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Energy-Efficient Advanced House with Integrated Mechanical System

Summary

The Advanced House represents the next generation of energy-efficient housing. The total energy requirements of the house have been reduced to an estimated 31% of the needs of a conventional home. This has been accomplished by incorporating such features, as a prototype, an Integrated Mechanical System (IMS), high-performance windows, energy-efficient lighting and appliances, high levels of insulation, airtight construction, and an energy-efficient fireplace. According to computer predictions, the advanced House will use 8340 kWh of energy annually for all heating and cooling; an additional 4042 kWh will be consumed by energy-efficient lights and appliances. Peak power demand will be below 10 kW, about half the peak demand of a standard house.

Highlights

Compared with a conventional house:

- Uses 31% of the energy
- Requires less than 50% of peak power
- Incremental cost 10%-20%

The two-story sun space.

The Principle

The Advanced House is a demonstration project, intended to inform designers, builders and consumers of the techniques that constitute total building energy efficiency. The house is innovative, yet practical: the majority of the showcase concepts use products that are now, or soon will be, available and affordable. None of the technologies compromise comfort or safety. The construction uses conventional Canadian construction techniques and does not require specialized trades people. The following discussion provides details on elements of the Advanced House.

The house

The Advanced House is a 250 m^2 house with a two-story south-facing sun space, four bedrooms, three bathrooms, a double garage and a large basement. It is situated in Brampton, near Toronto, and is on a corner lot with south-western exposure.

Integrated Mechanical System

The prototype IMS replaces the furnace, hot water tank, air-conditioner and heat recovery ventilation system of a typical low energy house. It consists of a cabinet and a separate storage tank unit. The cabinet contains a 150 litre hot water tank with an electric back-up heater, a liquid-liquid heat pump, a heating/cooling fan coil, and an exhaust-heat recovery coil. The thermal storage unit consists of a 450 litre insulated tank that contains an ice slurry.

The initial step in heat recovery is provided by an antifreeze loop that collects heat from greywater and exhaust air and moves the waste heat to the thermal storage tank. The heat pump then takes heat from the thermal storage tank and transfers it to the hot water tank.

Hot tapwater needs are provided directly by the hot water tank. In addition, when space heating is required, the hot water tank meets this need. Specifically, the hot water is circulated through the fan-coil unit. Return air from the house, mixed with fresh ventilation air from outside, is blown through the fan-coil unit, where it picks up heat prior to being distributed throughout the house.

When cooling is required, cold liquid from the thermal storage tank is circulated through the fan-coil unit. The household air is chilled as it is blown through the coils.

According to computer modelling, the IMS will require 8340 kWh of electricity annually, less than half the 16,600 kWh that an electric furnace and air-conditioner would use.

High-performance windows

All windows in the house are high-performance; the overall RSI-value (window and frame) is 0.91. The windows feature triple glazing, 12 mm argon filled spaces between the sheets of glass, two low-emissivity coatings, low-conduction spacers, and wood frames. Compared to standard double-glazed units, the windows annually save 3600 kWh (about 30% of what the total heating and cooling load would otherwise have been).

High levels of insulation

The Advanced House was framed conventionally, then a second wall was built on the inside to create a 241 mm cavity, which was filled with wet-blown cellulose. Exterior fibreglass sheathing provides additional above-grade insulation. The concrete basement was insulated with semi-rigid fibreglass on the exterior of the walls and below the floor slab. Dry blown cellulose was applied to the interior of the basement walls to provide additional insulation. The overall RSI values are: ceilings, 10.6; above-grade walls, 6.9; below-grade walls, 6.55; basement floor slab, 1.6. In addition to high levels of insulation, a sealed six mil polyethylene sheet, installed behind the drywall, provides a measured airtightness of under 1 air-change per hour at 50 Pascals pressure.

Energy-efficient lighting

Halogen, standard fluorescent and compact fluorescent lighting is utilized with expected savings of 800 to 1000 kWh per year.

Energy-efficient appliances

These save from 20 to 80% of the energy usually required to run a similar conventional appliance. Appliances include an efficient water-conserving dishwasher, a front-loading clothes washer and dryer, a microwave oven, a combination conventional and convection oven, and a highly insulated refrigerator (which uses just 20% of the energy required to run a typical refrigerator).

Two-story passive sun space

A two-story passive solar sun space (not intended as a heated living space) provides heat. Located at the back of the house on a south wall, the sun space is separated from the rest of the house by a masonry fireplace, two sets of french doors that open to the living room, a set of french doors that adjoin the kitchen, and three sets of french doors in the second story. Passive solar gains are stored in the masonry of the fireplace and in the sun space floor (the concrete slab and the backfill below). Heat transfer to the living areas takes place directly via the common walls and french doors. The second major benefit gained from the sun space is to preheat the incoming air, which is drawn through the sun space, where it is preheated prior to distribution to the house via the IMS (where additional heating is provided if required). Should the sun space become too hot, a temperature-activated roof window will exhaust the hot air.

Energy-efficient fireplace

As noted above, the contra-flow fireplace is located on an interior wall between the family room and the sun space. Wood heat is radiated to the house and stored in the surrounding masonry; combustion air comes from outside.

Computerized monitoring system

The Advanced House incorporates a PC-based data-collection system that monitors energy use through 63 sensors. This data will be used to assess the performance of the Advanced House.

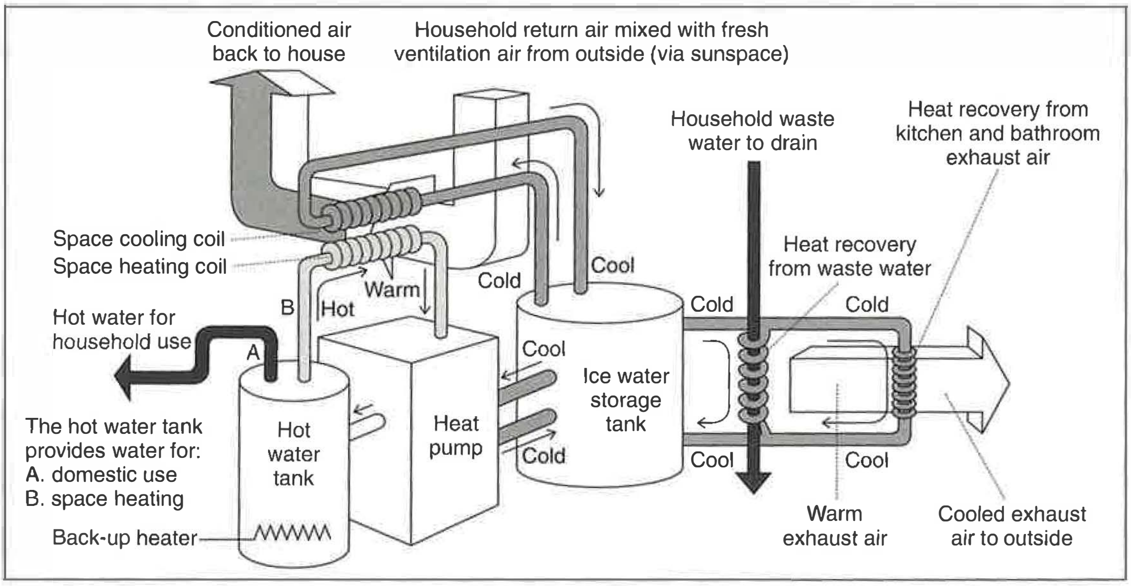
Other features

Apart from technologies designed to promote energy efficiency, a number of environmental features were incorporated into the Advanced House. Examples include water saving plumbing fixtures and ecological landscaping of the surrounding property.

Economics

Many features of the Advanced House cost more than conventional construction - but the extra expense can be recovered over time through energy savings. The overall incremental cost is from 10% to 20% of the construction cost, so a home valued at CAD 250,000 (the approximate value of the Advanced House, including the cost of the sun space) would have a CAD 25,000 to CAD 50,000 incremental cost. For estimated savings of CAD 2000 per year, the payback period is between 12.5 and 25 years. However, the payback for many of the individual features of the Advanced House is much better. For instance, the cost of the

Figure 1: Integrated Mechanical System diagram.



IMS is approximately equal to the combined cost of the replaced mechanical systems. And the high-performance windows represent a 30% incremental cost over conventional windows, resulting in a simple payback of 3 to 6 years.

The Advanced House contains about twice as much insulation as a conventional house. The cost of the insulation itself is therefore double - but insulation is a relatively low-cost material. The most costly part of the Advanced House insulation system is the extra wall framing, which adds 15-25% to the framing cost. Airtight construction increases the overall cost by about 1%.

The two-story passive solar sun space is the most expensive feature of the Advanced House. Although passive solar energy is an essential feature of the Advanced House concept, the incorporation of a large sun space is not. In this case, the sun space was designed to highlight the importance of passive solar, and to provide an architectural highlight to the Advanced House. The sun space is not necessarily intended for replication. The house was open to the public for four months and was sold in April 1991. It is now occupied by the owner. The house is continuously being monitored and the results will be made available.

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* IEA: International Energy Agency
OECD: Organisation for Economic Co-operation and Development

IEA

The IEA was established in 1974 within the framework of the OECD to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-one IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D). This is achieved, in part, through a programme of collaborative RD&D, consisting of forty-two Implementing Agreements, containing a total of over eighty separate energy RD&D projects.

The Scheme

CADDET functions as the IEA Centre for Analysis and Dissemination of Demonstrated Technologies for all IEA CADDET member countries.

This project can now be repeated in CADDET member countries. Parties interested in adopting this process can contact their National Team or CADDET. Demonstrations are a vital link between R&D or pilot studies and the end-use market.

Projects are published as a CADDET 'Demo' or 'Result' respectively, for on-going and finalised projects.