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CANADA'S GREEN PLAN

ADVANCED HOUSES PROGRAM
PROGRAMME DE MAISONS PERFORMANTES

DESIGN AND PERFORMANCE OF THE SASKATCHEWAN ADVANCED HOUSE

PREPARED FOR:

The CANMET Energy Technology Centre
Energy Technology Branch, Energy Sector
Department of Natural Resources Canada
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Advanced Houses Program
Under Natural Resources Canada's Advanced Houses Program, 10 demonstration houses across the country were designed, built and monitored. The Program challenged the building industry to develop and test innovative methods of reducing energy consumption, providing a better indoor climate, and reducing the environmental impact of housing. The result was the erection of ten of the most environmentally responsible houses in the world, and the accumulation of valuable knowledge and experience, now documented in the Advanced Houses Program reports.

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	Technical Requirements for Advanced Houses *By Dr. Robert Dumont, Saskatchewan Research Council; detailed requirements, including energy target formulas; includes 4 detailed commentary, 39 pages, 1991. Available in French as* Criteres techniques des maisons performantes	$10
	Assessment of the Advanced Houses Technical Requirements: Compliance Verification and Resultant Recommendations *Review of how the house designs did or did not meet the technical requirements and recommended adjustments for the requirements upon review, by Saskatchewan Research Council, 30 pages, 1996*	$10
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EXECUTIVE SUMMARY

In 1992, the Saskatchewan Advanced House was built in Saskatoon using innovative energy efficient technologies and environmentally advanced features. This house was one of ten constructed across Canada in 1992-93 as part of the Natural Resources Canada (NRCan) Advanced House Program begun in 1991.

The Saskatchewan Advanced House was a project of Carroll Homes Ltd. of Saskatoon.

House construction started in April, 1992 with the sod-turning, and the house officially opened on September 15, 1992 for public viewing. The house was sold and occupied in September 1993.

The energy performance of the house was predicted through computer simulation using the HOT 2000 computer program. A monitoring system was installed to assess the actual energy performance of the house and its innovative technologies. Manual meter readings were started in late December 1992 and continuous monitoring using a computer based data acquisition system began in January 1993.

The Advanced House was estimated to use 18,613 kilowatt hours per year (kWh/yr), based on computer simulation. The energy target based on the technical requirements for the house was 20,514 kWh/yr (60.2 kWh/m^2). Saskatoon has a heating climate of 5,997°C days (base 18°C).

For the year of occupied monitoring (September 1, 1994 - August 31, 1995) the total purchased energy consumption for the house was 31,322 kWh (91.9 kWh/m^2). This total excludes the natural gas space heating for the garage (6780 kWh) and the electrical energy (598 kWh) used by the monitoring equipment that did not contribute to useful space heating. The total purchased amount substantially exceeded the target for the house. One reason for this excess consumption is believed to be poor performance of the attic insulation, which is estimated to be responsible for an increase of 5490 kWh per year. A second major reason was the low efficiency of the condensing water heater/radiant floor heating system. Other factors which contributed to energy consumption higher than the target were as follows: pilot light gas consumption on the fireplace (1557 kWh/yr); an additional refrigerator-freezer added by the occupants (1037

kWh/yr); a freezer added by the occupants (452 kWh/yr); pump loads; and miscellaneous plug loads including a home theatre speaker system (1138 kWh/yr).

The radiant ceiling cooling system using no CFCs showed impressive coefficient of performance values ranging from 11.6 to 40.3; typical refrigeration systems have a COP value of about 3. The system also provided thermal comfort for the occupants.

The solar domestic hot water system using evacuated tube collectors and a large site-built tank proved to be successful in spite of a two month shut-down due to a pipe leak.

The 1.9 kW peak photovoltaic system provided 877 kWh of electricity used to power a high efficiency DC refrigerator, the HRV fan motors and the battery room exhaust fan.

A number of environmentally advanced features including low water use fixtures, low water use landscaping, low offgassing building materials, recycling bins in the kitchen area, outdoor composting bins, recycled materials such as a carpet made from PET plastic soft drink containers were successfully demonstrated.

A well-thought-out technology transfer and publicity plan ensured wide exposure to the innovations featured.

The occupant response to the house, in spite of energy consumption values exceeding the technical requirements, has been highly favourable.

RÉSUMÉ

En 1992, on a construit à Saskatoon la Maison performante de la Saskatchewan en ayant recours à des techniques novatrices favorisant l'efficacité énergétique et à des dispositifs révolutionnaires sur le plan de l'environnement. Cette maison comptait parmi les dix que l'on avait érigées un peu partout au Canada en 1992-1993 dans le cadre du Programme de la Maison performante de Ressources naturelles Canada (RNCan) lancé en 1991.

C'est la société Carroll Homes ltée de Saskatoon qui s'est chargée de concrétiser le projet de la Maison performante de la Saskatchewan.

La réalisation de la maison a débuté en avril 1992 avec l'inauguration des travaux pour en arriver à l'ouverture officielle au public le 15 septembre 1992. En septembre 1993, la maison était vendue et les nouveaux propriétaires venaient l'habiter.

Le rendement énergétique de la maison avait fait l'objet de prévisions en ayant recours à un programme de simulation basé sur le logiciel HOT 2000. On a, par la suite, procédé à l'installation d'un système de surveillance pour évaluer le rendement énergétique réel et les résultats obtenus à l'aide des diverses techniques révolutionnaires. Le relevé des compteurs a commencé à la fin de décembre 1992, alors que, en janvier 1993, s'amorçait la surveillance continuelle de la maison à partir d'un système informatique d'acquisition des données.

En se basant sur la simulation informatique, il a été estimé que la Maison performante de la Saskatchewan consommait quelque 18 613 kWh/année. L'objectif énergétique visé pour la maison en fonction des exigences techniques s'établissait à 20 514 kWh/année (soit 60,2 kWh/m^2). La ville de Saskatoon présente un climat chaud qui atteint, au total des journées, 5 997°C (selon une moyenne de 18°C).

Pour la période de surveillance de la maison lorsqu'elle était occupée, soit du 1er septembre 1994 au 31 août 1995, la consommation totale d'énergie achetée s'établissait à 31 322 kWh (91,9 kWh/m^2). Ce total ne comprend pas le chauffage par gaz naturel de l'espace occupé par le garage (6 780 kWh) et l'électricité (598 kWh) ayant servi à l'équipement de surveillance, deux formes d'énergie qui n'ont pas contribué au chauffage de l'espace utile. Le résultat total relativement à l'énergie achetée dépasse largement l'objectif fixé pour la maison. Selon les estimations, une des raisons de ce dépassement se retrouve dans le rendement inadéquat de l'isolation de l'entretoit, lequel serait responsable d'une

consommation accrue de 5 490 kWh par année. Une autre des principales raisons de ce bilan se situe au niveau de la faible efficacité du chauffe-eau et du système de chauffage par rayonnement à partir du sol. Parmi les autres facteurs qui ont contribué à une consommation énergétique plus élevée que l'objectif prévu, il y a les suivants : la consommation de gaz naturel du foyer contrôlée grâce à une veilleuse (1 557 kWh/année); un congélateur-réfrigérateur ajouté par les occupants (1 037 kWh/année); un autre congélateur ajouté par les occupants (452 kWh/année); les charges relatives aux diverses pompes; les différentes charges électriques, notamment celle relative à un système de haut-parleurs pour cinéma maison (1 138 kWh/année).

Le système de refroidissement par rayonnement à partir du plafond, qui fonctionne sans CFC, présente des valeurs de coefficient de rendement très impressionnantes s'échelonnant de 11,6 à 40,3 (les systèmes classiques de réfrigération présentent des valeurs à ce chapitre qui frôlent le chiffre de 3). Ce même système était également en mesure d'assurer le confort thermique des occupants.

Le système d'eau chaude domestique à énergie solaire, muni de capteurs à tube sous vide et d'un grand réservoir construit à même son emplacement, s'est avéré fructueux malgré une interruption de deux mois en raison d'une fuite dans les conduits.

Le système photovoltaïque de pointe de 1,9 kW a permis de produire 877 kWh d'électricité ayant servi à alimenter un réfrigérateur à haute efficacité énergétique fonctionnant à courant continu, les moteurs de ventilateurs échangeurs de chaleur et le ventilateur d'évacuation de la pièce des batteries.

On a fait la démonstration, avec succès, de plusieurs éléments révolutionnaires en matière d'environnement, notamment des appareils de plomberie à faible débit d'eau, l'aménagement paysager sans dépense excessive d'eau, des matériaux de construction qui ne dégagent pas trop de gaz, des contenants de recyclage dans l'espace réservé à la cuisine, des contenants de compostage à l'extérieur et des matériaux recyclés comme des tapis faits de bouteilles de boisson gazeuse en plastique de PET.

Une stratégie de transferts technologiques et une campagne de publicité habilement conçues ont contribué à largement faire connaître les procédés novateurs présentés.

La réaction des occupants en ce qui a trait à la maison, malgré des valeurs de consommation énergétique au-delà des exigences techniques, s'est avérée très favorable.

ACKNOWLEDGEMENTS

The Saskatchewan Advanced House was a project of Carroll Homes Ltd of Saskatoon. A project of this size could not have been assembled without the support and co-operation of many organizations and individuals.

The initiating sponsor, and key driver for the Advanced Houses Program, was CANMET, Natural Resources Canada. Tim Mayo, Robin Sinha, Joel Allarie, Frank Szadkowski, Gary Sharp, and Kevin Lee of CANMET all played a very helpful role in making the Saskatchewan Advanced House a reality.

Many other organizations have made significant financial and personnel contributions to the project including SaskEnergy (the Provincial Natural Gas Utility), SaskPower (the Provincial Electric Utility), the Saskatchewan Home Builders' Association, the Saskatchewan Research Council, the Sun Ridge Group, Fiberglass Canada, Dow Chemical, Crane Supply, Estevan Brick, and Honeywell Canada.

The authors would finally like to acknowledge the great co-operation provided by the Fehr family, owners of the Advanced House. They have been most generous to, and tolerant of, the monitoring team and many visitors.

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1.0 INTRODUCTION

The Saskatchewan Advanced House is one of ten houses built across Canada as part of the Advanced Houses Program of CANMET, Natural Resources Canada.

The official sod turning occurred in April 1992 as part of New Homes Week, and construction began in early May. The official opening was September 15, 1992.

The house represents a major advance in design and construction, incorporating significant innovations in energy efficiency and environmental features.

1.1 Background

1.1.1 Background on CANMET Advanced Houses Competition

The Advanced Houses Program was designed to accelerate the development of appropriate technologies by challenging the residential construction industry to build innovative, low energy environmentally friendly houses. The program provided opportunities for builders and manufacturers to field test new technologies, new ideas and concepts, and new ways of building better homes for Canadians.

The Advanced Houses Program was one of the first programs in the world to emphasize whole building performance, incorporating energy efficiency with environmental concerns, encouraging innovation while focussing on a product that would be acceptable to the current housing market.

The Saskatchewan Advanced House incorporated a number of innovative technologies including the following:

- ground source cooling using buried plastic piping and radiant ceiling panels
- photovoltaic system to provide part of the electricity used
- a residential light pipe
- a prototype HRV with DC motors
- a prototype sealed-combustion gas range and oven
- a solar thermal system with oversized thermal storage

1.2 Description of Team

Carroll Homes Ltd. of Saskatoon managed the project and constructed the house. John Carroll was the primary Saskatoon sparkplug behind the project. Carroll Homes also put together the team of sponsors for this project. The Sunridge Group from Saskatoon put together the Advanced House brochure and information sheets and was also responsible for advertising for the house, and arranging for the official opening ceremony. Keith Hanson of the Sunridge group was the key individual involved.

The Saskatchewan Research Council (SRC) was contracted to do the monitoring for the Saskatchewan Advanced House, and also assisted with the design of the house.

The major sponsors for the Saskatchewan Advanced House were CANMET of Natural Resources Canada, SaskEnergy, SaskPower, Fiberglass Canada, Dow Chemical, Crane Supply, Estevan Brick, and Honeywell Canada.

1.3 General House Description

1.3.1 House Location

The Saskatchewan Advanced House is located in Saskatoon, Saskatchewan in a new sub-division called Briarwood. The house address is 511 Braeburn Court. The house is a two storey structure with brick cladding and cement tile roof. A perspective view of the house is presented in figure 1.1.

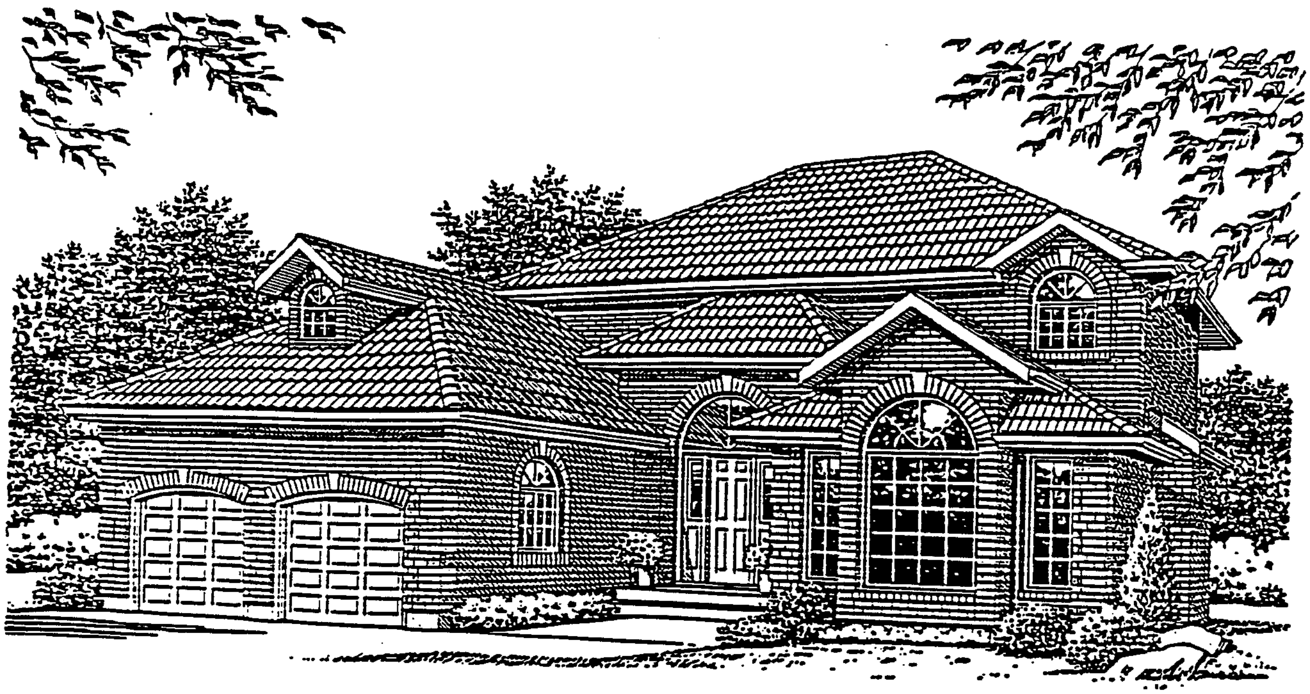

Figure 1.1. Perspective view of the Saskatchewan Advanced House from the northwest (Diagram courtesy of Sun Ridge Residential)

1.3.2 Description of house

Orientation
The back of the Advanced House faces south. The lot was specially chosen for this characteristic, as both the photovoltaic panels and the solar water heater are mounted on the south side of the house. Fortunately, there were a number of lots in the subdivision available with these characteristics.

Appendix A contains fact sheets on the Saskatchewan Advanced House. These fact sheets give more information on the building envelope, mechanical systems, windows, etc. The following is a summary of that information:

Structure and insulation levels:

Basement Floor

- 100 mm Styrofoam™ RSI 3.5
- 100 mm concrete

Basement Walls

- 38 mm Baseclad™ extruded polystyrene insulation from grade to footing (RSI 1.4)
- concrete wall
- 100 mm Styrofoam (RSI 3.5)
- RSI 2.5 Fibreglass batts
- 12 mm drywall

Above Grade Walls

- brick exterior cladding
- TYVEK building paper
- Oriented Strand Board sheathing
- double stud with two 38 mm x 89 mm wood frames spaced 300 mm apart
- three layers of high density Fiberglass™ batts RSI 2.5, RSI 3.9 and RSI 2.5. The batts have a 17% higher R value than conventional batts.
- sealed 6 mil (150 µm) CGSB-approved vapour barrier
- dry wall 12 mm

Windows

- Dorwin, manufactured in Winnipeg, Canada
- fibre-glass frames
- triple glazed
- two low E coatings
- Edgetech's Super Spacer™ (made from a blend of silicates and a moisture - absorbing desiccant material)
- argon gas filled

Ceiling

- RSI 12.3 Fiberglass™ blown wool
- radiant cooling pipes
- two layers of 12 mm dry wall

Mechanical systems

The integrated space heating and domestic hot water system provides heat for domestic hot water and hydronic radiant floor heating. A schematic of the system is presented in figure 1.2. A large volume solar domestic hot water preheat tank (3675 litres) stores heat from the solar collectors. A propylene glycol and water mixture is pumped through the Thermomax™ vacuum tube solar collectors to the solar preheat tank via a closed loop circulation system. Cold water from the municipal supply is circulated through copper tubing within the preheat tank before it reaches the domestic hot water heater (DHW). Hot water via a separate loop is pumped from the DHW tank to a water to water-glycol heat exchanger. This heat exchanger then transfers heat to a closed loop hydronic radiant floor heat system. The DHW heater is a high efficiency (MOR-FLO Polaris) condensing sealed combustion unit fired by natural gas.

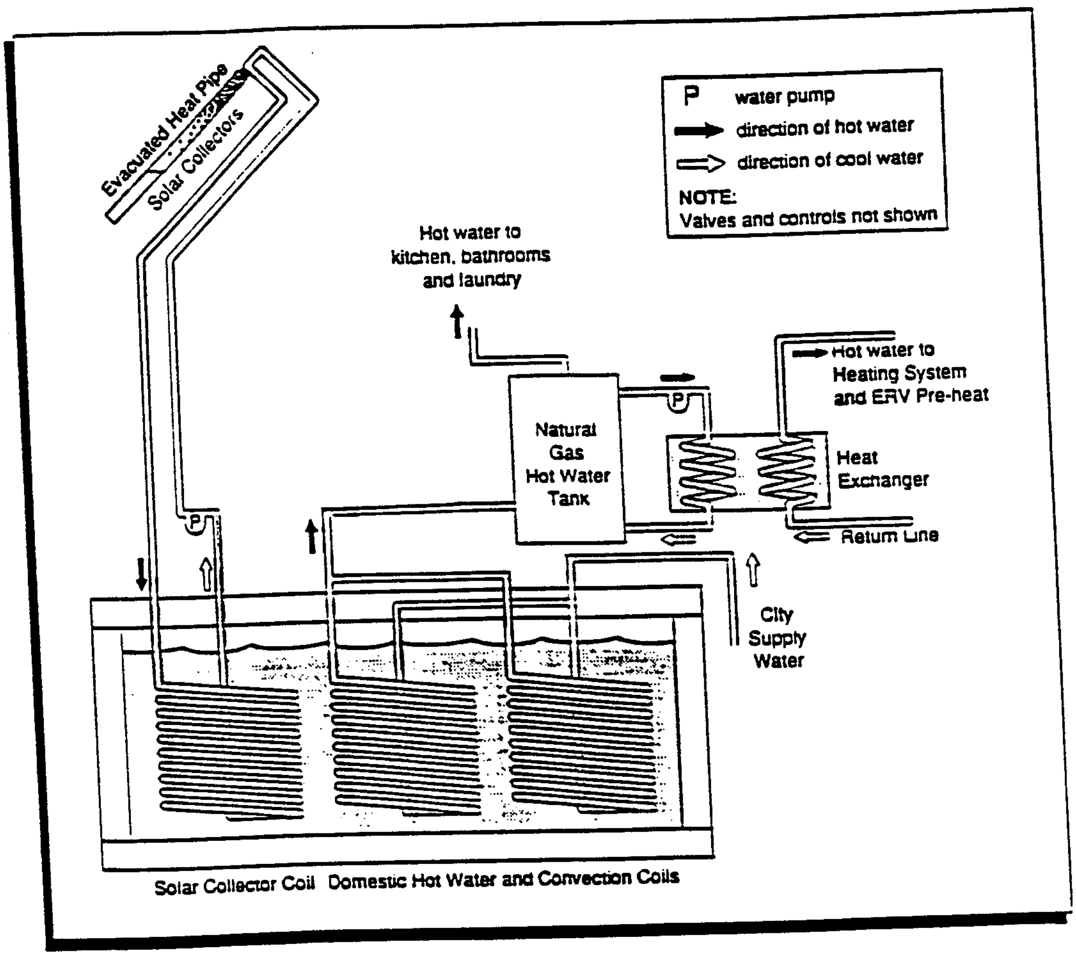

Figure 1.2. Space and domestic water heating system for the Saskatchewan Advanced House (Diagram courtesy of Sun Ridge Residential)

The Saskatchewan Advanced House uses a non-CFC cooling system. Cooling fluid is pumped through pipes installed under the basement floor and within the backfill space around the house. This cool fluid then is pumped through cooling pipes in the main floor and second floor ceilings. This system has been successful in cooling the house to a comfort level that satisfies the owners.

There are only three fans in the house; two DC powered fans in the heat exchanger and one small DC powered exhaust fan in the battery room.

The house heating system uses two AC powered pumps and the house cooling system uses one AC powered pump.

Lights and appliances

The Saskatchewan Advanced House has two electrical systems:

1. Provincial grid power (100 amp 240 volt conventional AC system)
2. 24 volt DC photovoltaic system
   - The PV system consists of 40 solar panels on the south side of the house with a peak output of 1.9 kilowatts. Thirty deep cycle 75 amp-hour batteries in the basement are used to store the electrical energy.
   - The PV system supplies power for the DC refrigerator, HRV fans, battery room exhaust fan and emergency lighting, all of which operate on 24 volts DC. No inverter is used on the system.

The Advanced House lights are either fluorescent, halogen, compact fluorescent or high pressure sodium. Fluorescent fixtures are used in the bathrooms and the basement while most of the other fixtures in the house use either compact fluorescent or halogen bulbs. The exterior lighting uses high pressure sodium lamps.

A light pipe is used to direct light to the north side of the house. Sunlight is directed through a 330 mm diameter aluminum pipe coated with 3M silverlux. Sunlight is channelled from the south roof surface to the ceiling in the north of the house.

The major appliances of the Advanced House are:

1. A General Electric Monogram dishwasher rated at 75 kilowatt hours per month on the Energuide Label.

2. A Medallion 850 General Electric Washing Machine rated at 103 kilowatt hours per month on the Energuide Label. The laundry dryer is a natural gas General Electric unit, Model GDG957LW129 (not rated by Energuide)

3. The kitchen range is a natural gas prototype unit manufactured by CGRI. This unit gave initial problems with the ceramic top which cracked three times. CGRI, after several visits, were able to adjust the range and the range has worked well since then. The homeowner likes the range; one disadvantage is that the electricity consumption of the gas range is fairly high.

4. The original refrigerator for the house was a DC powered Photocomm unit rated at 24 kWh/month. This fridge was moved to the basement when the homeowner took possession and replaced it with a larger G.E. Profile unit with an Energuide rating of 87 kWh/month.

5. A chest type freezer, Sears Model 43720-04, is located in the garage (Energuide rating of 35 kWh/month).

Control system

The Saskatchewan Advanced House has two control systems; one is the TotalHome™ Management System supplied by Honeywell. This system is able to control 16 lifestyle modes and up to 48 hardware security points. Lighting can also be controlled from this system as well as heating, cooling and appliances. The second control system uses thermostats located in the basement, main floor and first floor. These can be manually set for heating and cooling control.

Finishes

The Saskatchewan Advanced House uses selected paints and wood finishes to ensure a clean and healthy interior environment. Walls were painted with Ecologo water based paints. The cabinetry and millwork in the house were built from oak boards and oak plywood to avoid much of the urea-formaldehyde based glue commonly found in particle board. The woodwork color was achieved through the use of latex stain. The wood was then sealed to provide long term durability.

Plumbing

The toilets in the Saskatchewan Advanced House are Crane Magnum™ units which use six litres of water per flush. Shower heads are all restricted flow type and all faucets use aerators to reduce water flow.

Landscaping

The front yard of the Saskatchewan Advanced House is xeriscaped™ which eliminates the need for artificial watering once the plants are established. Various areas in the yard are covered by a wood mulch to protect the ground. This keeps the ground cool and wet and eliminates the need for watering. As the wood decays, the nutrients are absorbed by the soil and the remaining mulch is simply topped up. The wood mulch also reduces weeds.

The grass area in the backyard has a layer of clay about 300 mm below the surface to retain water. It is contoured to act as a holding basin for runoff. The eavestrough downspouts at the back of the house feed the lawn area. Rain water from the front roof feeds the plants in the wood mulch area.

The rear yard has been landscaped to provide a depression around the basement window. This allows for a much larger window than would normally be found in a full depth basement. The large window provides natural light to the basement area, reducing the need for artificial lighting.

Recycling

Bins were constructed within the kitchen cupboards to allow for sorting of recyclable materials, according to the Advanced House Technical Requirements (Dumont, 1992)

Domestic waste management

Compost bins were installed in the back yard to handle household and yard wastes for composting.

1.4 Publicity and Technology Transfer

A detailed report (Hanson, 1993) was produced on the publicity and technology transfer activities surrounding the house. The following is a summary of that report.

Target Audience

The Advanced House Project has been targeted at three major audiences --the potential home buying public, future home buyers and members of the building industry.

Positioning

The Saskatchewan Advanced House has been positioned to the public and the industry as a demonstration of advanced leading-edge technology and new products in an environmentally friendly style of housing that could become commonplace in the near future.

Marketing and Technology Transfer

Grand Opening Reception And Press Conference

On September 15, 1992 the Grand Opening of the Saskatchewan Advanced House was held. It was a first class opening attended by over 150 invited guests. The guests included an excellent representation from industry and government. Speakers at the opening included Mr. John Carroll (Builder)Mr. Frank Campbell (EMR-CANMET), Ms. Pat Lorje (Government of Saskatchewan), Mr. Wally Gillard (SaskPower), Mr. Russ Pratt (SaskEnergy), Dr. Don Figley (SRC), Mr. Joe Ehr (SHBA), Mr. Keith Hanson (Sun Ridge) and Mayor Henry Dayday (City of Saskatoon). All spoke highly of the project and expounded on its value to the community, the country and the world.

All major media sources covered the opening with enthusiasm. The Saskatoon Star Phoenix ran a number of articles describing the many features of the home from its natural gas appliances to the photovoltaic system. TV coverage was extensive, giving viewers a sense of what the project was all about. Newscasts in the weeks to follow included many endorsements for the project and urged the public to view this magnificent home. Radio coverage was equally extensive and beneficial.

Open house

During the fall Showcase of New Homes (September 1992), which the Advanced House was part of, the house was open weekdays from 7:00 to 9:00 PM and 1:00 to 5:00 PM on weekends and holidays. At the conclusion of the Showcase, viewing times changed to Tuesday and Thursday evenings plus weekends. In November a decision was made to keep the house open from 2:00 to 5:00 PM weekends and one night during the week with an organized tour starting at 7:00 PM.

Traffic during September was very heavy because of the spin-off benefits of the Showcase of New Homes and the Wish Home Lottery Project. Both events were considered important opportunities for the Advanced House. During September, the traffic in the Advanced House approached 8,000 visitors. After that time traffic held reasonably steady at approximately 500 visitors per week (except during the Christmas break).

Invited Tours

Mailing lists were prepared for the Home Builder Association members, New Home Warranty Program members, School Boards, Technical Schools, andUniversities. Groups were sent invitations to call to set up a tour of theAdvanced House at their convenience. Most tours for these groups were scheduled for February through June of 1993.

House Sign And Feature Signs

A colourful 4'x8' sign that carried the colour and design theme was placed in the front yard. This sign was eye appealing and clearly identified the project as well as the major sponsors.

Feature Signs were placed throughout the Advanced House. These attractive colour signs noted the special features of the house in simple, easy to understand terms. A total of 13 Feature Signs were displayed at the Advanced House and were positioned at specified features.

Information magazine
Prior to the publishing of the Advanced House Magazine, a 4 page brochure was produced which outlined the major features of the house and explained some of the technology transfer activities that were planned. This four page 8 1/2" x 11" two colour was very popular as it explained the house in very simple terms and referred to general concepts. This brochure was distributed from the house during tours and public open houses.

The 24 page, full color Advanced House magazine has received a very positive response from both the advertisers, the public and the industry. It was printed on recycled coated stock containing post-consumer paper. Highly illustrated, it describes in detail the many features of the Saskatchewan house.

A series of 8 fact sheets have been produced that describe in detail thefunctions and features of the house. The fact sheets provide more detailed and in-depth material than the Advanced House Magazine and are primarily for people looking for enhanced information on certain aspects of the house. The technical brochures and fact sheets identified in the marketingplan have been combined to form one informative brochure known as a "fact sheet". The topics focused upon are as follows:

* water conservation
* waste management
* photovoltaics
* solar hot water
* building envelope
* integrated mechanical system
* radiant heating and cooling systems
* air quality
* other systems being used in advanced houses
* appliances
* exterior finishes
* windows
* mechanical equipment
* ventilation
* product emissions

These fact sheets are 4 pages in length and include sponsor recognition. They have been printed in two colors on recycled paper and in sufficient quantity to satisfy those persons wishing more detailed information about the technical aspects of the project.

Media Promotions

Newspaper
The flow of traffic through the Advanced House was very heavy during the first 5 months of the demonstration period. Newspaper support for this project was very strong and has helped deliver interested parties to the house. Numerous newspaper articles have appeared in the local paper (Saskatoon Star Phoenix) and in newspapers throughout Saskatchewan.

An article that appeared in the Saskatoon Star Phoenix in January headlining "Efficient energy use realizes savings of mega-bucks" pays special attention to SaskPower's contribution to the economic benefits of energy conservation. A large portion of the article is dedicated to Ken Kelln with Conservation Lighting, the company responsible for the Photovoltaics in the Saskatchewan Advanced House.

The December 1992 publication of "The Professional Edge" (Association of Professional Engineers of Saskatchewan) published an article outlining the special features of this project.

The Star Phoenix Business Editor, Paul Martin wrote three articles on this project; one called "Builder Expends Energy on Conservation Prototype", the second "New Wave House For Sale in City" and the third, "High-Tech City Home More Than Just Hot Air".

Stories have also been run in newspapers in other parts of Canada, some of which we are aware of and others that we have only heard of.

Bill Stuffer
Two of the major sponsors of this project (SaskEnergy & SaskPower) included an insert in their monthly billings encouraging the general public to call for information or visit the Advanced House. These bill stuffers have gone to every home in the province. There has been an exceptional response to this insert.

Radio
Most of the local radio stations have run special features about the Saskatchewan Advanced House. Many stories were run during the early stages of the project. Some of the radio stations continue to run a feature following a newspaper article. The Saskatchewan Advanced House has been featured on the "C-95 Environmental File" on more than one occasion.

Television
While no paid television advertising has been necessary, the house has been covered extensively on television through special news features early in the program and follow up news inserts and stories as the project matured.
The Saskatchewan Advanced House has been filmed for inclusion in a number of environment programs some of which show on the CBC national network and others that show on local cable stations.

Media Conferences
On April 1st, 1992 a very successful media conference was held for the Sod Turning Ceremonies where the Advanced House was officially announced. A news release and background document was provided to all media and personal interviews were arranged with the team members. This media conference alerted the media to the upcoming event and tweaked their interest.

On September 15, 1992 a second media conference was held in association with the Grand Opening of the Advanced House. The media was provided with additional press materials and background information. The press coverage that resulted was extremely favourable.

Other activities

Forum '93
On February 18, 19, and 20, 1993 the Saskatchewan Home Builders' Association hosted Forum '93 in Regina. One entire day of the seminar (Feb. 19th)was dedicated to the Advanced House.

The Saskatchewan Advanced House also had a "display" at the Canadian Home Builders' Association National Conference in early February, 1993.

Other Publications
Saskatchewan Research Council - Communications Dept. requested two photographs of the house and any informational brochures we had available.
The information forwarded to them was used in an article on the Advanced House in their semi-monthly publication reaching 4000 subscribers around the world.

2.0 CONSTRUCTION OF THE ADVANCED HOUSE

Cross-sections of the foundation, wall and attic construction are found in Appendix A in the brochure entitled Building Envelope.

2.1 Construction Process

The official sod-turning was held April 1, 1992, and construction began in May. On September 15, 1992, the official opening was held. The Saskatchewan Advanced House was the second Advanced House to be officially opened.

2.2 Construction Waste Minimization

Manufactured truss joists and tech lam beams reduced the need for large dimension lumber. No piece of lumber greater than a 2 x 6 in (38 x 140 mm) size was used in the house

Drywall pieces were placed within stud walls to increase the mass of the house and reduce landfill material.

While the Advanced House was being built, many of the leftover construction materials were reused in the house, sometimes replacing expensive materials that would normally be bought. For example, the shorter lengths of lumber left over from the framing process were able to be reused for blocking and backing.

The waste from brick and roofing tiles were crushed and mixed with gravel for use as fill under the concrete slab for the garage and driveway. Other materials were sold or given away.

During construction there was an attempt to sort construction waste materials by placing them in separate areas in the back yard. However, because of the problems with materials being mixed, this did not prove satisfactory. As a consequence, separate metal bins were brought onto the site to keep separate the construction waste materials.

3.0 EXPECTED PERFORMANCE

3.1 Technical Compliance and Performance Predictions

- The Advanced House annual total energy target as proposed was 20,514 kWh using average year weather conditions.

The individual energy targets for the Saskatchewan Advanced House were as follows, calculated using the formulas presented in the Technical Requirements (Dumont, 1992) for the Advanced Houses Program.

Table 3.1 Annual Energy Targets Based on Average Year Conditions

Annual Energy Targets	**kWh/yr**
Space Heating	8911
Space Cooling	266
Domestic Hot Water	6900
Appliances, Space Heating Distribution	3838
Lighting	416
Outdoor Electricity Target	183
Total	**20514**

With a floor area of 341 m^2 including the basement, the total purchased energy target was 60.2 kWh/m^2 per year.

The projected space heating energy consumption of the Saskatchewan Advanced House, based on the building drawings and a computer calculation using Version 6.02 of HOT 2000, was 8986 kWh. The projected space cooling energy was difficult to estimate, given the prototype nature of the system used. A value equal to the amount used by a vapour compression system was projected (248 kWh). The domestic hot water energy consumption was estimated at 2100 kWh/yr based on the manufacturer's estimate of performance of the solar system, with the remainder of the energy supplied by the solar system panels.

Table 3.2 Projected Annual Energy Consumption Based on Average Year Conditions

Projected Annual Consumption	kWh/yr
Space Heating	8986
Space Cooling	248
Domestic Hot Water	2100
Appliances, Space Heating Distribution Energy (Fans, Pumps)	6676
Lighting	420
Outdoor Electricity Target	183
Total	**18613**

The appliance loads and space heating distribution energy loads were difficult to estimate as well, given uncertainties about the type of appliances used. Most of the major appliances were donated by General Electric. A value of 6676 kWh/yr was used.

The lighting was projected at 420 kWh/yr, based on the use of compact fluorescent lamps or halogen lamps for all interior fixtures. The outdoor electricity target of 183 kWh/yr was used as the projection.

Water efficiency techniques used to bring the house in compliance with the Technical Requirements in the house are listed in the following table:

Table 3.3. Water Efficiency Techniques

	Target	**Actual Measurement**
Toilets	< 7 litres/flush	6 litres/flush
Shower heads	< 10 L/min @ 551 Kpa (80 PSIG)	9.2 L/min
Water efficient landscaping	<50% outdoor use relative to common practice in area	· achieved · Xeriscaped™ front yard · grass areas contoured with clay layer 300 mm below surface to retain water

	Target	Actual Measurement
Clothes washer	Low water consumption/cycle	G.E. Model 850 Medallion with variable settings for water level Energuide rating = 103 kWh/month
Dishwasher	Low water consumption/cycle	G.E. Monogram variable settings Energuide rating = 75 kWh/month

The one disadvantage noted in the house with the water efficiency measures was the increased noise of the toilets when flushing. The pressure tank in the toilet was relatively noisy when discharged.

4.0 MONITORING PROGRAM

4.1 Background to monitoring program

The purpose of the detailed monitoring for the Saskatchewan Advanced House was to gather data on the performance of the house and its advanced systems. The actual measured performance could then be compared to the projected performance, and the targets.

4.2 Continuous long term monitoring

The overall house energy monitoring plan was developed by the Saskatchewan Research Council, Building Science Division, in consultation with the Natural Resources Canada National Monitoring Co-ordinator. The National Co-ordinator ensured that all of the Advanced Houses were evaluated to a consistent standard.

The actual Saskatchewan Advanced House monitoring plan included five major areas. These were air tightness, mechanical systems, indoor environment, utility consumption, and monitoring system electrical consumption.

To achieve proper data collection 52 analog channels, 7 counter channels and 13 digital channels were monitored using a SCIEMETRIC data logger. A separate datalogger supplied by the Saskatchewan Research Council monitored soil temperatures at 22 locations.

The monitoring equipment used in monitoring the Advanced House was a Sciemetric 8082 A datalogger for monitoring the house and a Sciemetric

System 200 datalogger for monitoring soil temperatures. Various types of monitoring devices were used including thermistors, thermocouples, voltage status sensors, current shunts, fluid pulse meters, kilowatt hour meters and natural gas pulse meters.

4.3 Indoor Air Quality Monitoring

The indoor environment was monitored according to the SRC protocol: "Advanced Houses Program Indoor Environment Monitoring Requirements". The "Initial Unoccupied" monitoring period was from April 22, 1993 to April 29, 1993. The "Final Occupied' monitoring period was from June 20, 1994 to June 27, 1994. The "Final Unoccupied" testing was not conducted due to the home being sold and the owners taking possession before the monitoring equipment could be provided.

Mr. Peter Piersol of Ortech Corporation, Mississauga, ON, provided the majority of the testing equipment and analysis. All tests (except Gastec readings) were performed over the same seven day periods. The testing protocol and the measurement equipment used were as follows:

1. Air exchange measurement -

The air exchange measurement system employs a miniature perfluorocarbon tracer (PFT) source and a passive sampler (CATS - capillary adsorption tube sampler) to determine a time averaged indoor tracer concentration, the reciprocal of which times the source rate is approximately equal to the average air exchange rate. By using multiple types of tracers (PFTs) in each zone or floor of a building, information on air exchange from the exterior and between interior zones can be determined. The house could be assumed to behave as one source and only one type of PFT could be used. However, houses usually behave as more than one zone and it is common practise for more than one source type to be used, particularly for multi-level houses such as the Saskatchewan Advanced House.

The house was divided into three zones: basement, main floor and second floor.

Storage and use of the sources and samplers was done according to Ortech's instructions. Following the seven day test period, the samplers were returned to Ortech with subsequent analysis by Brookhaven National Laboratory in Upton, New York.

All of the indoor air quality test results are provided in Section 5 of this report.

2. Formaldehyde in air concentration -

Two Air Quality Research Institute (AQRI) PF-1 formaldehyde monitors were used for each test period. One was used on the main floor and one on the second floor.

Sampling begins when the cap is removed from the end of the glass tube. Formaldehyde in air can then passively diffuse into the tube and collect on the filter at the end of the tube. The filter is treated with a non-toxic chemical (sodium bisulphite) that absorbs formaldehyde. The formaldehyde concentration is determined by laboratory analysis at Ortech. Ortech's instructions for storage and use of the monitors were followed.

3. Total volatile organic compounds (TVOCs) -

Volatile organic compounds (VOCs) include a variety of organic compounds. The sources in a residence include building materials, building contents and human activities. VOCs generally occur in low concentrations with different measurement techniques available. In the case of this house, two different techniques were used as Ortech changed the method during the project due to problems with the use of the active system by some monitoring teams.

For the 'Initial Unoccupied' test, a portable battery operated sampling pump was used to collect TVOC, on a multi-adsorbent Supelco tube. The tube was analysed by gas chromatography/mass spectrometry (GC/MS) and the amount of TVOCs collected together with the volume of air sampled is used to determine a time averaged indoor TVOC concentration. The flow rate of the monitor was pre-set and pre-calibrated by Ortech. The sampling period for this method of testing is five to seven hours. Sampling was done according to Ortech instructions.

For the 'Final Occupied' test, a passive 3M™ organic vapour monitor #3500 was used over the seven day test period. The contaminants enter the monitor by diffusion and are adsorbed by an active adsorbent medium (charcoal) inside the badge. The amount of contaminant adsorbed is determined by exposure time and contaminant concentration present in the sampled environment. Analysis was done using gas chromatography.

4. Radon -

Radon monitoring was conducted with a device provided by the Canadian Institute for Radiation Safety (CAIRS) designed for residential use. The monitor is an active track etch system which measures levels of radon daughters over a seven day period. Instructions on the use of the instrument were provided by CAIRS.

5. Airborne particulates -

The airborne particulate monitor used employed a small 120 volt sampling pump to collect airborne particulate on a preweighed PVC filter. The filter was contained in a cassette. The filter was reweighed after sampling and the amount of particulate collected together with the volume of air sampled was used to determine a time averaged indoor airborne particulate concentration. The flow rate of the sampling pumps provided were set and pre-calibrated prior to shipment. The sampling period for this test was seven days.

6. Various gases -

Short term (grab sample) measurements were made using Gastec™ color indicating tubes and a Gastec™ pump to monitor specific indoor pollutants. Gases measured include: carbon dioxide, carbon monoxide, nitrogen dioxide, ozone and sulfur dioxide.

4.4 Emissions Tests

As a component of the indoor environment testing, the house builder was supplied with Tedlar bags and instructions to collect various building products from their project for emissions testing in the SRC laboratory. The Saskatchewan team collected four samples which they considerable suitable for VOC or formaldehyde testing. They included: one carpet sample, two plywood samples and one linoleum sample. Of the four samples, only the linoleum sample was used in the building products emissions project.

The samples were collected on-site and sealed in Tedlar bags. The samples were stored in SRC's laboratory prior to testing.

4.5 One-time tests

Air flows at the registers were measured using a WALLAC flowmeter, while the HRV flows were measured using flow grids and a micro-manometer.

Commissioning tests were performed on all the instrumentation pieces.

5.0 MONITORED RESULTS

5.1 Overview

5.1.1 Summary of Data Collected

The Saskatchewan Advanced House was monitored manually from late December 1992 until January 1993, and then continuously using a datalogger until the end of August 1995. Extra submetering and continuous monitoring for garage floor heat, natural gas dryer and natural gas range gas consumption were installed in December 1994. The monitoring period for this report is from September 1, 1994 to August 31, 1995. This period was used to be consistent with the time period used for monitoring all the Advanced Houses across Canada.

5.1.2 Weather during the Monitoring Period

A plot of the monthly average ambient temperatures for the period from September 94 to August 95 is presented in figure 5.1. Also shown on the figure are the long term monthly average values as used in the HOT-2000 program. For the 12 month period, the heating degree day total was 5782 °C-d, which was 3.6% fewer than the long term average for Saskatoon of 5997 °C-d. The one month which had an average temperature significantly different from the long term average was January, 95. In that month the measured ambient temperature average was 4.2 °C warmer than the long term average.

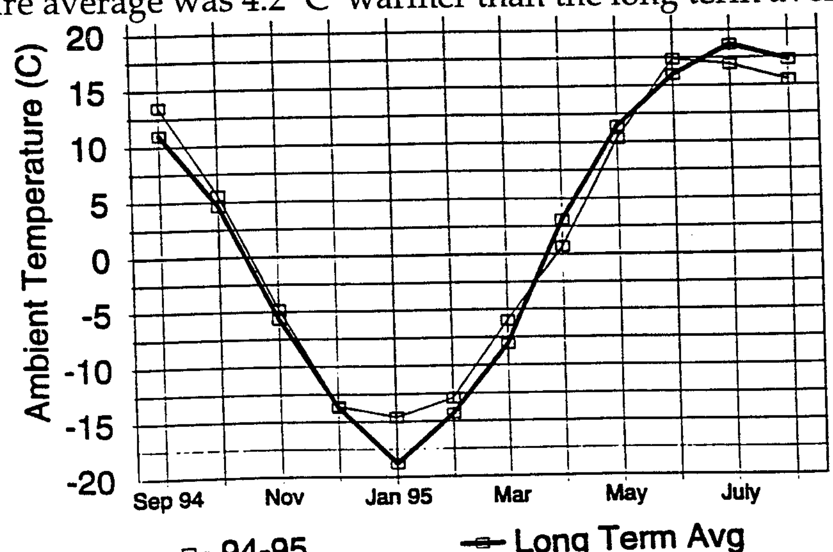

Figure 5.1 Monthly Ambient Temperatures During the Monitoring Period

Table 5.1. Saskatoon Heating Degree Days (base 18° C)

Long term used for HOT2000	One year data for September 1, 1994 to August 31, 1995
5997	5782

The solar radiation on a horizontal surface during the monitoring period is presented in figure 5.2. The long term average values are represented by the heavy line, and the monitoring period values by the narrow line. Through most of the monitoring period, the solar radiation values were below the long term average. The greatest deviations below the long term average occurred during the months of June, July, and August.

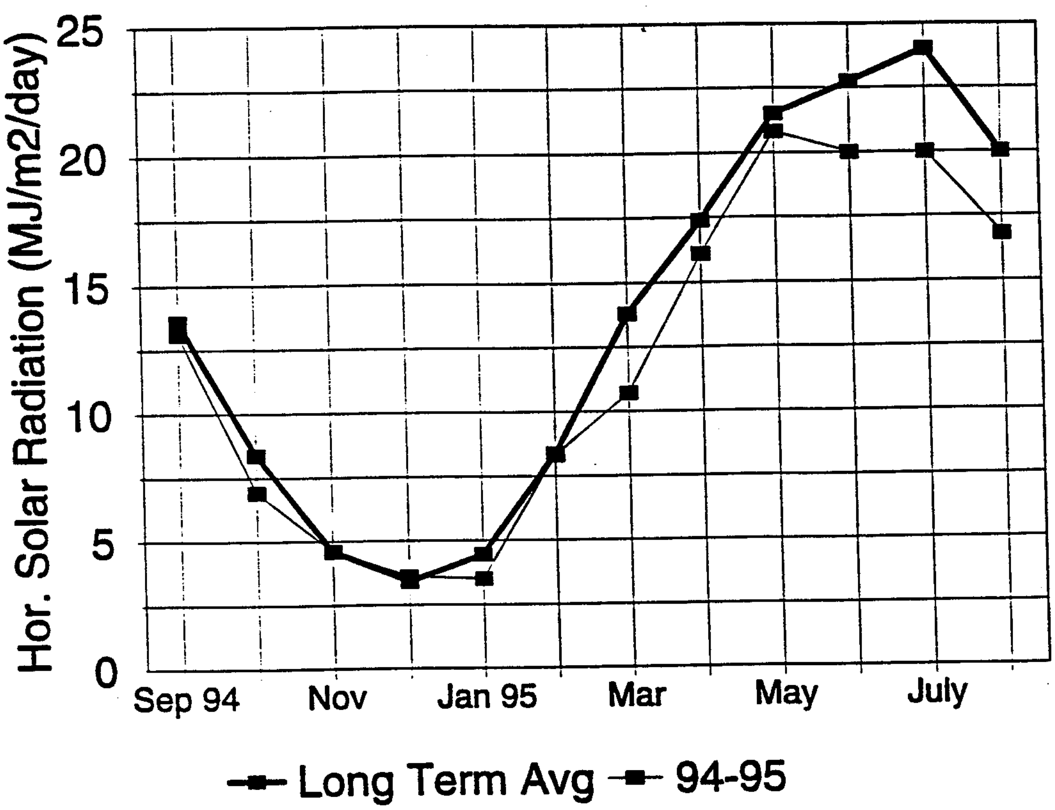

Figure 5.2 Horizontal Solar Radiation During the Monitoring Period

5.1.3 House Operation

Major events occurring during the monitoring period were as follows:

- Two natural gas pulse meters were installed November 7, 1994 for sub-monitoringthe kitchen range and the dryer.

- Garage floor heat was sub-metered as of December 10, 1994.

- Repairs to solar DHW preheat system were made on February 15, 1995
  - relocated glycol lines in attic
  - modified valve arrangement for filling and de-airing system
  - installed fluid check value
  - system recharged and has worked well since

- Natural gas leak detected and repaired on exterior line to range June 5, 1995.

The occupancy of the house during the one year period September 1, 1994 to August 11, 1995 varied between two and five adults.

5.1.4 Comparison of actual energy consumption to targets

A comparison of the annual purchased energy consumption for the house with the target value is presented in Table 5.2. The actual values exclude the space heating for the garage (6780 kWh) and one-half of the electrical energy for the monitoring equipment (0.5 x 1196 kWh). The reason for excluding one half of the electrical energy used by the monitoring equipment (computer, monitor, and data logger) is that only about one-half of the energy used by the monitoring equipment is useful for space heating. The remainder of the energy is released when there is no space heating requirement for the house.

Table 5.2 Actual Energy Consumption (September 1994 - August 1995) Versus the Target Value

	Target kWh	Purchased kWh
Heating	8911	21796
Cooling	266	68
Hot water	6900	* -160
Lights	416	247

	Target kWh	Purchased kWh
Appliances, etc.	3838	9184
Outdoor Electrical	183	187
Totals	**20514**	**31322**

* Actual is negative as energy supplied by solar system to the tank (3276 kWh) exceeded demand (3116 kWh). Because of heat losses from the tank, however, some supplementary natural gas energy was required for DHW. Because the natural gas fired water heater supplied both space and water heating, the natural gas required to heat the domestic hot water could not be directly measured.

5.1.5 Summary of Peak Loads

The peak loads for the house occurred on December 10, 1994 when the outdoor air reached a value of -33.9°C. At that time the natural gas consumption rate peaked at 20.8 kW.

Table 5.3 Winter Peak Loads

Date	Outdoor Air Temperature	Peak Natural Gas Consumption kW	Corresponding Peak Electrical Consumption kW
December 10, 1994	-33.9°C	20.8	2.4

The summer peak loads consisted of 10.9 kW for natural gas, and 2.1 kW for electricity.

5.1.6. Profiles of Natural Gas and Electricity Consumption

The monthly profiles of natural gas and electricity consumption are presented in figures 5.3 and 5.4.

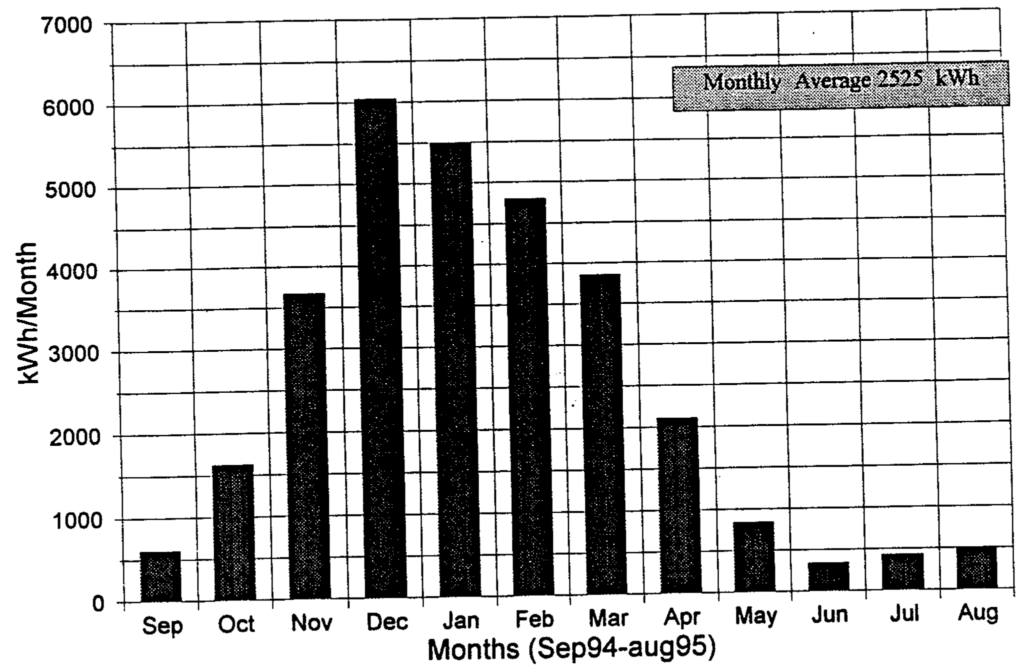

Figure 5.3. Monthly natural gas consumption

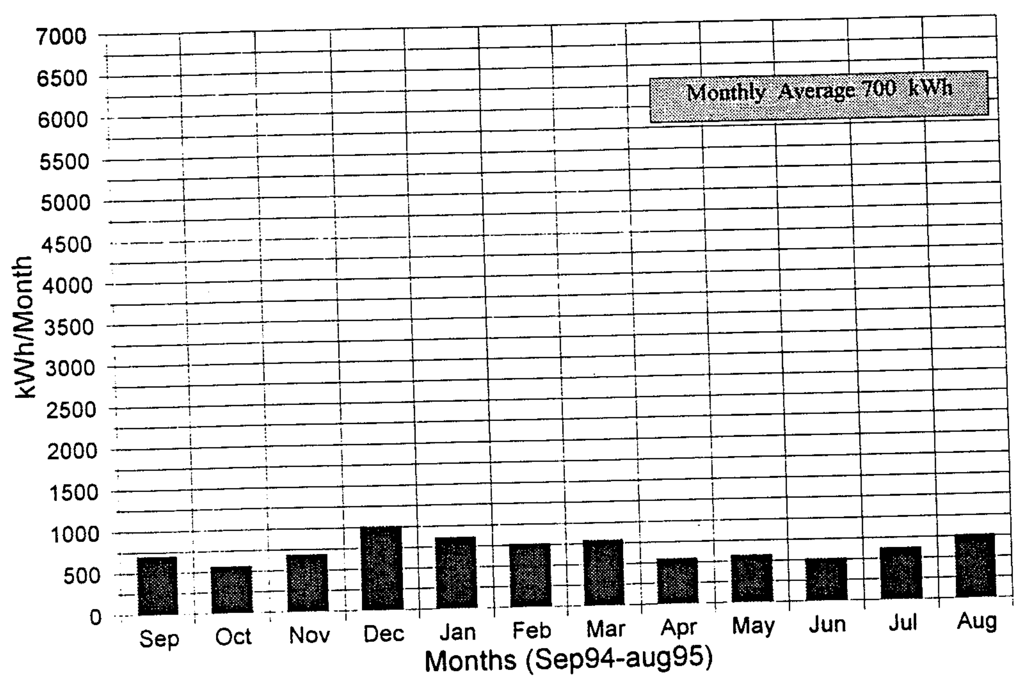

Figure 5.4. Monthly electricity consumption (AC grid)

Monthly graphs for the consumption of electricity by appliances that were submetered are presented in Appendix B.

In summary, the monthly average electrical consumption values for the submetered equipment were as follows:

Table 5.3. Submetered Electrical Energy Consumption

	kWh/month
Data Acquisition Computers & Loggers	99.7
G.E. Refrigerator	86.4
Freezer	37.7
Natural Gas Range Electrical Consumption	21.7
Inside Lights (Hard Wired)	20.6
Natural Gas Water Heater Electrical Consumption for Controls and Exhaust Fan	18.9
Dishwasher	14.3
Outside Lights	12.7
Battery Charger for PV System	10.4
Clothes Washing Machine	5.5
Natural Gas Clothes Dryer	4.0
Outside Plugs	2.9
Totals	**334.8**

Because of the expense, not all the plug circuits in the house were submetered. However, the energy consumed by circuits which were not submetered was able to be calculated by subtracting the sum of the submetered circuit readings from the total house meter readings.
The monthly values for the "unmetered" (or, to be more precise, not-submetered) electrical consumption are presented in figure 5.5. The average monthly value was 365 kWh.

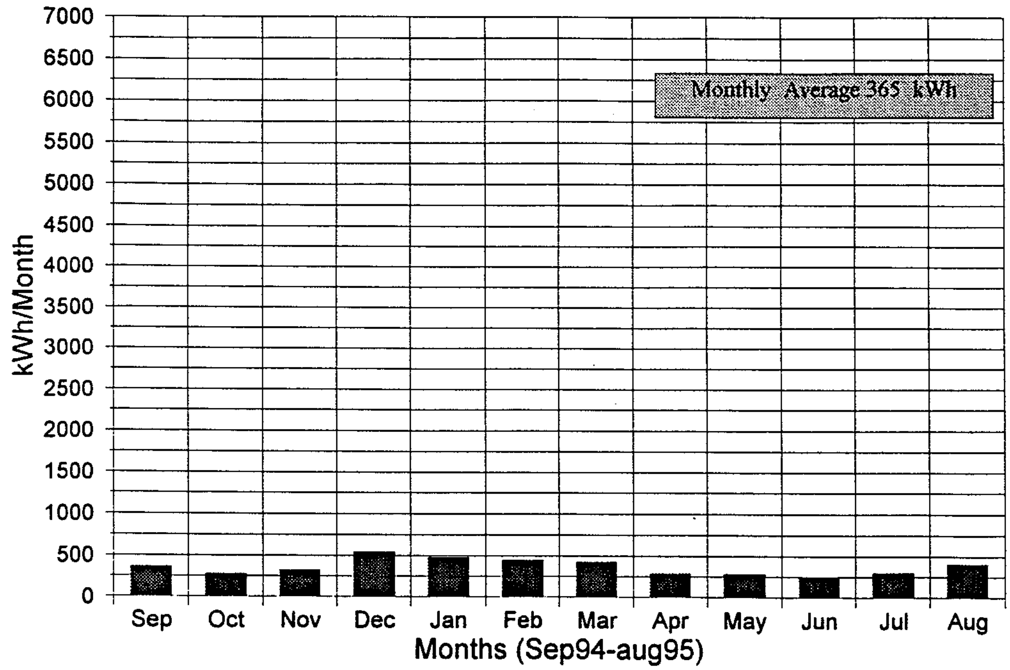

Figure 5. 5. Monthly electricity consumption of loads that were not submetered

The consumption on this plot represents the usage by the following devices:

Coffee maker - Black & Decker

Microwave oven - GE Space Saver

Solar system controller - Delta-T

Solar system pump - Armstrong SSCB30

Pump on DHW tank - Bell & Gossett SLC-25B

Pump on Hydronic System Glycol Loop - Armstrong SSC-B50

Pump on Radiant Ceiling Panel Glycol Cooling Loop - GRUNDFOS UP 26-64F

Bell circuit

Home automation circuit - Honeywell

Telephone system - Sony SPP-A40

Controller for HRV

Central vacuum cleaner - VACUFLO Model 360

Plug loads (plug-in lamps, television, radios, VCR, home theatre system, etc.)

As can be seen from the above figures, 52% (365 kWh/month out of 700 kWh/month) of the electrical consumption was consumed by the devices that were not submetered. In hindsight, it would have been useful to submeter these devices.
The following table presents the estimated consumption of the major non-submetered electrical loads in the house.

	Estimated electrical consumption kWh/month
Speakers for the home theatre	94
Solar system pump	3.9
Radiant floor heating pumps	19.8
Radiant cooling system pump	5.7
Subtotal	123.4
Remaining non-submetered loads	242

The largest consumers among these devices were the speakers for a large home theatre system. It is estimated that these speakers, even when in the off mode, consumed about 94 kWh per month. For comparison purposes, this consumption exceeded the useful output of the photovoltaic system. The four pumps on the system had relatively long run times and were major consumers among the devices that were not submetered. The solar loop pump had a measured electrical power of 29.6 watts, the radiant floor heatingpump used 88 watts, the pump to the water/glycol heat exchanger for the radiant floor heating used 70 watts, and the summer radiant cooling loop pump used 117 watts. The solar pump is estimated to have run for about 2/3 of the sunshine hours during the year, or 1600 hours. The electrical consumption of this pump for a year would equal about 47 kWh. The radiant floor heating pumps likely ran about 1500 hours for the year, and used about 237 kWh. The radiant cooling pump ran 382 hours for the year, and used 68 kWh.

5.1.6 One Time Electrical Power Measurements

Electrical loads were measured using a Lutron digital wattmeter. The following table presents the measurement results. It is interesting to note the substantial consumption of some appliances even when the units were nominally "off".

Table 5.4. One Time Electrical Load Measurements

LOAD	ON WATTS	OFF WATTS
Data acquisition units	Monitor on 156	Monitor off 126
Refrigerator (G.E.)	205	0
Telephone system	3	0
Freezer	92	0
Washer	487	0
Gas dryer	200	0
Gas range	400	0
Microwave	1270	7
Coffee maker/can opener		2
Dishwasher	346 washing 300 pumping	0
A/A heat exchanger		11
Honeywell total home system	--	13.5
Television	110	11
Video cassette recorder	16	6
Lights (hard wired) Outside (front)	269	0
CD player	15	1
Polaris water heater	85.5	5
Central vac	673	0
PUMPS		
Solar loop	29.6	0
Radiant floor heat	88	0
Radiant cooling loop	117	0
Pump to heat exchanger for radiant floor heat	70	0
Speakers for home theatre		130
TOTALS	**4,632.1**	**312.5**

5.1.7 D.C. Loads

The photovoltaic system produces 24 volt DC power. There were four DC electrical loads in the house, all of which were 24 volt loads: a refrigerator-freezer, the DC motors on the VAN Ee 2000+ HRV, a DC fan to exhaust hydrogen from the battery room, and emergency lighting. It was originally envisioned that DC pumps would be used on the solar system, and for the space heating and cooling pumps. Unfortunately, the only 24 volt DC pumps that could be located had unacceptably high sound levels due to the brushes, and, as a consequence, AC pumps were substituted.

Refrigerator-freezer

The electrical energy consumption of the Photocomm DC refrigerator-freezer is plotted in figure 5. 6. The monthly electrical consumption averaged a very low value of 17.5 kWh. This performance is **outstanding**, given that new 1992 conventional refrigerator-freezer units of that size use between 51 and 78 kWh per month, according to the 1993 Energuide booklet. As the refrigerator-freezer had been placed in the basement, it was subject to fewer door openings than had it been located in the kitchen.

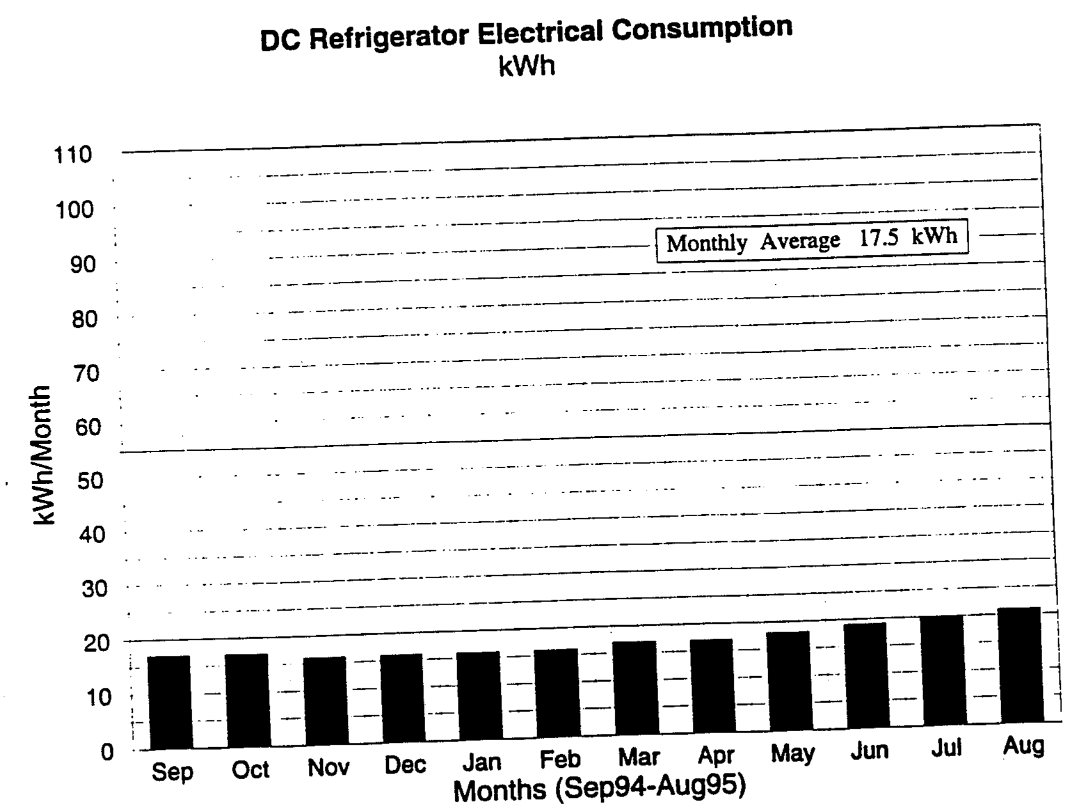

Figure 5.6. Monthly DC power consumption of Photocomm Refrigerator-Freezer

The manufacturer quotes a measured consumption of 24 kWh per month.

HRV Fan Motors

Brushless DC Fasco motors were used on the HRV. The monthly consumption values are plotted in figure 5.7. The reason for the major reduction in HRV energy consumption starting in December, 1994 was the reduced air flow setting. In November, the average monthly supply air flow was 56 L/s; in December the supply flow was reduced to 36 L/s. One of the great advantages of DC motors is the ease of speed control compared with AC motors.

In the Advanced House, there is no forced air heating system. As a consequence, a fully ducted HRV installation was used. The extra ducting involved in this system results in greater pressure drops, and higher energy consumption compared with a system with shorter ductwork.

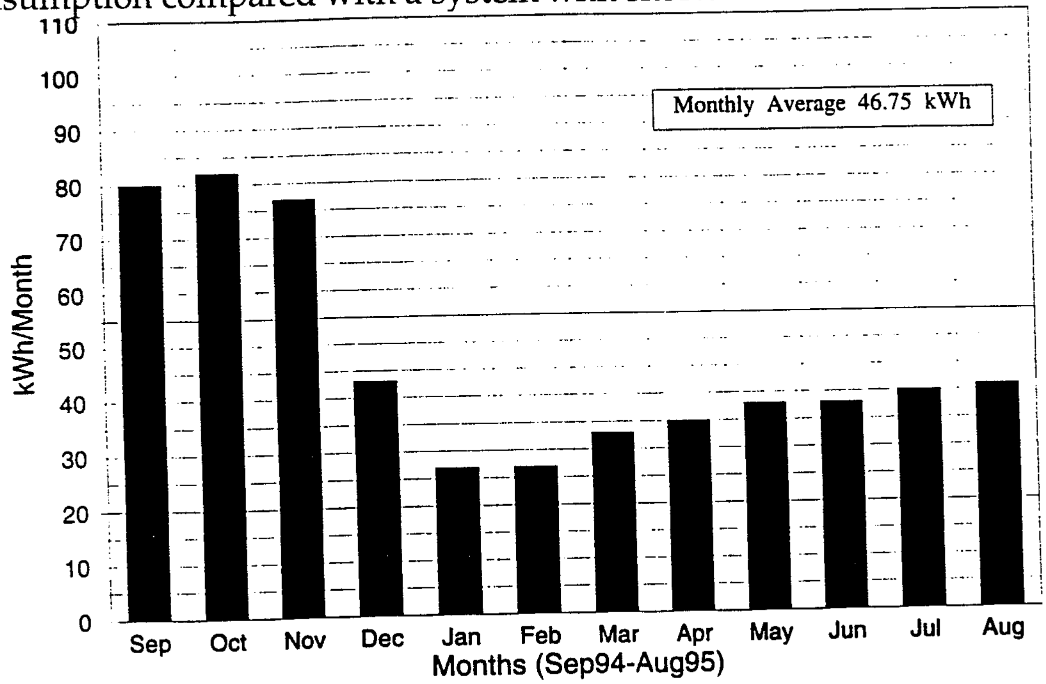

Figure 5.7.Monthly DC power consumption of HRV Fan Motors

The Advanced Houses Technical Requirements had a target for energy consumption for the HRV equal to 1.2 watts/(litre/second) of air flow when a 100% outside air system was used. For the Saskatchewan Advanced House, the corresponding measured consumption figures for the two flow rates used were as follows:

a. Air flow of 56 L/s

HRV Electrical Consumption	
AC Control System	11 watts
DC motors (2) on fans	109 watts
Air flow	56 L/s
Power consumption	2.1 watts/(litre/s)

b. Air flow of 36 L/s

HRV Electrical Consumption	
AC Control System	11 watts
DC motors (2) on fans	38 watts
Air flow	36 L/s
Power consumption	1.4 watts/(litre/s)

As can be seen, the power consumption values at both the higher and lower flow rates both exceeded the target of 1.2 watts/(litre/s). At the lower flow rate, the measured power consumption of 1.4 watts/(litre/s) was only slightly greater than the target of 1. 2 watts/(litre/s). In future projects, more careful design of the duct system to minimize frictional losses could be used to reduce the power consumption. The use of backward curved fans could also be used to reduce the electrical consumption.

Battery Room Exhaust Fan

The small axial flow DC fan in the battery room consumed an average of 0.9 kWh per month. A plot of the monthly consumption for this fan is presented in figure 5.8.

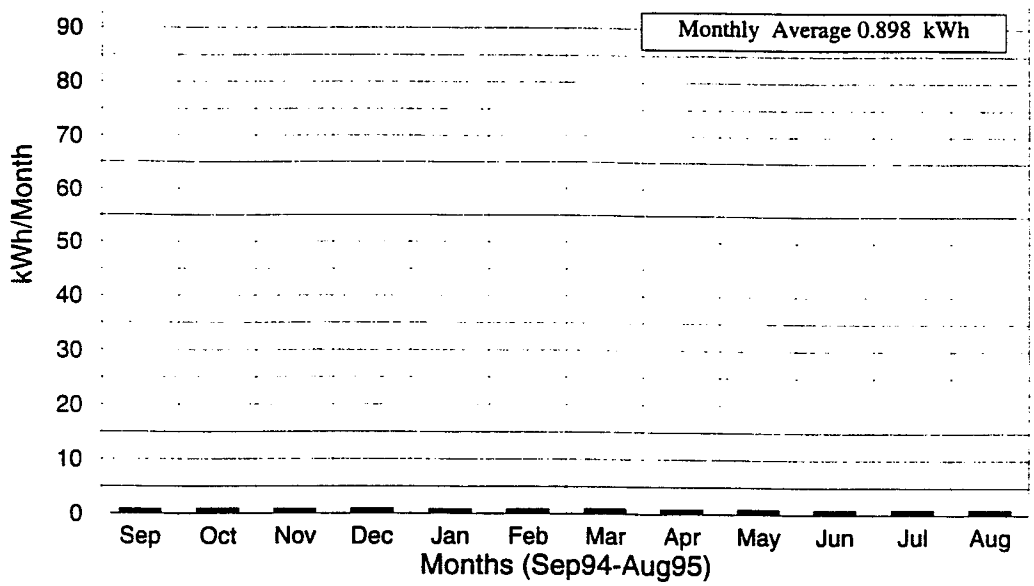

Figure 5.8.Monthly DC power consumption of battery room exhaust fan

Security Lighting

The DC security lighting would only be turned on if the AC main electricity was off for the house. As this did not occur during the monitoring period, there was no consumption associated with the security lighting.

The combined DC loads for the house were as follows:

Table 5.5 DC Electrical Loads

	kWh/year
Photocomm Refrigerator	210
HRV Fan Motors	781
Battery Room Exhaust Fan	10.8
Totals	**1001.8**

The battery charger had to supply the following amount of energy over the one year monitoring period.

Table 5.6 Electrical Energy Required by Battery Charger

	kWh/year
Battery charger	**124.8**

The net useful electrical energy supplied by the PV system was 877 (1001.8 - 124.8) kWh for the one year monitoring period.

The initial estimate was that the PV system would provide approximately 1 kWh per year per installed peak watt, or about 1900 kWh per year.

In the original design of the house, DC motors were planned for the solar system pump, the two radiant floor heating pumps, and the cooling pump. Because of noise problems, these DC pumps were not installed, and the DC loads on the system were much lower than anticipated. With a PV system connected to batteries, there is no ability to store energy beyond the capacity of the battery system. For this reason, the PV system output was measurably lower than anticipated. Had there been higher DC loads, the PV system output would have increased.

5.1.8 Total Water Consumption

Monthly total water consumption is presented in figure 5.9. The average monthly water consumption was 24,583 litres or 819 L/day. As can be seen, the water consumption was highest during the months of June, July, August and September due to exterior usage for gardening.

This consumption of 819 L/day represents a reduction of 24% compared to a sample of conventional Saskatoon homes.

Monthly water consumption was higher during the winter months of December, January, February and March because of higher occupancy. During these months there were times when 5 adults were living in the house. In most of the other months 2 or 3 adults were in the house.

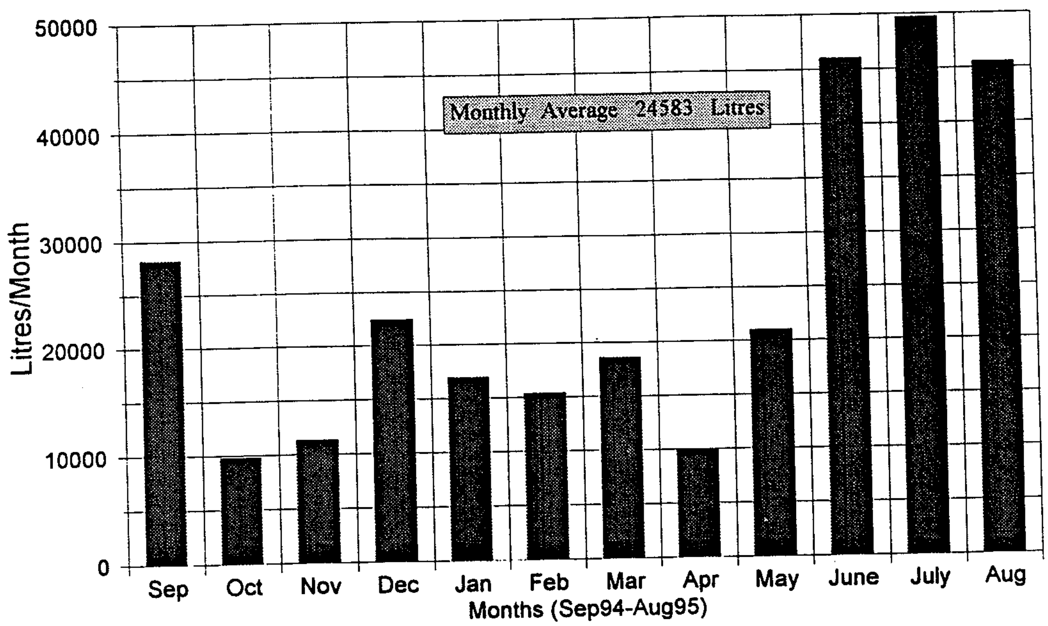

Figure 5.9. Monthly total water consumption

Monthly domestic hot water (DHW) consumption is presented in figure 5.10. The average monthly DHW water consumption was 5,692 litres or 190 L/day. This represents a reduction of 23% compared to the HOT-2000 default value.

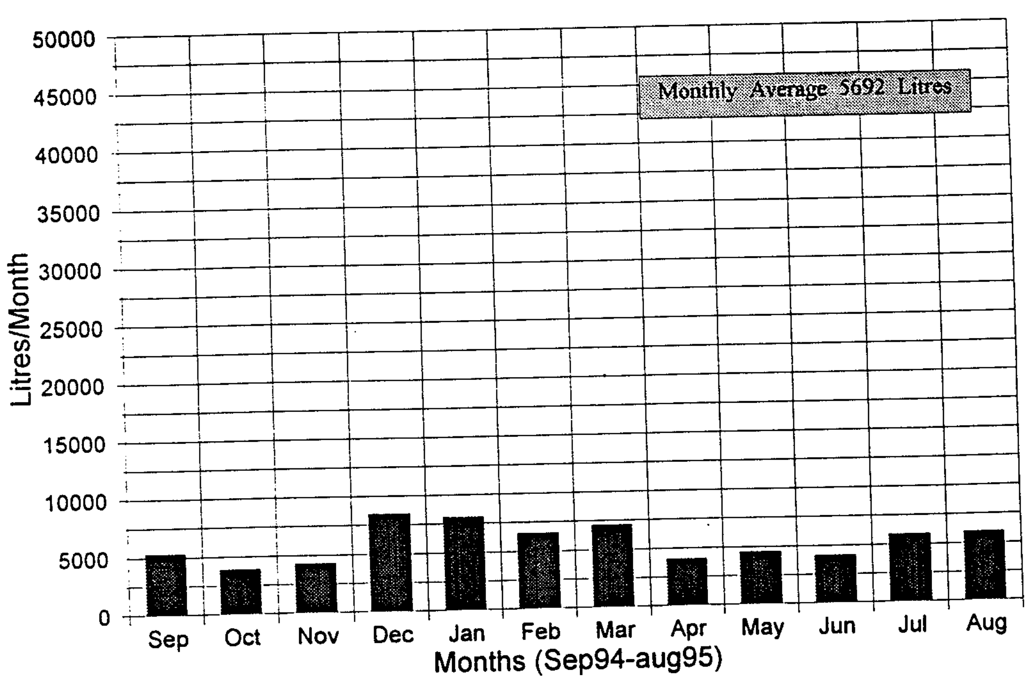

Figure 5.10. Monthly total DHW consumption

5.1.9 Discrepancies to targets

Space Heating

The space heating consumption (21,796 kWh) of the Saskatchewan Advanced House was considerably greater than the target (8911 kWh). There are a number of reasons for this.

1. Poor attic insulation performance
   Because of problems with leaks on a fitting connecting a copper pipe to the cross-linked polyethylene pipe carrying the glycol fluid from the solar collector to the storage tank, a considerable amount of work was performed in the attic. This work resulted in substantial compression of the low density glass fibre insulation in the attic space. A second problem with the attic insulation system was the placement of the aluminum heat transfer plates for the radiant cooling system in the second floor ceiling. These plates did not always lie flat against the horizontal gypsum board for the ceiling. Air spaces exist under many of the aluminum plates. As a consequence, there existed an opportunity for convective cells to operate in the attic insulation.

   The combined effect of the insulation compression and the convective cells was to dramatically reduce the effective value of the ceiling insulation. A graph comparing the attic air temperature with the outdoor air temperature for the house is presented in figure 5.11. As can be seen from the graph, the attic air temperature is consistently higher than the outdoor air temperature. By performing a steady state heat loss calculation, it was estimated that the attic insulation is providing a thermal resistance value of about RSI 2, when a nominal value of RSI 12.3 was installed.

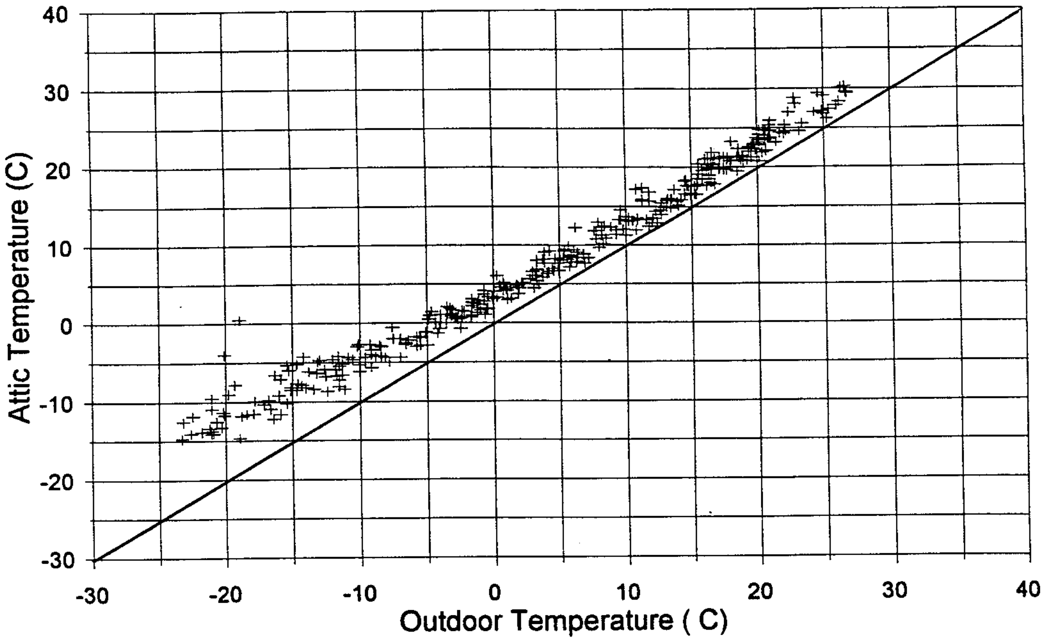

Figure 5.11. The attic air temperature versus the outdoor air temperature

A HOT-2000 run was performed to investigate the effect on the annual space heating of reducing the attic insulation level from RSI 12.3 to RSI 2. The calculated increase in space heat amounts to 5490 kWh per year.

Because of the magnitude of this problem, the attic insulation will be retrofitted. The compressed insulation will be topped up, and a layer of cellulose insulation will be added on top of the existing insulation to suppress convection cells.

2. Pilot light consumption of the natural gas fireplace.
   The natural gas fireplace used in the Advanced House has a continuously burning pilot light. The energy consumption of the light is substantial. The measured consumption of the pilot light amounted to 1557 kWh for the year. Although some fraction of this heat could remain in the house, it is likely that the thermosyphon air flow caused by the pilot light causes very little of the heat from the pilot light to remain in the house.

3. Problems with solar heating system
   The liquid solar collector system, comprising 6 square metres of vacuum tube collectors and a water storage tank of 3400 litres, was not functioning from December 10, 1994 to February 10, 1995 due to glycol leaks. As a consequence, the useful heat from the collectors was not available during this time. Although this heat is primarily used for domestic hot water, heat

losses from the tank do provide useful space heat. A plot of the temperatures in the 3400 litre storage tank for the 1 year monitoring period is presented in figure 5.12.
As can be seen from the figure, the solar storage tank temperatures were on average below 50°C throughout the monitoring period. Domestic hot water temperatures should be above about that temperature to limit the growth of legionella and other bacteria. One reason that the solar tank did not reach higher temperatures was the heat loss from the storage tank. The tank was insulated with RSI 3.5 batt insulation, but the large surface area of the rectangular tank caused amount of heat loss to increase relative to a smaller storage tank. In the winter months, the tank heat loss is useful for space heating, but in the summer period, tank heat losses increase the cooling load for the house.

When large solar storage tanks are used, the benefit of increased heat storage capacity must be weighed against the increased tank losses associated with the larger surface area. Increased amounts of tank insulation can be used to mitigate the problem of heat loss.

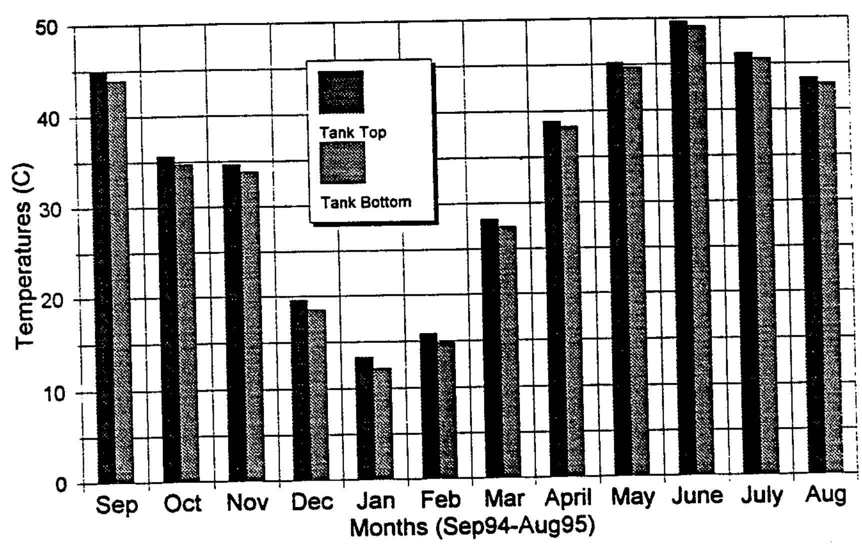

Figure 5.12. Solar storage tank temperatures

4. Reduced efficiency of the Morflo Polaris natural gas water heater system

There are four reasons why the space heating supply system was less efficient than projected. In the Hot-2000 computer projection, a value of 94% was used for the seasonal efficiency of the unit. Because of the following four factors, however, the actual efficiency was considerably lower.

1. High water temperature entering the water heater.

The Morflo Polaris unit provides both space and water heating for the house. The Morflo unit is advertised as a high efficiency condensing unit. The high efficiency of the Morflo unit is partly based on the assumption that relatively cool water (i.e cold potable water at approximately 2 to 15 ^{o}C) will be entering the unit, and that condensing conditions will occur on the combustion gas side for most of the operating hours throughout the year.

In the Advanced House. The domestic hot water is first preheated in the solar preheat tank. Thus, relatively warm water is fed to the Morflo unit throughout the year. As a consequence, the likelihood of condensing of the combustion gases is reduced because of the relatively high entering temperature of the potable water.

In addition, the heat exchanger for the radiant floor heating loops was undersized in terms of heat transfer effectiveness. The effect of this undersizing is dealt with in more detail on the next page.

2. Short cycling of the Morflo Polaris

The Morflo Polaris is a sealed combustion unit. Air is taken from outdoors for combustion, and the combustion gases are vented directly to outdoors. For safety reasons, the unit includes a purge air flow cycle for each firing. This purge cycle vents some of the heat out of the unit.

The Morflo also has a relatively small dead-band on the thermostat controlling the burners. While not measured, the thermostat dead band is likely only 2 or 3 degrees C. As a consequence, the unit has many more on-off cycles than would be expected . The thermostat deadband is likely appropriate for a normal water heating application, where hot water is removed from the water heater, and cold water is admitted. Under those conditions, the water heater will have long firing cycles.

In the Advanced House, however, the water heater is over-sized for the loads. The capacity of the unit is approximately 2.2 times the **peak** space heating loss of the house.

This combination of over-sizing of the heating capacity relative to the load and the narrow deadband on the thermostat contributes to lowered efficiency of the water heater.

Frequent cycling of the water heater burner reduces efficiency because of the purge cycles and transient heat storage effects. For instance, on December 4, 1994, the outdoor air temperature at 6 a.m. was -25.9 °C. For that one hour, the gas water heater went through 12 firing cycles, and the burner was on for 1423 seconds, for an average of only 119 seconds per burn cycle. A well-installed, properly sized furnace system in colder weather will typically have burn cycles of 720 seconds or more.

This large number of firing cycles each hour, in addition to reducing efficiency, results in greater mechanical wear on the gas solenoid valve and the combustion exhaust fan on the water heater, and reduces the life of these components.

3. Undersizing of the water- to- glycol heat exchanger used for the radiant floor heating loop

For optimum efficiency, it would be desirable to omit heat exchangers and use water to heat the radiant floor system. In the Advanced House, however, the garage has radiant floor heating, and would be prone to freezing if water had been used in the piping. (For example, if a pump or valve failed and the garage door were left open, the water in the radiant floor loops could readily freeze in cold weather). For this reason, a glycol mixture was used in the radiant floor heating loops, and a heat exchanger was needed in the system.

The heat exchanger used in the radiant floor heating system is a compact plate type heat exchanger. Its limited size affects its effectiveness. For instance, the outlet temperature of the glycol leaving the heat exchanger in the system is approximately 35°C (as measured by the data logging system) even though the inlet temperature of the hot water entering the heat exchanger is about 52°C, and the mass flow times specific heat values for the two flows are roughly equal. A larger heat exchanger would allow the outlet temperature of the glycol to be much closer to 52°C.

Another problem with the compact plate heat exchanger was the buildup of minerals and sediment on the water side of the exchanger. The exchanger had to be cleaned on the water side to restore its original effectiveness after several years of operation. There are plans to replace this heat exchanger with a unit that has a much higher effectiveness, and less constricting flow passages (to limit fouling of the heat exchanger on the water side.)

It is difficult to assign an exact efficiency penalty to the compact plate heat exchanger used in the system, as there was not enough instrumentation installed in the system to allow a detailed analysis. However, a heat exchanger in a system such as this will always cause a decrease in performance. The use of glycol, which has poorer heat transfer properties than water, also will cause the efficiency to fall.

4. Use of outdoor air for combustion

The Polaris water heater is a sealed combustion unit, drawing combustion air from outdoors. As the outdoor air temperature falls, less useful energy is transferred from the combustion gases to the water in the tank. It is difficult without detailed monitoring to assign a value to this lowered efficiency.

These four factors in the space heating system all contribute to reduced efficiency of the water heater as a space heating source.

During the detailed computer-based monitoring, it was not possible to quantify the reduction in efficiency of the water heater. Although the liquid flow meters with pulse outputs were commissioned properly and checked for calibration, the Sciemetric data logger pulse counting modules were over-counting the pulse outputs, and overestimating the flow rates. Thus this part of the data from the data logger was not usable.

In the HOT-2000 calculation for the house, an efficiency of 94% was assumed based on the manufacturer's literature. A more reasonable seasonal efficiency for the unit would likely be considerably lower when the effect of the factors outlined above are included.

A revised computer calculation of the space heating requirement was performed, using 94-95 weather data, actual occupancy loads, internal gains, and an attic insulation value of RSI 2.0. In order for the computer calculation to approximately match the measured performance of the house, the water heater efficiency seasonal efficiency had to be reduced to 60%.

It should be stated that the seasonal efficiency factor of 60% is a calculation based on a number of assumptions, and may not be indicative of the actual performance of the heating system. Further monitoring with more instrumentation would be required to more definitively assign a seasonal efficiency to the system.

The following table summarizes the original target for the house, the original computer projection of the house performance, the measured performance, and the revised computer calculation using 94-95 conditions and a water efficiency to the system.

The following table summarizes the original target for the house, the original computer projection of the house performance, the measured performance, and the revised computer calculation using 94-95 conditions and a water heater efficiency of 60%.

Comparison of Energy Use of House Components

	Original Target based on average year weather	**Original Computer Projection based on house design and average year weather**	**Measured Consumption for 94-95**	**Computer Calculation using 94-95 Weather, actual occupancy loads, actual internal gains, attic =RSI 2.0, water heater eff.=60%**
Annual Energy Use	**kWh/yr**	**kWh/yr**	**kWh/yr**	**kWh/yr**
Space Heating (excluding garage heat)	8911	8986	21796	20083
Space Cooling	266	248	68	68
Domestic Hot Water	6900	2100	-160	0
Appliances, Space Heating Distribution	3838	6676	9184	9184
Lighting	416	420	247	247
Outdoor Electricity	183	183	187	187
Total	**20514**	**18613**	**31322**	**29769**

As can be seen from the last two columns, a relatively low efficiency of 60% had to be assumed in order to get reasonable agreement between the measured and

Interior Temperatures in Winter

For the period from October 1994 to April 1995, the outdoor temperature averaged -5.3 °C. The interior temperature in the main floor south room averaged 22.9 °C, with no hours less than 18 °C and no hours greater than 26 °C.

Thus thermal comfort conditions were achieved throughout the winter. This temperature, however, was higher than the default temperature used in the HOT-2000 runs.

Interior Relative Humidity

October-April

For the period from October through April, the average relative humidity in the house was 17%, with a minimum of 8% and a maximum of 42%. For 97% of the time during the October to April period, the indoor relative humidity was below 30%, which is often used as a guideline for minimum winter relative humidity. Most houses on the Canadian prairies, however, also experience relative humidity values lower than 30% during the colder winter months, as values higher than 30% will often result in window condensation problems.

Saskatoon experiences low outdoor absolute humidity values during the heating season, as the outdoor temperatures are low. As the house is ventilated continuously with the heat recovery ventilator, the dry outside air tends to de-humidify the house. The Saskatchewan Advanced House does not have a humidifier.

A plot of the indoor relative humidity in the house over the 12 month monitoring period is presented in figure 5.13.

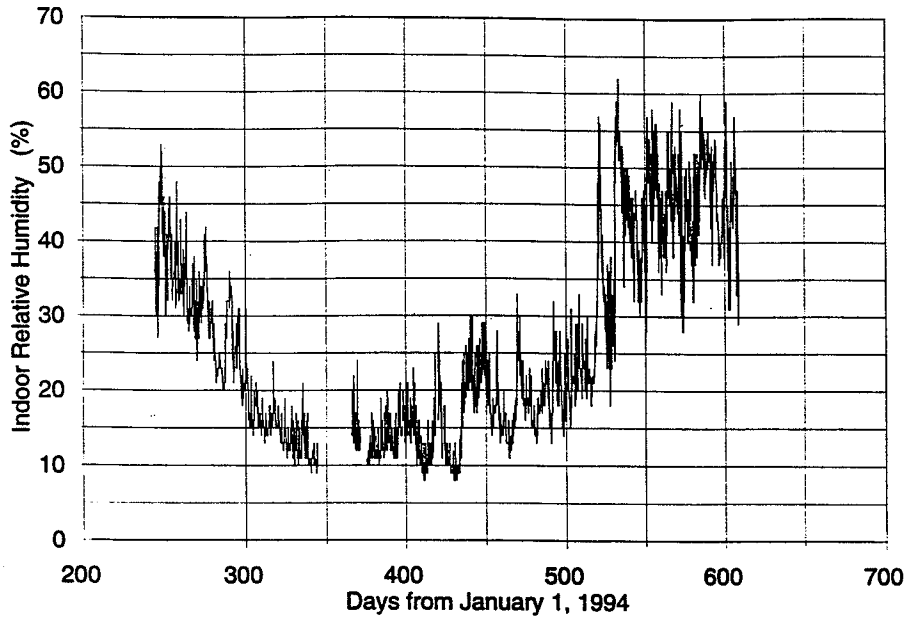

Figure 5.13 Relative humidity in the house over the monitoring period

May-September

For the period from May through September, the average relative humidity in the house was 37% with a minimum of 13% and a maximum of 62%. The percentage of time with the relative humidity above 60% was less than 0.5%. The percentage of time with the relative humidity in the 50%-60% range was 15%.

This low relative humidity in the summer period is of particular interest in the Saskatchewan Advanced House, as the radiant cooling panels used are susceptible to condensation if the relative humidity is too high. For instance, with air at a relative humidity of 50% and an air temperature of 22 °C, the dew point for the air is about 11 °C. Any surface which is at or below 11 °C will experience condensation. The radiant cooling system was found to have a minimum water temperature of 12 °C in the early spring. At the peak indoor relative humidity measured of 62% during the summer period, the dew point for a room air temperature of 25 °C is 17 °C. Thus there is a slight potential for condensation on the radiant cooling panels during periods of high indoor relative humidity and low liquid temperatures. No condensation damage was noted, however, from the radiant cooling panels on the Saskatchewan Advanced House.

In areas of the country, however, with higher outdoor relative humidity values in summer, and consequently, higher indoor relative humidity levels, the potential exists for condensation on radiant cooling panels using cool water. Measured such as de-humidification can be taken to minimize the risk of condensation.

Space Heat for the Garage

In-floor radiant heating was included in the double car garage for the house. The homeowner preferred to keep the temperature in the garage in the range of about +5 to +10 °C through the heating season. A plot of air temperature in the garage versus outdoor temperature is presented in figure 5.14.

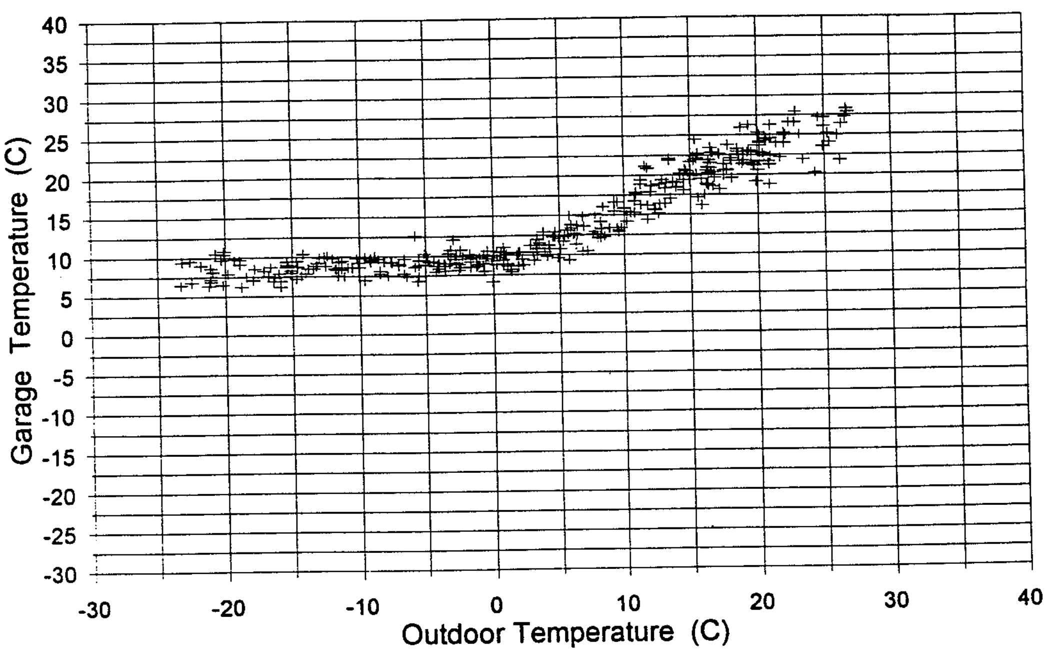

Figure 5.14. Garage air temperature versus outdoor air temperature

Although the attached garage was insulated, (Floor RSI 3.5, Walls RSI 3.5, Door RSI 2, Attic RSI 7.0), air leakage through the two garage doors was present, and a major thermal bridge existed at the junction of the floor slab and the perimeter grade beam. As a consequence, the heat loss in the heating season from the garage was very substantial. Metering of the liquid flow and temperatures was added in December, 1994; thus, for part of the year it was possible to quantify the heat flow to the garage.

The measured energy flows to the garage floor for the months from December, 1994 to May, 1995 were as follows:

Measured Space Heating Consumption of Garage

	kWh
December, 1994 (December 10-31)	743
January, 1995	1331
February, 1995	1031
March, 1995	714
April, 1995	269
May, 1995	0

Extrapolating the measured garage space heat to a full winter heating season, a value of 5424 kWh was calculated.

Space Cooling

The space cooling energy target for the Advanced House was 266 kWh.

The system was able to provide thermal comfort for the occupants, and, as noted in Appendix C, the owner has been very pleased with the system.

The space cooling energy consumption of the house was not measured directly. However, the power consumption of the pump on the space cooling system was measured at 117 watts, and the on-time of the pump was known from the data logging. Using these two figures, the electrical consumption of the cooling system over the monitoring period was 67.7 kWh, or well below the target value of 266 kWh. The cooling degree day number (base 18°C) for the year of monitoring were 105.6°C-d, which is very close to the long term annual average of 111.4°C-d .

The Coefficient of Performance (COP) value for the cooling system was very high compared with conventional (vapour compression) refrigeration systems. The COP values for the months when cooling was required were as follows:

Measured COP Values for the Cooling System

	COP
September, 1994	11.6
June 1995	40.3
July, 1995	31.7
August, 1995	26.1

Typical COP values for vapour compression refrigeration systems rarely exceed 5, and most wall air conditioners have a value less than 3. As can be seen from the above COP values, the COP was greatest in June, 1995, and declined as the months proceeded. This is due to the effect of the ground being coolest in spring, and warming through the summer months. The ground beneath and around the house is gradually warmed due to the combined effect of heat transfer from the piping system and heat transfer from the house and the air surrounding it.

The house has a large thermal mass due to the presence of the 38 mm thick concrete topping on the wooden floors, and the placement of scrap gypsum board in the interior partitions. The house has few windows on the east or west facades, and the south windows have overhangs to limit solar gains. Thus, although the measured output of the cooling system was only about half a ton (1.8 kW thermal) of cooling, that amount of cooling was able to maintain thermal comfort for the occupants.

Interior Temperature Conditions in Summer

For the summer of 1995 (May to Sept), the average temperature in the Saskatchewan Advanced House Main Floor South room was 23.2 °C, with no hours less than 20 °C, and only 4% of the hours more than 26 °C. The peak outdoor temperature reached 35.4 °C during that summer, with the average temperature outdoors equal to 16.8 °C.

The measured average temperature in the house was below the default setting in the HOT2000 program.

Domestic Water Heating

The annual energy target for DHW consumption was 6900 kWh. The measured energy demand for DHW was equal to 3116 kWh over the 12 month monitoring period. A plot of the DHW energy demand is presented in figure 5.15.

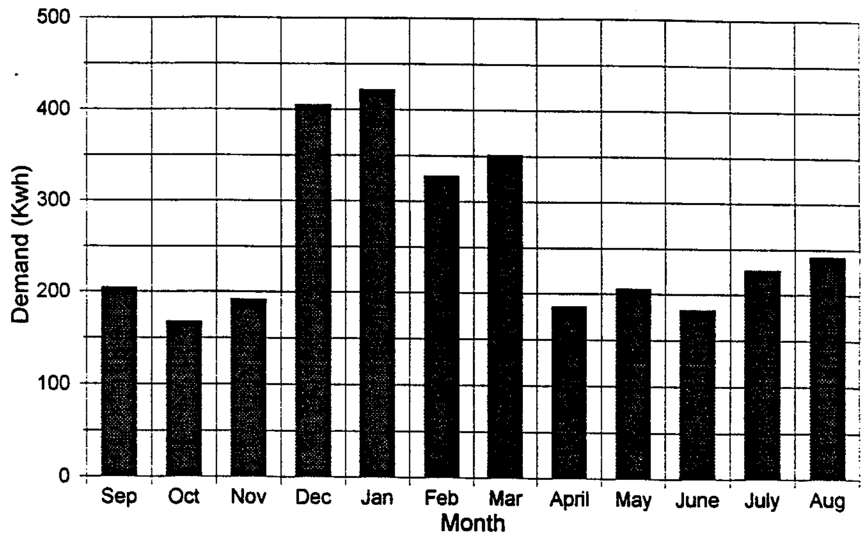

Figure 5.15. DHW Energy Demand

The house has an active solar DHW system that provided 3276 kWh of energy to the storage tank over the 12 month period. A plot of the energy delivered to the storage tank is provided in figure 5.16. Because of system problems with the solar DHW loop, the system was down from December 10, 1994 to February 10, 1995.

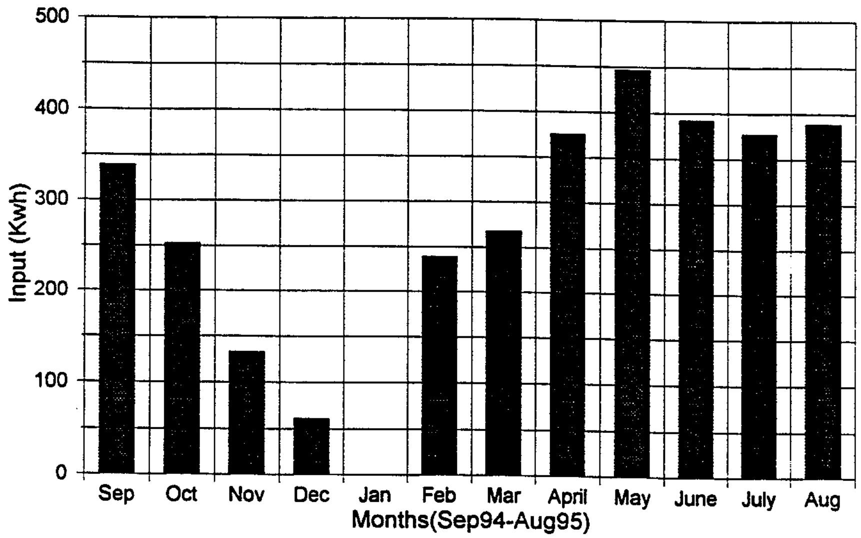

Figure 5.16. Energy delivered to the storage tank by the solar system

As can be seen from the above numbers, in spite of a system shutdown for 2 months, the energy which was supplied by the solar system (3276 kWh) to the storage tank exceeded the DHW energy demand (3116 kWh). Because of heat losses from the storage tank, however, supplementary heat from the natural gas fired water tank was required.

As shown in figure 5.3., the monthly natural gas consumption of the house is relatively small during the months of May through September, as the space heating requirements are very small. In addition, it may be seen from figure B6 (located in Appendix B) that the run time of the natural gas water heater is also small during this time period. The solar water heating system is able to cover a major portion of the domestic hot water load during the summer months. There is a soft copper tube heat exchanger located in the large storage tank that pre-heats the cold domestic water before it reaches the natural gas water heater.

During the summer time the only consistent use of natural gas is for the range and the pilot light on the natural gas fireplace.

Appliances, space heating distribution and ventilation distribution

The target for appliances, space heating distribution and ventilation distribution energy use was 3838 kWh for a year.

The measured consumption of the devices in this category were as follows:

Electrical Consumption of Appliances and Miscellaneous Equipment

Refrigerator, freezer, gas range, gas water heater, dishwasher, clothes washer, gas clothes dryer	2262 kWh
Miscellaneous devices (plug loads, solar system pump, radiant floor heating pumps) excluding: - the cooling system pump (67.7 kWh) (Air conditioning load) · the lighting inside (247 kWh), · the outdoor lighting and plug loads (187 kWh) · one-half the monitoring system energy consumption (598 kWh).	4947 kWh

Natural gas consumption of Appliances

Range (extrapolated value based on 3 months' readings)	1532 kWh
Dryer	443 kWh
Total	9184 kWh

As can be seen, the total energy consumption of the appliances, space heating distribution, and ventilation system (excluding the energy used by the DC fans on the HRV, which was supplied by the PV system) was very much greater than the 3838 kWh/year target.

The homeowner installed a double door refrigerator freezer which consumed 1037 kWh per year.

One of the unexpected loads was the consumption of the speakers on the home theatre system. In the off mode, the electricity consumption was 130 watts, or 1138 kWh for the 12 month period.

The natural gas consumption of the range was quite high, at approximately 1532 kWh for the monitoring period. In addition to the natural gas consumption, the electrical consumption of the range was 260 kWh. For comparison purposes, the electrical energy consumption of similar sized all-electric ranges is between 640 kWh and 860 kWh per year. Thus the gross energy consumption of the natural gas range at 1792 kWh per year was substantially higher than the consumption of similar electrical ranges. As electricity is considerably more expensive than natural gas (in Saskatchewan, the price of electricity is about 6 times the price of natural gas on a delivered energy cost basis), the natural gas range would have an operating cost advantage over the electric range.

Lighting

The energy target for indoor lighting for the house was 416 kWh for the 12 month period. The measured electrical consumption of the hard-wired electrical circuits for lighting was 247 kWh. Additional lighting was also used in the form of plug-in lamps, which were not sub-metered.

Outdoor Electricity Usage

The outdoor electricity usage target was 183 kWh. The measured consumption for the house was 187 kWh, just exceeding the target. This measured consumption consisted mostly of lighting, which amounted to 152 kWh, with the remainder used in plug loads.

6.0 INDOOR AIR QUALITY AND VENTILATION

Indoor air Quality

Results for the indoor air quality tests are presented in the following table:

Table 6.1. Indoor Air Quality Testing Results

	Initial Unoccupied April, 1993		Final Occupied June, 1994		Health Canada Exposure Guidelines
Air exchange (ach)	0.307		0.4		--
Formaldehyde (ppm)	0.087	0.073	0.047	0.035	0.10 (action level) 0.05 (target level)
TVOC (mg/m^3)	0.7		0.11		*
Radon (mWL)	6.0		3.0		100
Airborne particulates ($\mu g/m^3$)	<10		14		≤40 ALTER
Carbon dioxide (ppm)	500, 450, 450		500, 600, 500		<3500 ALTER **
Carbon monoxide (ppm)	<5		<5		≤11 ALTER 8 hr. average concentration

ALTER = Acceptable long term exposure rate

**ASHRAE has a more stringent guideline of 1000 ppm

All air quality readings were found to meet Canadian Residential Exposure Guidelines developed by Health Canada.

There is no Canadian guideline for Total Volatile Organic Compounds (TVOC). However, the current draft of the ASHRAE Standard 62 recommends that action be taken if the levels exceed 1.0 mg/m^3. Both TVOC measurements taken were well below the ASHRAE Action level. A more stringent guideline of 0.2 mg/m^3 has been suggested as the no-effect level by the Danish researcher Molhave.

Building Products Emission Testing

Only one product from the house was tested. The vinyl flooring sample had an emission factor of 9408 $mg/(m^2 \cdot h)$ for total volatile organic compounds.

There are no Canadian standards for material emissions; however, the Carpet and Rug Institute has developed a guideline of 500 mg/($m^2 \cdot h$). The vinyl flooring in the Advanced House was relatively odorous. As other materials used had relatively low offgassing, the total volatile organic compound level in the house was within standards.

Due to the limited number of building product samples received and tested for this house, no correlation can be established to the whole house TVOC measurement.

The ventilation flows measured using the Wallac Flow Meter and the flow grids were as follows:

Table 6.1. One Time Air Flow Measurements (L/s)

Date of test - May 1, 1995

Location	Supply		Exhaust	
	Operating speed	High speed	Operating speed	High speed
Basement Bathroom			7	12
Main floor				
N.W. Corner (dining/sitting room)	5	10		
Office/den	5	7		
Family room	4	7		
Kitchen			11	19
Half bath			7	14
Upstairs				
N.E. bedroom	5	7		
N.W. bedroom	3	5		
S.W. bedroom	4	6		
Main bath			6	6
Master bedroom	4	6		
Master bath			4	9
Totals	**30**	**48**	**35**	**60**
HRV flows using flow grid	28	50	37	63

The ducts were carefully sealed for leakage, and thus the totals of the register flows correspond well to the flows measured at the HRV.

7.0 DISCUSSION

The Advanced Houses Program set very ambitious goals for energy performance, requiring a reduction in energy consumption of 50% compared to the measured performance of R-2000 houses. As of the time of this report, the Saskatchewan Advanced House had not met the performance goals for the program. However, most of the reasons for the house not meeting the goals have been identified.

At the very high levels of performance required by the Advanced House Technical Requirements, **all** of the major system components must perform as projected, or the building will fail to meet the target.

Space Heating

The following are the major reasons why the space heating target was not achieved:

1. Attic Insulation
The insulation should have had a thermal resistance value of RSI 12.3; the actual performance was approximately RSI 2.0 due to compression and convection cells. The computer model estimates that this reduction in the effective thermal resistance of the attic insulation increased the annual space heating requirement of the house by 5490 kWh.

2. Fireplace Pilot Light Consumption
The pilot light has an annual consumption of energy of 1557 kWh. Natural gas fireplaces are available with intermittent ignition devices.

3. Low efficiency of the natural gas water heater/radiant floor heating system. It is estimated that the water heater was operating at efficiency levels much less than the rated 94% efficiency. High entering water temperatures, very short firing cycles, and a low effectiveness water-to-glycol heat exchanger on the radiant floor heating loop all contributed to low seasonal efficiency.

A HOT-2000 analysis was done of the house using measured data for interior temperatures, electrical base loads, air exchanger flows, air tightness, building characteristics including the attic insulation at RSI 2.0, and actual weather conditions for the 12 months of the monitoring period in 94-95. In order for the computer model projections to match the measured data, a seasonal efficiency value of 60 % had to be used for the natural gas water heater/radiant floor heat exchanger combination. This value of 60% seasonal efficiency is very much lower than the rated value of 94% provided by the manufacturer.

Future monitoring of the Advanced House will help to better understand this phenomenon of low seasonal efficiency of the water heater/radiant floor heat exchanger combination.

4. Space Heating of the Garage

The garage space heating used about 6780 kWh of natural gas during the monitoring period. (For comparison, the design target for space heating for the **entire** house was 8911 kWh). Major thermal bridges at the floor level, and air infiltration contributed to the relatively high consumption of the garage.

The use of a radiant floor heating system allows for a relatively straightforward system for heating a garage, but the energy consequences are substantial.

Space Cooling

The non-CFC space cooling system proved technically very successful. The COP values measured for the system greatly exceeded those of conventional systems. Optimization of the system by better placement of the ground cooling pipes in the cooler ground regime near the perimeter of the house, and by better attachment and thermal coupling of the ceiling cooling plates to the gypsum board ceiling is needed. For cost savings in future projects, the same radiant ceiling panels could be used for both cooling and space heating.

Alternatively, the radiant floor piping could be used to provide some space cooling. This latter system has only rarely been done. Designers of radiant systems are always concerned about condensation occurring on cool panels. In a floor system, concealed condensation under a rug or pile of boxes would be a potential concern with radiant cooling pipes in a floor.

In the Saskatchewan Advanced House, there was no evidence of condensation from the ceiling radiant cooling panels. The relatively warm water temperatures(>12° C) in the cooling loops and the dryness (low humidity) in the air in houses in the summer in Saskatchewan are responsible for the absence of condensation.

Domestic Hot Water

The Advanced House easily met the target of 6900 kWh for domestic water heating. The active solar water heating system with the large storage tank provided 3276 kWh for the year of monitoring, despite two months of shutdown due to pipe leaks. This amount of heat closely matched the actual consumption of domestic hot water (3116 kWh). However, heat losses from the large storage tank and the small natural gas heated tank required that supplemental natural gas heat be provided to the DHW.

In future projects of this type, a dedicated heat meter should be added to the combined space/water heating system to more clearly distinguish the actual fraction of the heat going to space heating and to domestic water heating.

During a hailstorm in 1994, 7 tubes on the vacuum tube collectors were broken. The glass cylinders used on the vacuum tubes did not appear to be of tempered glass. In an area such as Saskatoon, where hail storms occur with some frequency, it would appear that tempered glass units should be used.

Appliances, fans and pumps

The appliance, fan and pump energy consumption greatly exceeded the target of 3838 kWh. The total consumption amounted to 8617 kWh.

Although the consumption of the four major appliances (fridge, washer, dryer, dishwasher) was within specifications, the prototype natural gas range had a **substantial** electrical consumption (260 kWh) which was not anticipated. The natural gas range also consumed 1532 kWh of natural gas. By comparison, the Energuide rated consumption of all-electric ranges of a similar size is between 640 and 860 kWh per year.

A number of additional appliances and devices were used which contributed to the higher consumption. In addition, the energy used for pumps for the space heating and cooling systems was substantial.

The electrical energy consumption of devices even when they are nominally "off" is also a concern.

A set of home theatre speakers had a measured electrical consumption of 1128 kWh during the 12 month period.

Lighting Energy Consumption

The hard-wired lights were able to meet the lighting energy target for the Advanced House. The plug-in lamps were not submetered. In future projects of this type, a protocol to measure the energy consumption of all electric lights including plug-in lamps should be implemented.

Outdoor Electricity

The outdoor electricity consumption was just slightly over the target. Outdoor lighting was the main use for the electricity.

Indoor Air Quality

The following air quality readings(formaldehyde, radon, airborne particulates, carbon dioxide, and carbon monoxide) were found to meet the Residential Exposure Guidelines developed by Health Canada.

The interior relative humidity in the house during the winter months was lower than the value of 30% recommended in the Health Canada Residential Guidelines. There is no humidifier in the house.

The Total Volatile Organic Compound (TVOC) readings of 0.7 and 0.11 mg/m^3 were less than the proposed ASHRAE Standard 62 guideline of 1.0 mg/m^3 . The value of 0.7 mg/m^3 was, however, higher than the value of 0.2 mg/m^3 set as a no-effect level by Molhave.

Comparison with Other Houses

The purchased energy consumption of the house over the 12 month period from September 1994 to August 1995 was equal to 92.9 kilowatt hours per square metre. Conventional Saskatchewan houses built between 1970 and 1973 (Hedlin and Orr, 1977) had measured energy consumption values of 343 kilowatt hours per square metre per year. Compared to the conventional houses, the Advanced House showed a reduction of 72% in total energy consumption for an equivalent floor area basis.

. Measured Consumption of Houses

	Year Built	Annual Total Purchased Energy (Natural gas plus electricity) (kwh/m²)	Relative Value
Conventional Houses (Regina, SK)	1970-73	331	1.0
R2000 Houses in Canada Prairies	1984-86	147	0.44
Saskatchewan Advanced House	1992	91.9	0.28

8.0 Lessons Learned

The following describes the lessons learned by the Saskatchewan Advanced House Project.

Energy Performance Improvements On The Already Innovative R-2000 House Standard Are Achievable

In spite of some problems experienced, the Saskatchewan Advanced House improved on the performance of the R-2000 houses in the prairie climate by a substantial margin. Excluding the garage space heating, the Advanced House used 37% less energy per square meter than the monitored R-2000 houses in the Prairie Region.

A High Performance Envelope has Substantial Comfort Benefits

As evidenced by the homeowner's letter, the high thermal resistance walls, and windows, and tight exterior envelope add a real measure of comfort through all weather conditions. The Canadian prairies experience outdoor temperatures varying from +35°C to -40 °C, and the Advanced House provides excellent thermal comfort through all those conditions. The high performance windows virtually eliminate the chilling effect of cool window surface temperatures during winter. In addition, the windows virtually guarantee an end to condensation problems. Reduced sound transmission is also an advantage of the high performance envelope. As noted by the homeowner, "Four areas that the house excels in are **comfort**, built quality, brightness and efficiency."

Ground Loop Cooling Has Been Proven Technically Feasible

To our knowledge, the ground cooling loop with radiant ceiling panels used on the Saskatchewan Advanced House is a world first. The coefficient of performance values achieved exceed those of conventional air conditioning by up to **a factor of ten**. The system is very simple in comparison to a conventional air conditioner, with only a single pump and a thermostat used to control the circulation of the fluid. As this system was a pioneer, improvements are likely in second generation designs. Several approaches to reduce future installation costs include the following.

1. Reduce the length of the in-ground piping by concentrating the piping at the perimeter of the base of the foundation walls, where soil temperatures are cooler.
2. Eliminate the radiant cooling panels in the ceiling and use the floor radiant piping for both cooling and heating, or,
3. Eliminate the floor radiant piping, and use the ceiling panels for both cooling and heating.
4. Explore using a lower flow pump, with even smaller power requirements.
5. Optimize the spacing intervals for the in-ground piping.

The Electrical Consumption of Natural Gas Appliances Should Not Be Neglected

The electrical consumption of some natural gas appliances can be substantial. For instance, the prototype sealed combustion range used 260 kWh of electricity for the one year monitoring period. The range uses a purge fan and separate igniters for the range top and oven. By comparison, the electrical consumption of a similar sized all-electric range is in the range of 640 to 860 kWh per year. The total consumption of the natural gas range over the 12 month monitoring period was 1792 kWh.

Pilot Light Consumption is substantial

The one pilot light used in the house was on the natural gas fireplace. This pilot light used 1557 kWh per year, or **17% of the energy target for space heating** for the house. In future projects of this type, equipment with pilot lights should likely be prohibited.

The Seasonal Efficiency Value for Water Heaters Used as Space Heaters Can Be Measurably Less than Anticipated

For reasons outlined in the report (over-sizing of the water heater relative to the load, a narrow water heater thermostat deadband, an undersized water-to-glycol heat exchanger, and high entering water temperatures), the seasonal efficiency of the space heating system was much lower than the manufacturer's rated value of 94% for the water heater. As the use of these types of systems increases, it is important that well-designed **systems,** and not just assemblies of components, be developed. This low seasonal efficiency of the water heating system was the single most important reason why the space heating consumption of the Saskatchewan Advanced House was over the target.

The Energy Requirements of Electrical Equipment even when Off Can Be Substantial

A number of the electrical items in the house--television, VCR, CD player, natural gas water heater, microwave oven, coffee maker/can opener, and speakers for the home theatre-- all have electrical consumption even when they are nominally "off." The largest consumer in the "off" condition was the home theatre speakers, which use 130 watts or 1128 kWh per year. This consumption alone exceeded the useful output of the photovoltaic system on the Advanced House.

Water Use Reductions Can Be Achieved Through Careful Selection and Use of Equipment

The Advanced House used a total of 295,000 litres of water for the year. This is a reduction of 24% compared with conventional houses. The water saving toilets and water saving shower heads were key factors, as was the use of Xeriscaping for the front yard.

The hot water consumption was 77,700 litres for the year, which was 23% less than the 101,000 litres used as the HOT-2000 default value.

Further water savings would be possible now that water conserving front-loading washing machines are becoming readily available on the market.

Attic Insulation Performance Can Be Readily Degraded If Air Spaces Are Present On The Bottom Of The Insulation

It is known that the radiant cooling panels in the ceiling of the second floor of the house caused air spaces to occur on the underside of the blown fiberglass insulation. This in turn caused the attic insulation performance to decline dramatically, as evidenced by high attic air temperatures measured in the house. Loose fill, low density insulation is particularly prone to convection cells which can degrade the insulation performance.

Loads Used with Photovoltaic Electricity Should Be Very Carefully Chosen

The PV system on the Advanced House performed technically very well, given the relatively low loads imposed on it. Photovoltaic cell prices continue to decline, and more use of this decentralized electrical power generation is likely, given the environmental benefits.

Very careful attention, however, must be paid to **end-use loads** within the dwelling. In the Advanced House, the PV system provided only about 1/10 of the electrical energy used.

Good Indoor Air Quality is Achievable in New Construction, Provided Careful Material Selection and Adequate Ventilation Are Implemented

The indoor air quality in the Saskatchewan Advanced House was found to meet the residential guidelines on indoor air quality set by Health Canada, with the exception of indoor relative humidity in the winter months.

The one building product with a high odour level was a vinyl flooring product. Since the house was built, there are now guidelines in place for offgassing of many vinyl flooring products.

Implementation of New Technologies Will Require Significant Education of Builders, Trades, Suppliers, Designers, and Inspectors

Homebuilding is a strongly tradition-based activity. However, as new products, systems, and installation techniques are developed, the focus must shift to ongoing education. This process has already started, but the effort must be strengthened.

The Public and Private Sectors, Along with Industry Associations, Can Work Together Effectively to Advance the Energy and Environmental Performance of Dwellings

Sponsors from the public sector included CANMET, SaskPower, and SaskEnergy. The Industry Association sector was ably represented by the Canadian Home Builders' Association, and the private sector included a wide range of sponsors.

Despite some problems, the Saskatchewan Advanced House has successfully demonstrated advanced housing concepts in the energy and environment field. Led by the initiative of CANMET, the Saskatchewan Advanced House served to introduce new concepts of energy and environmental performance to the detached housing market.

Engineered wood products, recycled products, water conservation technologies, high performance windows, low-offgassing products, and radiant floor heating systems all have a higher profile as a result of the Saskatchewan Advanced House.

The involvement of many co-sponsors, while organizationally complex, and prone to possible compromises in the overall performance of the house, was successful. Such a model could be employed in future projects of this type provided rigorous performance standards are set.

9.0 REFERENCES

Dumont, R.S., "Advanced Houses Program Technical Requirements", CANMET Buildings Group, Energy, Mines and Resources Canada, Ottawa, ON, Canada, 1992.

Dumont, R.S., and Snodgrass, L., "The Saskatchewan Advanced House--Energy Efficiency and Environmental Responsibility in a Cold Climate House," Proceedings, Air and Waste Management Association Annual Conference, San Antonio, Texas, June, 1995

Hanson, K., "Saskatchewan Advanced House: Marketing and Technology Transfer Report," Sun Ridge Group, Saskatoon, January 1993

Hedlin, C.P., and Orr, H.W. "A Study of the Use of Natural Gas and Electricity in Saskatchewan Houses," Proceedings, 91st Annual Engineering Institute of Canada Meeting, 1977.

Snodgrass,L. , and Figley, D., "Evaluation of the WIRSBO Cooling System Installed in the Saskatchewan Advanced House. Phase 2--Data Collection and Performance Evaluation." Saskatchewan Research Council Report for WIRSBO Canada Ltd. November, 1993

APPENDIX A

Fact sheets on the Saskatchewan Advanced House

Saskatchewan ADVANCED HOUSE

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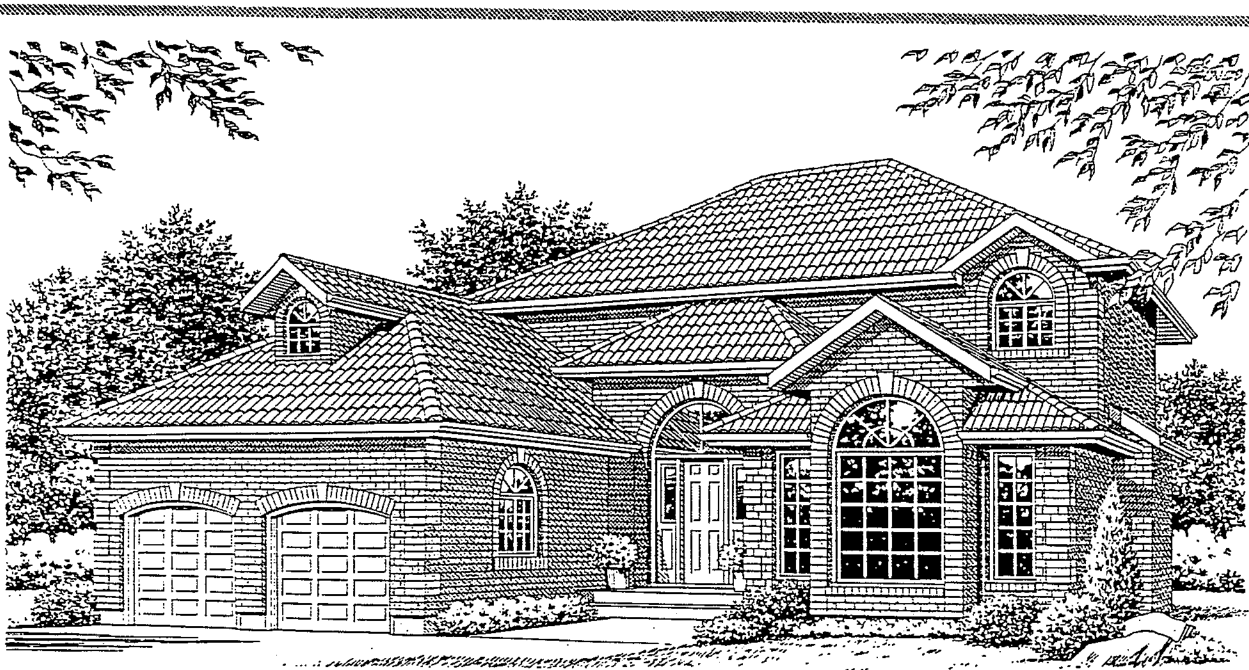

511 Braeburn Court - Briarwood HOURS: Mon. to Thurs. 7 - 9 pm Weekends 2 - 5 pm

SRC
Saskatchewan Research Council

Energy, Mines and Resources Canada / Énergie, Mines et Ressources Canada

CANMET

Canadian Centre for Mineral and Energy Technology / Centre canadien de la technologie des minéraux et de l'énergie

SaskEnergy

SaskPower

Special Features *of the* Advanced House

Space Heating and Domestic Hot Water

The advanced mechanical system integrates heating and domestic hot water functions into one interconnected network. The core of this network is the 3,400 liter heat storage tank which accepts heat from the solar collectors on the roof and provides heat to the infloor heating system and the domestic hot water system. Water temperature in the storage tank can reach 90 °C which is ample for all space heating and domestic hot water needs.

When the solar panels can't keep the temperature in the storage tank high enough, the high efficiency natural gas water heater will top up the domestic hot water to whatever temperature is desired.

When the house requires heat, a thermostat turns on the circulation pump that moves warm water from the heat storage tank to the infloor heating system. If the temperature of the water in the storage tank is not high enough to meet the needs of the the infloor heating system, the hot water heaters will increase the water temperature to the level required.

Photovoltaic System (Solar cells)

The south facing roof on the back of the house contains a large array of photovoltaic cells that convert sunlight into electricity. The electricity generated by these solar cells is stored in a bank of batteries located in the basement. The batteries supply power for the:

- pumps that circulate water through the infloor heating system and the cooling system,
- fans in the energy recovery ventilator,
- emergency lighting,
- refrigerator,

During times of reduced sunlight, the batteries may require support from a back-up battery charger which will supply additional energy as required to operate the system.

Radiant Infloor Heating System

Each of the floors in the house contains rows of pipes embedded in a layer of concrete. Warm water is circulated through these pipes transferring heat to the concrete and in turn to the room. This system of infloor heating, technically known as radiant floor heating, provides even heat and totally eliminates the cool spots found with forced air heating systems.

The pump used to circulate the heated water through the floor is powered by the photovolatic system.

Cooling System

The main and upper levels of the Advanced House are cooled by a conductive cooling system which has been installed directly behind the ceiling drywall. This system is composed of flat metal collector plates connected to flexible tubing through which water is circulated. Excess room heat is absorbed by the collectors, transferred to the water then pumped through cooling pipes installed under the foundation where the soil temperature remains constant at approximately 10°C.

Light Pipe

Sunlight is delivered through the roof of the house to the ceiling of the entrance hallway by a special pipe that allows light to bend around corners. The light pipe provides the stairway and hall with light from sunrise to sunset, eliminating the need for additional lighting during most of this time.

Heat Storage Tank

The heat storage tank contains 3,400 liters of water which absorbs and gives off heat as demanded by the heating and hot water systems. When the tank is at its maximum working temperature it contains over 1 billion joules of useable heat energy. The fundamental purpose of the heat storage tank is to temporarily hold the excess heat energy captured by the solar collectors until it can be used by the occupants for space heating and hot water.

Saving water

The Advanced House uses water saving toilets that employ pressurized water to provide a powerful siphonic flushing action that cleans the bowl and forcefully removes wastes. These toilets use only 6 liters of water per flush.

The yard has been contoured to take maximum advantage of rain water and minimize the need for regular watering. The plants and shrubs are hearty indigenous perennial varieties that need little or no watering. The grass has been planted in a layer of topsoil that has been placed on a layer of clay. The clay effectively keeps the water from soaking to great depths, thereby keeping it available for plant use.

Total Home Management System

The Honeywell Total Home Automation System is capable of controlling every light, plug, switch, appliance and electrical device in the home. Any light or appliance can easily be programmed to turn on or off at any time. The Total Home system is fully integrated with the security system and the telephone, giving it emergency dial capabilities. Total Home can be controlled from the touch pad control panels or from any telphone in the home or in the world.

The Total Home System also has an optional voice control module which allows the system to be controlled by voice commands from the occupants.

Electrical Energy Management System

The electrical energy management system provides instant readouts of the amount of electricity that's being used in the house at any time or over a period of time. Expressed in $ and ¢ the readout makes it easy to see how much or little electricity is used. As special bulk electricity purchases may be the way of the future, this system provides information on how much electricity is remaining and when the last purchase was made.

Appliances

The appliances in this house are very unique. The refrigerator is powered by the photovoltaic system. This refrigerator uses only 55 kwh/month which is a small fraction of that used by normal refrigerators.

The range is a sealed combustion unit that burns natural gas but does not use house air for combustion. Natural gas is burned using air brought in from outdoors and the exhaust gases are drawn back outdoors by a powered exhaust sytem. Heat is transferred to the glass ceramic cooking surface by conduction and radiation.

Solar Collectors

The Advanced House uses 6 square meters of Thermomax evacuated glass collector tubes to generate hot water for the heat storage tank. These collectors are unique in that they collect and transfer heat to the working solution by means of phase change heat transfer. The special fluid inside the heat pipe absorbes heat from the absorber plate and turns from liquid to vapour. The vapour travels to the condensor where it condenses to liquid again and repeats the cycle. By using the latent heat of phase change in the special fluid, the efficiency of this collector is increased dramatically.

Windows

The windows are custom built using some of the most advanced window construction techniques known to man. The frames are constructed of foam filled fibreglass to provide high R-values through the window frame. Two of the three panes of glass are coated with a low emissivity coating (Low-E) and the space between the glazings is filled with argon gas.

The edges around the window use the new "super spacer" which almost eliminates heat lost around the edges of the window.

Carpeting

Carpets in the Advanced House are made from recycled plastic soft drink bottles which are made from polyethylene terephthalate (P.E.T.). The bottles are collected by the carpet manufacturer where they are cleaned and cut into slivers suitable for high temperature extrusion. The carpet fibres are made by forcing the molten slivers through pin-point size apertures. The fibre is then spun into yarn, heat set, tufted, dyed and finished.

The P.E.T. carpet is resistant to staining, sun fading and it provides reduced static. Ever wonder where all those plastic pop bottles go?

Technology Transfer *and* Public Education Activities

The Saskatchewan Advanced House will be on display for the remainder of 1992 and during much of 1993. During this time a combination of public open houses and private tours will be used to allow all interested individuals and groups to tour and learn about energy conservation, the environment and new building technologies.

During the display period there will be ongoing activities and many handouts designed to enhance the learning experience of the visitor. The following listing provides a hint of some of the planned materials and activities:

- a consumer magazine describing the Advanced House in detail,
- a series of fact sheet publications that focus on individual technologies and/or products,
- school visitation program,
- seminars for trades and suppliers,
- a TV show and a video......

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Leading Edge Products

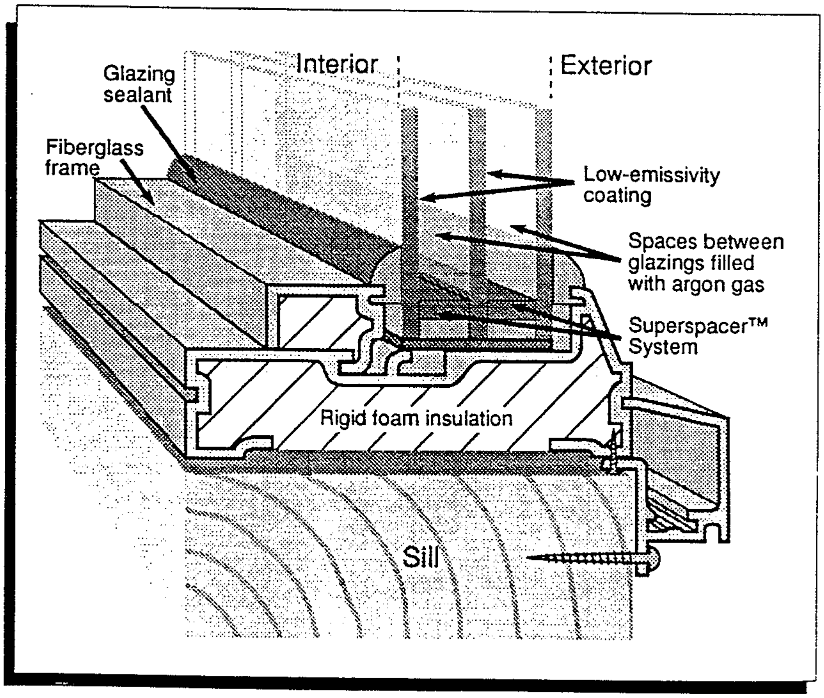
A number of new systems and approaches were used in the design and construction of the Saskatchewan Advanced House. In addition, many new, innovative and prototypical products were introduced. Three products that have received the most attention are the windows, the range and the refrigerator.

Windows

The windows in the Saskatchewan Advanced House incorporate most of the latest technology. The windows are triple glazed with a low E coating on two of the three glazings. This makes them perform as if they had four or five glazings. The low E coating blocks the long wave infrared radiation (heat) that is characteristically lost through most windows during the winter months. During the summer months, the low E coating stops the long wave infrared radiation (heat) from entering the home which results in a cooler indoor environment. The coating also prevents some ultraviolet light from entering the home which will reduce fading of furniture, drapes and carpeting.

Standard windows have air between the glazings. As this air circulates it leads to increased heat loss. The windows in the Saskatchewan Advanced House have argon gas between the glazings. Since Argon gas does not circulate easily, there is a reduction in the amount of heat that is lost.

When R values of windows are discussed, it is the R value through the centre of the glass that is usually referred to. The R value at the centre of the glass for a standard double glazed window is about R-2. The R value throughout the centre of the glass for these windows is about R-8.



These spacers are a blend of silicates and moisture-absorbing desiccant material. The flexible foam construction also makes an excellent sound damper.

The R value around the perimeter of the window is usually considerably less because of the heat loss through the spacer between the glazings. The spacers transmit heat easily from one side of the window to the other. The spacers used in the Advanced House windows have been designed to considerably reduce the amount of heat flowing through them. These spacers are a blend of silicates and moisture-absorbing desiccant material. The flexible foam construction also makes an excellent sound damper.

Another area where windows lose heat is through the frames. There are a number of materials typically used for framing including aluminum, vinyl and wood. The windows in the Saskatchewan Advanced House were constructed from fiberglass because it has a number of desirable performance characteristics.

First, fiberglass has a very low expansion and contraction rate which is equivalent to that of window glass. This means that the frame will not move to cause distortion or breakage of the glass in extreme temperatures.

Second, fibreglass will not warp, twist, rot, shrink, dent or bow. It does not turn brittle in the cold nor does it distort or lose strength at high temperatures. It is chemical resistant and maintenance free. These windows also contain foam insulation inside the fiberglass frame providing additional resistance to heat loss.

The final way that windows lose energy is through air leakage. This can take place either from leakage around the outside of the window between the window and the framing, or at the cracks along the operating parts of the window. The Saskatchewan Advanced House windows meet and exceed all the standards for air leakage. In addition, at the time of installation, the air barrier of the house was sealed to the frame of the window eliminating any air leakage between the window and the wall.

There are a number of benefits that the occupants will receive from these windows. Because of the much higher resistance to heat movement, the overall requirements for heating/cooling will be reduced resulting in lower energy bills. Also, since the windows lose much less heat, the interior of the windows will be warmer resulting in little, if any, window condensation. The windows will be much more comfortable to stand in front of on a cold winter day. Finally, as mentioned above, the low E coatings help protect the various fabrics inside the house from ultraviolet light.

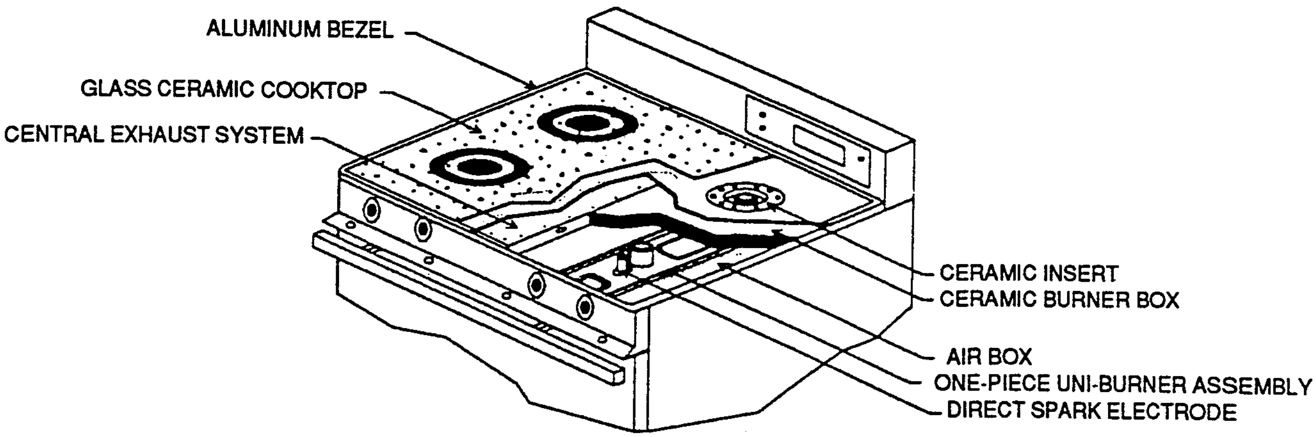
Sealed Combustion Gas Range

The Canadian Gas Research Institute (CGRI) has developed a sealed combustion range which eliminates the release of combustion products to the indoor environment. Standard gas range top burners are utilized with low-cost ceramic enclosures to remove combustion products from the burner area. The range top is sealed with a one-piece glass ceramic surface which provides for a modern, state-of-the-art gas appliance that retains the desired features of good controllability, reliability and uniform heating without sacrificing energy efficiency. The design includes direct spark ignition for the range burners. Heat is supplied to the cooking utensil by conduction through the glass ceramic surface and by radiation from the burner flame and ceramic enclosure.

The range and oven burners are connected to a central exhaust system. A small blower located at the rear of the range is used to exhaust combustion products outdoors. Combustion air is drawn directly from outdoors via a duct which is concentric with the exhaust duct. The vent system terminates outdoors with a vent terminal which has been shown to provide negligible change in range performance when subjected to 64 km/hr winds.

With sealed combustion, the appliance operates in an optimal manner independent

Schematic of Sealed Combustion Rangetop



of changes, such as depressurization, to the indoor environment.

During normal burner operation, the ceramic burner enclosures attain a temperature of approximately 660°C and glow bright red, transmitting radiant energy to the cooktop and the cooking utensil. The temperature of the glass ceramic cooktop is monitored by precious metal resistance strips etched on the underside of the glass. Should the cooktop temperature exceed a maximum permissible value, the gas valve is automatically de-energized and will not allow gas flow until the cooktop temperature falls to within the acceptable operating range.

Laboratory evaluation of the range top burners was conducted in accordance with the CGA CAN-1.1-M81 test protocol for domestic gas ranges. Top burner water-boil efficiency is in the range of 46% to 56%, comparable with, and in some cases exceeding, that of conventional ranges with more sophisticated burner technology. Before conversion to sealed combustion, the efficiency was consistently in the range of 43% to 45%. Therefore conversion to sealed combustion carries no energy penalty and in fact energy efficiency improvements as high as 24% can be expected with the sealed combustion range.

The five-minute combustion emission levels are well within the CGA limit of 800 ppm air free carbon monoxide (AFCO) and have satisfied the CGRI design goal of 400 ppm AFCO. Thermal response of the range burners is comparable with that of electric ranges. Proportional flow gas valves provide for a wide range of burner inputs with good repeatability and accuracy. The gas valve is coupled to a control knob which provides for flame control over a wide 320° arc, similar to the burner control knob found on electric ranges.

The temperature of the glass ceramic cooktop is monitored by precious metal resistance strips etched on the underside of the glass.

DC Refrigerator

The refrigerator/freezer in the Saskatchewan Advanced House runs on 24 volt DC and uses only a small fraction of the energy a normal fridge uses. This has significant benefits to the overall energy consumption of the house.

Photocomm Inc. is the manufacturer of the P-16 refrigerator/freezer. The P-16 has a 16 cubic foot capacity including 4.5 cubic feet in the freezer. The two door refrigerator /freezer has deep interior shelves and handy compartments in both the refrigerator and the freezer doors. The one piece liner is attractive and easy to clean.

(Cont'd)

The compressor for the P-16 has been placed on top of the unit so that the heat generated from its operation can escape without warming the refrigerator.

The Photocomm P-16 is one of the most efficient refrigerator/freezers available. The P-16's average daily power consumption is approximately 800 watt hours per day, which works out to about 24 kilowatt hours per month or about one quarter of what a typical refrigerator would use.

The compressor for the P-16 has been placed on top of the unit so that the heat generated from its operation can escape without warming the refrigerator. Extra insulation is used throughout the unit and all door seals are designed to be air tight. The overall dimensions are 32.5" wide by 71" high by 27" deep, including the top mounted compressor. Except for the vent area at the top, the P-16 can have zero clearance at the rear and the sides because of the top mounted compressor.

The P-16 runs on 24 volt DC. This means that in the Saskatchewan Advanced House, all the energy needed for this unit will come from the photovoltaic system. No energy will be purchased for its operation. At 100 kilowatt hours per month for a typical refrigerator, this amounts to a saving of 1200 kilowatt hours per year or $75 per year at 6 cents per kilowatt hour.

The Saskatchewan Advanced House recognizes the following sponsors and contributors without whose participation this project would not have possible.

Energy, Mines and Resources Canada / Énergie, Mines et Ressources Canada

CANMET

Canadian Centre for Mineral and Energy Technology / Centre canadien de la technologie des minéraux et de l'énergie

Saskatchewan Home Builders' Association, Inc.

Dorwin Accurate Glass

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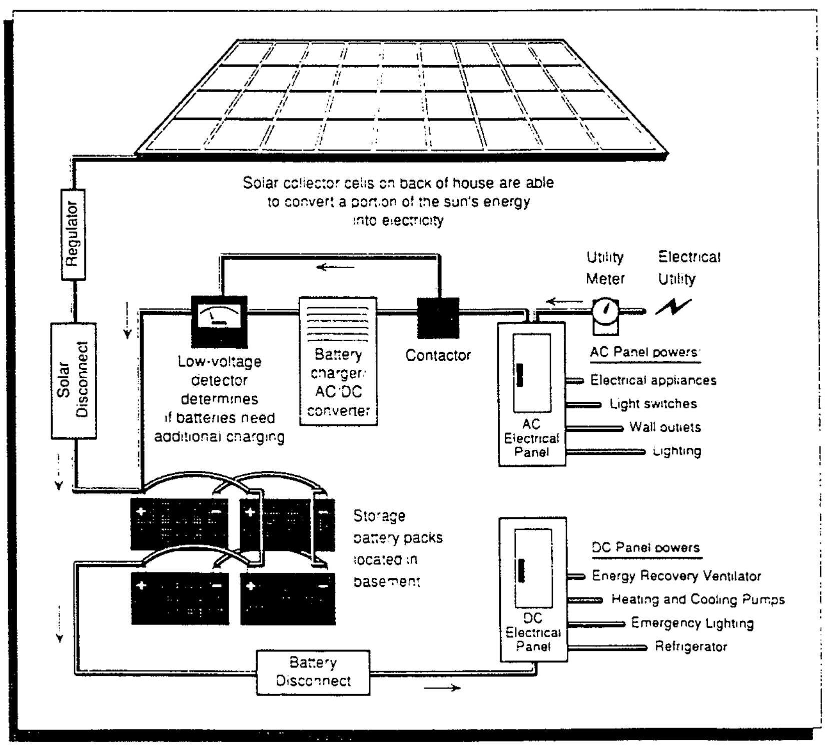
Photovoltaic System

How do solar cells turn sunlight into electricity? The phenomenon is known as the photovoltaic effect. Put simply, a wafer of silicon is coated or "doped" with specially charged materials — one carries a negative charge and the other a positive charge. When sunlight, which consists of photons, collides with the electrons in the doped materials, electrons are freed and begin to move through the circuit. This flow of electrons is known as electricity.

There are 40 solar cells mounted on the lower south facing roof of the Advanced House. The orientation of these cells is about 10° West of South. They are installed at an angle of 59° up from the horizontal, which is optimum for the Saskatoon location. Each of the Sieman M75 solar cells has the capability of producing up to 48 watts of electricity for a total of 1,920 watts (1.9 kilowatts). Each cell has an output of 3.02 amps at 15.9 volts. Wired to operate at 24 volts, these panels can produce 80 amps of power per hour in strong sunlight.

The electricity produced by the solar cells is stored in 30 deep-cycle 75 amp-hour batteries located in the basement of the Advanced House. These batteries provide a capacity of 1125 amphours at 24 volts. The batteries feed an 8 pole DC distribution panel. If excessive cloud cover reduces the amount of sunlight reaching the solar cells, the batteries can be recharged with energy supplied from the SaskPower utility grid. The 75-amp chargers runs off a 115-volt, 15-amp circuit from the AC distribution panel. A low voltage disconnect controls a relay which engages the charger.



This photovoltaic system will provide the electrical energy needed to operate the refrigerator, the Energy Recovery Ventilator, the pumps for the floor heating system, the pumps for the cooling system, and the pump for the solar hot water collectors.

This photovoltaic system will provide the electrical energy needed to operate the refrigerator, the Energy Recovery Ventilator, the pumps for the floor heating system, the pumps for the cooling system, and the pump for the solar hot water collectors. All pumps and appliances are 24 volt. The refrigerator will draw 33.3 amphours per day. The 2 motors on the energy recovery ventilator will draw 150 amphours per day while the 2 pumps for the radiant floor heating system will draw 100 amphours per day. The pump for the solar water heating system will draw 50 amphours per day. The total draw on the batteries is 333 amphours per day.

The system is designed to generate 100% of these electrical needs during the month of December, which is the month during which the output from the solar cells will be at a minimum. This means that for an average year, the backup charging system should not be used. There is some flexibility in the system as the batteries can store enough power to operate the heating, cooling, ventilation and refrigeration systems for almost one full week. For most months of the year, the excess capacity will go unused, however; in the future, programs may be available to sell excess electricity to the utility.

Most of the equipment that is being powered by the photovoltaic system will operate continuously. The winter operation of the heating system pumps will be offset during the summer by the operation of the cooling system pumps. The other equipment will operate year around. The photovoltaic system will supply about 3,000 kilowatt hours of energy per year.

The cost for the entire photovoltaic system (materials and labour) on the Saskatchewan Advanced House is approximately $35,000. This relatively large system includes the solar cells, the batteries, the backup charging system and the controls. There is a 15 year guarantee on the solar cells, but they are expected to last for 30 years or more.

Does this full size system make any financial sense? In a traditional home, the furnace fan, air conditioner, refrigerator and ventilation fans would consume approximately 4500 kilowatt hours of electricity per year. Using a 5% per year energy cost increase, the electricity provided by the photovoltaic system over 25 years would be worth approximately $14,000 (in 1993 dollars).

The system has the capacity to produce considerably more electricity than is needed in all months except December. If this excess electricity could be sold to the utility, the economic feasibility of this large system becomes evident.

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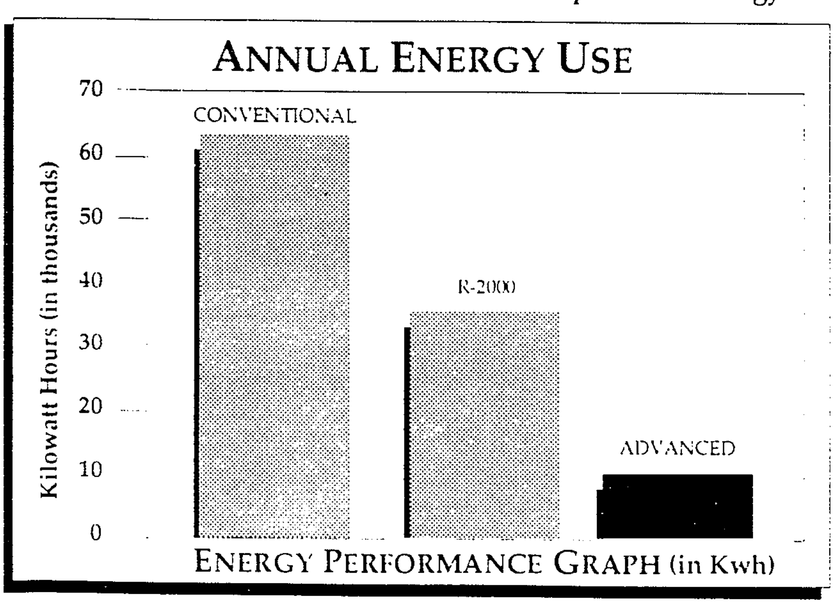
Building Envelope

One of the goals of the "Advanced Houses Program" was to construct demonstration houses specifically designed to consume approximately half the energy necessary to operate the already thermal efficient R-2000 homes. This meant implementing new and innovative heating and cooling systems, while substantially reducing heat loss through the ceiling, floors, walls, and basement.

Conventional homes use about 60,000 kilowatt hours of energy in one year. A comparably sized R-2000 home uses about 35,000 kilowatt hours. In contrast, the Saskatchewan Advanced House is expected to use only about 15,000 kilowatt hours of energy per year. The graph below illustrates the energy performance of these houses.



ENERGY PERFORMANCE GRAPH (in Kwh)

The energy requirements of the Saskatchewan Advanced House can be put into five categories: space heating, space cooling, domestic hot water, lighting and appliances. The quality of the building envelope will directly affect space heating and space cooling. The table on the following page shows the estimated purchased energy for all five categories. As can be seen, there are only 9142 kilowatt hours of energy required for space heating and cooling combined. This very low amount demonstrates the quality of the building envelope.

The energy efficiency of an envelope is judged by it's degree of insulation as well as its ability to be

There are only 9142 kilowatt hours of energy required for space heating and cooling combined. This very low amount demonstrates the quality of the building envelope.

Estimated Annual Space Heating Energy Consumption

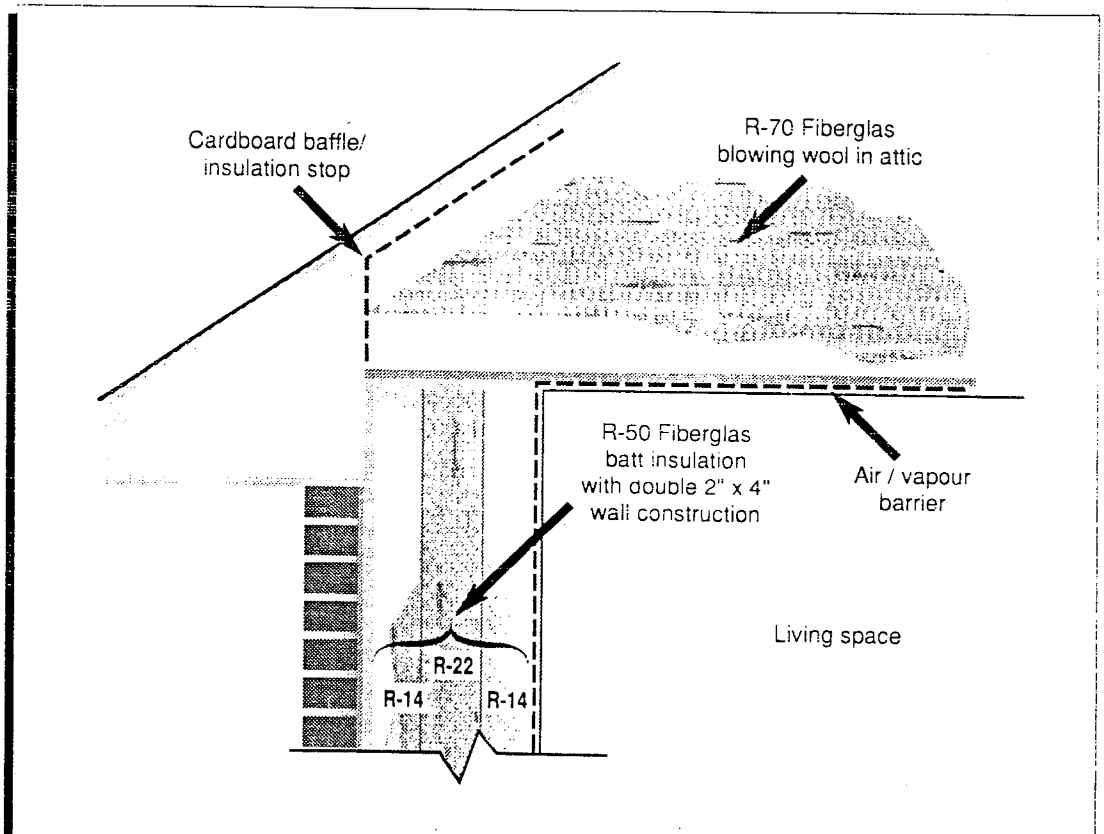
Item	Purchased Energy (Kwh)	Energy supplied by Photovoltaic System (Kwh)	Energy supplied by Solar System (Kwh)
Space Heating	8015	----	890
Space Cooling	----	237	----
Domestic Hot Water	----	----	4765
Lighting	1703	163	----
Appliances	2910	1064	----

Both the interior and exterior 2 x 4 walls have R-14 insulation batts while the cavity between the two walls uses an R-22 batt for a total R-value of 50.

air tight. These two components go hand in hand. The ceiling in the Saskatchewan Advanced House is insulated with R-70 blown fibreglass insulation. High heel trusses (7-1/2" heel) with an 8/12 pitch were used to achieve full insulation value throughout the entire ceiling area. A continuous sheet of polyethylene, installed throughout the ceiling area, acts as an air and vapour barrier. The poly sheet is continuous between the top plates of the interior walls and has also been sealed to the poly boxes in which the electrical outlets are installed. The clay tiles on the roof are expected to reduce the attic temperature which should in turn reduce the cooling load on the house. The thermal mass of the tiles will absorb much of the heat during the day and then dissipate it to the cooler night air.

Adhering to conventional methods, the exterior wall was designed as the load bearing wall, then erected and insulated. The interior non-load bearing wall was built with a 5-1/2" space between it and the exterior wall. Insulation was then installed in the cavity between the two walls. After the electrical and mechanicals were installed in the interior wall, it was insulated. High density insulation was used to provide increased insulation value in less space. Both the interior and exterior 2x4 walls have R-14 insulation batts while the cavity between the two walls uses an R-22 batt for a total R value of 50.

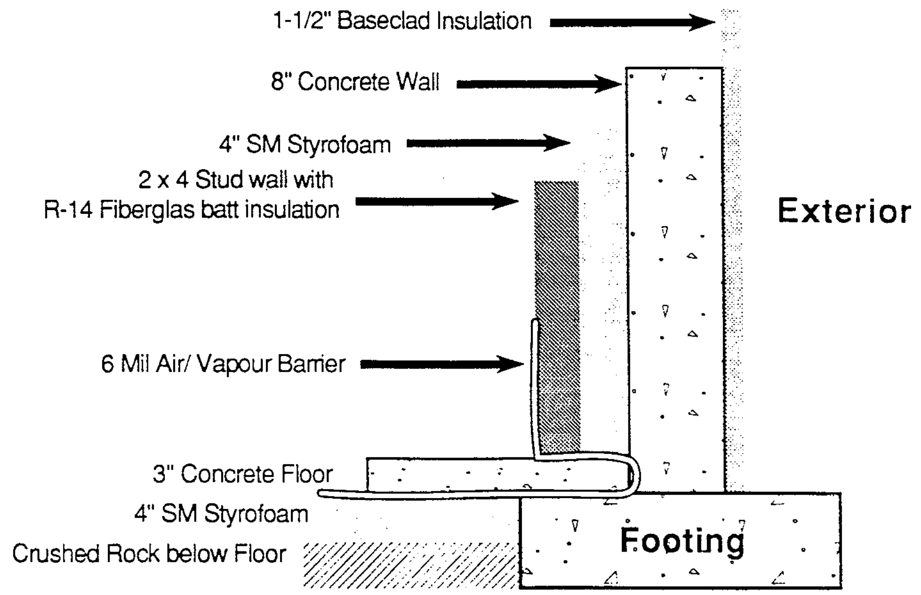
The continuous air/vapour barrier was installed using the same techniques applied to the air/vapour barrier in the



ceiling. All windows and doors were wrapped in polyethylene prior to being installed.

The entire exterior of the house was wrapped in a Tyvek air barrier. The air barrier will prevent any wind from entering the insulation and reducing its effectiveness. This, along with the high density to the insulation, should ensure the wall's peak performance. The brick exterior will work in much the same way as the clay tiles on the roof by providing a thermal lag which will assist both the heating and cooling systems.

Cross Section at Footing



The foundation walls are 8" poured in place concrete. The rim joists were wrapped in an air barrier making it continuous from floor to floor. On the inside of the concrete wall, 4" of SM Styrofoam insulation was installed. A stud wall was then installed tight to the Styrofoam insulation. After the electrical and mechanicals were put in, R-14 high density fibreglass batts were placed in the framed wall. The continuous air barrier was then put into place. Both the SM Styrofoam and the fibreglass insulation batts cover the wall from the top of the basement floor to the underside of the main floor joists. The header area was equally insulated. On the exterior of the foundation, 1-1/2" of Baseclad insulation was installed from the footing level to grade. This not only increased the insulation value below grade, it also improved drainage next to the foundation wall. This insulation scheme provides for a value of R-34 above grade and R-42 below grade.

The final component of the building envelope to be addressed was the basement floor. Generally speaking, basement floors have significant heat losses and should therefore be insulated. For the Saskatchewan Advanced House however, this was doubly important since radiant heating coils are run in the concrete floor and cooling coils are run in the ground below. If there is insufficient insulation, significant heat will be lost from the radiant floor into the soil below.

This house has 4" of SM Styrofoam insulation below the 3" concrete floor. This provides an R-20 value. There is a 6 mil poly moisture barrier between the insulation and the concrete floor. This poly not only acts as the moisture barrier, but also stops air movement into the basement through any cracks or control joints in the floor.

This house ha 4" of SM Styrofoam insulation below the 3' concrete floo. This provides a R-20 value.

This house should provide substantial long and short term savings thanks to reduced heat losses through the envelope. Each envelope component has a minimum of twice the thermal resistance that a typical house would have. The table below shows the expected heat loss by component for the building envelope and the corresponding savings in kilowatt hours per year.

As can be seen from the numbers in the table, the heat loss from the main components of the envelope is about 18,000 kilowatt hours less per year for the Saskatchewan Advanced House compared to a similar conventional house. If the heating is done using electricity at 6¢ per kilowatt hour, the savings would be about $1,100 per year currently or about $52,000 over the next 25 years assuming energy increases by 5% each year. If the same assumptions are made using natural gas at 2.5¢ per kilowatt hour, the savings would currently be about $450 per year or about $21,000 over the next 25 years. These both represent significant financial benefits to the homeowner.

Envelope Heat Losses

Component	Advanced House (in Kw-hr)	Conventional House (in Kw-hr)
Ceiling	1,488	2,666
Exterior Walls	3,103	9,210
Basement Walls Above Grade	610	1,724
Basement Walls Below Grade	1,312	3,064
Basement Floor	2,435	5,414
Windows	4,980	1,4666
Ventilation	5,516	10,172
Total Heat Loss	20,444	46,916
Heat Gains	13,392	21,530
Net Heat Loss	7,052	25,386

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Home Automation

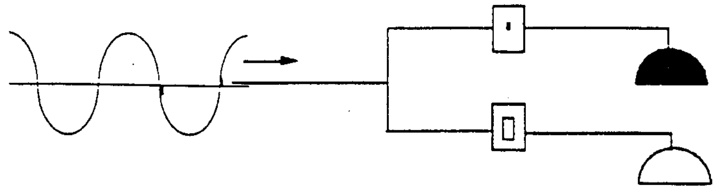
Home automation can be defined as home systems that work together to provide the simplified operation of two or more sub-systems. The Saskatchewan Advanced House has a number of control systems that make living in the home simple and comfortable. From the TotalHome™ System to the Electric Consumption Monitor to the heating and cooling system controller, this house will automatically control virtually all the functions of the house.

TotalHome™ System

Honeywell's TotalHome system links all security, heating, cooling appliances and lighting sub systems. The user simply selects a mode and the system arranges the desired pattern of protection, temperature and environmental operation, and sets present and scheduled electrical and lighting programs. A full line of optional compatible controls are also available to enhance the system.

The lighting control options include either the LiteCom or the Power Line Carrier system. The Saskatchewan Advanced House uses the Power Line Carrier option which is a 'wireless' solution because it uses the standard house wiring. Signals are sent over the existing house electrical wiring system. Conventional light switches and receptacles for independent control are replaced by Smart light switches and receptacles that can receive commands. Attached lights and appliances can be made to turn on or off.

Power Line Carrier



- Sends signals over existing power wiring
- Smart light switches and receptacles can receive commands
- Attached lights and appliances can be made to turn On or Off
- To make a "Home Automation" ready to replace conventional switches and receptacles

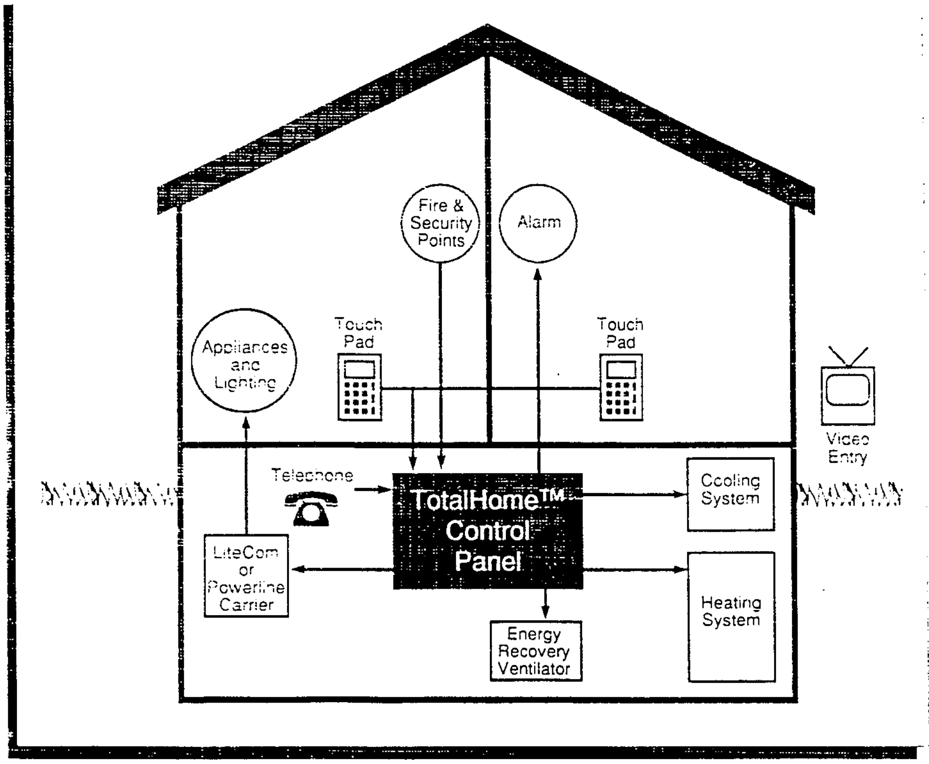
Point ID also allows the Customer Service Center to identify the exact door or window involved in an emergency.

Security is another feature of the TotalHome system. Small discreetly located sensors protect doors and windows and detect movement inside the home for added protection when asleep or away. Each protected point can be identified at the TotalHome panel. Point ID also allows the Customer Service Center to identify the exact door or window involved in an emergency. Partial arming allows you to selectively bypass certain points from the panel, while fully arming the rest of your system. Security patterns or modes may include points that are armed, disarmed or on watch, all at the same time for the ultimate in flexibility.

Temporary codes grant entry to others, such as babysitters, without divulging your master code. This feature can be restricted for extra security. Smoke and heat sensors detect fire and high temperature early. When seconds count, help is on the way — even if you're not at home. There are additional features to the security system as well that provide further benefits and flexibility to the user.

The TotalHome system will also integrate the heating and cooling of the home. By including chronotherms in the system, temperatures at various locations can be monitored. The system will then automatically control the heating or cooling to provide the pre-programmed environment. In the Saskatchewan Advanced House, chronotherms are used on each level of the house to monitor the temperature and shut down the heating or cooling system when the desired temperature is achieved.

The main benefit of the TotalHome system is that it can be pre-programmed for various modes. Each of these modes will automatically control the lighting, appliances, temperature and security of the house. For instance, in 'AT WORK' mode, the security system could be engaged, the temperature of the house reduced, and the lights and appliances could be automatically turned off with the exception of a few selected lights timed to turn on or off randomly to giving the house a lived-in look. Many other modes such as: 'GOOD MORNING', 'AT HOME', 'ON VACATION' and 'SLEEP' could all be programmed with their own specific set of instructions.

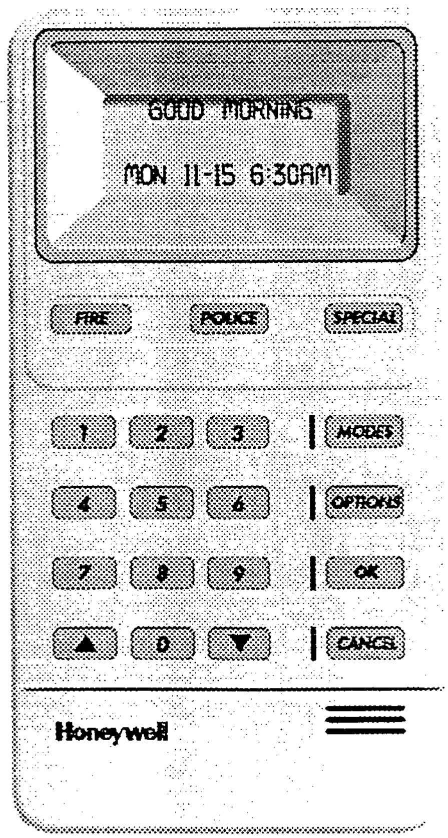


PowerStat

The PowerStat System is the new way of monitoring and purchasing energy. The system contains a monitor that is installed in the living area of the house and provides the homeowner with information about purchased energy, particularly electricity. This allows customers to keep track of their energy expenditure and provides feedback on energy consumption.

The PowerStat system provides convenience by allowing customers to buy their electricity when they have money available, and in any amount they choose. Rather than receiving a monthly bill, customers buy electricity on PowerCards. This can be done in person or by mailing a check to the utility for the dollar amount desired. The utility then either gives or mails the PowerCard to the customer, with the proper amount of electricity and the rate information encoded on the card.

The PowerCard is then run through the display box in the home, just like a credit card. The purchased electricity and rates are then entered. This purchased amount of electricity will flow into the house and be monitored by the PowerStat system. If the customer allows the dollar amount to drop to zero, the PowerStat will either extend service or disconnect service, depending on how the PowerCard has been encoded by the utility.



On the display box, customers can monitor, in easy to understand dollars and cents, the amount of electricity remaining in their account, the amount presently being used in cents per hour, the amount used yesterday, the amount used last month and the actual cost of each kilowatt-hour.

Heating and Cooling Controller

The heating and cooling system is controlled by a Techmar 135 differential controller inside the house that monitors exterior temperatures and makes adjustments to the mechanical system as necessary.

When the exterior temperature dips below 65°F, the Techmar controller engages the radiant heating system. At that time, water at 72°F begins circulating through the pipes. As the exterior temperature goes down, the temperature of the water being pumped through the heating pipes increases. At -25°F, the temperature of the water being circulated will be about 90°F. The heat loss characteristics of the house are very well known so the above temperatures will provide a very comfortable environment for the occupants.

Water temperatures have been selected to replace the exact amount of heat being lost from the house. Should the temperature of the room rise too high, the chronotherm will sense this and tell the TotalHome system to shut down the heating system.

A similar control mechanism is set up for the cooling system. When the exterior temperature reaches 80°F, the Techmar 135 controller activates pumps that circulate cool water through the ceiling of the main and upper levels. Again, because the heat gain characteristics of the house are well known, the amount of cooling is matched to the heat load. If the temperatures should get too low, the chronotherm tells the TotalHome system to shut down the cooling system.

Water temperatures have been selected to replace the exact amount of heat being lost from the house.

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Integrated Mechanical System

There are a number of components to the integrated mechanical system that interact to provide space heating and domestic hot water. These components include the solar collectors, the heat storage tank, the domestic hot water heaters and the heat exchangers. This entire system is designed to collect and store as much heat as possible from the sun to be used as needed. It is hoped that this will significantly reduce the amount of purchased energy required for both space and domestic hot water heating.

Solar Collectors

The solar collectors are located on the upper roof of the Saskatchewan Advanced House facing 10° west of south and are installed at an 8/12 pitch. There are 60 solar collectors providing 65 square feet of collector area. These collectors are expected to provide clean, useful energy throughout the year, even in unfavourable weather conditions.

There are two basic types of solar collectors: 'flat-plate' panels and evacuated heat-pipe collectors. The collectors for the Saskatchewan Advanced House are an evacuated heat-pipe solar collector manufactured by Thermomax Ltd., model THS200.

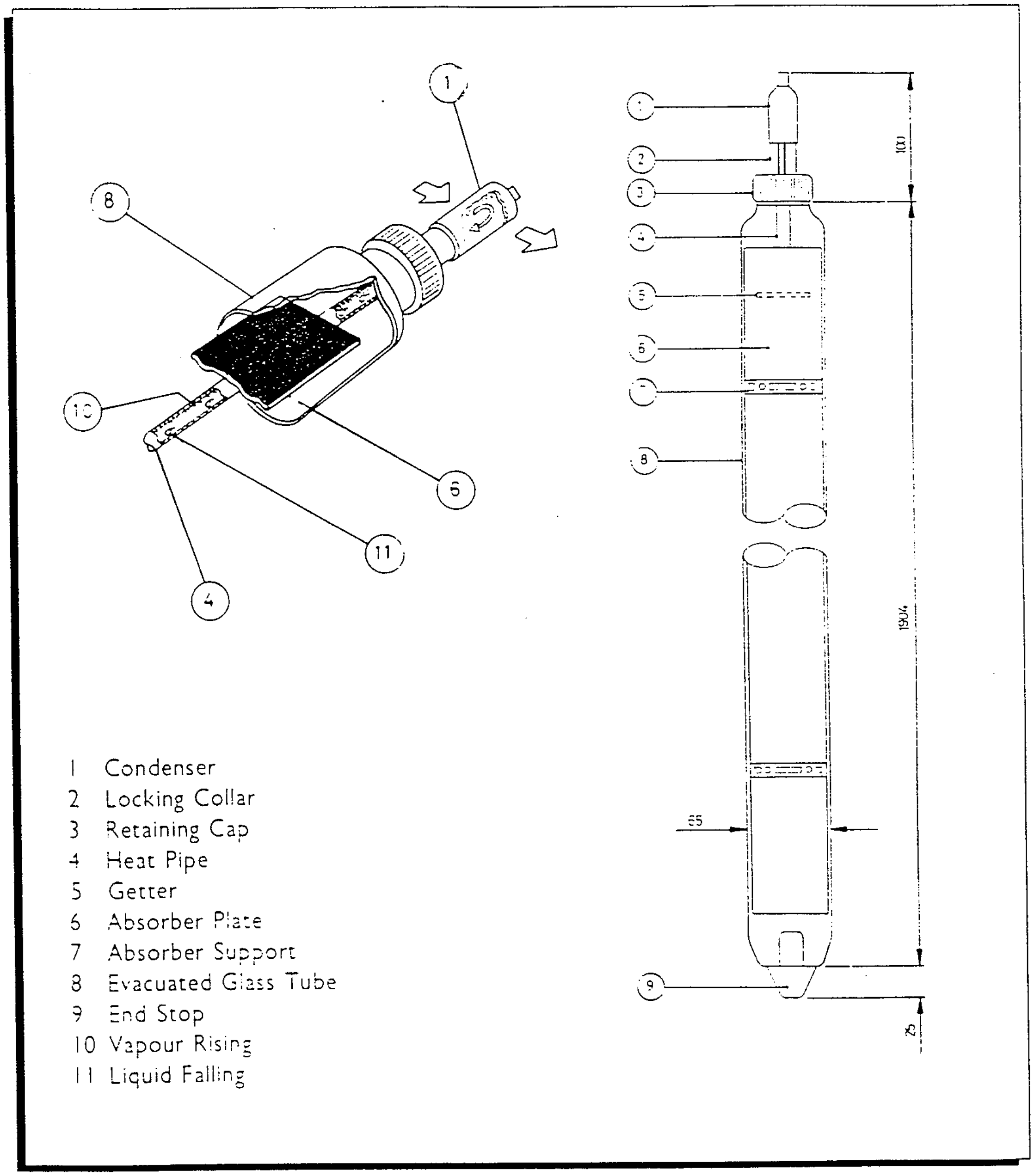
These collectors have an absorber plate treated with a semi-conductor layer. This special wavelength 'selective' coating ensures high energy absorption and low heat radiation losses. Infrared rays which pass through the clouds are also absorbed and converted into usable heat.

Transfer of heat from the absorber plate to the water is via an efficient heat conductor: the heat-pipe. This has very low heat capacity but fast heat conductivity. The heat-pipe also provides the system with a diode function, i.e.; heat transfer is always in one direction, from the absorber to the water and never in the reverse. Due to the physical properties of the heat-pipe fluid, the maximum working temperature can be controlled. This eliminates the need for a complicated control unit and ensures safety in the system.

The absorber with the heat-pipe is enclosed in a glass tube and the air inside is evacuated to eliminate thermal losses from conduction and convection. This results in a higher energy gain. The vacuum also protects the absorber plate, selective coating and the heat-pipe against rain, moisture, air and pollution. The model THS200 being used has a designed cut-off temperature of 95°C and is recommended for applications up to 75°C. The specially coated absorber plate has an absorption of better than 0.96 and an emmittance of less than 0.1. A schematic of the evacuated heat-pipe solar collector is shown below.

Piping runs from the manifold of the solar collectors to the heat storage tank in the basement. The piping runs primarily through the interior walls of the house, however since part of the loop is located outside the building envelope, precautions were taken to prevent freezing. The fluid used to carry the heat from the manifold to the storage tank is a 50/50 solution of ethylene glycol and water. A pump circulates the fluid through the piping at flow rates between 0.1 and 0.25 litres per minute per collector tube. For the system

Infrared rays which pass through the clouds are also absorbed and converted into usable heat.



on the Saskatchewan Advanced House, this works out to between 1.3 and 3.3 gallons per minute. Increased flow rates will only increase the system pressure drop without any improve-ment in system performance.

Heat Storage Tank

The heat storage tank is located in the basement mechanical room. The tank is constructed of 2 x 6 framing members, 1/2" plywood, 5 1/2" of fibreglass insulation and 2" styrofoam insulation (R-32 total). The tank was made waterproof through the use of an EPDM seamless liner. Capacity of the tank is 750 gallons.

Heat Exhangers

There are 3 heat transfer coils in the tank. The first of these coils is used to transfer heat from the solar collectors to the water in the storage tank. Based on a heat transfer coefficient of 50 BTU/hr-ft²-°F between the working fluid and the copper pipe, approximately 98 feet of 3/4" copper tubing was fabricated into a heat exchange coil and installed in the heat storage tank.

The other two coils in the heat storage tank are for heat extraction. These coils contain potable water and are connected to the hot water tanks situated above the heat storage tank. Water circulates through these heat extraction coils driven by the force of a thermosyphon. 56 feet of 3/4" copper tubing was needed for transfer of the heat required to raise the temperature of the water in the the tanks from 45° F to 125°F in 2 hours or less. A schematic of this arrangement is shown at right.

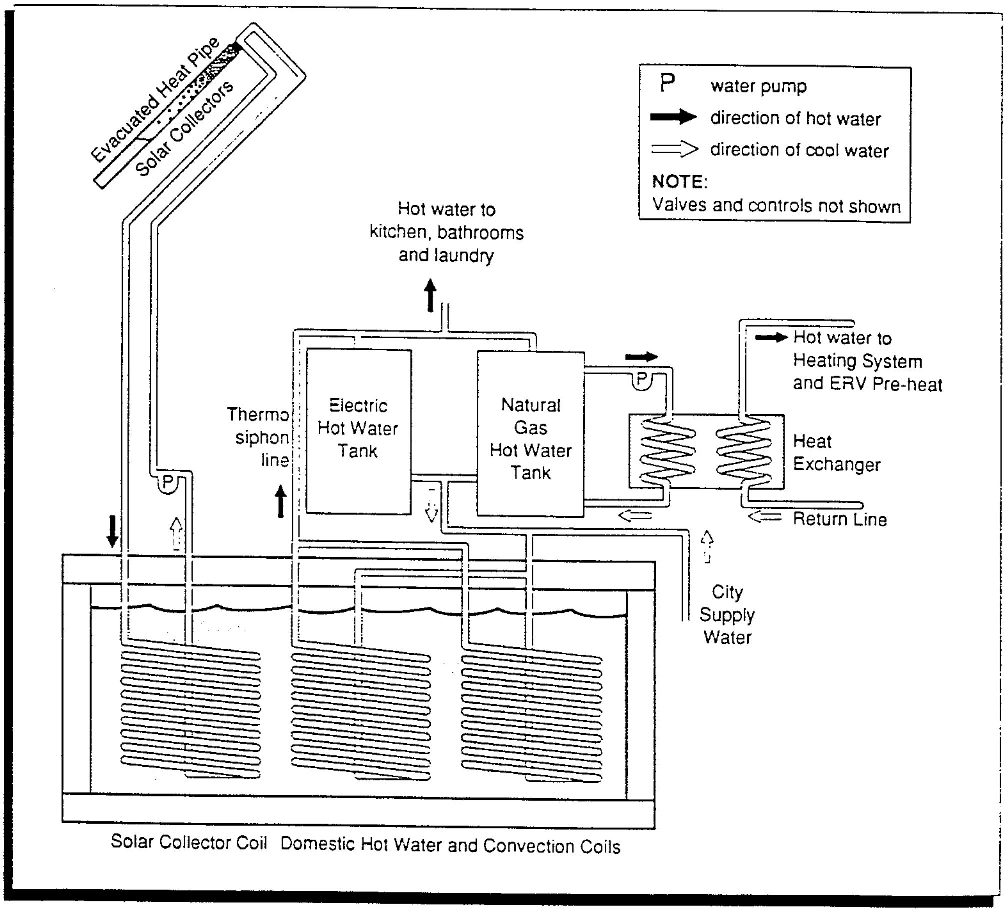
A heat exchanger is also used to take heat from the hot water heaters and transfer it to the radiant floor heating system. This water to water heat exchanger measures only 4" x 8" x 2" and is situated between the floor trusses in the mechanical room. Water is taken from the hot water tanks and the heat is transferred to the water circulating through the floor heating system.

Domestic Hot water Heaters

There are 2 domestic hot water tanks in the Saskatchewan Advanced House. One of the tanks is a 50 gallon electric tank while the other is a 30 gallon Pulsar sealed combustion natural gas tank. These tanks are connected in parallel and are an integral part to the overall mechanical system.

The domestic hot water heaters are designed to back-up the solar system when it cannot provide enough hot water for

Water circulates through these heat extraction coils driven by the force of a thermosyphon.



domestic use or space heating. The double tank system is used to provide extra storage capacity.

When hot water is used in the house, cold city water flows into the bottom of the two hot water heaters to replace the water used. When hot water use stops, the thermosyphon begins to transfer water heated in the solar storage tank to the hot water tanks. When space heating is required, a pump will circulate water from the hotwater tanks through the heating system heat exchanger. As the temperature in the hot water tanks is lowered, the thermosyphon will bring the tanks back up to temperature. If the thermosyphon can not bring the hot water tanks up to temperature quickly enough, purchased energy will be utilized to do so.

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Indoor Air Quality

Indoor air quality will likely be defined differently by everyone who is asked to define it. For those with allergies, it may mean the removal of pollen and dust from the air. For those with super sensitivity, it may mean the removal of virtually every contaminant in the air. For someone else, it may mean a fresh smelling, well ventilated house.

There are currently no standards to measure air quality. There are recommendations by Health and Welfare Canada about threshold levels for various contaminants above which action should be taken. Some of these contaminants include carbon dioxide, carbon monoxide, radon, formaldehyde and volatile organic chemicals. In the Saskatchewan Advanced House, most of these pollutants will be monitored during the next few years.

There are two strategies for controlling pollutants in any home. The first and best strategy is to eliminate as many of the pollutants as possible from entering the house in the first place. This is know as the exclusion strategy. The second option is to provide adequate ventilation to reduce the concentration of pollutants. Both of these strategies have been employed in the Saskatchewan Advanced House.

Exclusion

Various products used in the Saskatchewan Advanced House have been tested for offgassing. Offgasing is the process by which pollutants from new products enter the interior environment of the house. The four main pollutants targeted for exclusion were formaldehyde, radon, carbon monoxide and volatile organic chemicals.

Formaldehyde enters the house through construction materials and furniture or decorating materials. It is usually present in urea formaldehyde glues and binders. Formaldehyde can be found in certain panel sheathing, adhesives, some flooring products, furniture and draperies. When selecting these materials, one of the main considerations was the amount of formaldehyde that these selected products would produce.

Oriented strand board (OSB) was used for subflooring and also in the manufacture of the floor trusses. This material has lower emission rates than other particle boards. The cabinets and vanities were constructed with oak, plywood and solid boards. All

Formaldehyde enters the house through construction materials and furniture or decorating materials. It is usually present in urea formal-dehyde glues and binders.

Pollutant	Sources in the Home	Health Effects	Method of Pollutant Control
Formaldehyde Colourless gas with strong odour.	Various construction materials, including particle board, interior paneling, and drapes.	Nose, throat and eye irritation.	Substitute waferboard and exterior-grade plywoods for particle boards. Seal particle board with vapour-proof sealer, paint or varnish in cabinets and closets and on subflooring. Increase ventilation rates.
Radon Odourless, colourless radioactive gas.	Soil beneath and around the house foundation.	Believed to be cause of 5 to 10 percent of all lung cancers.	Seal floor drains, sumps, and all cracks, joints and penetrations through basement walls and slab. Ventilate crawl space and tightly seal subfloor joists and penetrations. Depressurize gravel bed beneath slab or isolate basement from rest of house and pressurize with air drawn from floors above.
Carbon Monoxide Colourless, odourless gas.	Kerosene heaters, wood-burning appliances, unvented gas appliances, and attached garages.	Nausea, headaches, and blue fingernails. Severe poisoning can cause brain damage in fetuses and can also be fatal.	Provide outside combustion air feed to firebox of all wood-burning appliances. Install tight-fitting doors on fireplaces and wood stoves. Vent gas ranges directly to outside. Provide adequately sized tempered make-up air for exhaust fans. Use induced draft or sealed draft hot water heaters and furnaces or place outside building envelope.
Organic Solvents	Household cleaners, solvents in paints and caulkings.	Irritation of eye, nose and throat. Can affect central nervous system.	Use solvent-based materials in well-ventilated areas. Substitute latex-based paints and caulks for solvent-based products.

The amount of radon present in the soil is highly variable and although it is uncertain what concentration this location has, precautions were taken to keep it outside the living environment.

adhesives used in the Advanced House were selected on the basis of their chemical composition. The tables and chairs were all made of solid wood and the foam cushions in the furniture contain no CFC's.

Radon was eliminated from the house by paying very close attention to the moisture and air barrier in the basement. Radon enters most houses primarily from the soil through cracks in the foundation walls and floor. The amount of radon present in the soil is highly variable and although it is uncertain what concentration this location has, precautions were taken to keep it outside the living environment. A continuous moisture barrier of 6 mil poly was installed under the basement floor. A continuous air barrier was installed on the inside of the basement wall insulation and connected to the basement floor moisture barrier. Even if small cracks should occur in the floor or walls, the continuous moisture and air barriers will keep out any soil gases, particularly any radon.

A layer of crushed rock was installed under the basement floor and tubes were installed through the footings into a granular backfill. This allows as much radon as possible to naturally escape through the soil. If radon buildup should become a problem, it is possible to install a vent into the crushed rock below the basement floor to provide mechanical subslab ventilation.

Carbon monoxide is a deadly gas that is both invisible and odourless. It is the by-product of combustion. In standard housing, the leading sources of carbon monoxide are from the furnace, water heater and fireplaces. If the combustion from using these appliances was 100% efficient, there would be no carbon monoxide produced. Since the combustion process is virtually never 100% efficient, there are various pollutants produced; carbon monoxide being one of the most serious. If there is any backdrafting of the chimneys, carbon monoxide can cause health problems for the occupants.

The Saskatchewan Advanced House has virtually eliminated all sources of carbon monoxide production. This house does not require a furnace since most of the space heating comes from the solar collectors. The natural gas water heater uses sealed combustion technology. This means that it is completely sealed and has no interaction with the inside environment of the house. Finally, the natural gas fireplace is direct vent, meaning that like the water heater, combustion products are vented to the outside. The home's prototype natural gas range/oven also uses a sealed combustion system to eliminate the risk of pollutants from entering the home environment.

present. A ventilation strategy will not only exhaust pollutants, but will also introduce fresh, clean air to reduce the concentration of pollutants.

There is a new ventilation standard being developed which will soon be adopted by the housing industry. The F326 Ventilation Standard will require all new homes to be ventilated on a continuous basis. This new standard also stipulates how the air is to be distributed. The Saskatchewan Advanced House has a ventilation system that already meets the F326 Standard.

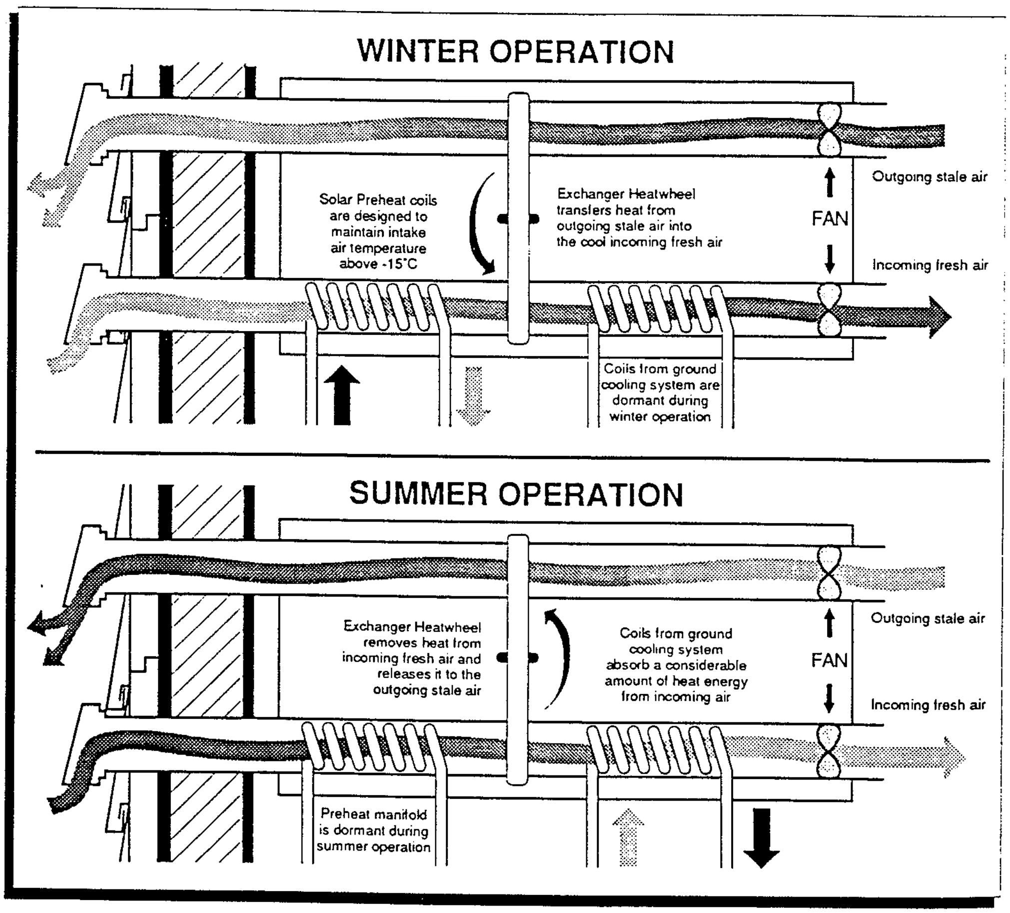
The main component of the ventilation system is the Honeywell Energy Recovery Ventilator. It is a ventilation unit that exhausts stale air from specific areas of the house and distributes an equivalent amount of fresh air to other areas of the house. This unit will be set to run continuously at 180 cubic feet per minute, but it has the

A ventilation strategy will not only exhaust pollutants, but will also introduce fresh, clean air to reduce the concentration of pollutants.

Volatile Organic Chemicals can be hazardous to your health and are particularly difficult to deal with if you have certain sensitivities. Most commonly they are found in paints and other finishing products. Only ECOLOGO latex paint and wood sealers were use in the Saskatchewan Advanced House. The paint used was an eggshell hy-hide latex paint. The cabinets and finishing used an enviroguard urethane sealer.

Ventilation

Proper ventilation practices and techniques complement the exclusion strategy for obtaining a high degree of air quality inside the home. Even with an excellent exclusion program, there are some pollutants



The ERV has a heat wheel which rotates and extracts heat from the exhausted air and which it puts back into the incoming fresh air.

capability to operate at 250 cubic feet per minute. This Energy Recovery Ventilator (ERV) standardly comes with 120 volt AC blowers. These have been replaced with 24 volt DC blowers in the Advanced House so that they can be powered by the photo-voltaic system. The ERV has a heat wheel which rotates and extracts heat from the exhausted air and which it puts back into the incoming fresh air. This feature re-covers about 80% of the energy that would otherwise be lost. The heat wheel also controls indoor humidity to some degree. In the winter, it extracts humidity from the exhaust air and puts it into the incoming fresh air. During the summer operation, humidity is extracted from the incoming fresh air and put into the exhaust air, thereby reducing indoor humidity levels.

In a house with a forced air heating system, the incoming fresh air would normally be fed into the duct work of the heating system and be distributed in that fashion. Since this house does not have a forced air heating system, a separate duct system has been designed and installed for the ventilation system. Each of the ducts have been specifically sized to supply or exhaust the required amount of air to or from each room.

The F326 Ventilation Standard requires that each room in the house either have stale air exhausted from it or have fresh air supplied to it. In the Saskatchewan Advanced House, each of the four bathrooms will have 30 cubic feet of air per minute continuously exhausted while the kitchen will have 60 cubic feet of air per minute continuously exhausted.

A supply duct runs to each of the other rooms in the house. The master bedroom is supplied with 30 cubic feet per minute while the remaining bedrooms and den are supplied with 20 cubic feet per minute. The family room and living room are supplied with 35 cubic feet per minute. All of these rates are on a continuous basis.

The Energy Recovery Ventilator contains the fans for moving all of the supply and exhaust air through the ducting system. The total amount of continuous exhaust is 180 cubic feet per minute. As this is a balanced system, the total amount of continuous supply is 180 cubic feet per minute. The ERV actually has a capacity to ventilate at 250 cubic feet per minute or about 40% higher than the continuous rate. There are controls in the main areas of the house to increase the ventilation rate to the maximum during those times when extra ventilation is required such as when cooking or entertaining.

Carroll Homes Ltd. and the Saskatchewan Advanced House Management Team recognize the following sponsors and contributors without whose participation this project would not have been possible.

Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET

Canadian Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

Honeywell

Saskatchewan Home Builders' Association, Inc.

APPENDIX B

Monthly Graphs of Energy Consumption

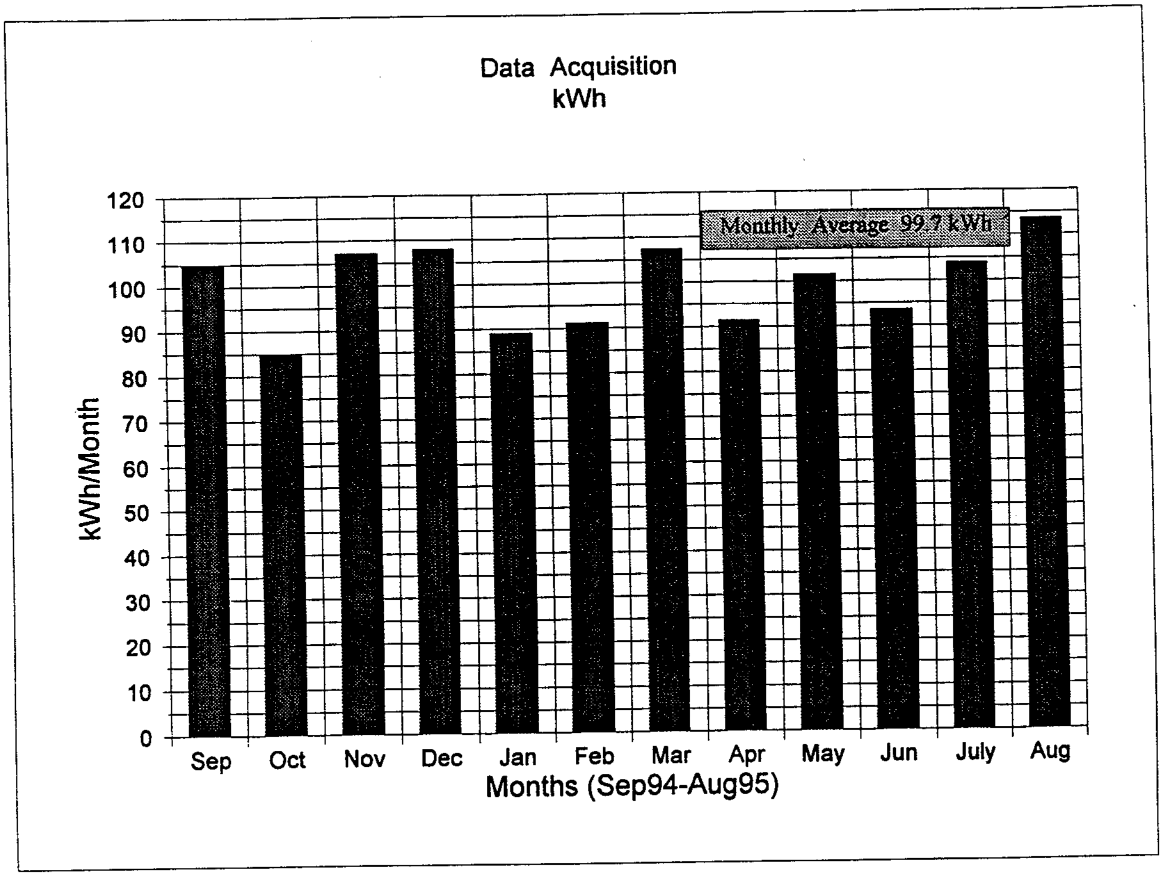


Figure B1. Monthly electrical consumption of data acquisition system

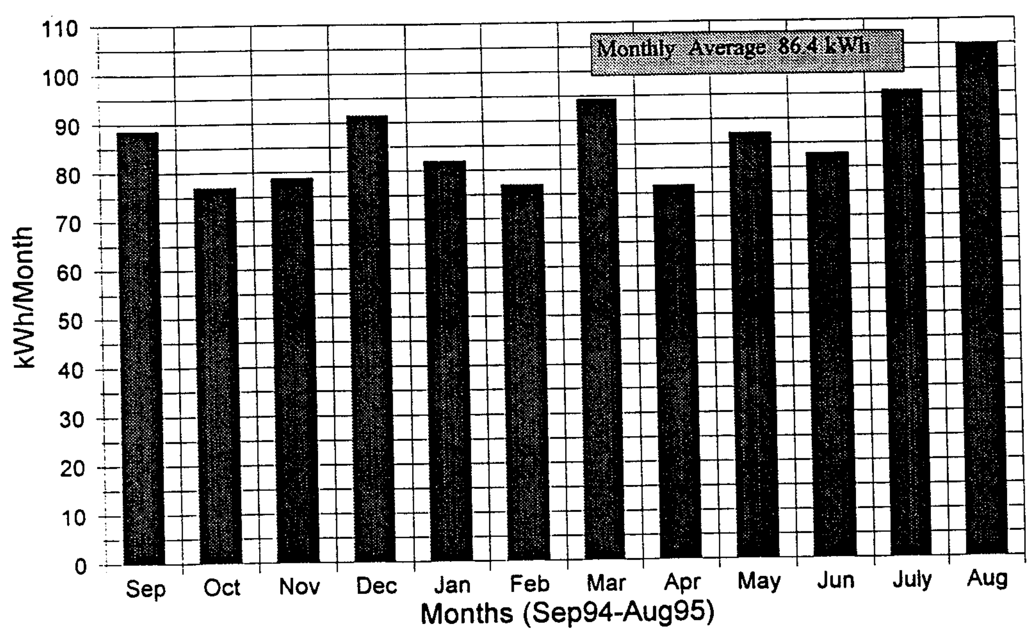


Figure B2. Monthly electrical consumption of AC refrigerator-freezer

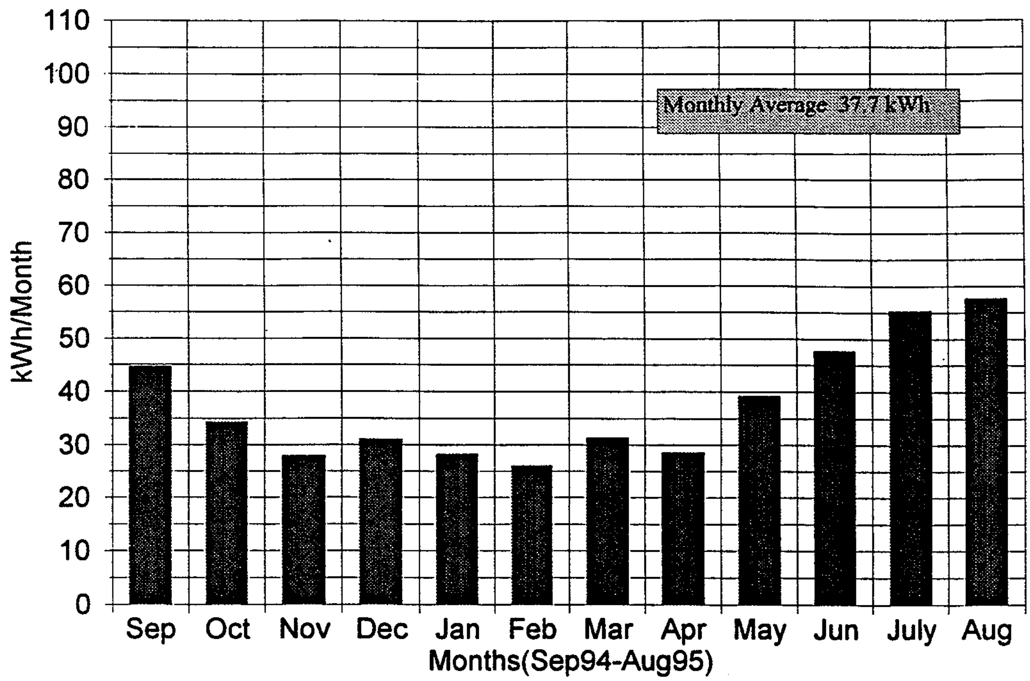


Figure B3. Monthly electrical consumption of AC chest freezer

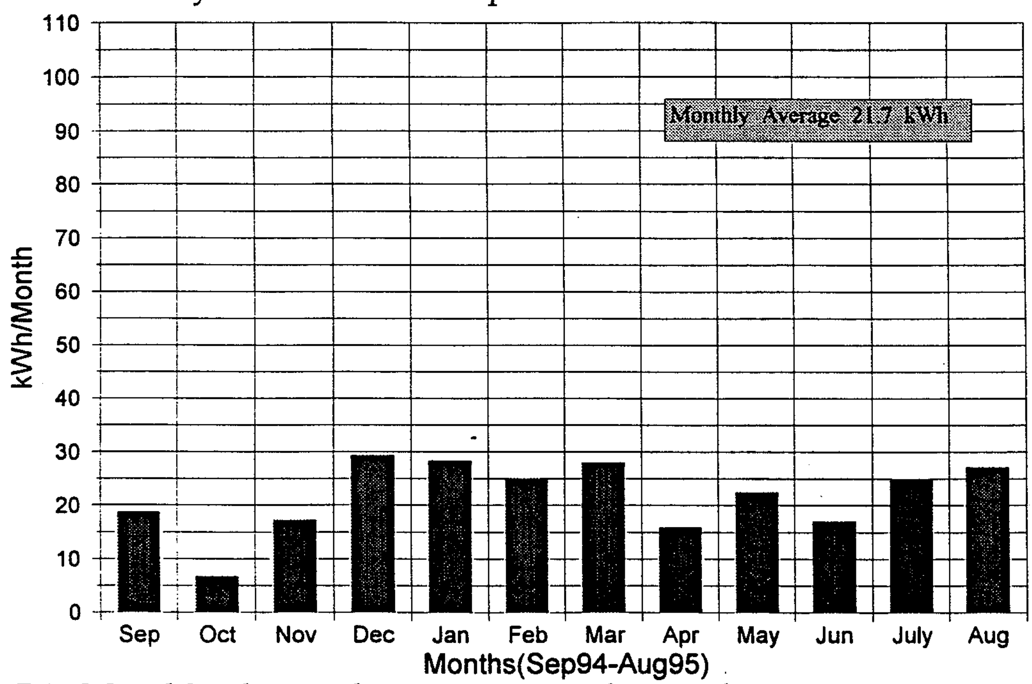


Figure B4. Monthly electrical consumption of natural gas range

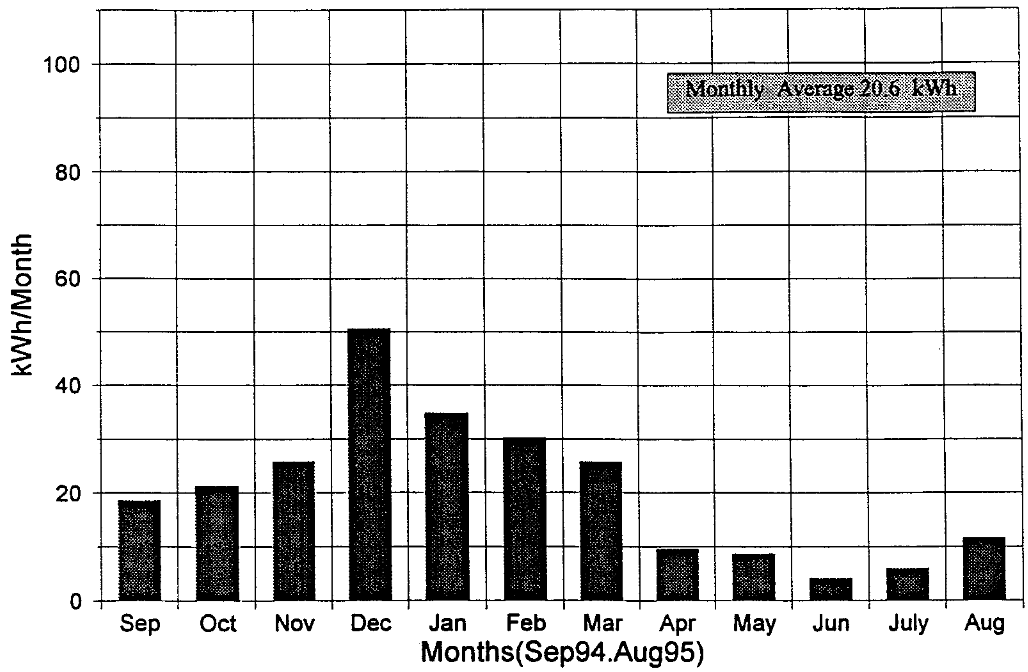


Figure B5. Monthly electrical consumption of AC inside lights

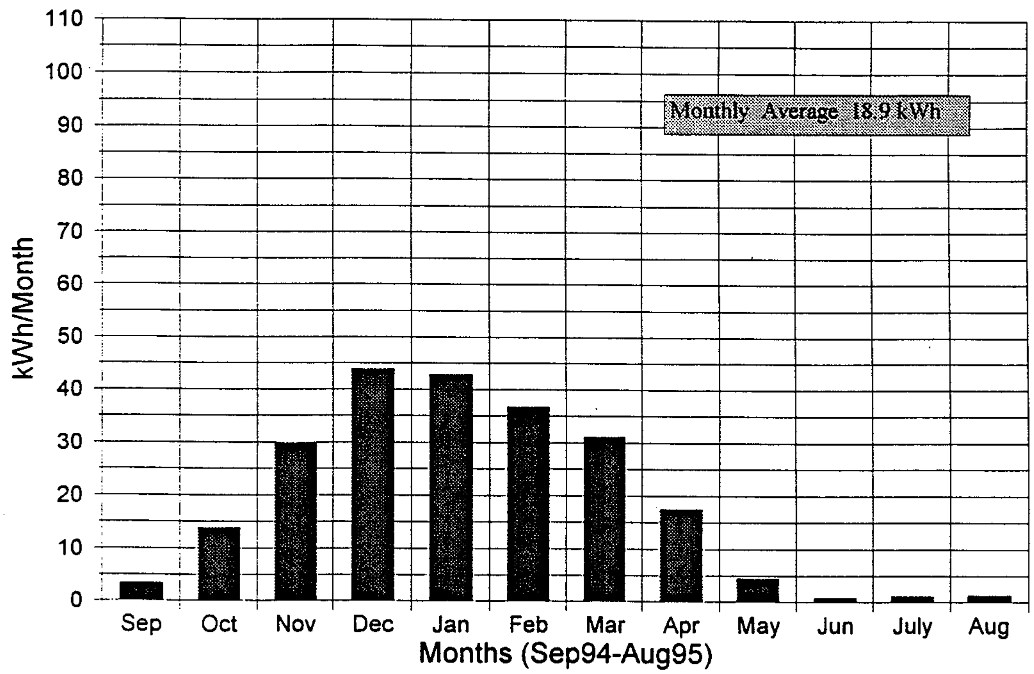


Figure B6. Monthly electrical consumption of natural gas water heater

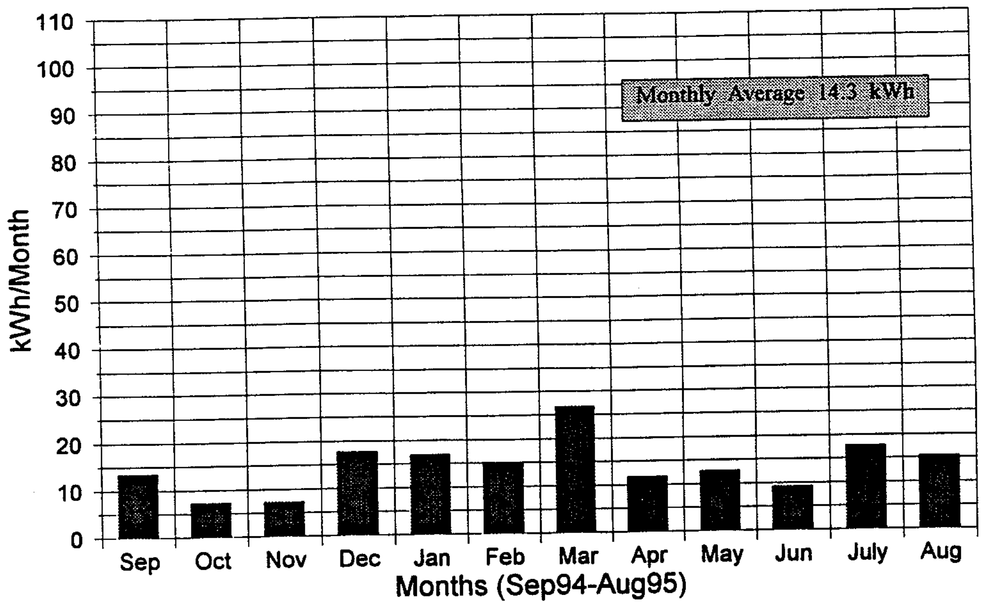


Figure B7. Monthly electrical consumption of dishwasher (excluding hot water)

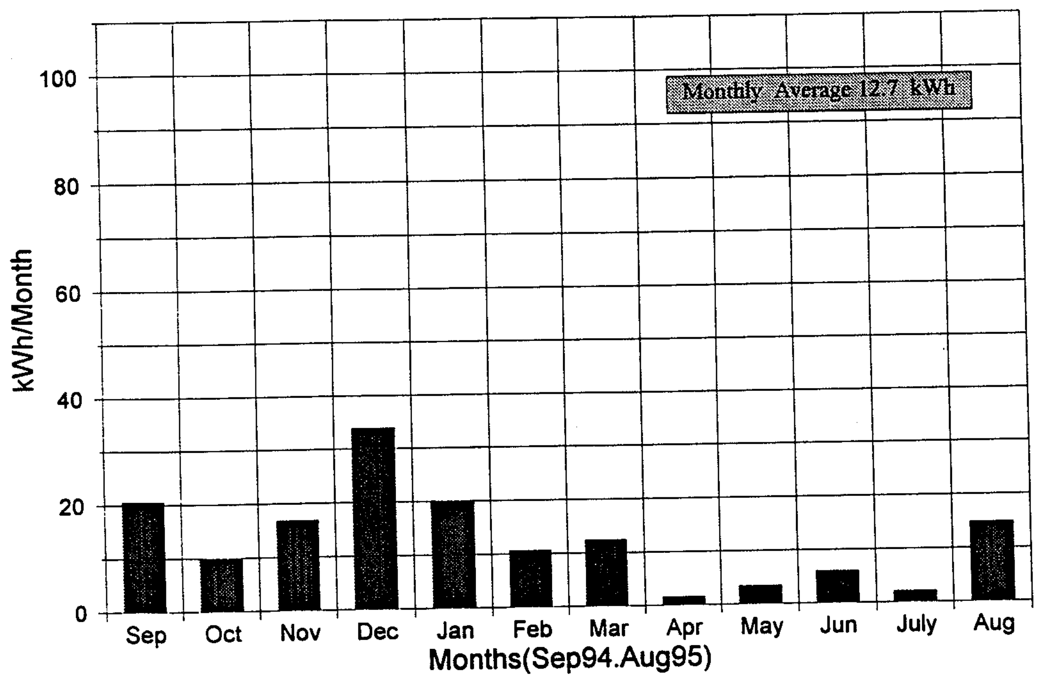


Figure B8. Monthly electrical consumption of AC outside lights

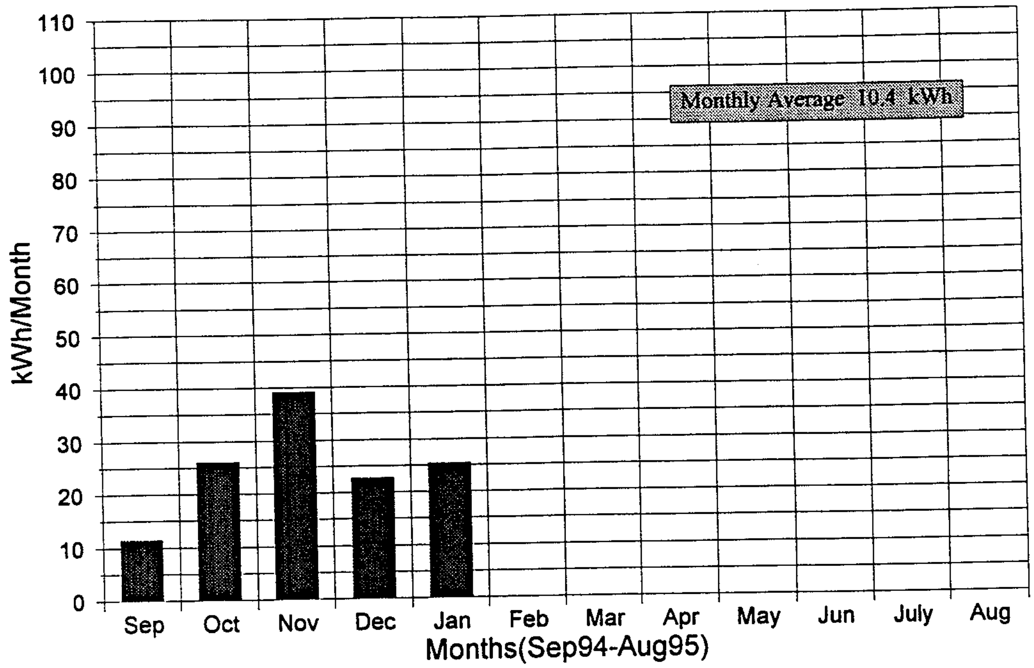


Figure B9. Monthly electrical consumption of AC battery charger

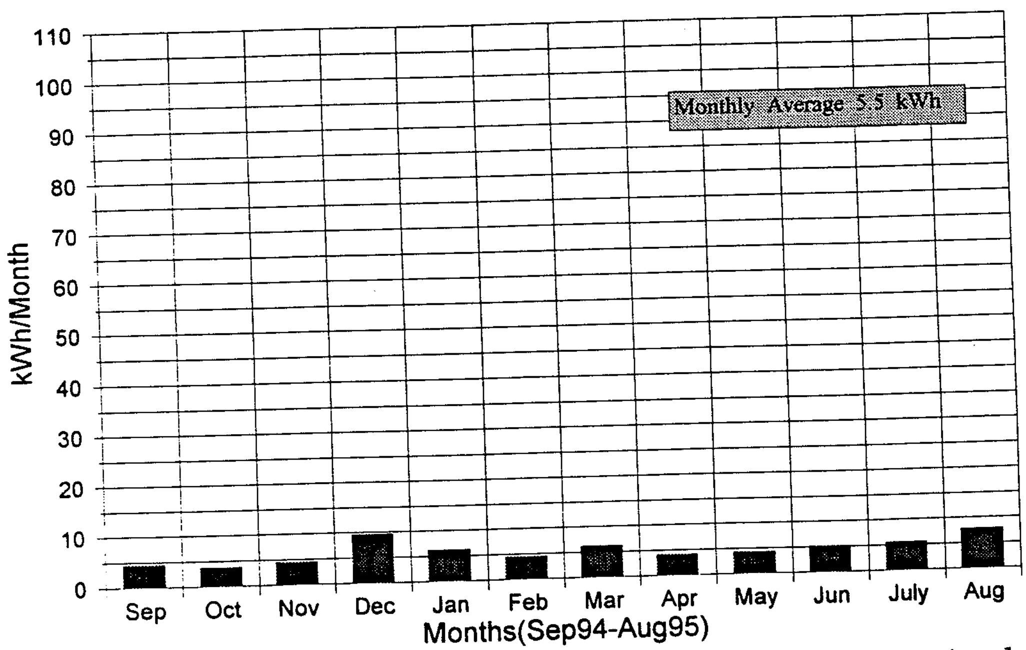


Figure B10. Monthly electrical consumption of washing machine (excluding hot water)

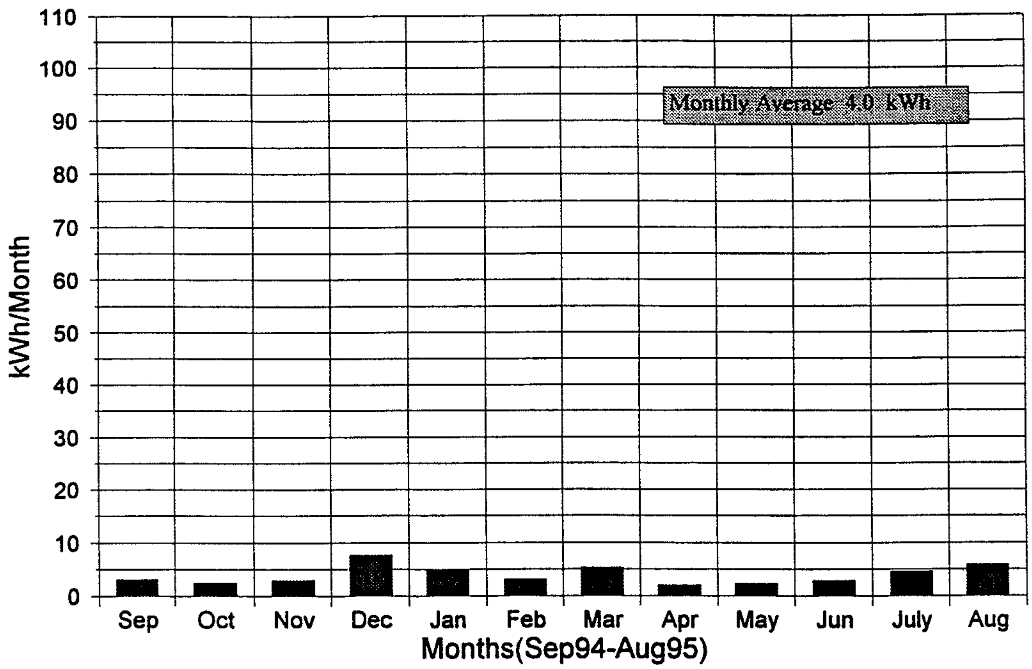


Figure B11. Monthly electrical consumption of natural gas clothes dryer

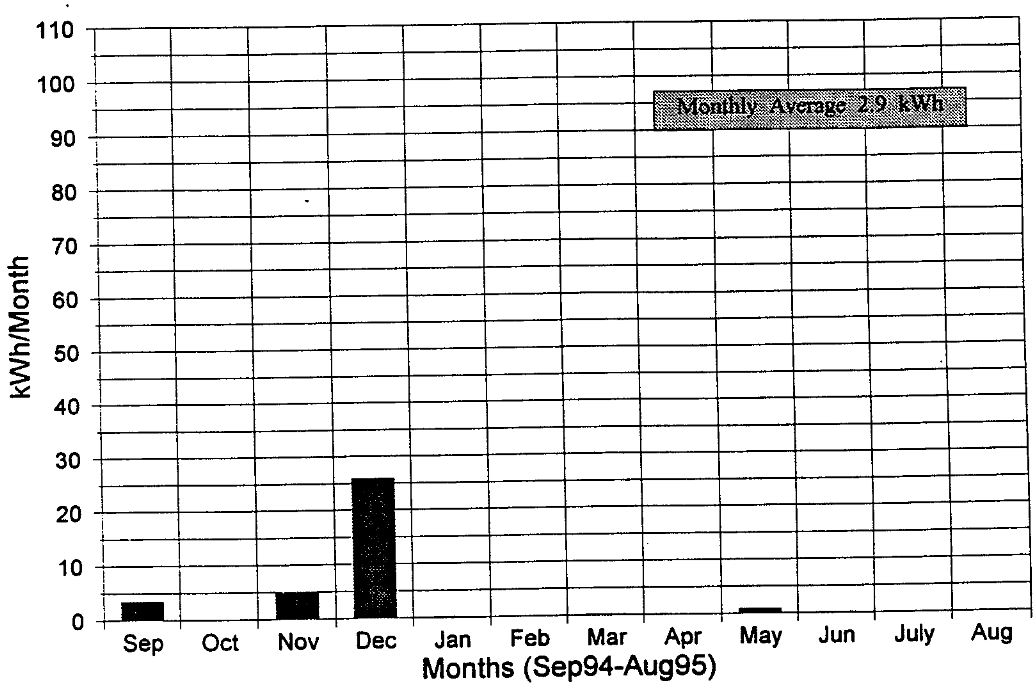


Figure B12. Monthly electrical consumption of AC outside plugs

APPENDIX C

Homeowner's Assessment

511 Braeburn Court
Saskatoon, SK
October 8, 1997

Saskatchewan Research Council
15 Innovation Blvd.
Saskatoon, SK
S7N 2X8

Dear Sir:

RE: Saskatchewan Advanced House

A lot of people, representing many different agencies and interests were co-ordinated to try and build a better house. After all the energy expended, the data analyzed, did they succeed? Here is the opinion of the people who live in the Saskatchewan Advanced House.

Living in the Saskatchewan Advanced House has been, for the most part, a very enjoyable experience. Four areas that the house excels in are comfort, built quality, brightness and efficiency.

<u>Comfort</u>
The radiant floor heating and radiant cooling systems coupled with the constant ventilation supplied by the Heat Recovery Ventilator, provide for cosy winters and comfortable summers. In winter, you can walk up to any window without feeling chilled, and the floors are always warm. In summer, the coolness of the house is very natural - different from an air-conditioned environment - like walking into the shade of a tree. The air in the house is always fresh, never stale, and condensation on windows is non-existent. The best thing is that this comfort is achieved in a low tech, environmentally friendly way - circulating water.

<u>Built Quality</u>
If the house were a car, it would be an armor-plated Rolls-Royce. The 18" thick walls, insulation, complete masonry exterior, concrete tile roof, concrete floors, and triple-glazed gas filled windows, work together to provide a living environment that "feels" safe and secure to live in. The quietness inside is a novelty at first until you get adjusted to it. You can be in the midst of a pelting summer downpour, and not even know it is raining unless you <u>look</u> outside. You can be snowblowing the front driveway and not hear a thing just inside the front door. And, of course, there is no such thing as squeaking or flexing floors.

<u>Brightness</u>

If Saskatoon has the most hours of sunlight per year on the continent, this house was designed to let a good deal of it into the house. With plenty of southern exposure, the house is airy and bright year round. The lightpipe provides light to the north-facing half of the house.

Efficiency

With all of the energy saving features, it costs $.41/square foot to run the house in 1995 including power, gas, water and sewage. The house could be run for a little less if we were to reduce our electric power consumption by not leaving exterior lights on etc. As it is, we are still well below the operating cost for a house of standard construction (even with a double heated garage) and are receiving a far greater standard of comfort.

As with many things in life, one would be hard pressed to live in a house of standard construction after living in this house. The physical and psychological comfort provided through all climate extremes, makes one wonder how much better it can get.

Sincerely,

Terry Fehr
Owner
Saskatchewan Advanced House