Association of Professional Energy Consultants

Energy Efficient, Cost Effective, Solar House

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Outline

- Overview
- Design
- Construction
- Energy efficient equipment
- Modeling and Results
- Proposed PV Solar Panels
- Conclusions

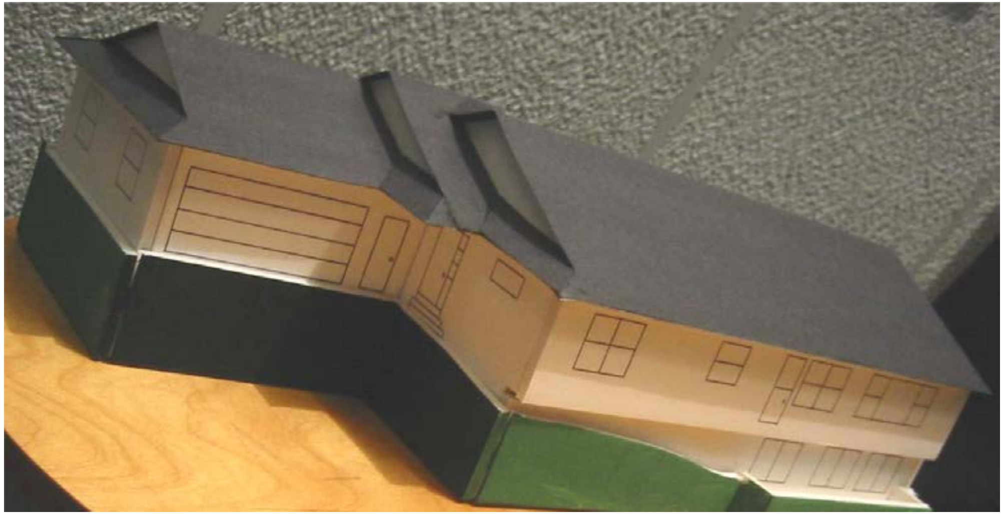
Overview

- The objective of the research was to construct an energy efficient house using commonly available products
- The house was analyzed to see if solar collectors were added would the energy use of the house approach net zero

Design

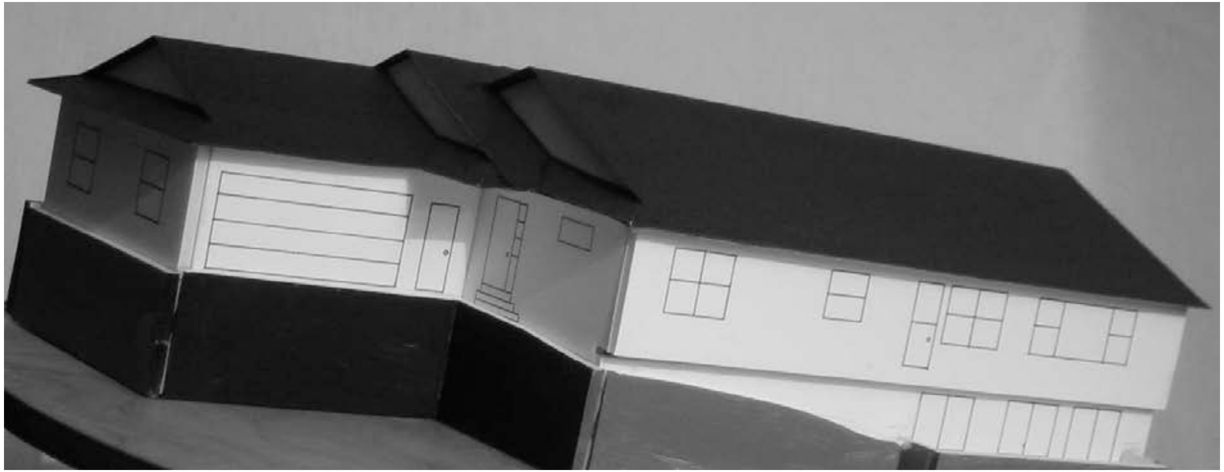
- The house was designed using a heliodon to see how the sun shines on the house particularly during the winter and summer
- Proper orientation and overhangs allowed sun to shine in winter but not summer
  - 0.61 m (2 ft) overhang over the main level
  - 0.41 m (1.3 ft) overhang over the basement
- Many windows facing south
- House 12° east of south to allow sun in
- Garage on northwest corner blocked hot summer sun and cold winter wind

Design



- Model and actual house shown on summer solstice

Design



- Model and actual house shown on winter solstice

Design

- Picture of family room at noon on winter solstice

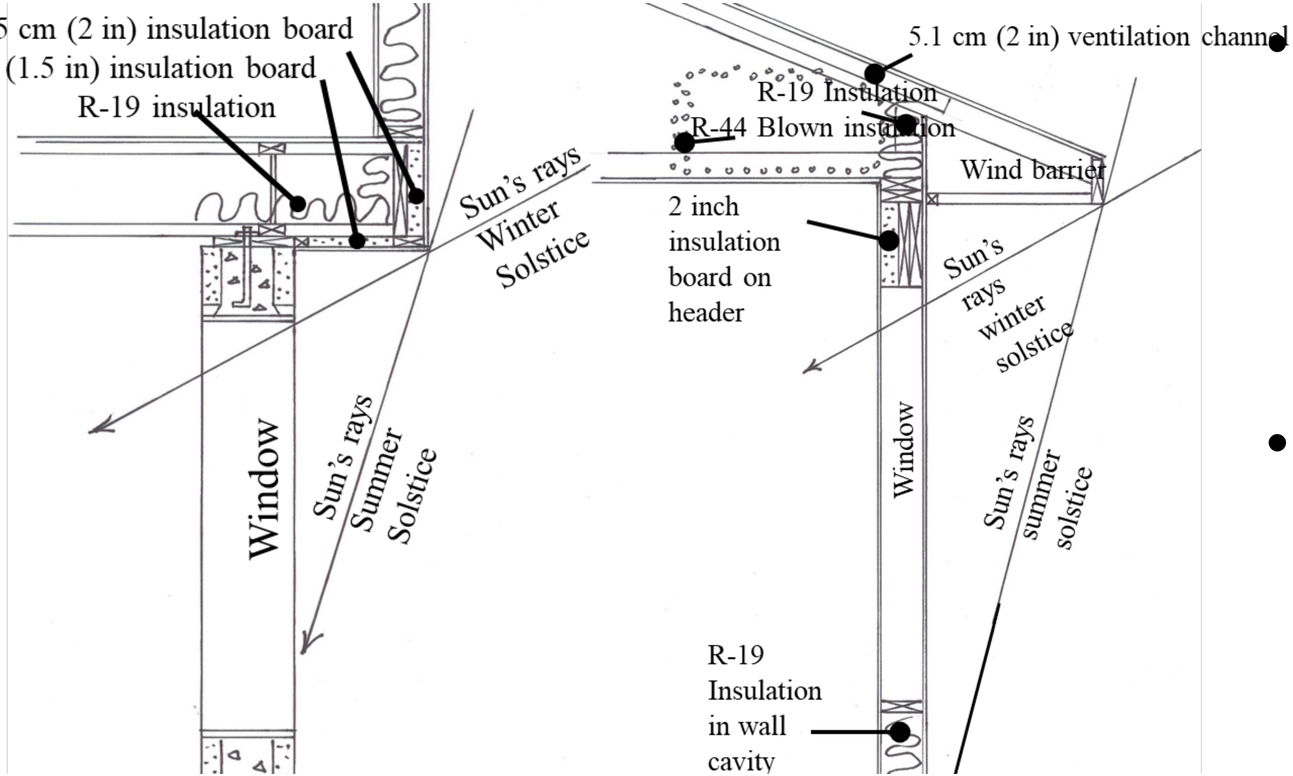
Design

- Larger windows faced south
- Smaller windows faced north
- Master bedroom windows faced east

Construction

- Walls of main level made of nominal 2”x6” wood; commonly made windows and doors used
- R19 fiberglass insulation was used
- Each cavity and wires and pipes out of thermal envelope were caulked
- The combination of fiberglass insulation and caulking was cost effective and good
- Air tight electrical boxes used on upstairs exterior walls
- Double-pane, argon-filled, low-emissivity coated windows used

Construction



- Basement walls used insulated concrete forms (R-25)
- Rigid insulation (R-10) on rim joist

Energy Efficient Equipment

- Two-stage, Ground Source Heat Pump (GSHP) and desuperheater provided heating, cooling, and some of the hot water
  - Small unit (10.5 kW; 3 RT) was chosen because passive solar design reduced the amount of heating and cooling
  - Six vertical loops 15.2 m (50 ft) deep and 3.0 m (10 ft) apart all connected below the surface
- Front loading clothes washer conserved hot water and fast spin cycle reduced drying time
- LED lights are replacing fluorescent lights

Data Collection

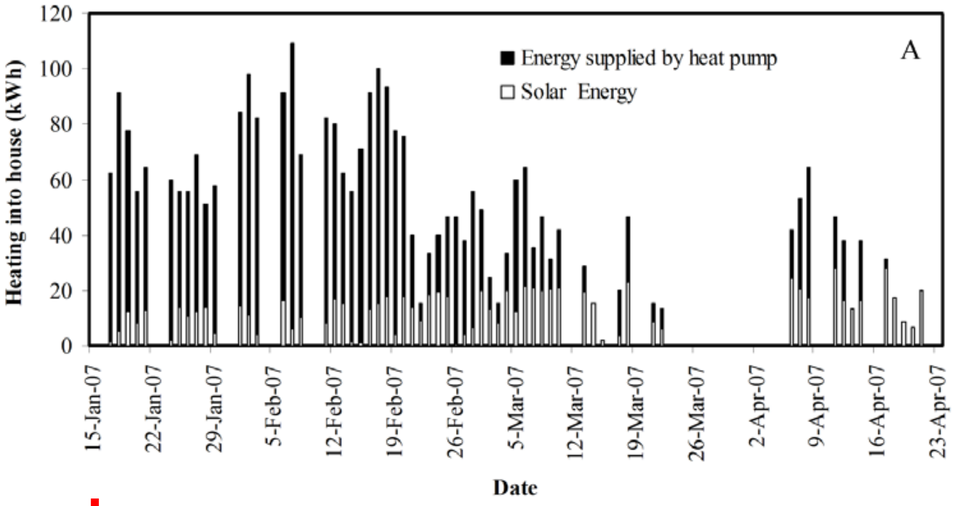
- Beginning 15 Jan 2007 electrical meters measured
  - GSHP
    - Heating
    - Cooling
    - Electric resistance heat
  - Hot water
  - Remaining electricity measured by outside house meter was lights, appliances, and plug loads

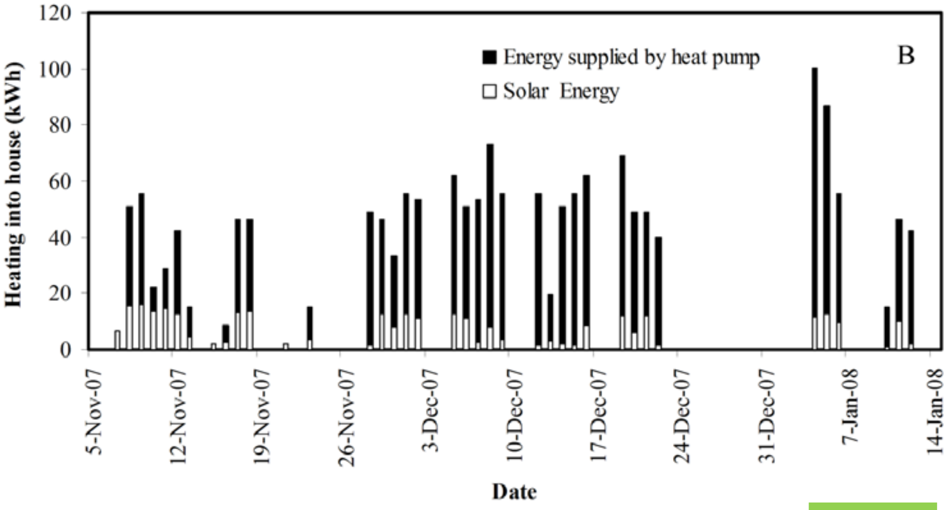
Passive Solar Modeling

- Amount of heat gained from passive solar determined with correlation using daily
  - Electricity consumed by GSHP
  - Outdoor air temperature
  - Solar radiation
  - Outdoor air temperature and solar radiation obtained from weather station 8 km (5 mi) away
- Correlation accounted for 88% of electricity used by heating and predicted 23% of heating needed came from passive solar

Passive Solar Modeling

- Using COP of the GSHP, graphs were made showing heat from passive solar and GSHP



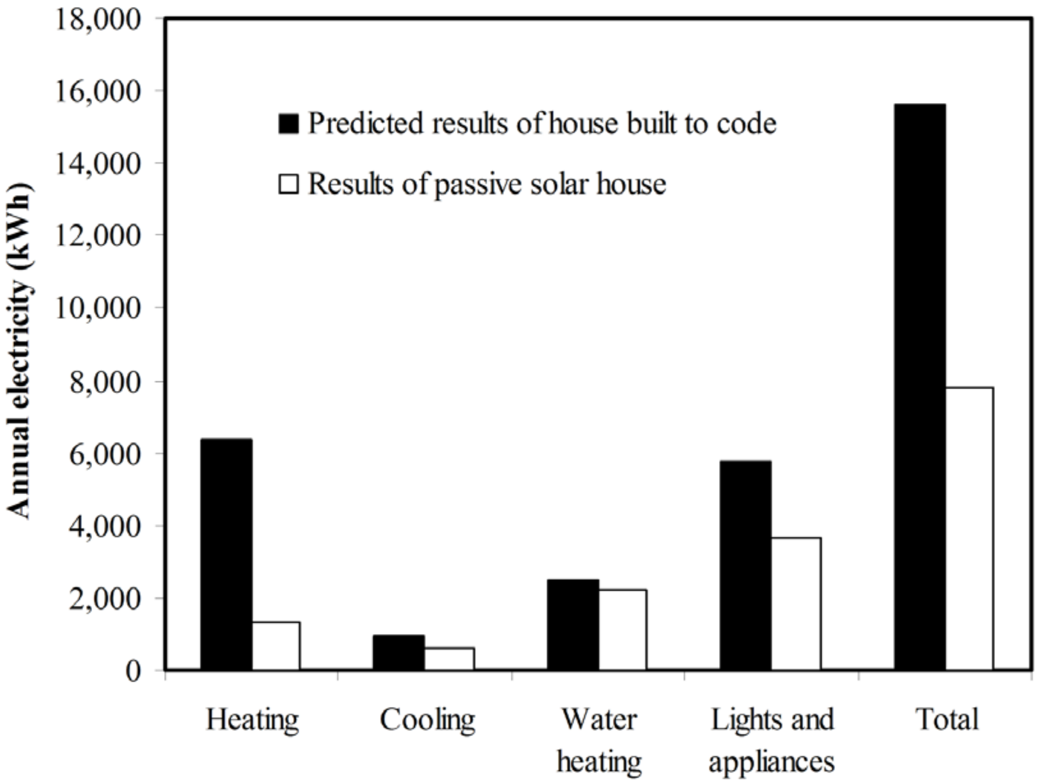


Total Energy Modeling

- Commercial software simulated actual electricity use of house
- Model was calibrated by changing schedules of
  - Lighting; Appliances; Bathing; Washing
- The calibrated model was altered to meet IECC 2004 code
  - Same window area used but equally facing all directions
  - Same occupant behavior
  - Same weather data

Total Energy Modeling

- The passive solar house used 50% less electricity compared to simulated house built to code



Total Energy Modeling

Actual house	Simulated code house	Increased price of actual house	Annual energy savings of actual house (E) = Electricity (kWh) Thermal: (H) = Heating (GJ) (C) = Cooling (GJ)
Passive solar orientation	Windows equally distributed all directions	$0	Not determined
15 cm (6 in) thick insulated above grade walls	10 cm (4 in) thick insulated above grade walls	$290	(H) 2 (C) ≈ 0
Double pane, argon filled, low-e windows; U=0.3	Double pane windows; U=0.4	$699	(H) 2 (C) 7.7
Rim joist insulated to R-10	Uninsulated rim joist	$157	(H) 0.4 (C) ≈ 0
Insulated concrete forms R-28 for basement walls	Block basement walls with R-10 continuous insulation	$1,754	(H) 3 (C) -0.4
Ground source heat pump	Air source heat pump	$4,518	(E) 2502 during heating (E) 168 during cooling (E) 2670 Total
CFL in all light fixtures	Incandescent light bulbs	$42	(E) 1,762
Energy-star front loading clothes washer also providing reduced drying time, and side-by-side refrigerator	Same size and features standard clothes washer and refrigerator	$530	(E) 44 refrigerator (E) 78 clothes washer (E) 94 clothes dryer (E) 216 Total
Totals		$7,990	(H) 7.4 (C) 7.3 (E) 4,648

- Table shows
  - Changes made
  - Increased cost of changes
  - Energy savings from savings

Total Energy Modeling

- Assuming additional heating and cooling provided by air source heat pump with electric backup and 0.10 $/kWh
- $43.20 savings from better windows during cooling
- $124.15 savings from better windows and wall insulation during heating
- $464.80 of electricity due to more efficient heat pump, appliances, and lights
- $632.15 total savings without accounting for additional passive solar energy and a 12.6 year simple payback period

PV Solar Panels

- An estimate obtained for PV solar panels on the garage
  - Passive solar orientation naturally has a large south facing roof
- A 4.35 kW DC (3.84 kW AC) system just fit on garage
- In the southern Illinois climate, this system would produce during the first year 6,685 kWh
- The last 12 months (Sep 2019 – Aug 2020) the house used 11,431 kWh
  - More and older occupants than in 2007

PV Solar Panels

- If the tree was removed and replanted to in front of garage
- Another 4.35 kW DC system, or more, would fit on south roof of house
- The same roof angle and orientation exists, the power produced should be the same

Marion Mt. Vernon Carbondale Centralia APEC Southern Illinois

PV Solar Panels

- 4.35 kW DC system costs $13,050 with no incentives
  - Illinois offers Solar Renewable Energy Credit of $6,636.55 for this system
  - US Government offers 26% energy tax credit in 2020; $3,393 for this system
- If all incentives are obtained the system would cost $3,020.45

Conclusions

- The GSHP with hot water desuperheater, compared to air source heat pump, provided greatest energy savings
- Hot water heat pump and a separate preheat tank for GSHP work well and provides some hot water in summer
- Compact Fluorescent Lights (CFL) and now LED lights had the shortest time to recover initial cost compared to incandescent lights

Conclusions

- To reduce moisture in the house a heat recovery ventilation system and dehumidifier, used in summer, were installed
- From 2007 to 2019 annual energy use increased from 8,000 kWh to 11,431 kWh
  - Number of occupants in house increased from 4 to 6
- Currently no PV solar panels have been installed
  - Homeowner cannot claim full amount of federal incentive

Thank you

Questions and Comments