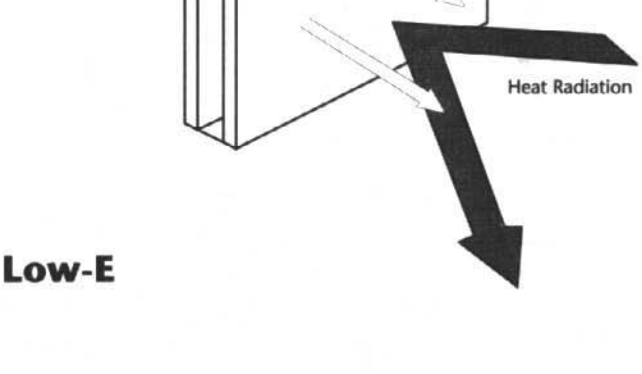
KWH (kilowatt hours): The energy delivered by 1,000 watts of electric power in one hour. There are 3,413 BTU in one kilowatt-hour of electricity converted to heat at 100 percent efficiency.

KWH/(FT 2 x YR) (kilowatt hours per square foot by year): Each case study house had electric heat and a separate meter to measure it, determining the number of kilowatt hours the house used in the year-long study. To compare houses of different sizes, the heat use in kilowatt hours for the year is divided by the number of square feet of heated floor space. This yields a standard kilowatt hours/(square foot x year).

Leakage area: The results of a blower door test are used to calculate the leakage area in a building. A small leakage area indicates the building is tight.

Low-E: A term used to describe windows, skylights and glass doors with microscopically thin, metal coatings. These coatings admit sunlight, but reflect heat radiation. Low-E windows save energy, because they have lower heat loss rates than conventional windows. They also reflect heat, causing occupants to feel warmer.

Non-heat recovery ventilation (NHRV): Mechanical exhaust fans and fresh air systems used in homes to maintain comfort, improve indoor air quality and prevent moisture collection. The majority of MCS homes built today have ventilation systems with mechanical exhaust fans and fresh air vents. The heat in the exhaust air escapes, but the benefits of ventilation outweigh the cost of that loss. All houses must ventilate at least .35 air changes per hour to be healthy dwellings. Only about 50 percent of all homes do so naturally. Even so, natural ventilation occurs mostly in cold weather or when the wind blows. This is why building a tighter house and ventilating that house is necessary to maintain comfort and quality indoor air.



Low-E

Optimal glazing level: The area of window that can be put in a specific building to best balance: 1) the gains acquired from sunlight, and 2) the accompanying heat-loss factor. Every square foot of window replaces insulated wall. For this reason, the amount of window area in a building and its placement is critical to energy efficiency and comfort.

Perm rating: A measurement used to signify resistance to the flow of water vapor. Lower numbers are more resistant.

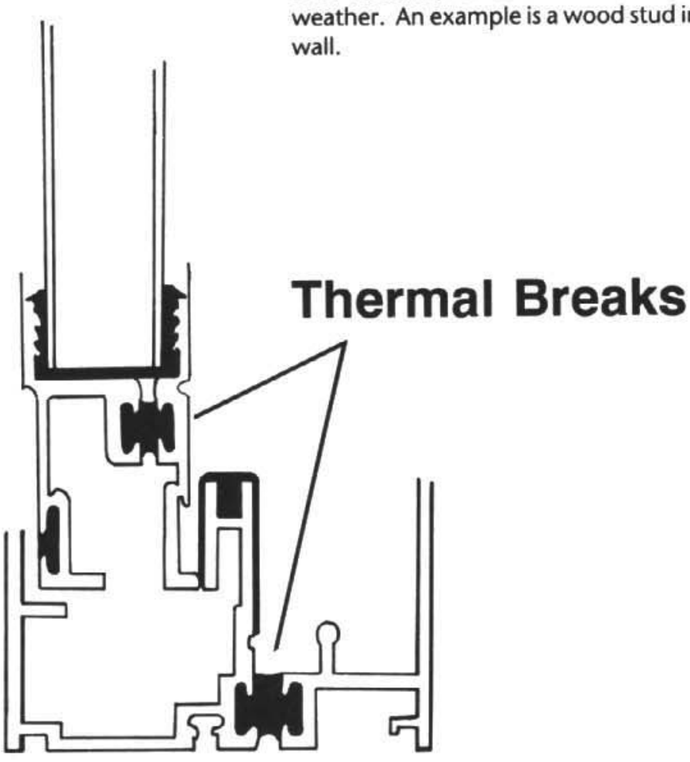
Polyisocyanurate foam board: A rigid insulation material usually faced with foil on both sides. This product is most often found in applications where it will be protected against weather (i.e., non-structural exterior wall sheathing).

R-value: A measurement of a material's resistance to heat flow. The R-values of materials are added to produce the total R-value of a building surface. The higher the R-value, the greater the resistance to heat flow.

Solar gain: Light energy that passes into the envelope through windows and converts to heat-energy inside the heated space. There is a distinction between total gains and usable solar gains. If solar gains cannot be absorbed or used in the heated space on arrival, the air inside that space will overheat, unless that solar gain is vented or cooled.

Thermal break: Use of an insulating divider to interrupt heat flow through highly conductive materials such as aluminum, steel or concrete. Thermal breaks are used in metal clad, foam insulated doors, aluminum windows and between non-insulated, concrete structures adjacent to insulated structures. An example is the thermal break between a carport slab and an adjoining concrete-slab, house floor. The illustration below shows the thermal breaks in a cross-section of a sliding aluminum window frame.

Thermal bridge: A path through the building envelope, which serves as a conduit, passing heat to the outside in cold weather, or to the inside in hot weather. An example is a wood stud in a wall.



Thermal mass: A popular term for heat storage capacity. All matter has mass and some heat storage capacity. Some types of matter have more heat storage capacity than others. "Thermal mass" is used to distinguish specific, common, building materials with high heat storage capacities—those which can absorb incoming solar gains. A house that maintains a comfortable temperature has glazed areas that balance the capacity of the heat storage mass. Gypsum wallboard makes up most of the heat storage capacity in a standard building, and the most common additional capacity is a concrete-slab floor.

TIM (thermally improved metal): A metal—usually aluminum—window or glass door frame which has a thermal break. Without thermal breaks, a metal window cannot be energy efficient. Thermal breaks increase a metal frame window's performance to within 80 to 90 percent of a wood or vinyl window frame with the same air spaces and coatings.

U-value: A measurement of the ability of a material to conduct heat. The thermal performance of windows and doors is commonly stated in U-values. A U-value is equal to 1/R. The lower the U-value, the better the material's insulating ability. The heat loss rate of a building surface is the product of the U-value and the surface area, or the UA.

Vapor barrier: That barrier which prevents water vapor in heated, interior air from escaping into walls and ceilings where condensation takes place. Such condensation reduces the effectiveness of insulation and creates moisture collection. A vapor barrier should have a perm rating of one or less. Examples are building paper (asphalt-impregnated felt), polyethylene plastic sheeting, aluminum foil, and vapor retardant paint.

Vapor-retardant paint: Paint, which seals surfaces against the transfer of water vapor and is used in combination with Advanced Drywall Approach to provide a vapor barrier.

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Ken Eklund	author and technical editor
Joy L. Smith	text editor and communication consultant
Diane Ficks	illustrator
Ken Baker	project manager and contributing author
Steve Benner	contributing author and project concept
RCDP staff	photographers

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Photos:
Top photo, page 5
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RCDP houses--RCDP staff, Idaho, Montana, Oregon and Washington

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